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Analysis of the Meteorology Associated With the 1997 NASA Glenn Twin Otter Icing Events

Ben C. Bernstein
National Center for Atmospheric Research, Boulder, Colorado

November 2000

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Space Administration

Glenn Research Center

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Note that at the time of printing, the NASA Lewis Research Center was undergoing a name change to the NASA John H. Glenn Research Center at Lewis Field. Both names appear in these proceedings.

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Foreword

Supercooled Large Droplet (SLD) icing conditions were implicated in at least one recent aircraft crash, and have been associated with other aircraft incidents. Inflight encounters with SLD can result in ice accreting on unprotected areas of the wing where it cannot be removed. Because this ice can adversely affect flight characteristics of some aircraft, there has been concern about flight safety in these conditions.

The FAA held a conference on in-flight icing in 1996 where the state of knowledge concerning SLD was explored. One outcome of these meetings was an identified need to acquire SLD flight research data, particularly in the Great Lakes Region. The flight research data was needed by the FAA to develop a better understanding of the meteorological characteristics associated with SLD and facilitate an assessment of existing aircraft icing certification regulations with respect to SLD.

In response to this need, NASA, the Federal Aviation Administration (FAA), and the National Center for Atmospheric Research (NCAR) conducted a cooperative icing flight research program to acquire SLD flight research data. The NASA Glenn Research Center's Twin Otter icing research aircraft was flown throughout the Great Lakes region during the winters of 1996–97 and 1997–98 to acquire SLD icing and meteorological data.

The NASA Twin Otter was instrumented to measure cloud microphysical properties (particle size, LWC, temperature, etc), capture images of wing and tail ice accretion, and then record the resultant effect on aircraft performance due to the ice accretion. A satellite telephone link enabled the researchers onboard the Twin Otter to communicate with NCAR meteorologists, who provided real-time guidance into SLD icing conditions. NCAR meteorologists also provided pre-flight SLD weather forecasts that were used to plan the research flights, and served as on-board researchers.

This report contains a description of the weather systems and meteorological features existing at the time SLD icing research flights were conducted during the winter of 1996–97. The information contained in this report complements microphysical data acquired during the SLD icing research flights, and provides a larger scale meteorological context for it. This combined set of microphysical and large-scale weather features was intended to provide a basis for developing a better understanding of SLD and its formation mechanisms.

This report was prepared by Ben C. Bernstein of NCAR.

Table of Contents

Overview of Premier Cases

This part of the document contains an analysis of the meteorology associated with the premier icing encounters from the January-March 1997 NASA Twin Otter dataset. The purpose of this analysis is to provide a meteorological context for the aircraft data collected during these flights. For each case, the following data elements are presented:

1) A detailed discussion of the Twin Otter encounter, including locations, liquid water contents, temperatures and microphysical makeup of the clouds and precipitation aloft,
2) Upper-air charts, providing hand-analyzed locations of lows, troughs, ridges, saturated/unsaturated air, temperatures, warm/cold advection, and jet streams,
3) Balloon-borne soundings, providing vertical profiles of temperature, moisture and winds,
4) Infrared satellite data, providing cloud locations and cloud top temperature,
5) 3-hourly surface charts, providing hand-analyzed locations of lows, highs, fronts, precipitation (including type) and cloud cover,
6) Hourly plots of icing pilot reports, providing the icing intensity, icing type, icing altitudes and aircraft type,
7) Hourly, regional radar mosaics, providing fine resolution of the locations of precipitation (including intensity and type), pilot reports of icing (including intensity and type), surface observations of precipitation type and Twin Otter tracks for a one hour window centered on the time of the radar data, and
8) Plots of data from individual NEXRAD radars at times and elevation angles that have been matched to Twin Otter flight locations.

Outages occurred in nearly every dataset at some point. All relevant data that was available is presented here. All times are in UTC and all heights are in feet above mean sea level (MSL).

Cases included

970115, 970124, and 970204

Description of plots in this document

The following pages provide a complete description of the attributes of the plots that accompany each case, including the data elements covered and how they have been represented.

Upper-air charts

Analyses are made at 300, 500, 700 and 850 mb. On all charts, trough axes are indicated as yellow lines, and areas of saturated/near-saturated conditions are shaded green. Saturated/near-saturated conditions are those where the dew-point depression (temperature minus the dew point; DDP) is < 8 C at 300 mb and < 5 C at 500, 700 and 850 mb. Contours of constant geopotential height (MSL) are indicated as solid black lines, while contours of constant temperature are indicated as dashed black lines.

On 300 mb charts, jet stream winds are indicated as follows: > 150 knots in purple, > 110 knots in red, > 90 knots in red-hatching.

On 500, 700 and 850 mb charts, dry areas (DDP > 10 C) are shaded orange, isotherms (lines of constant temperature) are brown, areas of warm and cold temperature advection (the wind is bringing in warmer or colder air, respectively) are indicated with red and blue arrows, respectively. The arrows indicate the direction of the warm or cold advection.

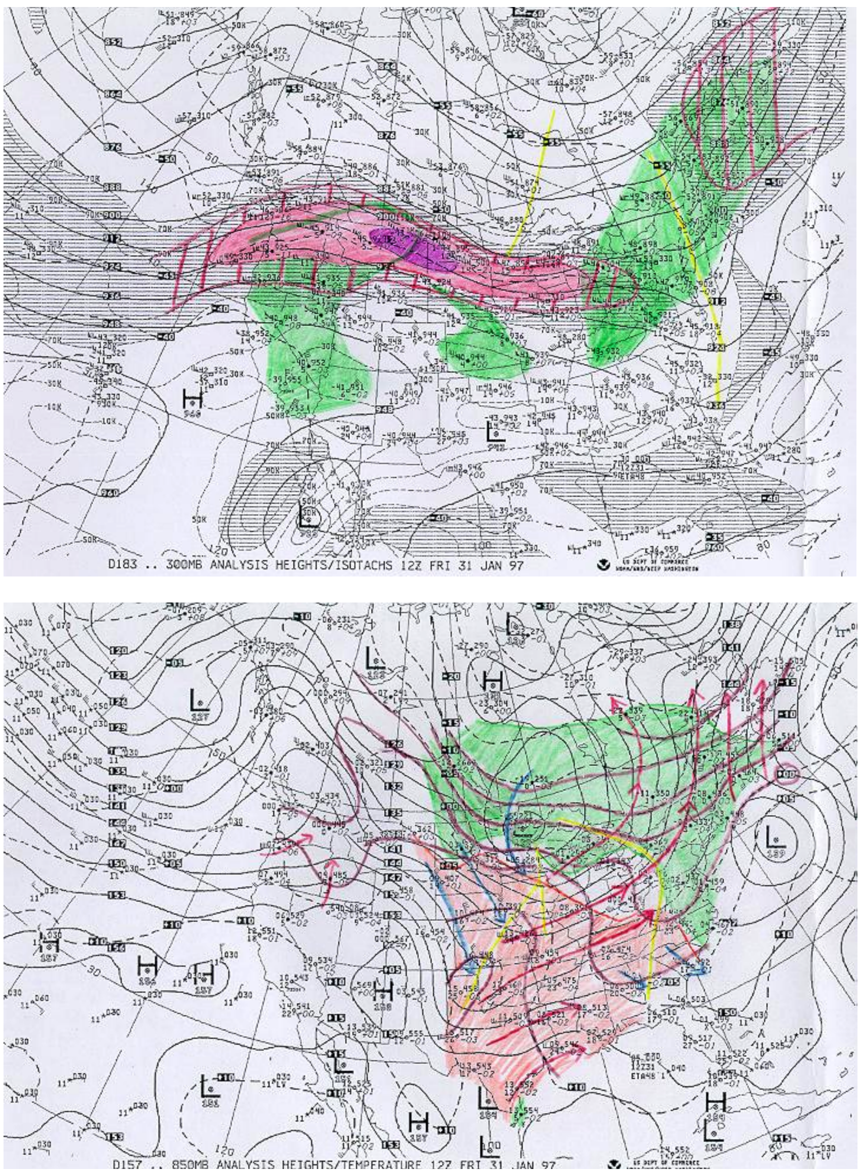


Figure 1 – Example upper-air charts at 300 and 850 mb.

Balloon-borne soundings

On sounding charts, profiles of temperature, dew point and winds are plotted. Solid lines of constant temperature are skewed, run from the lower left to the upper right, and are given every 10 C. Altitude is indicated on the left side of the chart in kilometers. Wind barbs are given on the right hand side of the chart, where a half-barb indicates 5 knots, a full barb indicates 10 knots and a flag indicates 50 knots of wind speed. The wind barbs indicate the direction that the wind is from.

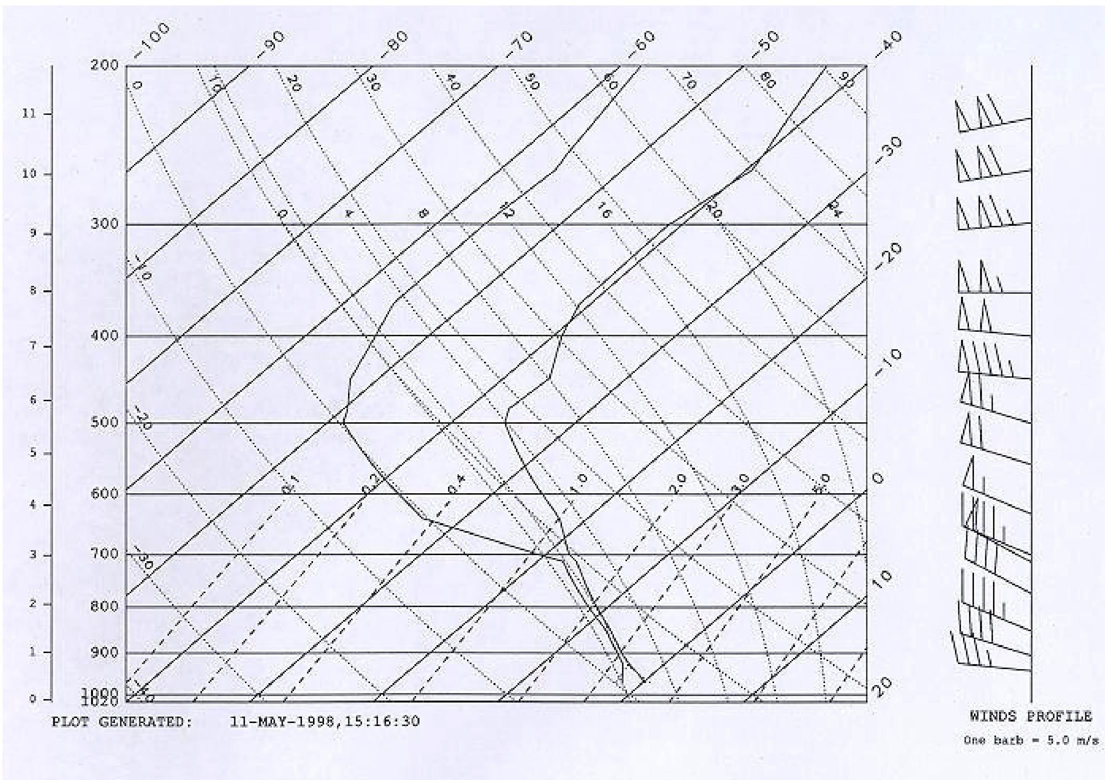


Figure 2 – Example of balloon-borne sounding data.

Satellite imagery

On visible satellite images, clouds and snow cover show up as white/bright areas, while ground and water typically show up as black/dark areas. On infrared satellite images, the temperature of the cloud top, ground or water are indicated. Temperature ranges for each color on infrared imagery are given at the bottom of each image. Each color represents a 5 C range of temperature values (e.g. –12.5 to –7.5 C), and the number (e.g. –10) represents the central temperature value for that color.

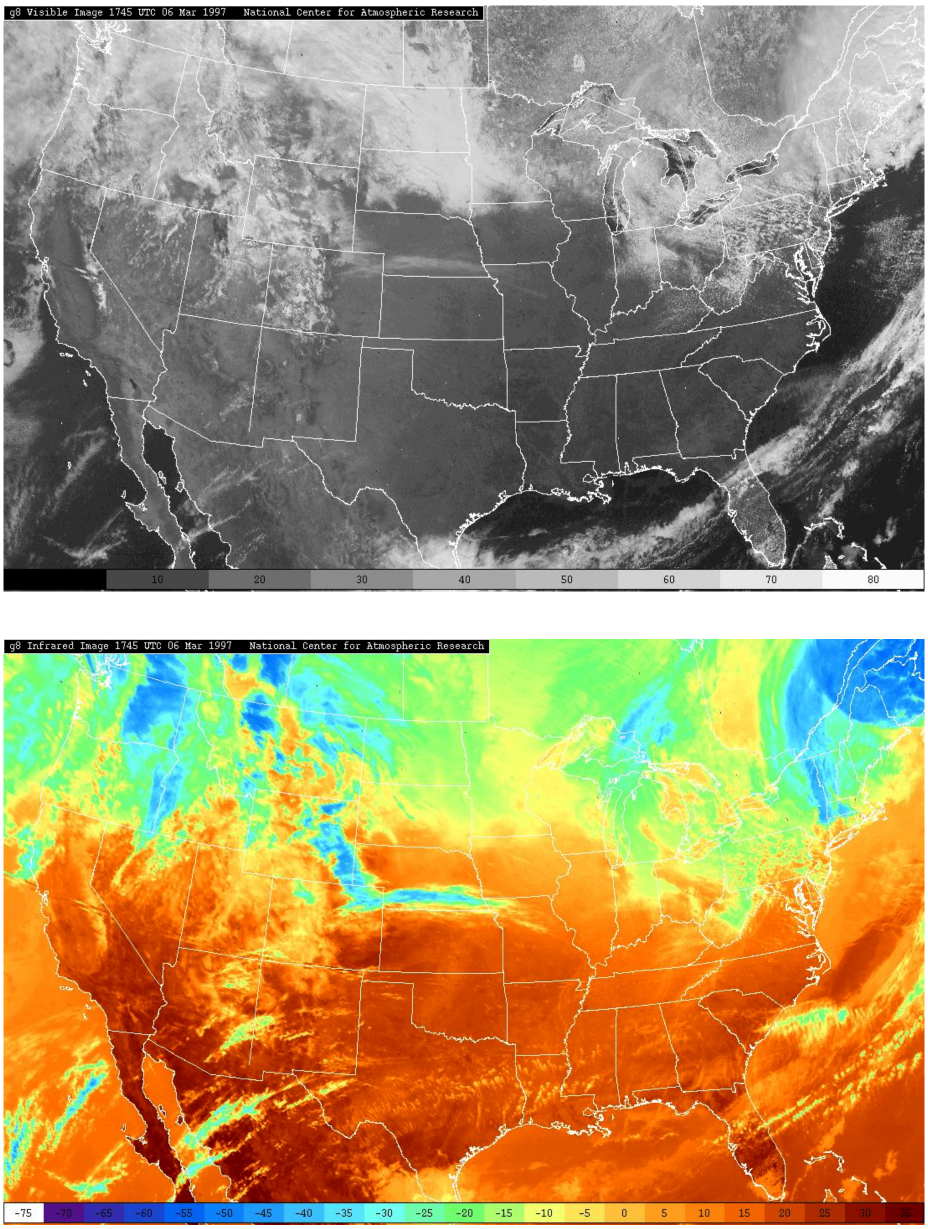


Figure 3 – Example visible and infrared satellite images.

Surface charts

On surface charts, high pressure centers are indicated with an ‘H’, low pressure centers are indicated with an ‘L’, and contours of constant pressure are indicated with solid black lines. Fronts are indicated as heavy black lines with: cold fronts - pointed barbs, warm fronts - rounded barbs, stationary fronts - pointed barbs on one side and rounded barbs on the other, and occluded fronts - pointed and rounded barbs on the same side. Trough axes are indicated with dashed lines. Precipitation areas are shaded as follows: rain/drizzle – green, snow – blue, freezing precipitation (ZL, ZR, IP) – red.

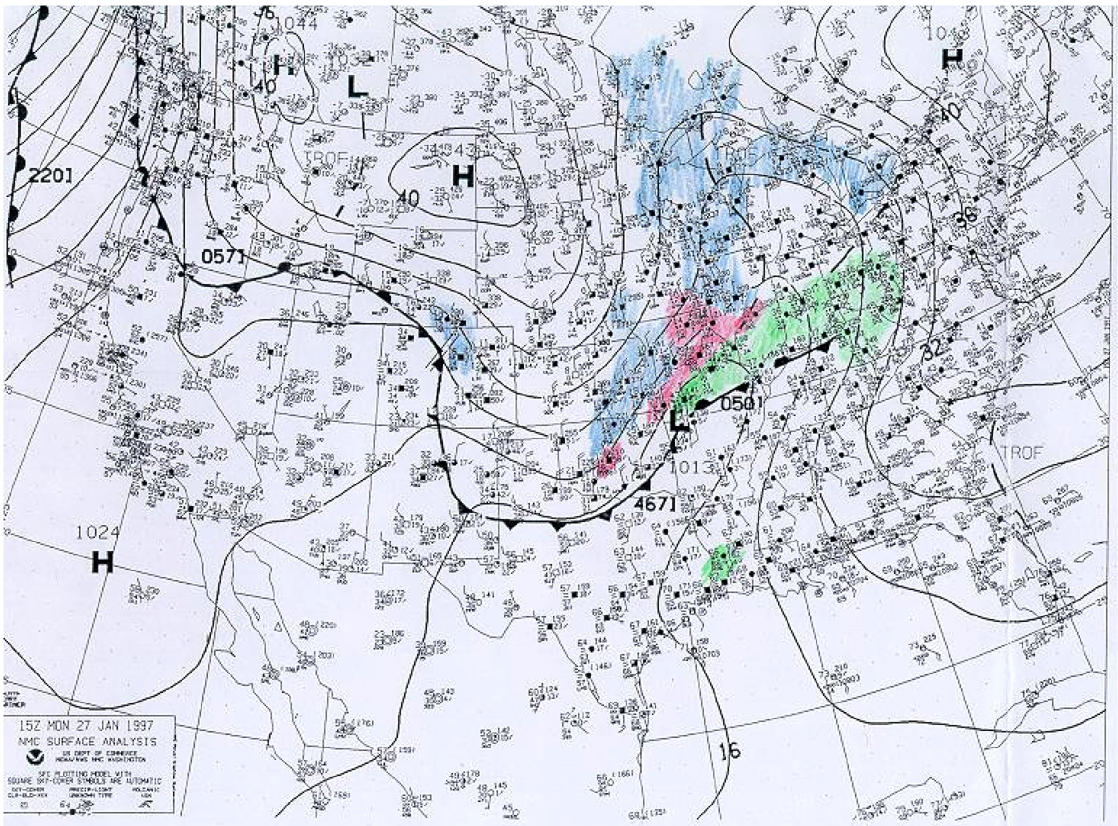


Figure 4 – Example surface chart.

Radar mosaic charts

On regional radar mosaic charts, locations of precipitation with radar reflectivity values of at least VIP 1 (>18 dBZ) are given. The precipitation is color-coded by precipitation type (freezing precipitation (ZL, ZR, IP) - red and magenta, rain - green and yellow, snow - blue) and intensity (VIP level 1-6). A color bar indicating precipitation type and intensity can be found at the bottom of each chart. Pilot reports of icing are indicated as follows:

ICING TYPES –

R=rime, C=clear/glaze, X=mixed, U=unknown

ICING INTENSITIES –

small font = trace, trace-light or light

medium font = light-moderate or moderate

large font = moderate-severe or severe

NASA Twin Otter tracks are plotted for a one-hour time window centered on the valid time of the chart. A '+' is plotted at the aircraft's location every 2 minutes, and an 'x' is plotted at the aircraft's location every 10 minutes.

Precipitation type reported by surface stations is also plotted in yellow. The symbols for the precipitation type are given at the bottom-right portion of the chart.

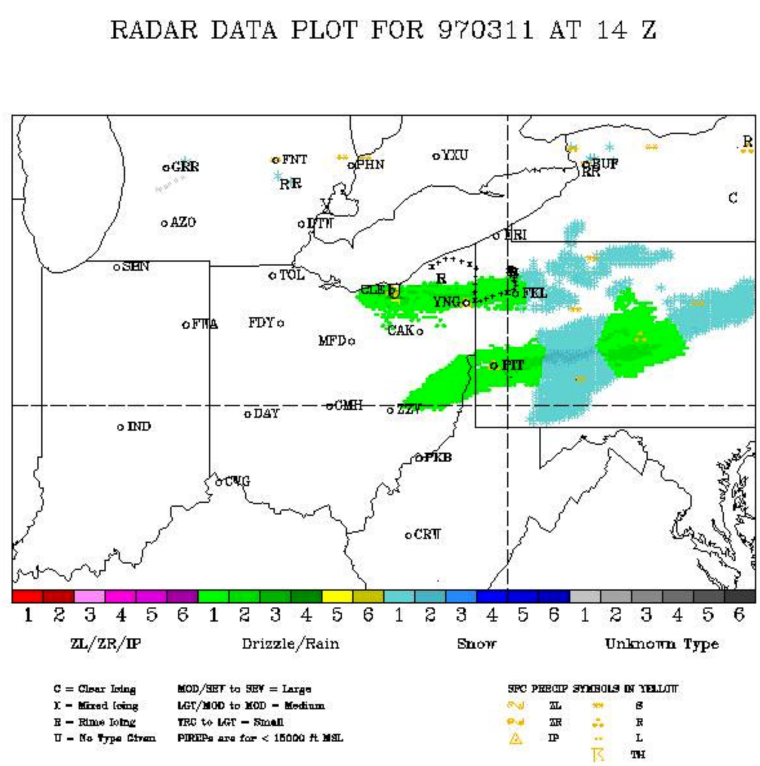


Figure 5 – Example regional radar mosaic chart.

Pilot reports of icing

Pilot reports (PIREPs) of icing are given for a one-hour time window that is indicated at the top of the chart. Icing PIREP indicators are given at the bottom of the chart. The size and color of the PIREP indicates its intensity, while the letter plotted indicates its type (R=rime, C=clear/glaze, X=mixed, U=unknown). The aircraft type is plotted just up and to the right of the R, C, X or U, and the base and top of the reported icing altitudes are given just below the aircraft type (100's of feet MSL).

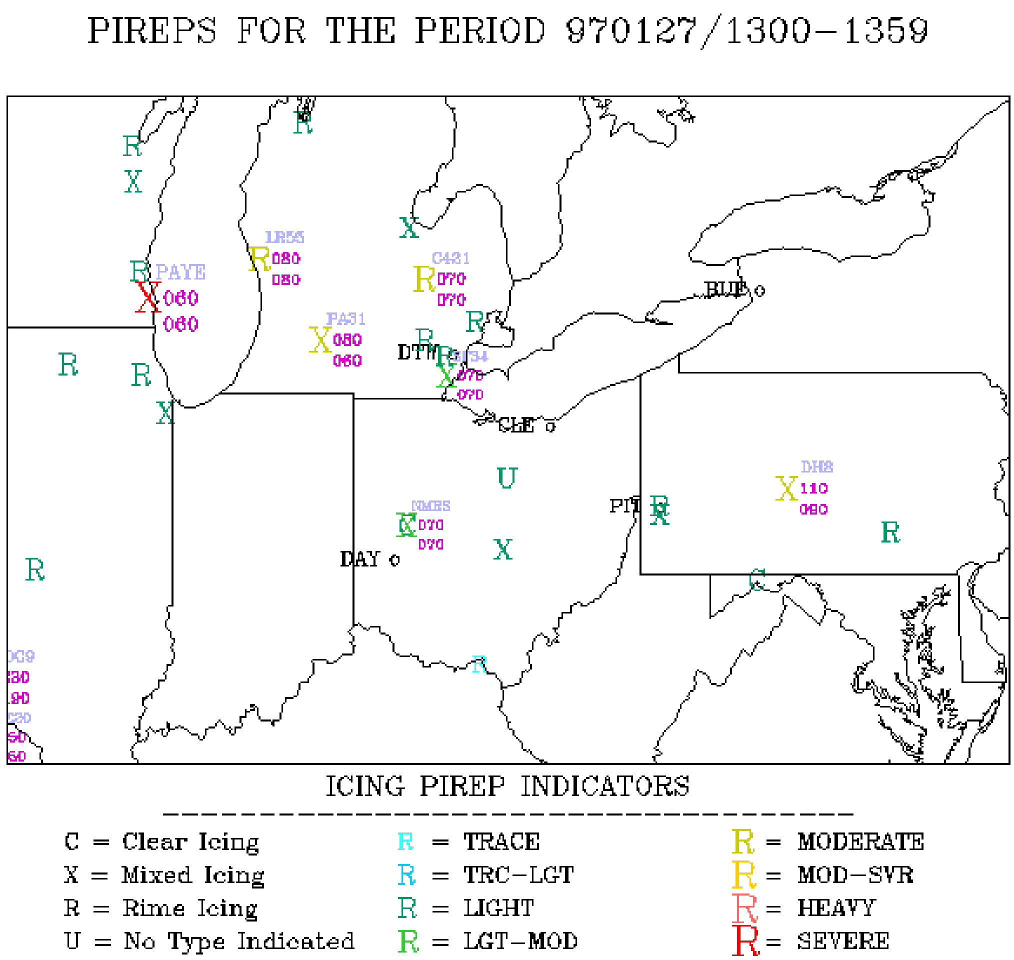


Figure 6 – Example plot of icing pilot reports.

Twin Otter 2D-Grey Probe Imagery

Sample images from the Twin Otter's OAP 2D-Grey probe are given for each time period of consistent microphysical conditions for at least 10 seconds.

A table is included for each Twin Otter flight, and it indicates the following information for each time period: start and end time (hhmmss; UTC), altitude range (feet above mean sea level - MSL), static temperature range (Celsius), King probe liquid water content range (zero removed; g/m^3), description of 2-D gray imagery, letter of example 2-D gray probe image, letter of related NEXRAD images, aircraft range, azimuth and elevation angles from relevant NEXRAD, description of radar reflectivity patterns around the aircraft, and comments. Xls=crystals, LWC = liquid water content.

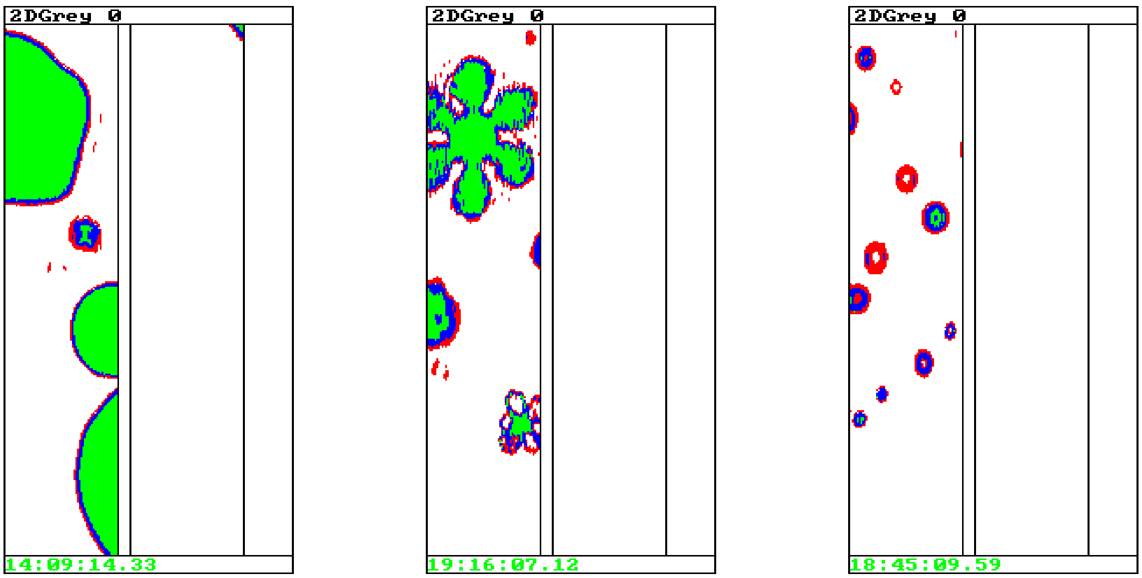


Figure 7 – Example 2D-Grey probe images.

Individual NEXRAD radar imagery

Plots from individual NEXRAD radars at times and elevation angles matched to Twin Otter flight locations are used to provide a direct comparison between flight data and NEXRAD reflectivity. Radar range rings are typically given for every 20 km, and azimuth lines are plotted every 30 degrees, beginning at 0 degrees (north). The time and elevation angle are given at the top and a color bar of reflectivity values is given at the bottom of each plot.

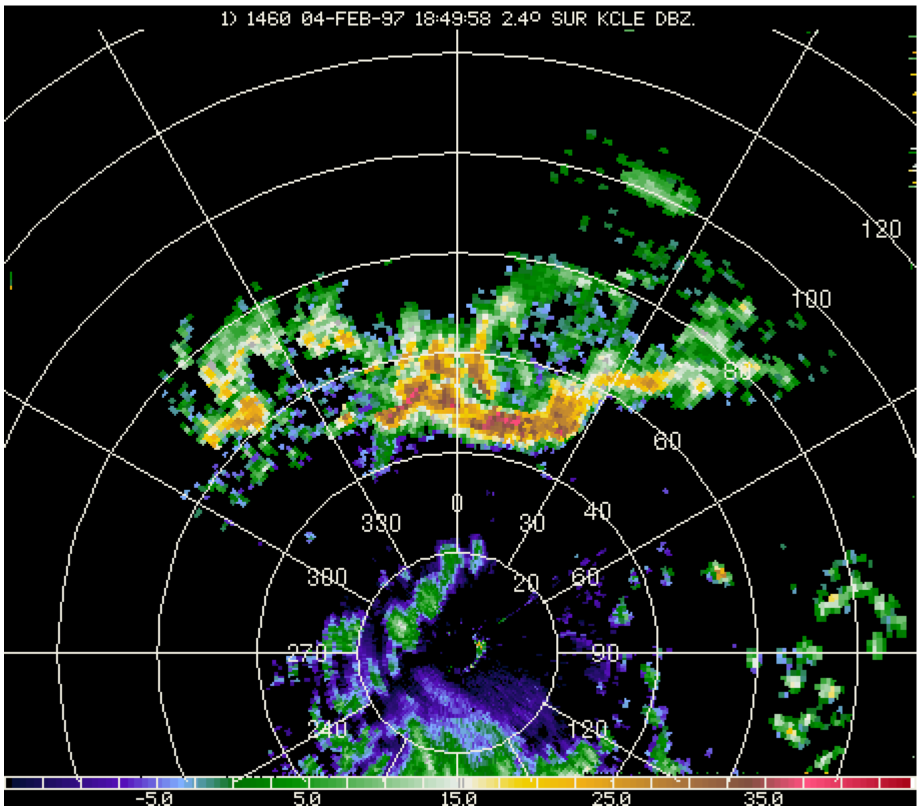
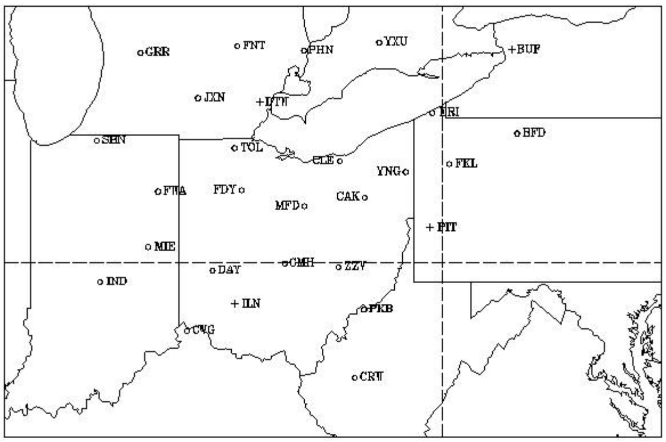


Figure 8 – Example individual NEXRAD radar plot.

Station locations

A map of commonly referenced station locations, as well as the matching 3-letter codes is given below. This map covers what is referred to in the document as the "forecast area."

STATION LOCATIONS



CODE	STATION NAME
CLE	Cleveland, Ohio
YNG	Youngstown, Ohio
CAK	Canton-Akron, Ohio
MFD	Mansfield, Ohio
TOL	Toledo, Ohio
FDY	Findlay, Ohio
DAY	Dayton, Ohio
CMH	Columbus, Ohio
ILN*	Wilmington, Ohio
ZZV	Zanesville, Ohio
CVG	Cincinnati, Ohio
IND	Indianapolis, Indiana
FWA	Fort Wayne, Indiana
MIE	Muncie, Indiana
SBN	South Bend, Indiana
GRR	Grand Rapids, Michigan
FNT	Flint, Michigan
JXN	Jackson, Michigan
PHN	Selfridge AFB, Michigan
DTW*	Detroit, Michigan
YXU	London, Ontario
BUF*	Buffalo, New York
ERI	Erie, Pennsylvania
FKL	Franklin, Pennsylvania
PIT*	Pittsburgh, Pennsylvania
BFD	Bradford, Pennsylvania
PKB	Parkersburg, West Virginia
CRW	Charleston, West Virginia

* denotes a sounding site

January 15, 1997

Freezing rain, freezing drizzle and mixed conditions over Indianapolis, Indiana

January 15, 1997 - Flight No. 1

Overview

This case of freezing rain, freezing drizzle and mixed conditions occurred over Indianapolis between 1310 and 1524 UTC. The synoptic weather scenario over Indiana on January 15 was fairly classic for freezing rain and ice pellets. It featured a low pressure center approaching from the west, bringing deep, warm, moist air northward from the Gulf of Mexico to ride over a layer of cold air in place at the surface. In this document, the case will be discussed beginning at the synoptic scale (upper air charts, satellite data, surface maps, soundings) to give an overview of the weather, and ending at the mesoscale (radar and satellite data) and microscale (probe data), where fine details will be highlighted.

Upper air chart analysis-1200 UTC, January 15th

At 1200 UTC, a sharp trough extended from Minnesota to the Texas Panhandle at 300 millibars (Fig. 1a). Moisture was evident at this level across most of Indiana, Illinois, Wisconsin and Michigan, while slightly drier air existed over Missouri, Kansas and Oklahoma. A weak ridge was in place over the Indiana/Ohio border, with dry air to the east of the ridge axis. A jet streak (area of enhanced wind speed within the jet stream) with wind speeds of 90+ knots existed just ahead of the trough axis. A secondary circulation in the exit portion of the jet streak may have been the cause of a moist/dry couplet, with the moist conditions over Lake Michigan and the dry conditions over southern Illinois/Indiana and Kentucky. Temperatures in the saturated air on the north side of the couplet were -45 to -50 C.

The main trough axis and weak ridge were evident in nearly the same locations at 500 millibars (Fig. 1b). A very distinct, narrow (200-300 km wide) swath of moisture extended from Oklahoma to Lake Michigan, with Indianapolis located at the eastern edge of the moisture. The air was much drier to the southeast and northwest of the moisture swath, with dew point depressions of 18 C at Nashville and 13 C at Omaha. Temperatures were approximately -22 C over Indiana at 500 millibars. A much broader area of saturated conditions was in place over most of the Midwest ahead of the main trough at 700 millibars, which was in nearly the identical location as it was at 300 and 500 millibars (Fig. 1c). Weak, warm advection was occurring from Louisiana to Indiana, and temperatures were approximately -6 C over Indianapolis.

At 850 millibars, a weak trough axis extended from eastern Iowa to the Virginia/North Carolina border. This weak trough, located over Indianapolis, was the upward extension to the developing surface warm front, to be discussed later. Indianapolis was on the eastern edge of an area of saturated conditions which covered the High Plains and most of the Midwest (Fig. 1d). Warm advection was very apparent over Wisconsin, Illinois, Indiana, Ohio, Michigan and states directly to their south, while cold advection was occurring to the west of the Mississippi River. Temperatures over Indianapolis at this level (~5000 feet) were approximately -1 C.

Upper air chart analysis-0000 UTC, January 16th

By 0000 UTC on 16 January, the main trough progressed eastward to about the Missouri/Illinois border at all levels (Figs. 2a-d). The saturated conditions at 300 millibars moved eastward to cover all of the Great Lakes and Northeast, and as far south as Tennessee and North Carolina. Dry conditions prevailed to the west of the trough. At 500 millibars, the previously narrow swath of moisture had broadened somewhat, and covered the central Great Lakes and states to their south. Weak warm advection was in place over the eastern Great Lakes and Northeast. At 700 and 850 millibars, the broader swath of warm advection and saturated conditions covered most of the area to the east of the Mississippi River (the approximate location of the main trough), except for some dry air along the eastern seaboard. In general, the trough, as well as the deep warm advection and the saturated conditions ahead of it all moved eastward between 1200 UTC on 15 January and 0000 UTC on 16 January, bringing those conditions across the Indianapolis area just after 1200 UTC on 15 January.

Satellite IR temperature analysis

The infrared satellite image for 1145 UTC (Fig. 3a) roughly reflects the moisture pattern seen in the 1200 UTC upper-air charts. The coldest cloud top temperatures (CTTs; < -40 C) were evident over Wisconsin, Illinois, and western Indiana and Michigan, as seen on the 300 and 500 millibar charts. Relatively warm CTTs (-10 to -20 C) were in place over Ohio and extreme eastern Indiana, representing the saturated conditions between 700 and 500 millibars. By 1345 UTC (Fig. 3b) the cold cloud shield progressed northeastward to cover nearly all of Michigan and Indiana. Indianapolis was predominantly covered with CTTs < -35 C, but close inspection of zoomed infrared imagery (Fig. 3c) reveals breaks in the upper cloud shield where CTTs were only -20 to -25 C. These pockets of slightly warmer cloud tops passed over and to the southeast of Indianapolis during the period of the research flight, as seen in close-up infrared imagery from 1415 to 1645 UTC (Figs. 3d,e). The higher CTTs tend to indicate less efficient snow formation aloft, causing similar gaps in the precipitation field, as seen in NEXRAD echoes to the southeast of Indianapolis. Radar data will be discussed in a later section.

Surface map, regional radar and PIREP analysis

A fairly strong (1030 millibar) high-pressure system was centered over eastern Virginia, while a weak, elongated low pressure system was centered over northern Kansas at 1200 UTC on 15 January (Fig. 4a). This 1008 millibar low was attached by a long trough axis to a stronger (996 millibar) low located just to the north of the Minnesota/Canada border. The southern low featured two additional trough axes, one of which extended southeastward to the Texas/Louisiana border, while the other extended eastward across the southern borders of Illinois and Indiana. The second of these troughs separated relatively cold air to the north from relatively warm air to the south. At 1200 UTC, snow was occurring predominantly to the north of the second trough, across northern Illinois, eastern Iowa, and along the Minnesota/Wisconsin border. Freezing rain was occurring to the south of the trough, across southern Missouri and most of Arkansas (Figs. 4a, 5a). Fairly cold air was in place in the wake of the high-pressure center, across areas to the north of the east-west oriented trough. Temperatures in these areas (including Indiana) were in the teens.

Positions of the main weather features on the surface map did not change much by 1500 UTC, but the area of freezing rain moved quickly northward into Missouri, extreme southern Illinois and central Indiana, reaching Indianapolis at approximately 1317 UTC (Figs. 4b, 5b-d). Snow was occurring across northern Indiana, just to the north of the freezing rain. Data from the research aircraft, which will be discussed in the mesoscale analysis section, reveal the existence of a layer of air with temperatures above freezing just below 850 millibars. This was important to the formation of the freezing rain.

Many PIREPs were made in the area of interest. Most were of light intensity and rime or mixed type, but some moderate rime icing was also reported (Fig. 6). The PIREPs were found both within the freezing rain layer in the areas of precipitation and at a variety of altitudes along the edges of the precipitation shield.

Mesoscale and microscale analysis

A detailed analysis of the mesoscale and microscale structure of the clouds sampled on this day is given in tabular format (see Table 1). Each period of time was chosen based upon apparent consistency in 2d-grey probe imagery for a period of at least ten seconds. The table includes the range of times (UTC), altitudes (feet MSL), static temperatures (C), liquid water content from the King probe with zero removed (g/m3), a brief description of the 2d-grey imagery (phase, small/large drops, crystal habit), an assessment of the radar reflectivity pattern in the location of flight, and comments. A quick overview of the results is given in the text here. Images from the 2D-grey probe and the Cleveland NEXRAD are given in Figs. 7 and 8.

The aircraft took off from Wright-Patterson Air Force Base (Dayton, Ohio) at approximately 1310 UTC. Between 131028 and 133728 UTC, the aircraft climbed to an altitude of 3930 feet (all altitudes MSL) in clear air, and flew toward the west-northwest. The eastern end of the precipitation shield was entered at 133728 UTC, where a mixture of messy ice crystals (irregulars, columns, dendrites), aggregates and freezing drizzle was observed through ~1350 UTC. The aircraft descended and flew within an altitude range of ~2400-3000 feet, in a mixture of freezing rain, freezing drizzle, messy crystals and blobs (solid looking, oddly shaped particles) just beneath the "warm nose" (a layer of air with temperatures above freezing sandwiched between two layers of subfreezing air) until ~1455 UTC. Snow fell from the subfreezing layer above, then melted to form rain or drizzle in the warm nose and subsequently fell into the subfreezing layer below to become freezing rain or freezing drizzle. During a gradual climb between 1454 and 1516 UTC, the aircraft reached the bottom of the warm nose at ~2900 feet, encountered temperatures as warm as +2 C at ~3200 feet (1456 UTC), and then reached the top of the warm nose at ~5600 feet (1512 UTC). A mixture of rain, drizzle, messy crystals, blobs and aggregates was observed within this layer. The Twin Otter ascended above the warm nose and flew within the upper subfreezing layer between ~151200 and ~151940. At these altitudes, no freezing rain or rain was observed, indicating that the freezing rain in the lower subfreezing level was likely to have developed via the melting process described earlier in this section. Freezing drizzle was observed in the upper subfreezing level, indicating that at least some of the freezing drizzle in the lower subfreezing layer may have been formed via the collision-coalescence process. It is possible, however, that some of it developed via small crystals melting and subsequently supercooling, since some smaller crystals were observed above the warm nose. Large aggregates and cloud-sized droplets were also found in the upper subfreezing layer.

The aircraft began its final descent from 5900 feet at ~151630 UTC, and landed at Indianapolis at ~152355 UTC. During descent, the aircraft passed through the upper subfreezing layer, the warm nose, and the lower subfreezing layer, providing a detailed sounding of the "classic" freezing rain process. As seen earlier, aggregates, messy crystals, some small drops and some freezing drizzle were observed above the warm nose (4600-5900 feet). Rain, drizzle, messy crystals, aggregates and some cloud-sized drops were observed within the warm nose (2600-4600 feet), and freezing rain, freezing drizzle, blobs, some messy crystals, some small drops, and possibly some ice pellets were observed beneath the warm nose (0-2600 feet).

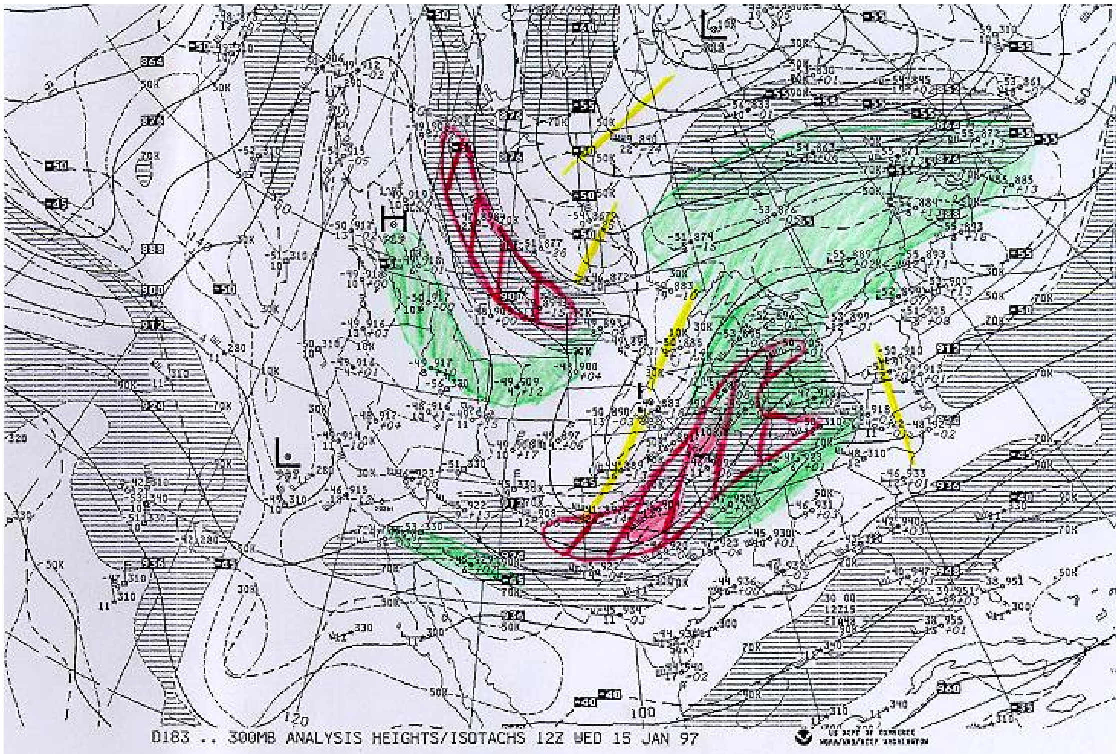
Liquid water contents were quite low throughout the flight, and cloud-sized drops were only observed during a few brief periods. Conditions were mixed most of the time, but a few brief periods where water was dominant did occur. These were usually in patches of relatively low reflectivity (< 20 dBZ or so). A bright band was very evident and the location of this feature corresponded well with that of the layer of above freezing temperatures observed by the Twin Otter. Reflectivities were typically > 40 dBZ in the bright band and 15-30 dBZ elsewhere.

970115 - Flight #1

Row	Start/end time (UTC)		Alt Range (ft MSL)		T-static range (C)		LWC - KingZR		Description of 2D-grey imagery	2D Imgs
1	131028	131138	530	1700	-6.5	0	0	0	None	None
2	131138	133728	1700	3930	-1	2	0	0	None	None
3	133728	134828	3830	3930	-3.1	2	0	0	Messy irregs, some col,need,dend,aggs and possible ZL	A
4	134829	134948	3910	2950	-3	-0.8	0	0.02	Fewer & smaller xls, no aggs, some poss ZL	B
5	134948	135358	3000	2600	-3	-2.3	0	0	Possible ZL mxd w/irregs, cols& "blobs"	C
6	135358	135530	2450	2600	-2.7	-3	0	0.01	Aggs/dendr/stell/irreg/blobs with possible ZL	D
7	135530	135918	2400	2550	-2.3	-3.5	0	0.01	Fewer xls, just col/irreg w/lots of blobs/ZR/ZL, no aggs	E
8	135918	140118	2400	2800	-2	-2.1	0	0.01	Nearly all ZR & ZL, some blobs, a few irregulars	F
9	140118	140400	2900	2500	-1.7	-2.5	0	0.01	Blobs, ZR, some ZL, messy small & large crystals	G
10	140400	140520	2340	2500	-2.2	-2.5	0	0	Blobs, ZL (no ZR), messy crystals	H
11	140520	140650	2400	2500	-2.2	-2.4	0	0	Blobs, ZR, ZL, mess big xls, a few messy aggs	I
12	140650	140728	2400	2500	-2.2	-2.4	0	0	Nearly all ZR & ZL, some blobs	J
13	140728	141400	2440	2850	-0.8	-2.5	0	0.01	ZR, ZL, some blobs, lg & sm messy xls	K
14	141400	142000	2850	2950	-1	0	0	0.01	ZR, ZL, some blobs, lg & sm messy xls, a few aggs	L
15	142000	142230	2850	2950	-0.8	0.4	0	0.01	ZL, aggs, blobs, some ZR and messy xls	M
16	142230	142710	2850	2950	-0.5	-2	0	0.01	Aggs, ZL, lg & sm messy crystals	N
17	142710	142820	2850	2950	-0.5	-1.2	0	0.01	ZR, ZL, blobs, lg & sm messy crystals, aggs	O
18	142820	144020	2850	2950	-1.9	-0.6	0	0.01	Ditto	P-Q
19	144020	145410	2850	2950	-1.7	0.6	0	0.01	Ditto, plus R & L	R-S
20	145410	150120	2850	3500	0	2	0	0.01	R, L, blobs, lg & sm messy crystals, aggs	T-U
21	150120	150212	3500	4400	0.8	1.1	0	0.01	Aggs, some L, big messy crystals, blobs	V
22	150212	150350	4400	4900	0.1	0.6	0	0.02	Cloud drops, L, aggs, big messy crystals	W-X
23	150350	150600	4850	4950	0.3	0.5	0	0.01	Aggs, L, messy xls, few plates/stellars/needles/cols	Y-Z
24	150600	151110	4850	4950	0.2	0.4	0	0.01	Aggs, L, plates/columns/needles, mess crystals	AA-BB
25	151110	151240	4900	5850	0.3	-0.6	0	0.02	Aggs, L/ZL, messy crystals, some small drops	CC
26	151240	151630	5830	5950	-0.5	-0.8	0	0.02	Aggs, ZL, messy crystals, some small drops	DD
27	151630	151840	5900	4600	-0.6	0	0	0.05	Aggs, L/ZL, messy xls, columns, small drops	EE
28	151840	151940	4600	4100	0	1	0	0.04	Aggs, L, messy xls, some small drops	FF
29	151940	152100	4100	2600	1.7	0	0	0.01	R, L, some aggregates and messy crystals	GG
30	152100	152355	2600	600	0	-5.7	0	0.02	ZR, ZL, blobs, few messy xls, some small drops, IP(?)	HH-II

970115 - Flight #1

Row	Rad Imgs	Range-km	Azimuth	Elev. ang	Description of Radar Reflectivity around A/C	Comments
1	A	182-190	87-88	0.0-0.3	E of all echo	Climbing to first freezing level
2	A-E	103-182	65-89	0.3-0.6	Approaching E edge of echo	T bouncing around 0 C, flying NW @3800' most of time
3	E-G	66-103	58-64	0.6-0.9	Crossing patchy -10 to 25 dBZ echo	Warmest @start, cooling as A/C heads SW
4	G	61-66	58-58	0.7-0.9	Crossing -5 to 0dBZ patch - patch moving quickly ENE	Descending
5	H	46-61	54-58	0.6-0.8	Moving SW from 0 dBZ echo toward 25 dBZ pocket	"Blobs" are solid looking, oddly shaped particles.
6	H	41-46	51-54	0.7-0.8	Crossing narrow pocket of 25-30 dBZ	Below the "warm nose"/melting layer
7	H-J	28-41	42-51	0.7-1.1	Exited narrow pocket, heading SW across 15-25 dBZ	Getting into more ZR
8	J-K	21-28	37-42	1.1-1.8	In 15-25 dBZ, just below bband @ 2800	bband=bright band, climb to 2800', ZR > 1mm diam
9	K-L	12.0-21.0	19-37	1.8-2.8	In 2-20 dBZ just below bband	Descend to 2500 & fewer images @end
10	L-M	10.0-12.0	359-20	2.8-3.2	In pocket of 5-15dBZ early, then 15-25dBZ	Very few images, just below and in bottom of bband
11	M	10.0-11.0	325-356	3.1-3.4	Flying SW just below bband, 20-25dBZ	More images, going to nearly all ZR
12	M	11.0-11.0	314-325	2.9-3.1	Ditto, bband slightly lower to SW, A/C reaching base	Very few crystals
13	M-O	11.0-15.0	218-314	2.1-3.1	In & just below base of bband, 25-40 dBZ	Clim to 2900, changing to all ZR/ZL @end
14	P-S	7.0-22.0	218-356	1.8-6.1	In bband, 25-40 dBZ	Nearly all ZR/ZL first 80 sec, aggs @end
15	U	22-35	356-3.0	1.2-1.8	Same, moving NE into higher dBZ last half of period	Aggs increasing, ZR/R ending
16	T-U	35-47	3.0-12.0	0.9-1.2	Turn SE in 25-45 dBZ, in lower half of bband	Lowest T was at at the furthest N point
17	V	36-40	12.0-16.0	1.0-1.1	In lower half of bband, 35-45 dBZ	Aggs decreasing, ZR starting
18	V-Y	12.0-36.0	0.0-37.0	1.1-3.3	Along base of bband, across 20-35 dBZ	Aggs off & on, increasing @end
19	Z-FF	11.0-18.0	182-360	2.2-3.7	At base bband (20-35dBZ), then in bband (35-40dBZ)	More aggs @times, blobs like misshapen drops
20	DD-HH	7.0-23.0	46-182	1.8-7.3	In heart of bband (40-45 dBZ)	Climbed into warm nose @3400' by 1456Z, leveled
21	HH-II	9.0-9.0	28-46	5.7-7.8	Heading NW in area of 40-50 dBZ, upper half of bband	Bigger, cleaner looking aggs
22	HH-II	9.0-10.0	353-28	7.8-8.5	Just below top of bband @4900', 40-45 dBZ	LWC comes and goes quickly
23	HH-II	10.0-11.0	314-353	7.4-7.8	Ditto, but 35-40 dBZ	Some small drops, heading SW
24	JJ-KK	11.0-20.0	264-314	4.0-7.4	Ditto	Xls more discernable at times
25	LL-OO	20-23	258-264	3.9-4.4	25-40 dBZ, climbed to top of bband	LWC briefly returns
26	NN	23-32	247-258	3.0-4.2	Along & just above bband top, 20-30 dBZ	Some cleaner xls, climed to top alt of 5950'
27	OO-QQ	28-32	233-247	2.6-3.0	Descend to top of bband, 30-40 dBZ	Start final descent into IND
28	QQ	23-28	230-233	2.5-2.7	Into top part of bband, 30-40 dBZ	In the top of the melting layer
29	QQ	15-23	228-230	2.4-2.8	Descending through bottom 1/2 of bband, 25-45 dBZ	Bottom part of melting layer
30	PP-QQ	4.0-15.0	230-244	0.0-2.4	Bottom of and beneath bband in 20-35 dBZ	Descending thru supercooled layer, IP observed by crew



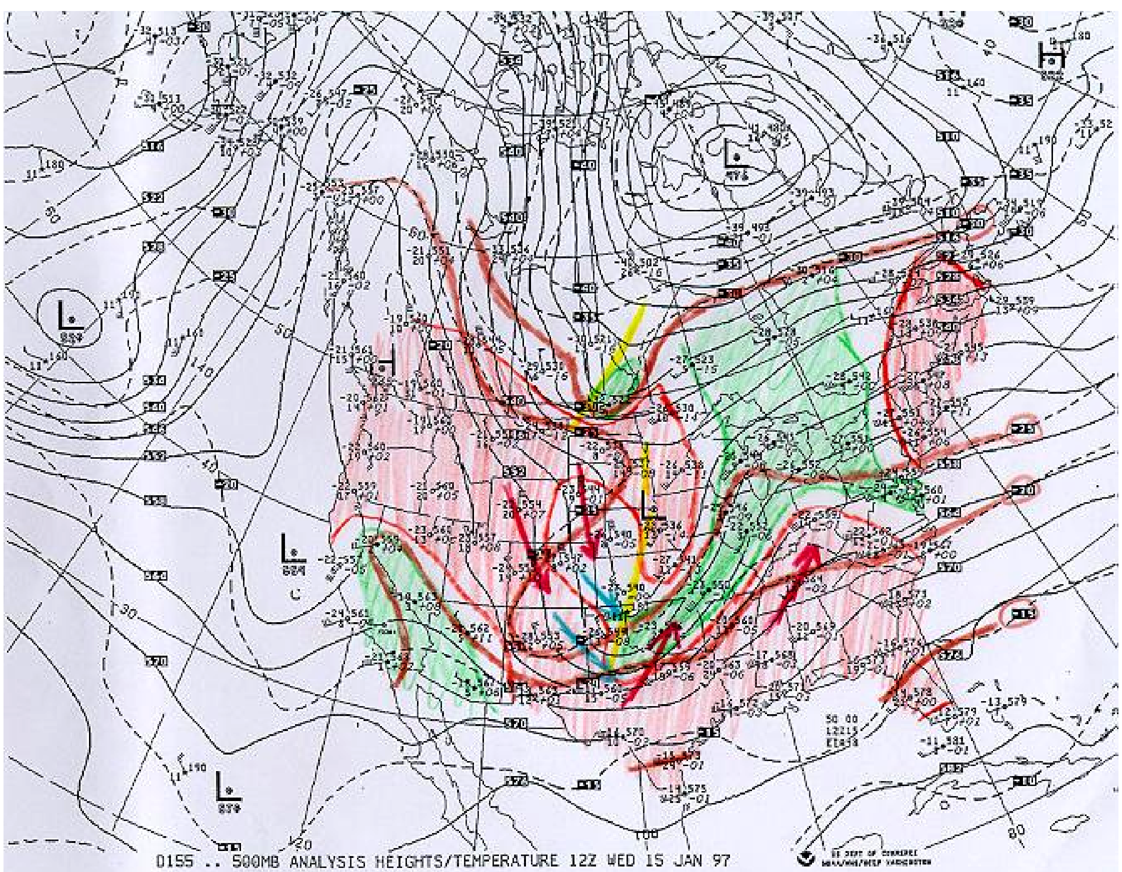


Figure 1 – Upper-air charts for 970115, 1200 UTC at a) 300 and b) 500 mb.

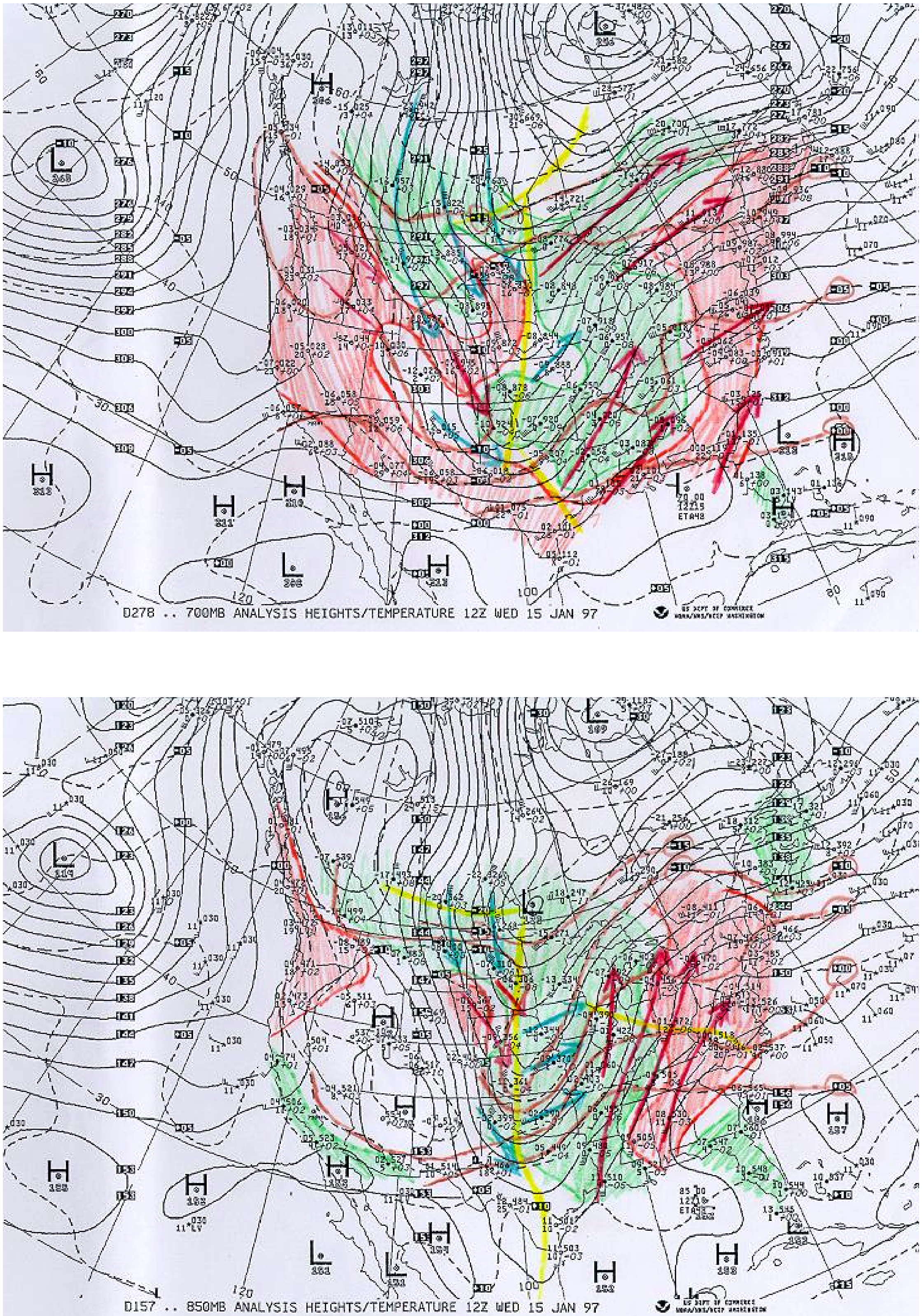


Figure 1 – Upper-air charts for 970115, 1200 UTC at c) 700 and d) 850 mb.

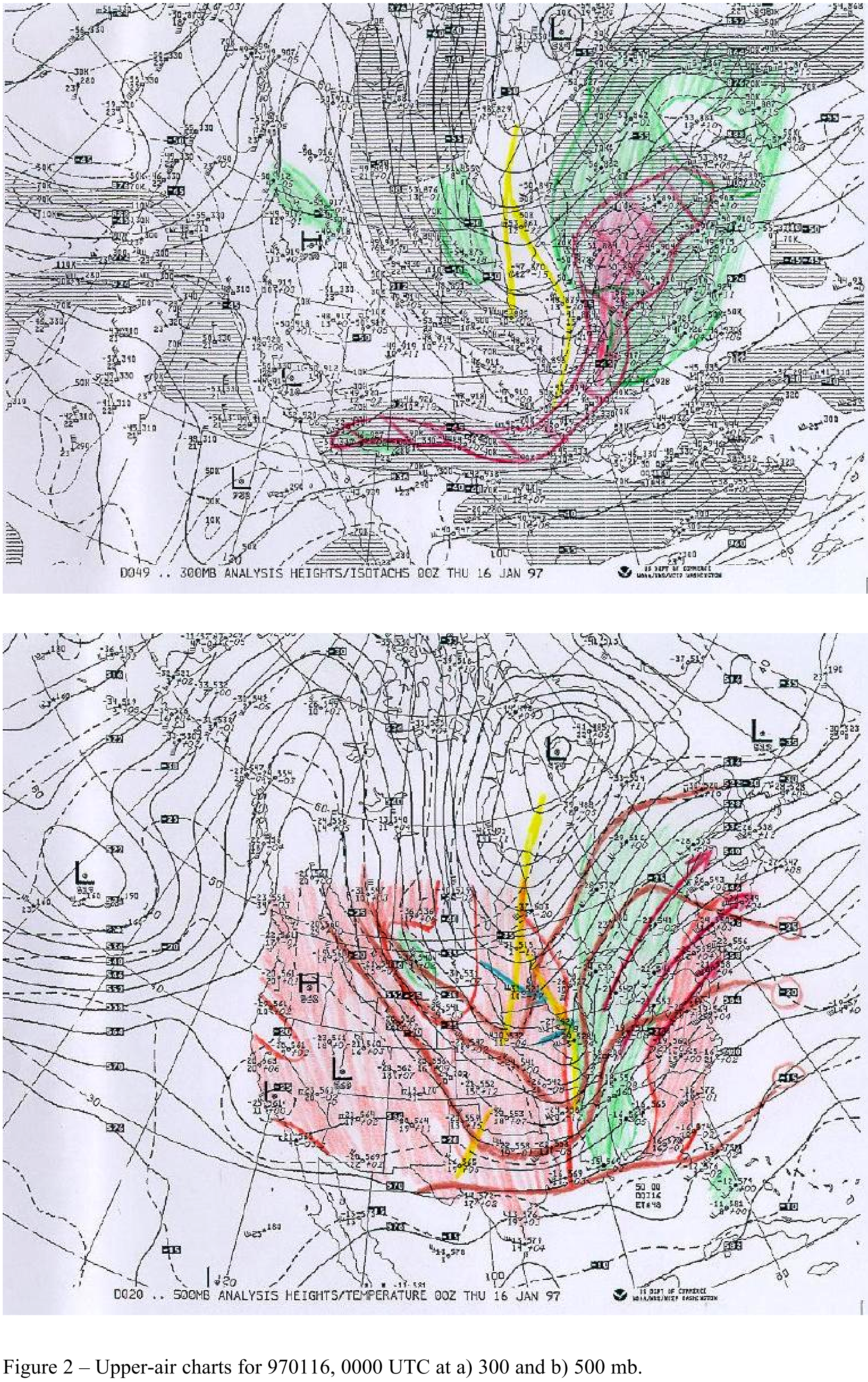


Figure 2 – Upper-air charts for 970116, 0000 UTC at a) 300 and b) 500 mb.

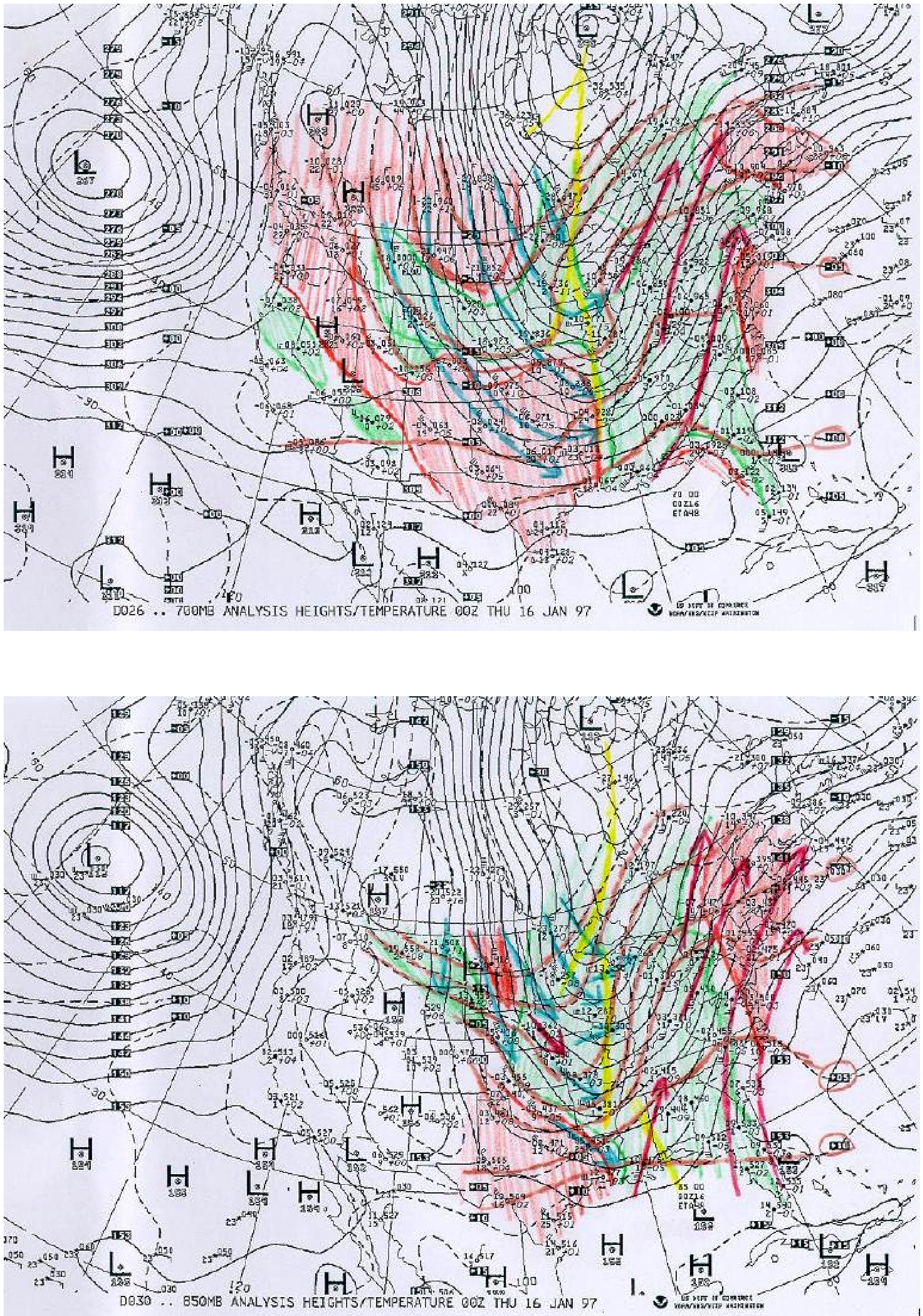


Figure 2 – Upper-air charts for 970116, 0000 UTC at c) 700 and d) 850 mb.

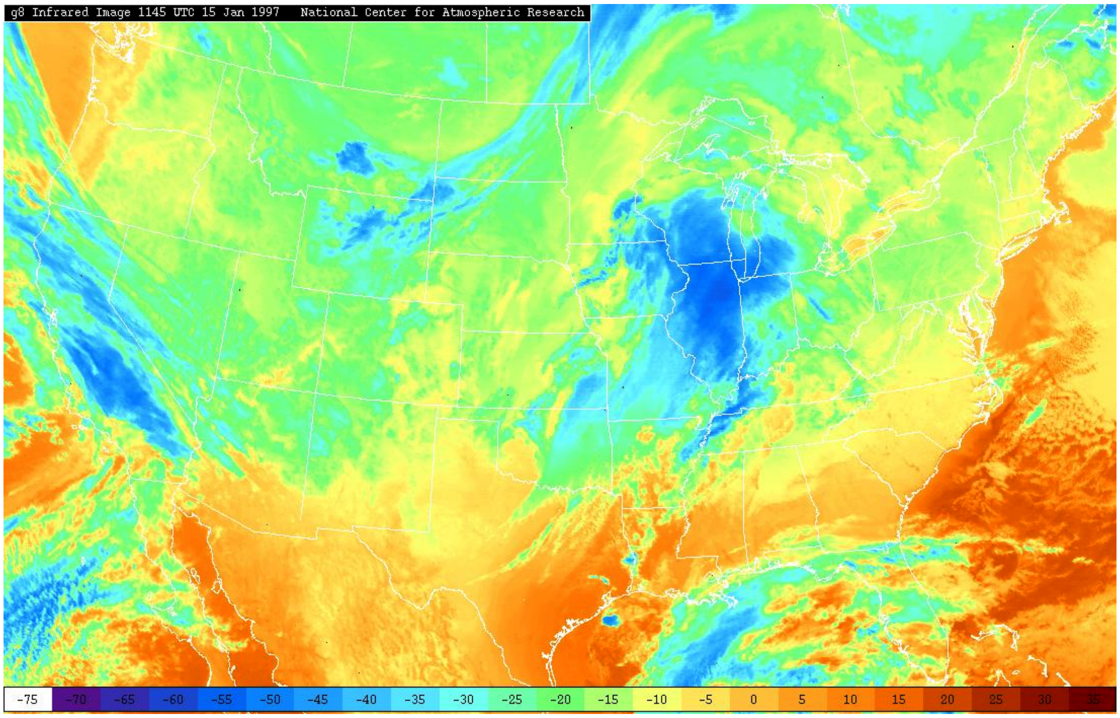
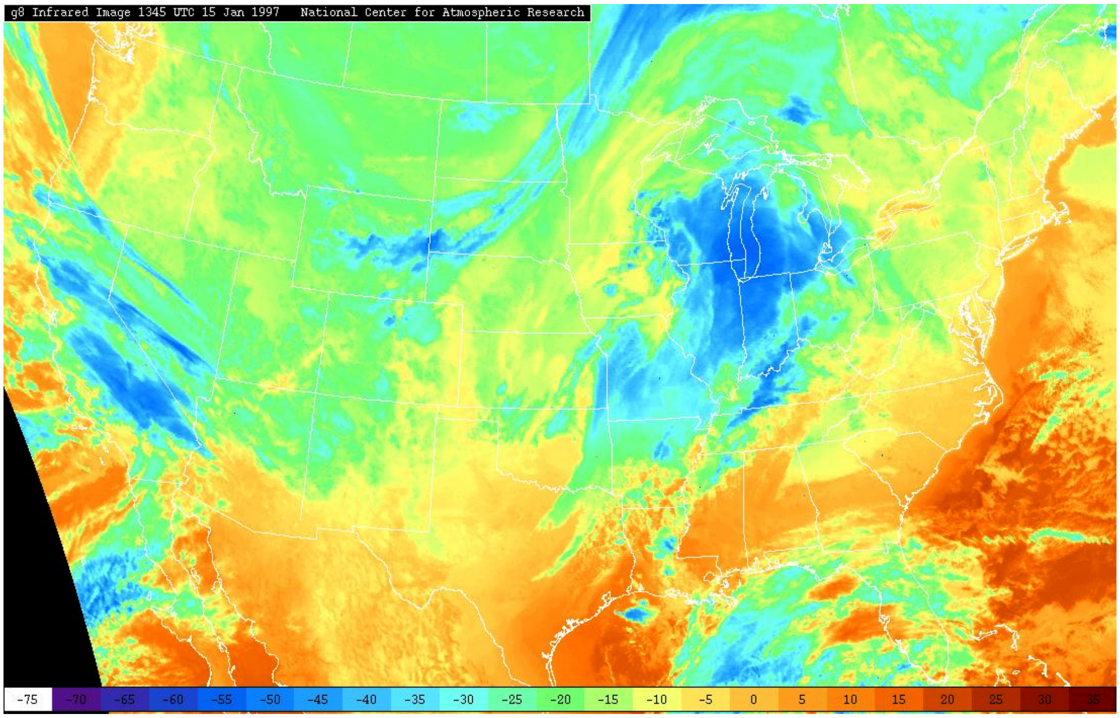


Figure 3 – GOES-8 infrared satellite data for 970115 at a) 1145 UTC.



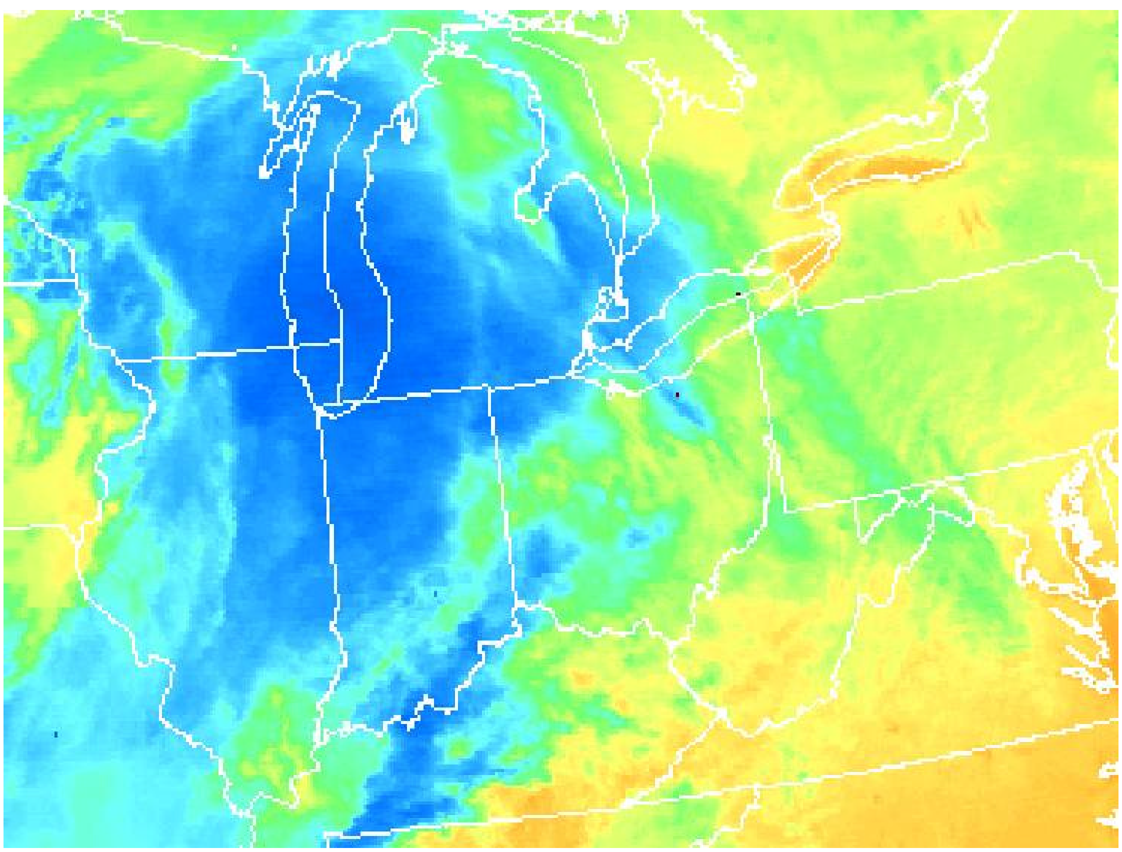


Figure 3 – GOES-8 infrared satellite data for 970115 at 1345 UTC, for b) continental United States, and c) Ohio Valley region.

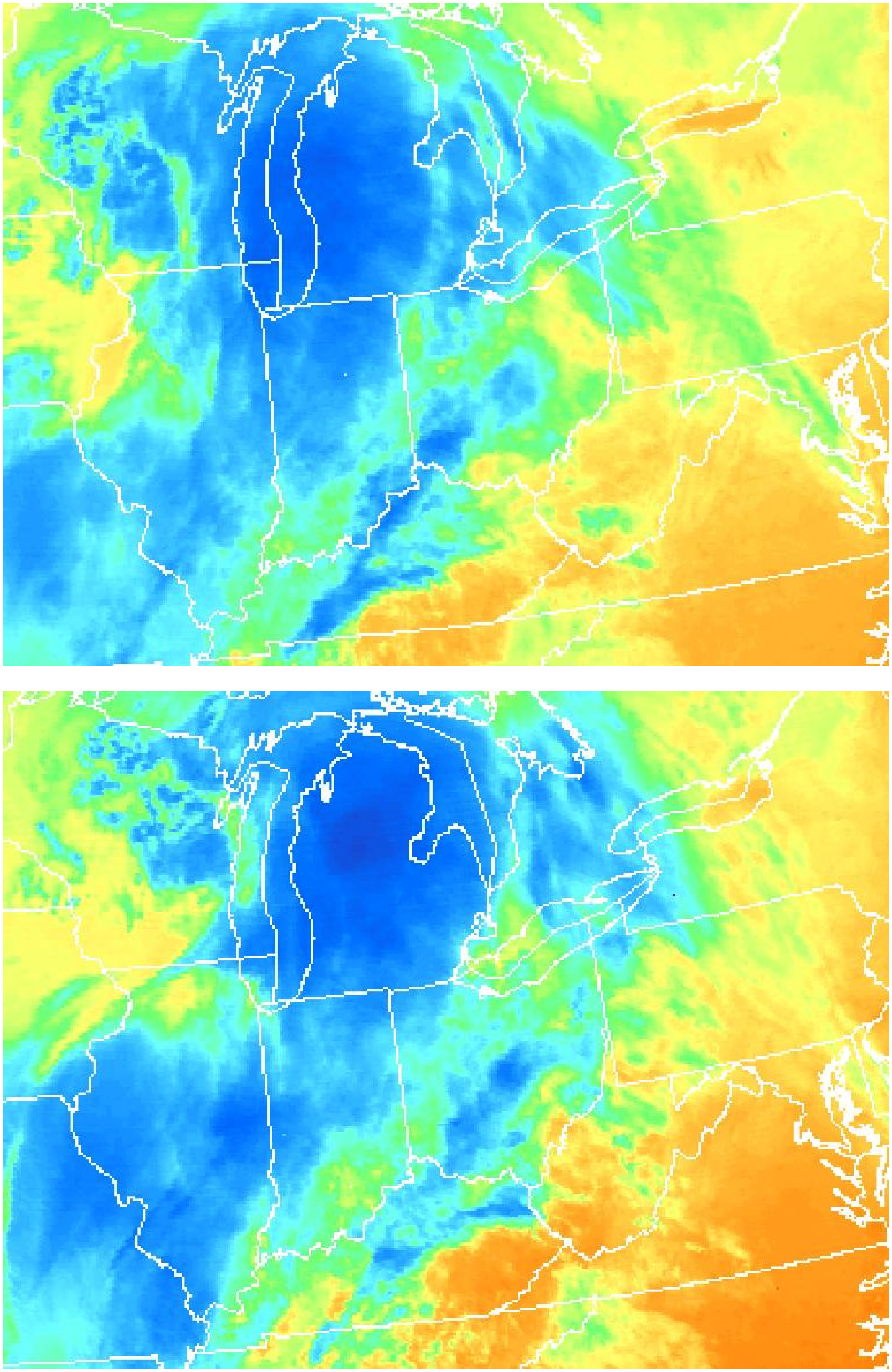


Figure 3 – GOES-8 infrared satellite data for 970115 for Ohio Valley region at d) 1445 and e) 1615 UTC.

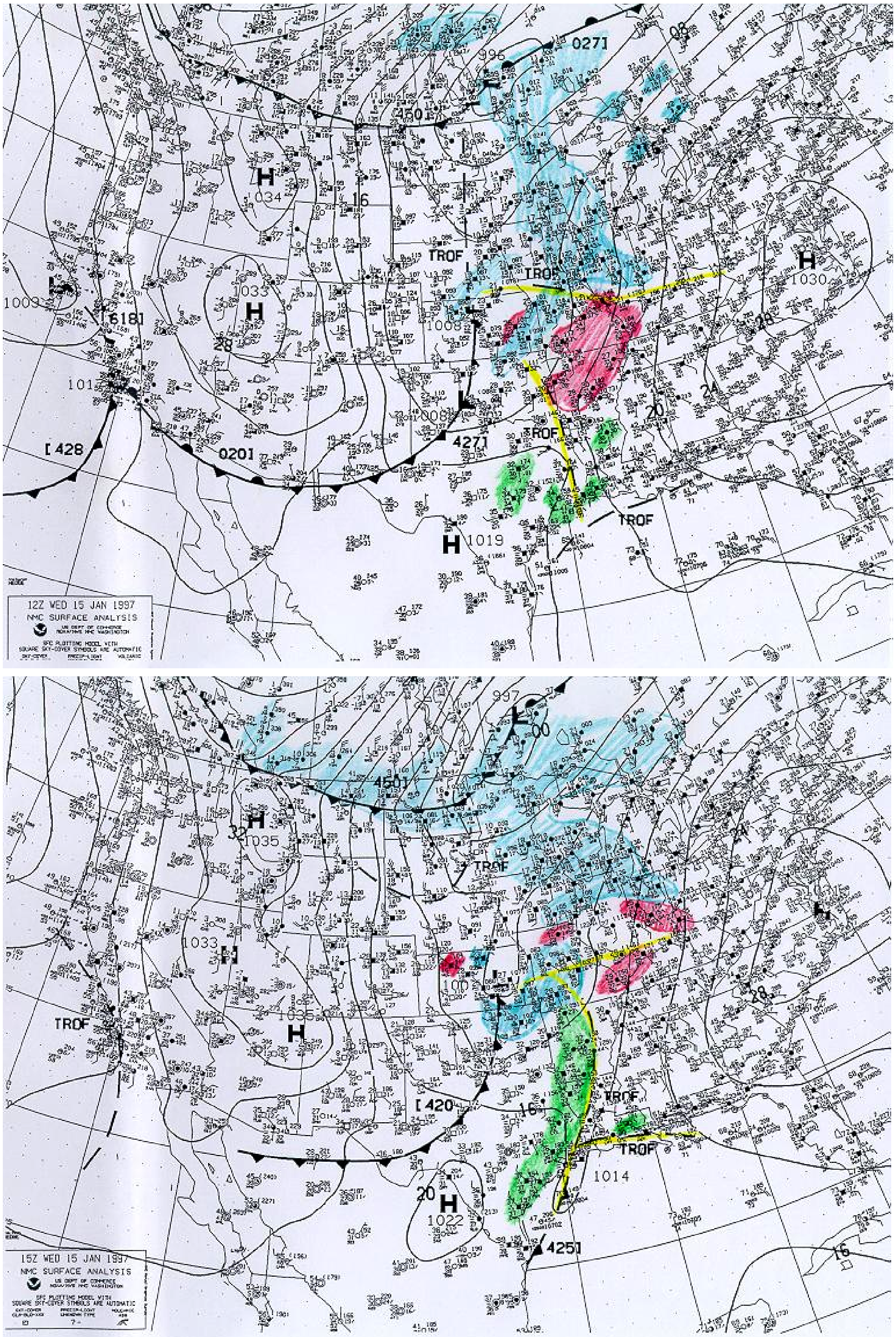


Figure 4 – Surface charts for 970115 at a) 1200 and b) 1500 UTC.

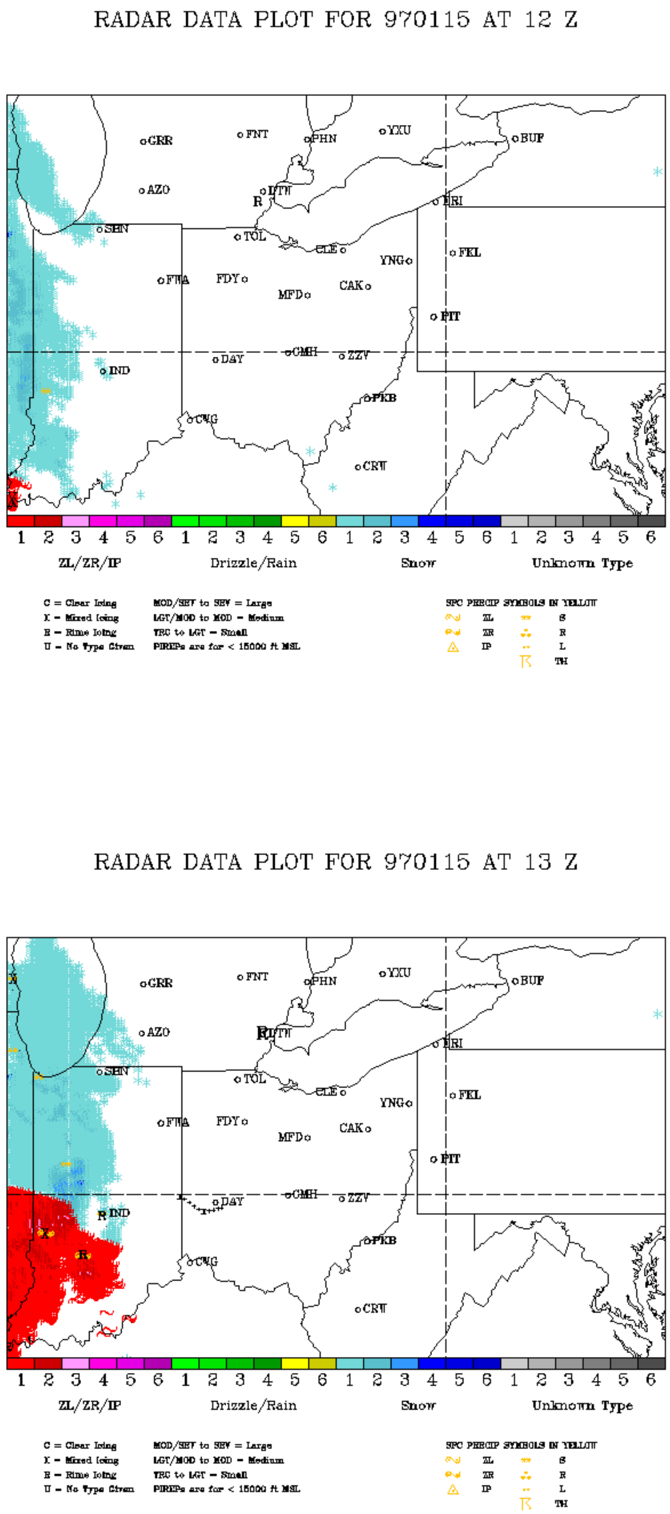
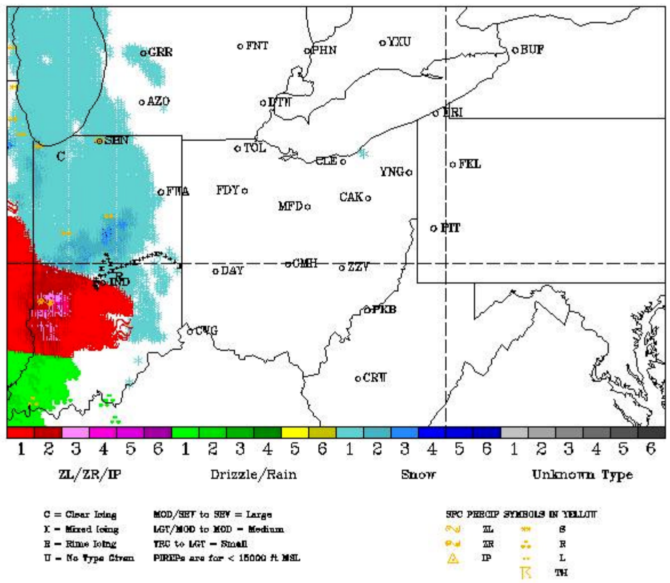


Figure 5 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970115, a) 1200 and b) 1300 UTC.

RADAR DATA PLOT FOR 970115 AT 14 Z



RADAR DATA PLOT FOR 970115 AT 15 Z

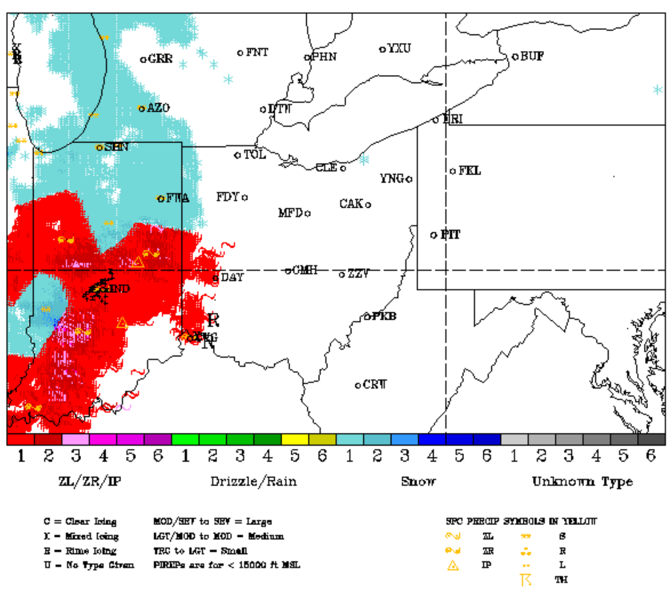
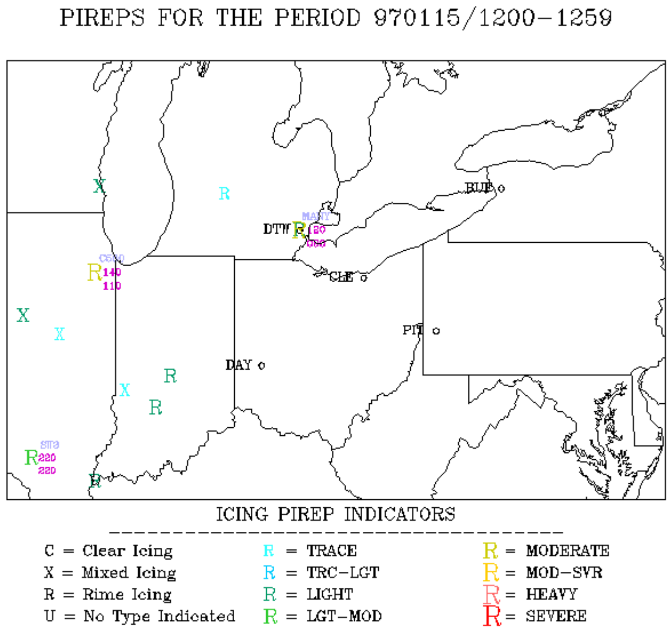


Figure 5 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970115, c) 1400 and d) 1500 UTC.



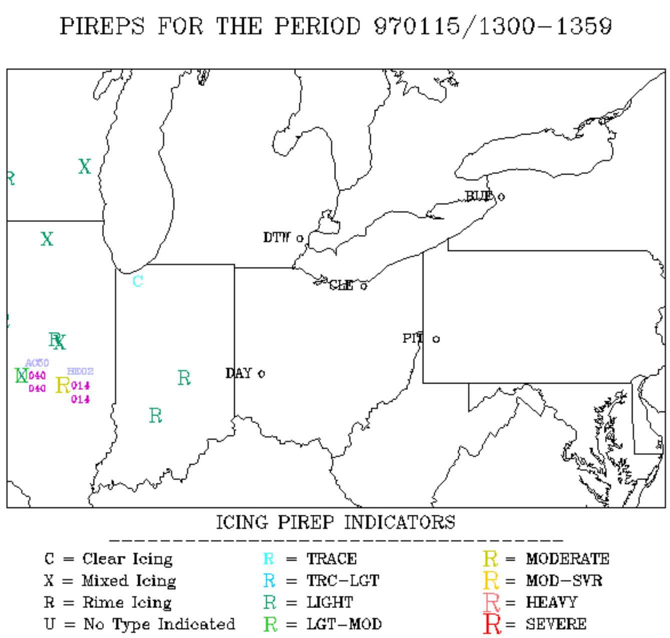
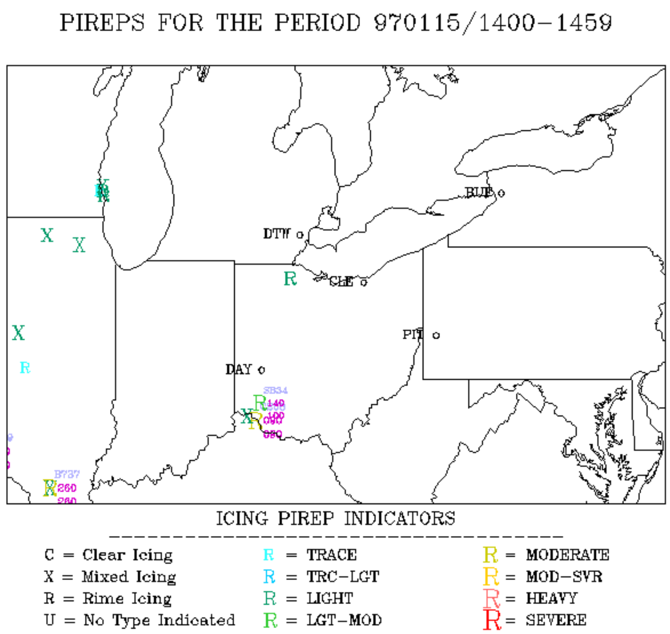


Figure 6 – Pilot reports of icing for 970115, a) 1200-1259 and b) 1300-1359 UTC.



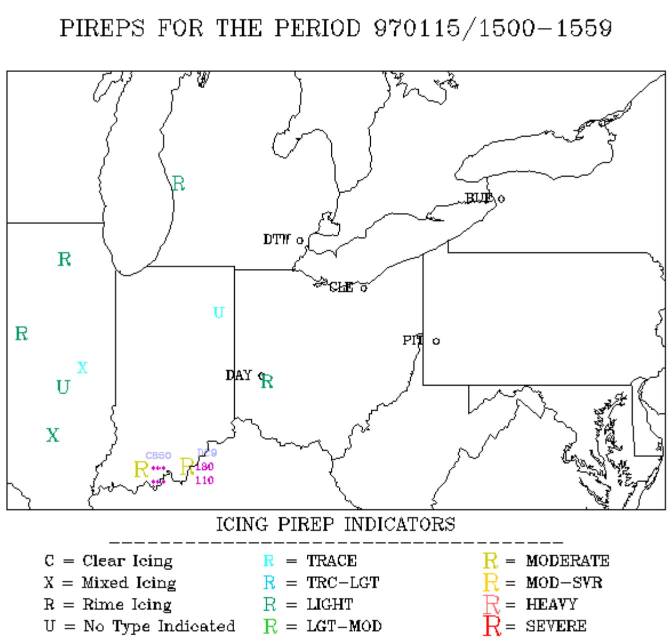


Figure 6 – Pilot reports of icing for 970115, c) 1400-1459 and d) 1500-1559 UTC.

970115 - Flight #1

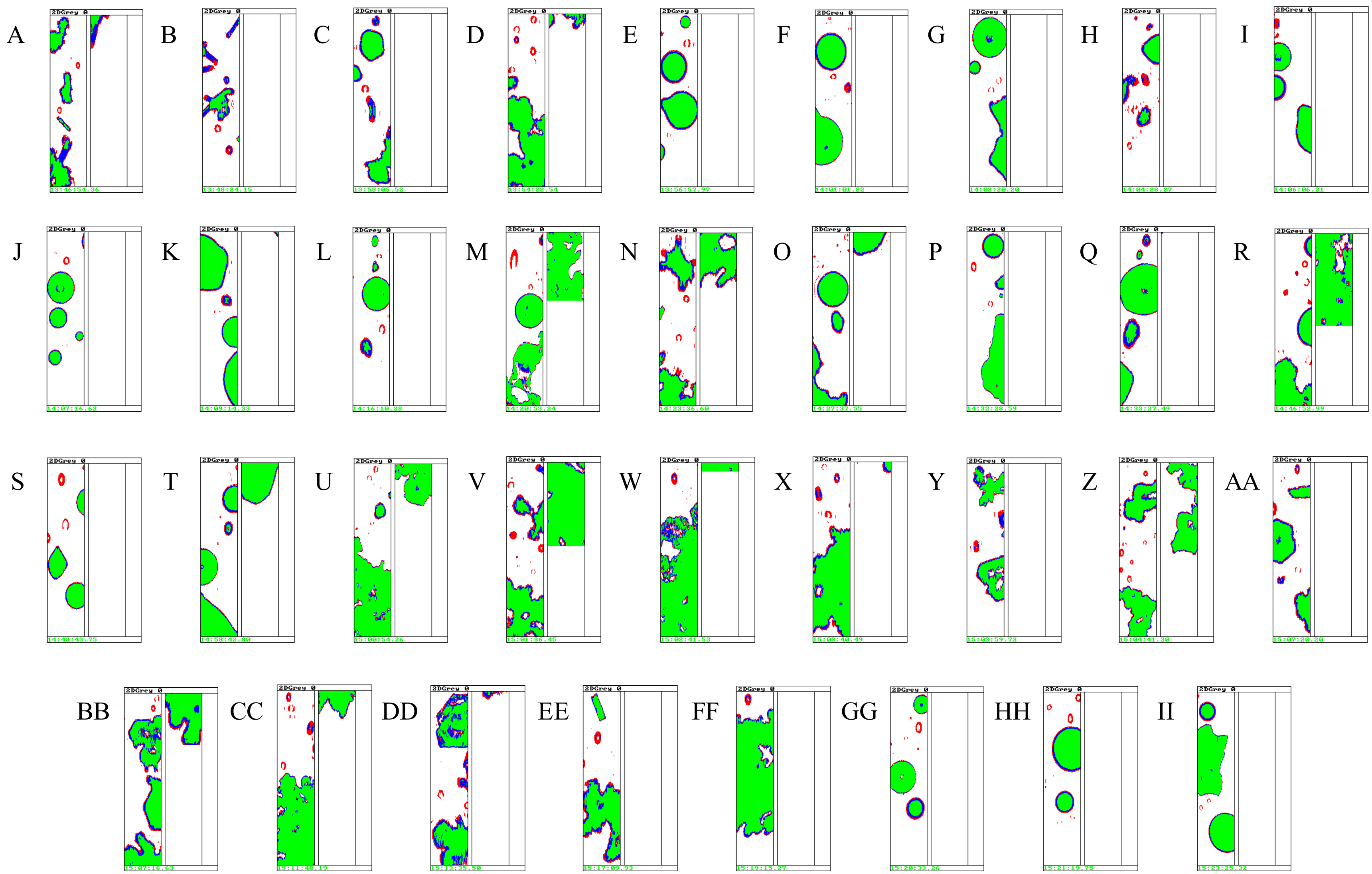


Figure 7 - 2D-grey probe imagery for flight 1.

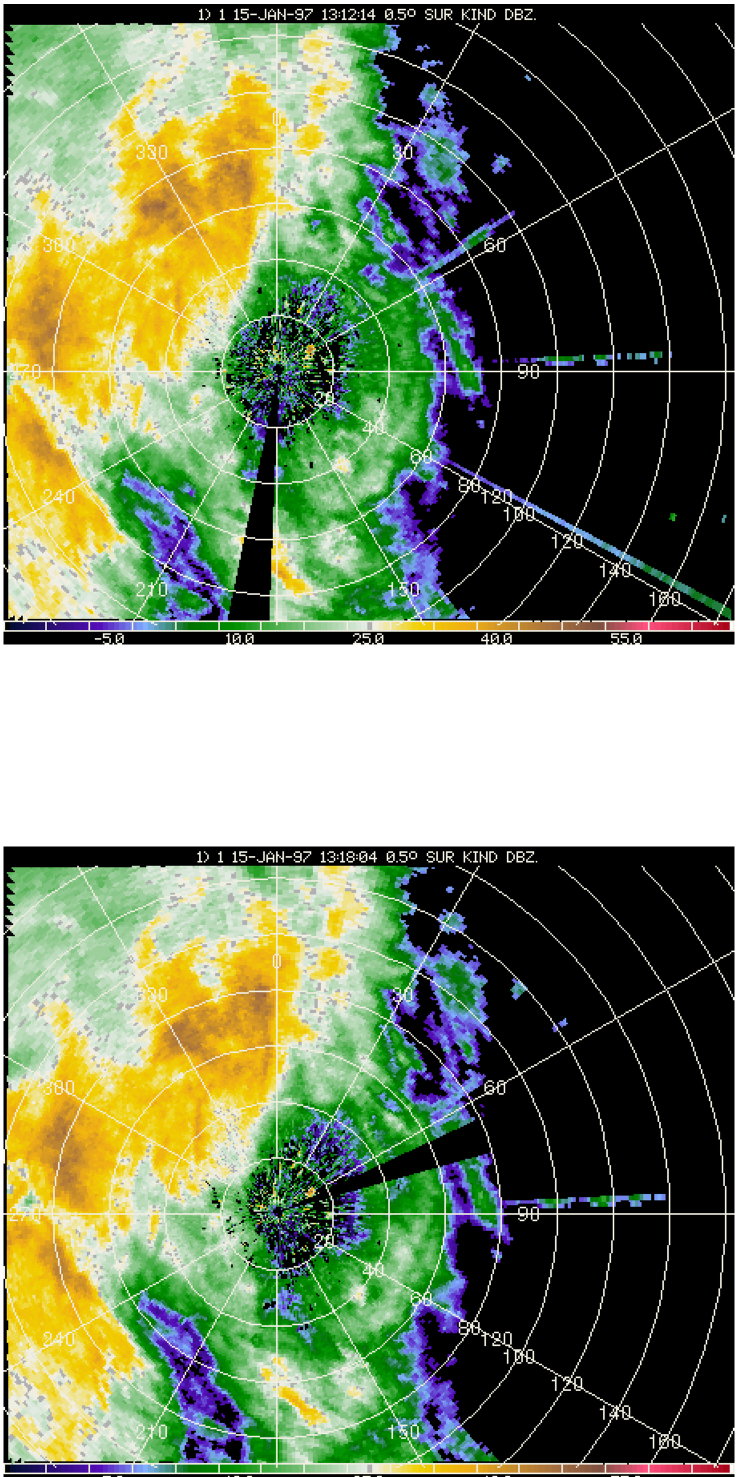
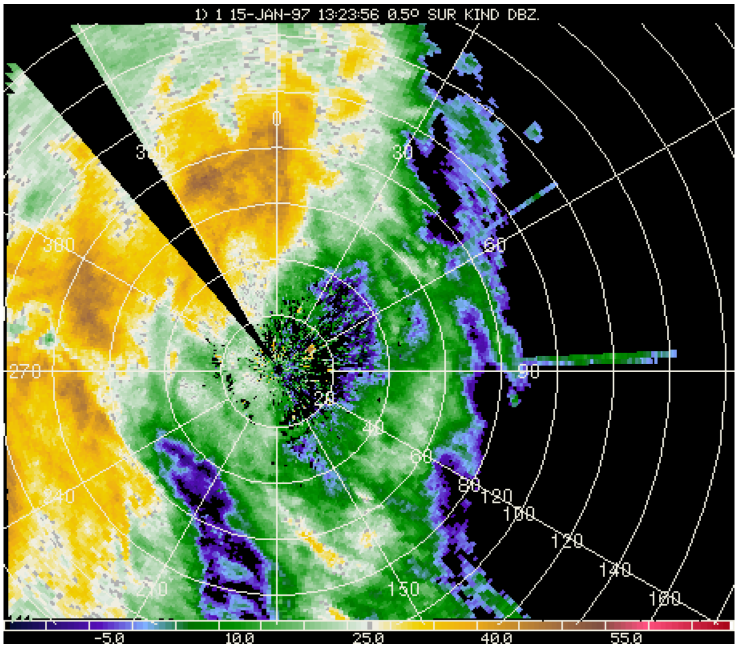


Figure 8 – Indianapolis NEXRAD data for 970115, a) 1312 and b) 1318 UTC (0.5 degrees elevation).



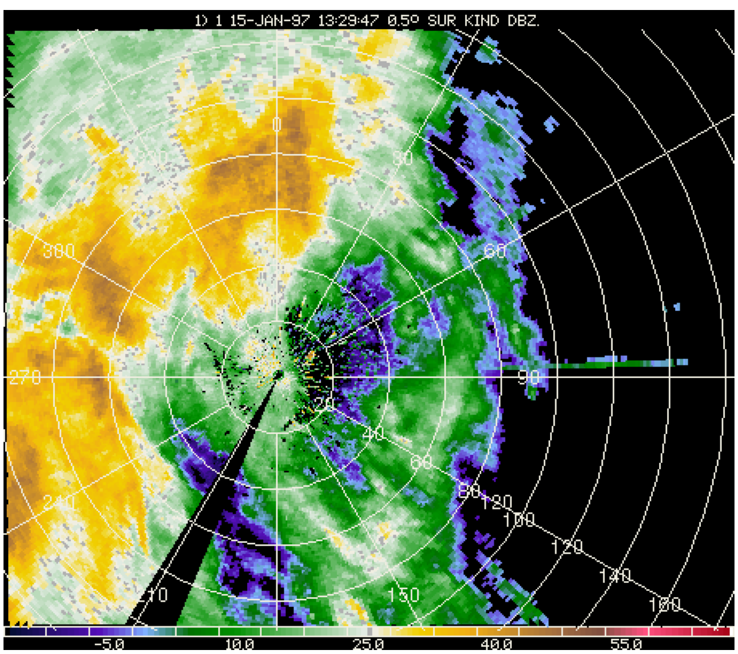
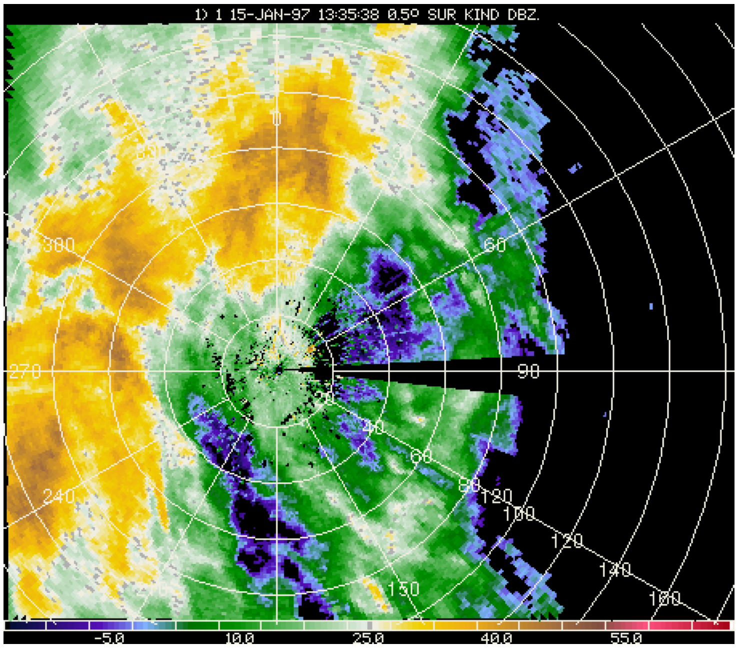


Figure 8 – Same, but for c) 1323 (0.5) and d) 1329 UTC (0.5).



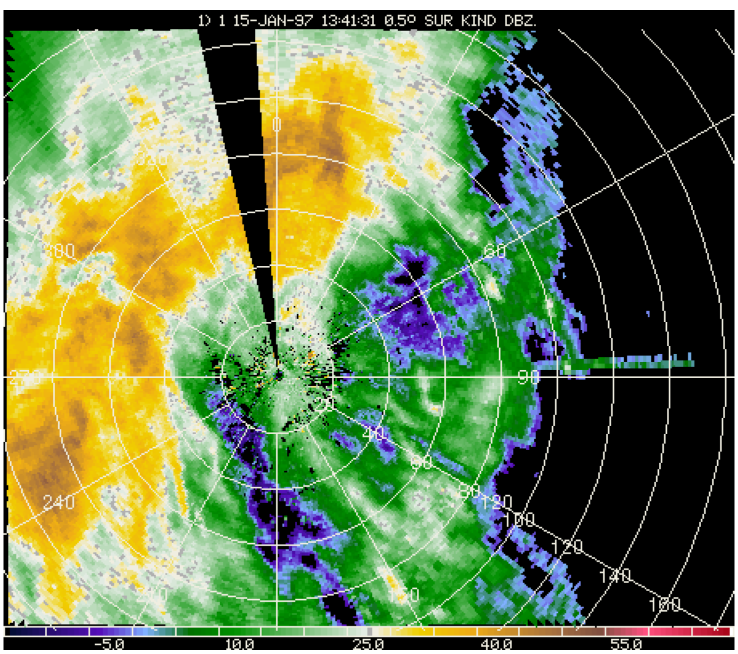
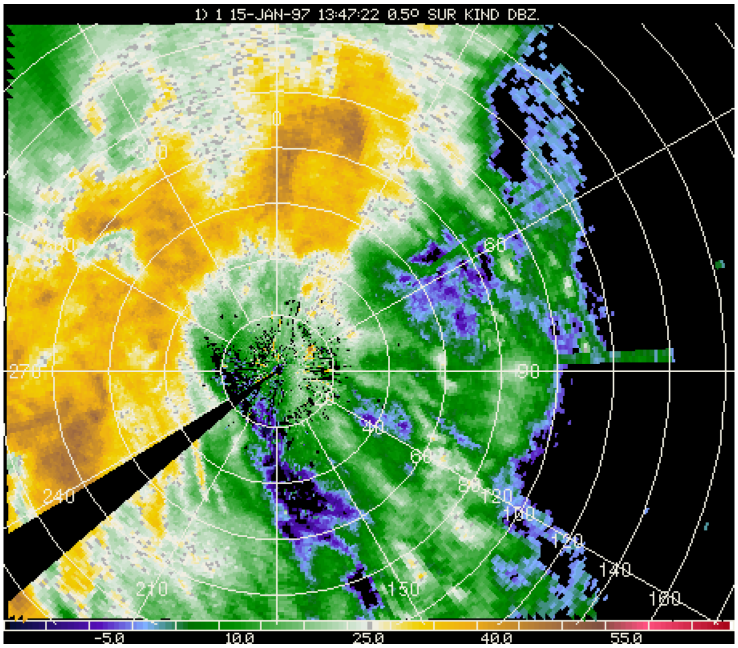


Figure 8 – Same, but for e) 1335 (0.5) and f) 1341 UTC (0.5).



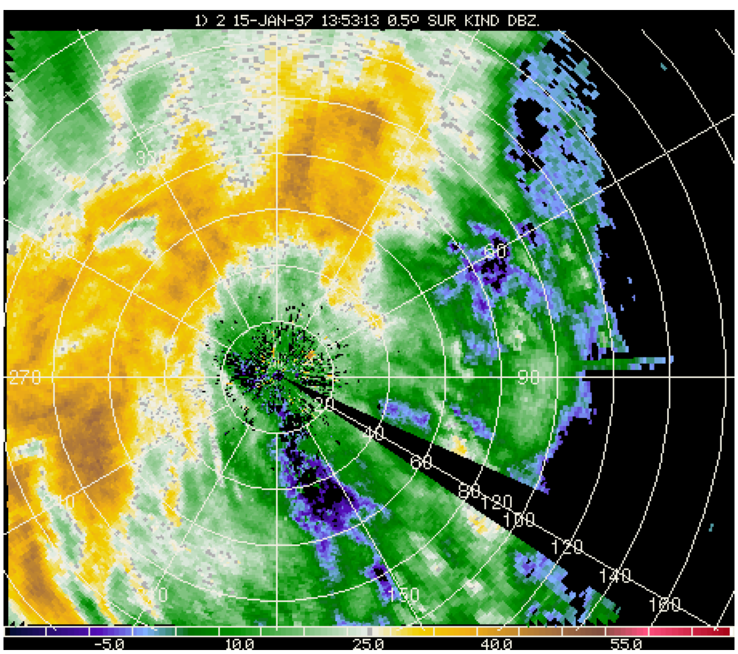
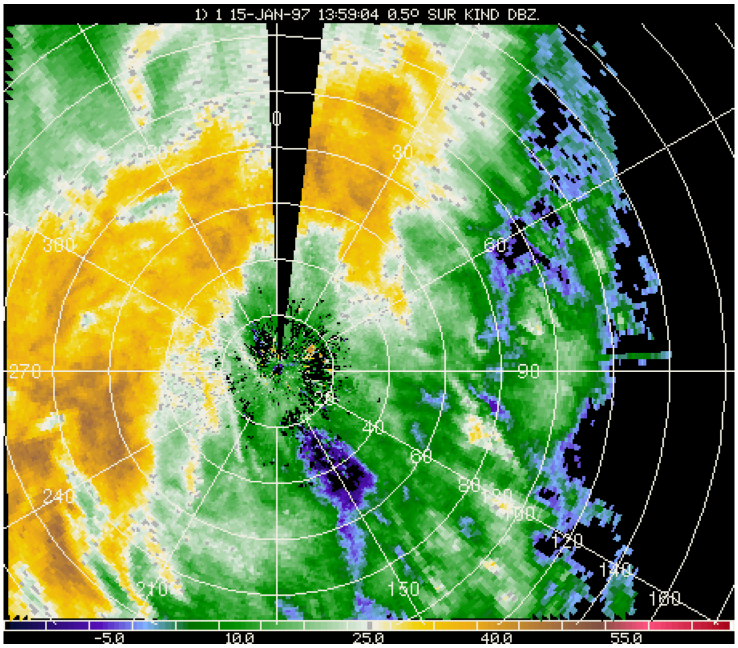


Figure 8 – Same, but for g) 1347 (0.5) and h) 1353 UTC (0.5).



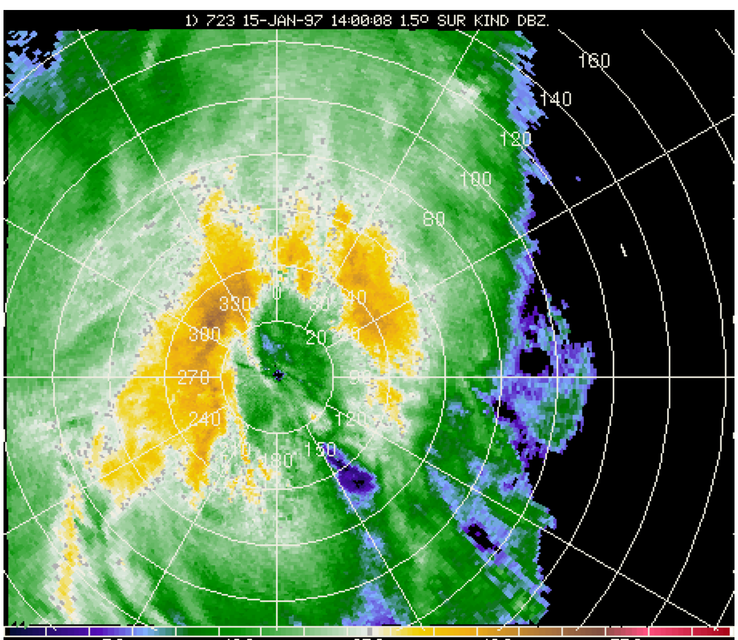
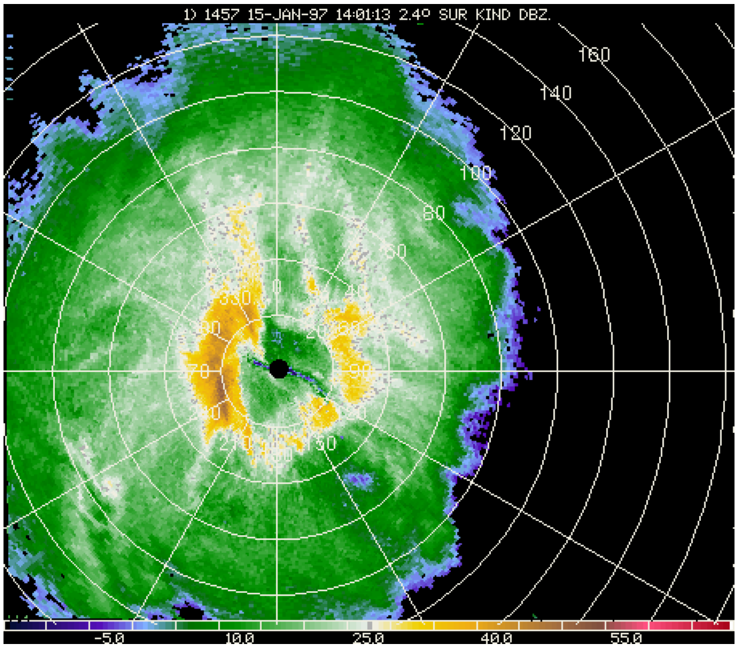


Figure 8 – Same, but for i) 1359 (0.5) and j) 1400 UTC (1.5).



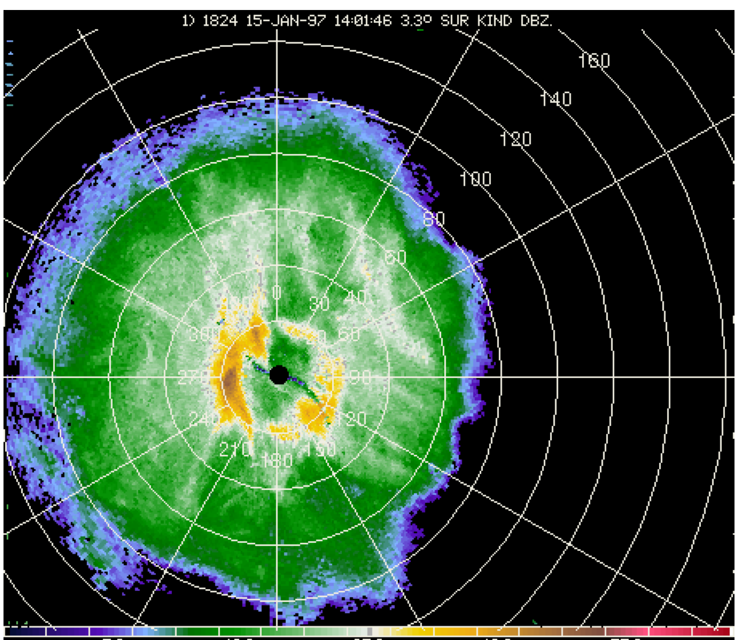


Figure 8 – Same, but for k) 1401 (2.4) and l) 1401 UTC (3.3).

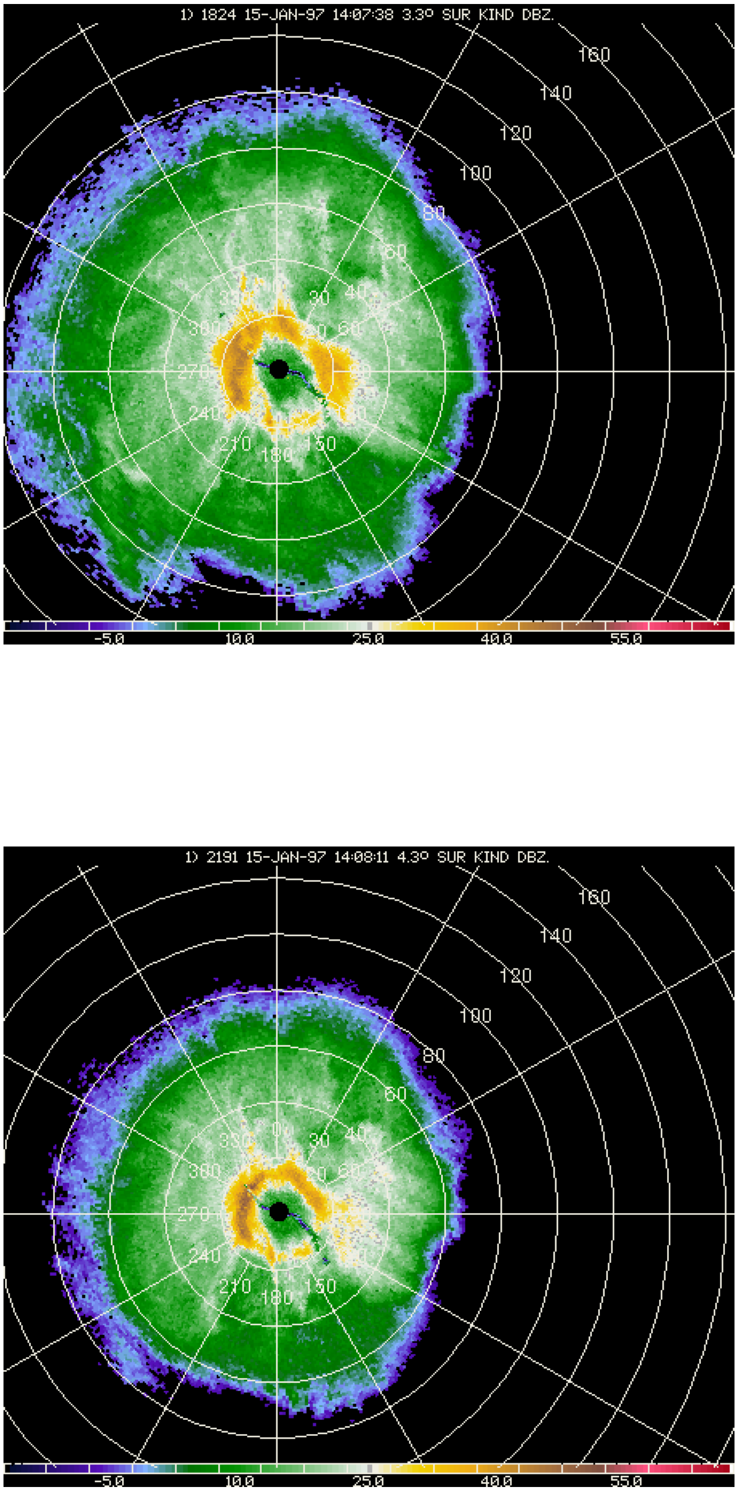
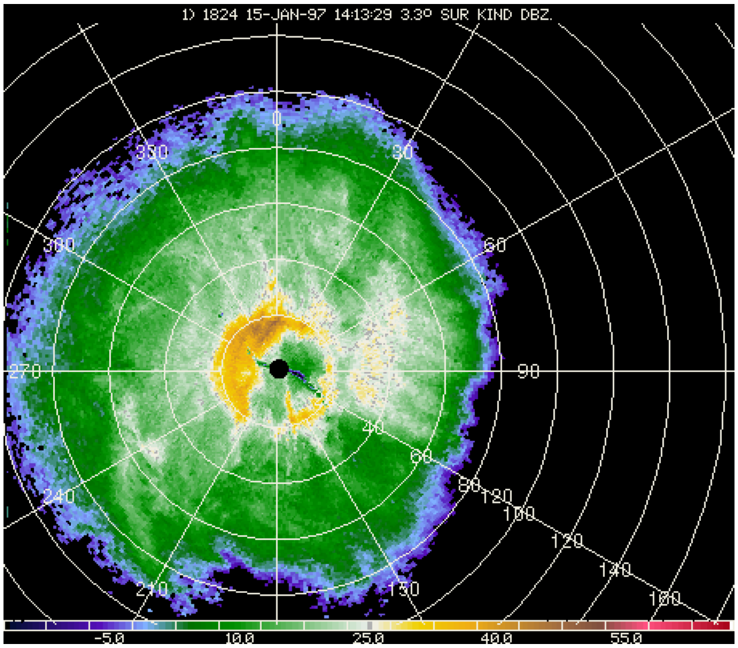


Figure 8 – Same, but for m) 1407 (3.3) and n) 1408 UTC (4.3).



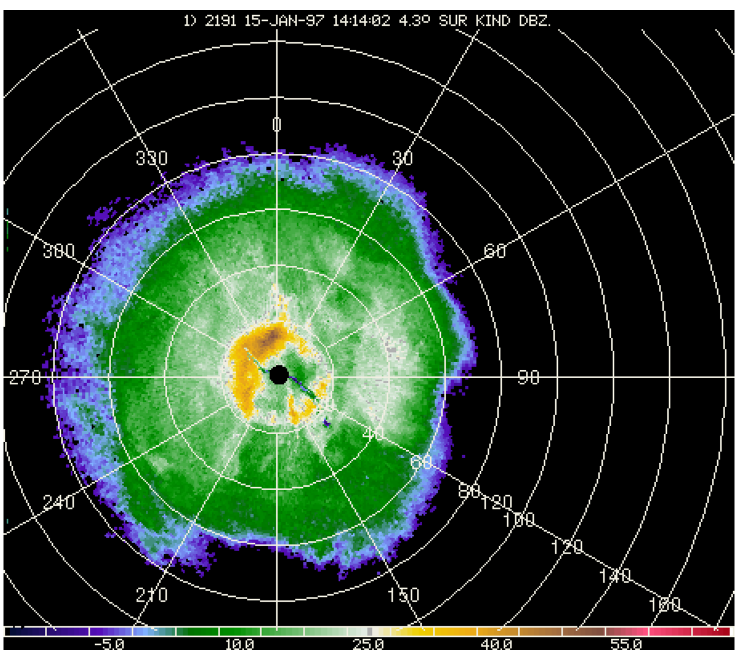
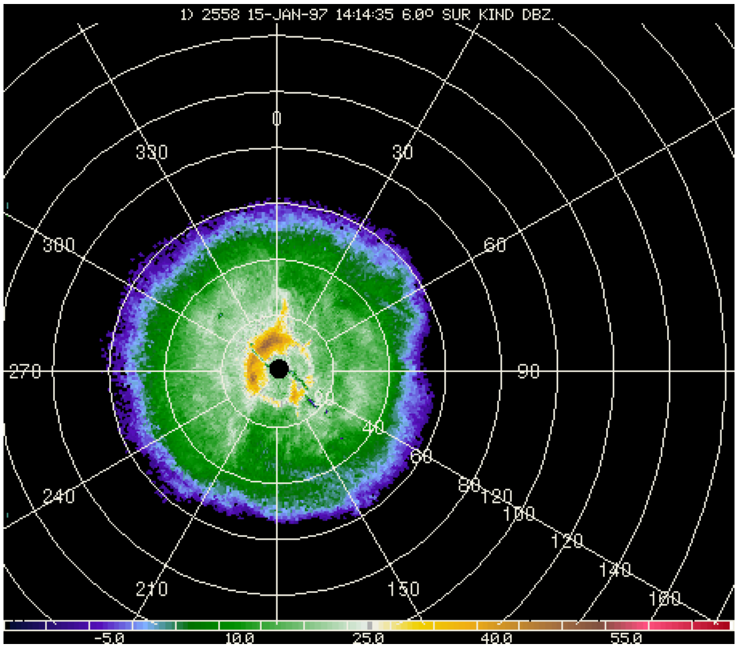


Figure 8 – Same, but for o) 1413 (3.3) and p) 1414 UTC (4.3).



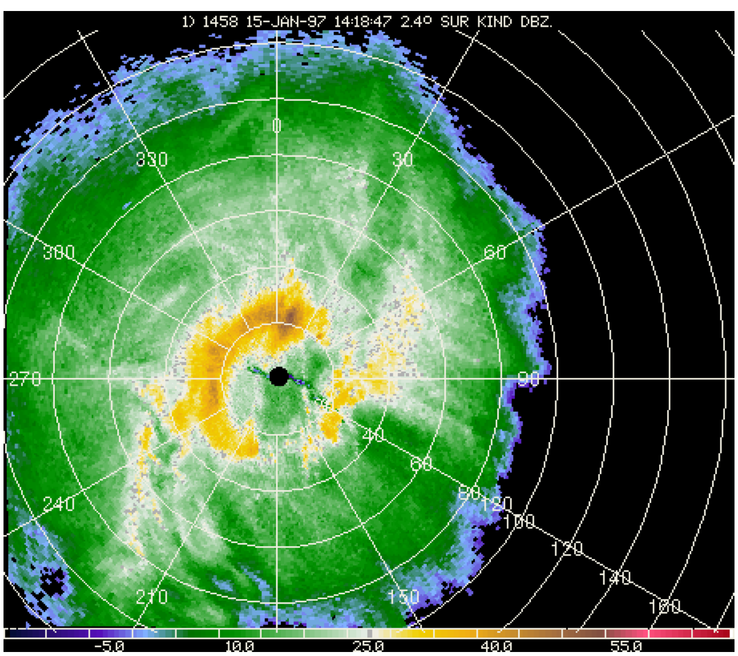
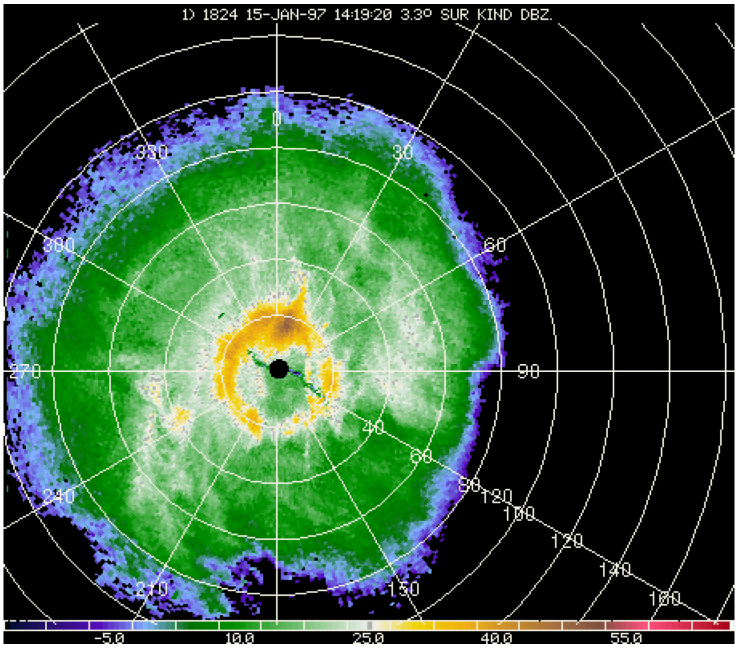


Figure 8 – Same, but for q) 1414 (6.0) and r) 1418 UTC (2.4).



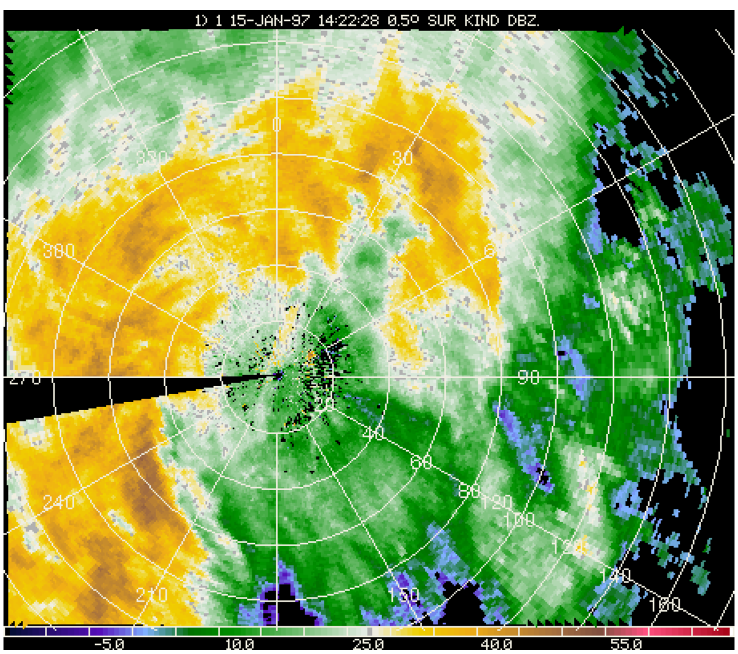
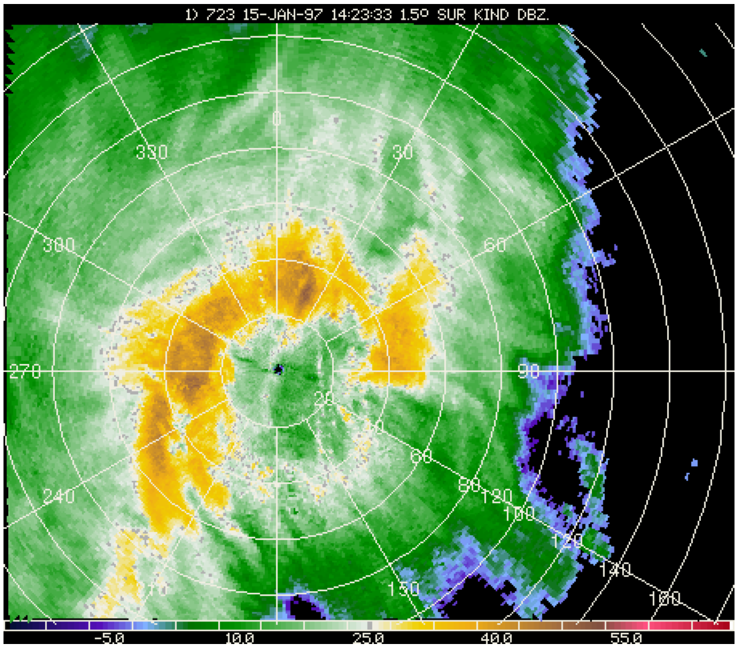


Figure 8 – Same, but for s) 1419 (3.3) and t) 1422 UTC (0.5).



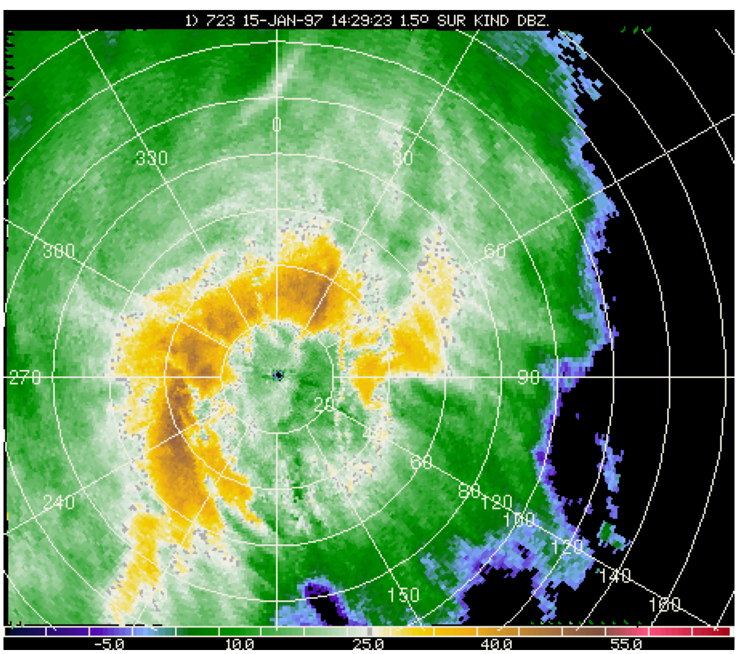
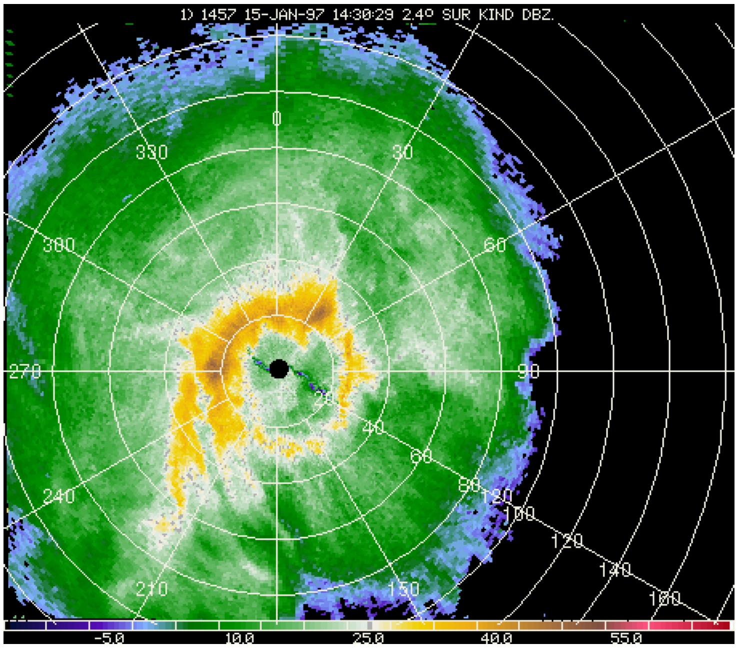


Figure 8 – Same, but for u) 1423 (1.5) and v) 1429 UTC (1.5).



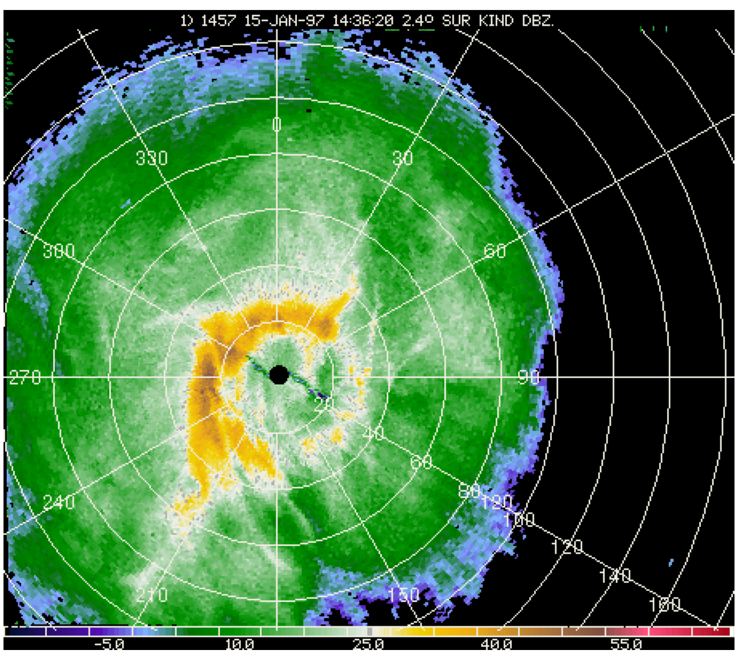
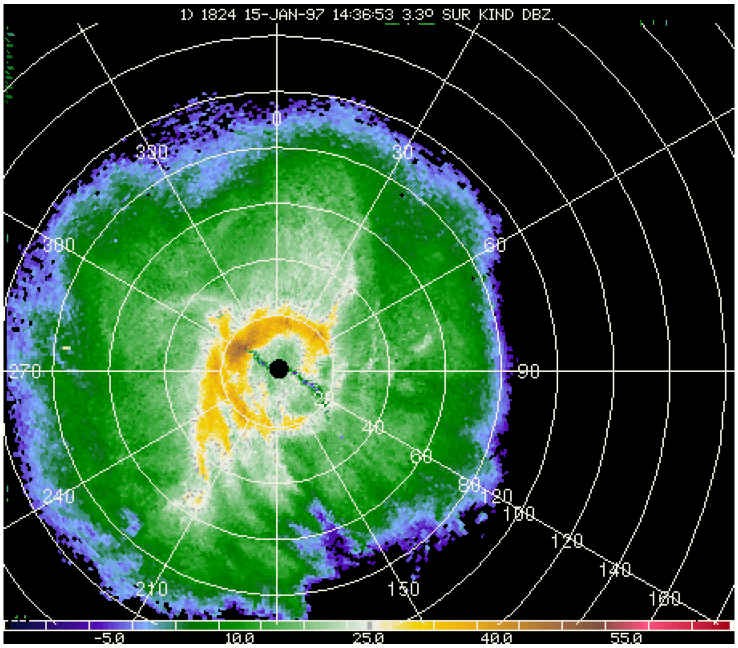


Figure 8 – Same, but for w) 1430 (2.4) and x) 1436 UTC (2.4).



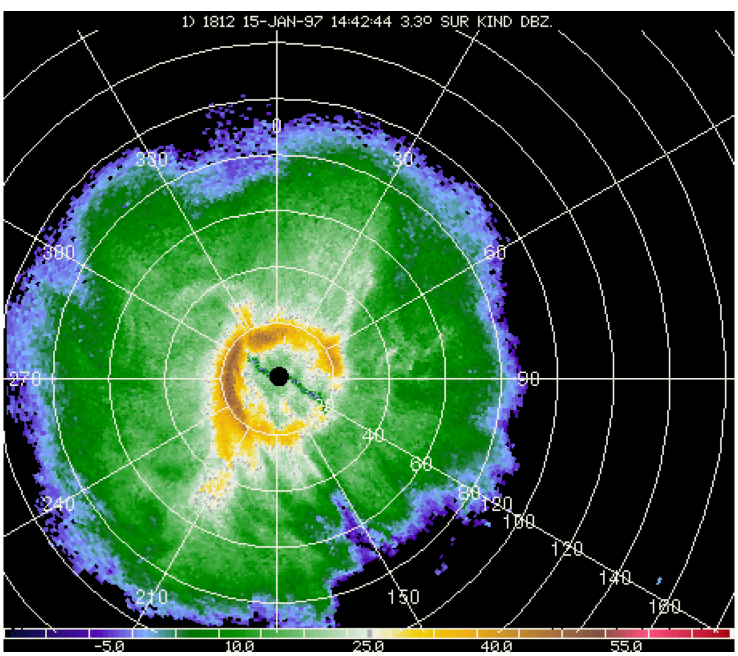
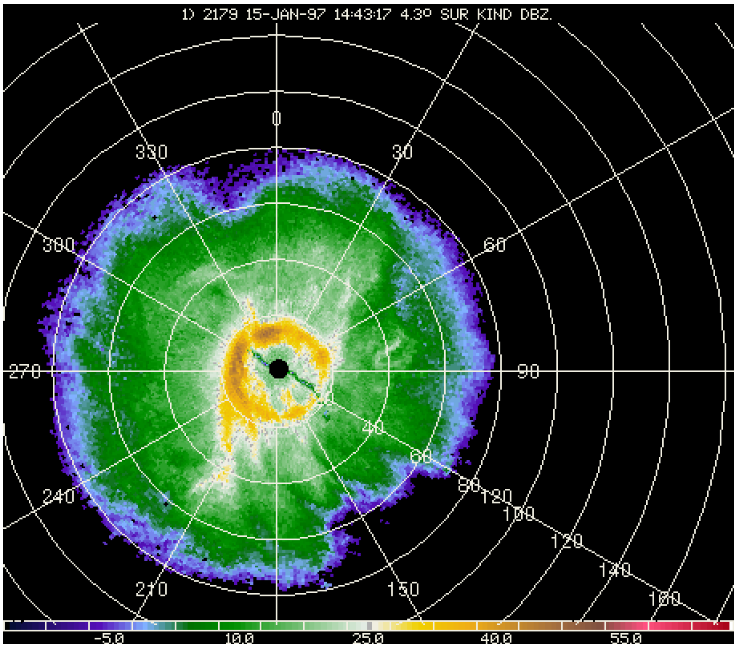


Figure 8 – Same, but for y) 1436 (3.3) and z) 1442 UTC (3.3).



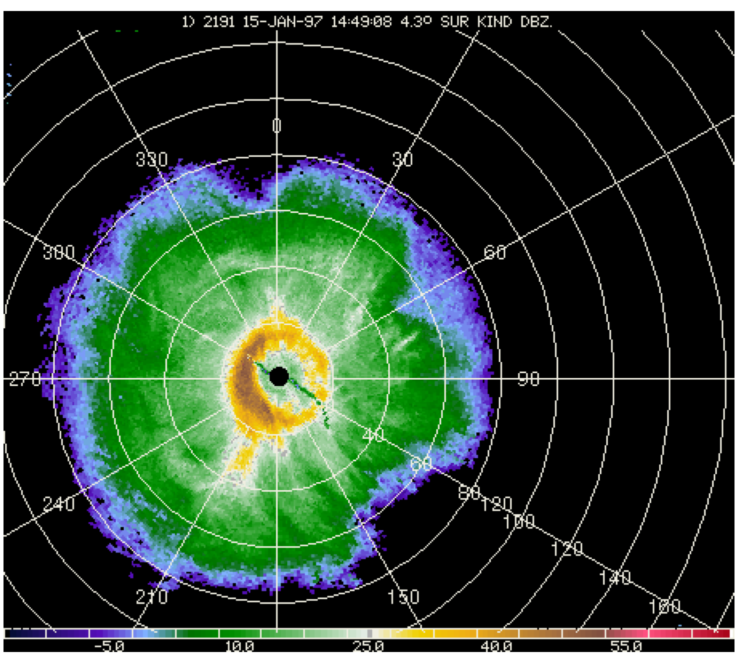
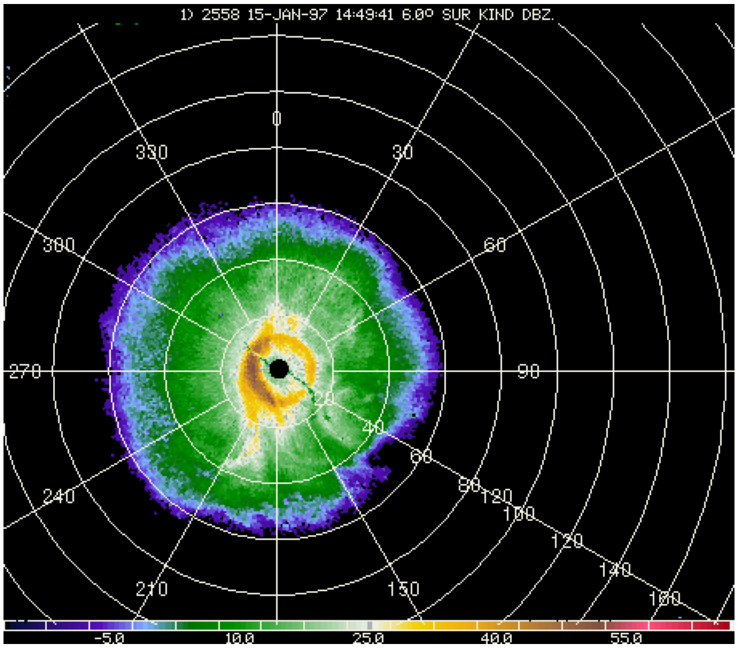


Figure 8 – Same, but for aa) 1443 (4.3) and bb) 1449 UTC (4.3).



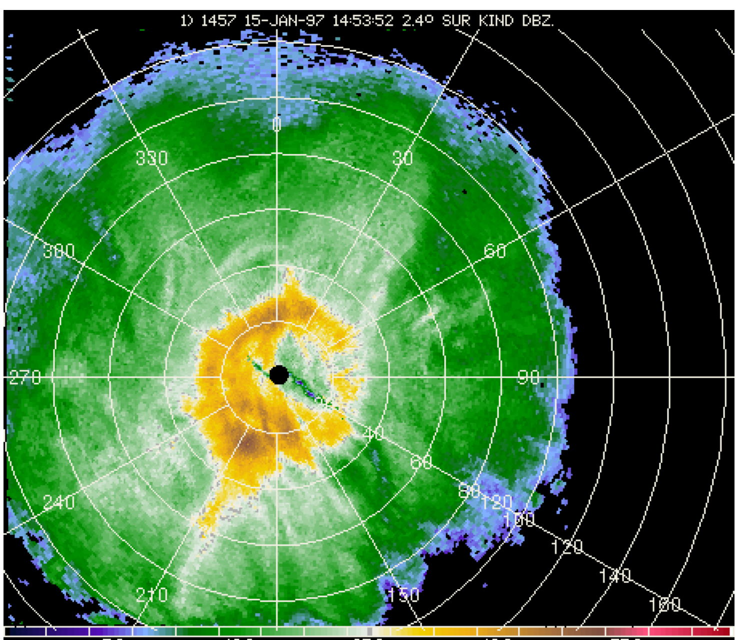


Figure 8 – Same, but for cc) 1449 (6.0) and dd) 1453 UTC (2.4).

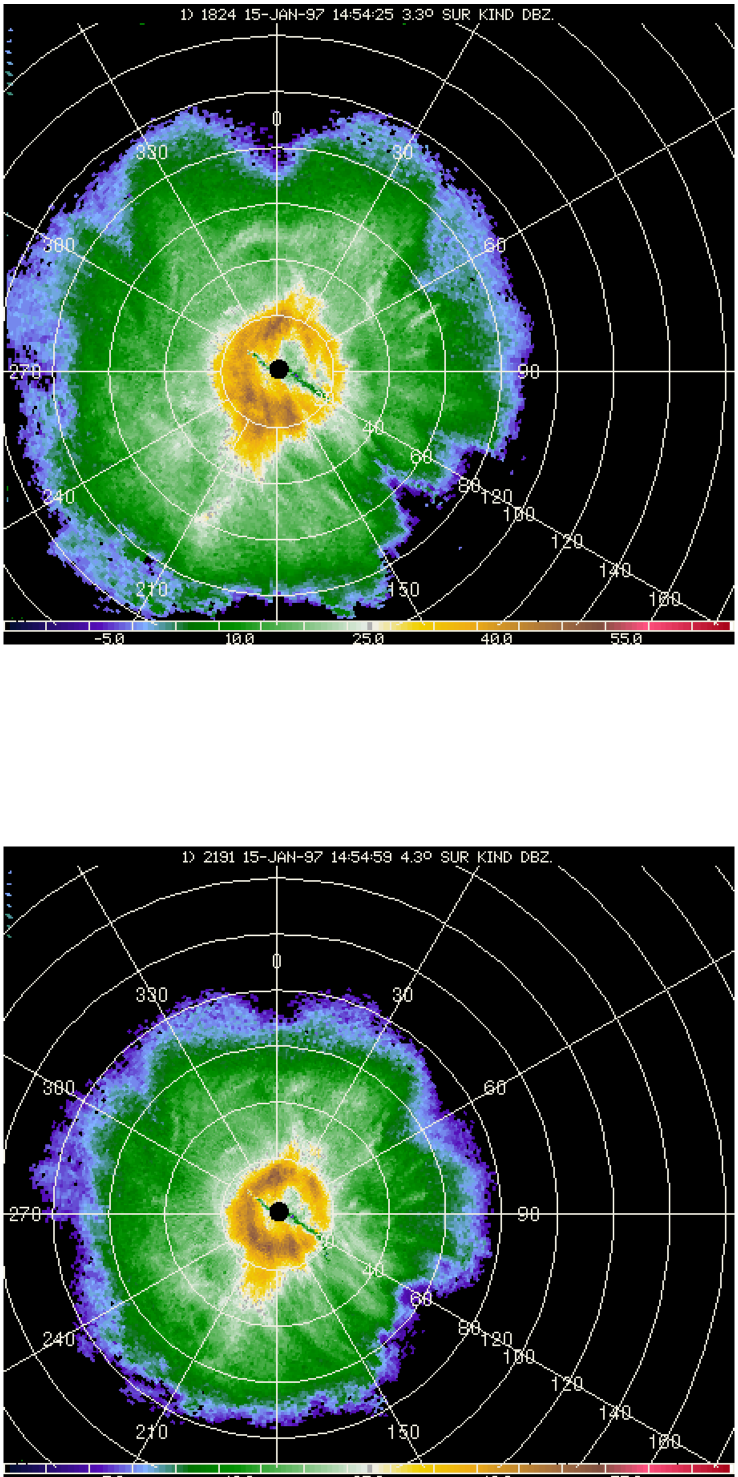


Figure 8 – Same, but for ee) 1454 (3.3) and ff) 1454 UTC (4.3).

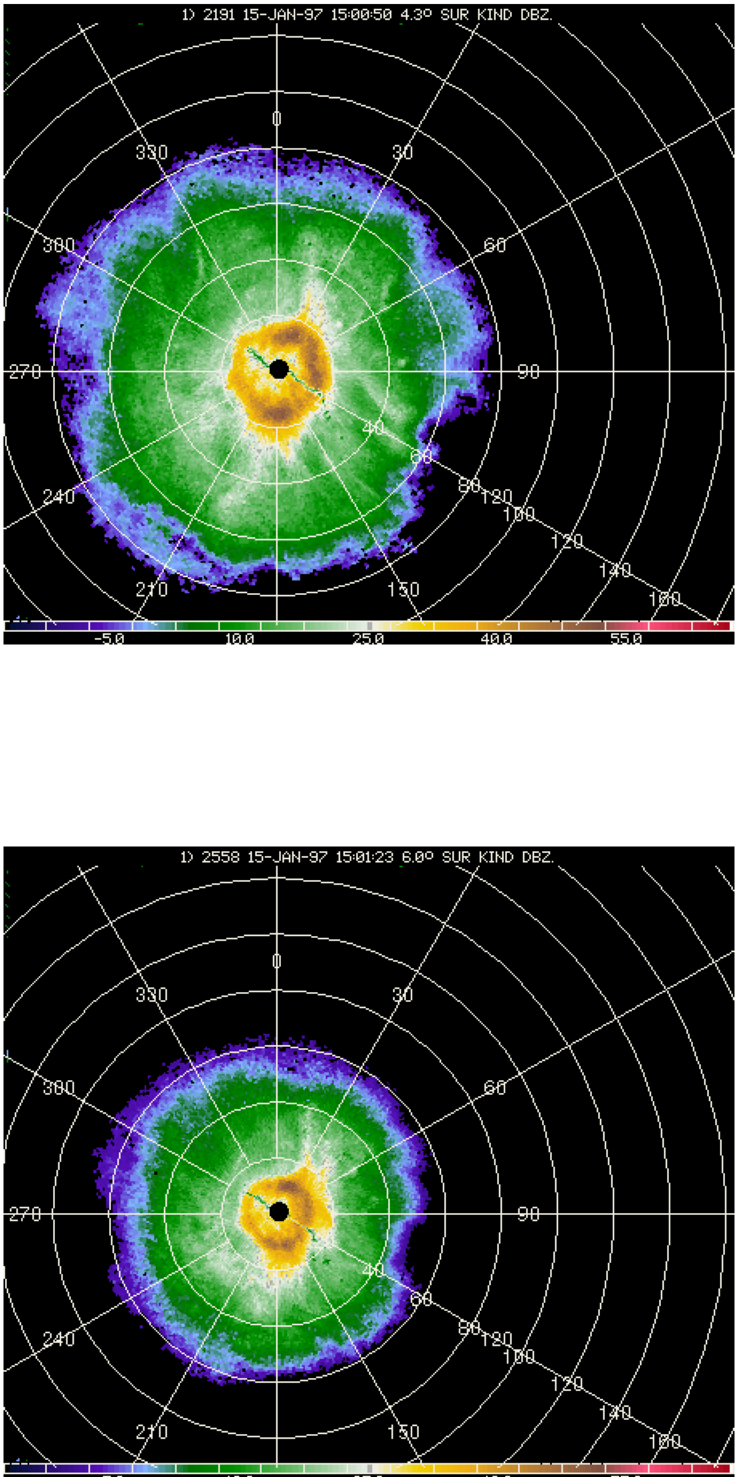
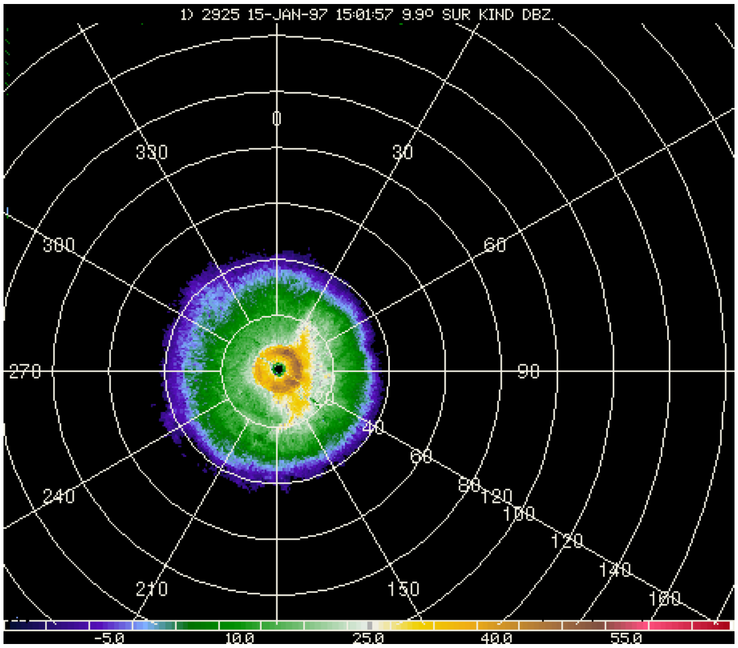


Figure 8 – Same, but for gg) 1500 (4.3) and hh) 1501 UTC (6.0).



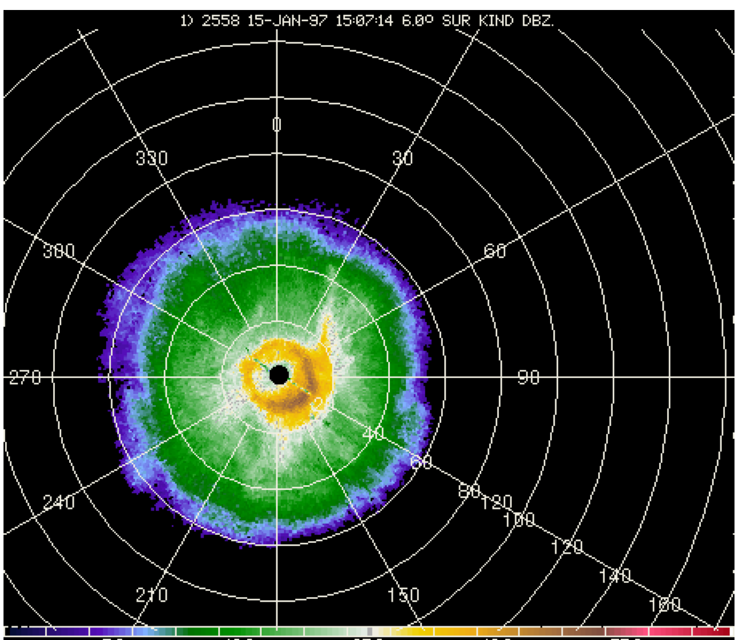


Figure 8 – Same, but for ii) 1501 (9.9) and jj) 1507 UTC (6.0).

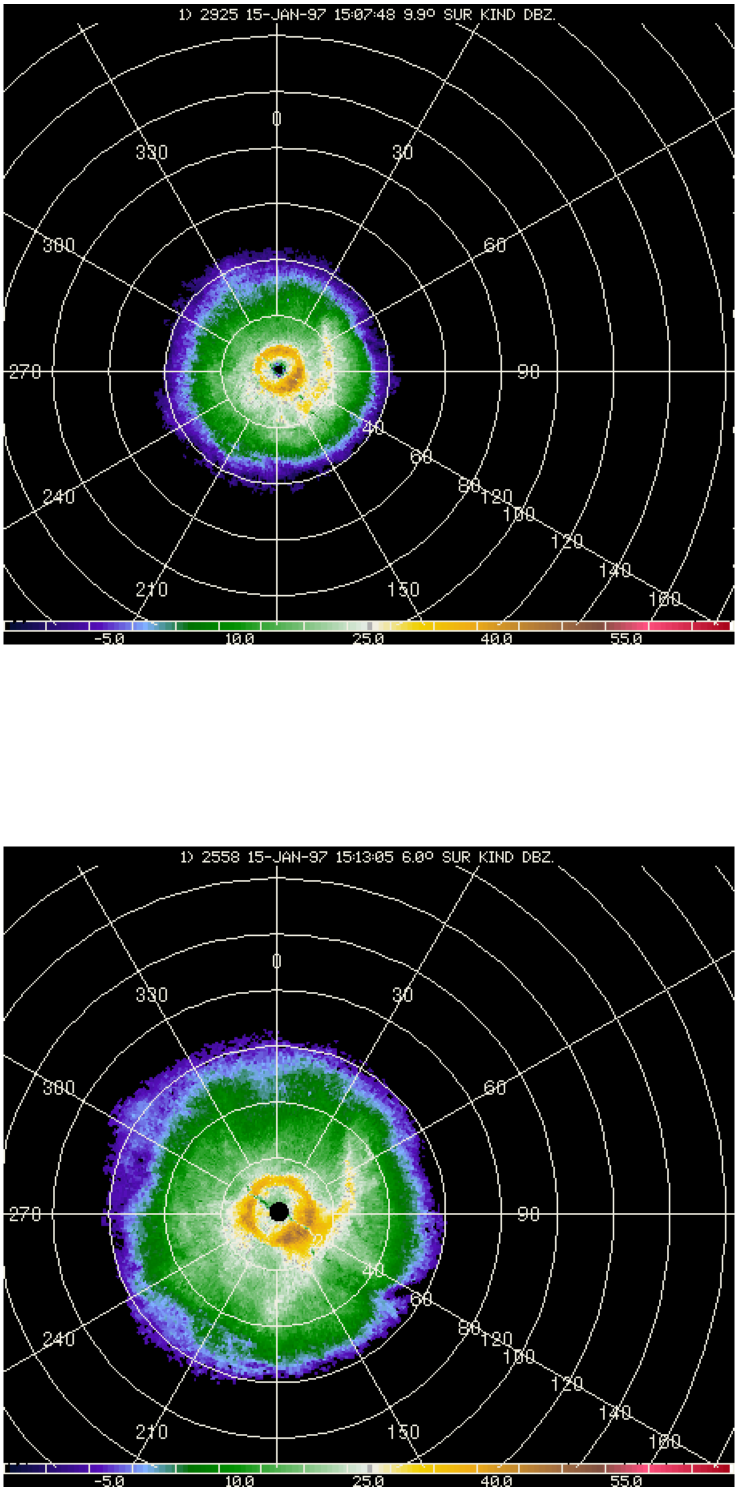
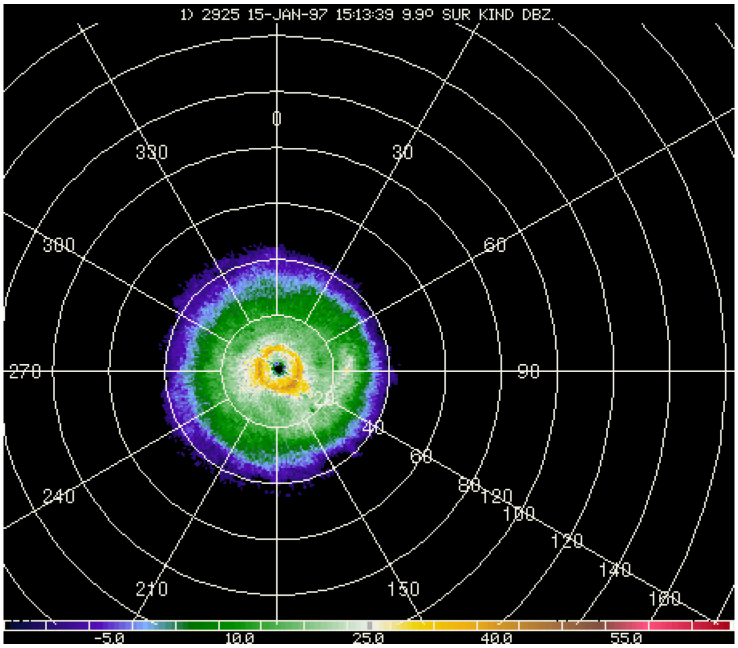


Figure 8 – Same, but for kk) 1507 (9.9) and ll) 1513 UTC (6.0).



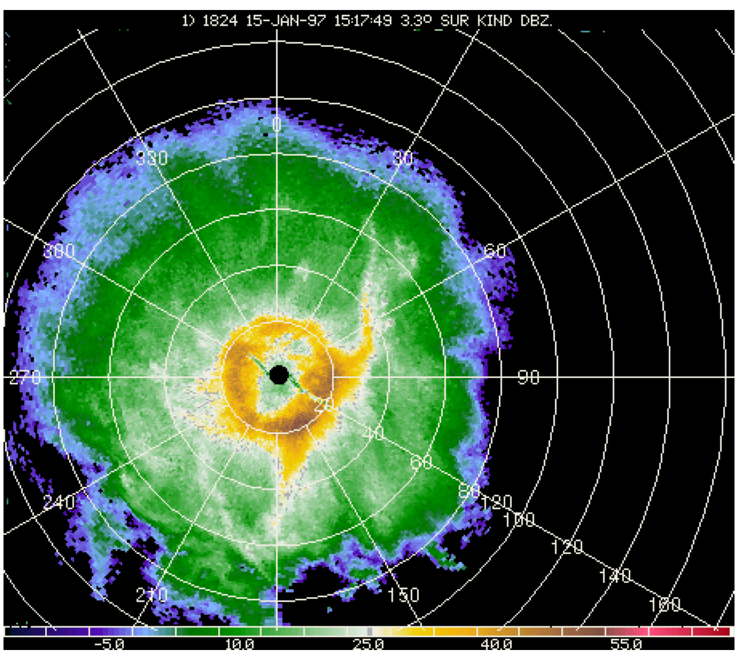
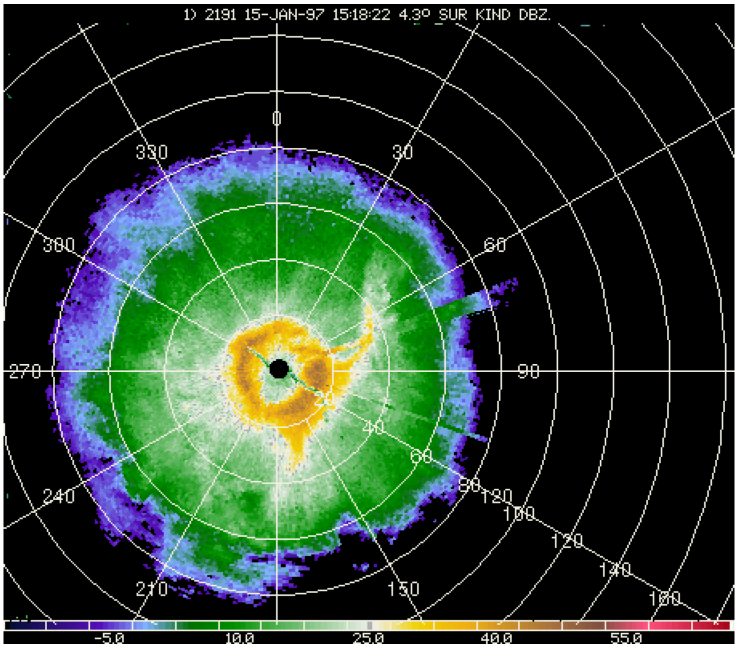


Figure 8 – Same, but for mm) 1513 (9.9) and nn) 1517 UTC (3.3).



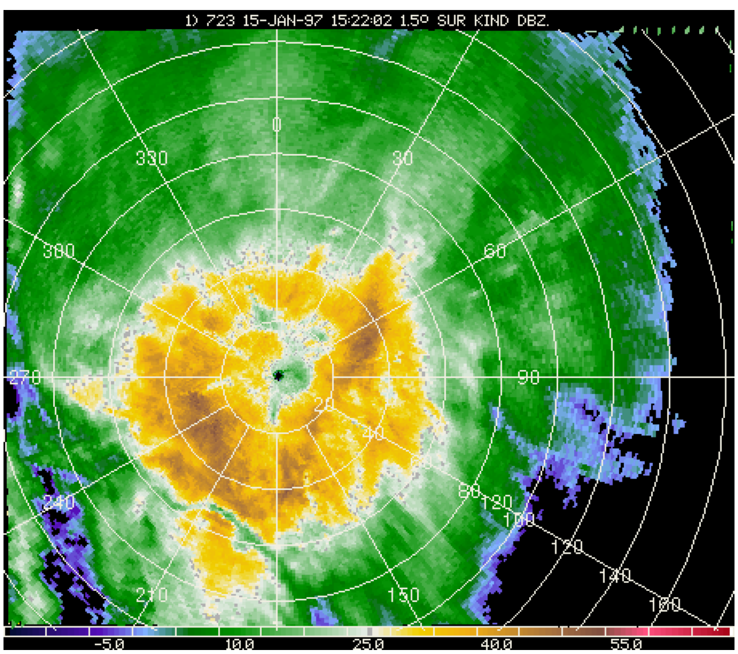


Figure 8 – Same, but for oo) 1518 (4.3) and pp) 1522 UTC (1.5).

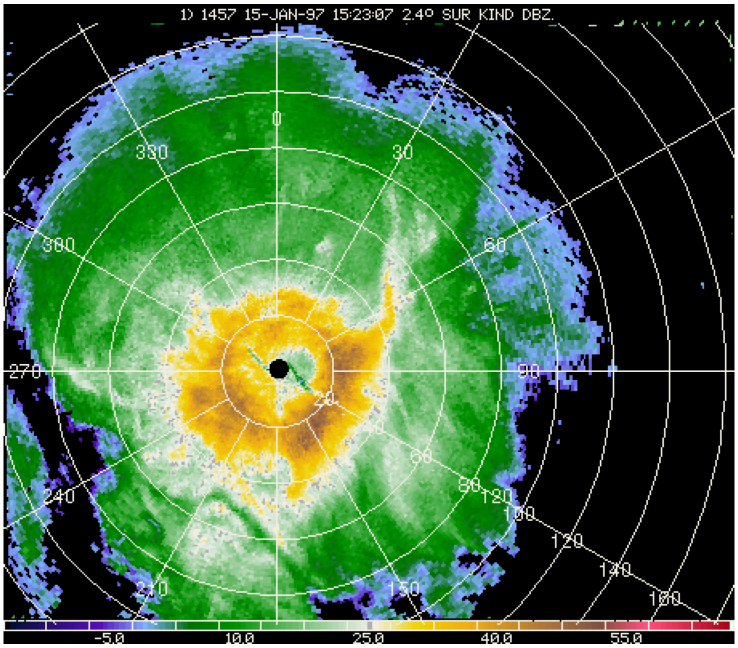


Figure 8 – Same, but for qq) 1523 (2.4).

January 24, 1997

Freezing drizzle and mixed conditions over Mansfield and Cleveland, Ohio

January 24, 1997 – Flights No. 1 and No. 2

Overview

This case of freezing drizzle and mixed conditions occurred over Youngstown and Canton-Akron between 1710 and 1918 UTC (flight 1) and over Mansfield and Cleveland between 2015 and 2152 UTC (flight 2). On this day, a high-pressure area centered over Maine left a shallow layer of cold air in place over Ohio. A weak, low-pressure area moved northward toward Chicago during the course of the day, bringing in a deep layer of warm, moist air above the cold pool. Freezing drizzle and mixed conditions formed above 9,000 feet as this overrunning situation combined with an influx of dry air aloft. In this document, the case will be discussed beginning at the synoptic scale (upper air charts, satellite data, surface maps, soundings) to give an overview of the weather, and ending at the mesoscale (radar and satellite data) and microscale (probe data), where fine details will be highlighted.

Upper air chart and sounding analysis-1200 UTC, January 24th

At 300 millibars, a weak ridge was in place over Cleveland, while a weak trough approached from the southwest (Fig. 1a). The trough essentially separated relatively dry air to the west from moist air over the Great Lakes and Upper Mississippi Valley. The exception to this was a pocket of dry air passing just north of Cleveland, that was collocated with a weak jet maximum of approximately 90 knots. A fairly similar pattern was evident at 500 millibars, with two weak troughs over the High Plains and saturated conditions over the Great Lakes and Ohio Valley (Fig. 1b). Warm advection and weak divergence were evident in the saturated area ahead of a thermal ridge that extended from western North Carolina to Lake Superior. Some weak, cold advection and dry air from the southwest had reached southern Missouri at this time, signaling the approach of an area of downward motion at 500 millibars.

The pattern was more complicated at 700 millibars (Fig. 1c). The main trough was farily pronounced and extended southeastward across central Missouri. A weaker trough positioned across northern Kentucky was becoming evident just ahead of it. This weaker through (the upward extension of a surface warm front draped across Tennessee) roughly separated the moist air, which had reached the Kentucky-Ohio border, from a broad swath of dry air across the Northeast states and from Ohio to Minnesota. Temperatures in the moist air were between -10 and 0 C. Strong warm advection was occurring across the Great Lakes states, but the lack of moisture (DPD = 21 C at Detroit, 19 C at Buffalo, and 11 C at Pittsburgh; DPD = dew point depression) precluded the formation of clouds the Cleveland area at this altitude and time.

At 850 millibars, the Kentucky trough/warm front was much more evident and another trough running from Minnesota to Texas became somewhat amplified (Fig. 1d). Strong warm advection was evident across the eastern third of the U.S., as 20-30 knot south and southwest winds brought warm air northward ahead of the main trough. Again, very dry conditions existed over the Great Lakes and Northeast states, while saturated conditions were in place to the south and west. Another weak trough extended across the northern borders of Ohio, Pennsylvania and New Jersey and was also evident at the surface, separating very cold air to the north from relatively warmer air to the south. Temperatures were well above freezing across Ohio at 850 millibars, while they were below freezing at the surface, providing a classic setup for freezing rain. Sounding data from Wilmington, Pittsburgh, and Detroit indicated that the freezing rain layer could have been between 1000 and 5000 feet deep (deepest at Detroit) if precipitation was falling at that time and the temperature structure remained intact (Figs. 2a-c). As moisture moved into the area over the next 12 hours, freezing rain did develop across Ohio, but the freezing rain layer was shallower and warmer due to the erosion of the cold surface layer by warm advection. NCAR-CLASS (Cross-chained Loran Atmospheric Sounding System) soundings taken at Cleveland indicate that the height of the lowest freezing level (the top of the potential freezing rain layer) dropped from 3150 feet to 2300 feet and the minimum temperature in the cold surface layer warmed from -3.5 C to -1.8 C between 1422 and 1904 UTC (Figs. 2d,e).

Upper air chart analysis - 0000 UTC, January 25th

By 0000 UTC, the upper trough at 300 millibars progressed slightly toward the east, while the dry air that was initially behind it advanced across the Ohio Valley (Fig. 3a). A wedge of dry air advanced as far as Buffalo in the location of a 130-knot jet streak, which appears to have accelerated the influx of dry air over Ohio. The same structure was in place at 500 millibars, with very dry air (DDP = 23 C at Pittsburgh, 20 C at Wilmington) reaching all of Ohio within a local wind speed maximum of ~80 knots (Fig. 3b). The saturated air across the Ohio Valley at 1200 UTC moved into the Northeast states, and continued to cover the northern Great Lakes. At 700 millibars, saturated conditions persisted over the project area except for southwest Ohio, which the dry wedge had reached by this time (Fig. 3c). The

Kentucky trough/warm front at 700 millibars progressed northward to reach Buffalo and northern Michigan. Warm advection and overrunning were still in place across northeastern Ohio, providing lift there, while cold advection and dryer air were evident at Wilmington. Temperatures across Ohio were -6 to -3 C at this level (~10,000 feet).

At 850 millibars, saturated conditions covered nearly all of the eastern half of the country (Fig. 3d). The Kentucky and Lake Erie troughs that were evident in the 1200 UTC analysis merged to form one upper trough/warm front just north of Lake Erie by 0000 UTC. Warm advection, temperatures in the -10 to 0 C range and saturated conditions between 850 and 650 millibars provided a good environment for the development of freezing drizzle in this layer. However, the existence of deeper, colder clouds over northeast Ohio until ~2100 UTC caused the freezing drizzle to be mixed with snow crystals, bringing about mixed conditions during most of the both flights. As the wedge of dry air moved in from the southwest, the cold cloud shield over Ohio began to breakup, allowing the SLD to become more prominent. The Twin Otter encountered a breaks in the cloud decks during flight 1, which kept snow that was falling from the upper cloud deck from reaching the liquid/SLD cloud deck below, and during flight 2, when the upper cloud deck was eliminated over Mansfield, thanks to the dry intrusion. Satellite, radar and aircraft data will bear this out in more detail in later sections.

Satellite IR temperature analysis

Infrared satellite data from 1215 UTC, January 24th reflect the locations of moisture indicated on the upper air charts, with deep, cold clouds covering much of the eastern _ of the U.S. (Fig. 4a). Ohio, Indiana and portions of the surrounding states had cloud top temperatures colder than -50 C. Some breaks in the cold cloud shield were evident over Illinois and Kentucky, while clear skies covered much of the Arkansas/Texas area, well upstream of Cleveland. This notch of dry air moved swiftly northeastward, reaching the Kentucky/Indiana border by 1800 UTC, while cold clouds, with some pockets of slightly warmer/shallower clouds, persisted over Ohio (Figs. 4b-d). These deep, cold clouds were in place during flight number one, but radar data will provide evidence of gaps in the precipitation shield and breaks between precipitation layers. These gaps and breaks provided locations where ice crystals from the cold cloud aloft were not able to survive into the lower cloud deck, and allowed pockets of all-liquid cloud and freezing drizzle to survive. As the upper level dry slot entered Ohio around 2000 UTC and reached the

Mansfield/Cleveland area by 2100 UTC (Figs. 4e,f), mid-level clouds with cloud top temperatures of -10 to -25 C were left in place. These clouds provided an icing environment as the deep, cold clouds moved out of the area. Still, during much of flight 2, cloud top temperatures at the aircraft flight locations were cold enough (< -15 C) that snow was probably still being produced aloft. Snow production became more sporadic with time, however, as evidenced by the somewhat spotty nature of the radar echoes (see next section).

Surface map, radar mosaic and PIREP analysis

The surface map for 1500 UTC (Fig. 5a - 1200 UTC was not available) had a strong (1044 millibars) high-pressure area centered over Maine, with cold, dry air in place to the northeast of Cleveland. A trough was in place across Lakes Erie and Ontario, as seen at 850 mb. A broad, weak low-pressure area was centered near Missouri and Arkansas, with a warm front which extended southeastward to the South Carolina coast and a trough which extended northeastward to the West Virginia/Ohio border. This trough was a developing warm front, separating cold air over Ohio from warm air over Tennessee and Kentucky, and became the main warm front by 1800 UTC (Fig. 5b). A swath of rain, drizzle, and freezing rain preceded the developing warm front, with the freezing rain occurring along the northern edge of the precipitation shield. Between 15 and 2100 UTC (Figs. 5a-c), a lobe of the low pressure center and the developing warm front moved northeastward into southern Ohio. Snow, freezing rain, and ice pellets reached the Cleveland area by 1700 UTC. According to the regional radar mosaic (Fig. 6), the precipitation shield was fairly solid over the location of flight 1, except that the aircraft approached some areas of pocketed reflectivity near the southwestern edge of the precipitation shield, near the end of the flight. It was during this portion of the flight that the Twin Otter sampled areas of all liquid cloud and freezing drizzle that was not mixed with ice crystals. Just behind the warm front, an area of spotty, light precipitation, including drizzle, moved into Ohio by 1800 UTC, reaching the Cleveland area by 0000 UTC (Fig. 5d). These breaks in the precipitation shield represent the location of the dry intrusion aloft. Radar mosaic data from this period indicate the location of the intrusion of dry air aloft, as a major gap in the reflectivity pattern moved northeastward into central Ohio by 1800 UTC (Fig. 6). PIREPs were located both inside and outside of reflectivity pockets. Moderate mixed, clear and rime icing was reported between 8000 and 16,000 feet, while a report of freezing rain and moderate icing was made in the 1800-

2000 foot range over Canton-Akron at 1730 UTC, possibly from the Twin Otter (Figs. 6 and 7). Icing was evident both in the air above the warm front (above 5000 feet) and in the freezing rain layer close to the surface, but temperatures were much more favorable for icing above the warm front on this day.

Mesoscale and microscale analysis – Flight 1

A detailed analysis of the mesoscale and micro-scale structure of the clouds sampled on this day is given in tabular format (see Table 1). Each period of time was chosen based upon apparent consistency in 2d-grey probe imagery for a period of at least ten seconds. The table includes the range of times (UTC), altitudes (feet MSL), static temperatures (C), liquid water content from the King probe with zero removed (g/m^3), a brief description of the 2d-grey imagery (phase, small/large drops, crystal habit), an assessment of the radar reflectivity pattern in the location of flight, and comments. A quick overview of the results is given in the text here. Images from the 2D-grey probe and the Cleveland NEXRAD are given in figures 8 and 9.

Between 170956 and 171310, the aircraft climbed through multiple freezing levels near Cleveland, encountering temperatures between –0.9 and +3.2 C from the surface to 4300 feet. Warm freezing rain, rain, drizzle and messy crystals were observed in this layer. Above this upper freezing level, temperatures fell steadily with height to about –6.5 C at 10,900 feet, and a mixture of ice crystals, small droplets and possibly some out-of-focus freezing drizzle was observed. Radar reflectivity in these locations was somewhat pocketed at times and varied between 15 and 30 dBZ or so. A descent to 1300 feet near Youngstown revealed a very similar structure, but slightly colder temperatures (down to –1.8 C) within the freezing rain layer below 2700 feet. This layer was too warm to allow significant icing to form on the aircraft and was not sampled further. Reflectivity was 20-25 dBZ within the ZR layer and 25-40 dBZ in the bright band caused by the melting of crystals near 2500 feet MSL.

Upon climbing back to 11,000 feet at 1753 UTC, the aircraft continued to encounter a mixture of crystals and droplets, but more in-focus ZL started to become evident with time. Altitudes near 11,000 feet continued to be sampled until ~1815, and LWC values did not exceed 0.1 from the beginning of the flight until that time. The combination of tracking southwest to the reach the southwestern edges of the precipitation swath and further climbing to 12,000-14,000 feet allowed the Twin Otter to reach a location which was more dominated by ZL and cloud-sized droplets. While within areas of reflectivity greater than

~5 dBZ, the aircraft encountered mixed conditions and LWC values of less than 0.05. However, when the Twin Otter reached the southwestern edge of the precipitation shield and began sampling pockets of no echo (below detectable limits) and reflectivity of –5 to 5 dBZ, consistent areas of in-focus ZL and cloud-sized droplets, with LWC up to 0.55, were observed. Some ice crystals (columns and irregulars) were mixed with the water droplets at times during this period (1828-1849 UTC). LWC values tended to reach minimum values when the crystals were present. After 1849 UTC, the aircraft descended and headed back to Cleveland to refuel. Radar imagery during the latter stages of this flight, when the good LWC and ZL were observed, reveal a break in the precipitation shield (see gap between echo ring near 80 km and solid echo inside 60 km on Fig. 9pp). This break in the precipitation shield indicates a discontinuity in the falling precipitation from the cold cloud aloft into the potential liquid and ZL cloud below.

Mesoscale and microscale analysis – Flight 2

A detailed analysis of the mesoscale and micro-scale structure of the clouds sampled on this day is given in tabular format (see Table 2). A quick overview of the results is given in the text here. Images from the 2D-grey probe and the Cleveland NEXRAD are given in figures 10 and 11.

Between 201550 and 202205 UTC, the aircraft climbed through multiple freezing levels over Cleveland, with temperatures fluctuating between -1.2 and +1.5 C, reaching the highest freezing level at 7200 feet MSL. A mixture of rain, drizzle and a few crystals was observed in this range of altitudes, with cloud drops mixed in above the cloud base (4260 feet MSL). Temperatures decreased gradually with height to -4.9 C as the aircraft continued to climb to 11,000 feet. Mixed conditions of freezing drizzle, cloud drops, columns, needles and irregular crystals persisted in this layer, with some variability in the relative proportions of those particle types. Liquid water contents seemed to vary inversely with crystal concentrations, reaching maximum values of ~ 0.4 g/m^3. Data from the Cleveland NEXRAD radar indicated that the aircraft was flying through pocketed precipitation and tended to be passing through or near patches of 10-20 dBZ reflectivity when crystals were prevalent in the 2D-grey imagery and water content was low. When the aircraft was within areas of lower reflectivity, droplets were more dominant and water contents were relatively high. This pattern continued as the aircraft flew northwestward from Cleveland at altitudes between 9900 and 11,000 feet from 202815 to 204845 UTC. A few periods were observed where essentially only water drops (cloud and freezing drizzle) were present and water contents reached 0.3 g/m^3, but most of the time, the conditions were mixed in character.

The aircraft flew south toward Mansfield from 202845 to 212920 UTC, remaining at altitudes between 9000 and 11,000 feet. As described in this synoptic weather section, dry air began to reach the Mansfield area around this time. This is evident in the radar data as the southwest edge of the precipitation shield moved northeastward and became more patchy. The aircraft was flying in and out of the patches near the southwest edge of the precipitation shield in this time frame. Mixed conditions continue to dominate, but some periods occurred where only water droplets were observed, including an 11 minute period from 211830 to 212920 UTC. Although occasional patches of columns, dendrites and even aggregates were observed, much of the 2D-grey imagery indicated a mixture of small, out of focus freezing drizzle and cloud droplets. While the aircraft flew through patchy areas of -5 to 20 dBZ, peak liquid water content values of up to 0.45 g/m^3 were measured along the interfaces between high and low reflectivity areas. Again, greater amounts of crystals were observed when the aircraft flew within patches of 15+ dBZ, though this pattern was not always consistent during the portion of the flight near Mansfield.

The aircraft flew back toward Cleveland from 212920 to 215300 UTC, gradually descending from 9800 feet to the surface, continuing in and out of mixed and all-water conditions with widely varying liquid water contents. Overall, freezing drizzle and cloud droplets were observed during much of the flight, mostly mixed with crystals of many shapes in sizes. Occasional periods of pure or nearly pure freezing drizzle and cloud water conditions were sampled lasting as long as 11 minutes.

970124 - Flight #1

Row	Start/end time (UTC)		Alt Range (ft MSL)		T-static range (C)		LWC - KingZR		Description of 2D-grey imagery	2D Imgs
1	170956	171013	800	1200	2.1	0	0	0	Warm rain to 1mm, some L	A
2	171013	171051	1200	2000	0	-0.9	0	0	Same, with a few messy crystals and ZR	B
3	171051	171206	2000	3200	0	3.2	0	0	A few messy crystals at top of layer, some rain	C
4	171206	171310	3200	4300	2.8	0	0	0.01	Aggs, messy xls, cols	D
5	171310	171710	4300	8100	0	-4.3	0	0	Aggs, iregs, cols, few plates	E
6	171710	172130	8100	10900	-4	-6.4	0	0	Ditto, plus some small drops	F
7	172130	172205	10900	10900	-6.4	-6.6	0.01	0.04	Small drops, some aggs & crystals	G
8	172205	172355	10800	10900	-6.4	-6.7	0	0.03	Small drops, with more aggs & crystals	H,I
9	172355	172558	10900	10900	-6.4	-6.6	0.01	0.05	Mostly small drops, small cols, irregs & aggs	J
10	172558	173057	10900	4300	-6.4	0	0	0.01	Cols, needles, aggs, poss some oof ZL	K
11	173057	173525	4300	2600	0	0.6	0	0.06	Aggs, irregs, some poss oof L	L
12	173525	173610	2600	2300	0.7	0	0	0	L, R, messy aggs and crystals	M
13	173610	173941	1300	2700	0	-1.8	0	0.01	ZR, ZL, a few messy crystals and blobs	N
14	173941	174100	2700	3500	0	1.1	0	0.04	R, L, messy aggs & xls, some small drops	O
15	174100	174135	3500	4200	0.1	0.6	0.02	0.04	More small drops, some messy crystals	P
16	174135	174238	4200	5100	0.3	0	0	0.02	More aggs, messy xls, possibly some L	Q
17	174238	174535	5100	7600	0	-3	0	0.01	Aggs, irregs, cols, poss some ZL	R
18	174535	174910	7600	10700	-3	-5.6	0	0.09	Cols, irregs, small drops, needles, some ZL	S
19	174910	175250	10700	11000	-5.6	-6.2	0	0	Ditto, but few/no small drops	T
20	175250	175840	10700	11000	-6.2	-6.7	0	0.01	Irregs, aggs, cols, possible ZL	U
21	175840	180425	10800	11000	-5.8	-6.2	0	0.01	Cols, irregs, ZL, occasional aggs	V
22	180425	180740	10800	10900	-5.5	-5.9	0	0.07	Ditto, with small drops and no aggs	W
23	180740	181510	10800	11200	-5.3	-6	0	0.01	Cols, irregs, ZL, few/no small drops	X
24	181510	181620	11200	12000	-6	-7	0	0.04	Ditto, with small drops, more ZL, fewer crystals	Y
25	181620	181755	11900	12000	-6.9	-7.2	0	0.04	ZL, irregs, small drops	Z
26	181755	182330	11900	12000	-6.9	-7.5	0.05	0.13	Small drops, ZL, a few irregs	AA
27	182330	182600	12000	11500	-7	-6	0.02	0.12	ZL, small drops	BB
28	182600	182640	11500	10900	-6	-5	0.01	0.06	Ditto, with columns	CC
29	182640	182730	10900	10300	-5	-4	0	0	ZL, columns, needles	DD
30	182730	182820	10300	9800	-4	-3.2	0	0.2	Small drops, ZL, columns, needles	EE
31	182820	183629	9900	8000	-3.2	0	0	0.3	Small drops, oof & in-focus ZL, some xls @times	FF
32	183629	183735	9900	10600	-3	-5	0	0.01	Cols, ZL, few small drops	GG
33	183735	184030	10600	12100	-4.4	-6.6	0.01	0.55	Small drops, cols & ocnl oof ZL in lower half	HH
34	184030	184720	12100	14000	-6.6	-10.1	0.02	0.5	Small drops, borderline ZL and some small ZL	II
35	184720	184911	12500	9800	-7.4	-3.1	0.01	0.5	Ditto, with cols & irregs below 11200 ft	JJ
36	184911	184945	9800	9200	-3.1	-1.8	0	0.02	Cols, irregs, small ZL	KK
37	184945	185514	9200	8900	-1.5	-2.5	0	0.2	Small drops, cols, some ZL, few irregs	LL
38	185514	185635	8900	9000	-2.3	-2.7	0	0	ZL and columns	MM
39	185635	190000	9000	8000	-2.6	-3	0	0.1	Ditto with cloud drops and irregs	NN

970124 - Flight #1

Row	Rad Imgs	Range-km	Azimuth	Elev. ang	Description of Radar Reflectivity around A/C	Comments
1	A-C	1.0-2.0	85-88	0.5-3.0	N/A - inside hole at center of plots	None
2	D-F	2.0-4.0	88-89	3.0-6.3	Ditto	Probably not cold enough for ZR & ZL to stick to AC
3	F	4.0-6.0	89-102	6.2-7.0	Bottom of bright band - 40 dBZ	Max T=+3.2 at 2700'
4	F	6.0-9.0	102-109	7.0-7.5	Climbing through bright band, 40-45 dBZ	Top half of warm nose
5	H,I	9.0-20.0	109-119	6.5-7.8	Above bright band, 20-30 dBZ	Smaller cols, maybe some small drops @end
6	H,I	20-34	115-117	5.6-6.9	Moving SE into lower reflect. (25-->15 dBZ)	Pockets mostly small drops, fewer/smaller aggs
7	H,J	34-36	117	5.3-5.6	~15-20 dBZ, somewhat variable	Possibly a few oof ZL drops
8	J	36-44	117-119	4.3-5.3	Ditto, echo tops well above a/c, lower SW	Ditto
9	J,M	44-53	119-120	3.5-4.3	10-20 dBZ, more crystals at the end	Ditto
10	L-O	53-64	120-128	1.2-3.5	In patch of 20-30 dBZ	Descent, fewer small drops, fewer aggs @start
11	M-P	53-57	128-141	0.6-1.2	20-35 dBZ, getting into melting zone	In weak warm nose, weak bright band
12	PP,QQ	57-60	141-143	0.5-0.6	In melting zone, ~40 dBZ	Ditto
13	P,Q	60-70	143-149	0.2-0.5	At or below 0.5 scan, which showed 20-40 dBZ	Below weak, poorly defined warm nose
14	P,Q	69-70	145-149	0.5-0.7	25-40 dBZ, pocketed	In weak warm nose
15	Q,R	69-69	143-145	0.7-0.9	10-25 dBZ, bright band not obvious near A/C	In weak warm nose
16	Q,R	69-69	139-143	0.9-1.2	10-25 dBZ, pocketed	Pockets of small drops, in top of warm nose
17	Q,S	69-71	129-139	1.2-1.8	10-25 dBZ, crossing pockets	Aggs tail off @end of period
18	S,S2	71-78	116-129	1.8-2.4	20-30 dBZ on 1.5 scan, 10-20 dBZ on 2.4 scan	Ocnl aggs early, small drops ending
19	S2,T,T2	78-91	103-116	2.1-2.4	20-25 dBZ on 1.5 scan, 15-20 dBZ on 2.4 scan	Few aggs at the end
20	S2,T2,T-V	89-97	94-103	2.0-2.1	Within & along edges of 10-25 dBZ	More aggs, in-focus ZL at the end
21	V	78-89	98-106	2.1-2.4	In 10-25 dBZ	ZL now more evident
22	X	73-78	106-111	2.4-2.6	In 15-20 dBZ, NW of 25+ dBZ pocket	Pockets with small drops
23	Y,Z	64-73	111-127	2.6-3.1	Ditto	Climbing @ end, some large irregs present
24	Z	63-64	127-129	3.1-3.3	0-15 dBZ, nearing upper end of echoes on 3.3 scan	Climbing, ZL now larger and dominating
25	Z,BB	63-63	129-133	3.3-3.4	Ditto	More small drops & less ZL @end
26	Z,BB	63-64	133-147	3.3-3.4	Refl. = -5 to 10 dBZ, hitting SW edge/top of echoes	Fewer crystals with time
27	DD	64-66	147-153	3.1-3.3	Refl. = -5 to 5 dBZ, hitting SW edges on 3.3 scan	Descend, few cols @end, top of cloud deck @12k?
28	CC,DD	66-67	153-154	2.9-3.1	Ditto on 3.3 scan, 0-10 dBZ on 2.4 scan	Small drops ending, cloud base @11.5k?
29	CC,DD	67	154-156	2.7-2.9	Ditto	No small drops, between decks
30	CC,EE	67-68	156-158	2.5-2.7	0-10 dBZ, in solid echo on 2.4 scan	LWC coming up, cols disappearing, in lower deck
31	EE,FF	68-76	158-173	1.9-2.5	Ditto, approaching SW edge	Freezing level at 8k, lower LWC SW of CAK
32	FF	76-78	173-174	2.3	Refl. = -5 to 0 dBZ on SW edge	Between cloud decks
33	FF,GG	78-83	174-178	2.4-2.6	Patchy -5 to 0 dBZ, in hole to the SW at end	Peak LWC at 12kft
34	GG,HH	66-86	171-181	2.6-3.4	In SW edges of echoes, in a hole/gap for first half	Small pockets of cols & irregs early
35	II,JJ	58-66	162-171	2.9-3.4	Getting back into SW part of echo, -5 to 5 dBZ	Poss break between cloud decks near 12.4k
36	II,JJ	56-58	160-162	2.8-2.9	In SW part of echo, up to 10dBZ	Another break in cloud decks
37	II-MM	41-56	150-160	2.8-3.8	Pockets of -5 to 10 dBZ echoes	Pockets of all-small drops and ZL
38	LL,MM	37-41	156-160	3.8-4.2	Ditto	Cloud break near 9k
39	NN-QQ	21-37	150-160	4.2-6.7	Ditto	In and out of clouds, double layer evident on high tilts

970124 - Flight #2

Row	Start/end time (UTC)		Alt Range (ft MSL)		T-static range (C)		LWC - KingZR		Description of 2D-grey imagery	2D Imgs
1	201550	201635	800	1650	1.5	0	N/A	N/A	Warm rain & drizzle, no ice	A
2	201635	201710	1650	2400	-0.7	0	0	0.01	R & L, few messy xls	B
3	201710	201738	2400	2900	0	0.4	0	0.01	R & L, few cols/irregs, one stellar	C
4	201738	201906	2900	4260	-0.6	0	0	0.01	R & L, few cols/needles, ocnl messy big xls	D
5	201906	201920	4260	4500	0	-0.7	0	0.02	R & L, few irreg	E
6	201920	202040	4500	6000	-1.2	0	0	0.1	Mostly bigger cloud drops, ocnl L/R (decr w/time)	F
7	202040	202205	6000	7200	0	1.1	0	0.1	Mostly cld drops mxd w/poss L, some irr/col/agg	G
8	202205	202340	7200	8300	0	-1.6	0	0.04	Mostly bigger cld drops mxd w/possL, few lg. irr/col	H
9	202340	202425	8300	8800	-1.6	-2.4	0.02	0.05	Mix cloud/ZL, xls decreasing in number and size	I
10	202425	202520	8800	9500	-2.4	-3.5	0.05	0.2	Mix cloud/ZL, some small xls	J
11	202520	202630	9500	10200	-3.5	-4.1	0.2	0.43	Ditto, some col/irreg	K
12	202630	202715	10200	10700	-4.1	-4.3	0	0.25	Mix cloud/poss ZL, more cols/needs	L
13	202715	202815	10700	11000	-4.3	-4.9	0	0.15	Ditto	M
14	202815	203155	10000	11000	-4.9	-3.5	0	0.01	Lots of col/ned/irr, few agg mxd w/poss ZL & cld drops	N
15	203155	203325	10000	10100	-3.4	-3.7	0	0.01	Small/fewer large col/ireg, few aggs mxd w/possZL/cld	O
16	203325	203345	10000	10050	-3.4	-3.6	0	0.2	Mix cloud/poss ZL w/some col/ireg/aggs	P
17	203345	203540	9900	10050	-3.6	-3.8	0	0.3	Nearly all water, ocnl col/irreg	Q
18	203540	204215	10000	10100	-3.7	-5.1	0	0.02	Mix cld/possZL/col/irg/few agg, xls decr. some @ end	R
19	204215	204330	9950	10050	-5.1	-5.4	0	0.1	Fewer xls (col/irreg), more cloud drops, few aggs	S
20	204330	204845	10000	10100	-5.3	-5.7	0	0.01	Mix cloud/poss ZL & lots of irreg/col/aggs	T
21	204825	204935	10050	10300	-5.3	-5.4	0	0.05	Mix cld/ZL, fewer xls, decreasing to almost none	U
22	204935	205020	10300	10900	-5.4	-5.1	0	0.05	Mix cloud/ZL, ocnl column/irregular	V
23	205020	205430	10900	11050	-5.4	-6	0.05	0.15	Mostly cld, some ZL, all water xcpt few xls early	W
24	205430	210135	10950	11070	-4.9	-5.7	0	0.25	Lots of cols/aggs mxd w/poss ZL & cloud drops	X
25	210135	210250	10900	11070	-4.8	-5.5	0	0.05	Fewer xls (col/ireg/aggs) mxd w/cloud drops, poss ZL	Y
26	210250	210635	10500	11050	-4.6	-5.4	0	0.02	Lots of aggs/cols/irregs mxd w/cloud drops & poss ZL	Z
27	210635	211015	10500	9800	-4.6	-3.3	0	0.1	Fewer xls (aggs/cols/irregs), few dndr mxd w/cld/posZL	AA
28	211015	211345	9080	9800	-1.9	-3.1	0	0.1	More xls (agg/col/dendr/col/ireg) mxd w/possZL & cld	BB
29	211345	211635	9100	9200	-1.8	-2	0	0.1	Fewer xls mxd w/ZL & cloud	CC
30	211635	211830	9050	9200	-1.6	-1.9	0	0.03	More xls mxd w/possZL & cloud	DD
31	211830	212920	9050	10150	-1.8	-4	0.03	0.45	Mostly cld drops, some ZL, patches of col/dnd/agg	EE
32	212920	213110	9200	9350	-1.7	-2	0	0.04	Mix of cloud/possZL/xls(cols/irreg/dend(?))	FF
33	213110	213800	9150	9800	-0.7	-2.6	0.05	0.23	Mostly cloud & small ZL drops, some col/irreg	GG
34	213800	213910	9300	9400	-1.9	-2.1	0	0.01	More xls (irreg) mxd w/larger ZL & cloud	HH
35	213910	214650	6800	9300	0	-2.1	0	0.25	Mostly small ZL & cloud drops w/some irregs/cols	II
36	214650	215300	650	6800	0	2	0.1	0.3	Bigger L & even R mxd w/cloud drops, no ice	JJ

970124 - Flight #2

Row	Rad Imgs	Range-km	Azimuth	Elev. ang	Description of Radar Reflectivity around A/C	Comments
1	A	1.0-3.0	82-87	1.8-6.5	25-30dBZ on edge of SW-NE oriented band on 1.5	T falling to freezing level
2	B	3.0-4.0	87-89	6.5-8.1	Within ~30dBZ area on 9.9 scan	750m subfreezing layer, minT @ 933mb
3	C	4.0-5.0	88-89	8.0-8.3	Ditto	Warm layer to +0.4C
4	C	4.0-6.0	88-109	8.1-8.3	Ditto	Just below cloud base.
5	C	4.0-4.0	108-115	8.1-14.3	Ditto	Entered cloud base, R & L appear to be decreasing
6	C,D	4.0-4.0	115-153	14.3-16.0	Ditto, 2024Z/9.9 scan shows 30+ dBZ moving NE	A/C entering 10-20 dBZ
7	D	4.0-5.0	153-182	23.5-25.0	In 10-20 dBZ on 9.9 scan	Another >0C layer, at the top of the melting zone
8	D	5.0-8.0	182-200	18.4-23.5	Ditto, little evidence of bright band	Cross highest freezing level, xls decreasing @end
9	D	8.0-9.0	200-203	16.3-18.4	In 10-20 dBZ on 9.9, near 20+dBZ echo to NW	
10	D	9.0-12.0	203-206	14.0-16.3	Ditto, but echo to N of A/C now on 9.9 scan	LWC gradually rising
11	D	12.0-14.0	206-209	12.5-14.0	Ditto, double layer seen in lack echo 20-30km on 9.9	LWC > 0.3 most of period
12	F	14-16	209-213	12.0-12.5	Ditto	LWC decreasing during period
13	E,F	16-18	213-215	11.0-12.0	25+dBZ beneath A/C on 6.0 scan	More LWC when fewer cols/needles
14	E,F	18-29	215-219	6.1-11.0	Poss between layers,clipping 25+dBZ on 6.0 scan	Starting SW track on 220 deg radial
15	E,G,H	29-33	219-220	5.2-6.1	Exited into speckles of -5 to 10 dBZ to SW on 6.0 scan	Mostly < -10 dBZ on 4.3 scan
16	G,H	33-34	220-221	5.1-5.2	In -5 to 0 dBZ hole in echo @4.3, outside echo on 6.0	LWC rising (Nevz), King off by ~0.5 suddenly
17	G,H	34-37	221-229	4.7-5.1	In hole & along edges of 10 dBZ echo to NW/N	LWC=0.3 til 2035, lower LWC when more xls, King OK
18	G-J	33-41	230-280	4.3-5.3	Into 5-15dBZ area to N, hitting W edge of echo @end	
19	J	41-44	280-288	4.0-4.3	N into -10 to 0 dBZ along W edge of echo	
20	K,L	44-49	288-299	3.6-4.0	N back into 10-25dBZ on 3.3/4.3, hole follows/lags A/C	Some big aggs
21	L	42-44	293-296	4.0-4.2	Back S into -10 to 5 dbZ hole	Begin climb to 11000ft
22	M,N	40-42	291-293	4.2-4.7	Into -10 to 0 dBZ on 4.3 scan, < -10 dBZ on 6.0 scan	LWC incr/xls decr. @end, hole moved N to meet A/C
23	M,N	38-40	274-291	4.8-5.1	Crossing hole, -10dBZ or less on 4.3, none on 6.0	Consistent LWC
24	O,P	40-48	251-274	4.0-4.8	SW through 5-25 dBZ S of hole.	LWC max N edge echo, all LWC/few xls @start
25	R	48-50	249-251	3.9-4.0	In 20-25 dBZ	Bright band becoming more evident on 3.3 scan
26	R	50-57	241-249	3.2-3.9	Moving SW across widespread 15-25 dBZ echoes	Begin descent at end
27	R,S	57-65	234-241	2.6-3.2	Crossing subtle pocket of 10-20 dBZ	Continue descent
28	U	65-73	230-234	2.2-2.6	Clipping pocket of 20-30dBZ on 2.4 scan	Descent ends 211135 @9000'
29	T,U	73-80	226-230	2.0-2.2	SW into 10-20 dBZ on 1.5	
30	V,W	80-85	225-226	1.9-2.0	Pockets on 1.5 and 2.4 scans	Xls decrease at the end
31	V-Y	75-89	213-225	1.9-2.1	Into patchy echo on SW edge of shield, -5 to 20 dBZ	Peak LWC around edges
32	Z,AA	78-79	218-219	2.0-2.1	Away from edges, back in 15-20 dBZ	Xls decr. last 30 seconds
33	Z-CC	79-84	218-222	1.9-2.1	Near SW edge shield on 2.4, in 10-20 dBZ on 1.5	Pretty steady LWC, lower w/xls present, all water @start
34	BB,CC	84-85	222-223	1.9-1.9	Ditto	
35	BB-EE	40-85	219-223	1.9-2.8	Along SW edge @start, moving NE though 15-30 dBZ	Lower LWC when xls present, fairly steady around 0.15
36	EE,FF	7.0-40	219-227	2.8-4.0	Through pocket 25-35dBZ on 2.4, part of bright band?	Descent to near surface

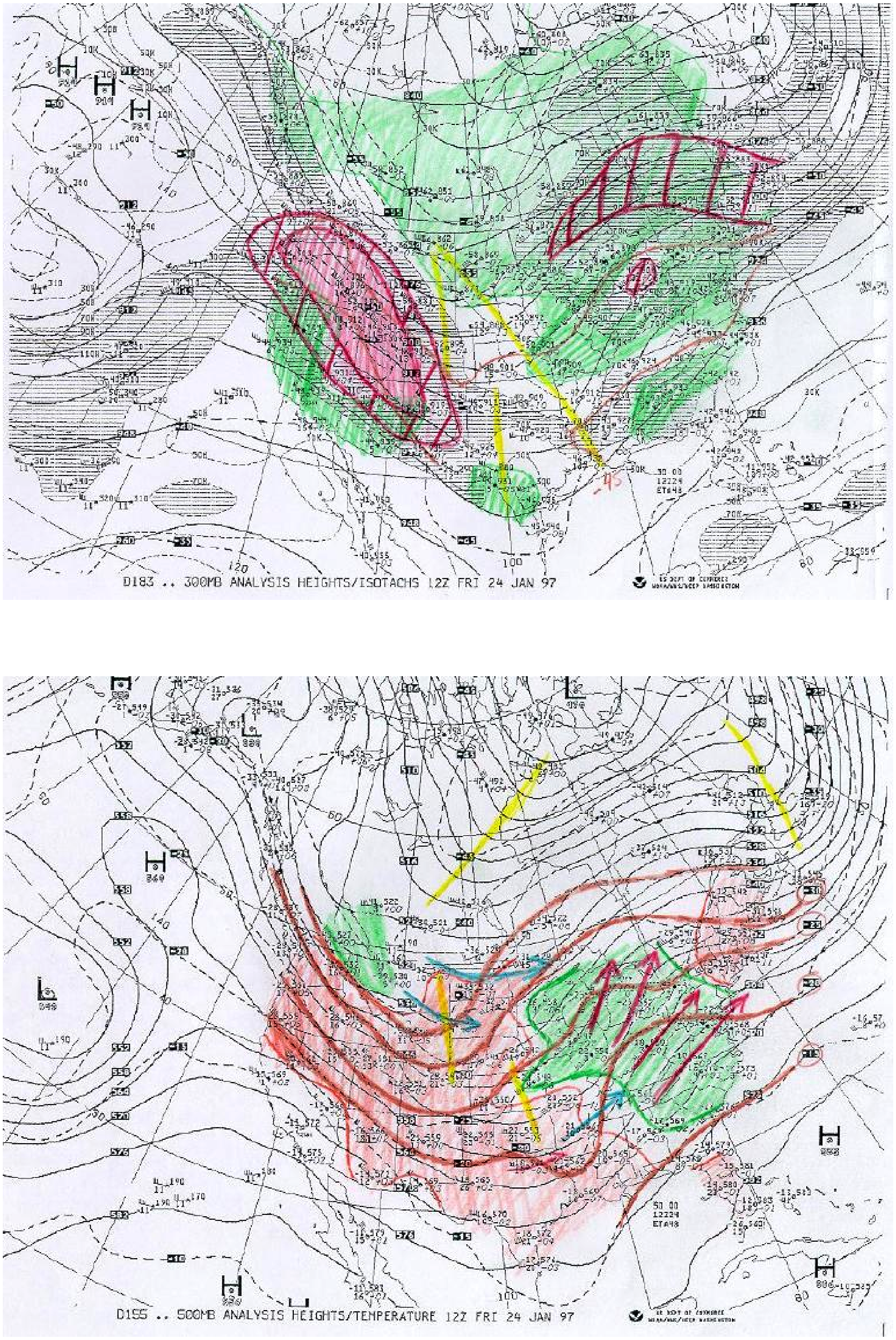
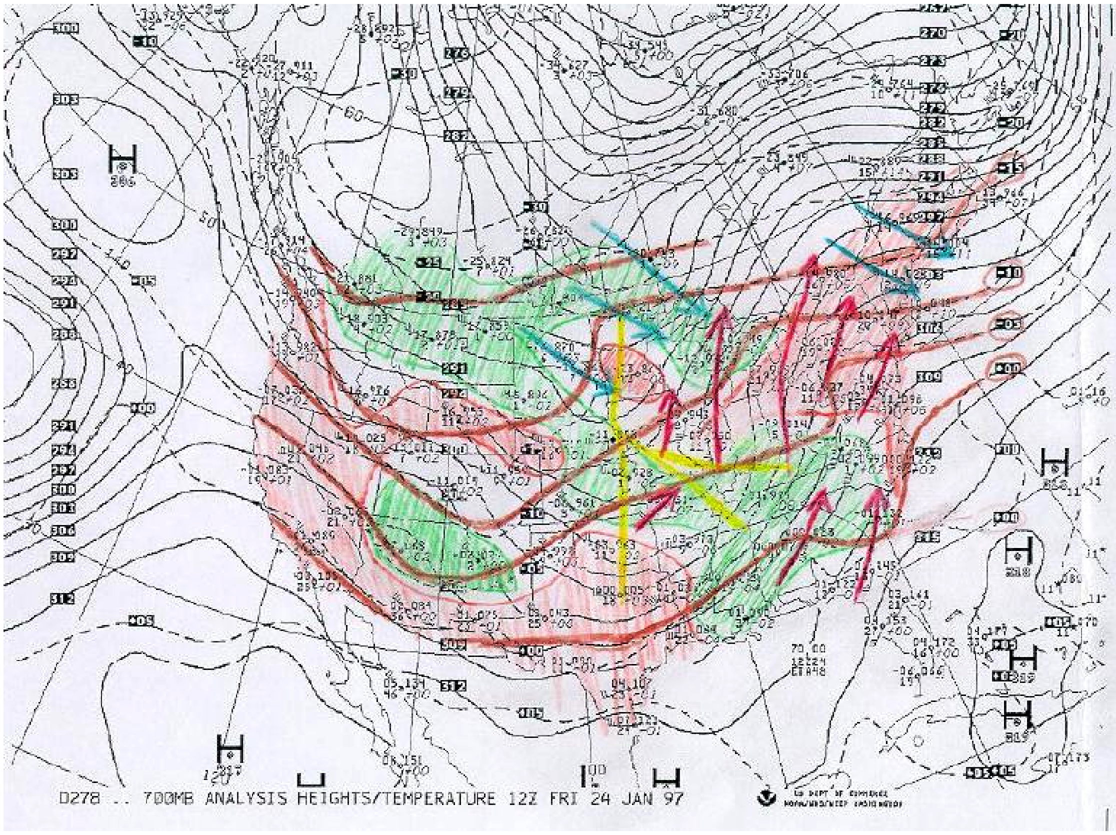


Figure 1 – Upper-air charts for 970124, 1200 UTC at a) 300 and b) 500 mb.



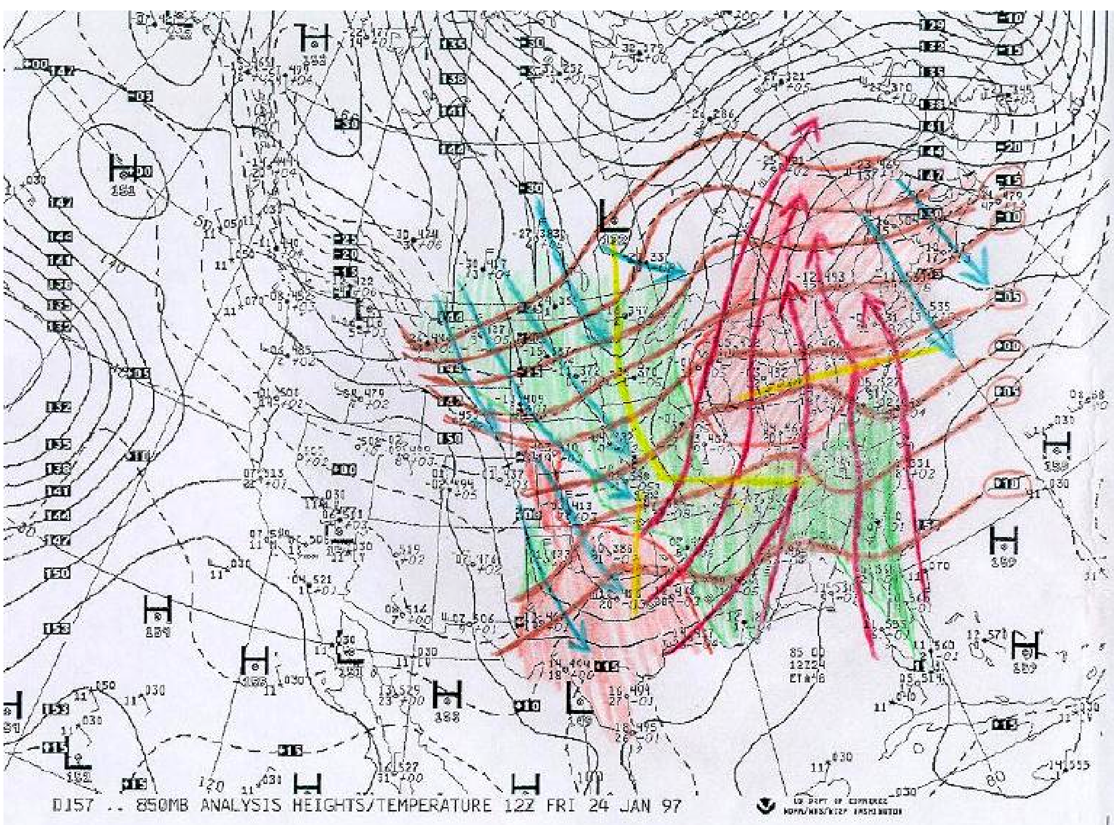


Figure 1 – Upper-air charts for 970124, 1200 UTC at c) 700 and d) 850 mb.

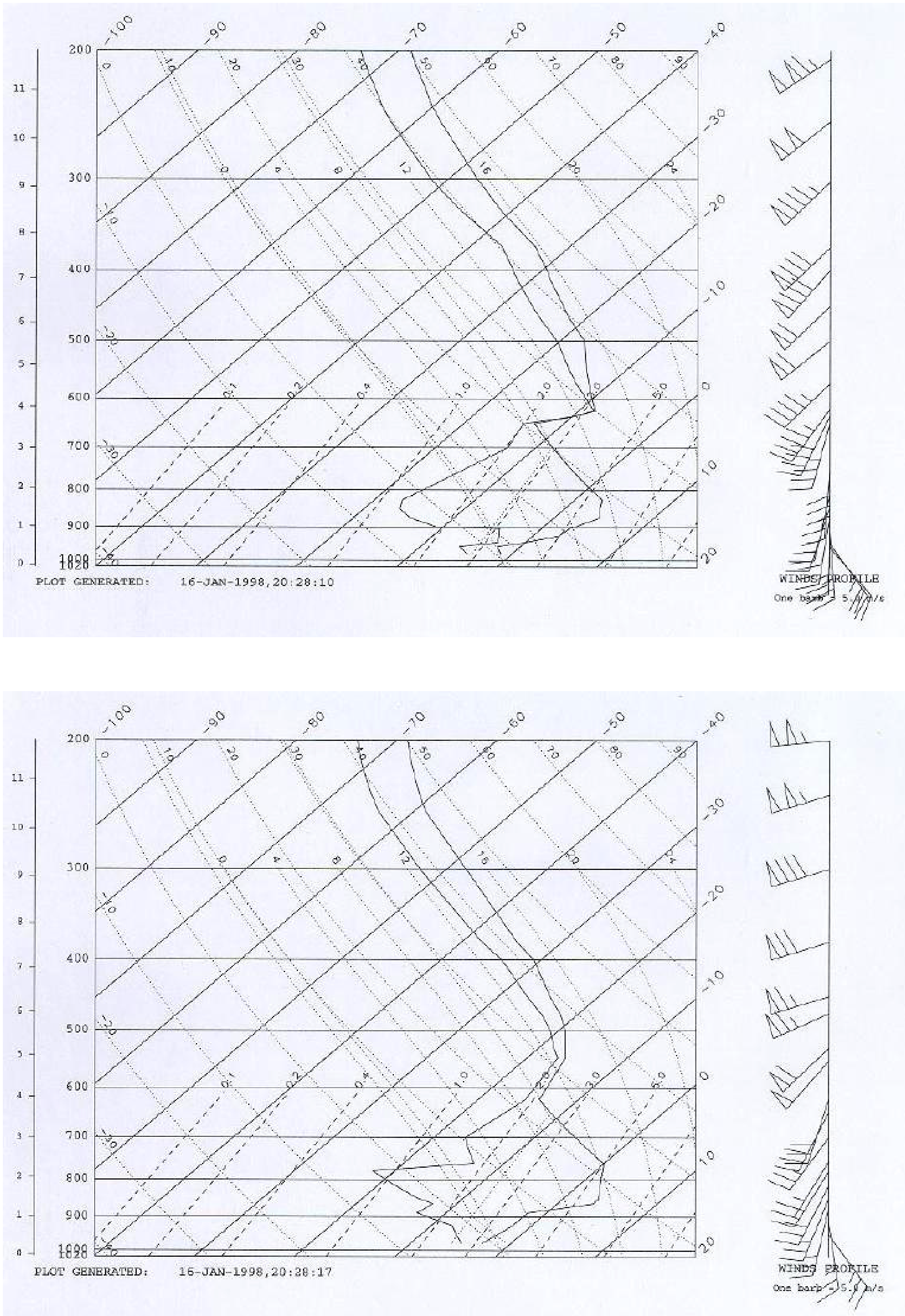


Figure 2 – Balloon-borne soundings for 970124, 1200 UTC from a) Wilmington and b) Pittsburgh.

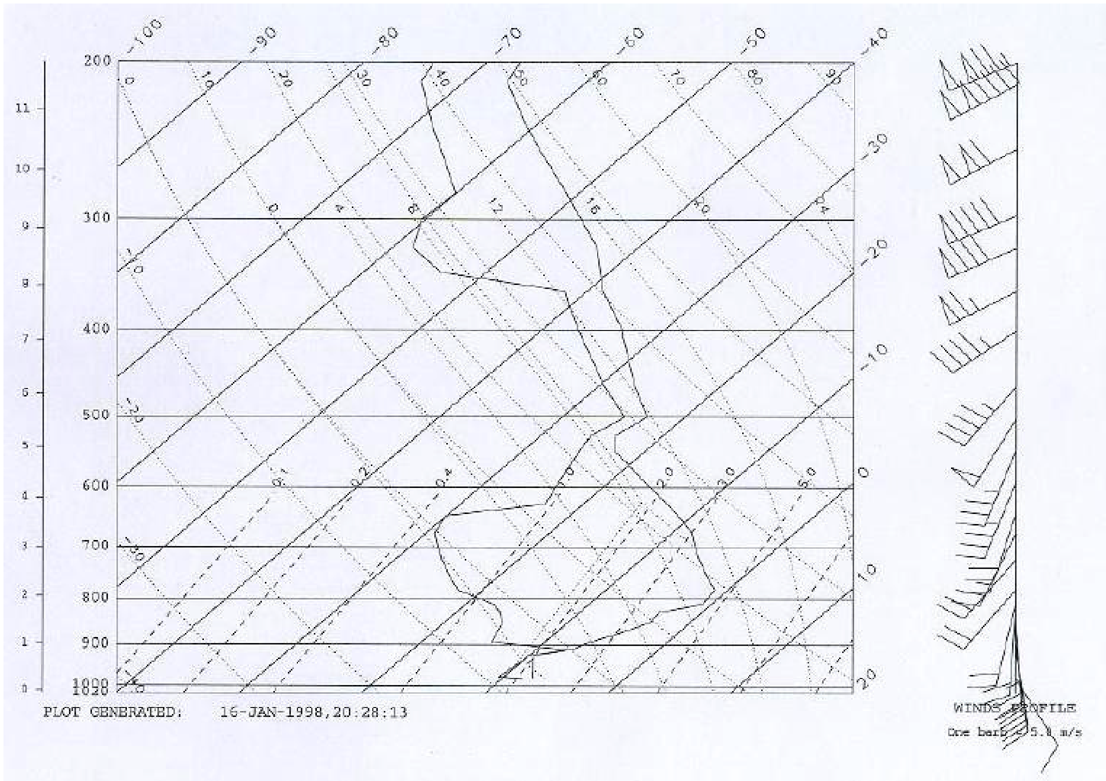


Figure 2 – Balloon-borne soundings for 970124, 1200 UTC from c) Detroit.

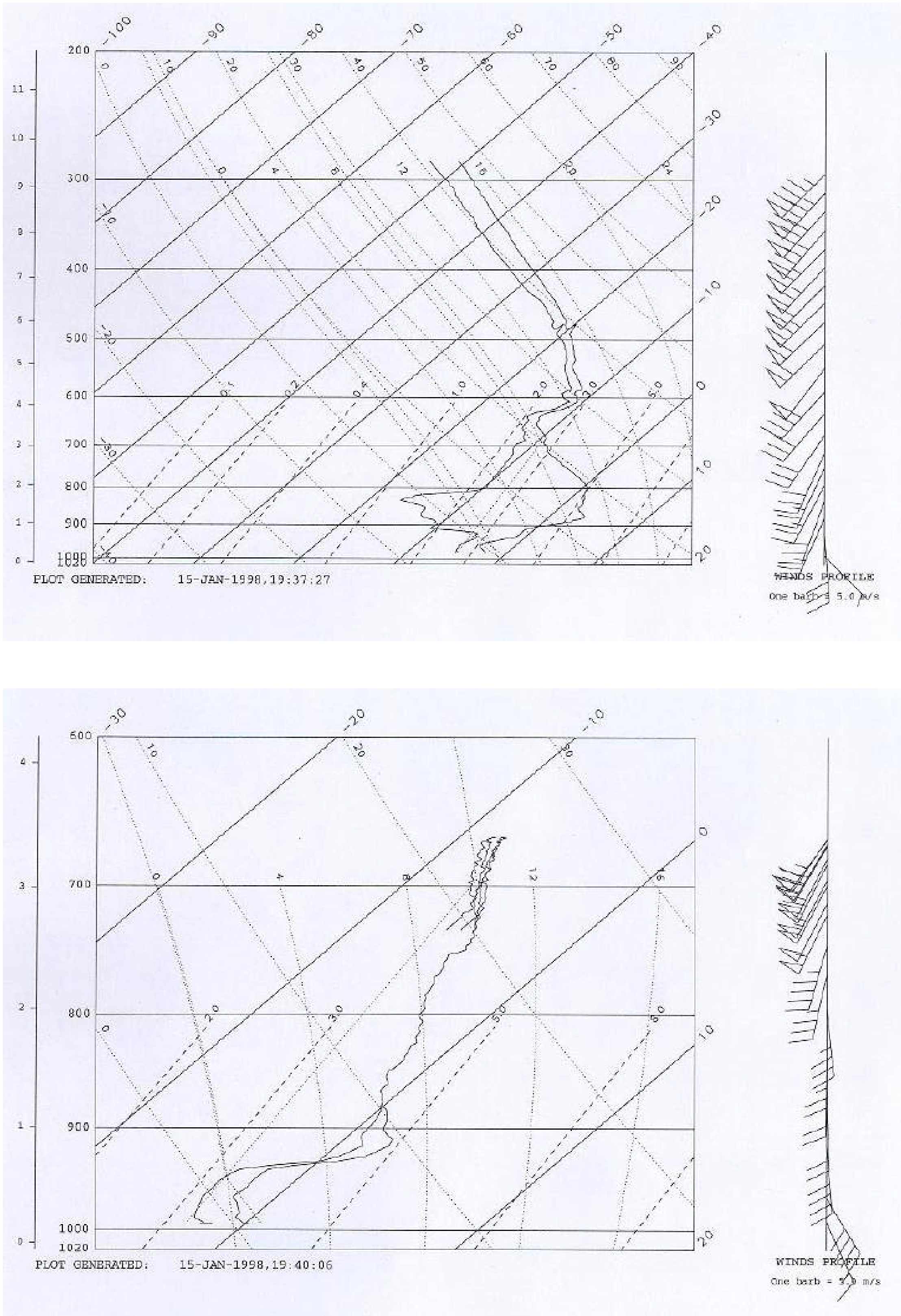
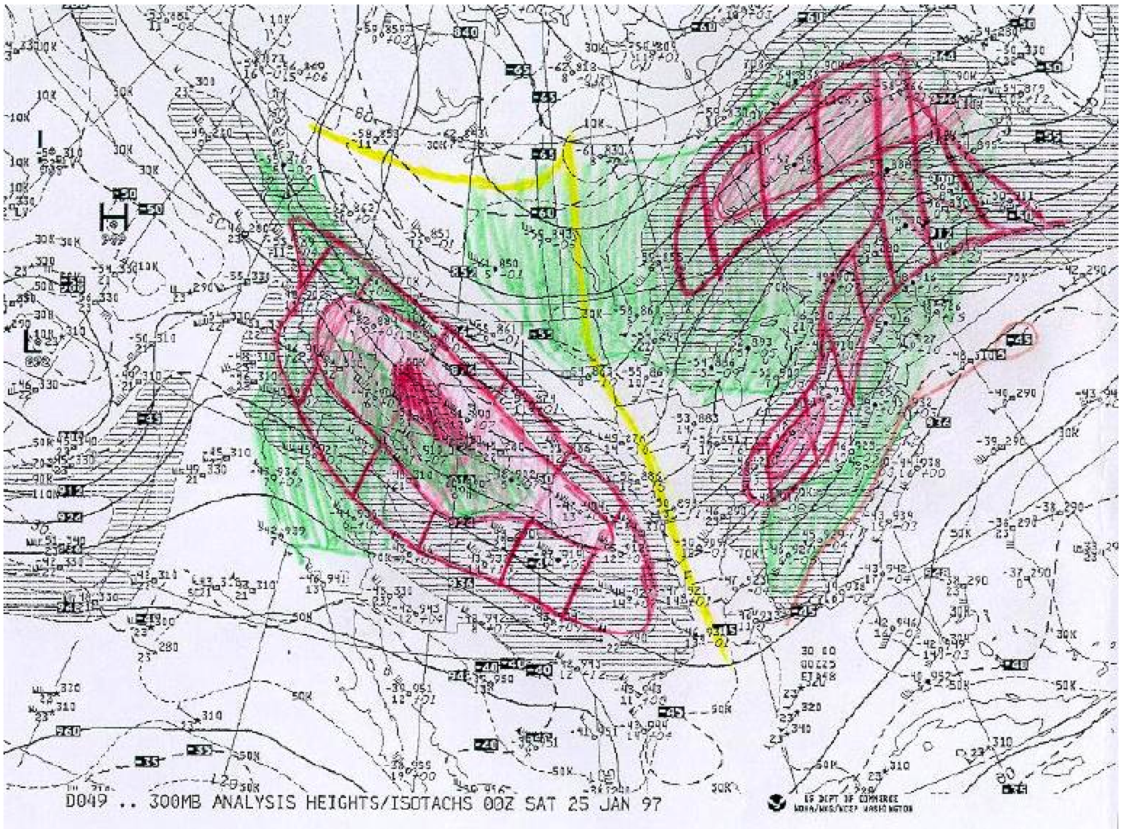


Figure 2 – Balloon-borne soundings from Cleveland for d) 1422 and e) 1904 UTC.



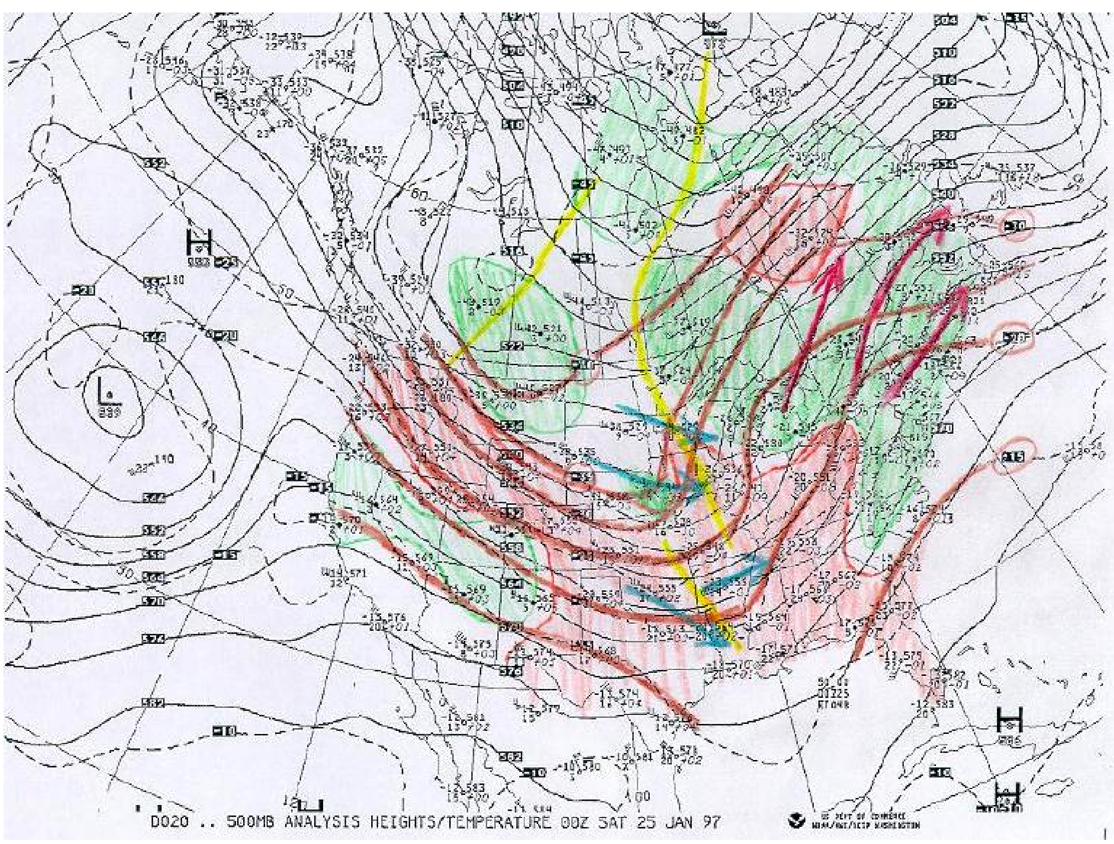


Figure 3 – Upper-air charts for 970125, 0000 UTC at a) 300 and b) 500 mb.

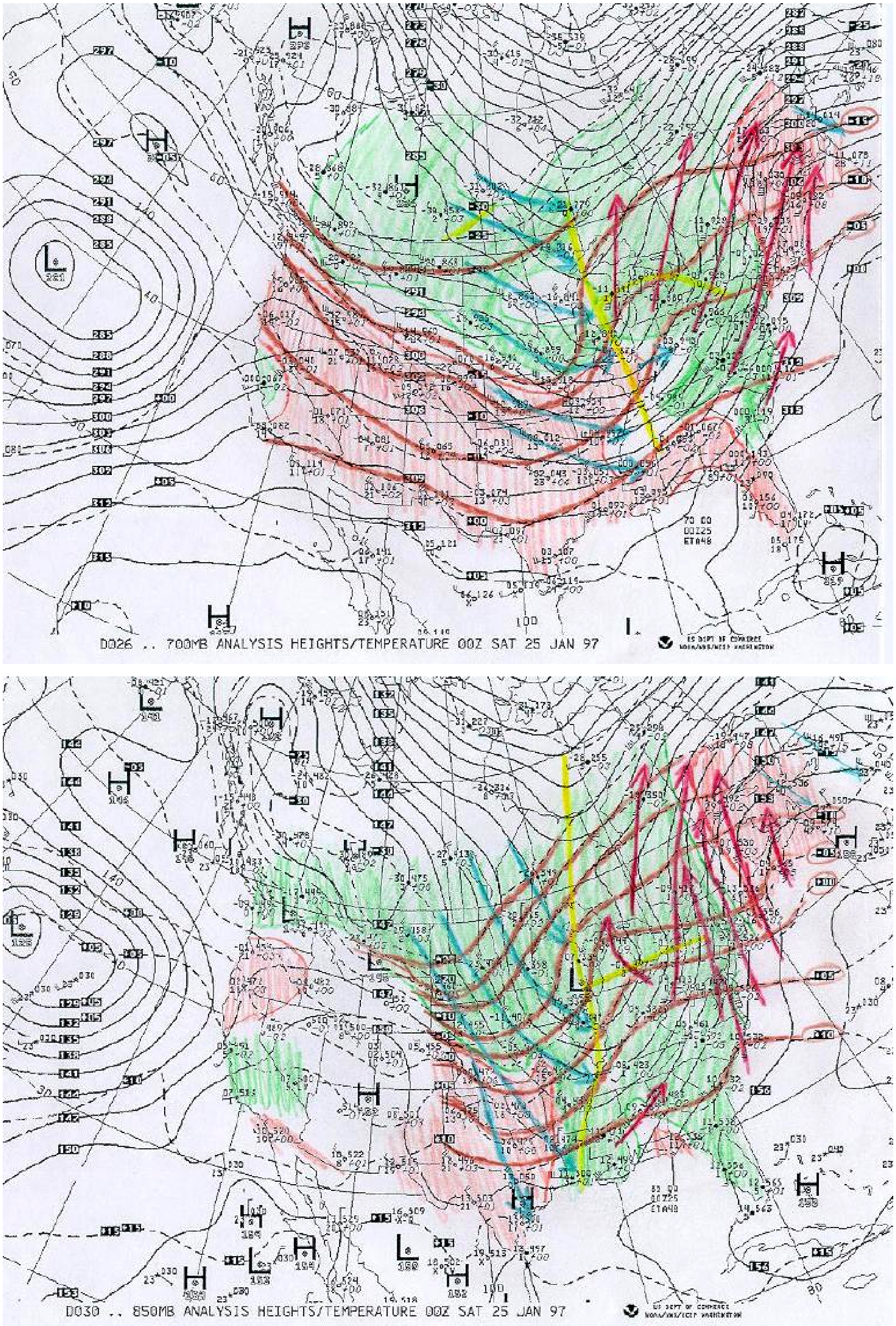
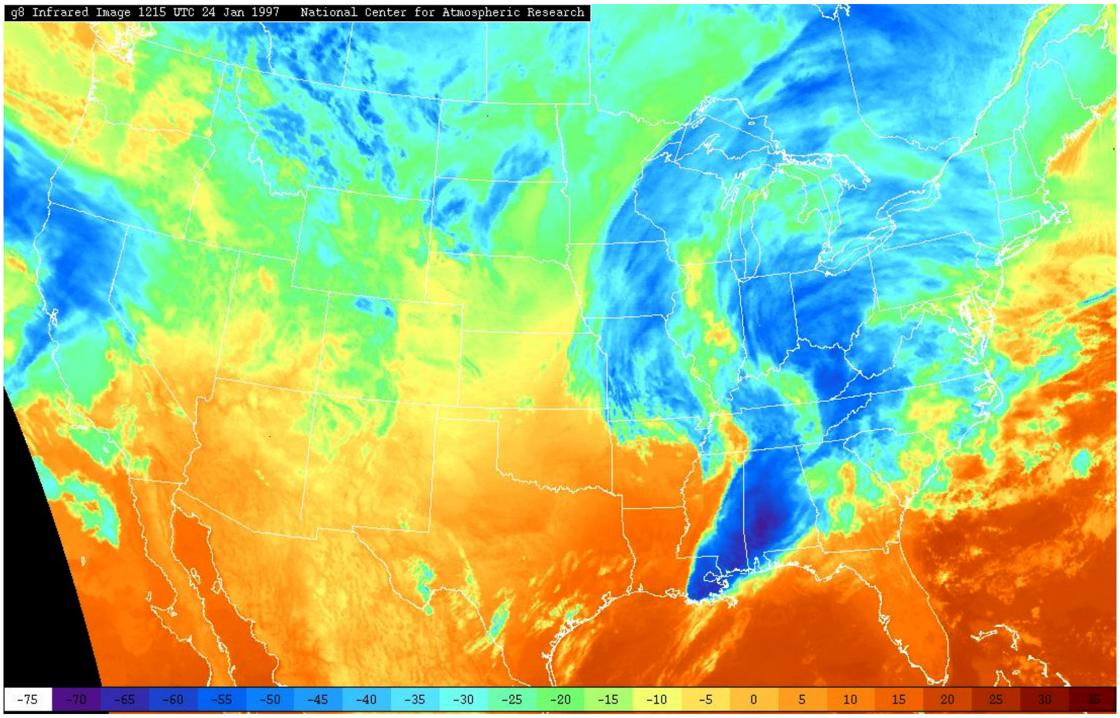


Figure 3 – Upper-air charts for 970125, 0000 UTC at c) 700 and d) 850 mb.



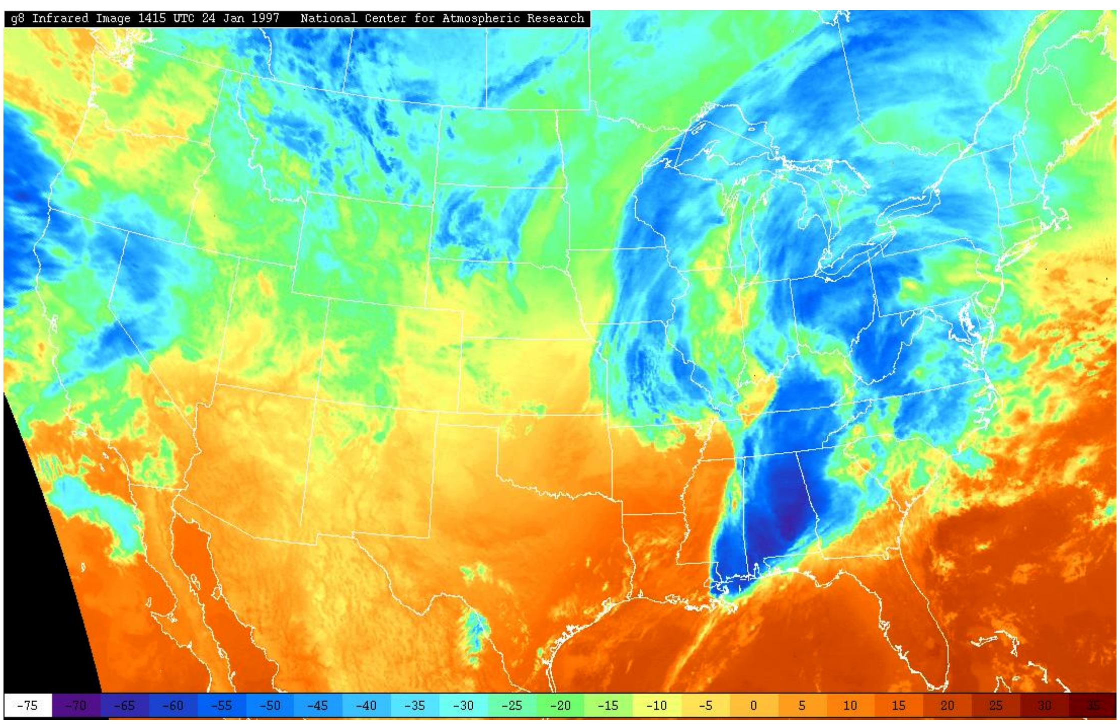


Figure 4 – GOES 8 infrared satellite data for a) 1215 and b) 1415 UTC.

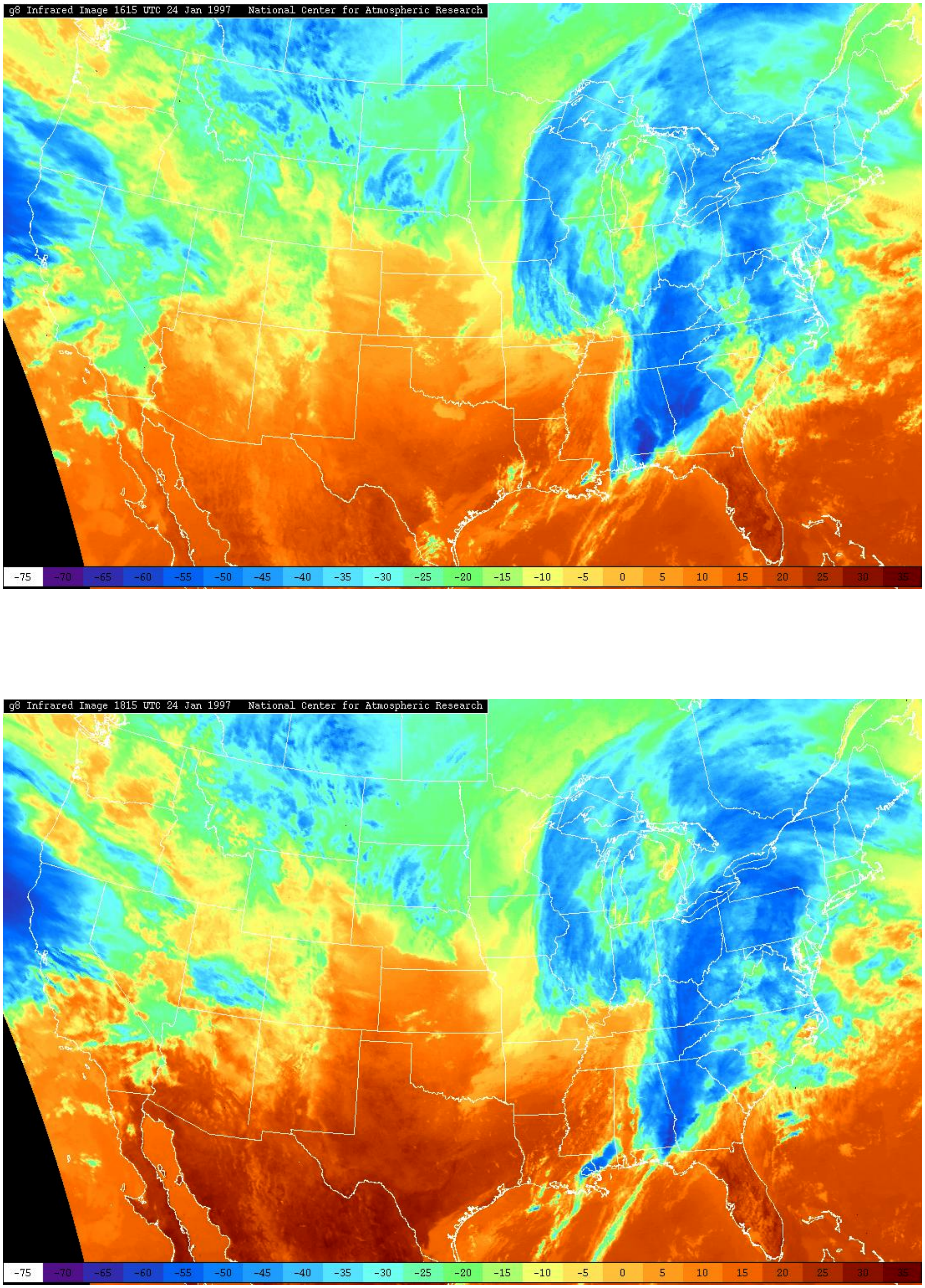
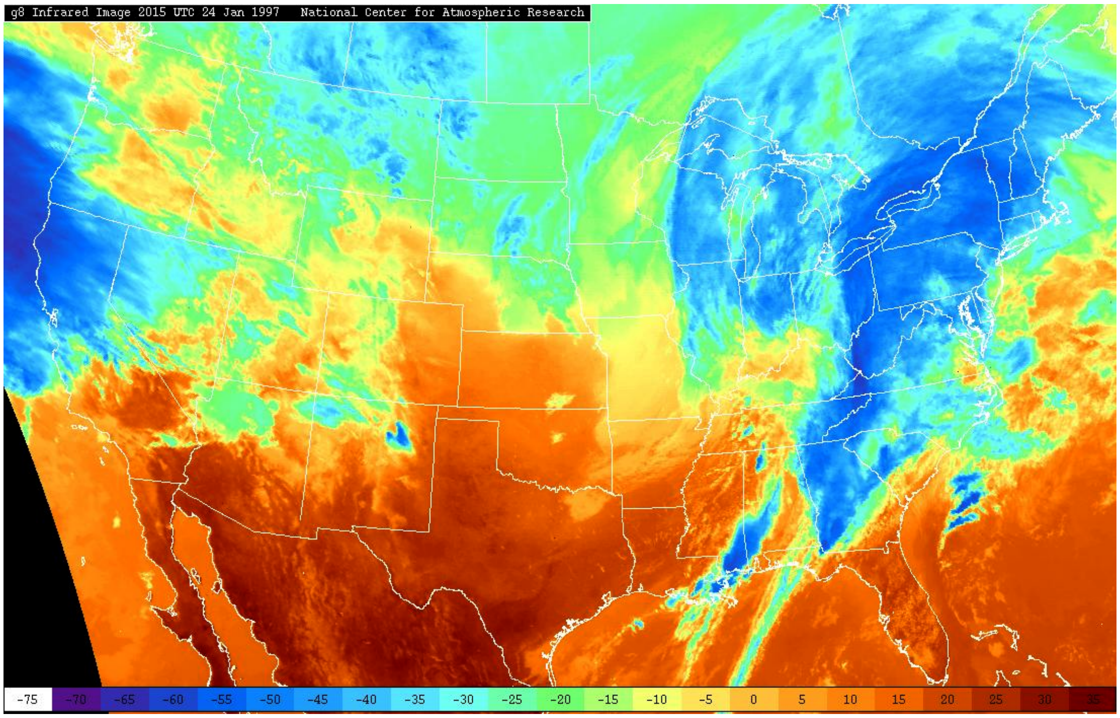


Figure 4 – GOES 8 infrared satellite data for c) 1615 and d) 1815 UTC.



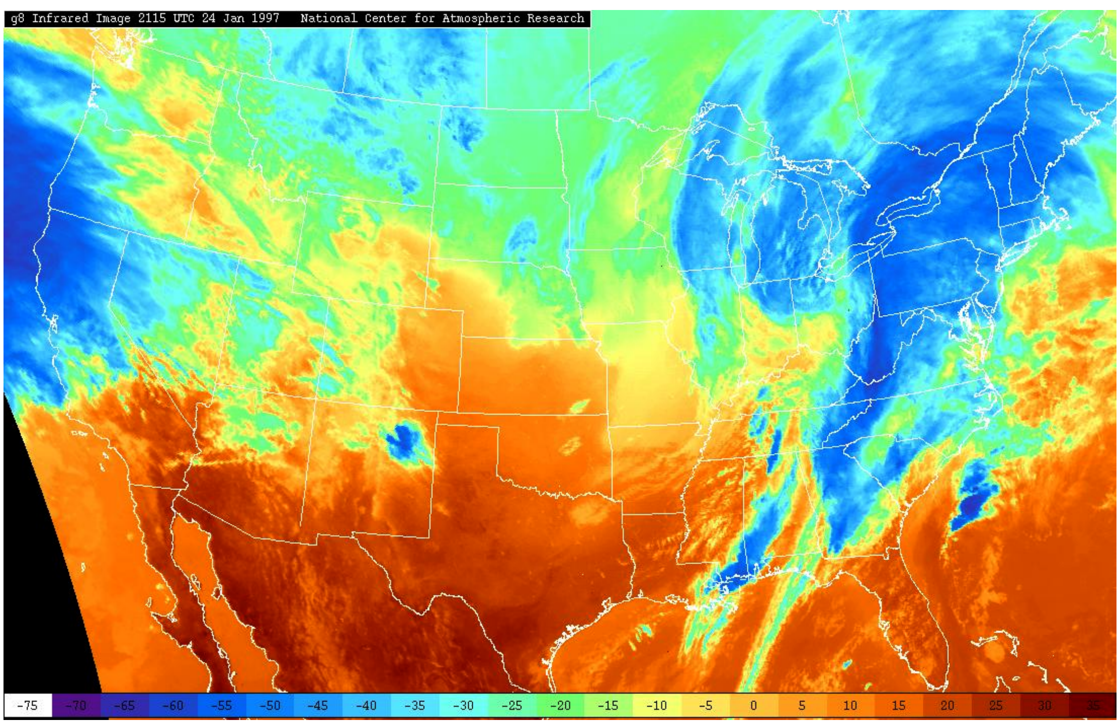


Figure 4 – GOES 8 infrared satellite data for e) 2015 and f) 2115 UTC.

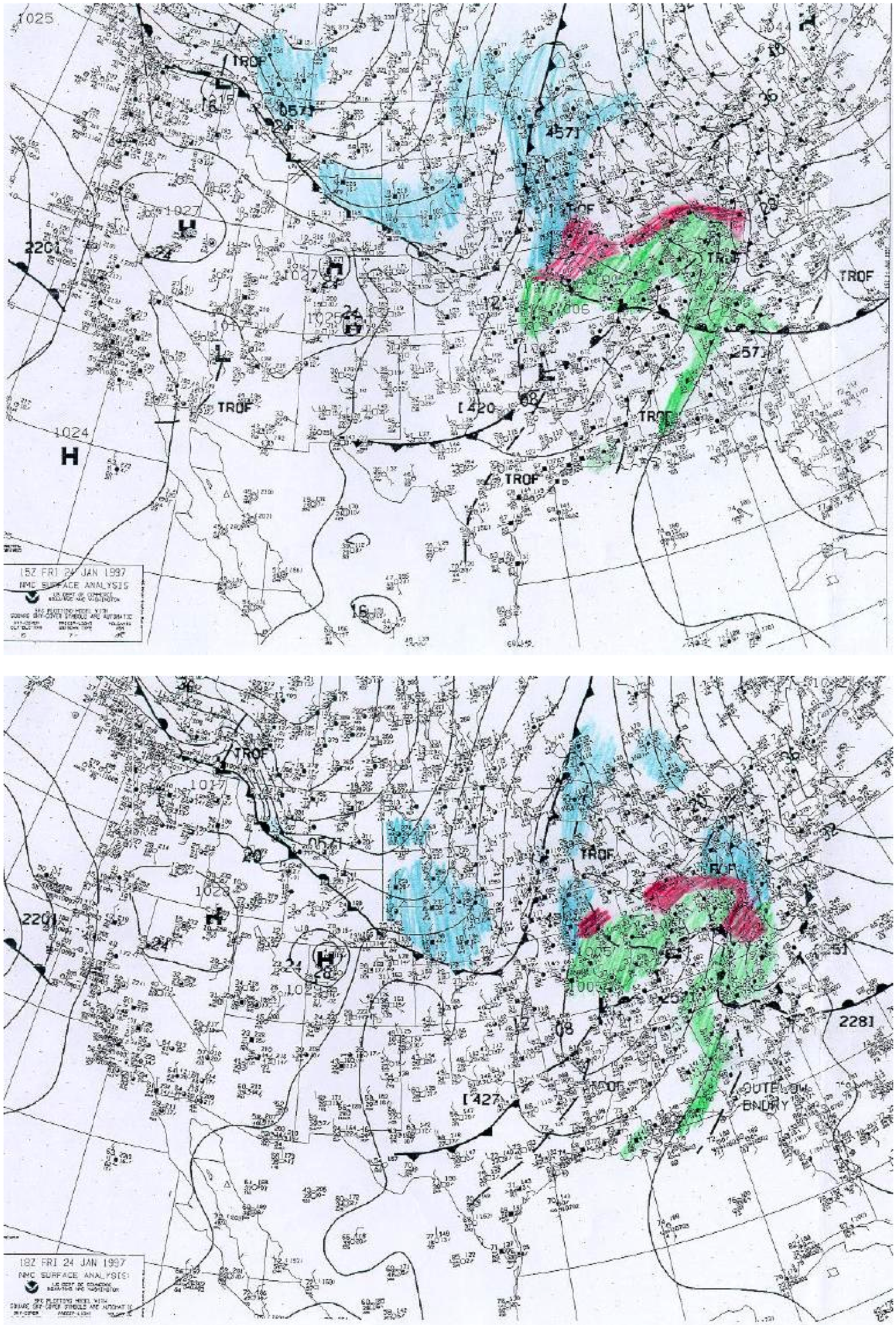


Figure 5 – Surface charts for 970124, a) 1500 and b) 1800 UTC.

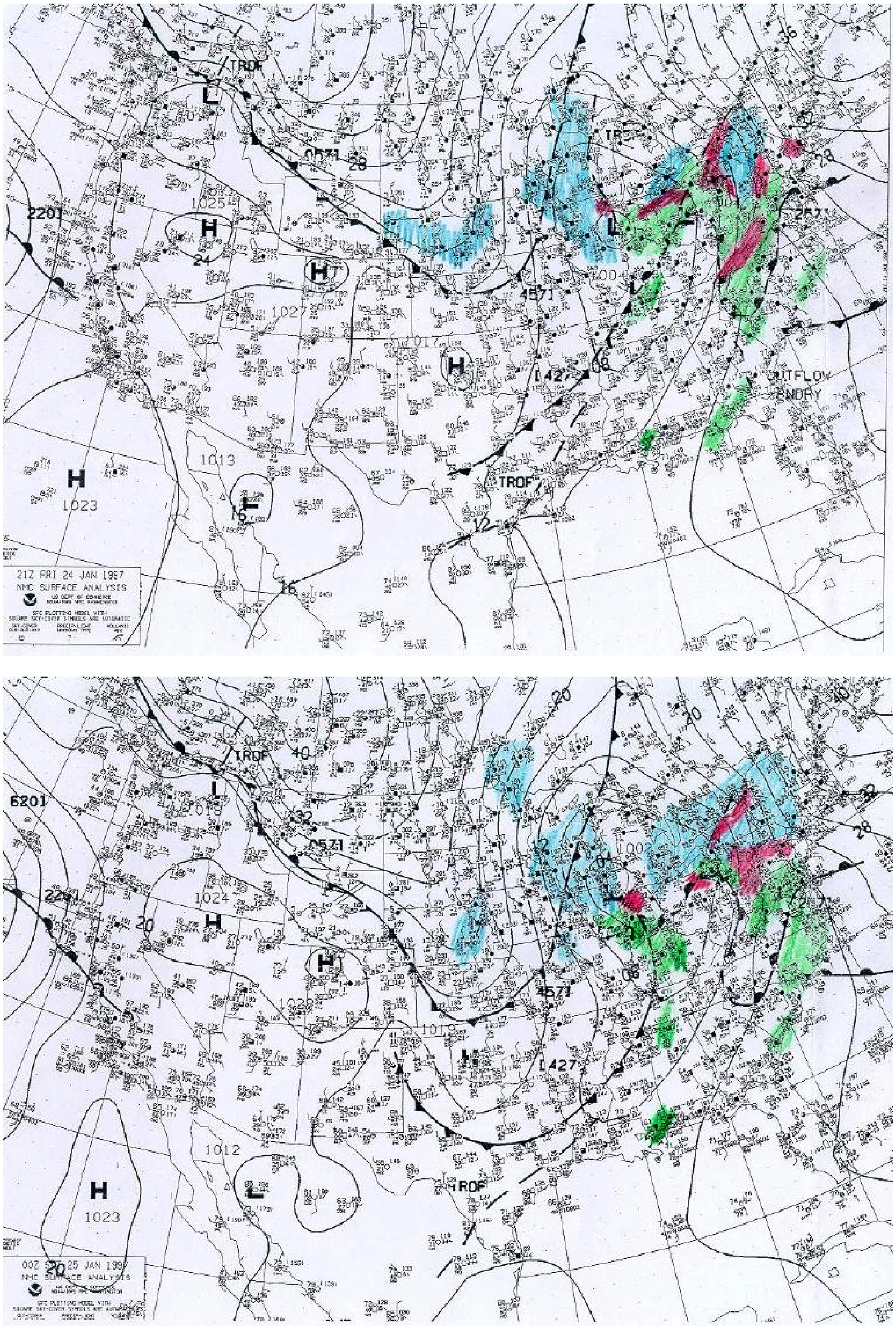


Figure 5 – Surface charts for c) 970124, 2100 and d) 970125, 0000 UTC.

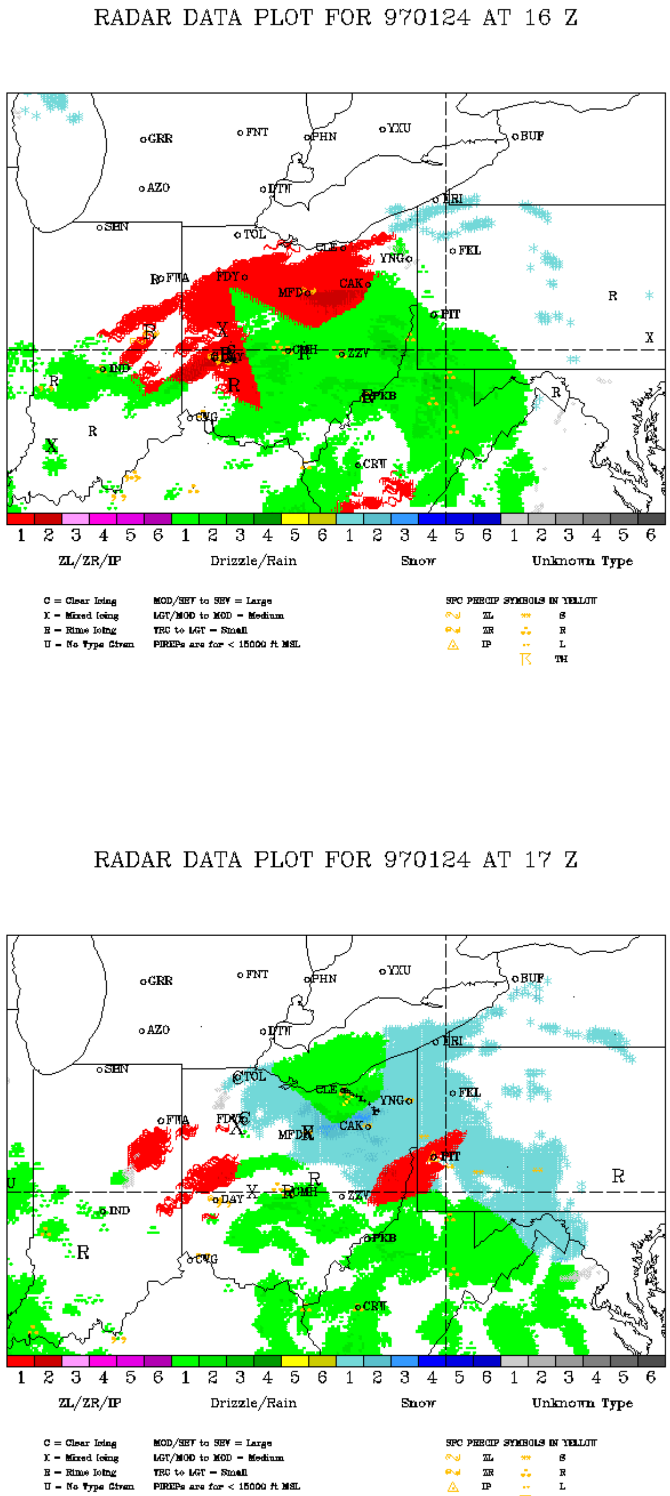
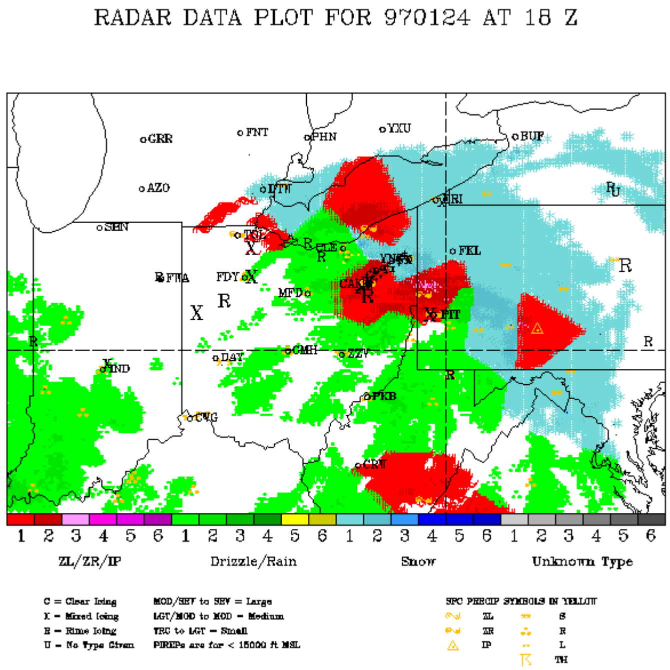


Figure 6 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970124, a) 1600 and b) 1700 UTC.



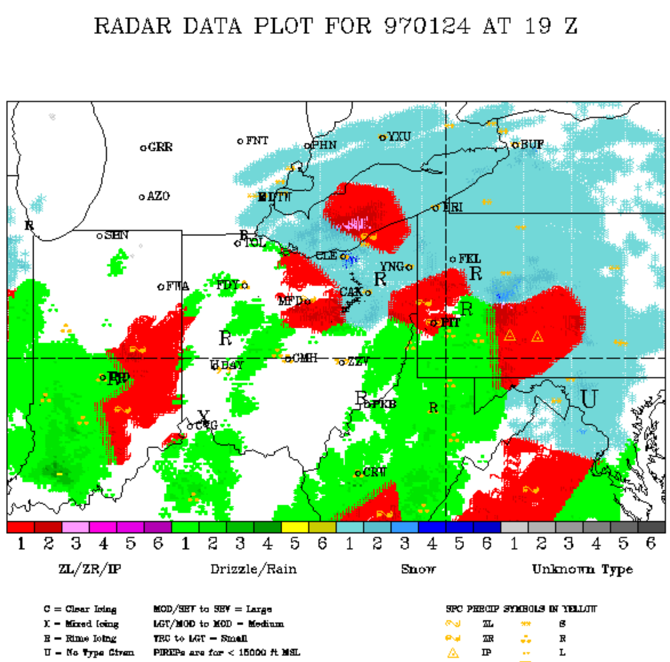
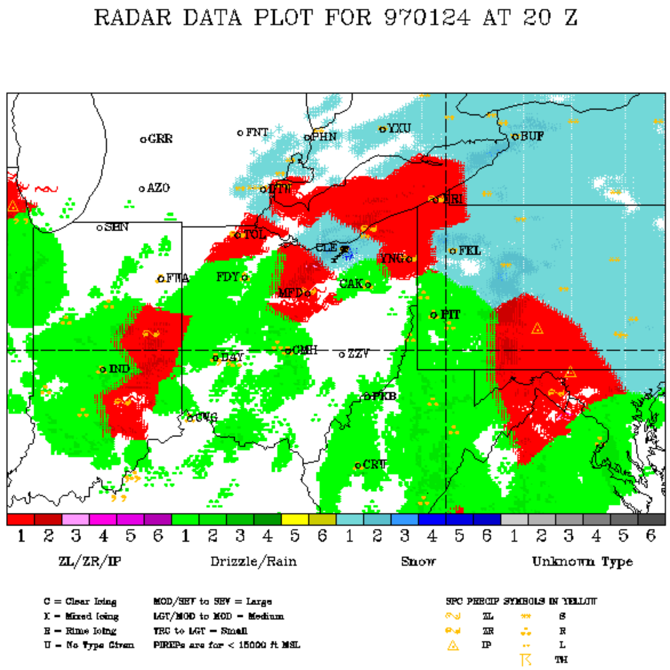


Figure 6 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970124, c) 1800 and d) 1900 UTC.



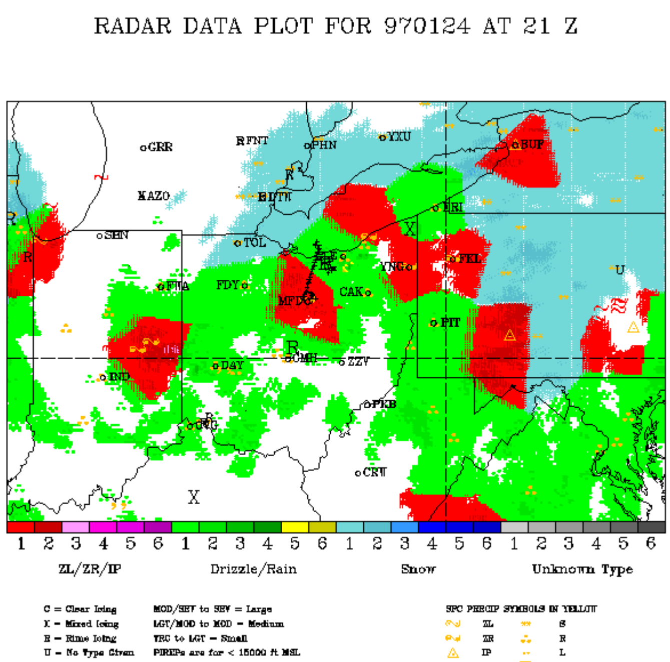


Figure 6 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970124, e) 2000 and f) 2100 UTC.

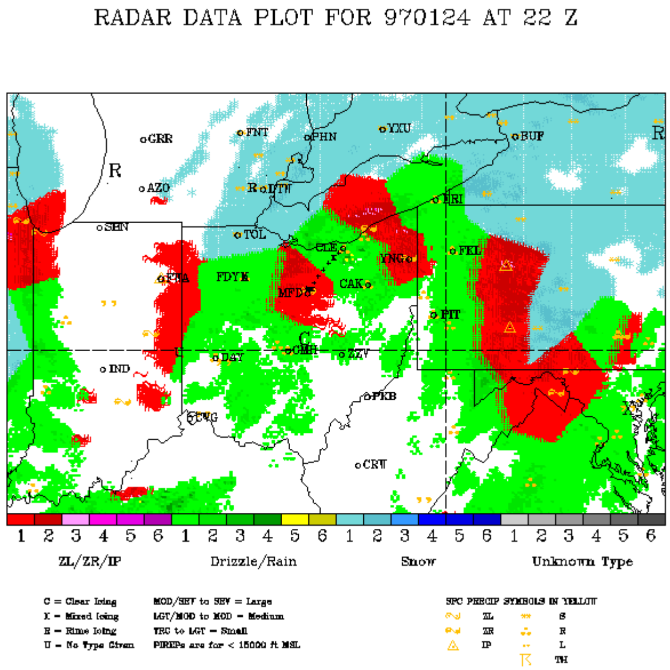


Figure 6 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for g) 970124, 2200 UTC.

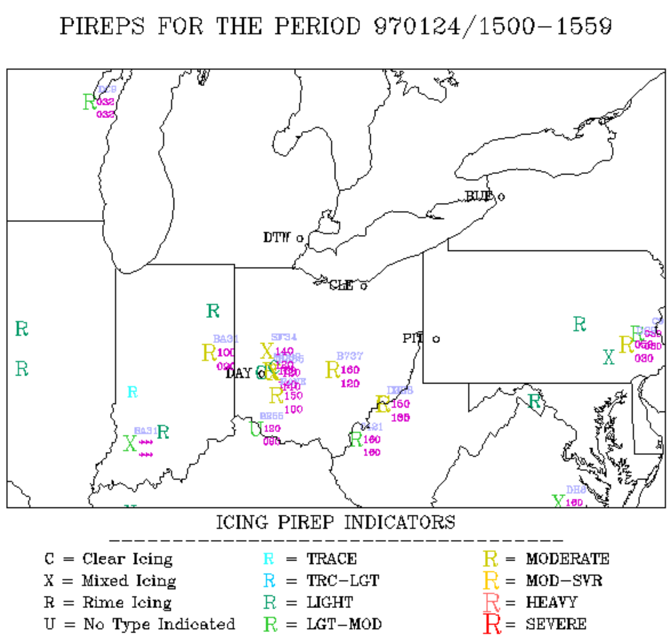
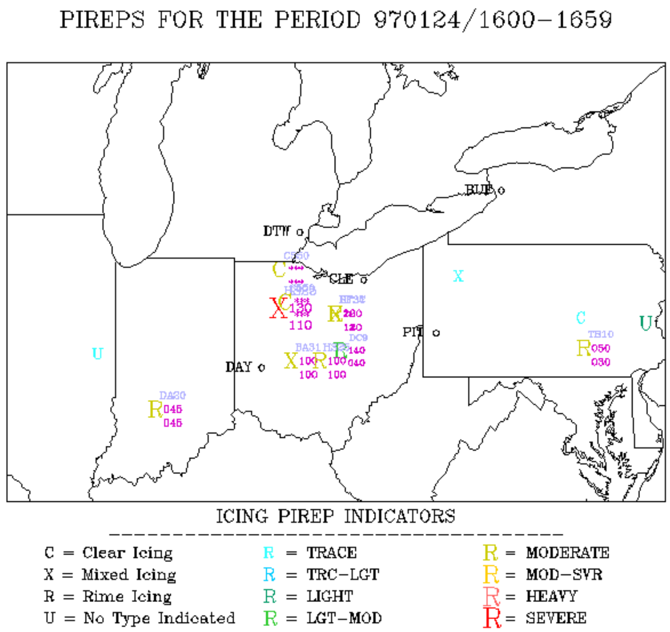


Figure 7 – Pilot reports of icing for 970124, a) 1500-1559 UTC.



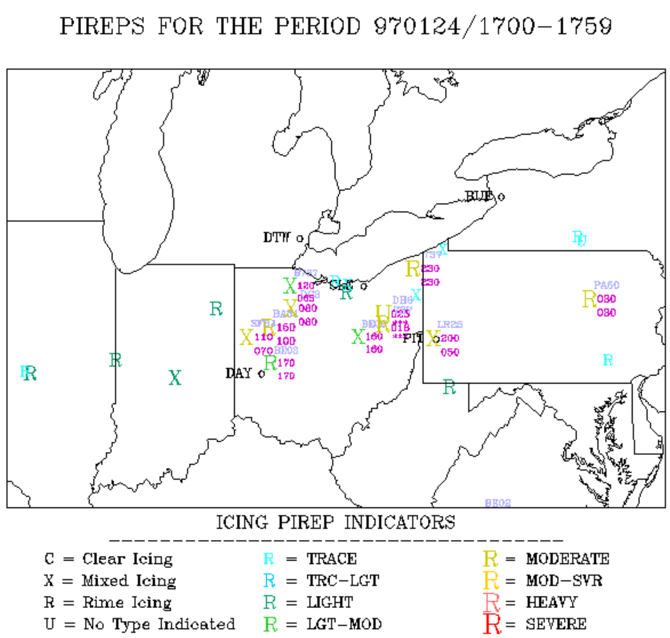
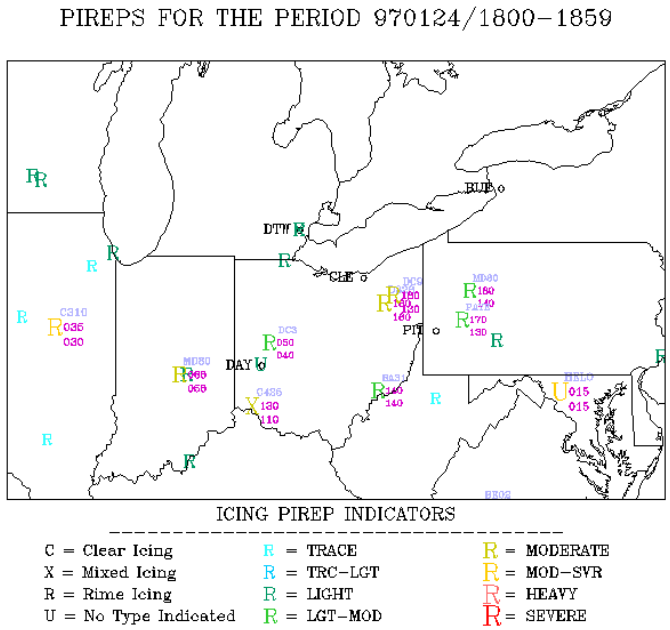


Figure 7 – Pilot reports of icing for 970124, b) 1600-1659 and c) 1700-1759 UTC.



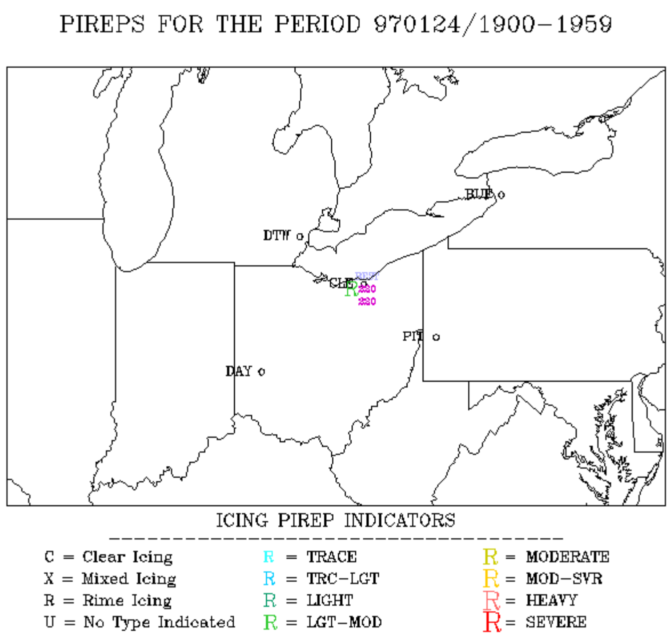
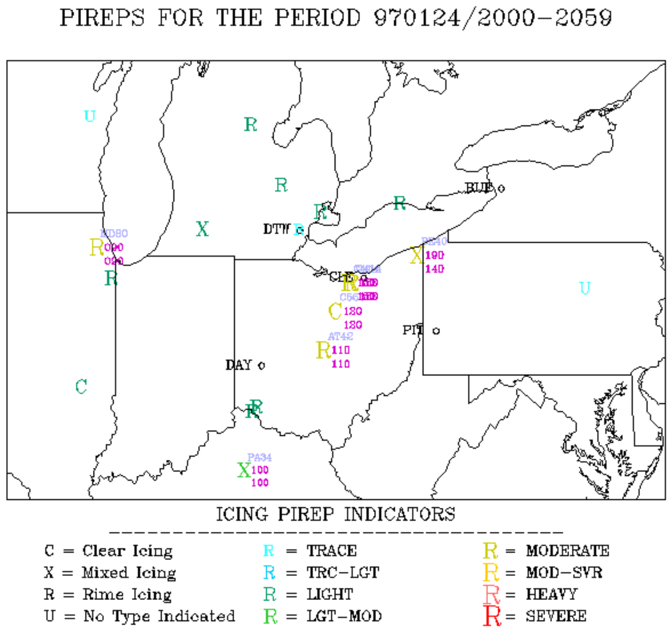


Figure 7 – Pilot reports of icing for 970124, d) 1800-1859 and e) 1900-1959 UTC.



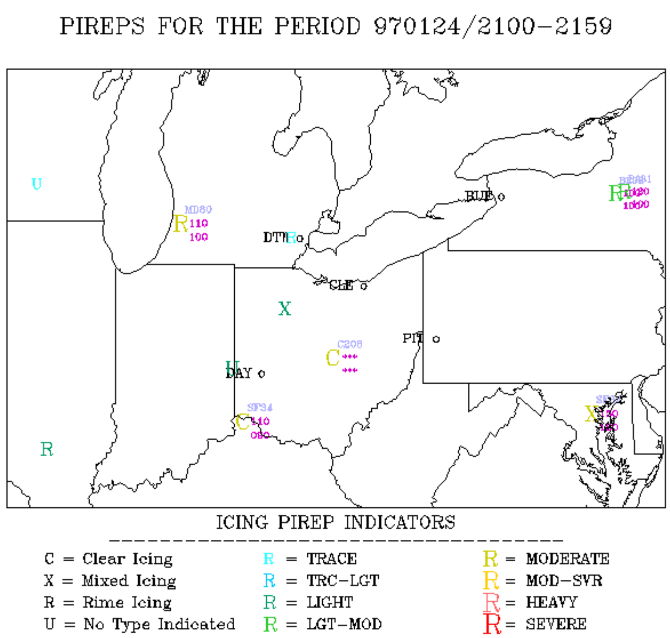


Figure 7 – Pilot reports of icing for 970124, f) 2000-2059 and g) 2100-2159 UTC.

970124 - Flight #1

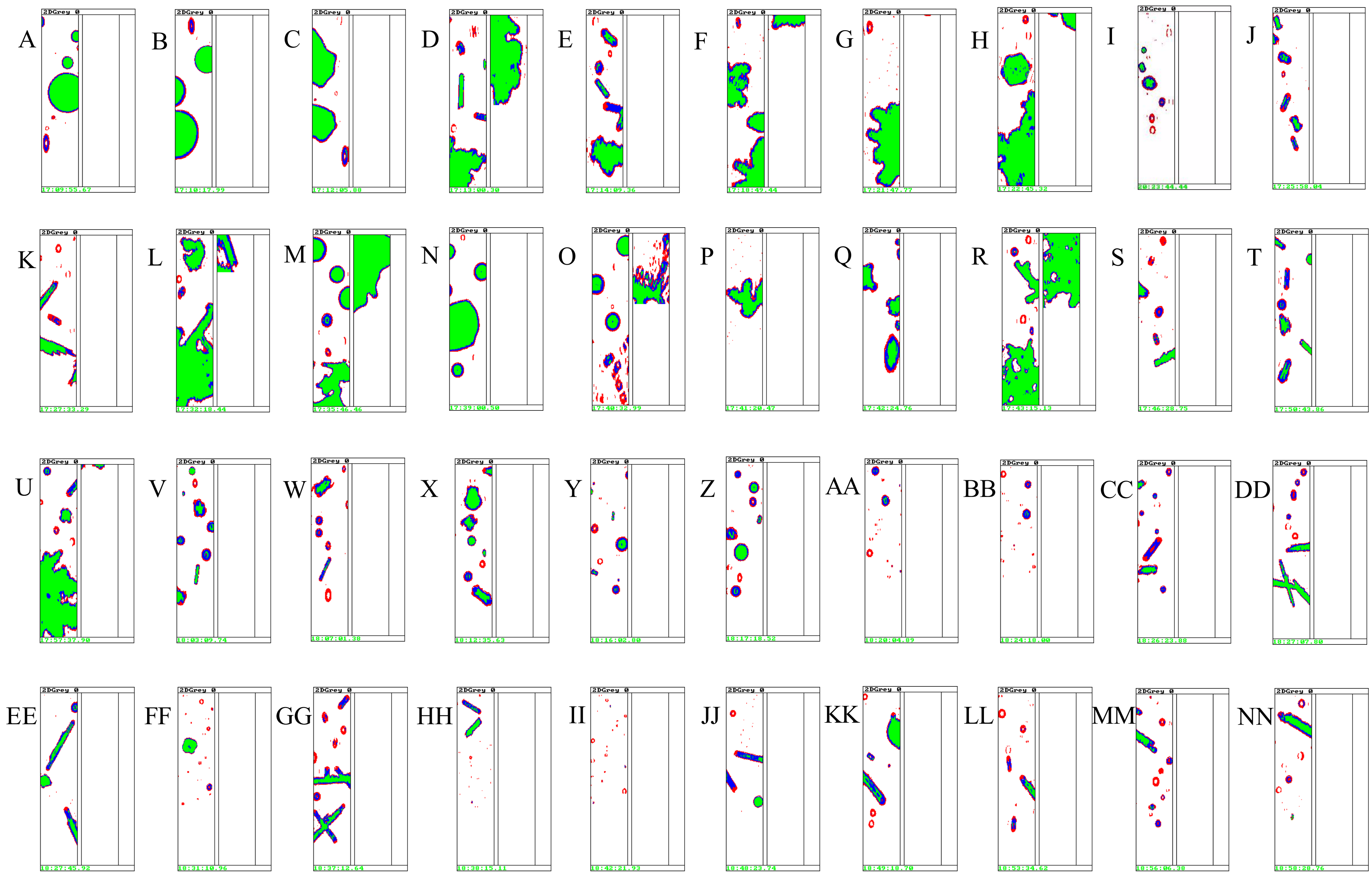


Figure 8 - 2D-grey probe imagery for flight 1.

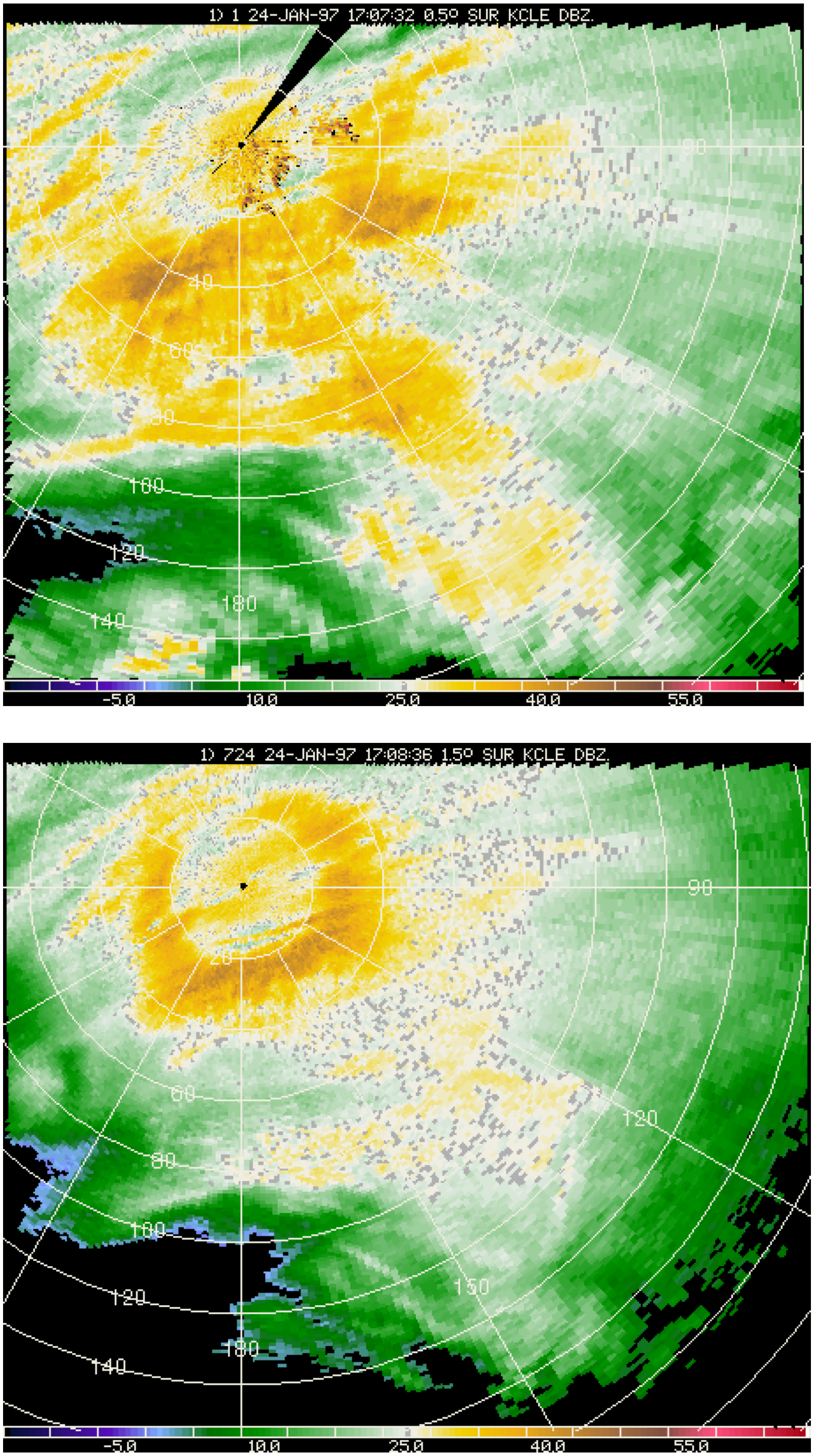
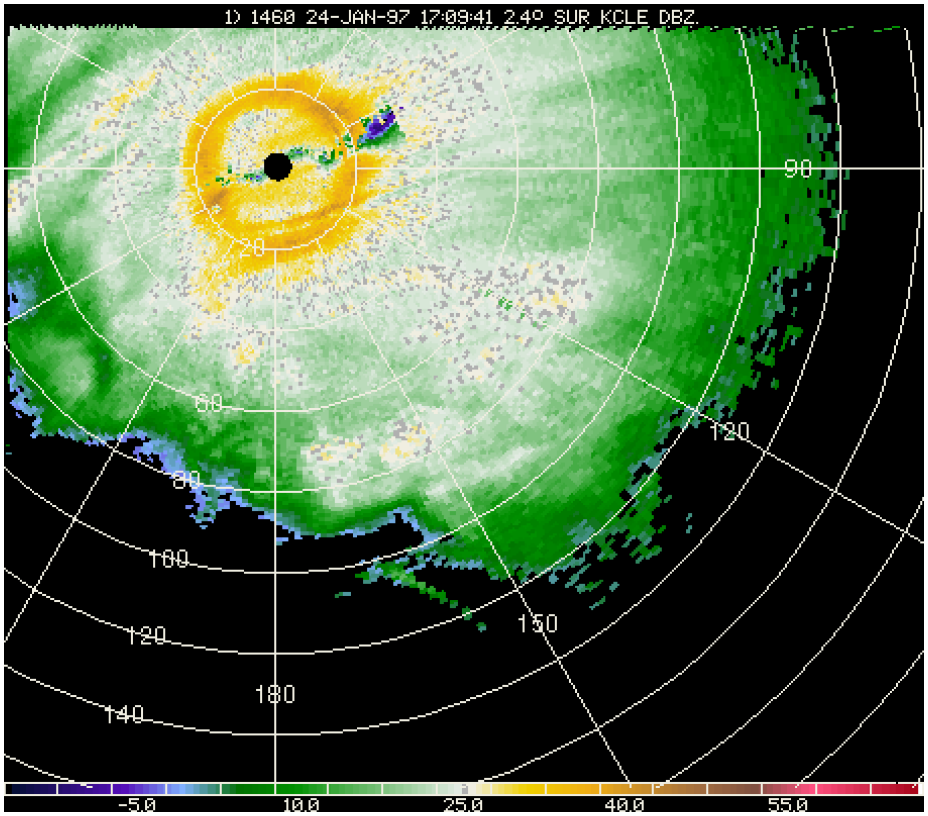


Figure 9 – Cleveland NEXRAD data for 970124, a) 1707 (0.5 degrees elevation) and b) 1708 UTC (1.5 degrees elevation).



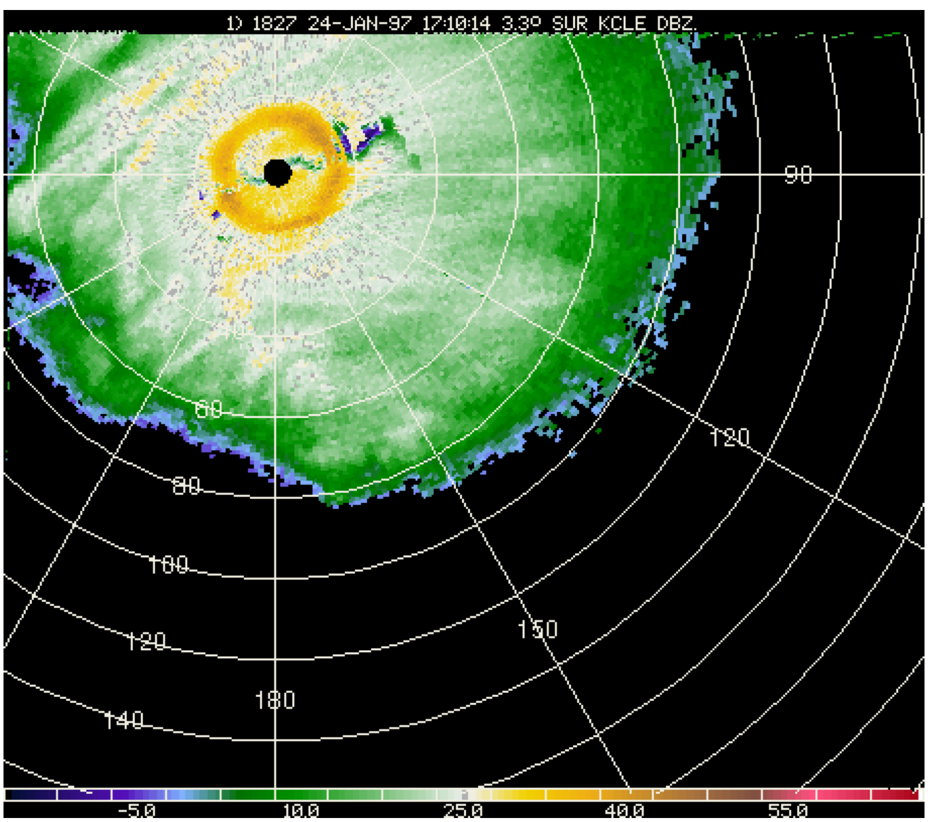


Figure 9 – Same, but for c) 1709 (2.4) and d) 1710 UTC (3.3).

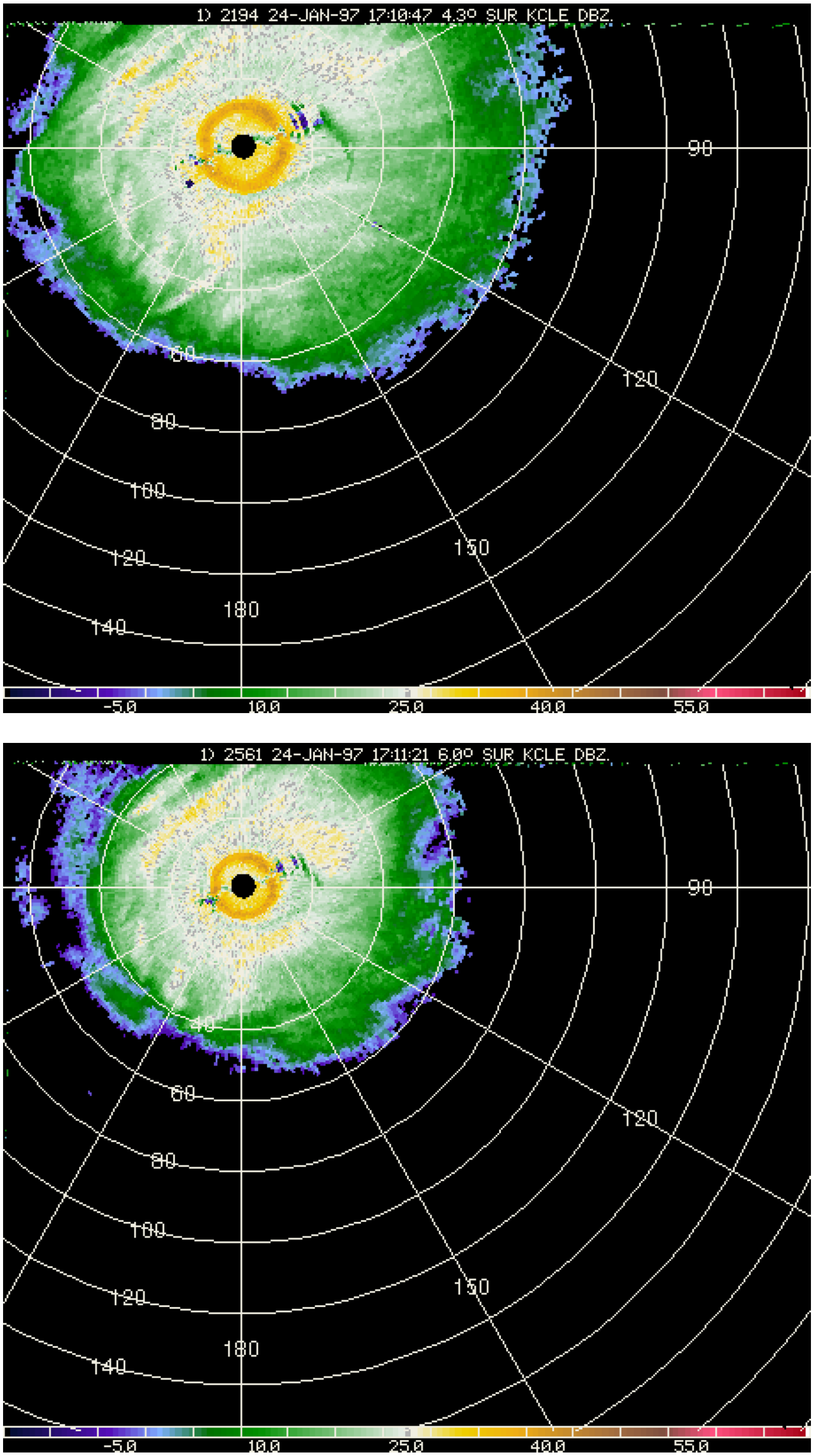
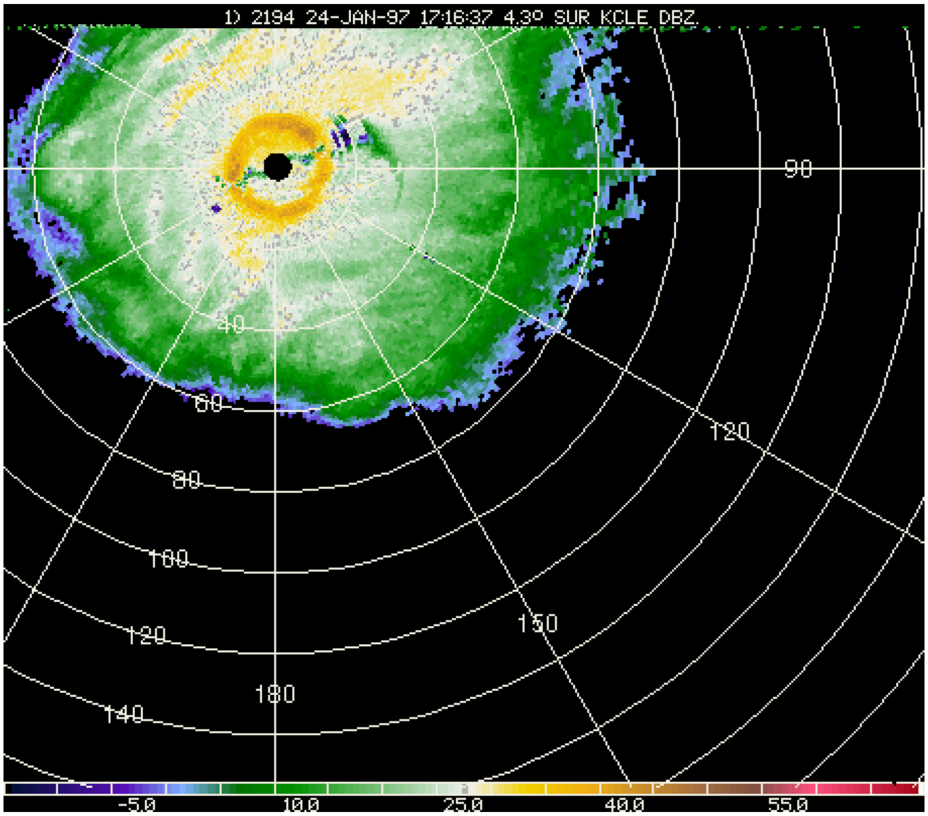


Figure 9 – Same, but for e) 1710 (4.3) and f) 1711 UTC (6.0).



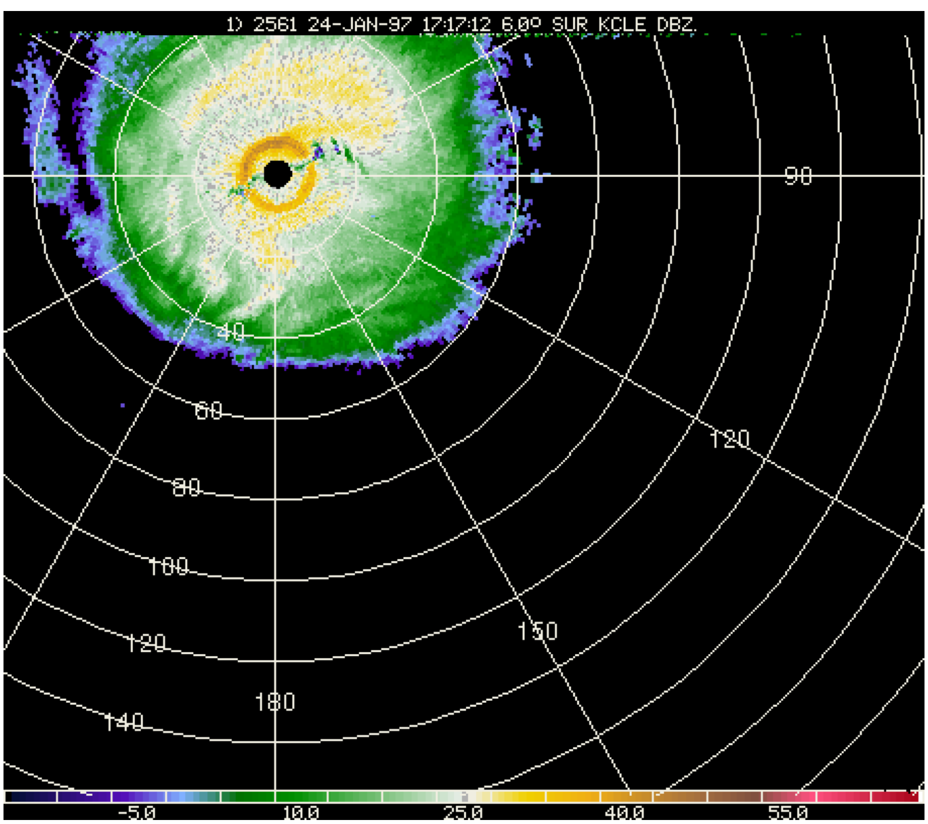


Figure 9 – Same, but for g) 1716 (4.3) and h) 1717 UTC (6.0).

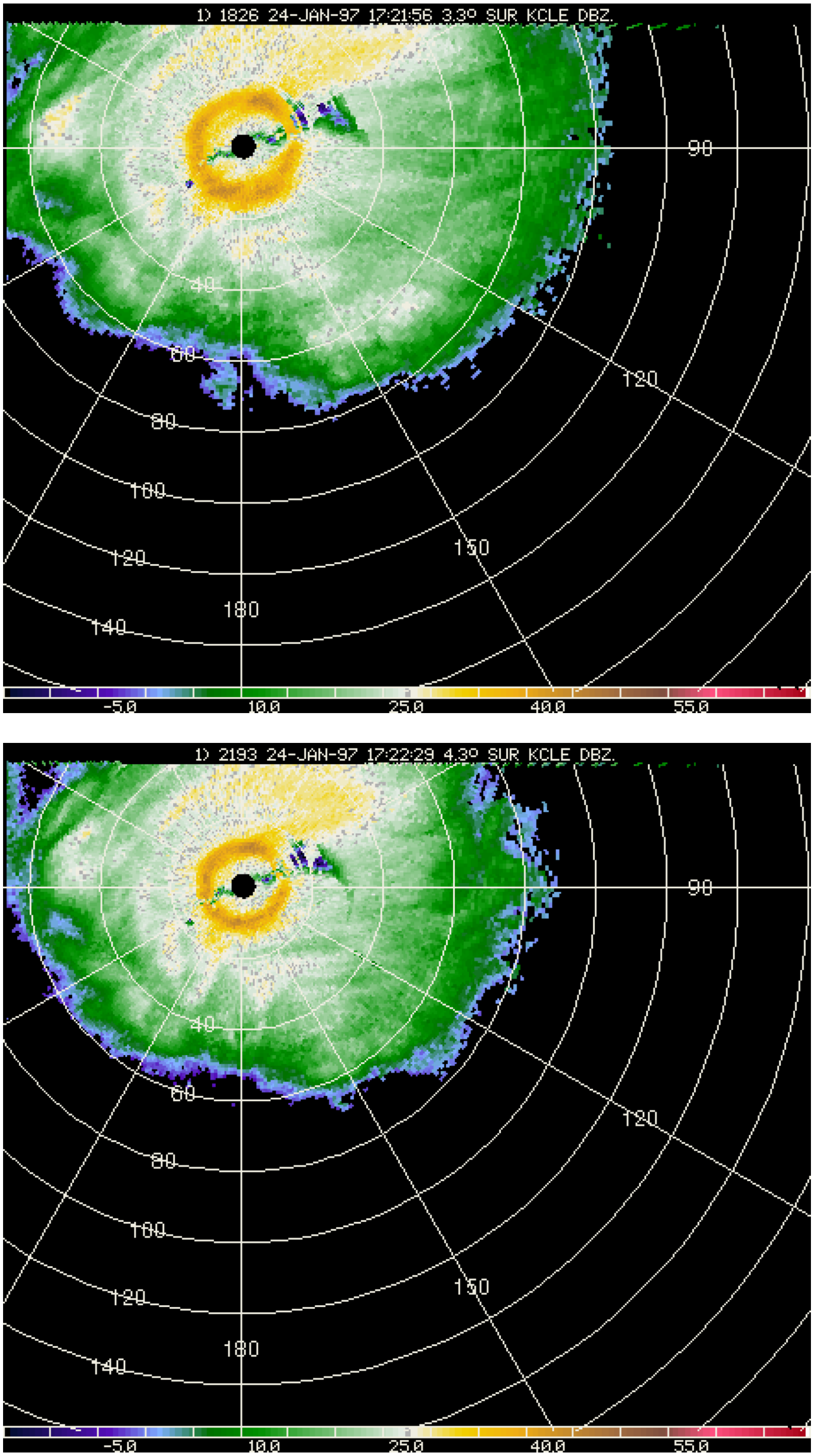


Figure 9 – Same, but for i) 1721 (3.3) and j) 1722 UTC (4.3).

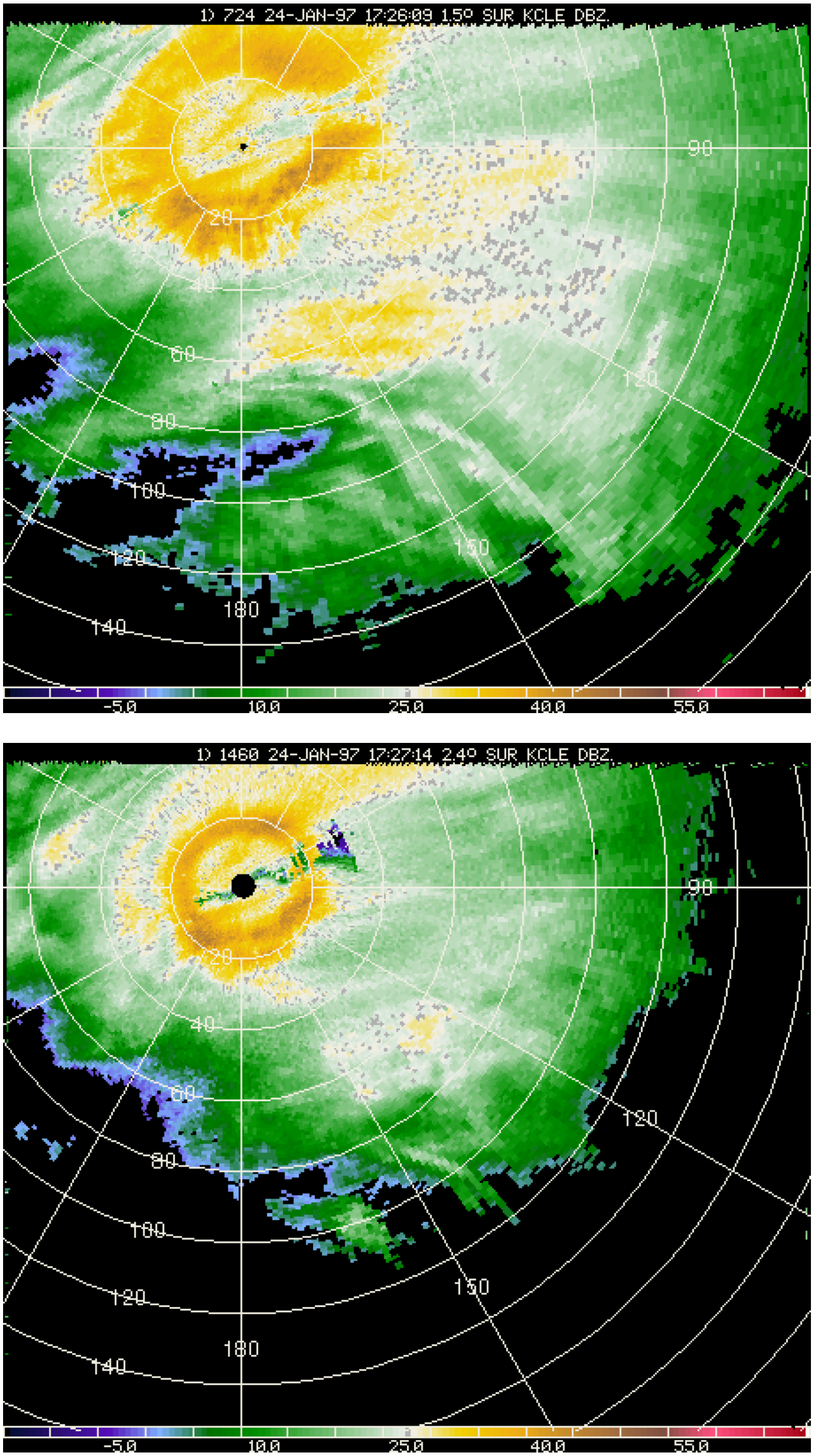
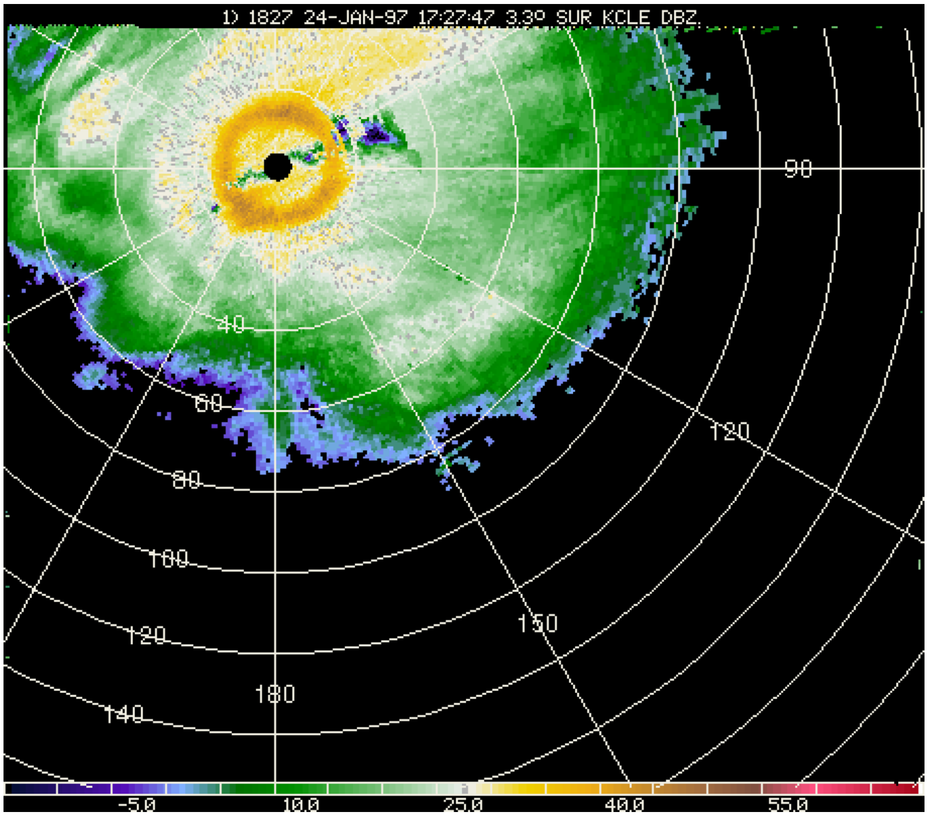


Figure 9 – Same, but for k) 1726 (1.5) and l) 1727 UTC (2.4).



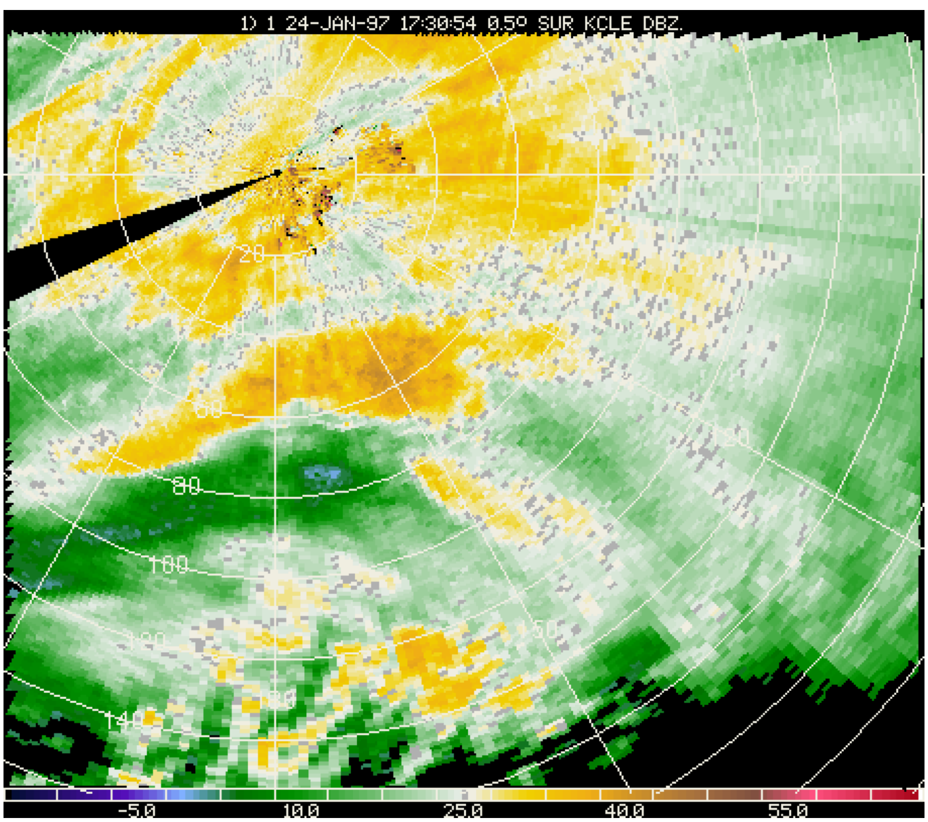
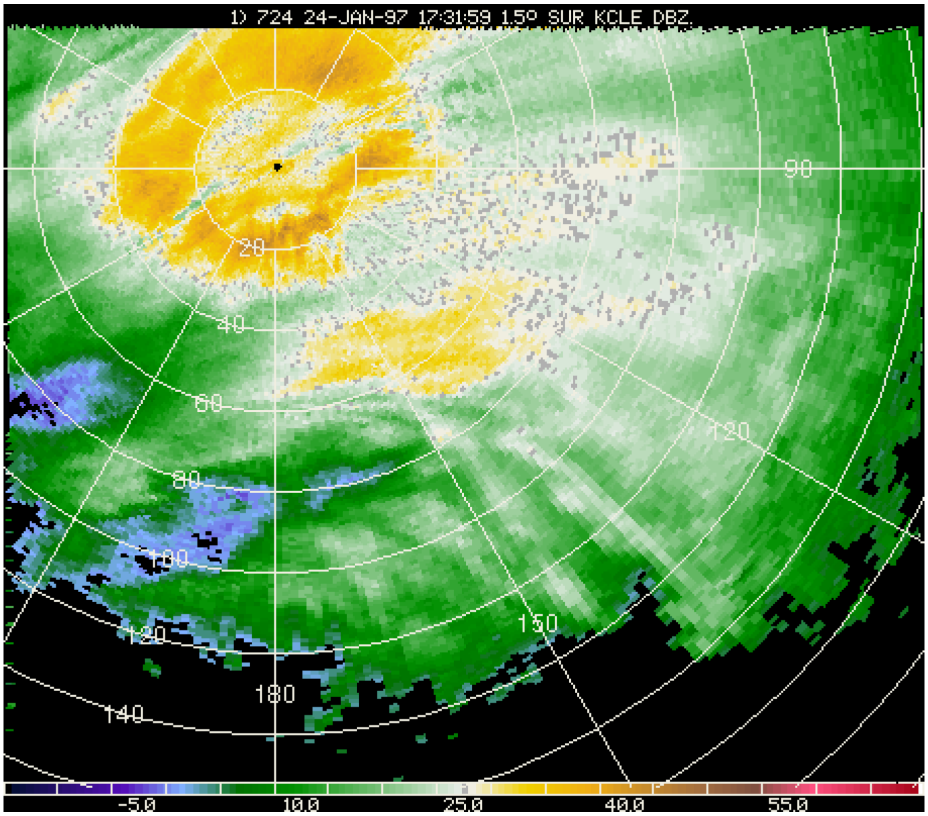


Figure 9 – Same, but for m) 1727 (3.3) and n) 1730 UTC (0.5).



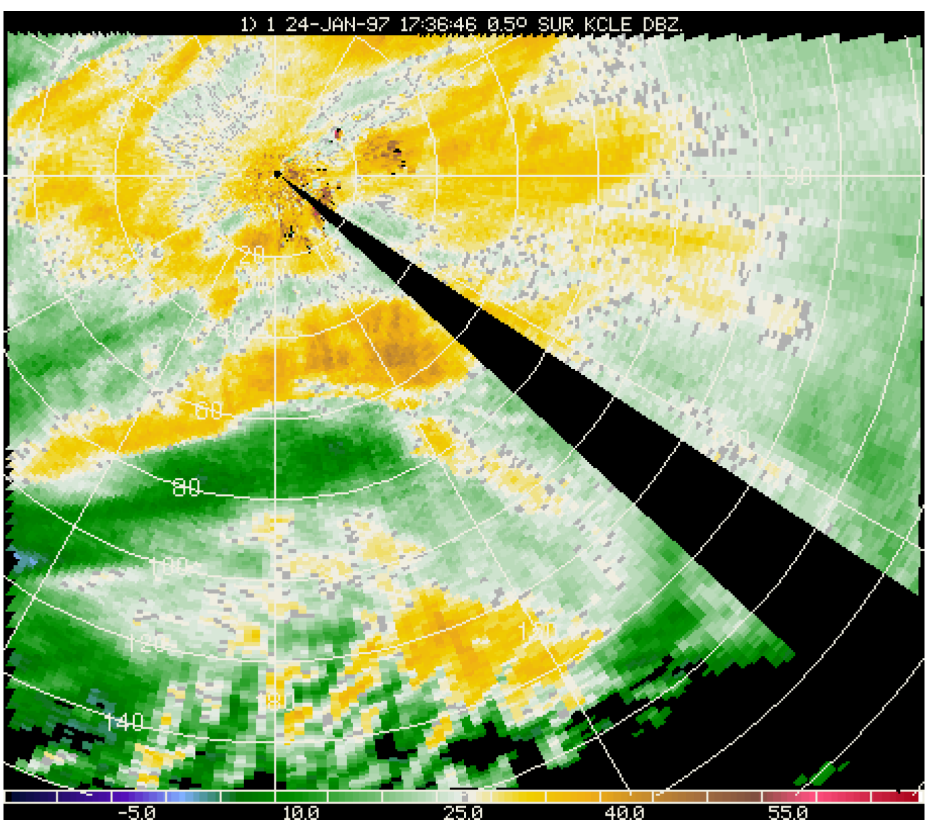
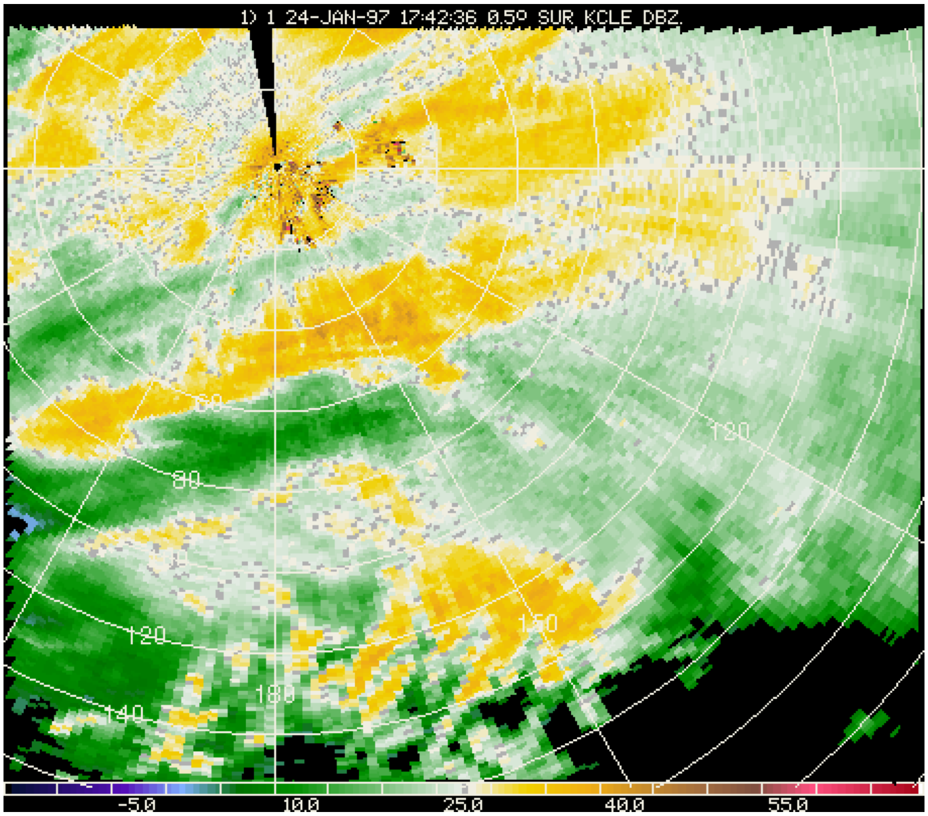


Figure 9 – Same, but for o) 1731 (1.5) and p) 1736 UTC (0.5).



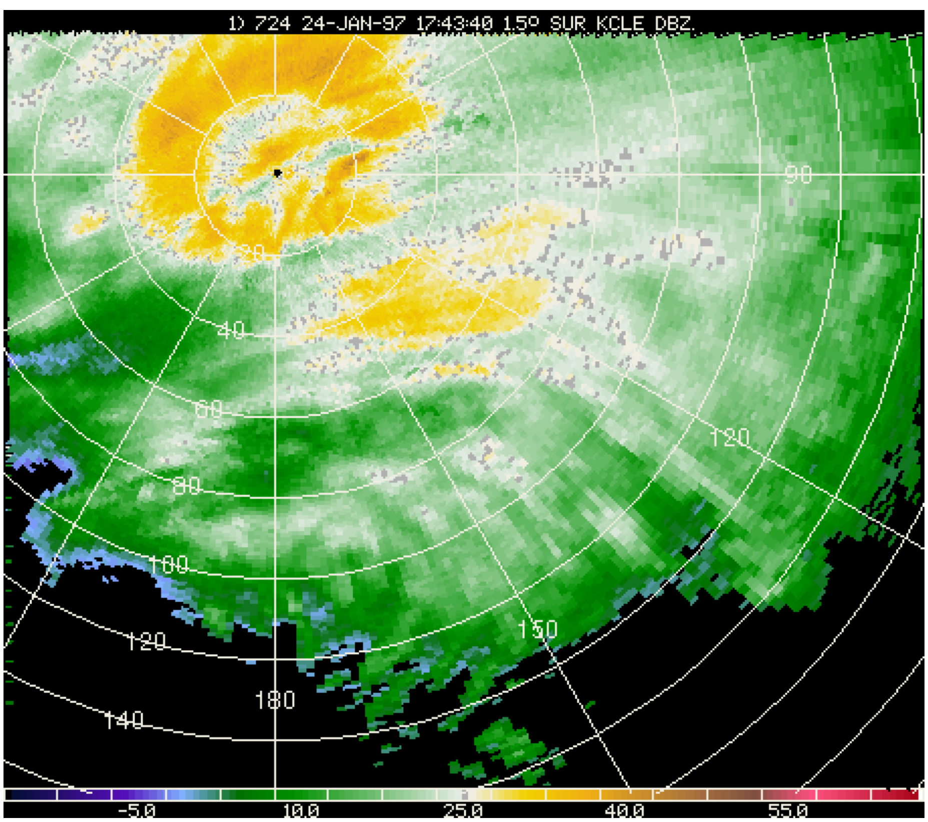


Figure 9 – Same, but for q) 1742 (0.5) and r) 1743 UTC (1.5).

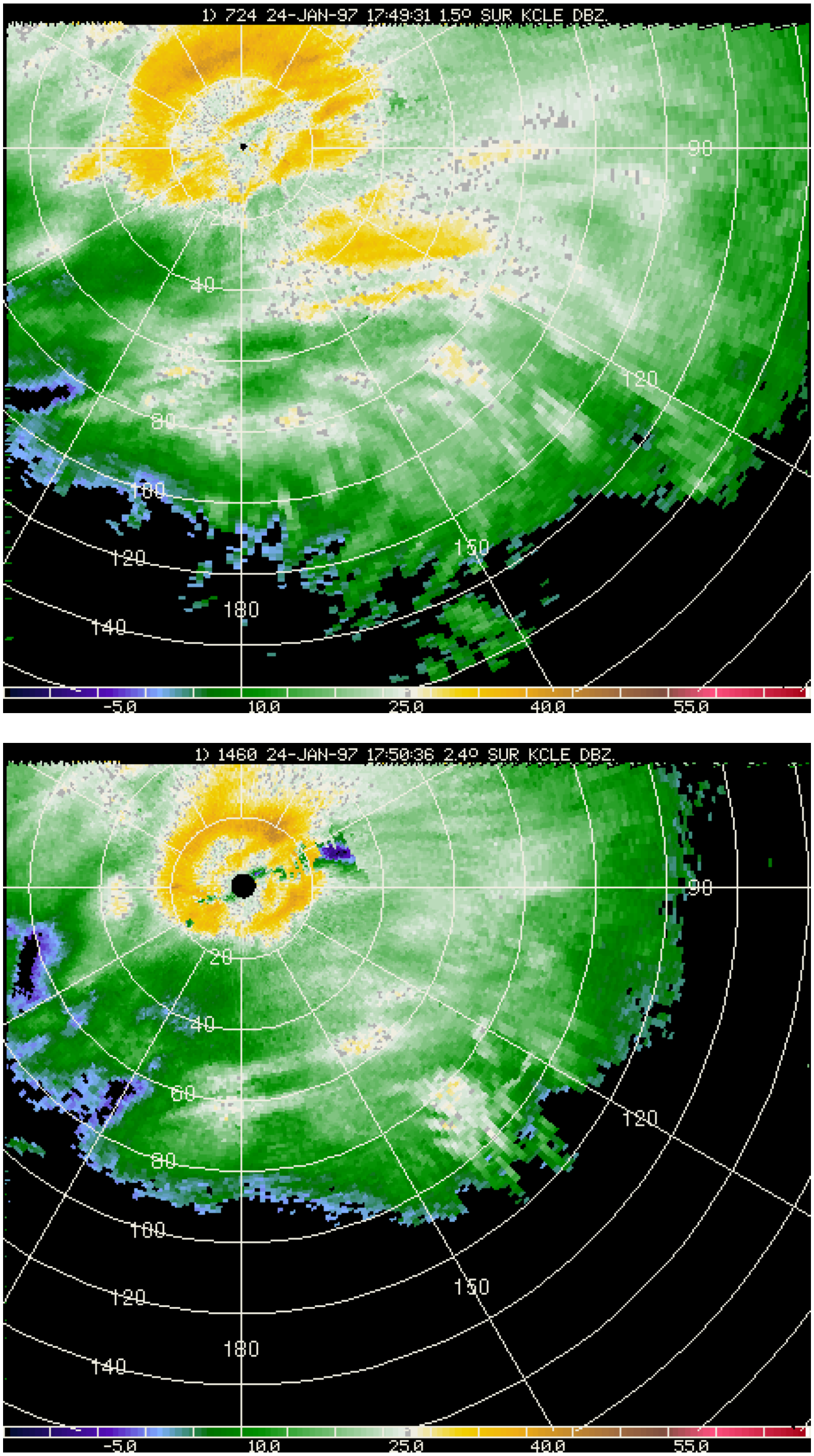


Figure 9 – Same, but for s) 1749 (1.5) and s2) 1750 UTC (2.4).

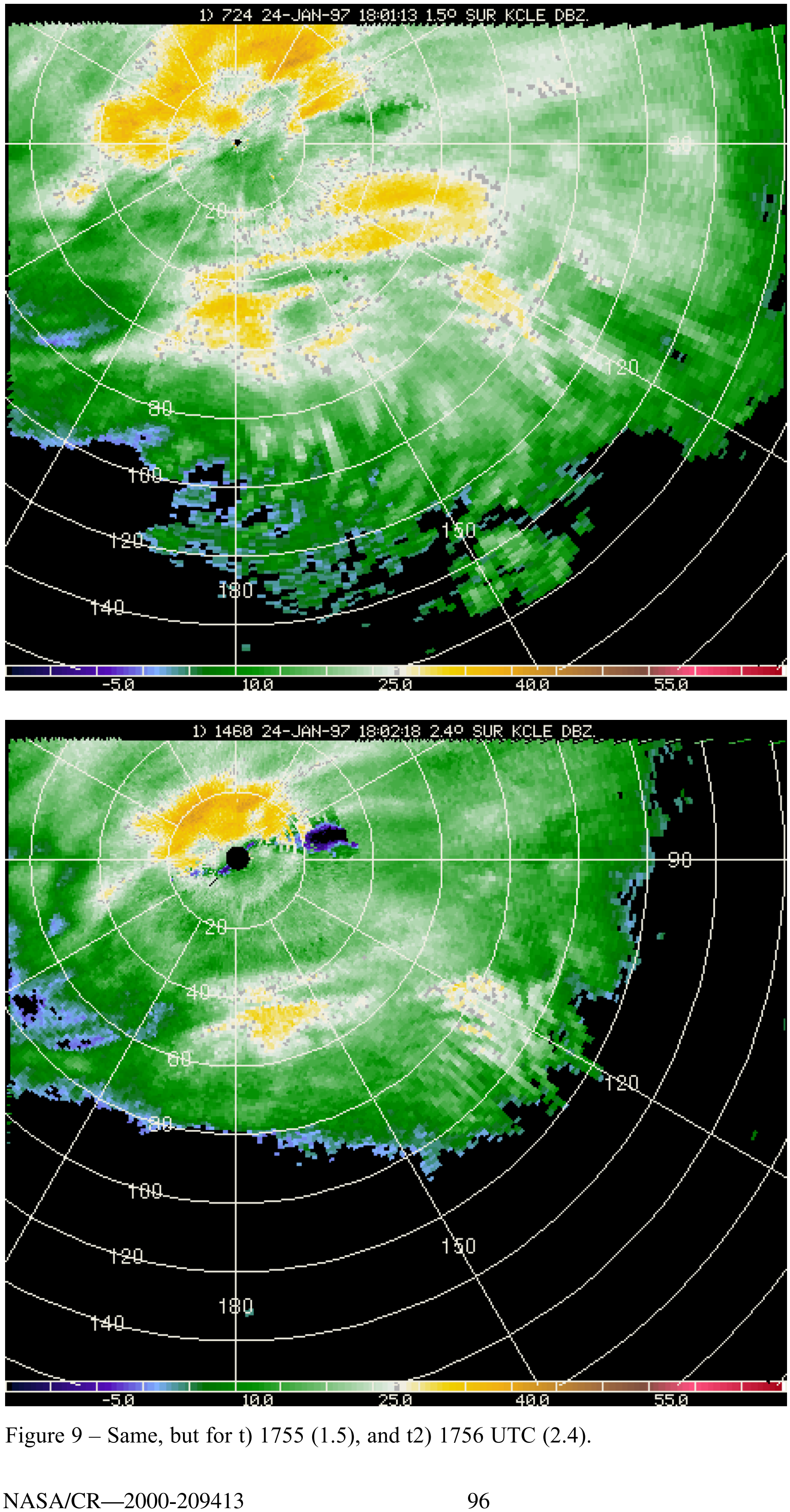


Figure 9 – Same, but for t) 1755 (1.5), and t2) 1756 UTC (2.4).

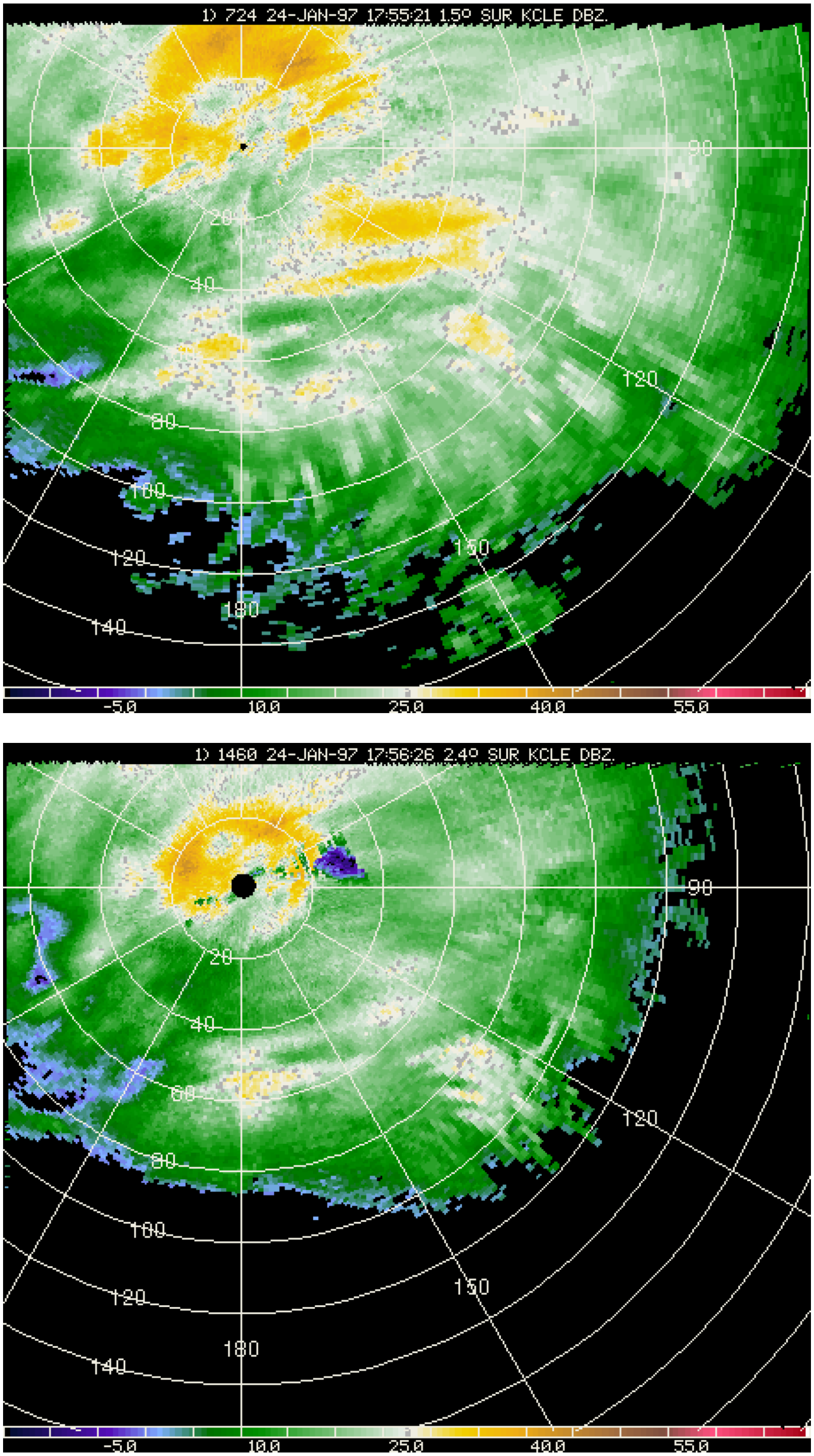


Figure 9 – Same, but for u) 1801 (1.5) and v) 1802 UTC (2.4).

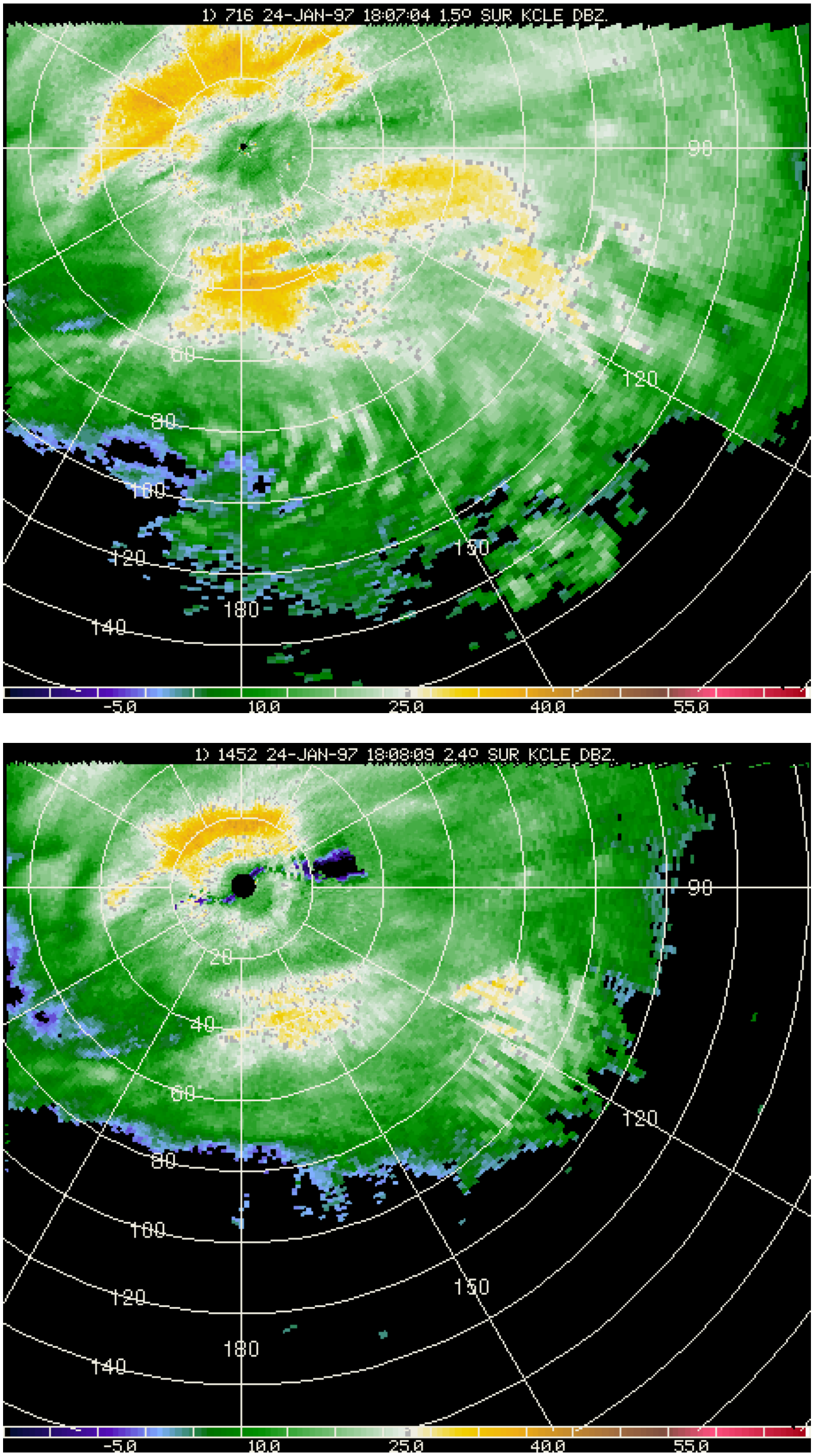
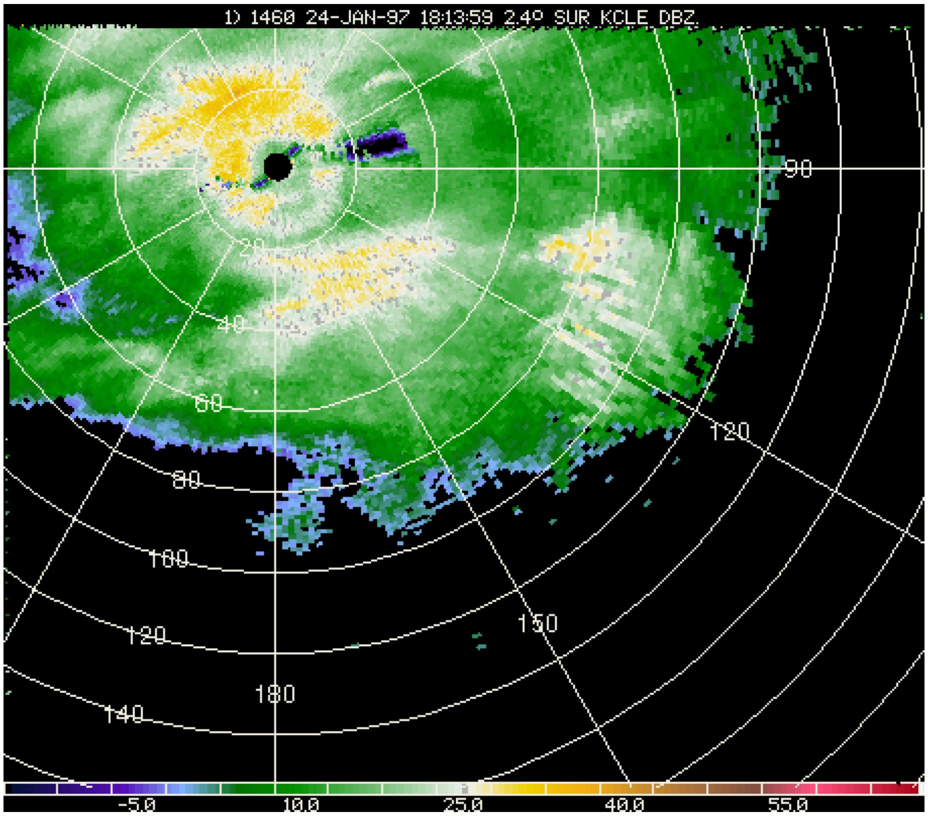


Figure 9 – Same, but for w) 1807 (1.5) and x) 1808 UTC (2.4).



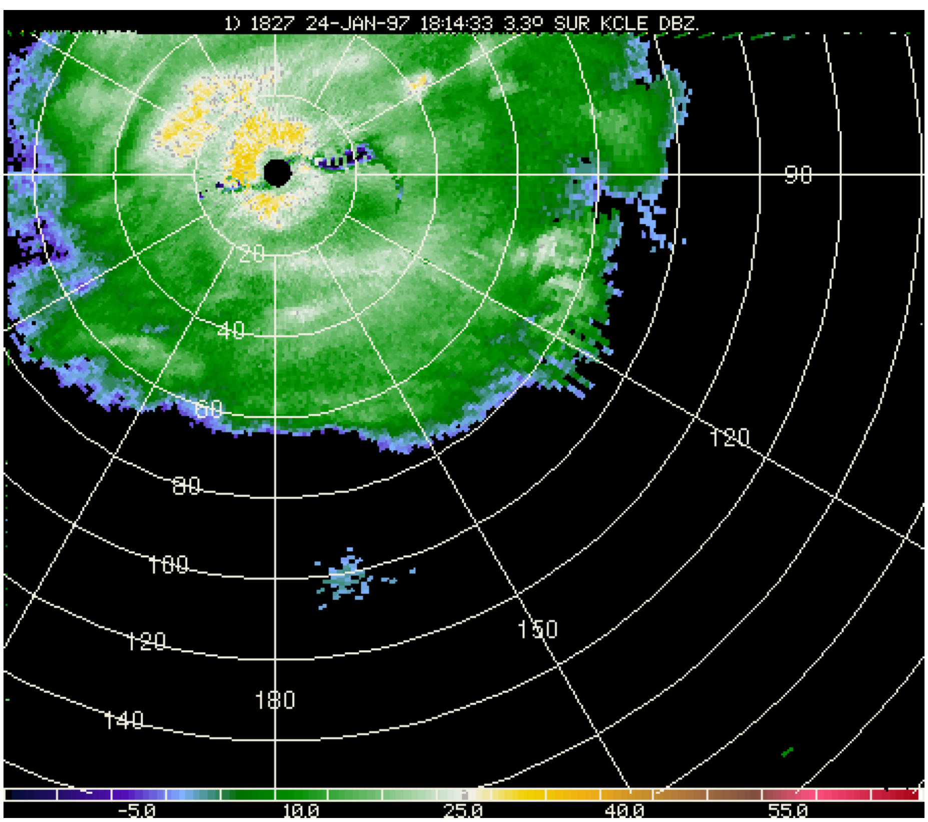
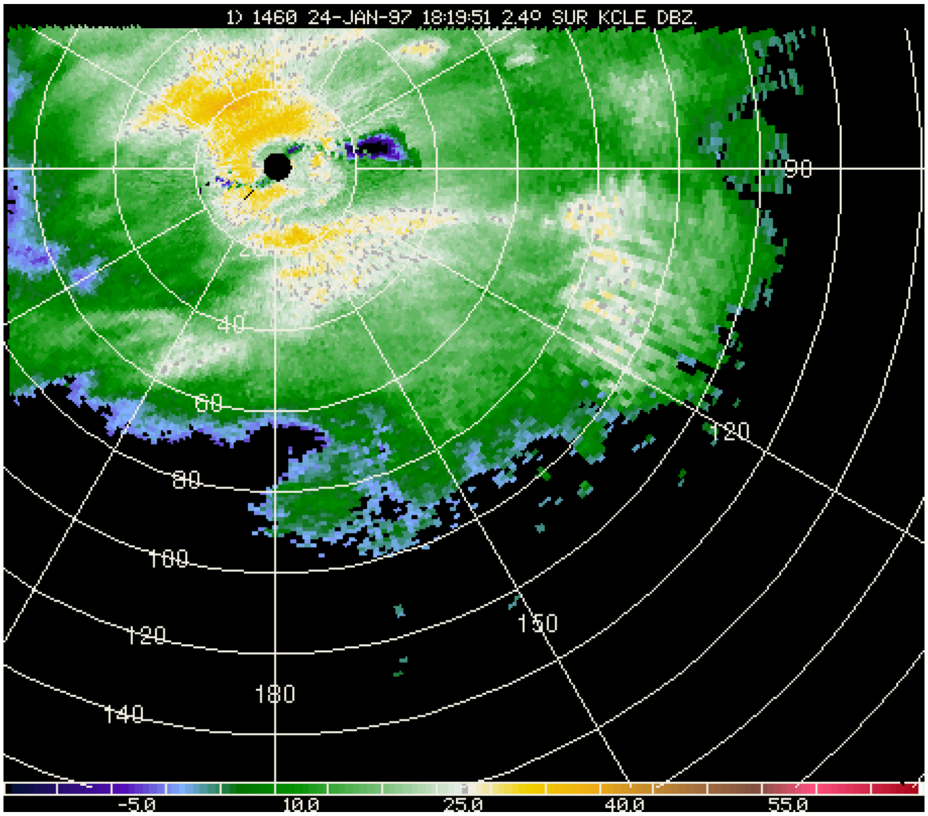


Figure 9 – Same, but for y) 1813 (2.4) and z) 1814 UTC (3.3).



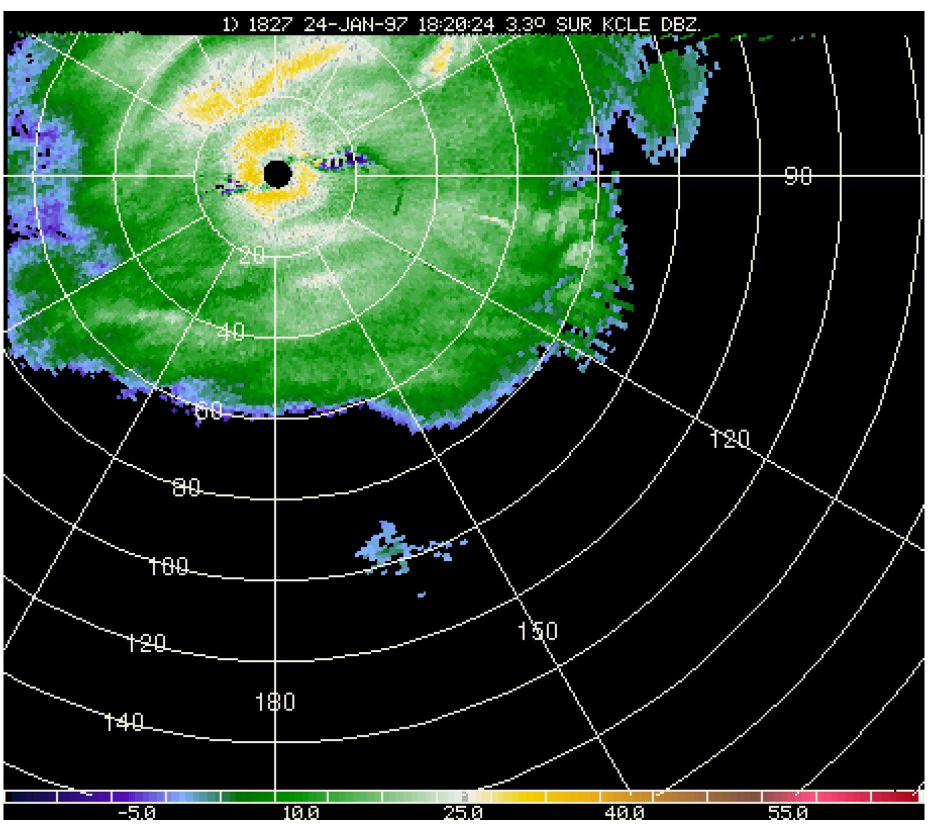


Figure 9 – Same, but for aa) 1819 (2.4) and bb) 1820 UTC (3.3).

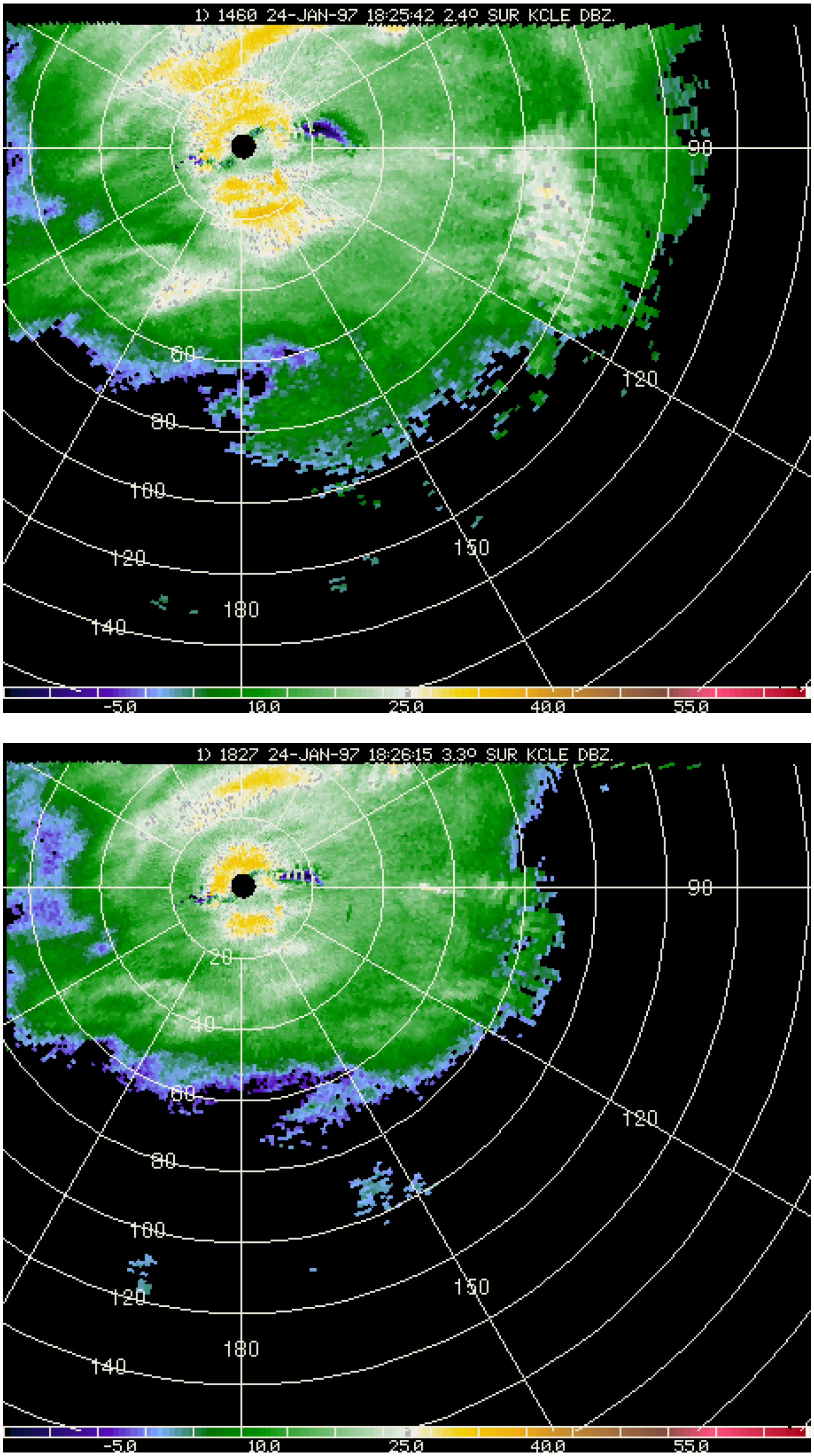


Figure 9 – Same, but for cc) 1825 (2.4) and dd) 1826 UTC (3.3).

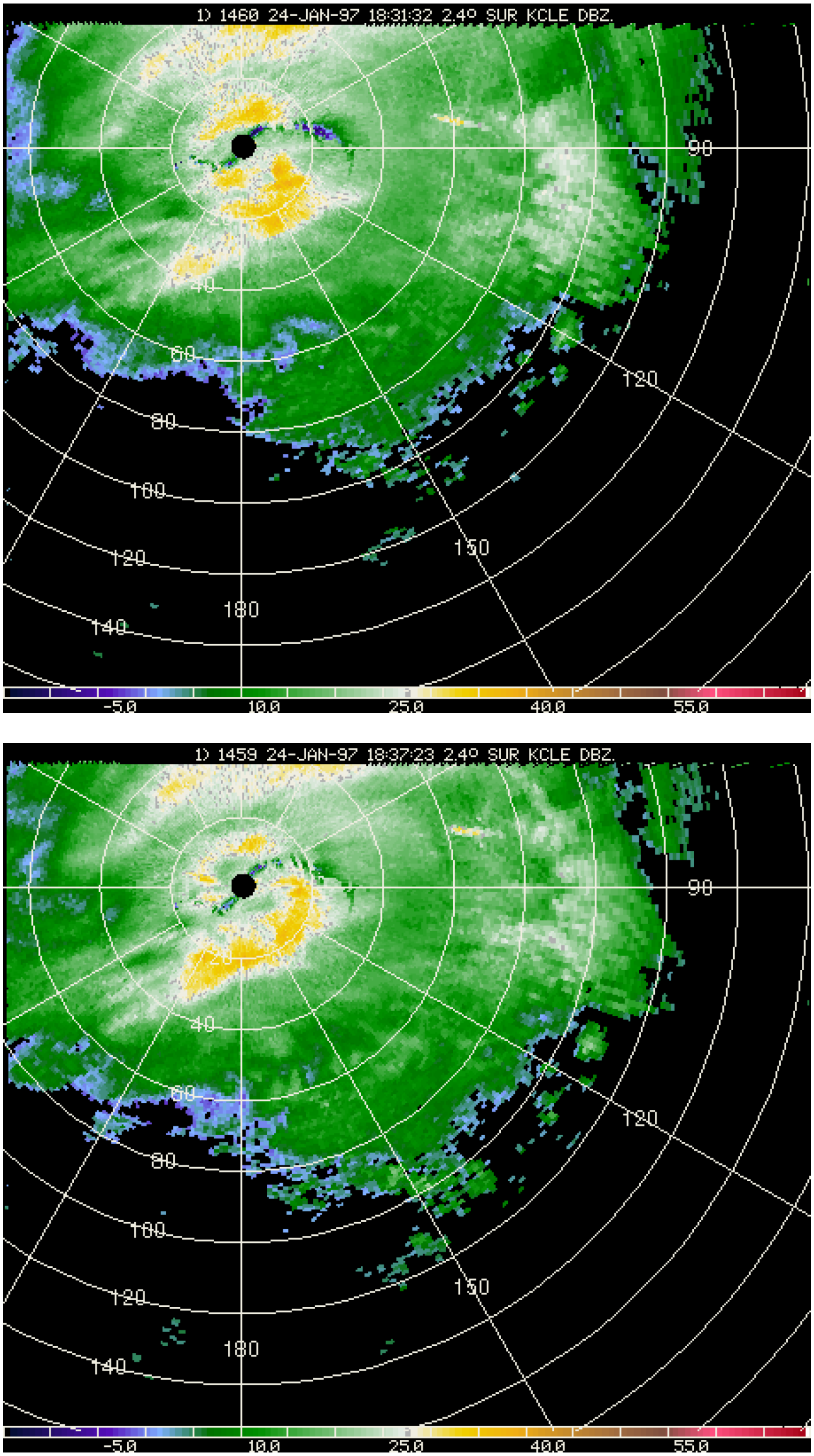


Figure 9 – Same, but for ee) 1831 (2.4) and ff) 1837 UTC (2.4).

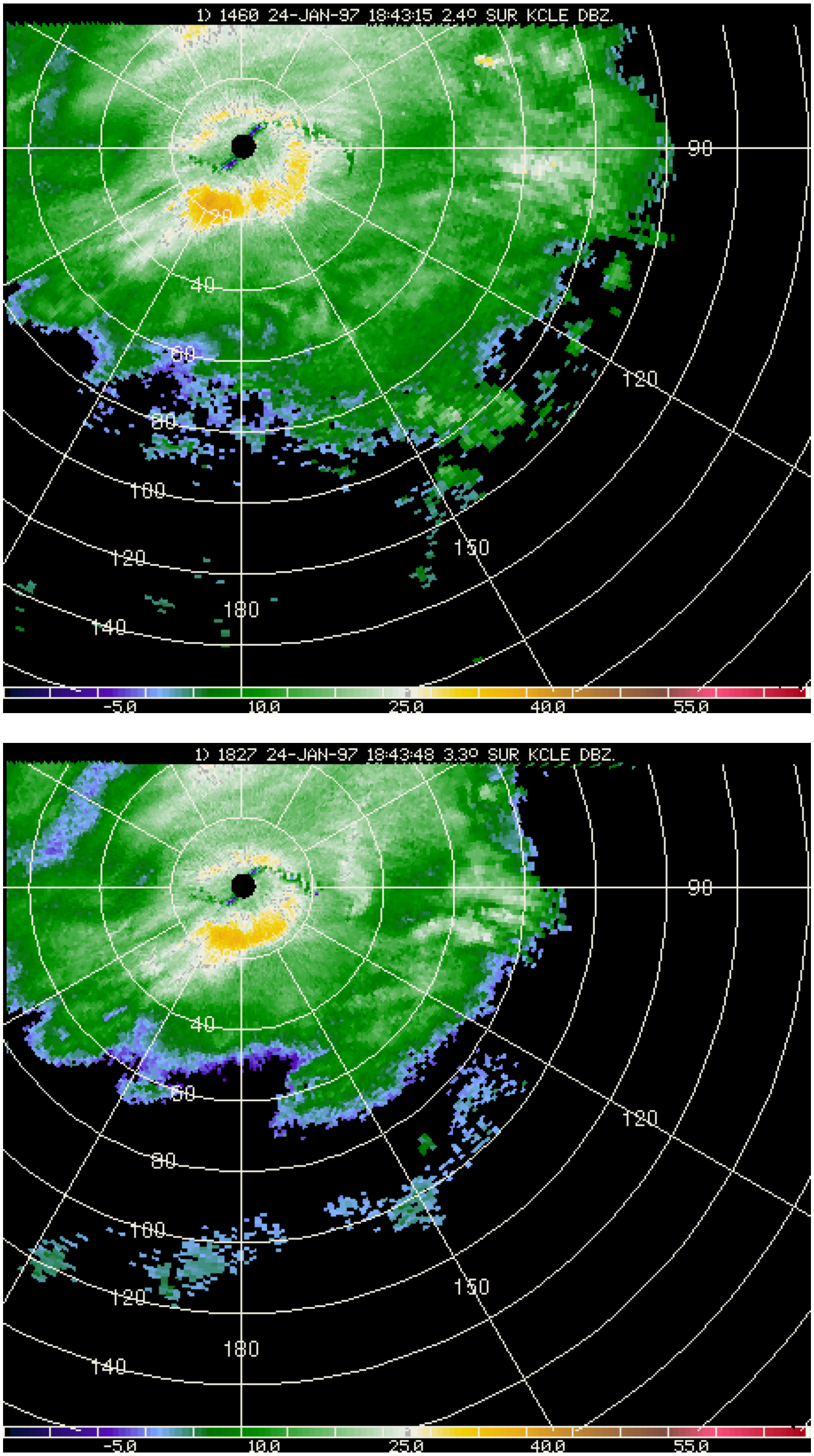


Figure 9 – Same, but for gg) 1843 (2.4) and hh) 1843 UTC (3.3).

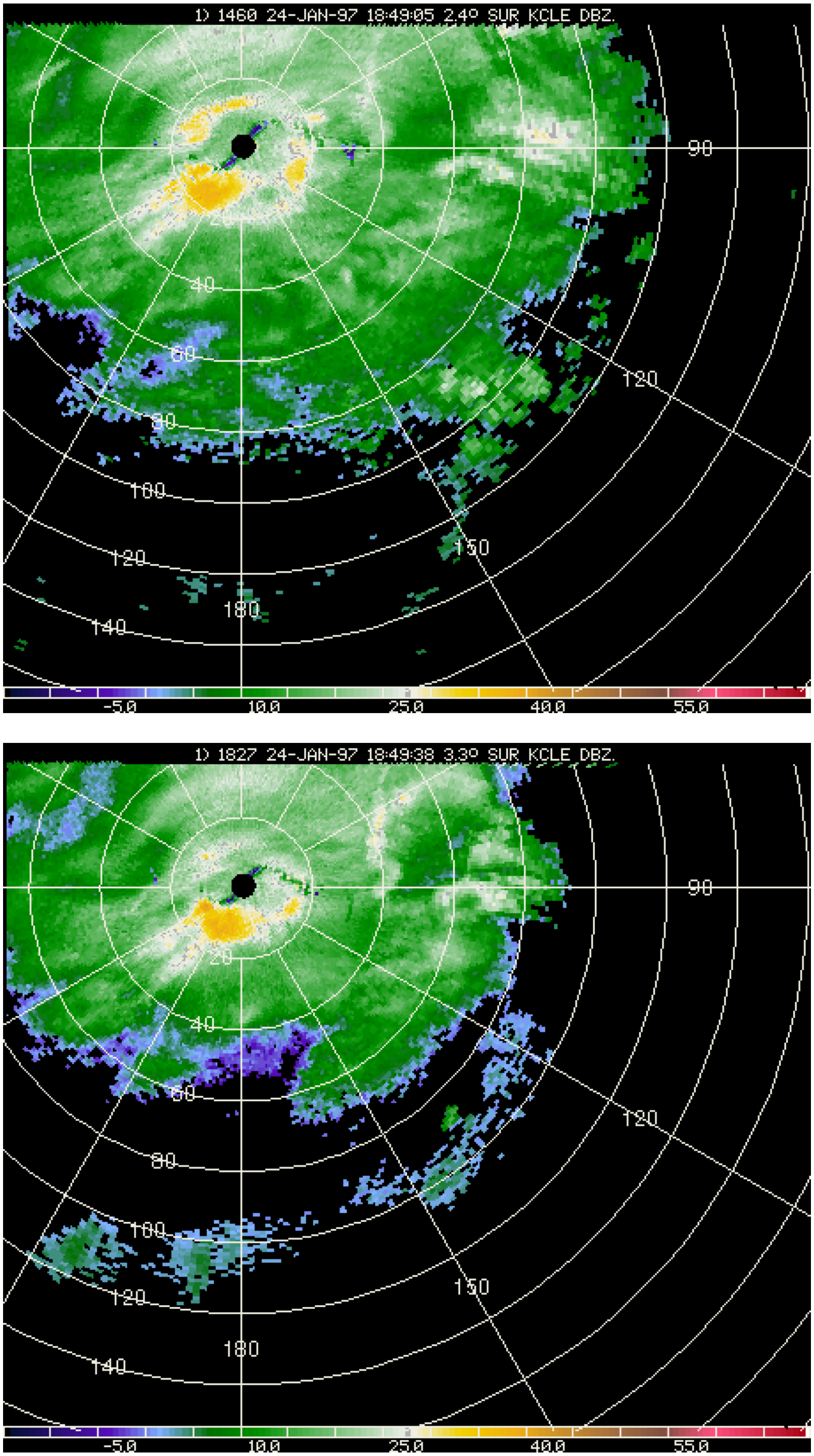
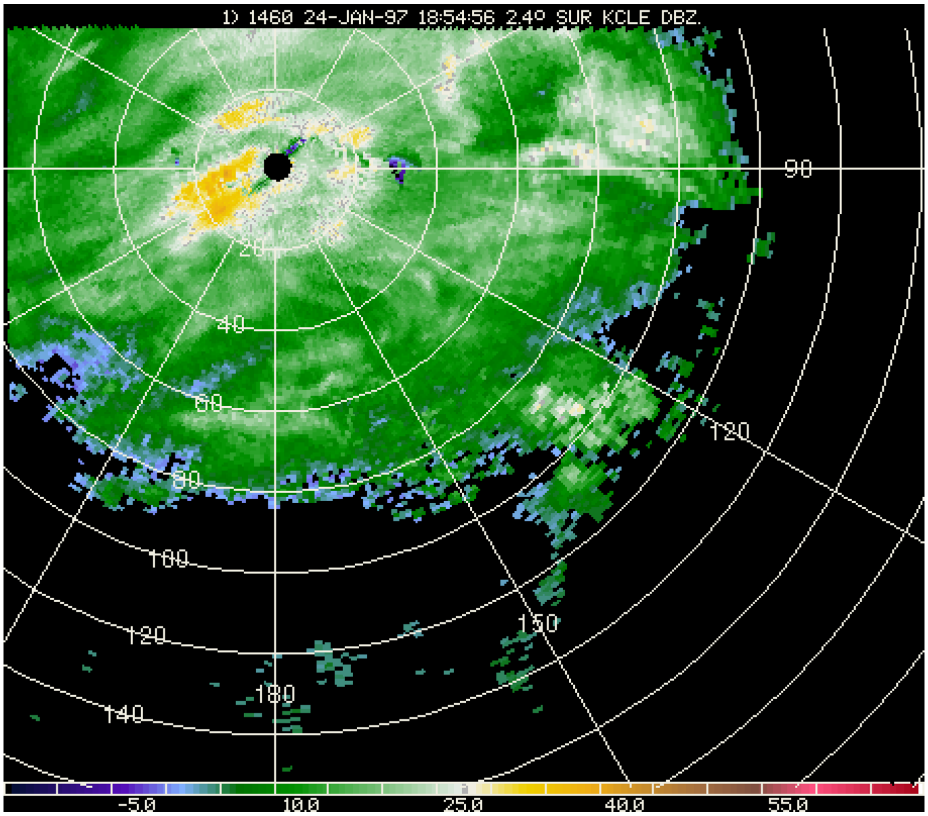


Figure 9 – Same, but for ii) 1849 (2.4) and jj) 1849 UTC (3.3).



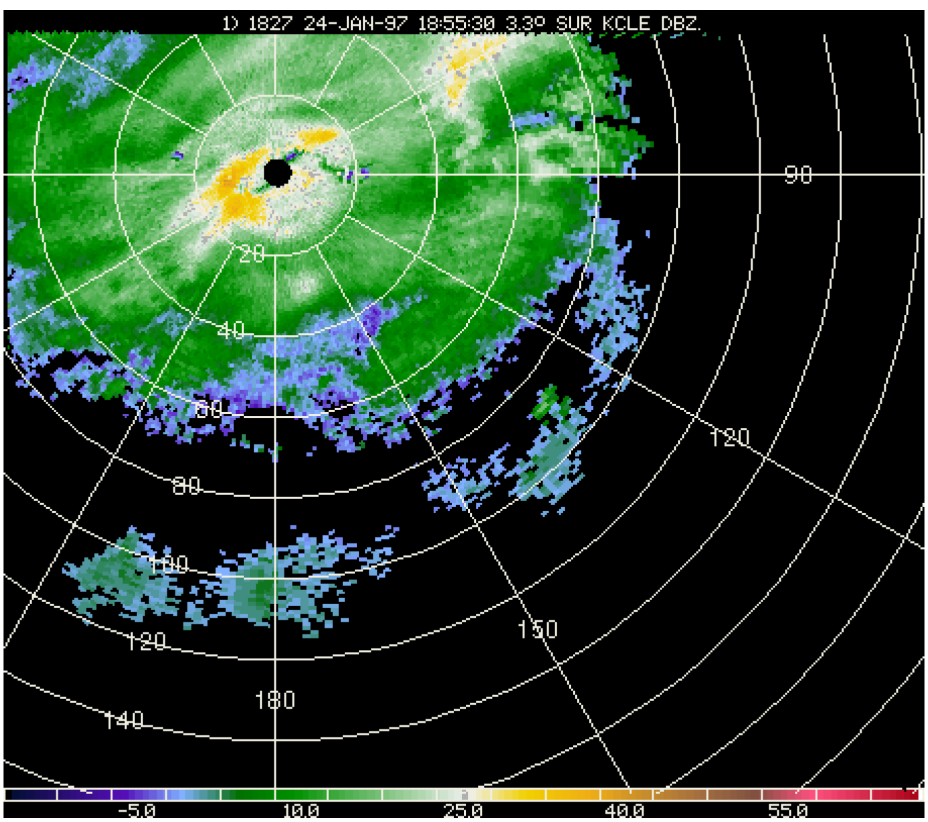
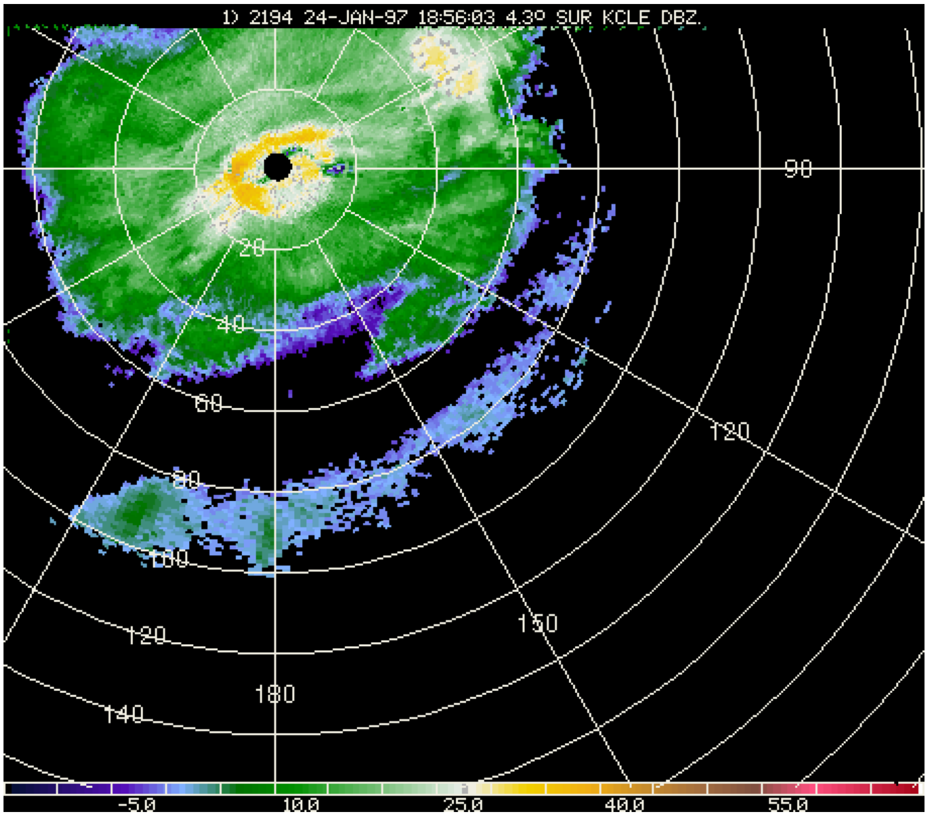


Figure 9 – Same, but for kk) 1854 (2.4) and ll) 1855 UTC (3.3).



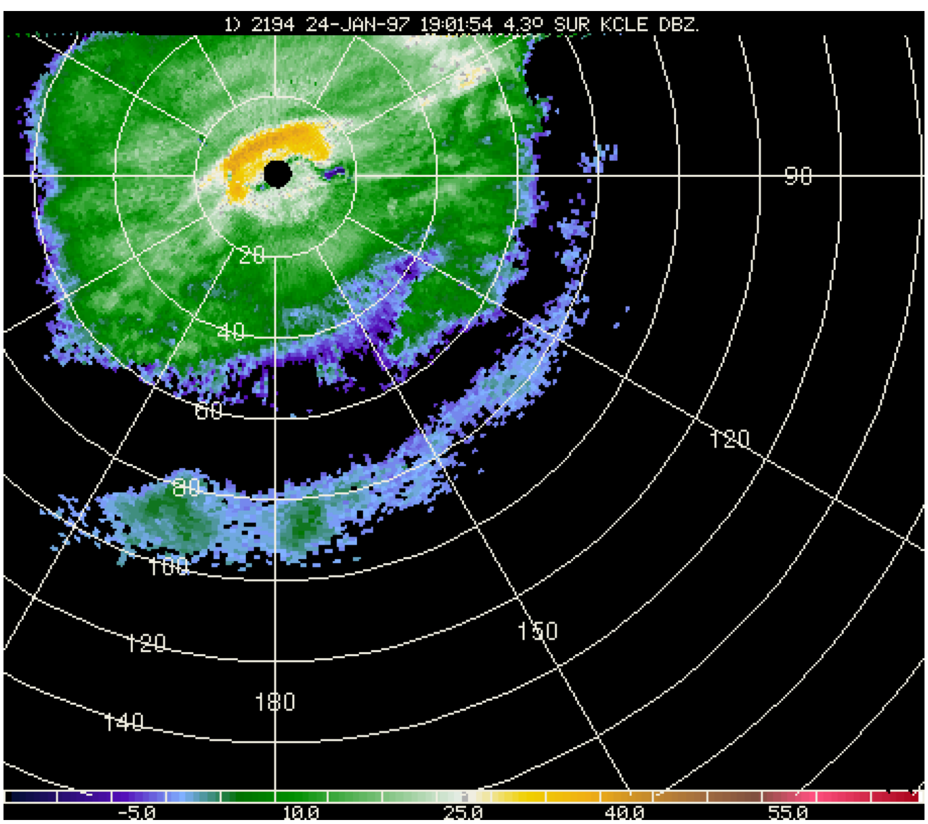


Figure 9 – Same, but for mm) 1856 (4.3) and nn) 1901 UTC (4.3).

970124 - Flight #2

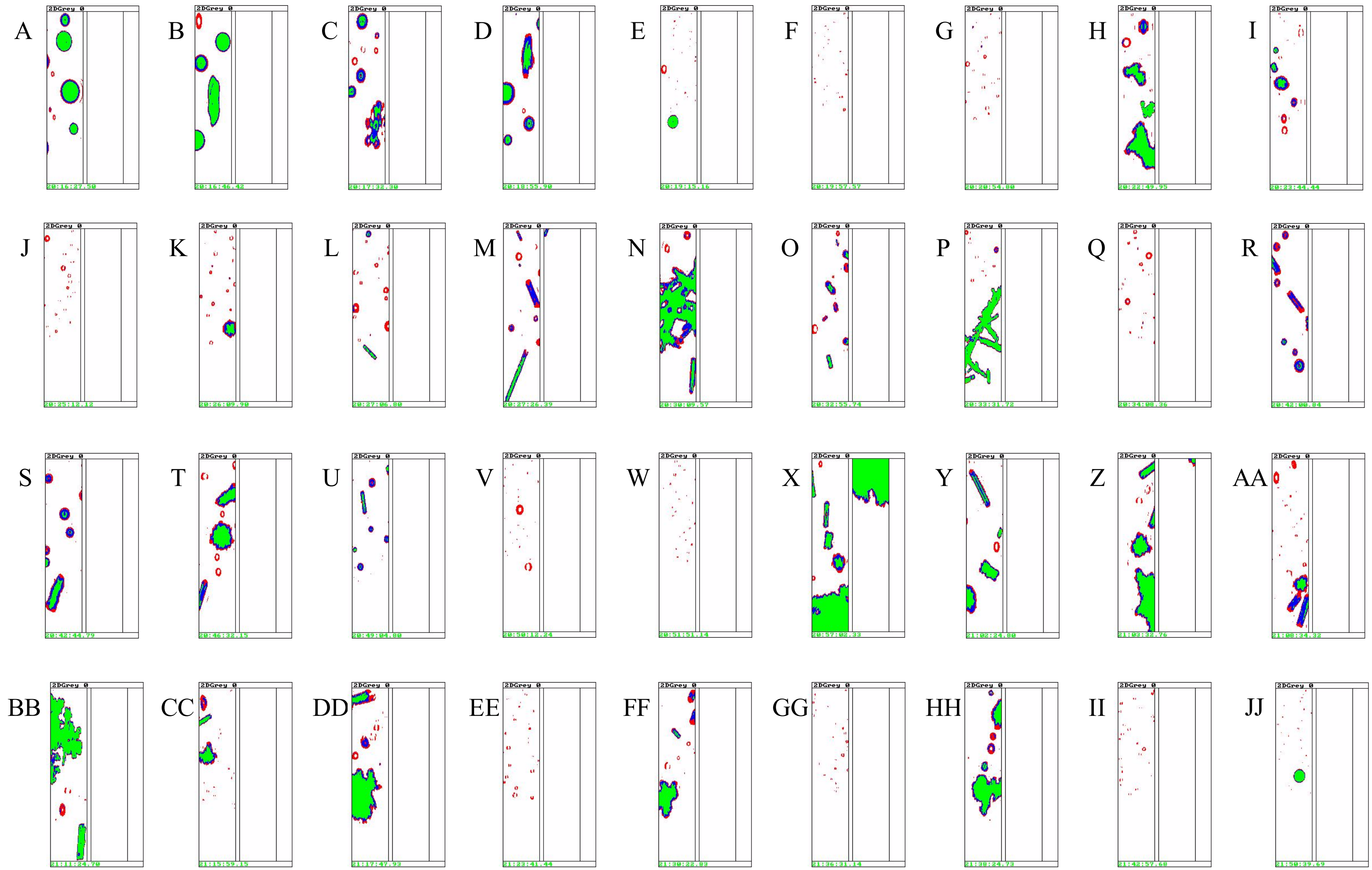
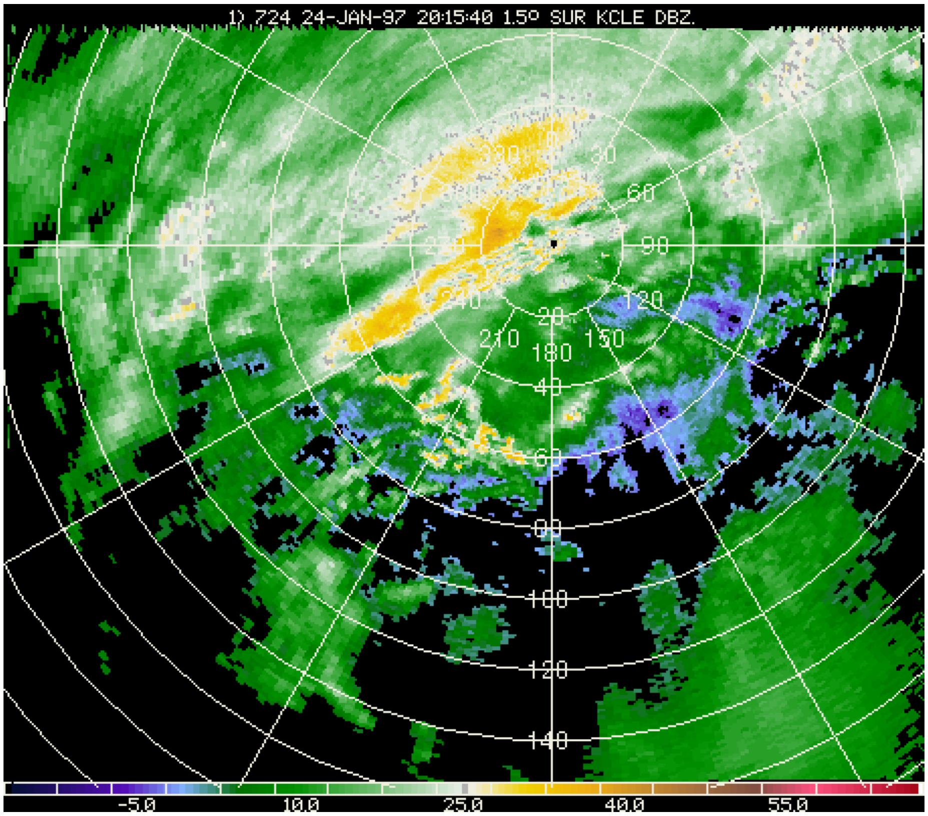


Figure 10 - 2D-grey probe imagery for flight 2.



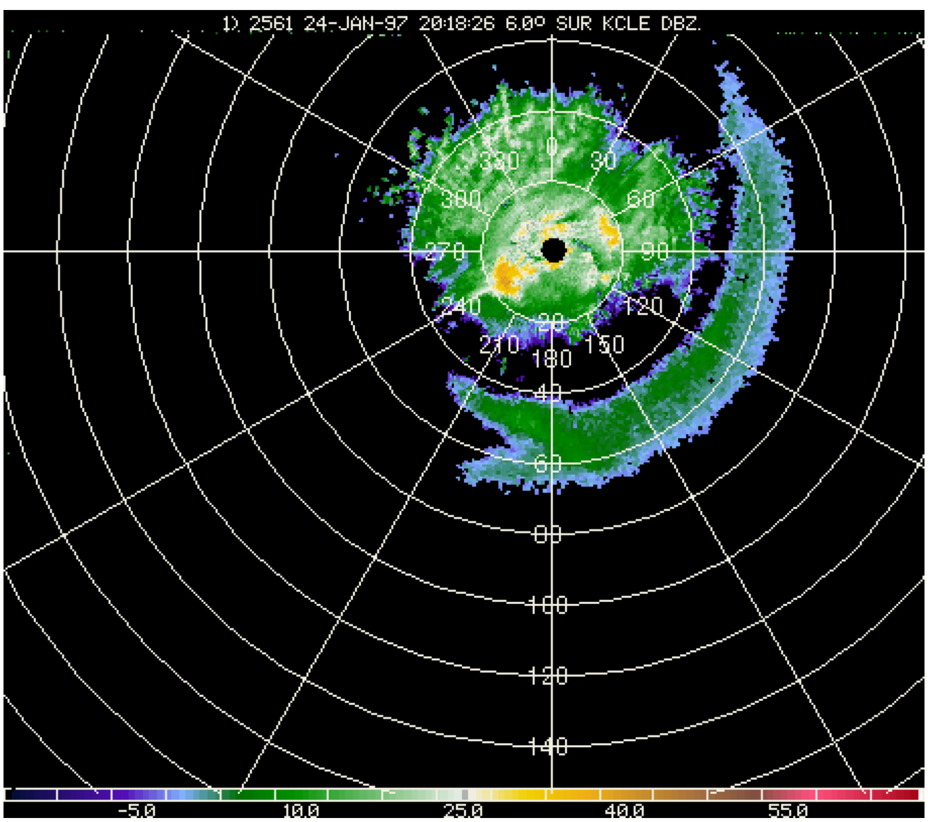


Figure 11 – Cleveland NEXRAD data for 970124, a) 2015 (1.5 degrees elevation) and b) 2018 UTC (6.0 degrees elevation).

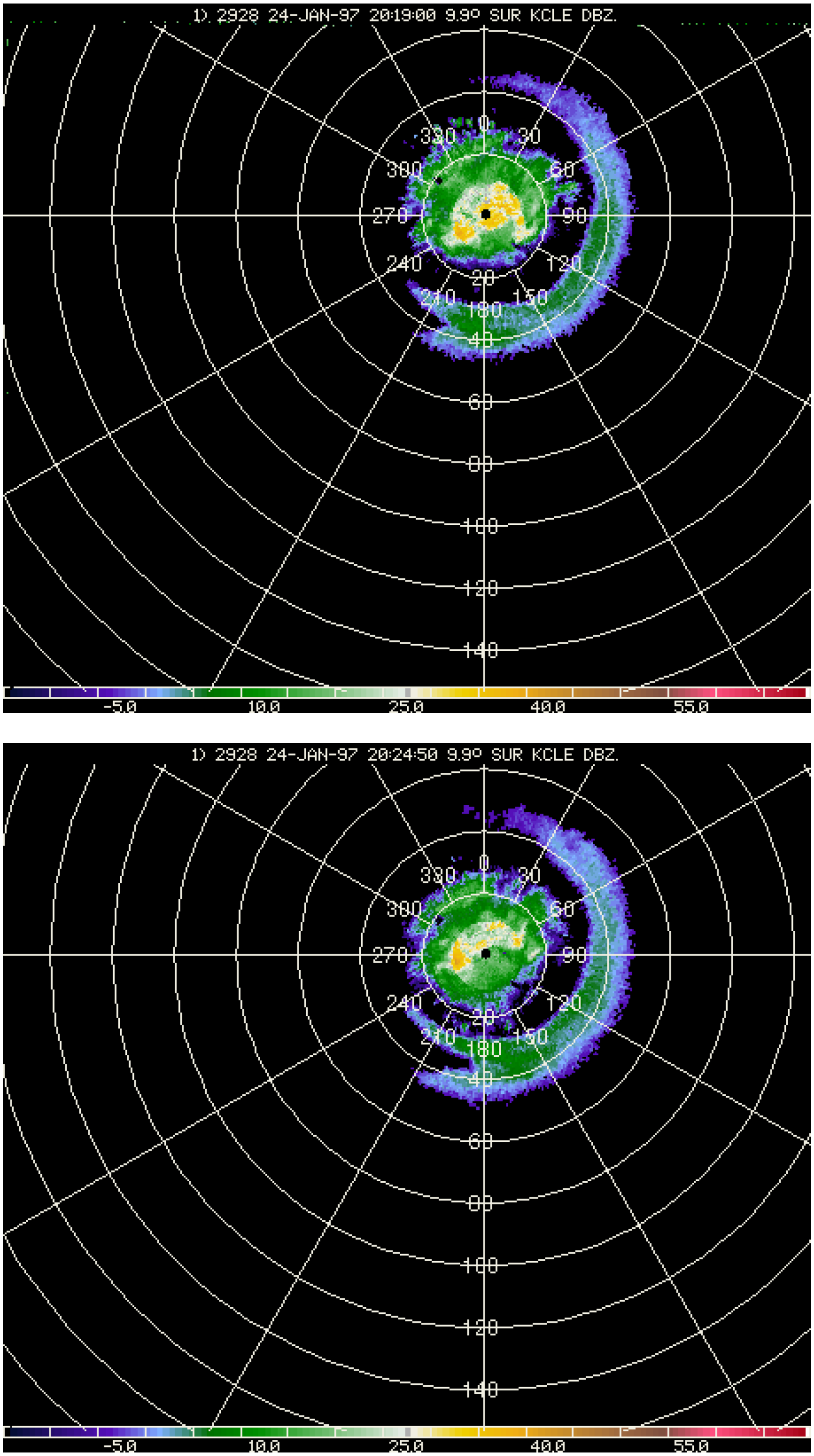
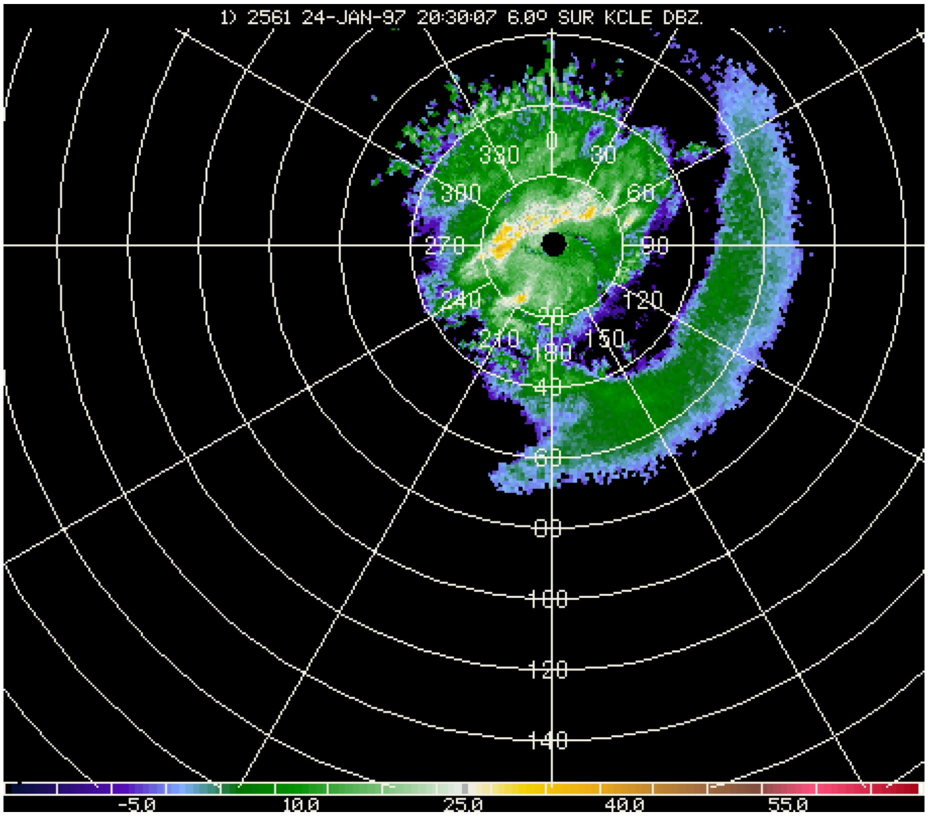


Figure 11 – Same, but for c) 2019 (9.9) and d) 2024 UTC (9.9).



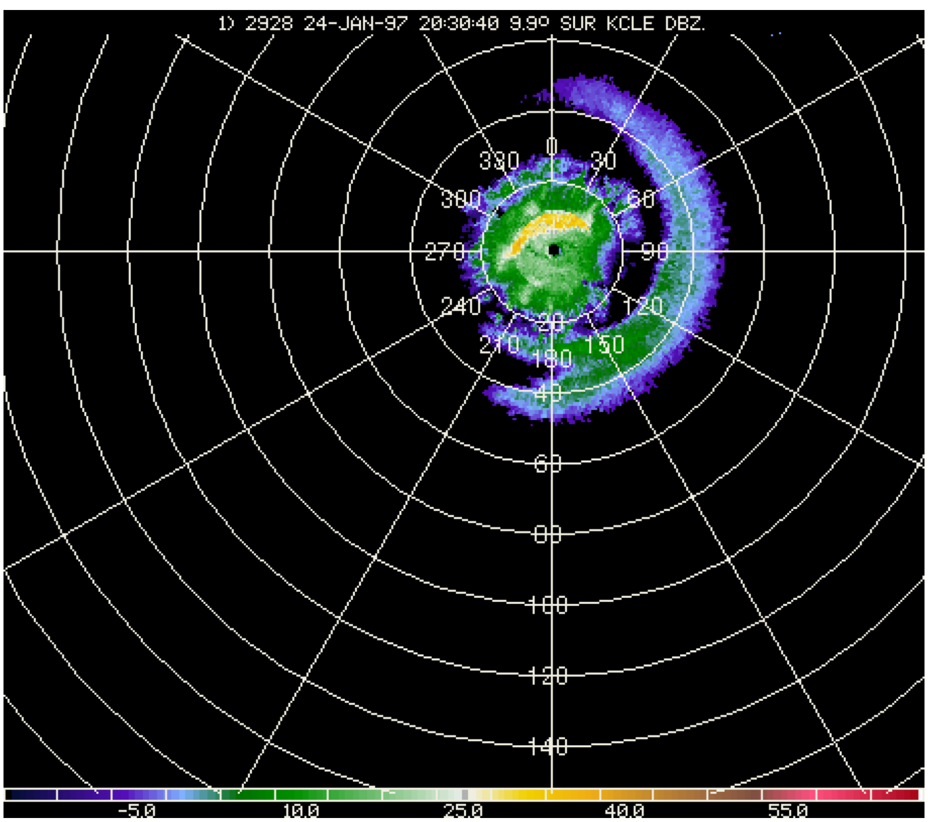
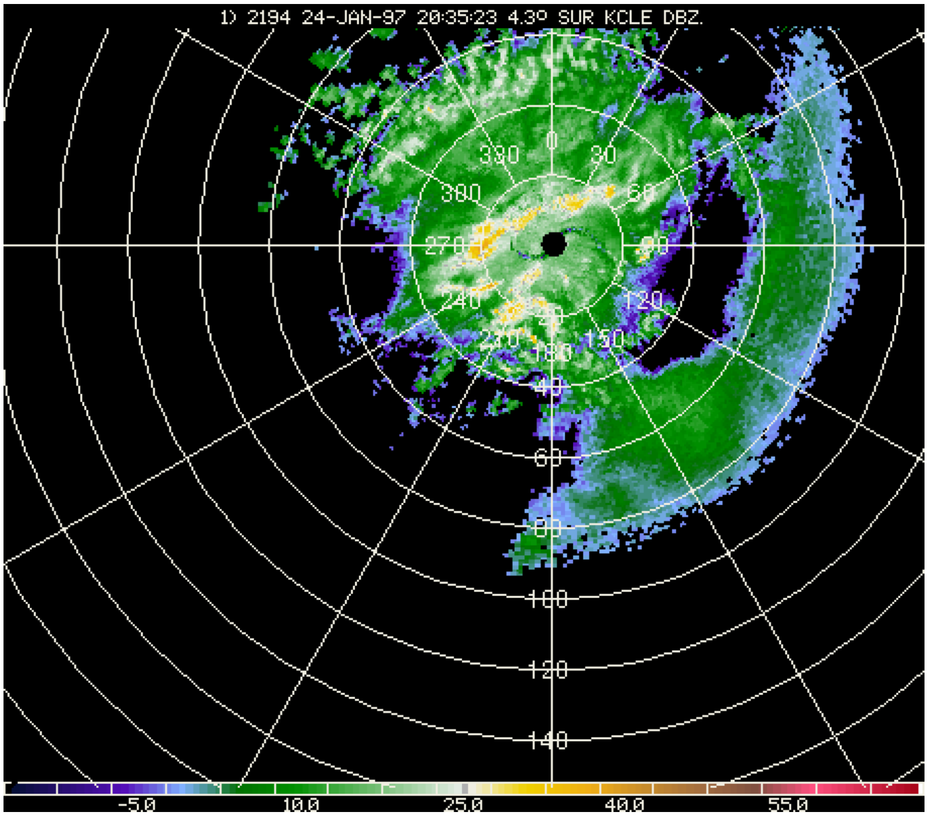


Figure 11 – Same, but for e) 2030 (6.0) and f) 2030 UTC (9.9).



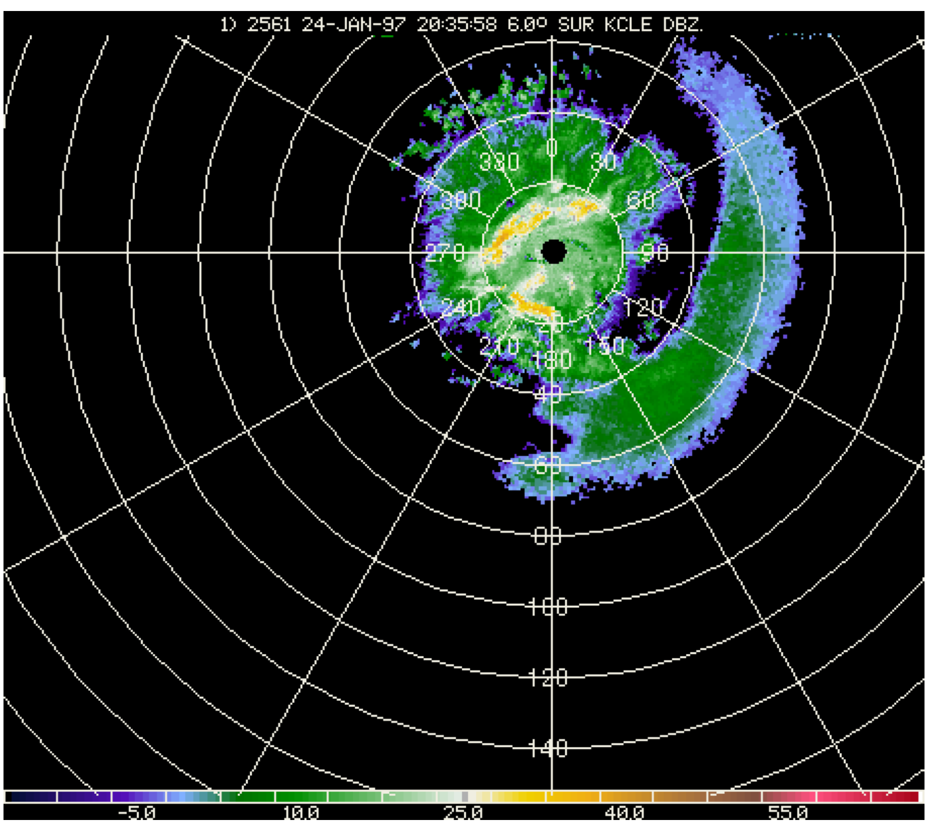


Figure 11 – Same, but for g) 2035 (4.3) and h) 2035 UTC (6.0).

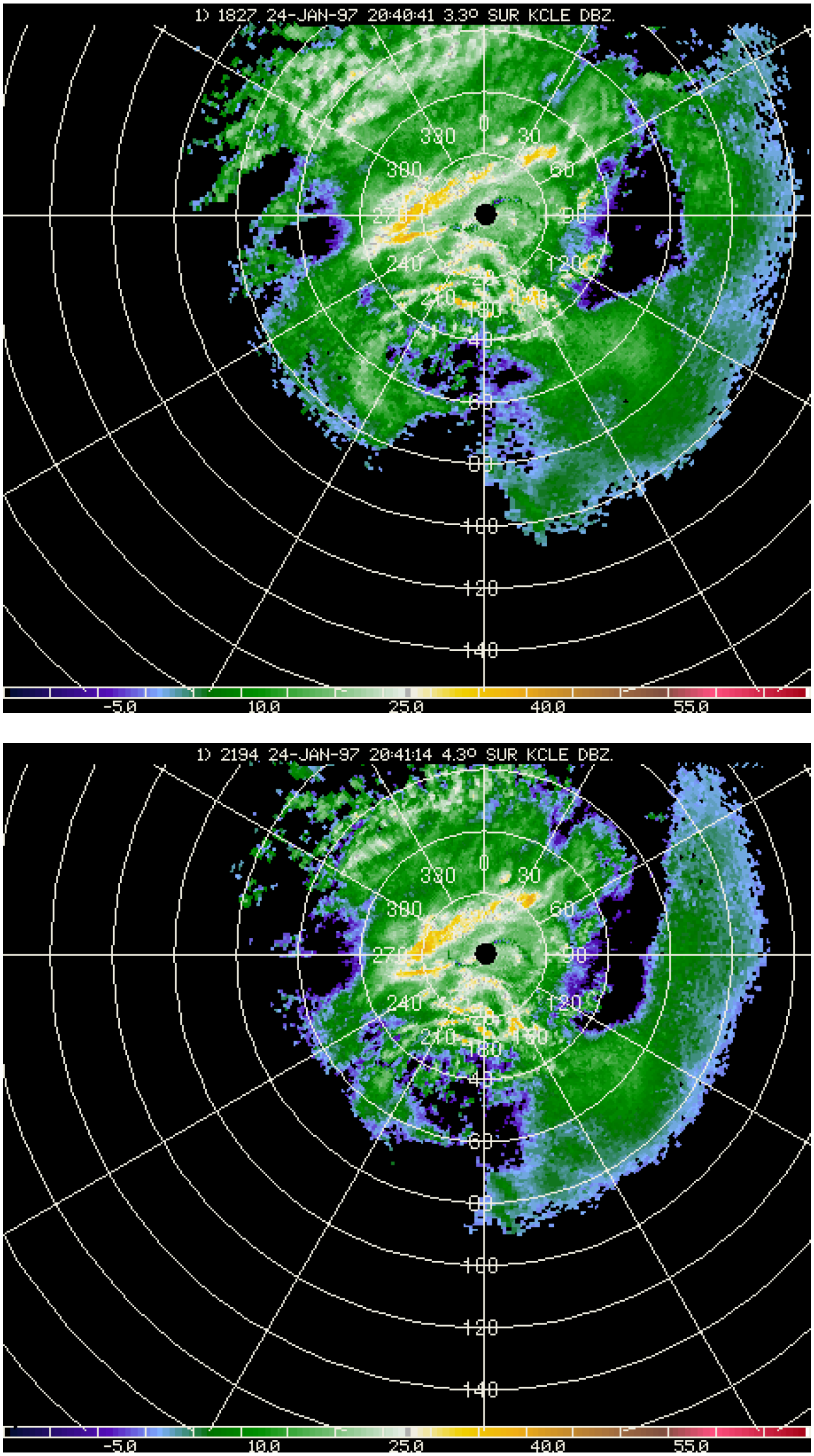


Figure 11 – Same, but for i) 2040 (3.3) and j) 2041 UTC (4.3).

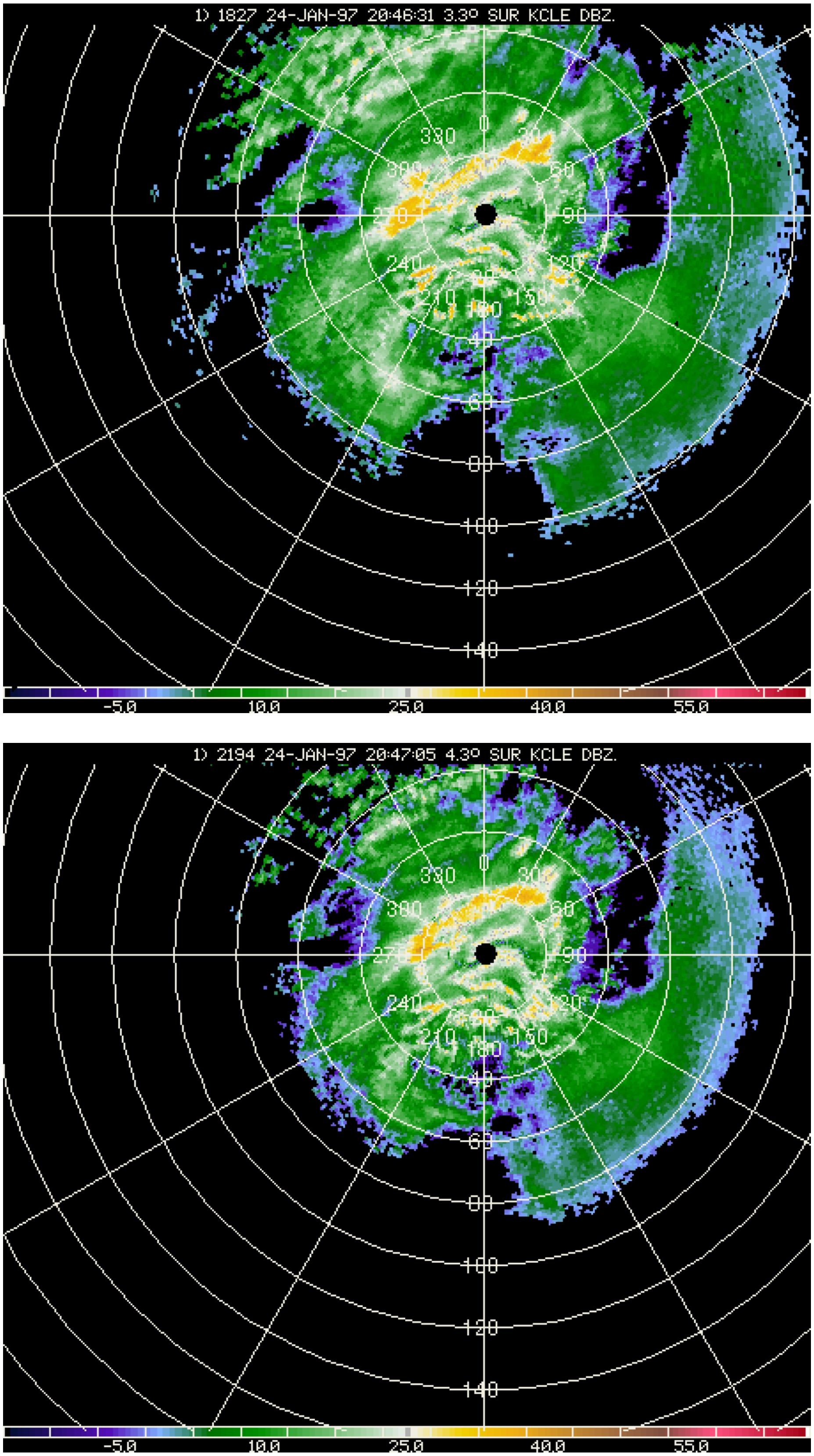


Figure 11 – Same, but for k) 2046 (3.3) and l) 2047 UTC (4.3).

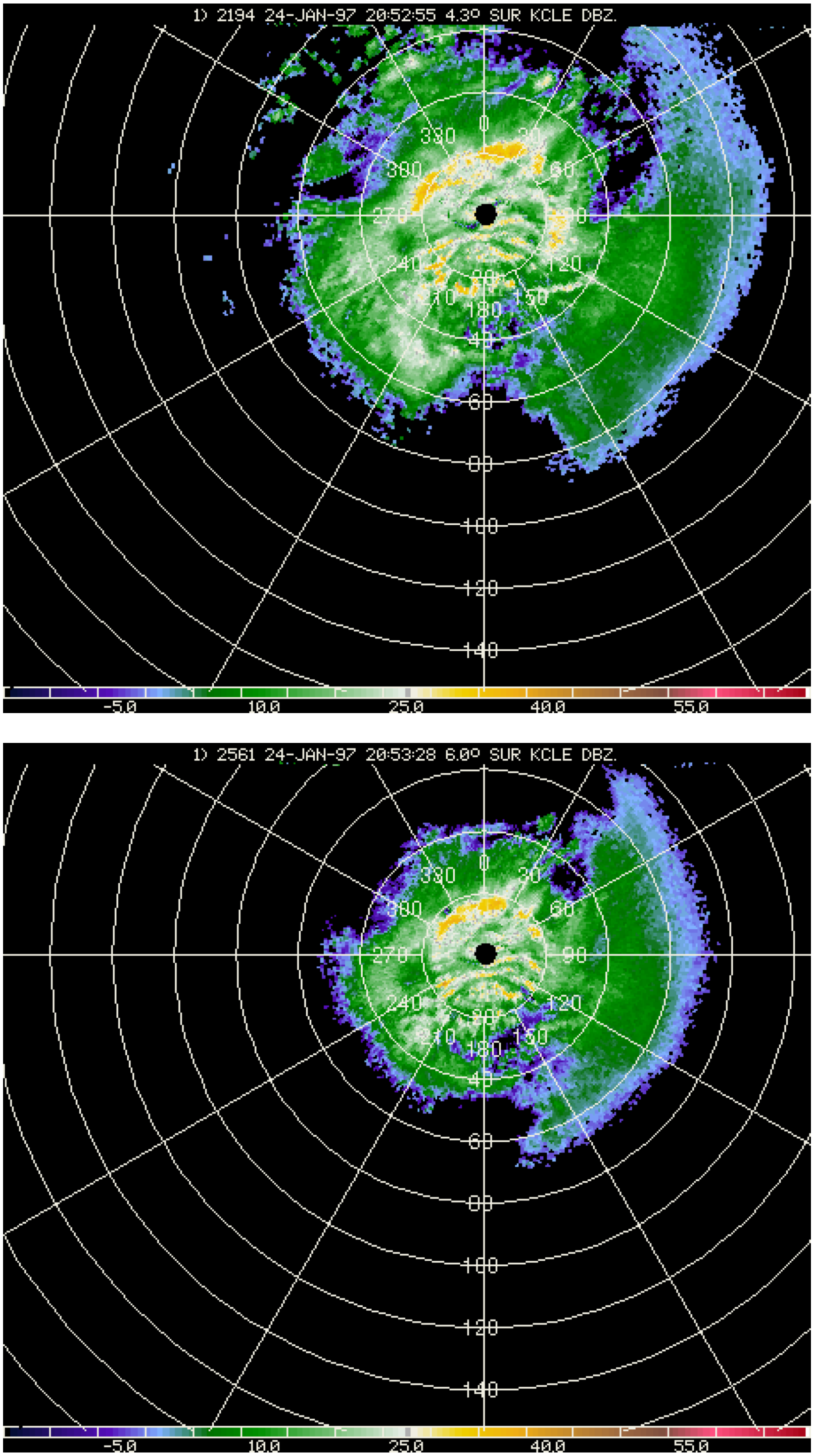


Figure 11 – Same, but for m) 2052 (4.3) and n) 2053 UTC (6.0).

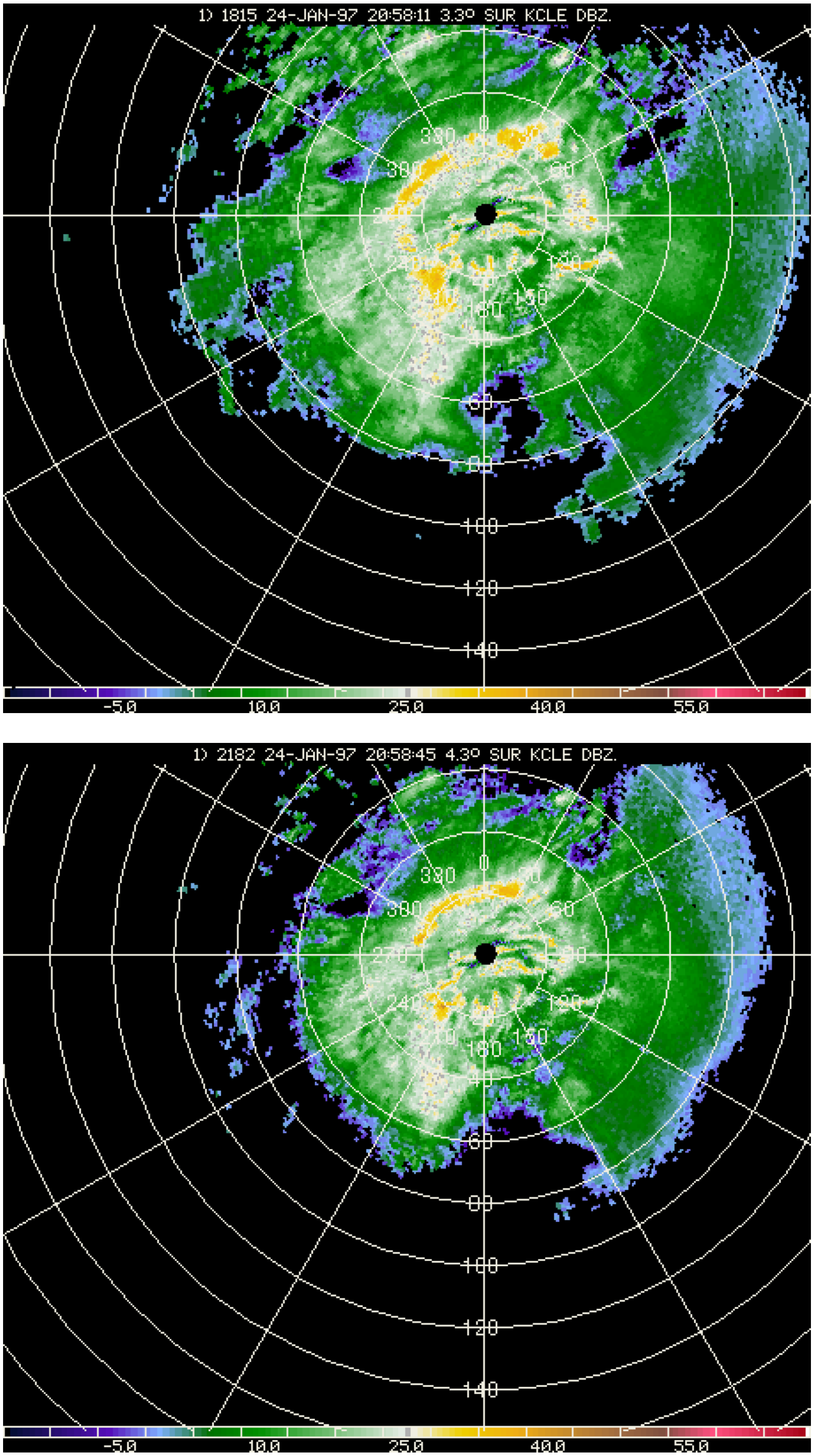
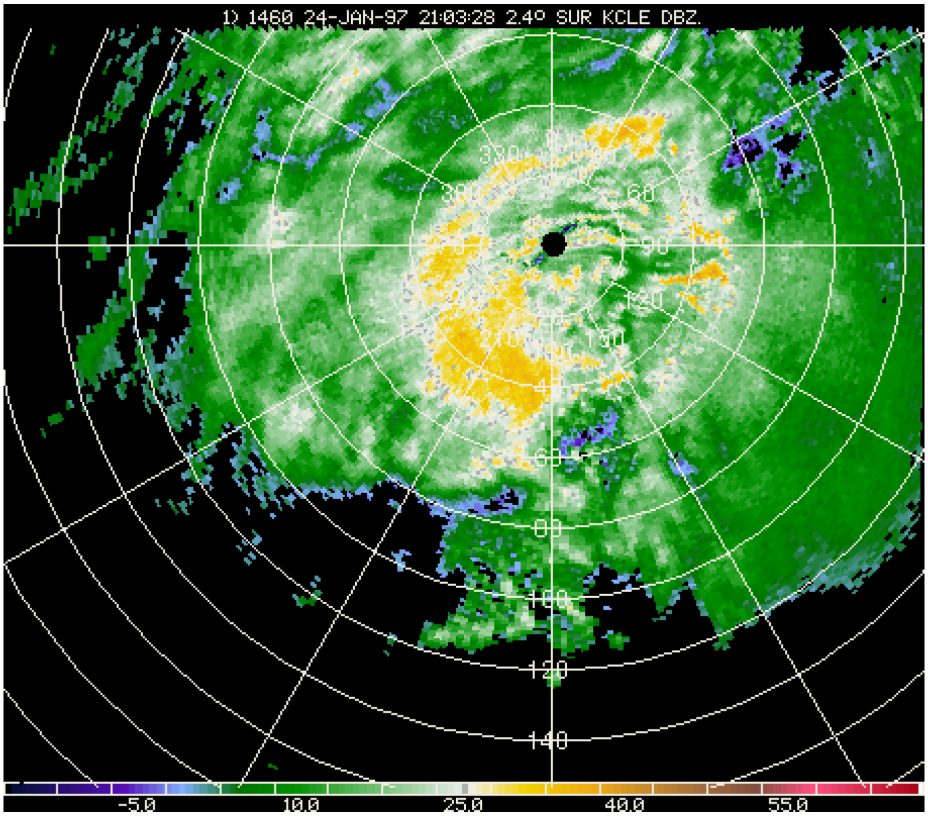


Figure 11 – Same, but for o) 2058 (3.3) and p) 2058 UTC (4.3).



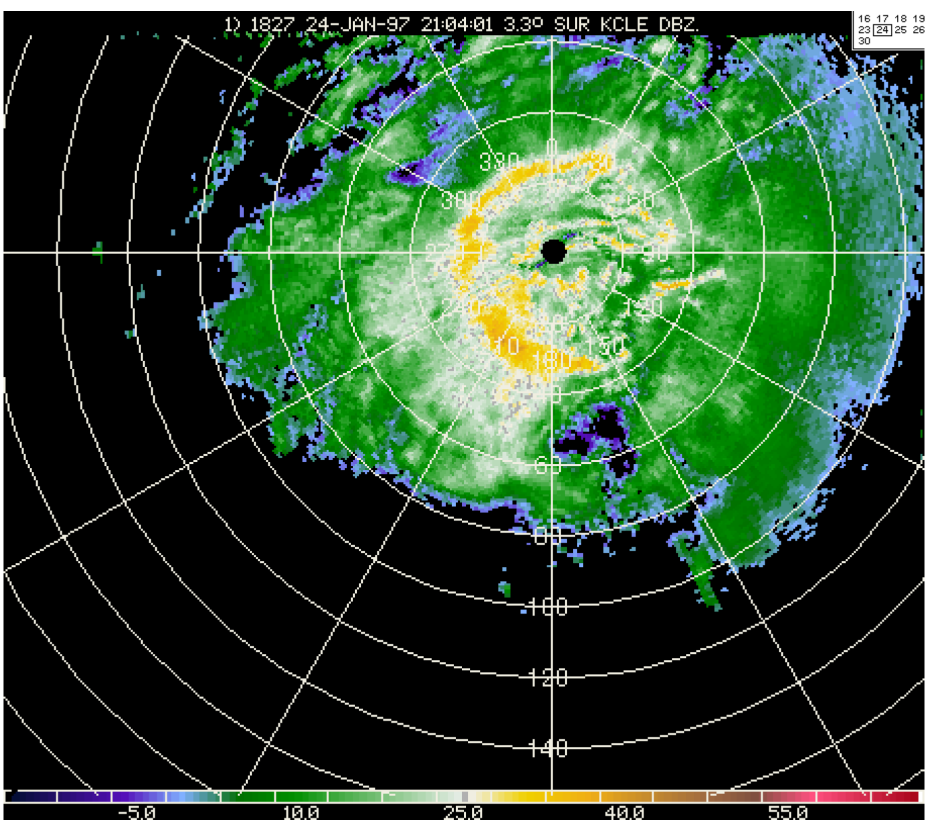
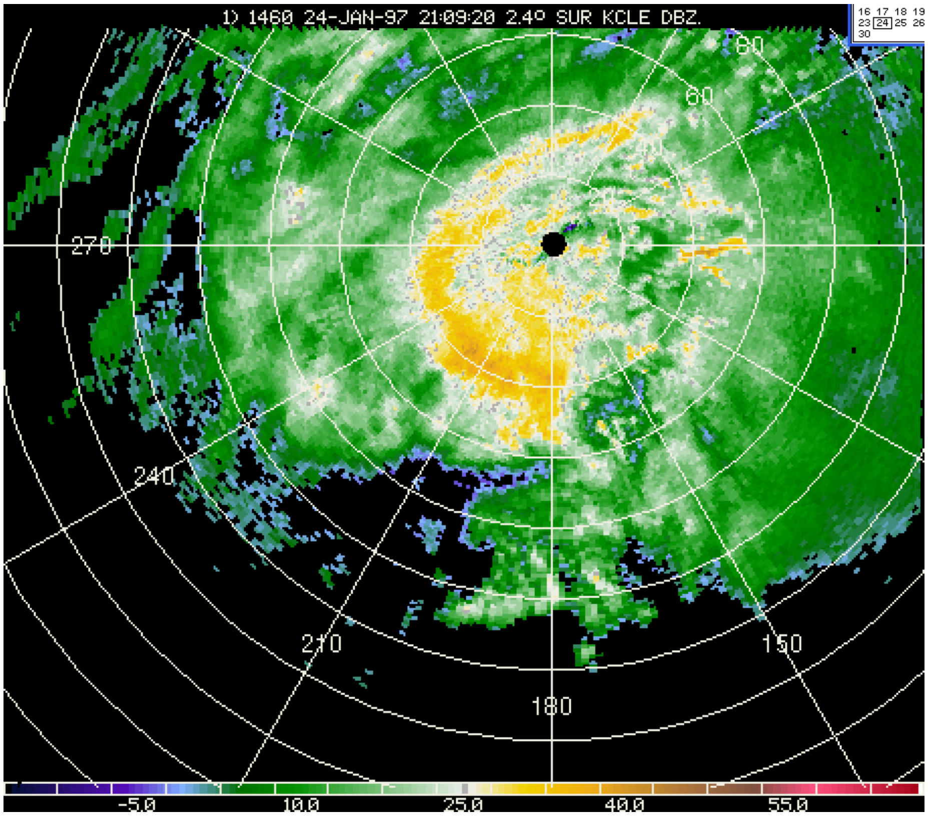


Figure 11 – Same, but for q) 2103 (2.4) and r) 2104 UTC (3.3).



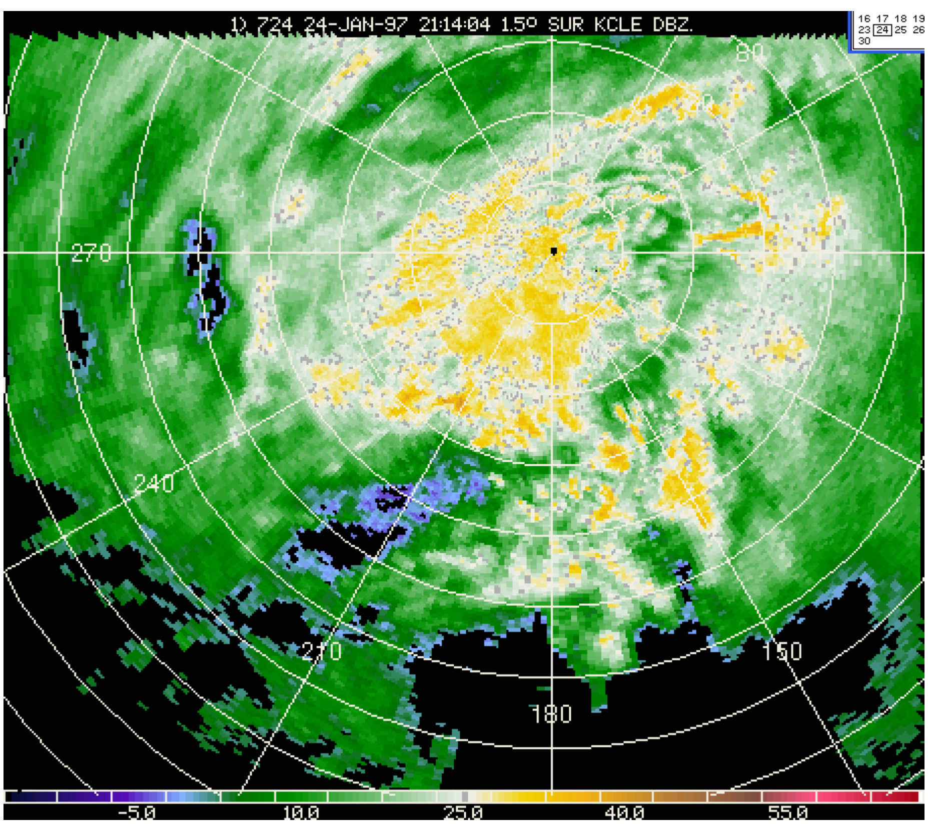


Figure 11 – Same, but for s) 2109 (2.4) and t) 2114 UTC (1.5).

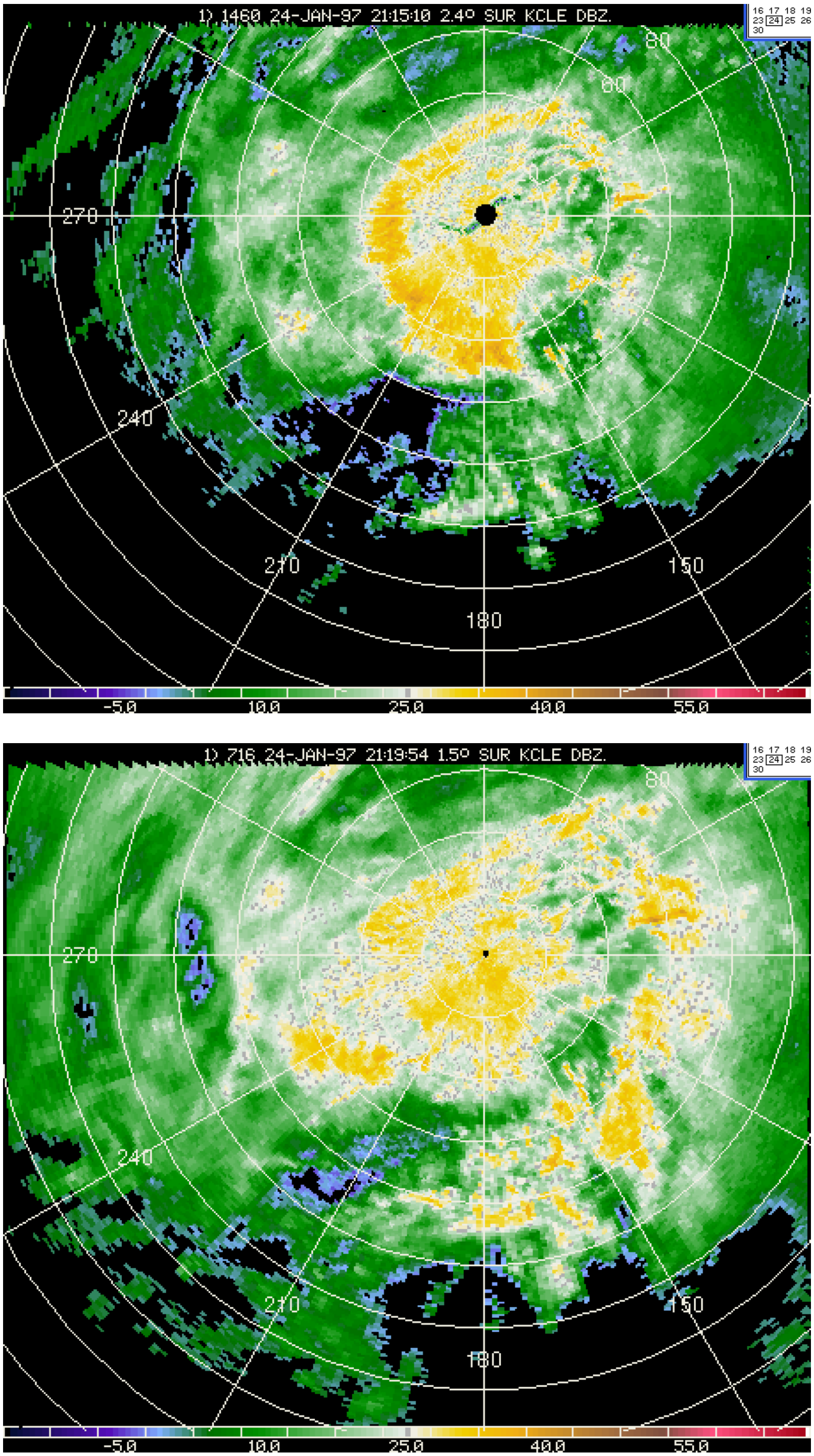
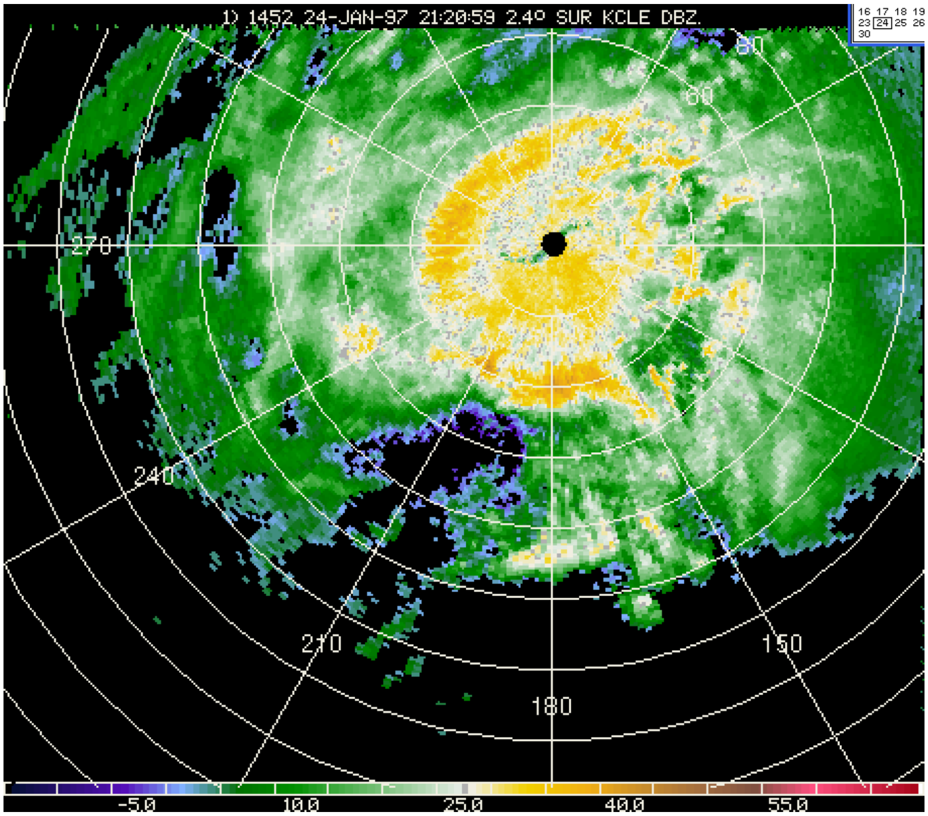


Figure 11 – Same, but for u) 2115 (2.4) and v) 2119 UTC (1.5).



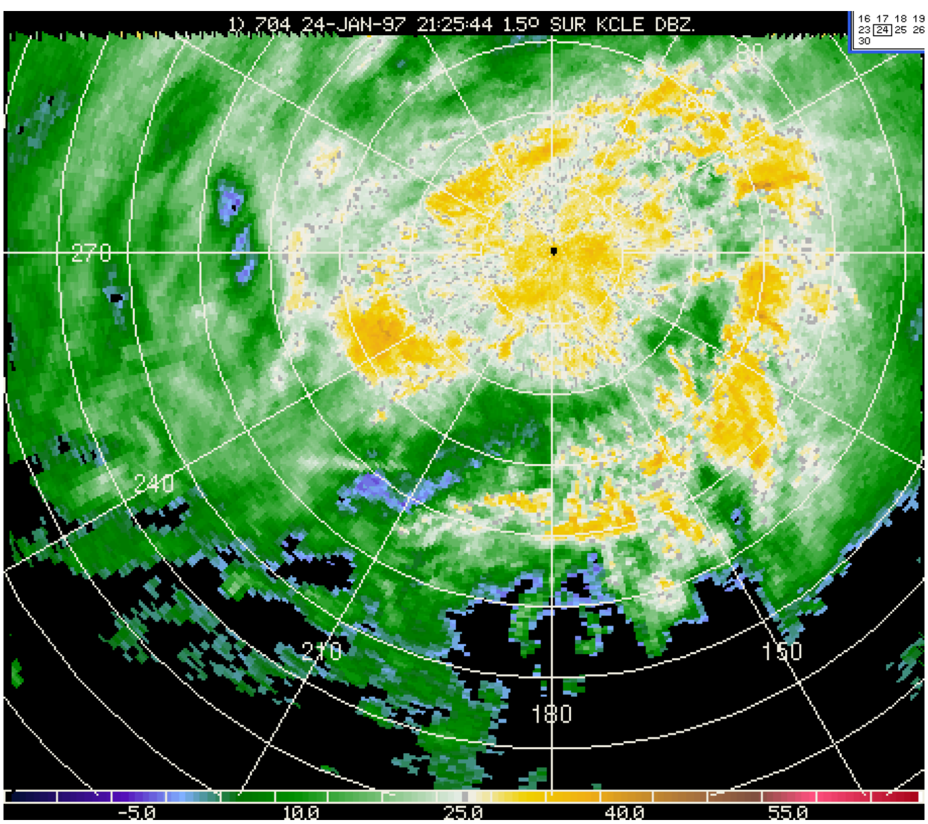
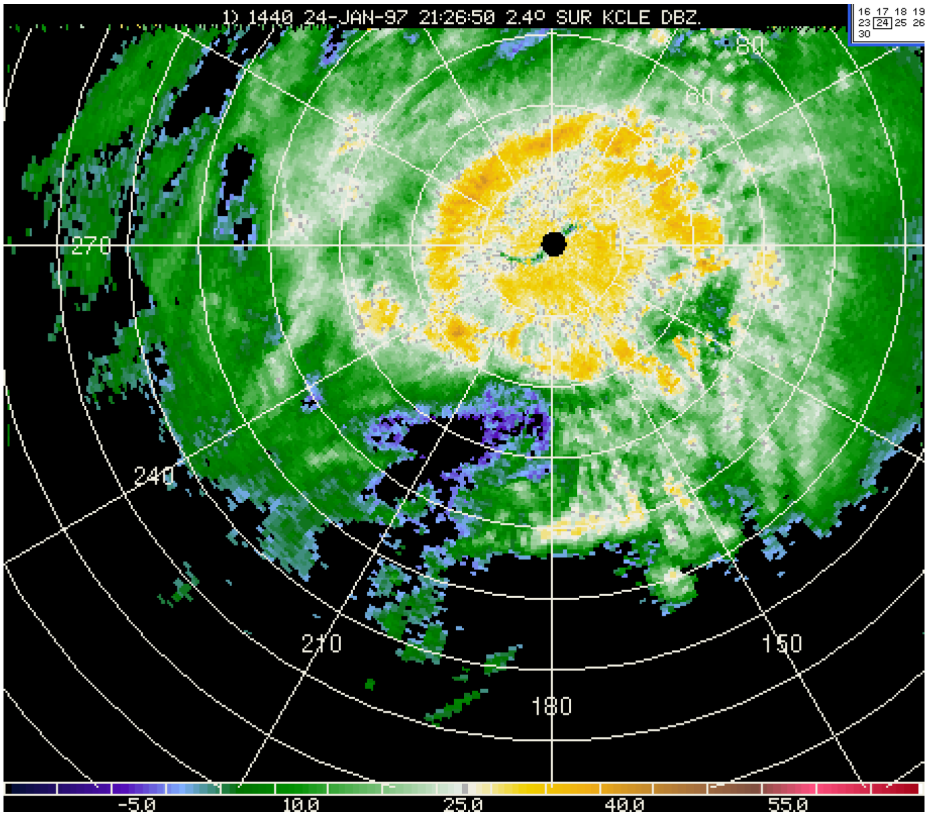


Figure 11 – Same, but for w) 2120 (2.4) and x) 2125 UTC (1.5).



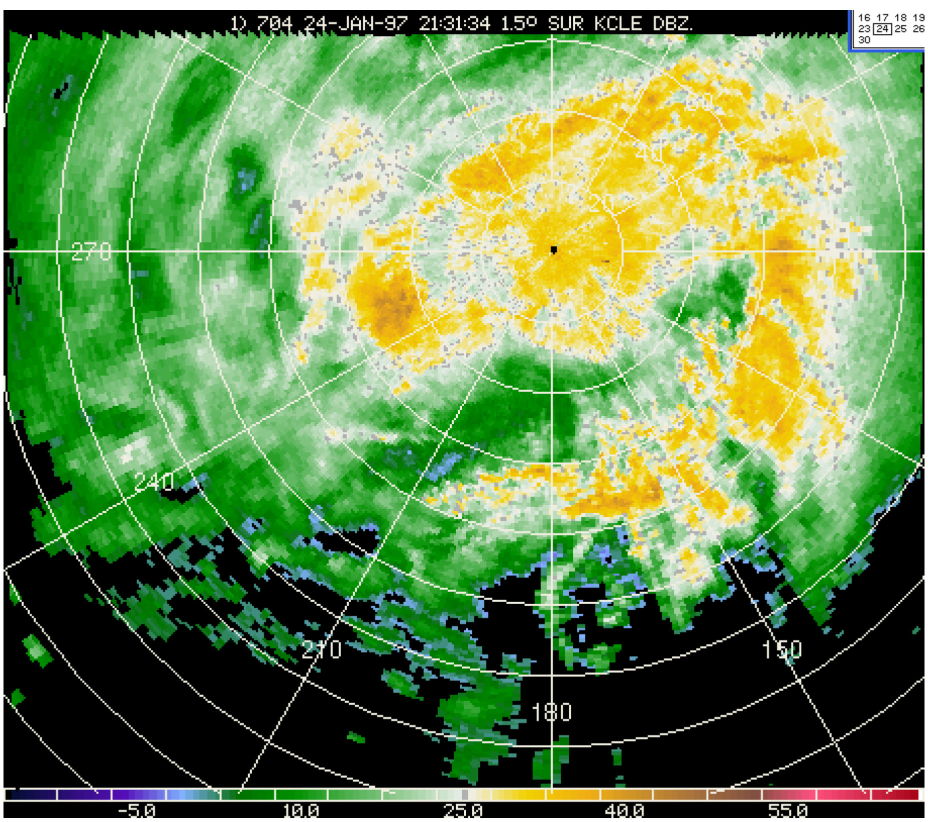


Figure 11 – Same, but for y) 2126 (2.4) and z) 2131 UTC (1.5).

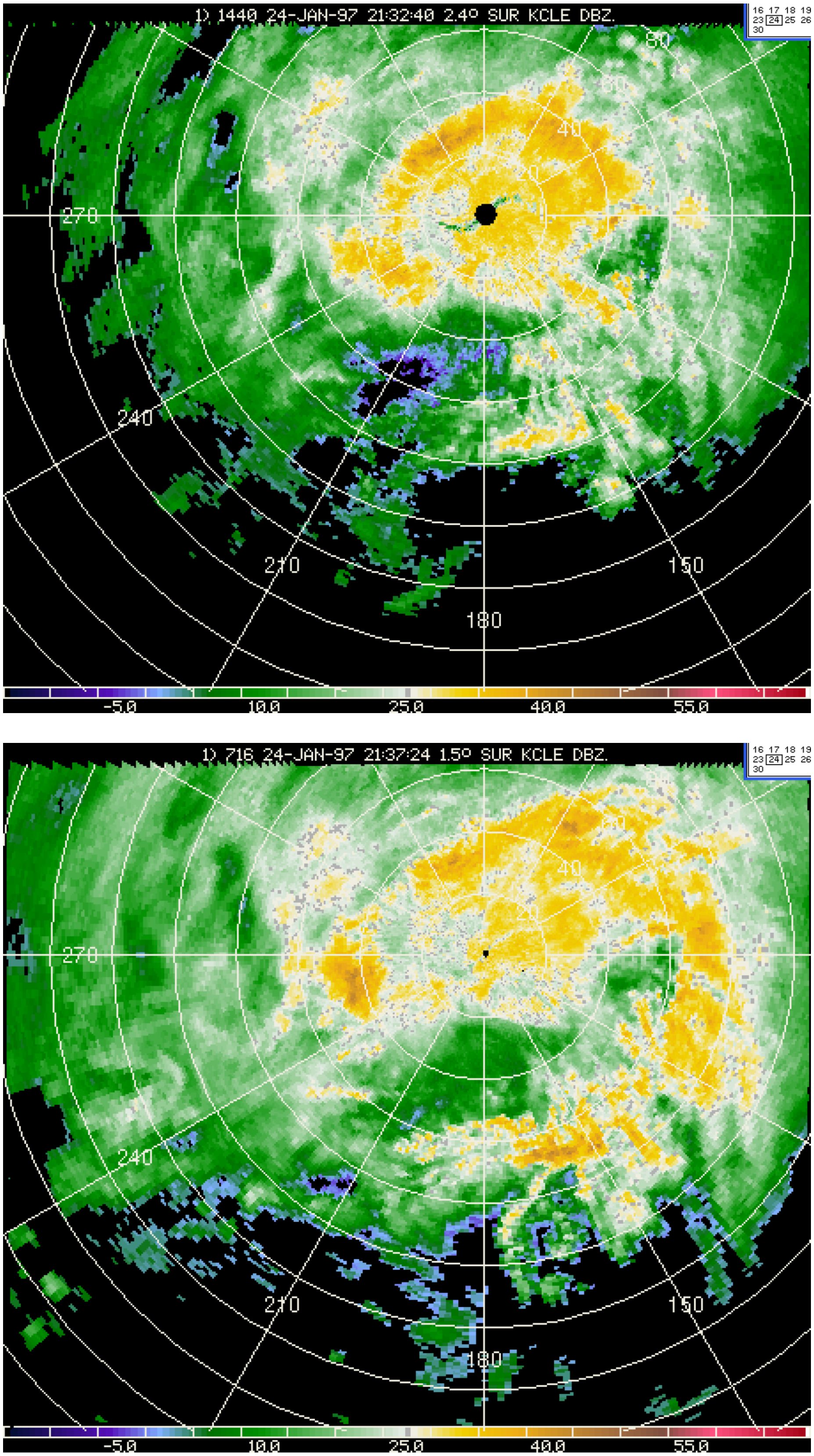
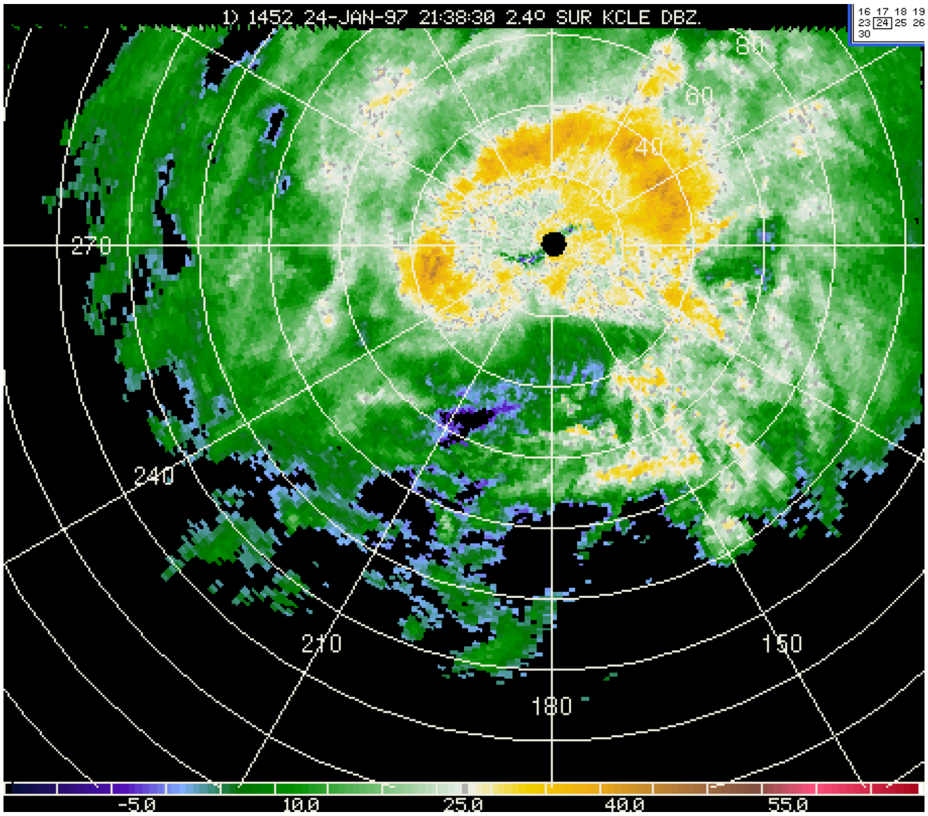


Figure 11 – Same, but for aa) 2132 (2.4) and bb) 2137 UTC (1.5).



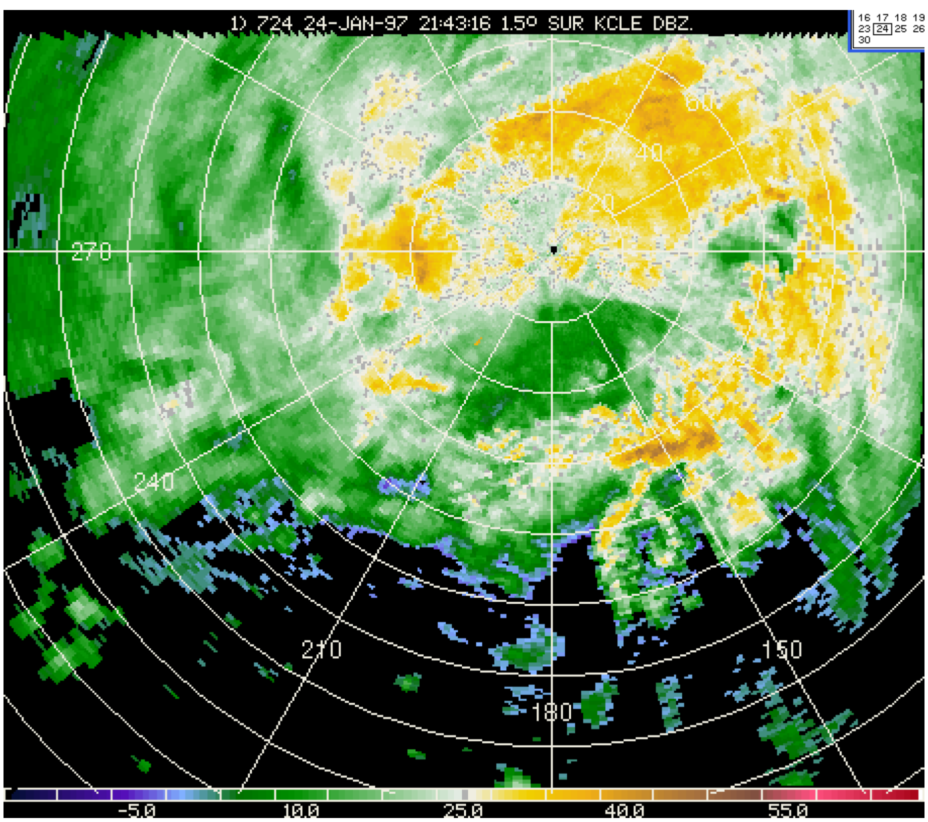


Figure 11 – Same, but for cc) 2138 (2.4) and dd) 2143 UTC (1.5).

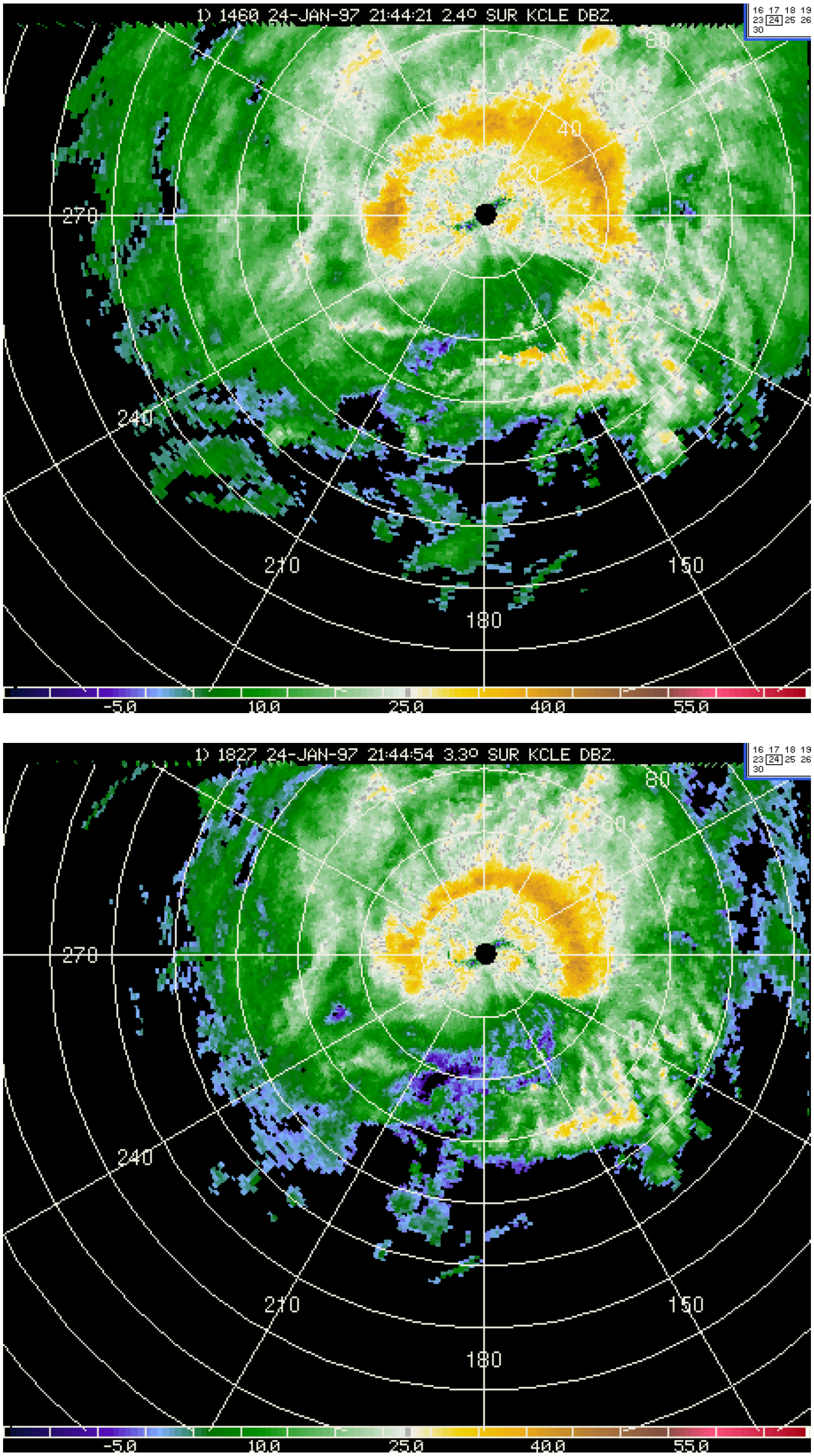


Figure 11 – Same, but for ee) 2144 (2.4) and ff) 2144 UTC (3.3).

February 4, 1997

Freezing drizzle and mixed conditions over Lake Erie

February 4, 1997 - Flight No. 2

Overview

This case of freezing drizzle and mixed conditions occurred over central Lake Erie between 1754 and 2005 UTC. The synoptic weather scenario on February 4th was rather complicated. There was a deep, strong, low pressure system centered to the west of the project area, and a high-pressure center moving off to the northeast. In this document, the case will be discussed beginning at the synoptic scale (upper air charts, satellite data, surface maps, soundings) to give an overview of the weather, and ending at the mesoscale (radar and satellite data) and microscale (probe data), where fine details will be highlighted.

Upper air chart analysis-1200 UTC, February 4th

At 1200 UTC, an elongated, open low center extended from southwestern Iowa to northeastern Montana at 300 millibars (Fig. 1a). A trough was evident in the height field extending southeast from the low over Iowa to Mississippi. High altitude moisture was evident along the East Coast and wrapped westward across the northern Great Lakes to the north of the low center. Dry air was evident to the southwest, south and southeast of the low. Although two jet maxima were evident across the High Plains and New England, neither seemed to be directly related to the moisture field at 300 millibars.

At 500 millibars (Fig. 1b), the low over southwestern Iowa became closed, while a trough extended back toward the second low over Montana. Several other troughs extended from the main low, most notably one which again extended to the southeast and appeared to be the dividing line between moist air and warm advection over the eastern states and dry air over the southern plains states. This trough was mostly evident in the moisture field, but significant height falls were occurring along and just ahead of the trough (50 decameters at Nashville). Much weaker height falls and rises were evident behind the trough. Strong height falls in Illinois were mostly due to the approach of the low center, and are not representative of trough passage. The moisture pattern at 500 millibars is similar to that seen at 300 millibars, with moisture wrapping from the East Coast across the Great Lakes to the north side of the low center. However, the boundary between moist air and dry air was better defined at 500 millibars and the moisture plume wrapped in a comma shape around the low pressure center over Iowa. The dry air had wrapped up into the front side of the low center reaching Illinois and eastern Iowa at 1200 UTC.

The pattern was similar at 700 millibars (Fig. 1c), but the low centered over southwest Iowa had several closed contours. The dry air from the southwest had only reached central Missouri at this level. Saturated conditions were now evident across all of Ohio, Indiana and southern Michigan. The trough axis to the southeast of the low separated the moist air and warm advection to the east from the dry air and cold advection to the west. At this level, a trough extending across the southern edge of the Great Lakes was more evident and featured a significant wind shift. Dry air was evident at both 500 and 700 millibars across eastern Canada, New York and New England, essentially to the northeast of a ridge axis extending from western New York to Lake Superior. Temperatures across the project area at 700 millibars were between 0 and -7 C. At 850 millibars (Fig. 1d), the closed low was centered slightly to the east of the 700mb low, with an obvious trough extending across the southern Great Lakes. Dry air was evident to the north of this trough while saturated conditions existed and to the south of it. Temperatures at this level were all above freezing and strong warm advection was present across the project area.

Upper air chart analysis-0000 UTC, February 5th

Examination of the upper air charts at 0000 UTC on 5 February 1997 shows that the low center progressed toward Chicago at all levels (see Figs. 2a-d). The dry air at 300 and 500 millibars progressed eastward with the system, reaching northern Ohio and western Pennsylvania, while saturated conditions existed over New England and most of New York. The upper level trough that was initially over the southern Great Lakes at 700 millibars moved northward into southern Ontario. This trough tilted toward the north with height, and was the upward extension of a surface trough to be discussed later. The trough which extends southward from the low center appears to have intensified, as an area of cold advection to the west caught up with the trough. This helped to develop a north-south oriented cold front from the surface to 700 millibars by 2100 UTC.

Satellite IR temperature analysis

Infrared satellite imagery from 1509 UTC (earliest time available - Fig. 3a) mimics the combination of the upper air moisture fields, with deep, cold clouds covering the eastern states and extending westward to the north of the low center. Dry air ahead of the Iowa low is evident in the warmer infrared temperatures across Illinois, Indiana, western Ohio, southern Michigan and southern Wisconsin. The progression of the upper air pattern and its attendant cloud features is clearly seen in the satellite infrared temperature plots for 1515 to 2045 UTC (Figs. 3a-f). The cold cloud tops (CTT < -40C; CTT = cloud top temperature) moved eastward with time, with their western edge passing Cleveland (CLE) around 1700 UTC and reaching well into Pennsylvania by 2039 UTC. The passage of this feature was well correlated with the cessation of the significant precipitation at most surface stations (e.g. CLE at 1729 UTC). Surface analyses at 1800 UTC will show a significant gap in the precipitation field between the cold cloud shield to the east of CLE and a second cold shield over Indiana associated with the developing cold front. An area of warmer cloud tops existed between these two areas of deeper, colder clouds. Cloud top temperatures in these warmer clouds, which were present over Lake Erie at the time of the flight, were approximately -13 C during the period of flight number 2.

Surface map, upper-air sounding and icing PIREP analysis

Standard surface maps were not available for the period between 0900 and 1500 UTC on February 4th. Analysis from the ETA model (not shown) is used here for surface low positioning at 1200 UTC. NEXRAD radar mosaic data was not available for February 4th. Thus the mosaic data cannot be discussed in relation to other features. Data from the Cleveland NEXRAD will be discussed in the mesoscale analysis section.

A well-organized, low pressure center moved from southeast Iowa toward Chicago between 1200 and 1800 UTC. At 1800 UTC, the 1006 millibar low was centered over Chicago and featured a warm front which extended across southwestern Ohio to the Tennessee/North Carolina border, and a surface trough which extended across southern Michigan and Lake Erie (Fig. 4). Ahead of the warm front, freezing rain and some freezing drizzle was reported across central Michigan, southern Ontario, western New York, and central Pennsylvania, while rain was occurring in western Pennsylvania. Stations across most of Ohio, including Cleveland, had been reporting rain in previous hours, but this rain had moved to the east, leaving the Cleveland area beneath non-precipitating, overcast clouds. Rain ended at Cleveland-Hopkins airport at 1729 UTC and at Cleveland-Cuyahoga between 1645 and 1745 UTC. The period with no rain lasted until 1935 UTC, and was associated with the gap in the upper cloud shield, as discussed earlier.

As mentioned earlier, a surface trough extended eastward from the low pressure center, across Lake Erie, just north of Cleveland. Surface winds to the south of this trough were from the southeast, and temperatures were in the mid-40s. Stations around Cleveland were reporting overcast skies with cloud bases of 8000-10,000 feet. To the north of the trough, surface winds were from the east, temperatures were in the low 30s, ceilings were 1000 feet or less, and a mixture of freezing rain, freezing drizzle, ice pellets, snow and rain was falling. The surface trough tilted northward with height, as seen on the 850 and 700 millibars charts for 0000 UTC, 5 February. Warm advection and overrunning conditions were evident at all levels, indicative of a warm frontal structure.

Sounding data from Detroit at 1200 UTC and Buffalo at 0000 UTC (Figs. 5a,b) showed that a freezing rain temperature structure existed just ahead of the surface trough, with saturated conditions aloft, a layer of above-freezing air (a "warm nose") near 850 millibars, and a sub freezing layer below. Fluctuations between precipitation types and intensities across the area appeared to be dependent upon the depth and strength of the warm nose and the depth of the saturated layer above. In places where deep, efficient clouds were in place, snow probably existed above the warm nose, fell through it and then into the subfreezing layer below to form freezing rain and ice pellets. When more shallow, less efficient clouds (warmer cloud top temperatures) were in place, the lifting from the warmer frontal structure and overrunning produced supercooled liquid water and SLD aloft. During the first flight on this day, the Twin Otter flew into the former situation near Cleveland at ~1500 UTC, finding mostly ice crystals and little supercooled liquid water. During the second flight, the Twin Otter flew into the latter situation, encountering both small and large supercooled liquid water drops and relatively few ice crystals.

Pilot reports of icing were made across the region during the period of interest. Nearly all of the PIREPs were made within the areas of warmer cloud tops indicated in the GOES-8 infrared imagery, were at altitudes between 9000 and 15,000 feet MSL, from light to moderate in intensity and of all icing types (Fig. 6).

Mesoscale and microscale analysis

A detailed analysis of the mesoscale and micro-scale structure of the clouds sampled on this day is given in tabular format (see Table 1). Each period of time was chosen based upon apparent consistency in 2d-grey probe imagery for a period of at least ten seconds. For each period, the table includes the range of times (UTC), altitudes (feet MSL), static temperatures (C), liquid water content from the King probe with zero removed (g/m^3), a brief description of the 2d-grey imagery (phase, small/large drops, crystal habit and appearance), an assessment of the radar reflectivity pattern in the location of flight, and comments. A quick overview of the results is given in the text here. Images from the 2D-grey probe and the Cleveland NEXRAD are given in figures 7 and 8.

Between 175400 and 180830 UTC, the plane climbed from the surface to the freezing level, crossing an inversion (possibly the warm front) between 2000 and 4400 feet. The freezing level was encountered at approximately 8900 feet AGL during the ascent. The period of flight from 180830 to 192500 UTC was spent above the freezing level, between 8900 and 13900 feet, where temperatures were between 0 and -11 C. Liquid water content varied greatly in this range of altitudes, with values from 0 to 0.5 grams per cubic meter. A variety of conditions were sampled, including freezing drizzle, cloud-sized droplets, and ice crystals (columns, needles, stellars, plates and aggregates). A combination of drops sizes from ~10 to ~200 microns was most common when areas of only liquid were being sampled, but there were many periods where mixed conditions (drops mixed with ice crystals) existed. Freezing drizzle and cloud-sized droplets were observed both inside and outside of areas of reflectivity detectable by the Cleveland NEXRAD radar (down to about -10 dBZ, depending upon range). Freezing drizzle was observed through the entire range of altitudes from 8900 to 13900 feet (just below cloud top), and drizzle was observed at altitudes beneath the freezing level. The freezing drizzle and warm drizzle (temperature above freezing) were observed within, beneath and between cloud layers at all locations from Cleveland to 105 km north of this site (the northern end of the flight track). Thus, the freezing drizzle layer was approximately 5000 feet deep and extended across at least 100 km in the north-south direction on this day. Note that the aircraft did sample from just below cloud top down to the freezing level both upon takeoff and when ~105 km to the north of Cleveland. Freezing drizzle was observed throughout that depth at both locations, giving profiles of the SLD conditions over Cleveland and near the northern end of the flight path.

Ice crystals were observed outside of reflectivity areas, but their concentrations seemed to be highest within echoes of at least -5 dBZ. Columns and needles were most commonly observed at altitudes below approximately 10,000 feet, though they were occasionally seen above this level. At higher altitudes crystal habits were often difficult to distinguish or were irregular in appearance, but occasional stellar and dendritic crystals were observed. Some aggregation was evident at times.

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Row	Start/end time (UTC)		Alt Range (ft MSL)		T-static range (C)		LWC - KingZR		Description of 2D-grey imagery	2D Imgs
1	175400	175600	600	2000	7	3.4	0	0	Warm drizzle (100 to 250 microns)	A
2	175600	175930	2000	4360	3.4	6.6	0	0	Warm drizzle (L), a few breaks	B
3	175930	180010	4360	4900	6.6	5.5	0	0	L, a few breaks	C
4	180010	180300	4900	6000	5.9	3.9	0	0.2	L with cloud drops	D
5	180300	180830	6000	8900	3.9	0	0	0	Intermittent L & cloud drops	E
6	180830	180935	8900	9000	0	-1.2	0	0	Mix of poss ZL, columns, needles (?), irregs	F
7	180935	180952	8900	9000	-1.1	-1.2	0	0.1	A few xls (irreg), mostly cloud drops, some poss ZL	G
8	180952	181015	8880	8930	-0.9	-1.1	0	0.08	More cols & irregs, mixed w/poss ZL & cloud drops	H
9	181015	181045	8830	8950	-1	-1.1	0	0.13	Small drops, few poss ZL, some cols, irregs, other ice	I
10	181045	181315	8850	11100	-1	-4.7	0	0.1	Ditto	J
11	181315	181500	11100	12300	-4.7	-7.4	0	0.07	Cloud & ~50 micron oof drops, ocn'l cols, irr, likely ZL	K
12	181500	181808	12400	12900	-7.6	-8.8	0	0.05	Plenty of ZL, some cloud drops, ocnl ice 181730-45	L
13	181808	181910	12800	12900	-8.6	-8.8	0	0.05	Larger ZL (200+ mic), few junky xls	M
14	181910	182135	12850	13100	-7.8	-8.7	0	0.1	Mix ZL & cloud drops, ocn'l junky xls	N
15	182135	182420	13200	13900	-8.9	-10.5	0.01	0.25	Mix ZL & cloud drops, sizes fluctuate, no ice	O
16	182420	182512	13400	13700	-9.4	-10.5	0.1	0.2	Mix ZL & cloud drops, ocn'l xls	P
17	182512	183135	13400	13800	-9.1	-10.2	0.01	0.4	Mix ZL & cloud drops, size/LWC vary, ocn'l stellars(?)	Q
18	183135	183202	13600	13700	-9.5	-9.7	0.04	0.06	ZL, cloud drops & more xls, poss ocnl aggs	R
19	183203	183405	13200	13700	-9.1	-10	0	0.3	Mix ZL & cloud drops, no ice	S
20	183405	183445	13350	13450	-9.1	-9.1	0.03	0.1	Mix ZL, cloud drops and some stellar (?) and unknown	T
21	183445	184005	13300	13800	-8.6	-10.1	0	0.5	Mix ZL & cloud drops, no ice	U
22	184005	184112	13600	13800	-9.7	-10.5	0.01	0.1	Mostly cloud drops, a few oof ZL to 100 microns	V
23	184112	185310	13500	11300	-5.5	-10.5	0	0.1	Mix ZL & cloud drops, a few xls & aggs	W
24	185310	185400	11300	9700	-5.5	-2.9	0	0.05	Mix ZL & cloud drops, columns	X
25	185400	185610	9700	8000	-2.9	0	0	0.15	Small drops w/some ZL & some ice	Y
26	185610	185830	8000	9250	0	-1.5	0	0.01	A mess! Drops, columns, needles, stellars (?)	Z
27	185830	190100	9250	11000	-1.5	-4.5	0	0.06	Xls decreasing with height	AA
28	190100	190310	11000	12400	-4.8	-7.2	0	0.15	Cloud drops & small ZL, occn'l columns	BB
29	190310	191100	12500	13900	-7.2	-11	0	0.4	Cloud drops & small ZL, no ice	CC
30	191100	191440	13300	13700	-9.7	-11	0	0.3	Cloud drops & small ZL, occn'l plates starting	DD
31	191440	191705	13400	12300	-10.6	-7.4	0	0	Fewer images, stellars & plates	EE
32	191705	191745	12300	11500	-7.4	-6.2	0.01	0.05	Mix ZL & cloud drops, ocn'l column & unknown xls	FF
33	191745	192420	11500	8450	-6.2	-0.5	0	0.4	Mix ZL & cloud drops w/off/on columns, few aggs	GG
34	192420	192500	8450	7800	-0.5	0.3	0.1	0.5	Mix L & cloud drops, ocnl columns & unknown	HH

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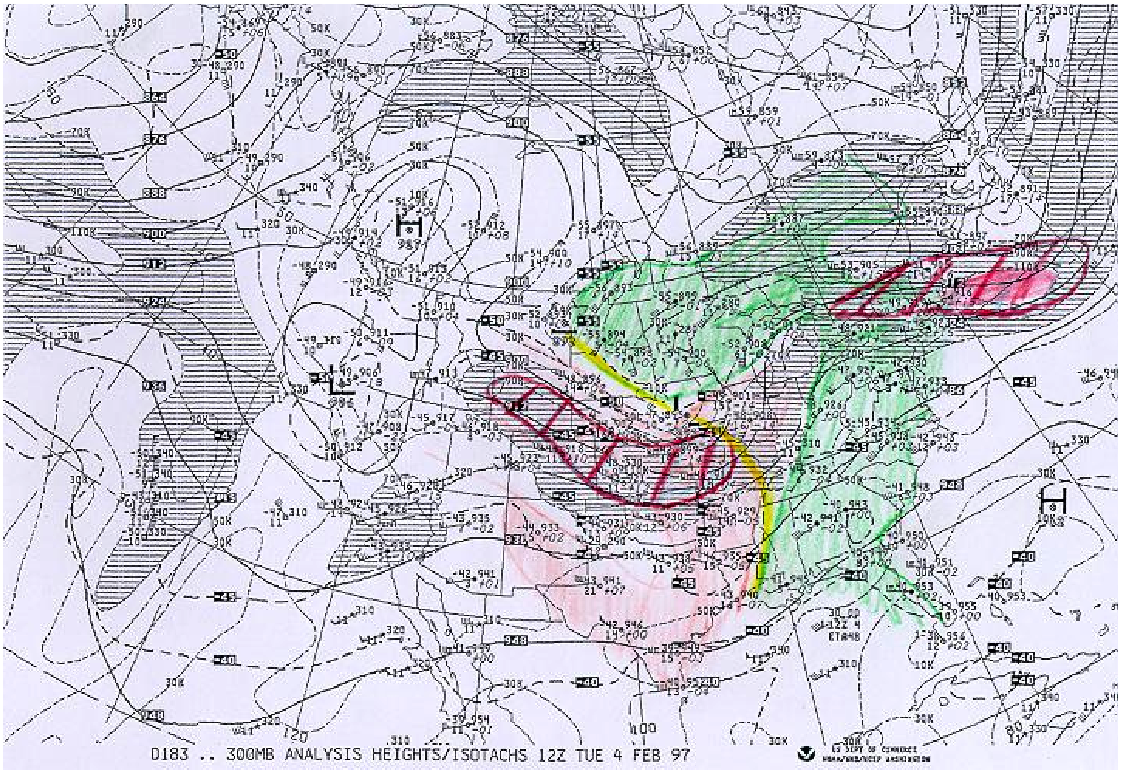
Row	Rad Imgs	Range-km	Azimuth	Elev. ang	Description of Radar Reflectivity around A/C	Comments
1	A,B	0-4.0	78-108	0.0-7.0	No info	T falling w/height
2	B	4.0-7.0	108-172	7.0-12.3	No info	Inversion layer
3	B	5.5-6.7	172-184	11.1-12.2	No info	Above inversion, enter cloud base @4900'
4	B	5.4-7.2	184-273	10.9-17.5	No info	In cloud
5	C,D	7.2-24	273-295	6.2-12.8	Main area of reflectivity is to the NW	In & out of cloud pockets
6	C,D	24-29	292-295	5.2-6.2	Clipping SW edge of 5-30 dBZ pocket	
7	C,D	29-30	294-295	5.0-5.2	Ditto	
8	C,D	30	295-297	4.8-5.0	Reaching NW part of reflectivity pocket	Reflectivity getting patchy
9	C,D	32-33	297-300	4.6-4.8	Ditto, -15 to 5 dBZ	
10	C,D	27-33	300-318	4.6-7.1	Entering NW portion of pocket, 0-18 dBZ	
11	E	27-32	318-329	6.9-7.1	In NW portion of pocket, 5-18dBZ, exiting it at end	Exiting to NW
12	E	32-42	329-352	5.4-6.9	Exited pocket into area of no echo	
13	G,H	42-46	352-358	4.9-5.4	No echo on 6.0 elev, patchy -10 to 5dBZ on 4.3 elev	
14	G,H	46-59	358-6.0	4.0-4.9	Along edges of -10 to 5 dBZ echoes	Going to lower tilt (4.3), no echo at 6.0
15	F,G	59-72	6.0-11.0	3.4-4.0	No echo on 4.3, patchy -10 to 0 dBZ on 3.3 elev	
16	J	72-77	11.0-12.0	3.1-3.4	Patchy -10 to 5 dBZ echo @ 3.3 mostly dissipated	Echo dissipated beyond 70km, A/C @72-77 km range
17	J	74-82	8.0-15.0	3.0-3.3	At the edge of a pocket of +5 dBZ on 3.3 scan	Xls in 5 second patches
18	J	80-81	15-16	3.0-3.1	Ditto	
19	I,J	78-83	13-15	2.8-3.1	Ditto, above and near some 5-20 DBZ on 2.4 scan	
20	K,L	83-86	13-14	2.8-2.8	No echo on 3.3, in/out of -5 to 5 dBZ on 2.4 scan	
21	K,L	82-91	8.0-14.0	2.6-3.0	Ditto	
22	K,L	79-82	8.0-8.0	3.0-3.1	Ditto	
23	M-P	76-98	8.0-15.0	2.2-3.1	N of solid 5+ dBZ echoes on 2.4, near bits of 0-5 dBZ	Begin descent to 8000'
24	Q,R	90-95	13-14	1.8-2.2	N of echoes on 2.4, in patchy -5 to 10dBZ on 1.5 scan	
25	Q	95-106	14-16	1.3-1.8	In and out of patchy -5 to 10 dBZ	Reached freezing level
26	Q	106-110	16-18	1.3-1.5	In 5-15 dBZ on 1.5 scan	Begin ascent
27	Q,R	99-106	17-18	1.5-2.0	Going to 5-10 dBZ on 1.5 scan, no echo on 2.4 scan	
28	S	95-99	15-17	2.0-2.3	N edge of patchy -5 to 5 dBZ	
29	S,T	76-95	10.0-15.0	2.3-3.2	0-15km N of main echoes, approaching them from N	
30	U,V	77-85	14-25	2.8-3.1	In/out of patchy 5-10 dBZ on 2.4, no echo on 3.3 scan	
31	U,V	85-90	25-33	2.4-2.8	In hole in echoes, W of patch of 5-10 dBZ on 2.4 scan	
32	W	88-90	33-34	2.3-2.4	In gap between patches of 5-10 dBZ	
33	W,Y	70-88	23-34	2.0-2.3	Moving SW though gap, and into 5-25 dBZ at the end	Heading south
34	X,Y	68-70	21-23	2.0-2.1	Passing thru WE edge of 5-25 dBZ echoes into a hole	Remainder of flight at T>0C



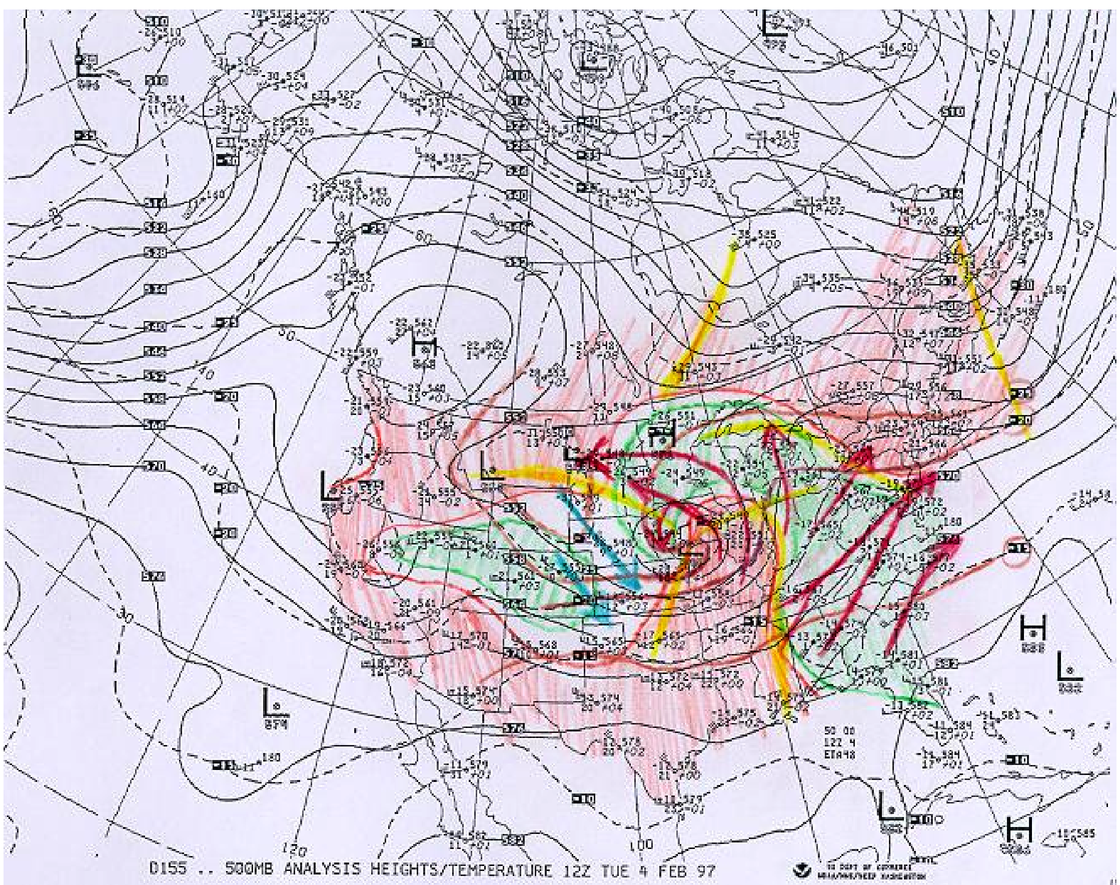
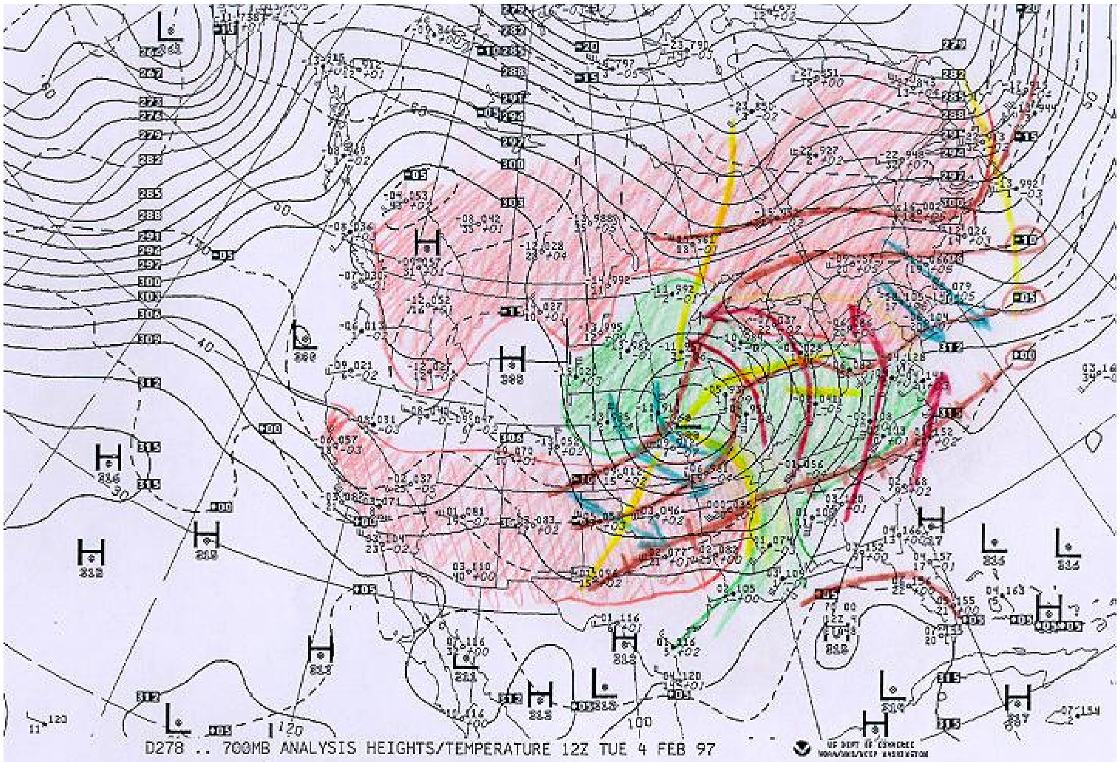


Figure 1 – Upper-air charts for 970204, 1200 UTC at a) 300 and b) 500 mb.



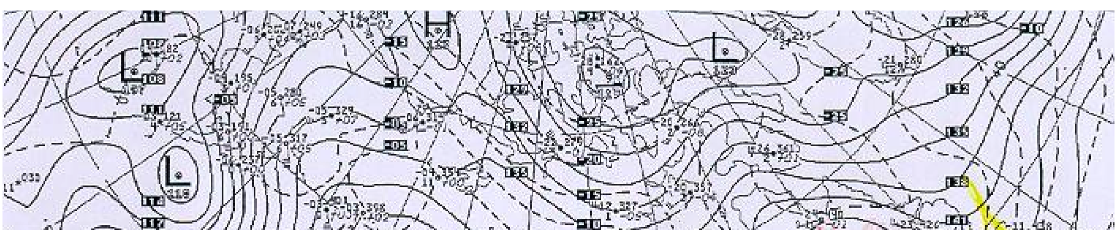


Figure 1 – Upper-air charts for 970204, 1200 UTC at c) 700 and d) 850 mb.

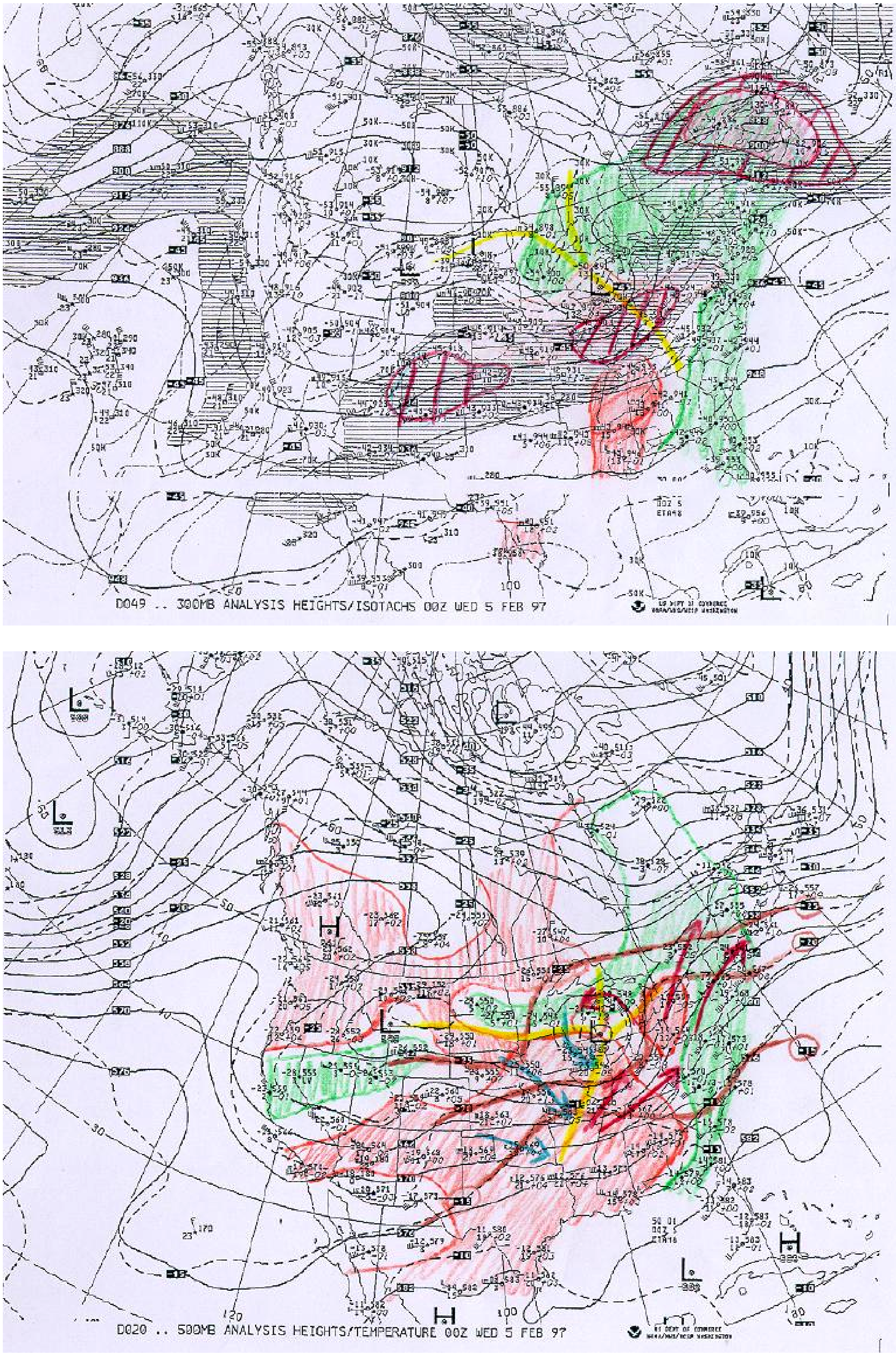


Figure 2 – Upper-air charts for 970205, 0000 UTC at a) 300 and b) 500 mb.

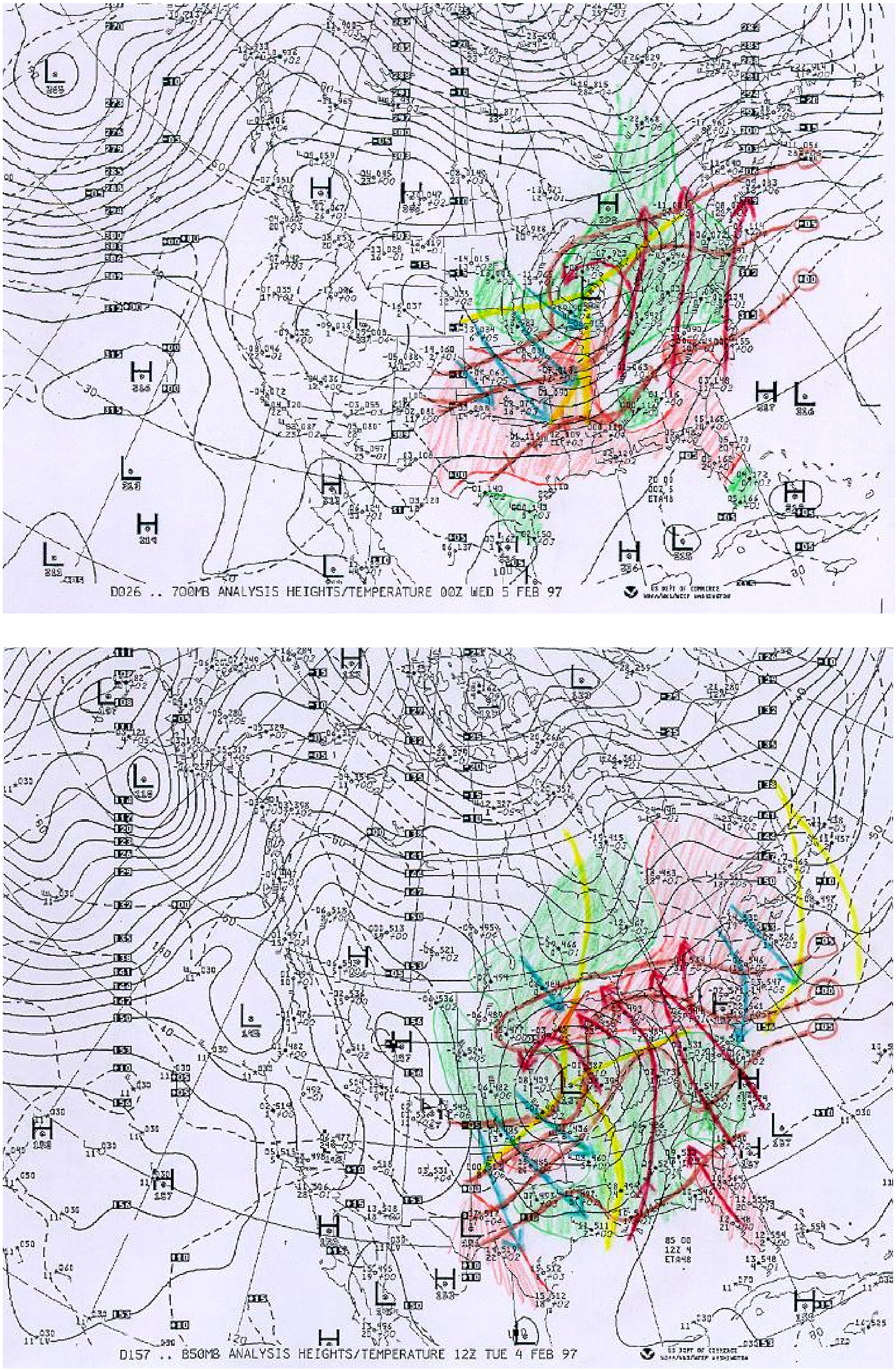


Figure 2 – Upper-air charts for 970205, 0000 UTC at c) 700 and d) 850 mb.

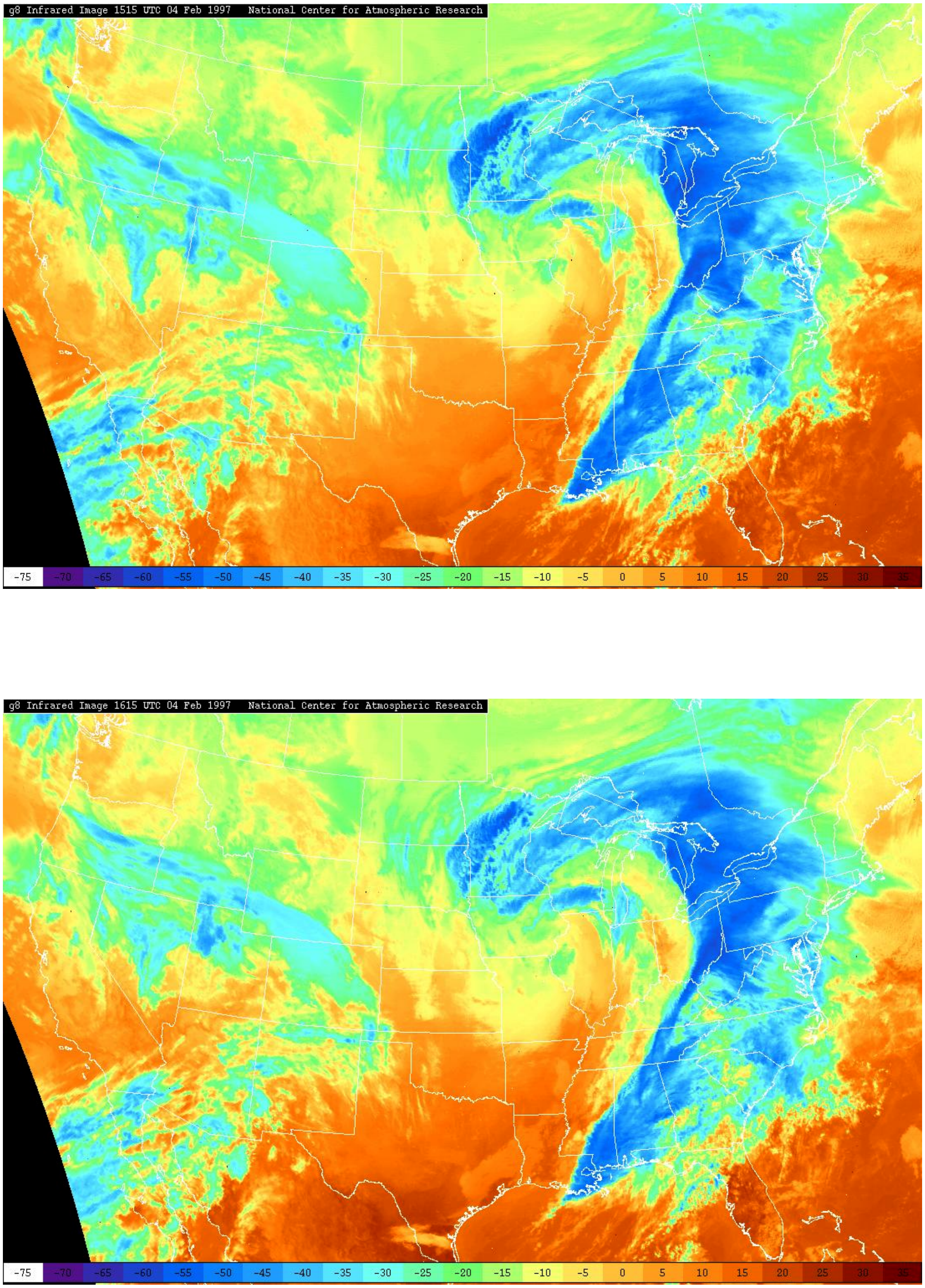
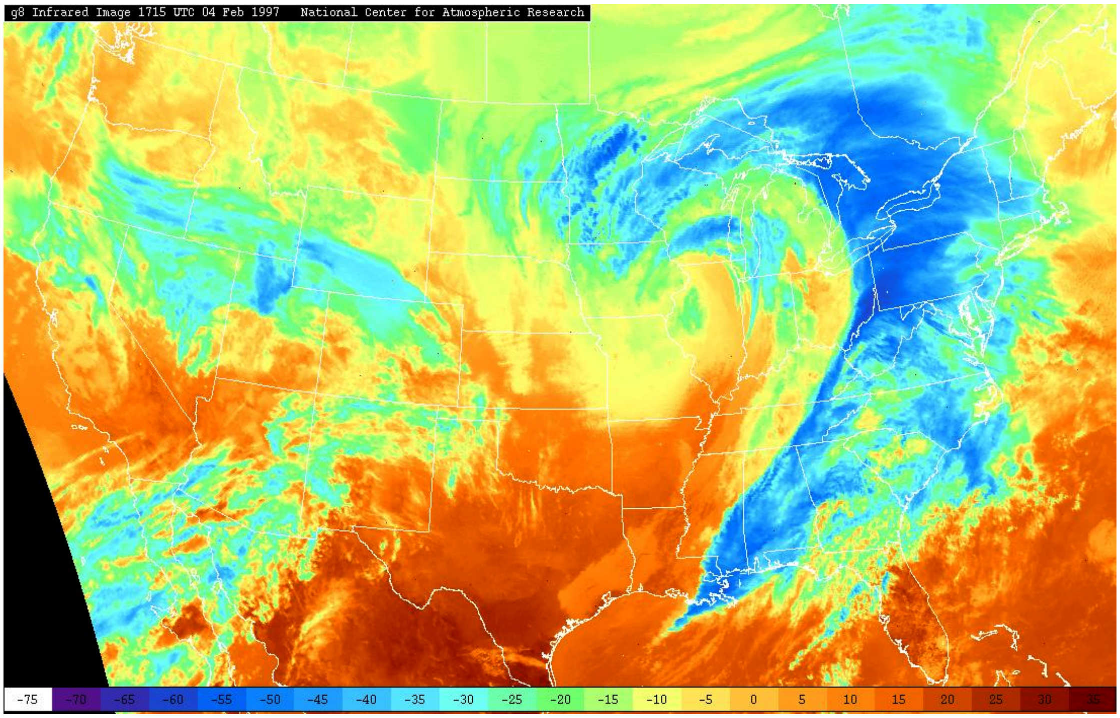


Figure 3 – GOES-8 infrared satellite imagery for 970204, a) 1515 and b) 1615 UTC.



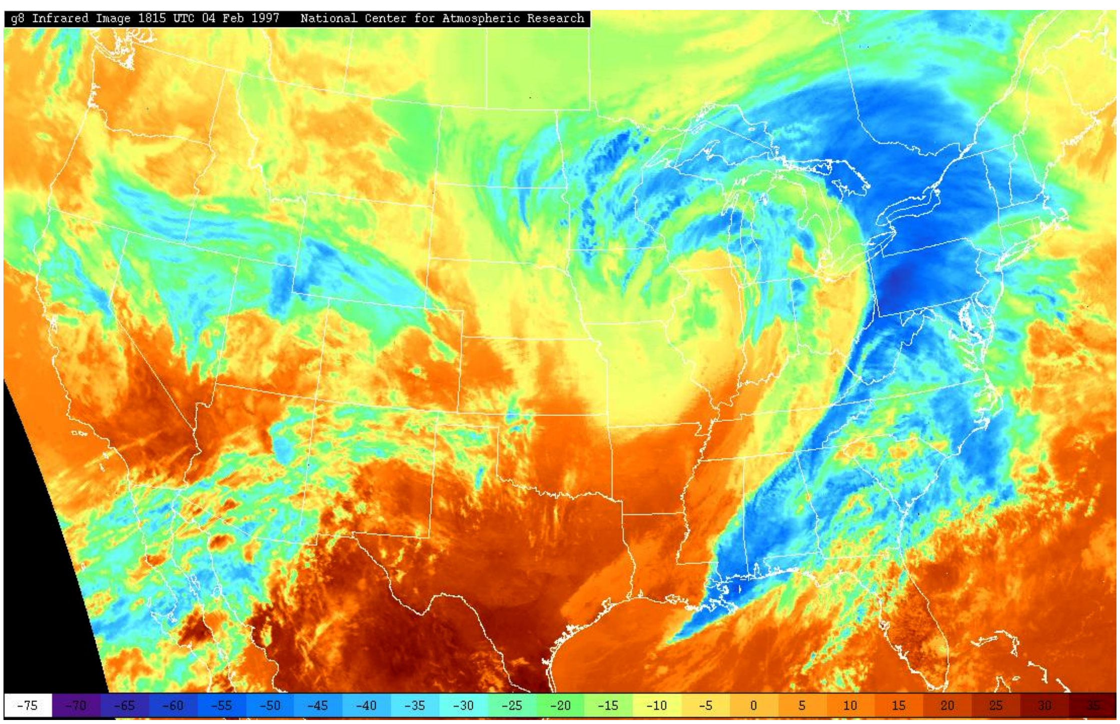
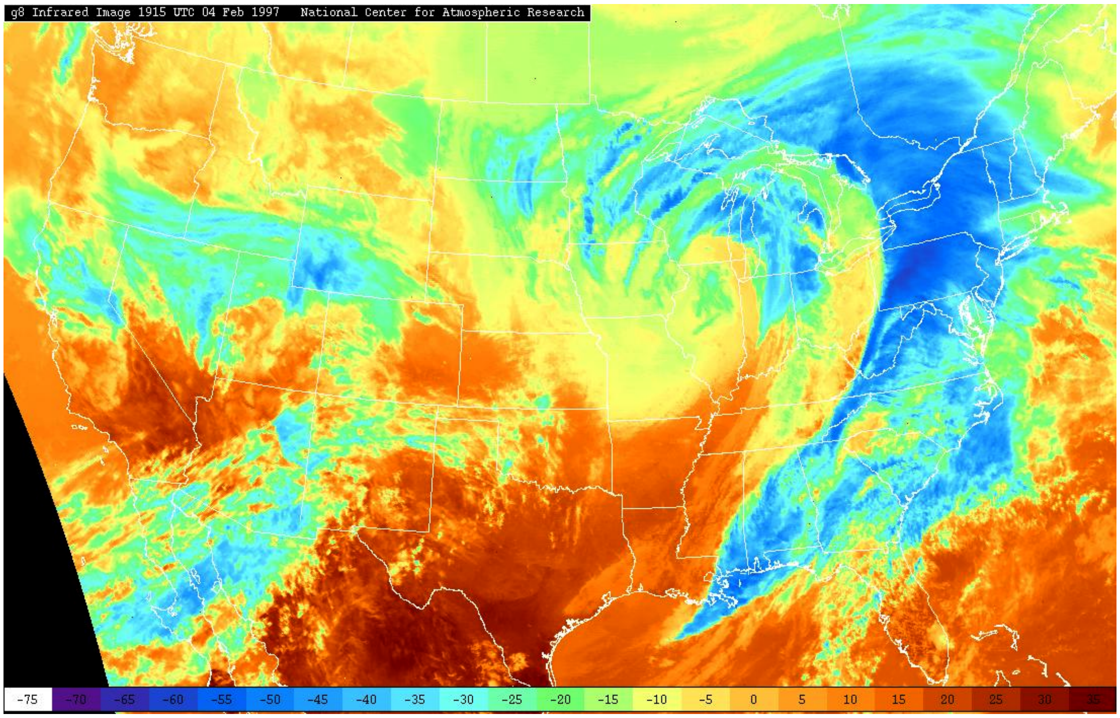


Figure 3 – GOES-8 infrared satellite imagery for 970204, c) 1715 and d) 1815 UTC.



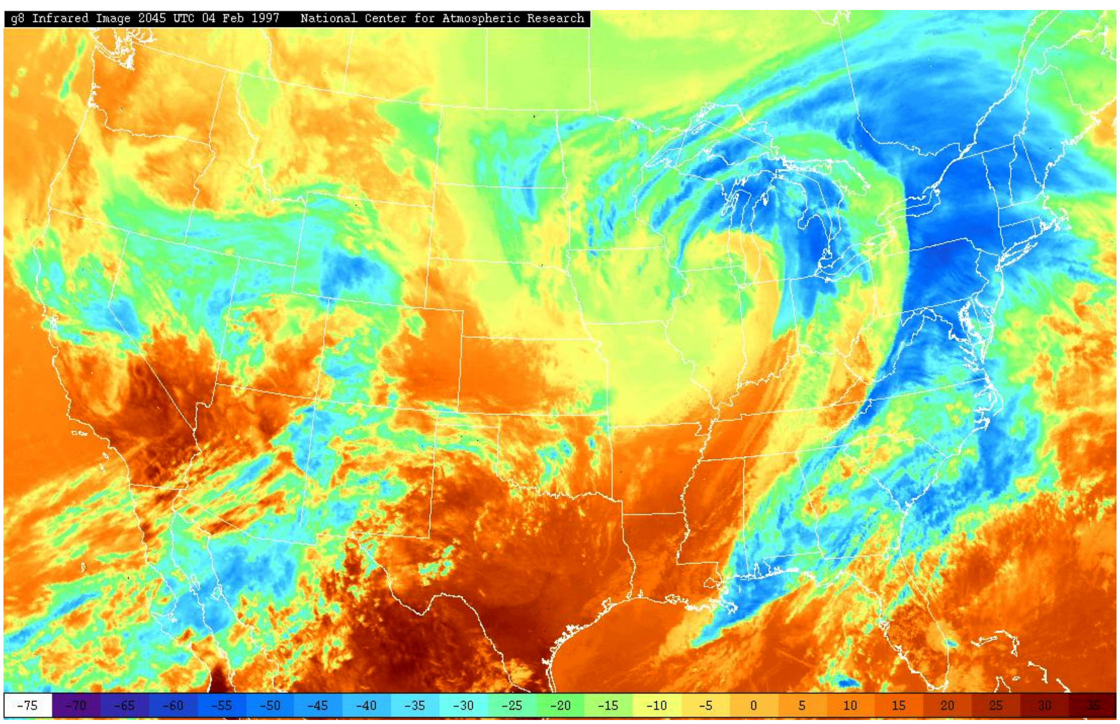


Figure 3 – GOES-8 infrared satellite imagery for 970204, e) 1915 and f) 2045 UTC.

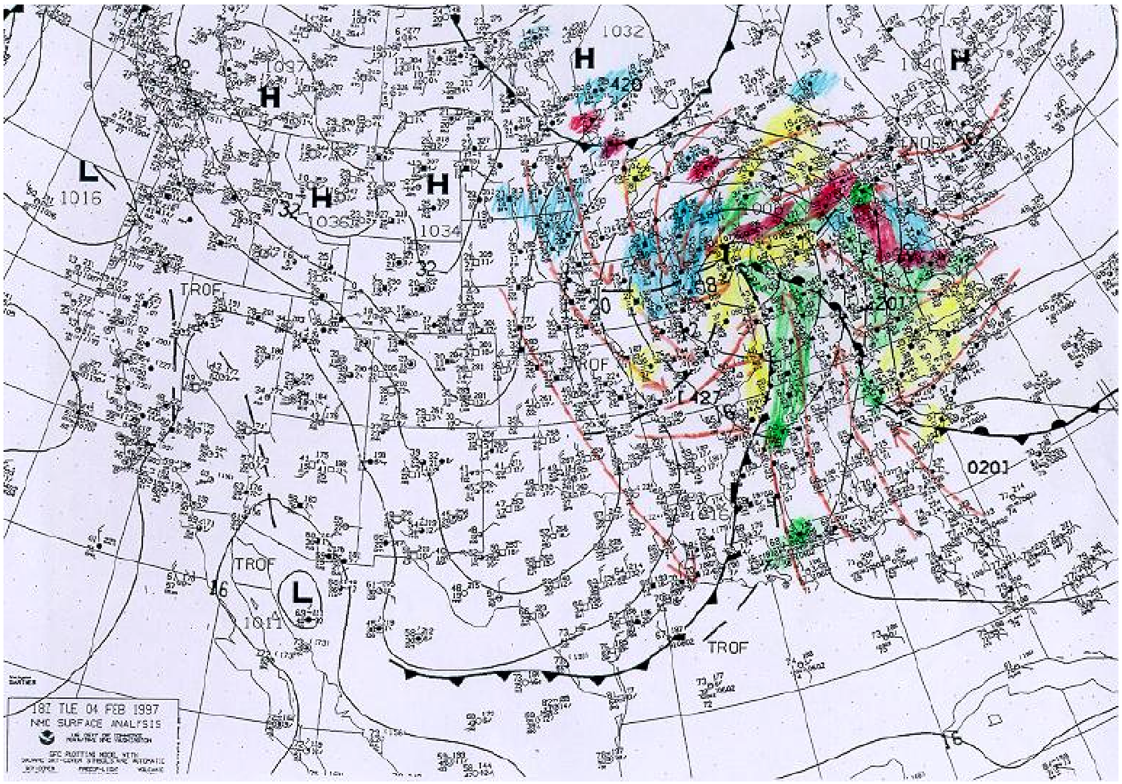
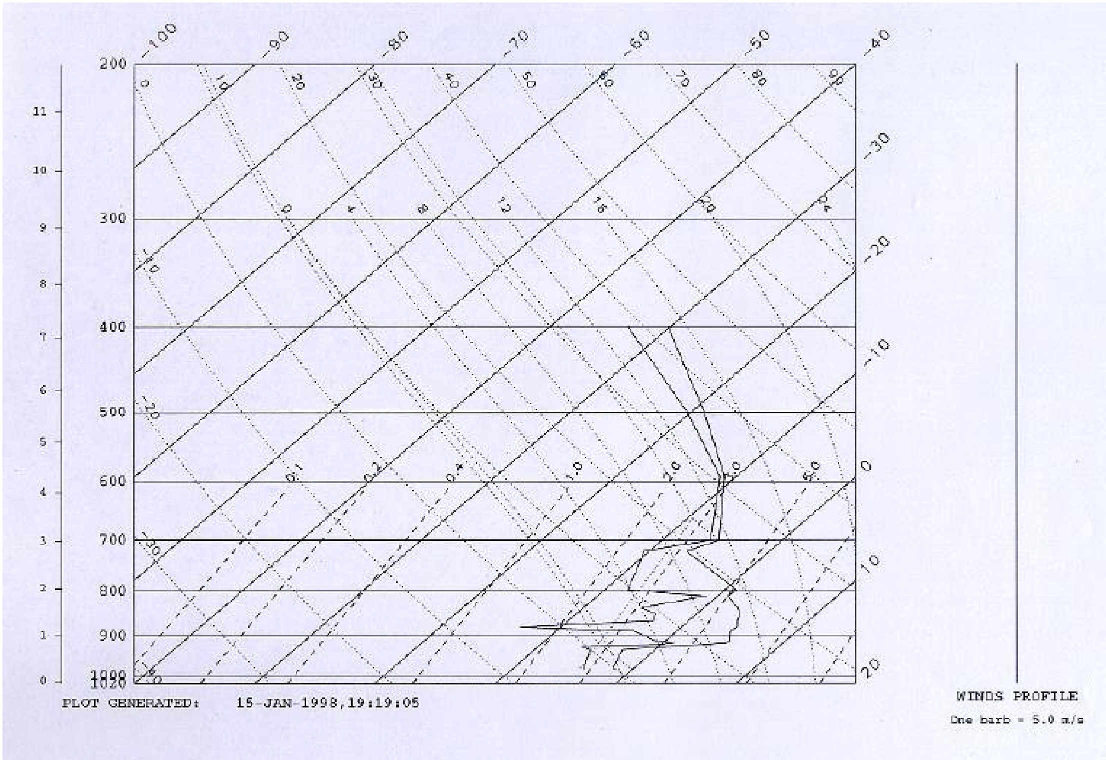


Figure 4 – Surface chart for 970204, 1800 UTC.



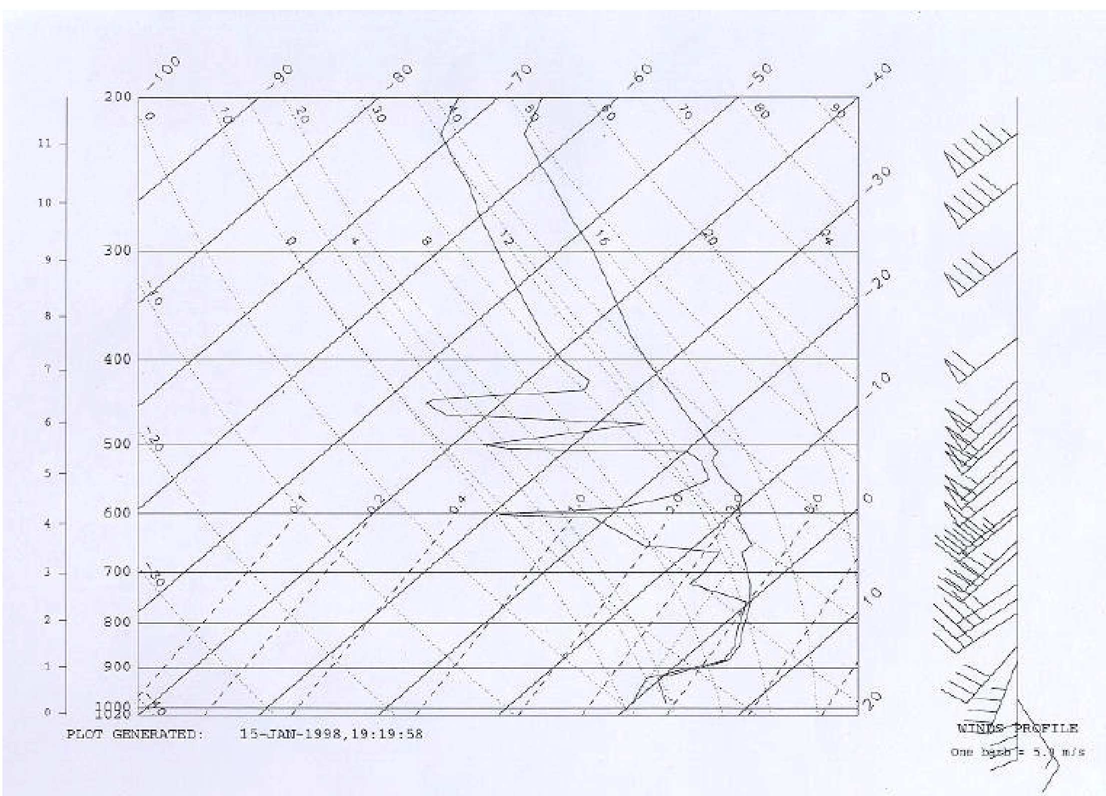
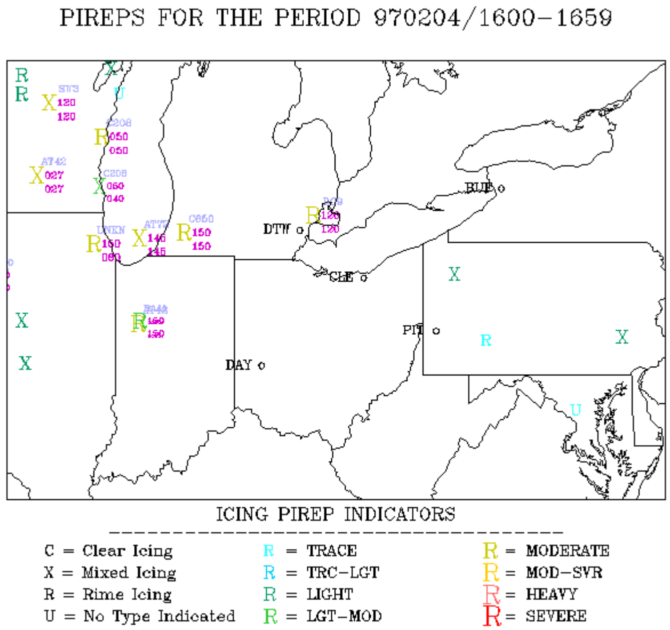


Figure 5 – Balloon-borne sounding data for a) 970204, 1200 UTC at Detroit and b) 970205, 0000 UTC at Buffalo.



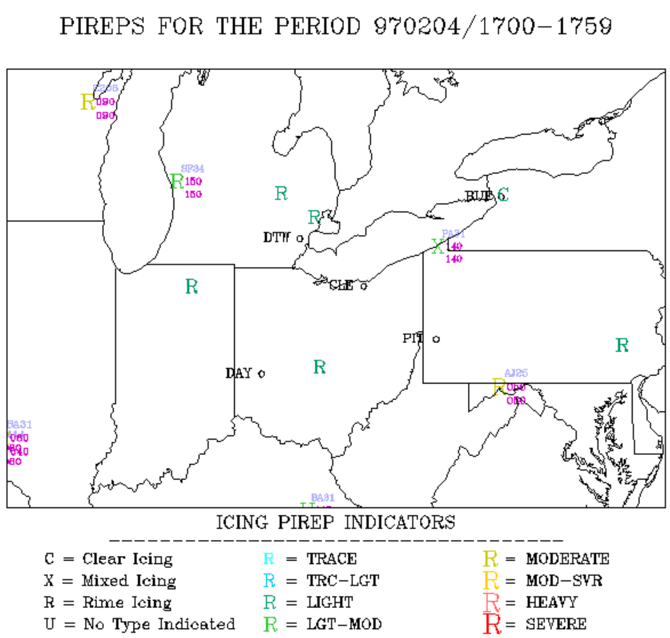
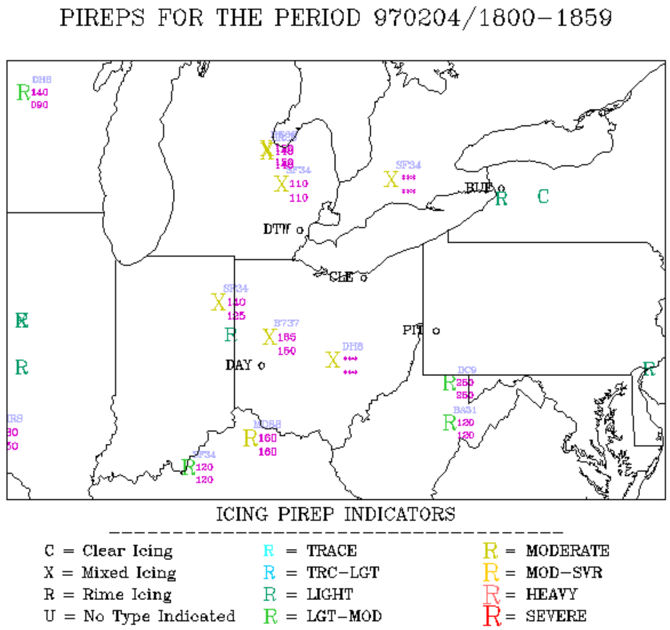


Figure 6 – Pilot reports of icing for 970204, a) 1600-1659 and b) 1700-1759 UTC.



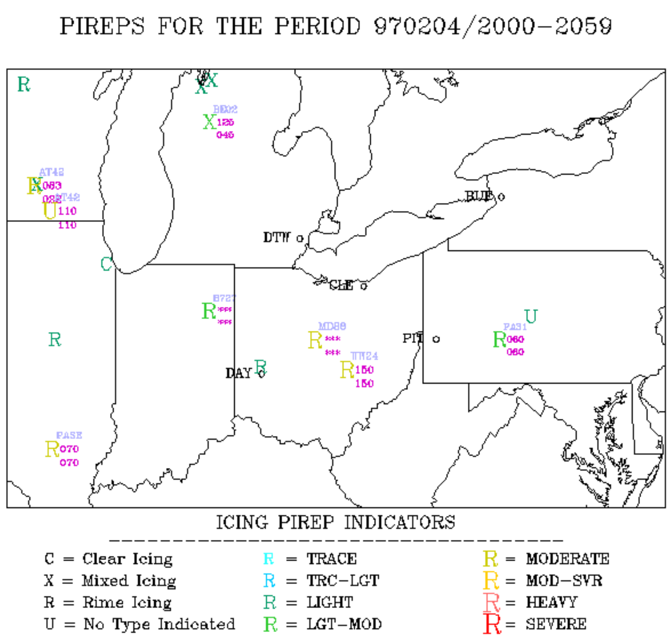


Figure 6 – Pilot reports of icing for 970204, c) 1800-1859 and d) 2000-2059 UTC. No PIREP data was available for 1900-1959 UTC.

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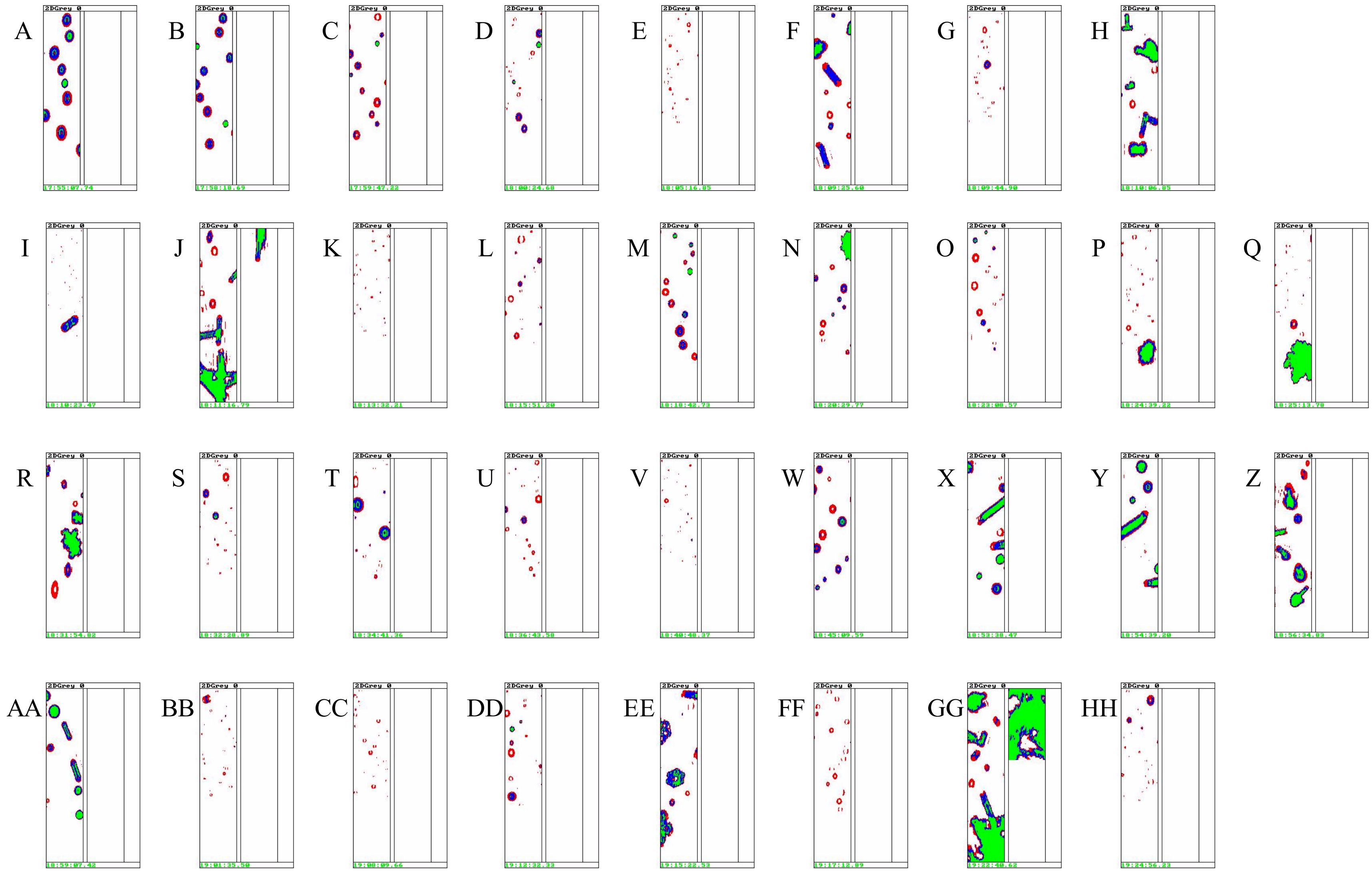
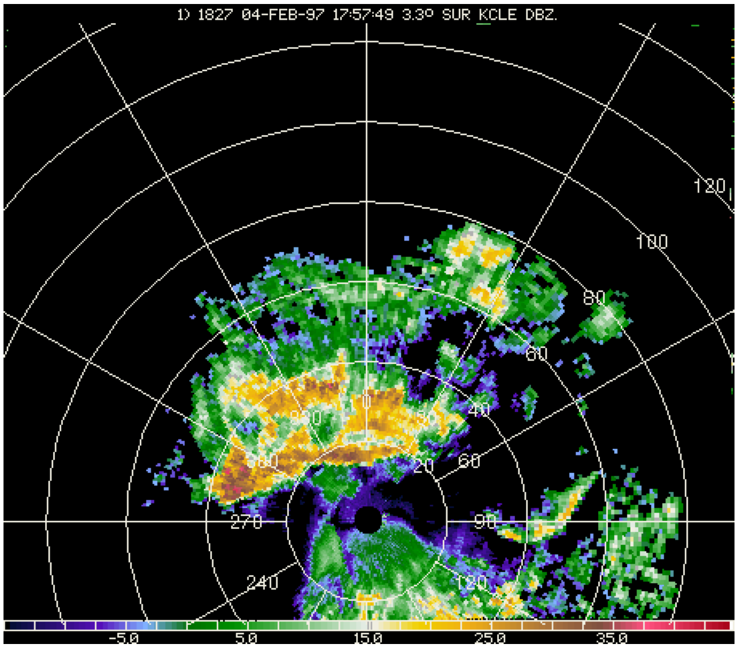


Figure 7 - 2D-grey probe imagery for flight 2.



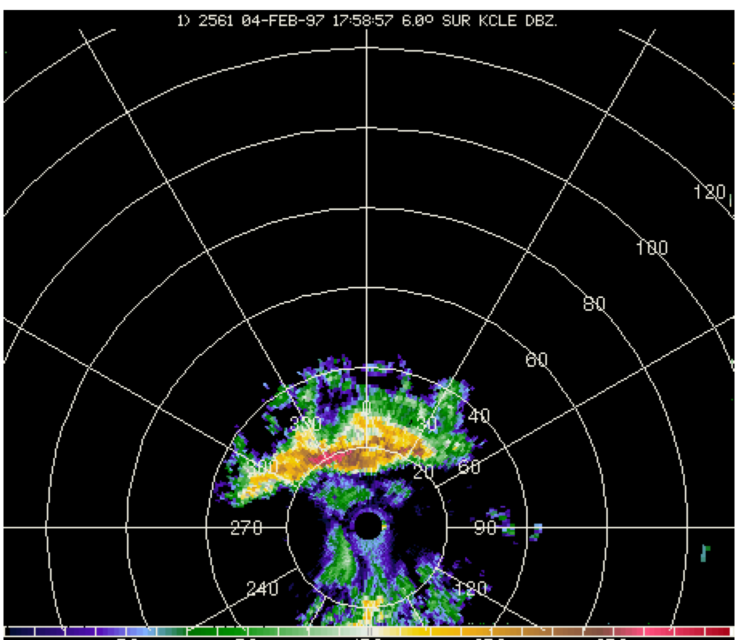
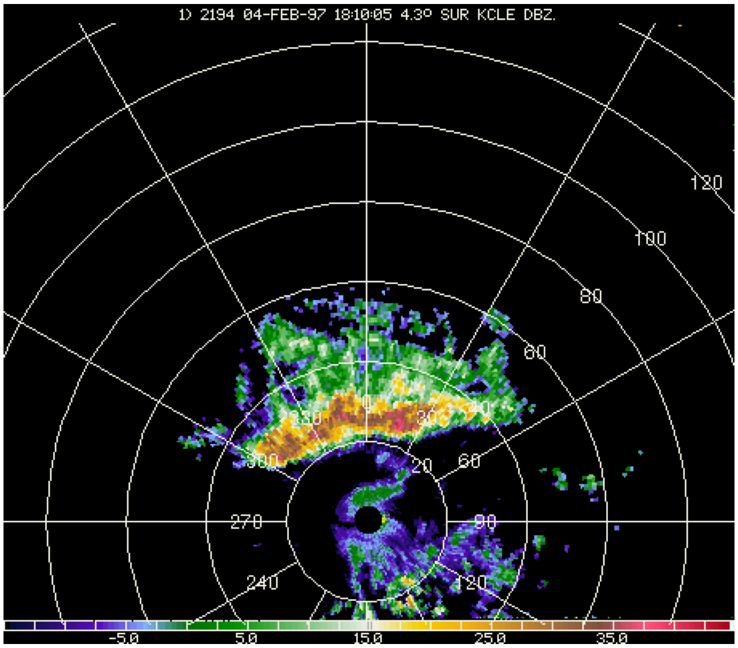


Figure 8 – Cleveland NEXRAD radar imagery for 970204, a) 1757 (3.3 degree elevation angle) and b) 1758 UTC (6.0 degree elevation).



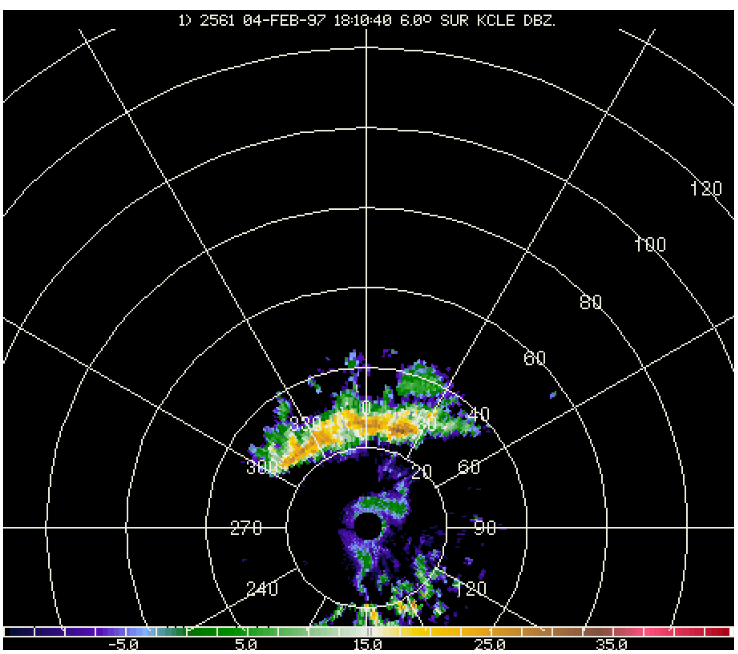
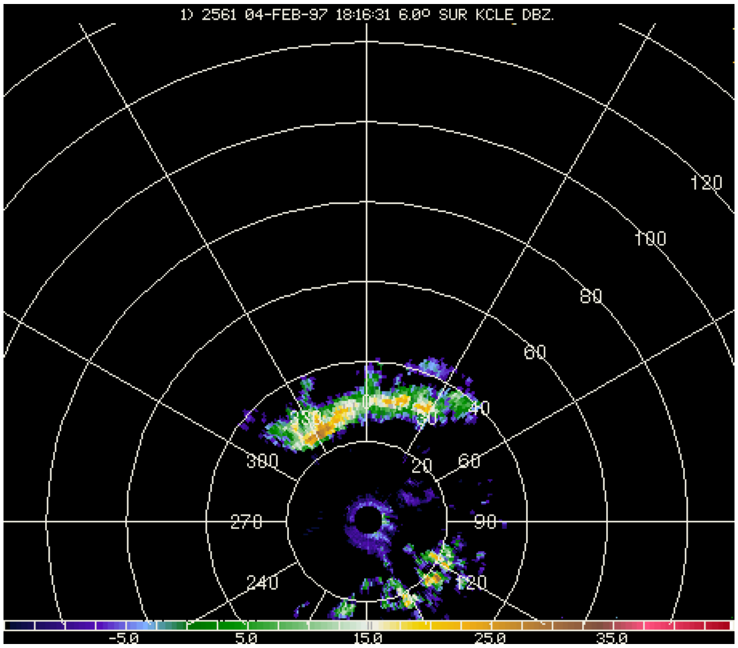


Figure 8 – Same, but for c) 1810 (4.3) and d) 1810 UTC (6.0).



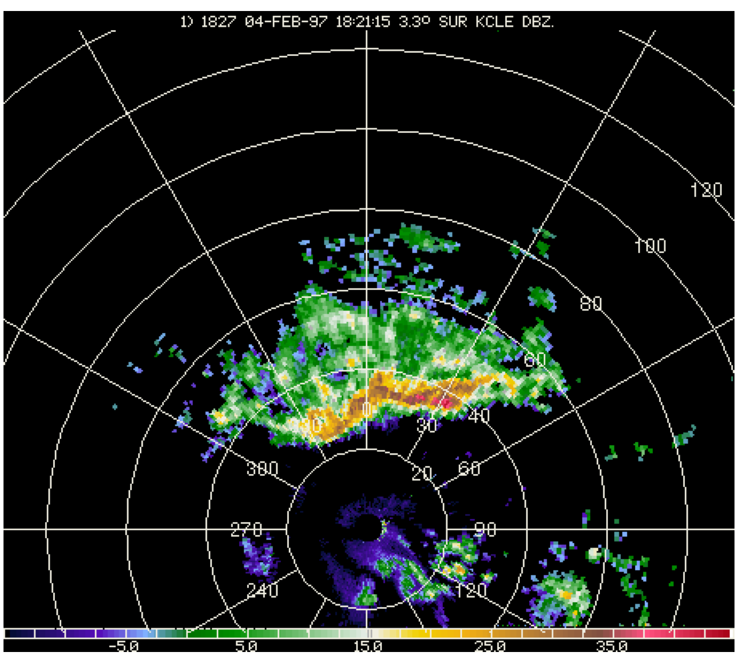
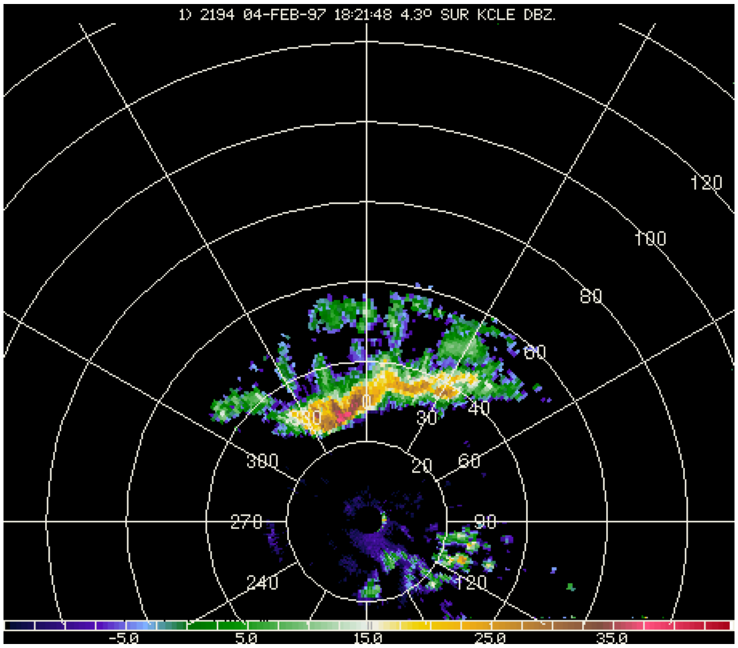


Figure 8 – Same, but for e) 1816 (6.0) and f) 1821 UTC (3.3).



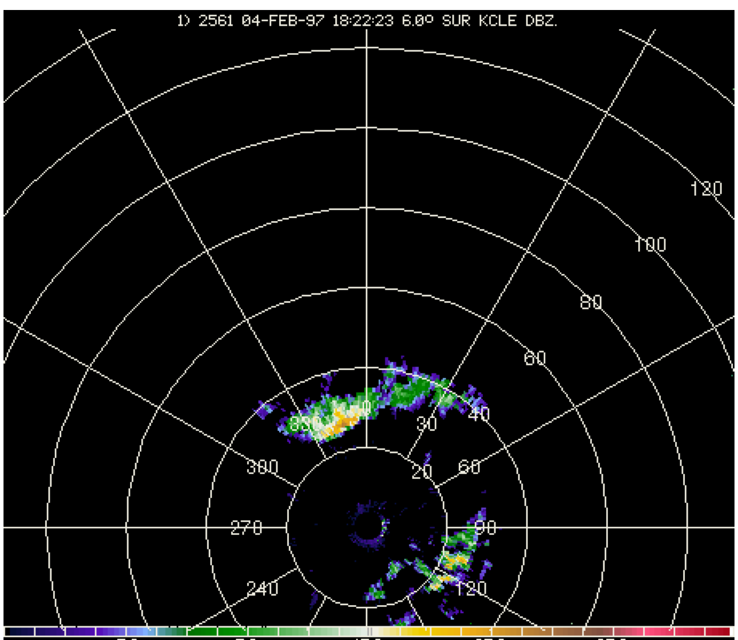
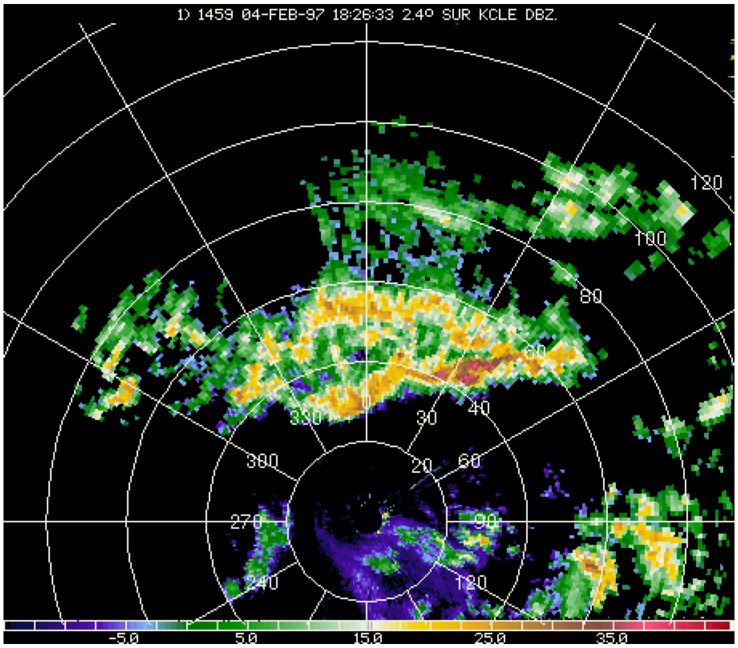


Figure 8 – Same, but for g) 1821 (4.3) and h) 1822 UTC (6.0).



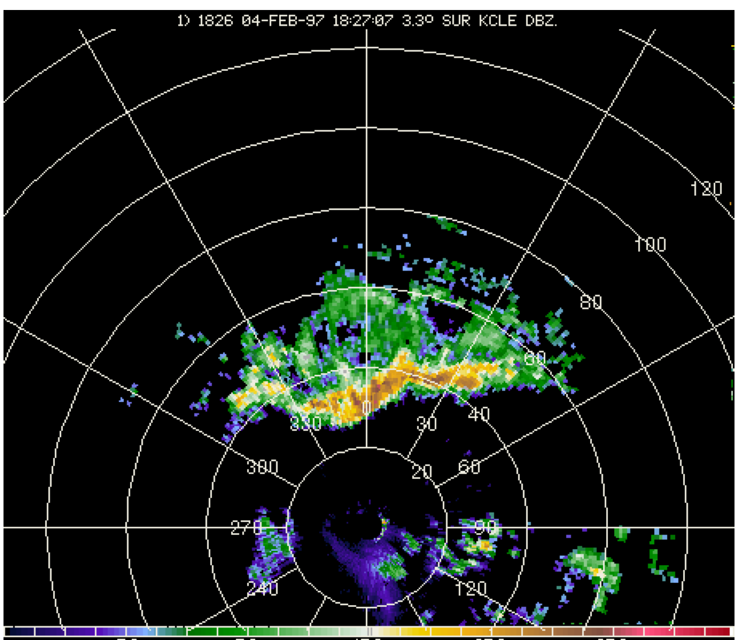


Figure 8 – Same, but for i) 1826 (2.4) and j) 1827 UTC (3.3).

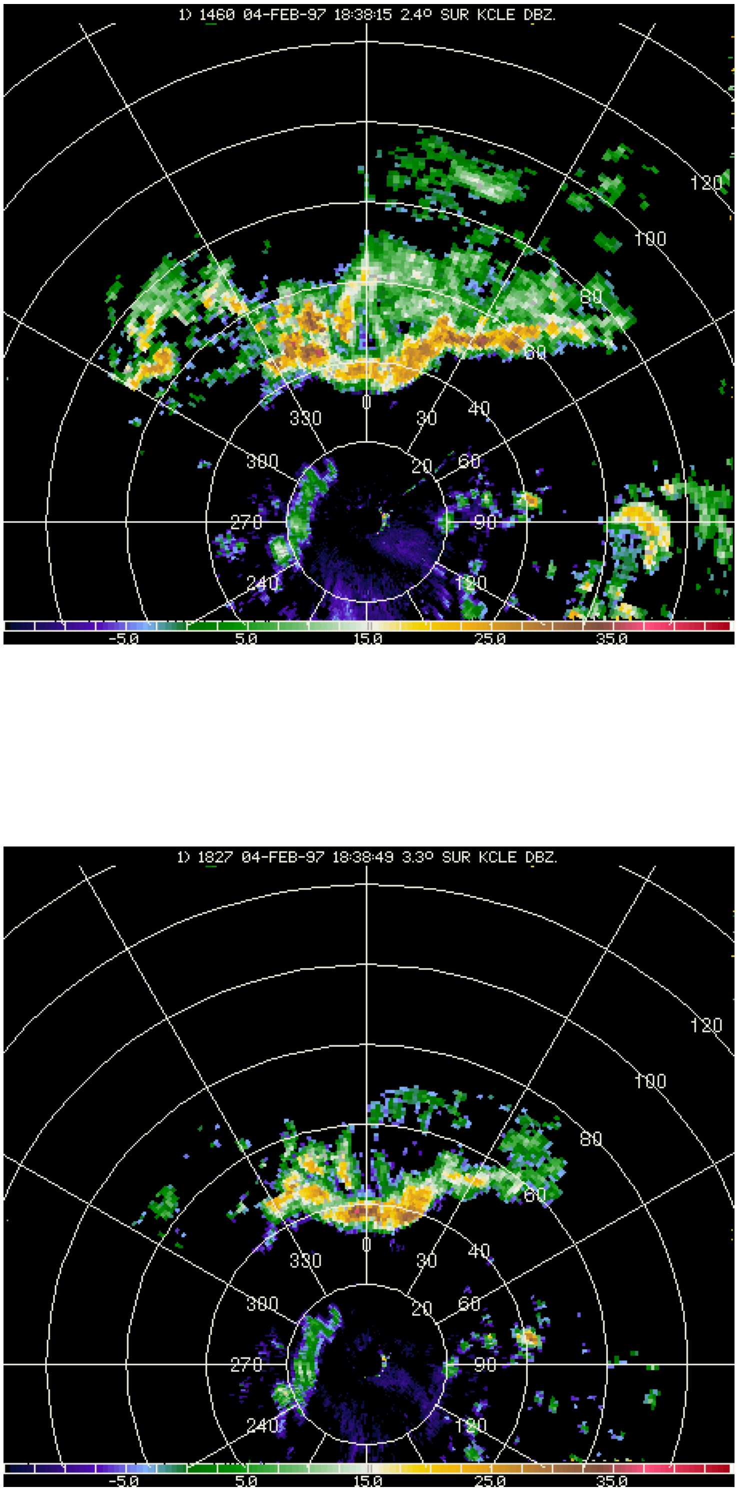
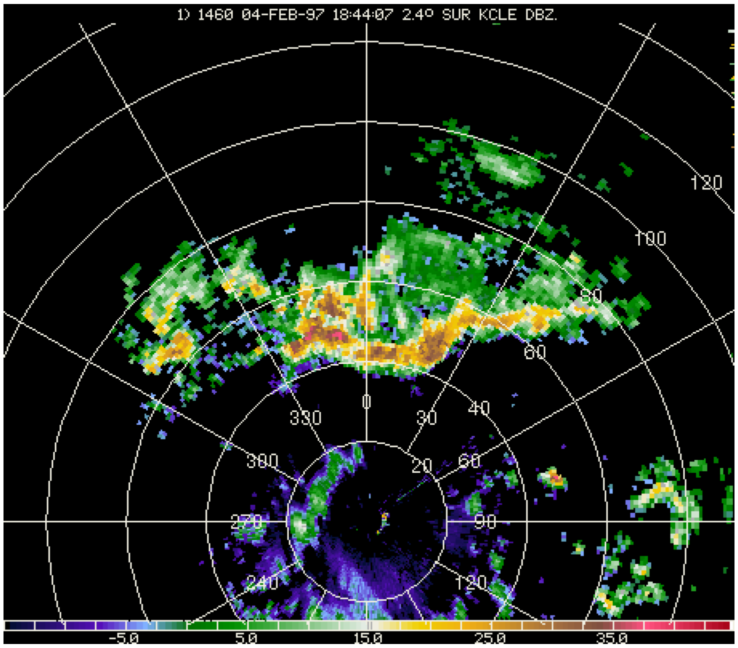


Figure 8 – Same, but for k) 1838 (2.4) and l) 1838 UTC (3.3).



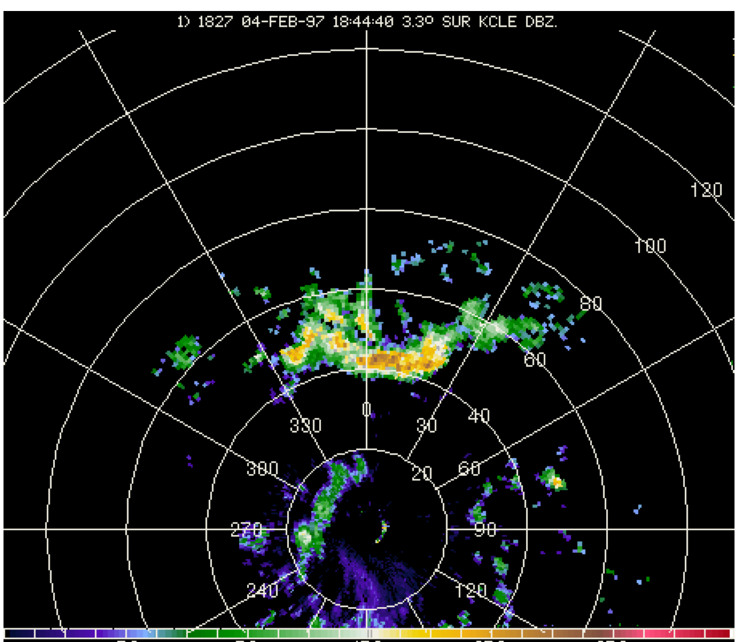
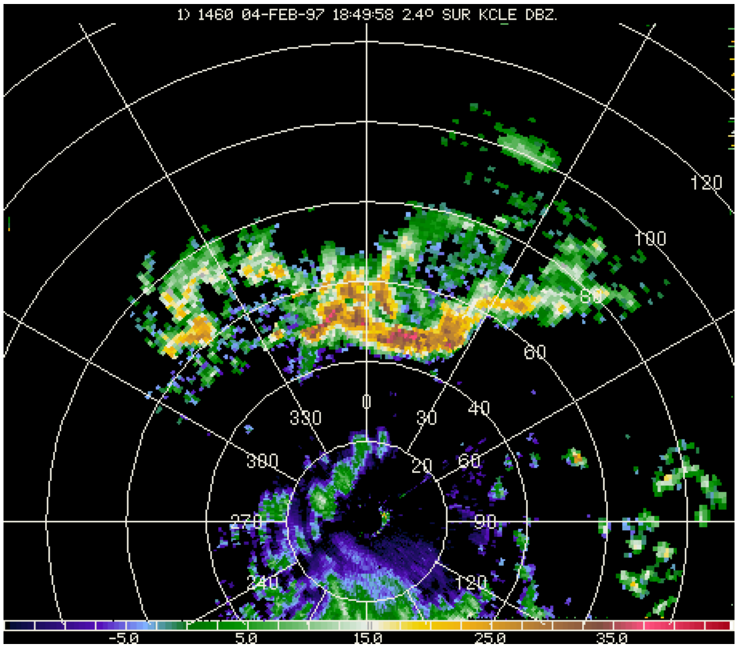


Figure 8 – Same, but for m) 1844 (2.4) and n) 1844 UTC (3.3).



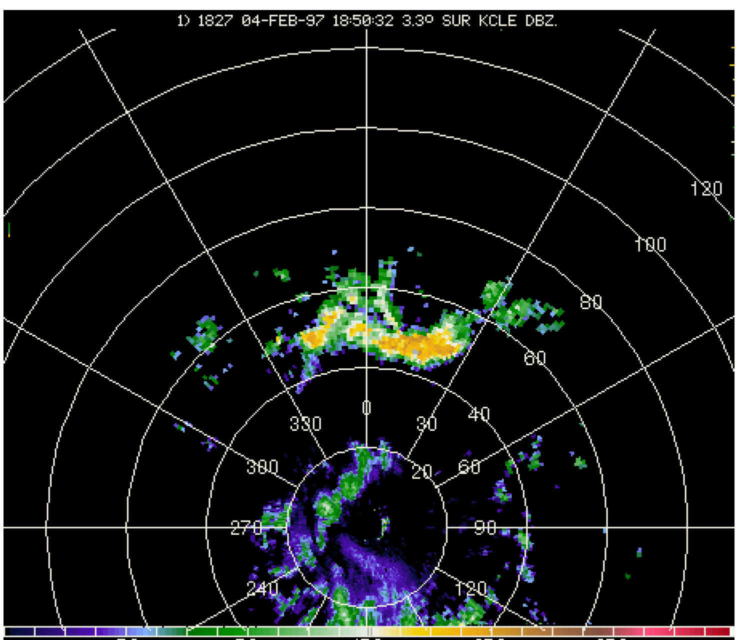
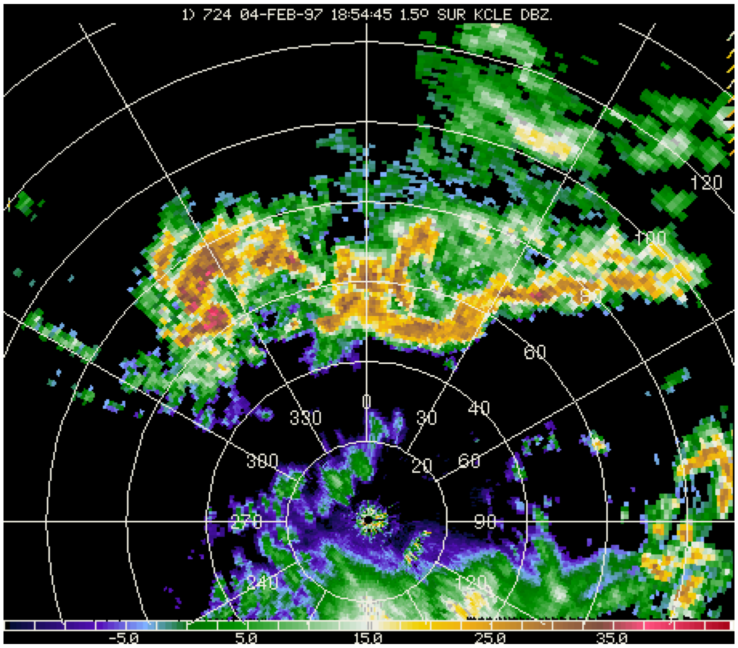


Figure 8 – Same, but for o) 1849 (2.4) and p) 1850 UTC (3.3).



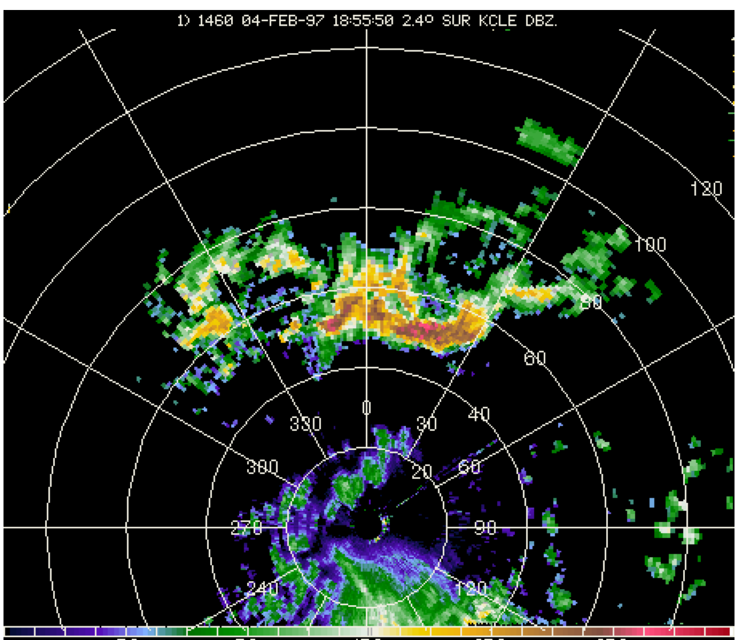
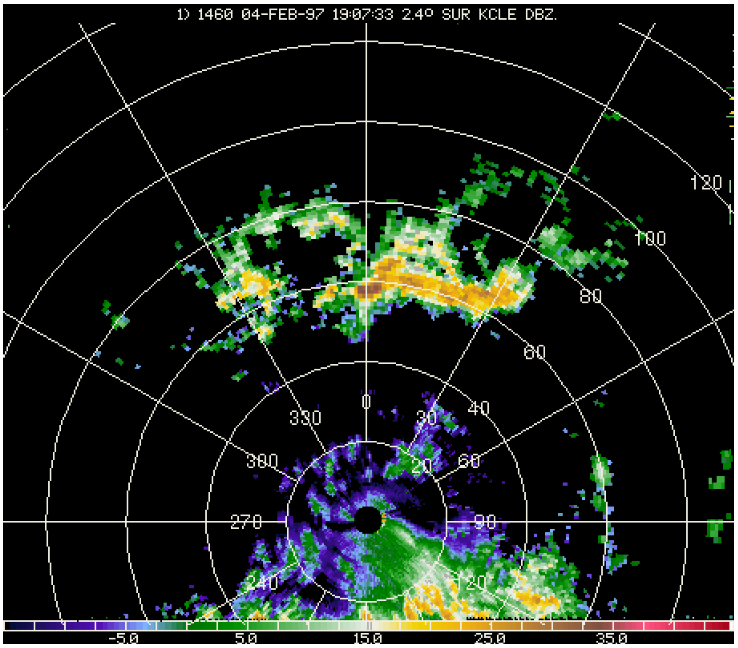


Figure 8 – Same, but for q) 1854 (1.5) and r) 1855 UTC (2.4).



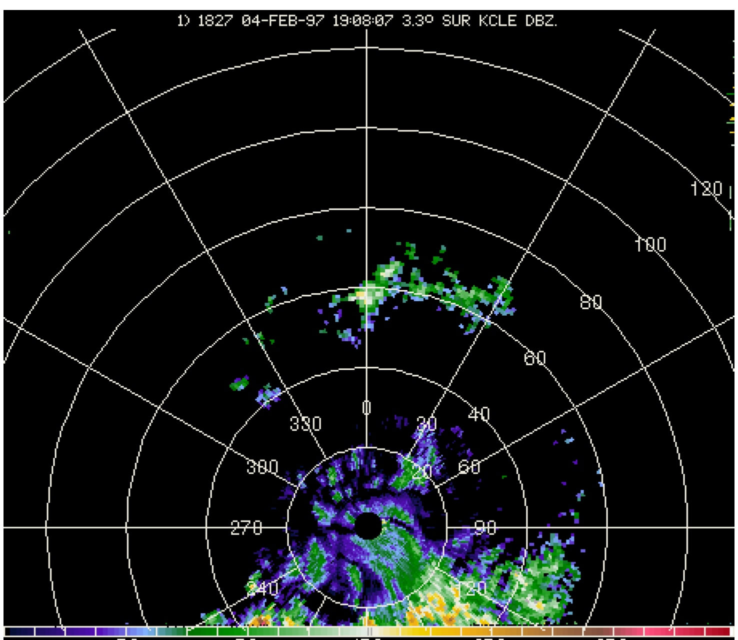
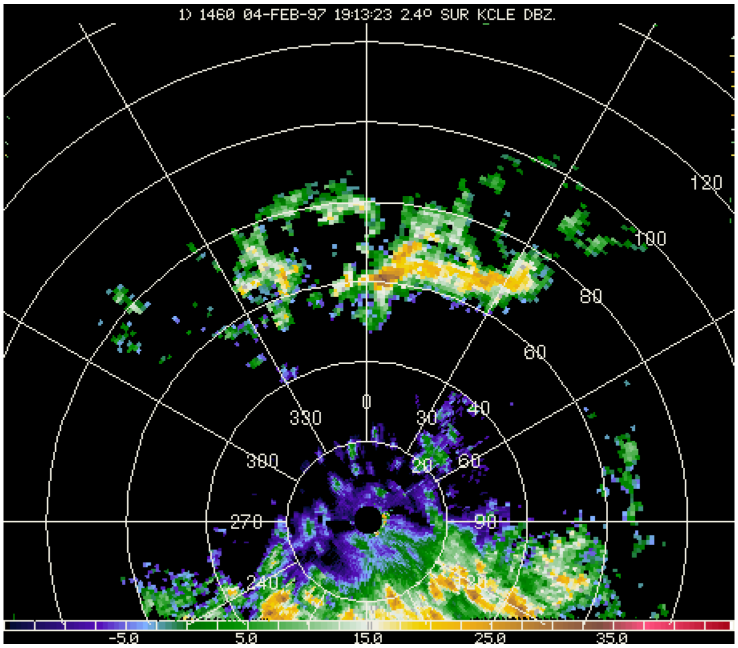


Figure 8 – Same, but for s) 1907 (2.4) and t) 1908 UTC (3.3).



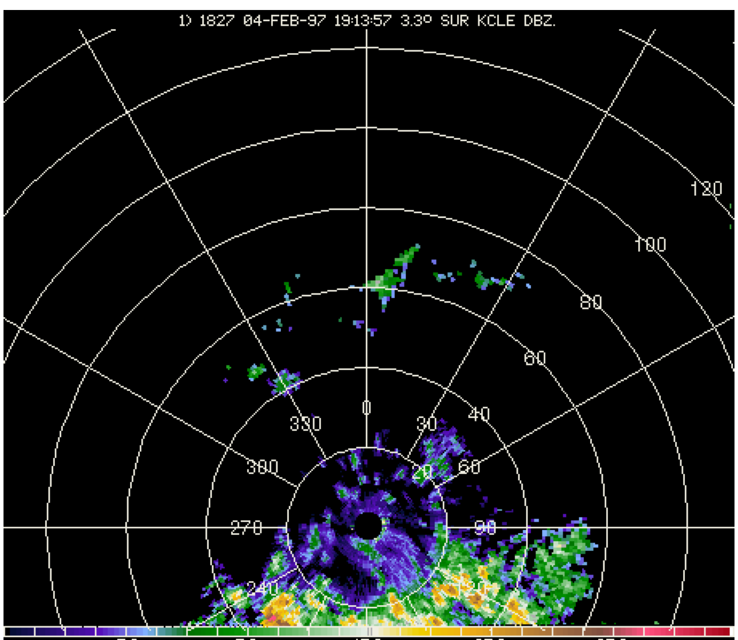
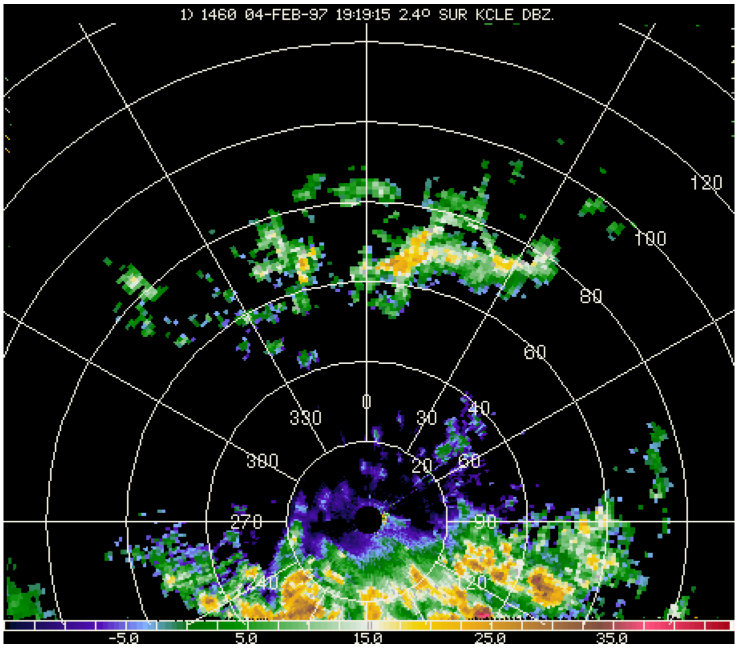


Figure 8 – Same, but for u) 1913 (2.4) and v) 1913 UTC (3.3).



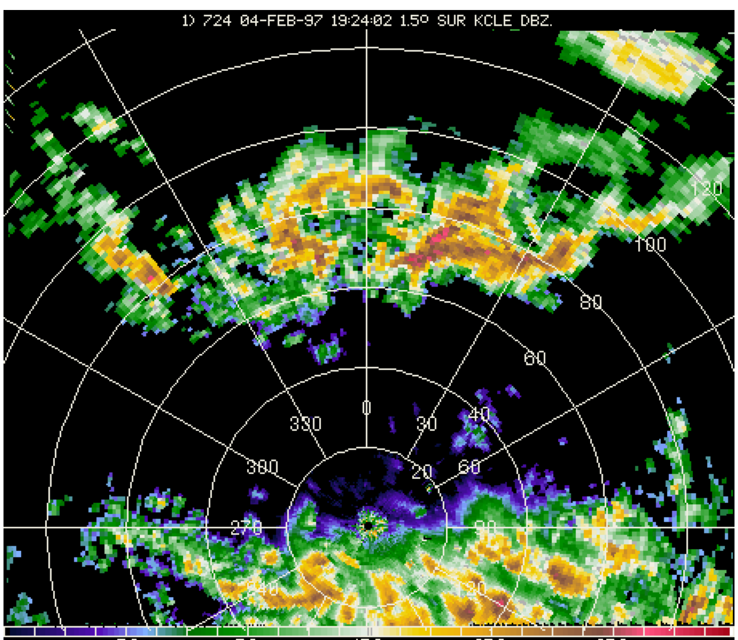


Figure 8 – Same, but for w) 1919 (2.4) and x) 1924 UTC (1.5).

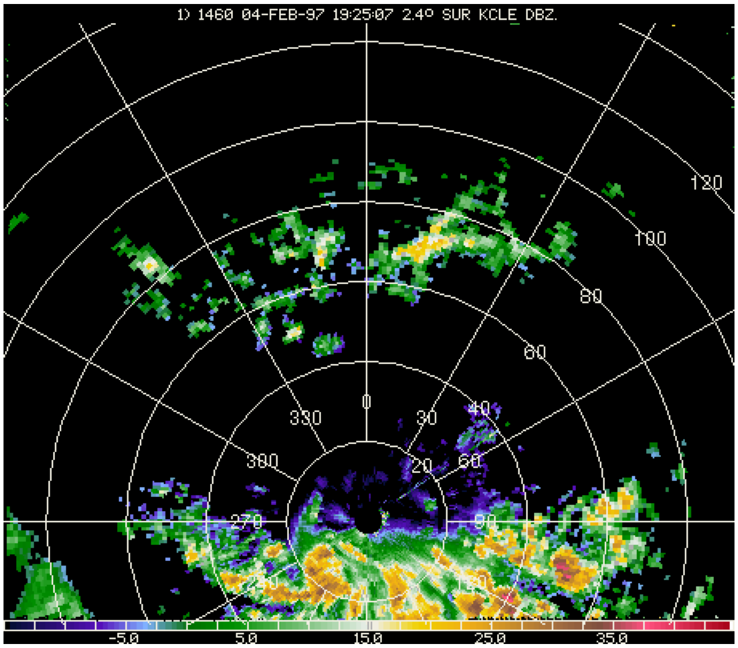


Figure 8 – Same, but for y) 1925 UTC (2.4).

Overview of Remaining Cases

This part of the document contains a basic analysis of the meteorology associated with the remaining icing encounters from the January-March 1997 NASA Twin Otter dataset. The purpose of this analysis is to provide a meteorlogical context for the aircraft data collected during these flights. For each case, the following data elements are presented:

1) A discussion of the Twin Otter encounter, including locations, liquid water contents, temperatures and microphysical makeup of the clouds and precipitation aloft,
2) Upper-air charts, providing hand-analyzed locations of lows, troughs, ridges, saturated/unsaturated air, temperatures, warm/cold advection, and jet streams,
3) Balloon-borne soundings, providing vertical profiles of temperature, moisture and winds,
4) Infrared and visible satellite data, providing cloud locations and cloud top temperature,
5) 3-hourly surface charts, providing hand-analyzed locations of lows, highs, fronts, precipitation (including type) and cloud cover,
6) Hourly, regional radar mosaics, providing fine resolution of the locations of precipitation (including intensity and type), pilot reports of icing (including intensity and type), surface observations of precipitation type and Twin Otter tracks for a one hour window centered on the time of the radar data, and
7) Hourly plots of icing pilot reports, providing the icing intensity, icing type, icing altitudes and aircraft type.

Outages occurred in nearly every dataset at some point. All relevant data that was available is presented here. All times are in UTC and all heights are in feet above mean sea level (MSL).

Cases included

970115, 970122, 970123, 970127, 970131, 970204, 970205, 970306, 970311, 970314, 970320, 970325

Description of plots in this document

The following pages provide a complete description of the attributes of the plots which accompany each case, including the data elements covered and how they have been represented.

Upper-air charts

Analyses are made at 300, 500, 700 and 850 mb. On all charts, trough axes are indicated as yellow lines, and areas of saturated/near-saturated conditions are shaded green. Saturated/near-saturated conditions are those where the dew-point depression (temperature minus the dew point; DDP) is < 8 C at 300 mb and < 5 C at 500, 700 and 850 mb. Contours of constant geopotential height (MSL) are indicated as solid black lines, while contours of constant temperature are indicated as dashed black lines.

On 300 mb charts, jet stream winds are indicated as follows: > 150 knots in purple, > 110 knots in red, > 90 knots in red-hatching.

On 500, 700 and 850 mb charts, dry areas (DDP > 10 C) are shaded orange, isotherms (lines of constant temperature) are brown, areas of warm and cold temperature advection (the wind is bringing in warmer or colder air, respectively) are indicated with red and blue arrows, respectively. The arrows indicate the direction of the warm or cold advection.

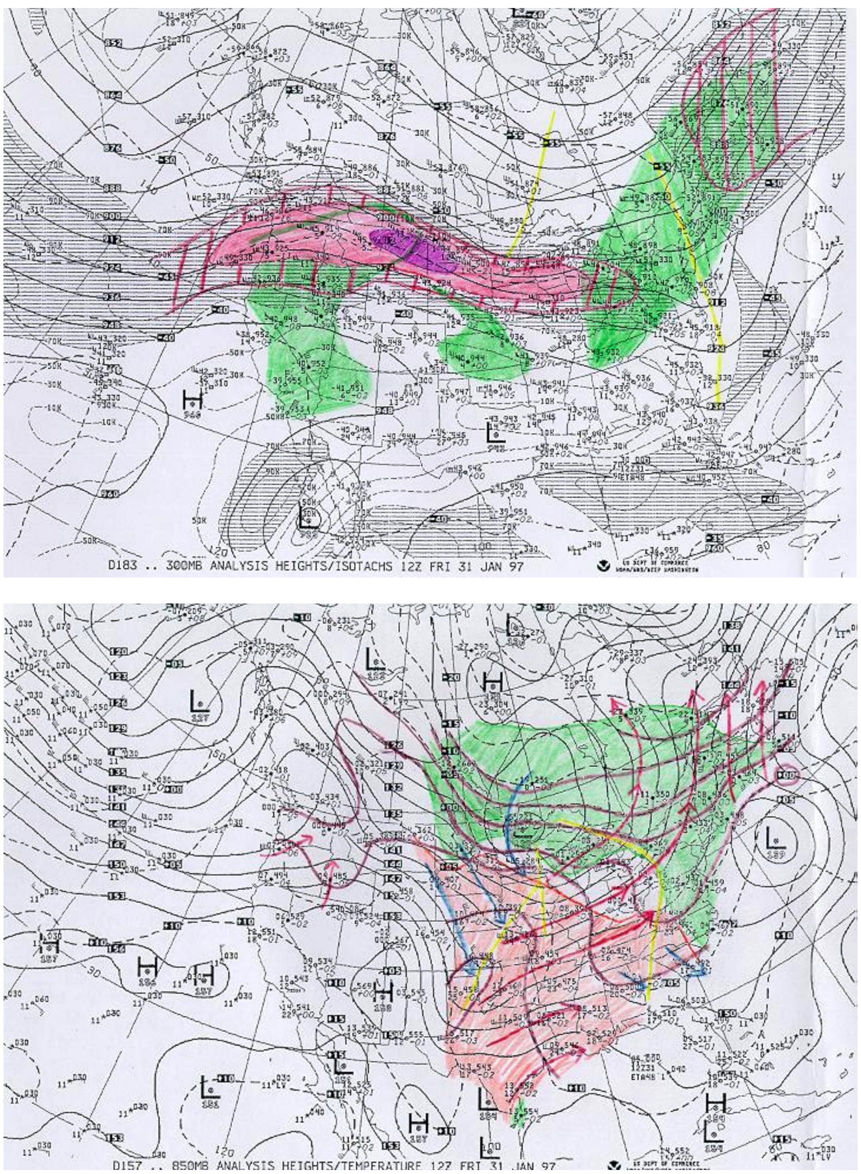


Figure 1 – Example upper-air charts at 300 and 850 mb.

Balloon-borne soundings

On sounding charts, profiles of temperature, dew point and winds are plotted. Solid lines of constant temperature are skewed, run from the lower left to the upper right, and are given every 10 C. Altitude is indicated on the left side of the chart in kilometers. Wind barbs are given on the right hand side of the chart, where a half-barb indicates 5 knots, a full barb indicates 10 knots and a flag indicates 50 knots of wind speed. The wind barbs indicate the direction that the wind is from.

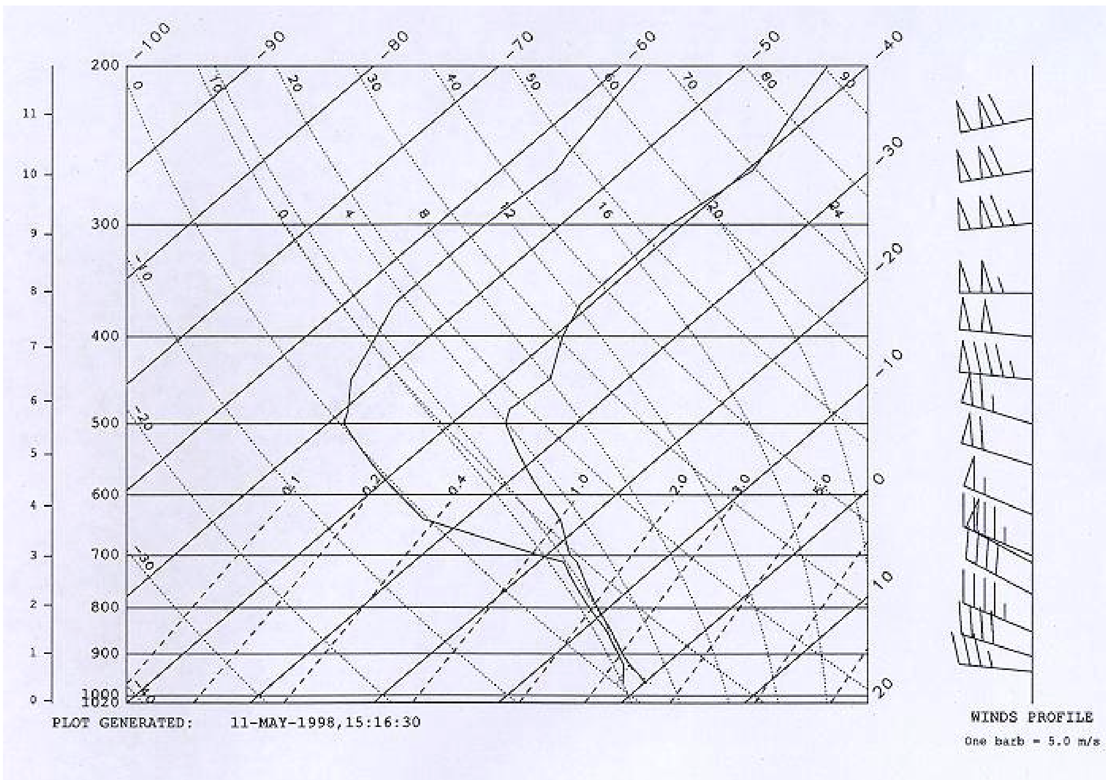
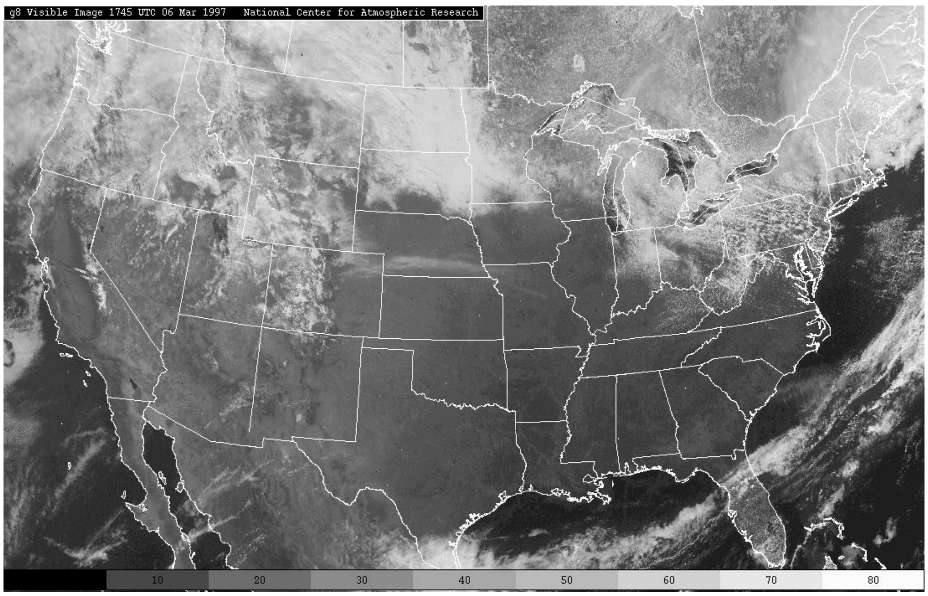


Figure 2 – Example of balloon-borne sounding data.

Satellite imagery

On visible satellite images, clouds and snow cover show up as white/bright areas, while ground and water typically show up as black/dark areas. On infrared satellite images, the temperature of the cloud top, ground or water are indicated. Temperature ranges for each color on infrared imagery are given at the bottom of each image. Each color represents a 5 C range of temperature values (e.g. –12.5 to –7.5 C), and the number (e.g. –10) represents the central temperature value for that color.



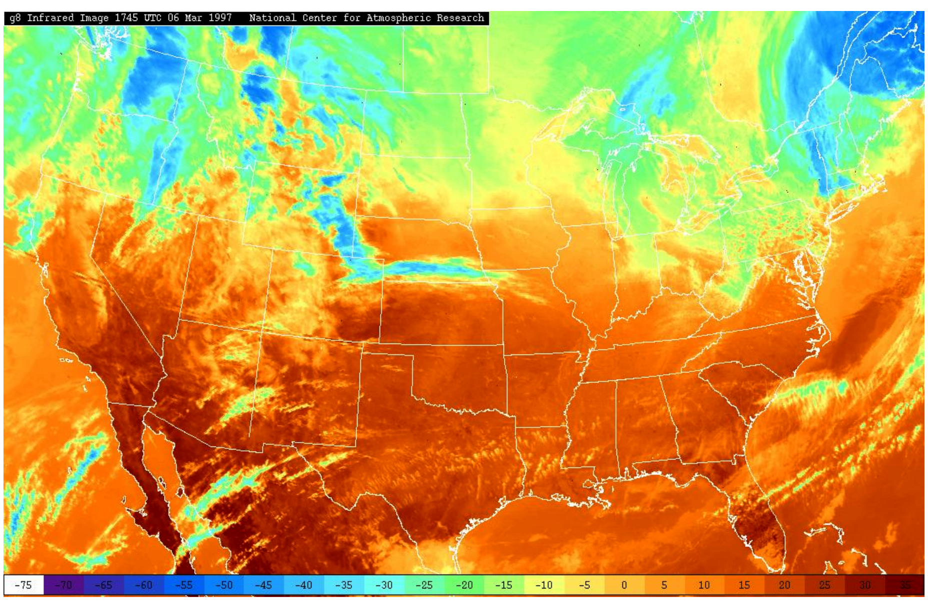


Figure 3 – Example visible and infrared satellite images.

Surface charts

On surface charts, high pressure centers are indicated with an ‘H’, low pressure centers are indicated with an ‘L’, and contours of constant pressure are indicated with solid black lines. Fronts are indicated as heavy black lines with: cold fronts - pointed barbs, warm fronts - rounded barbs, stationary fronts - pointed barbs on one side and rounded barbs on the other, and occluded fronts - pointed and rounded barbs on the same side. Trough axes are indicated with dashed lines. Precipitation areas are shaded as follows: rain/drizzle – green, snow – blue, freezing precipitation (ZL, ZR, IP) – red.

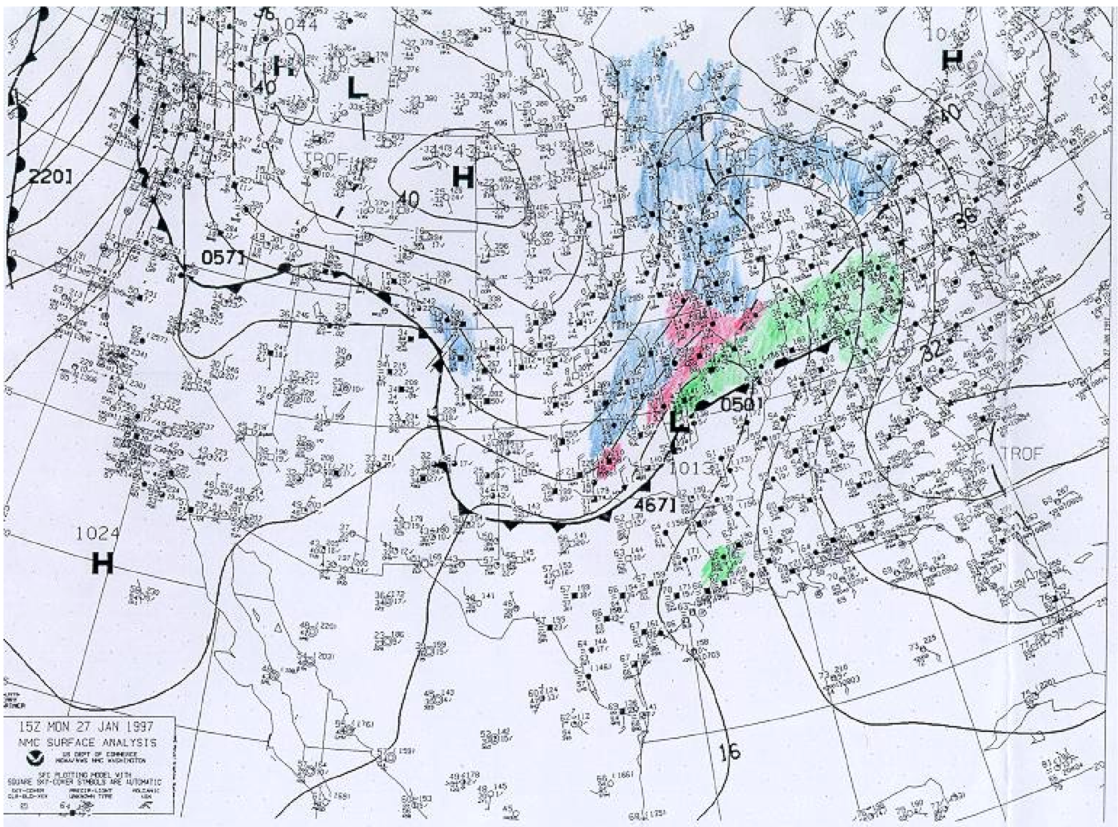


Figure 4 – Example surface chart.

Radar mosaic charts

On regional radar mosaic charts, locations of precipitation with radar reflectivity values of at least VIP 1 (>18 dBZ) are given. The precipitation is color-coded by precipitation type (freezing precipitation (ZL, ZR, IP) - red and magenta, rain - green and yellow, snow - blue) and intensity (VIP level 1-6). A color bar indicating precipitation type and intensity can be found at the bottom of each chart. Pilot reports of icing are indicated as follows:

ICING TYPES –

R=rime, C=clear/glaze, X=mixed, U=unknown

ICING INTENSITIES –

small font = trace, trace-light or light

medium font = light-moderate or moderate

large font = moderate-severe or severe

NASA Twin Otter tracks are plotted for a one-hour time window centered on the valid time of the chart. A '+' is plotted at the aircraft's location every 2 minutes, and an 'x' is plotted at the aircraft's location every 10 minutes.

Precipitation type reported by surface stations is also plotted in yellow. The symbols for the precipitation type are given at the bottom-right portion of the chart.

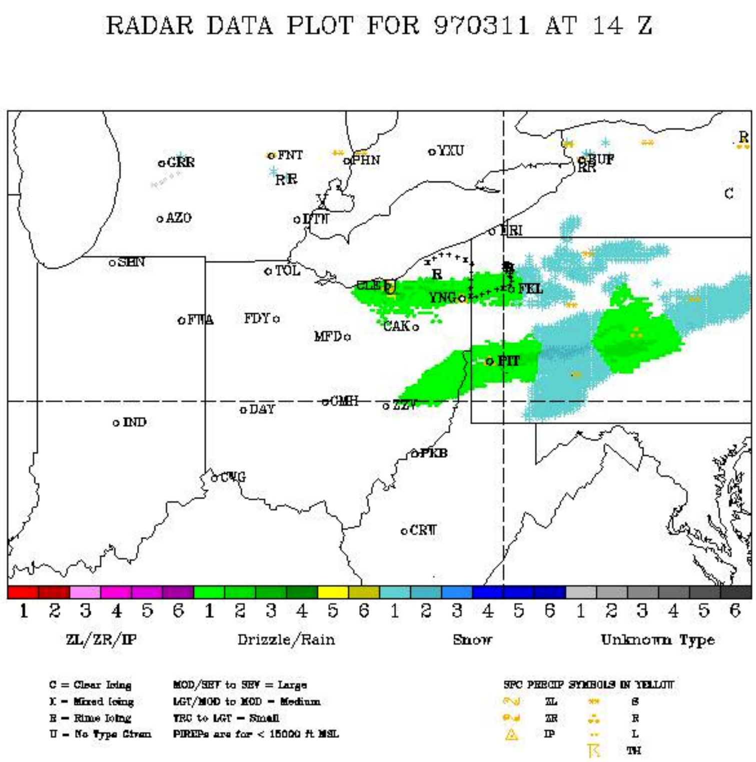


Figure 5 – Example regional radar mosaic chart.

Pilot reports of icing

Pilot reports (PIREPs) of icing are given for a one hour time window which is indicated at the top of the chart. Icing PIREP indicators are given at the bottom of the chart. The size and color of the PIREP indicates its intensity, while the letter plotted indicates its type (R=rime, C=clear/glaze, X=mixed, U=unknown). The aircraft type is plotted just up and to the right of the R, C, X or U, and the base and top of the reported icing altitudes are given just below the aircraft type (100's of feet MSL).

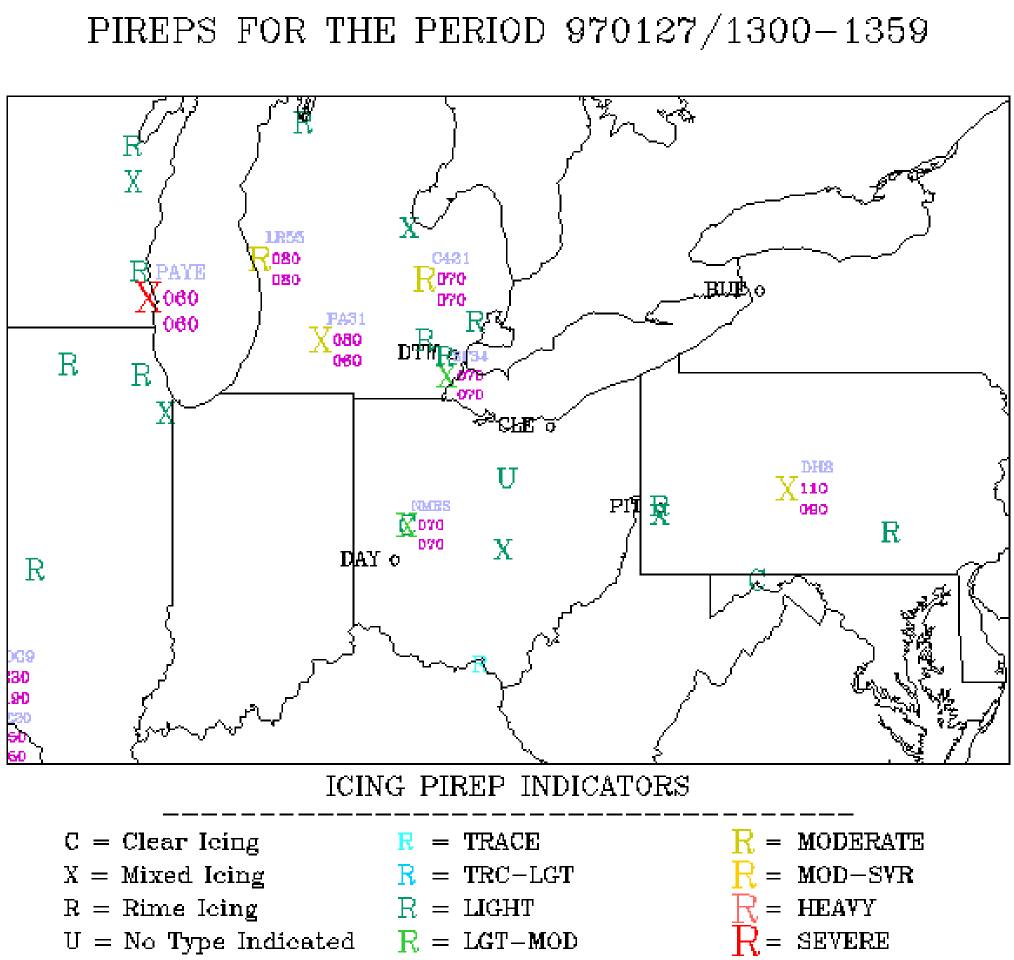
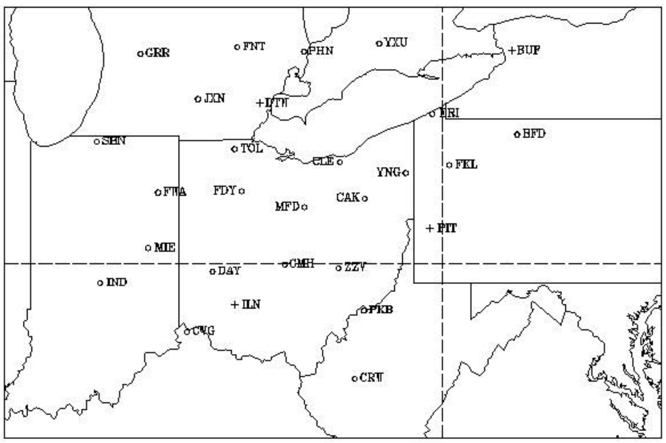


Figure 6 – Example plot of icing pilot reports.

Station locations

A map of commonly referenced station locations, as well as the matching 3-letter codes is given below. This map covers what is referred to in the document as the "forecast area."

STATION LOCATIONS



CODE	STATION NAME
CLE	Cleveland, Ohio
YNG	Youngstown, Ohio
CAK	Canton-Akron, Ohio
MFD	Mansfield, Ohio
TOL	Toledo, Ohio
FDY	Findlay, Ohio
DAY	Dayton, Ohio
CMH	Columbus, Ohio
ILN*	Wilmington, Ohio
ZZV	Zanesville, Ohio
CVG	Cincinnati, Ohio
IND	Indianapolis, Indiana
FWA	Fort Wayne, Indiana
MIE	Muncie, Indiana
SBN	South Bend, Indiana
GRR	Grand Rapids, Michigan
FNT	Flint, Michigan
JXN	Jackson, Michigan
PHN	Selfridge AFB, Michigan
DTW*	Detroit, Michigan
YXU	London, Ontario
BUF*	Buffalo, New York
ERI	Erie, Pennsylvania
FKL	Franklin, Pennsylvania
PIT*	Pittsburgh, Pennsylvania
BFD	Bradford, Pennsylvania
PKB	Parkersburg, West Virginia
CRW	Charleston, West Virginia

* denotes a sounding site

January 15, 1997

Flight #2 – Over northeast Indiana and northern Ohio from 1652 to 1842 UTC.

Brief overview

Two flights were made on this day. An in depth analysis of the first flight can be found in the "premier cases" document. That flight was made into classical freezing rain and freezing drizzle conditions in the vicinity of Indianapolis. The second flight was made in similar conditions over Indianapolis, Muncie (IN), and Toledo as an area of freezing rain and drizzle moved northward along the Indiana-Ohio border, decreased in areal extent, and became both shallower and warmer. Conditions were marginal for ice accretion at and above minimum vectoring altitudes (approximately 2500 feet), since the temperature was warmer than –3 C there, the base of the warm nose was only 500 feet above, and it had temperatures greater than +5 C within it. This provided very little time for the rather warm rain and drizzle drops to supercool before being sampled by the Twin Otter. The majority of the second flight was made within this very warm mixture of freezing rain and freezing drizzle near 2500 feet, but the warm nose and upper sub-freezing layer (above the warm nose, height greater than 6000 feet) were also sampled. As expected, rain and drizzle dominated the warm nose, while aggregates and a mixture of crystals were found in the sub-freezing layer above. Very little liquid water content was observed during the flight, with maximum values of 0.1. Most, if not all, of the freezing rain and freezing drizzle occurred below cloud base. Most of this flight took place within or along the northern edge of a SW-NE oriented swath of reflectivity running across the southern half of Indiana and the northwestern third of Ohio.

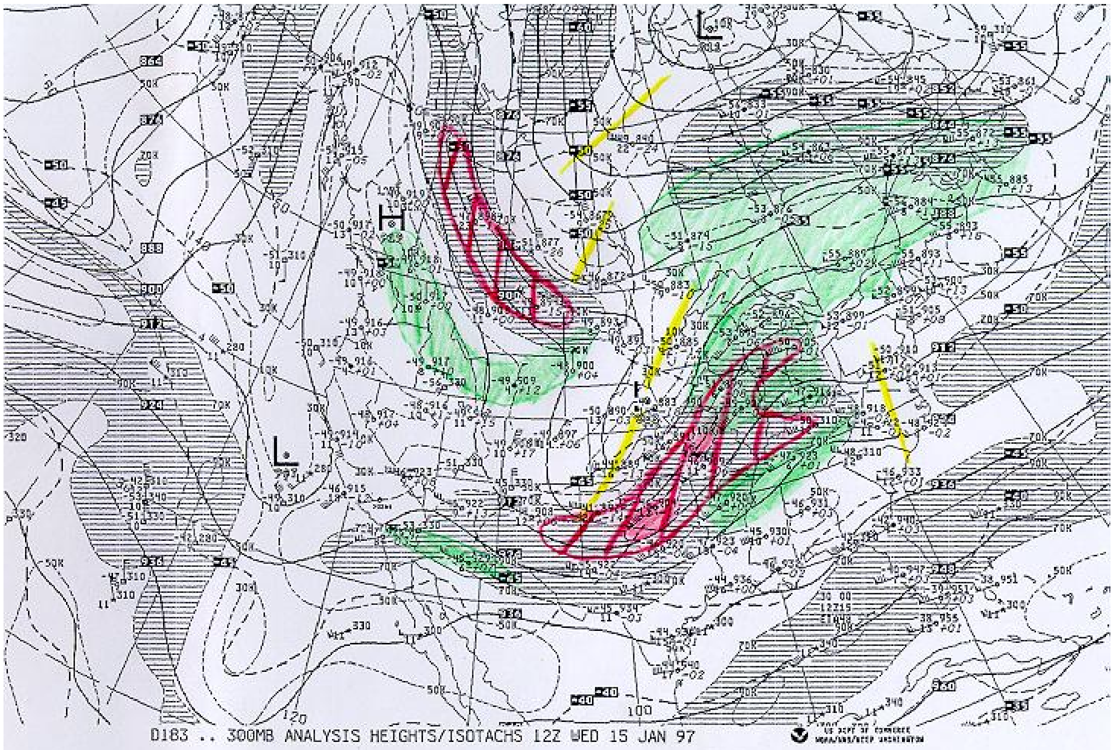
Relevant weather features

At 1200 UTC, a north-south oriented trough extended from the North Dakota/Minnesota border to the Texas Panhandle at 500 mb (Fig. 1). Ahead of the trough, a ribbon of moisture was present from Oklahoma to Lake Michigan, then widened to cover all of the Great Lakes. The moisture covered the northwestern half of Indiana, while dry air was present to southeast. At 700 mb, moisture was more widespread ahead of the trough, covering the forecast area, except for eastern Ohio, southeast Ontario, New York, Pennsylvania, and West Virginia. Weak warm advection was present to the south and southwest of Indianapolis. At 850 mb, moisture was present to the west of the Ohio-Indiana border and good warm advection was present across the forecast area, while a weak trough axis was becoming evident across central Indiana.

Surface maps for 1200 UTC (Fig. 2) also indicate this weak trough/warm front across southern Illinois and southern Indiana, extending from a weak, 1008 mb low centered over Kansas and Oklahoma. A 1030 mb high was centered over the Virginia-North Carolina coast and was responsible for the cold, dry, low-level air in its wake across the forecast area. An area of freezing rain was present across northern Arkansas, southeast Missouri and southern Illinois, while snow was falling north of there. The freezing rain and snow moved northward into Indiana by 1500 UTC, with Indianapolis located just south of the transition between freezing rain and snow (colocated with the leading edge of the warm nose of above-freezing air aloft). By 1800 UTC, the transition zone was just south of the Indiana-Michigan and Ohio-Michigan borders, while patchy freezing rain was occurring across northern Indiana. Also, a weak, 1008 mb low developed in western Tennessee, and the trough axis across southern Indiana became a more well-defined warm front.

Satellite data from 1145 UTC (Fig. 3) indicates deep, cold cloud covering much of the forecast area to the west the Ohio-Indiana border, with some warmer cloud in eastern and southern Indiana and across Ohio. Deep cloud continued to consistently cover northern Indiana, but only intermittently cover southern and eastern Indiana between 1200 and 1900 UTC. These clouds are an indication that significant amounts of ice crystals and aggregates were developing aloft and falling toward the surface. Pockets of dry air, present at a variety of altitudes and locations eliminated this precipitation over some areas, and the radar mosaic roughly reflects where the precipitation was able to survive to the surface. Between 1300 and 1800 UTC, the radar data indicate that the precipitation area and classical freezing rain setup moved northeast across Indiana into Michigan and northwest Ohio (Fig. 4). The surface subfreezing layer weakened with time and fell apart over northwest Ohio and southeast Michigan, eliminating the freezing rain layer by 2100 UTC. The erosion of the surface subfreezing layer is quite evident in a Cleveland sounding taken at 2006 UTC by the NCAR CLASS van (Fig. 5).

PIREPS of icing (Fig. 6) up to moderate intensity were found both at low altitudes (in the freezing rain layer – 0 to 3000 feet) and in the upper sub-freezing layer (above the warm nose – 6000 to 15000 feet).



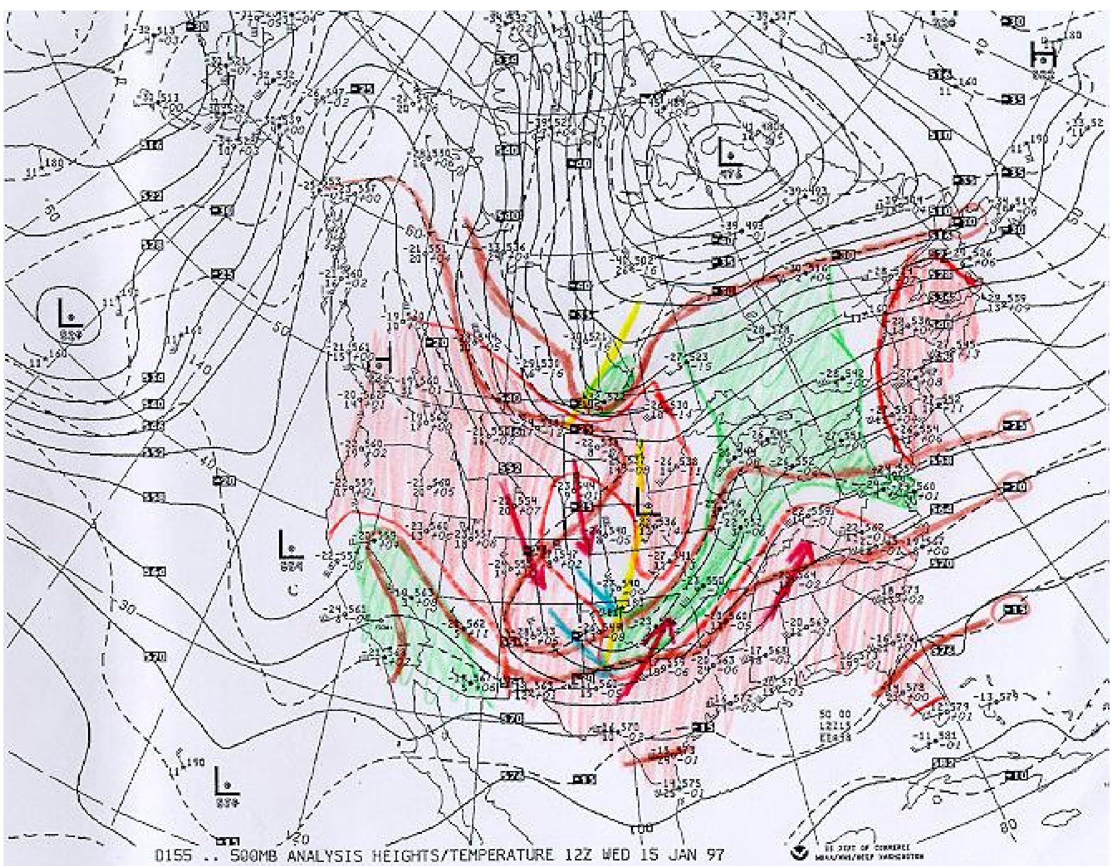


Figure 1 – Upper-air charts for 970115, 1200 UTC at a) 300 and b) 500 mb.

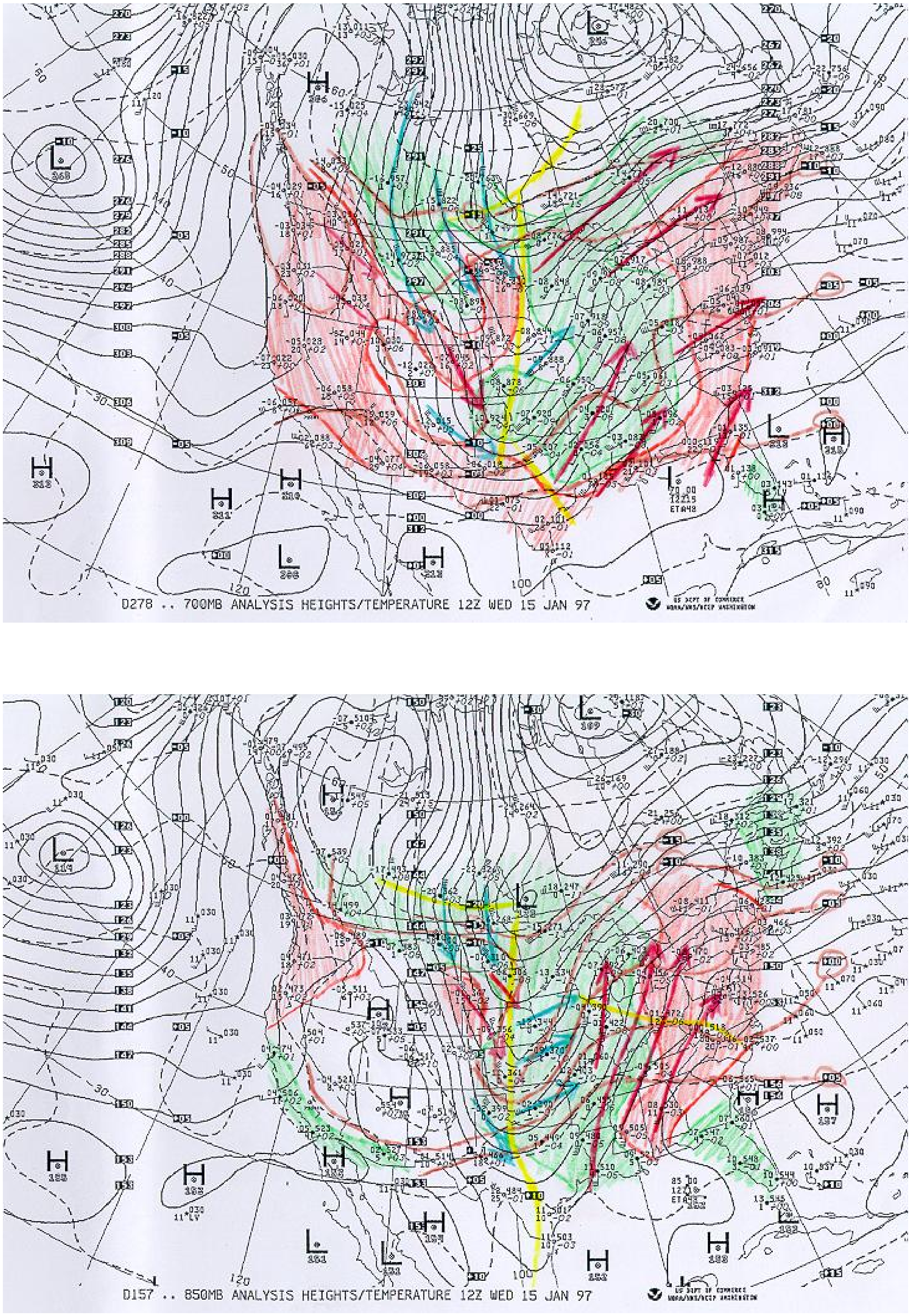


Figure 1 – Upper-air charts for 970115, 1200 UTC at c) 700 and d) 850 mb.

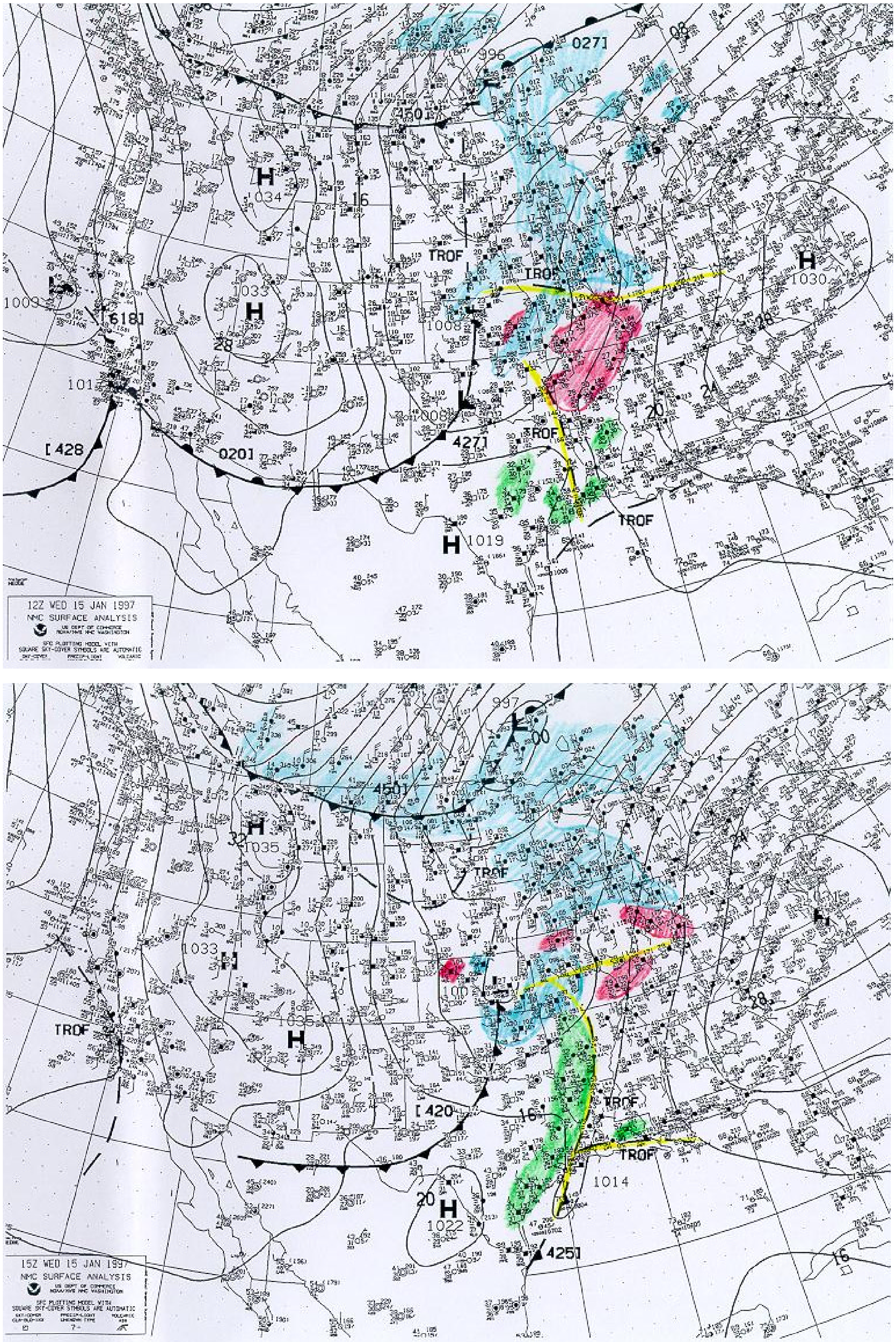


Figure 2 – Surface charts for 970115, a) 1200 and b) 1500 UTC.

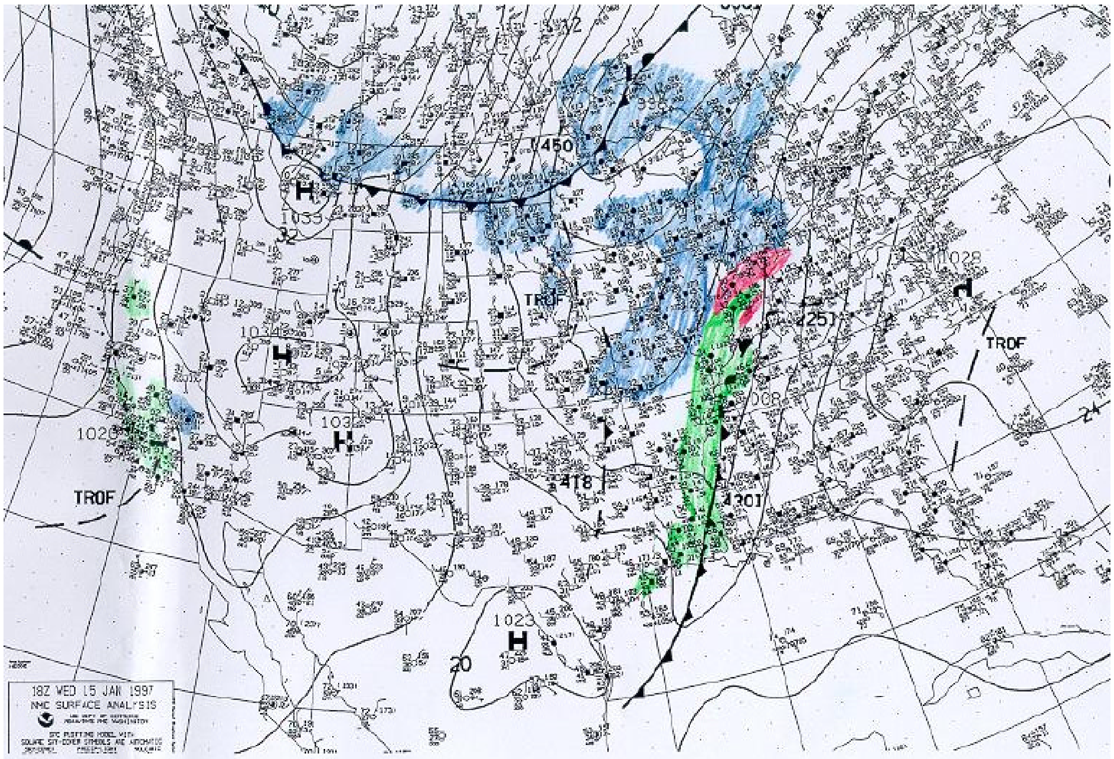


Figure 2 – Surface chart for 970115, c) 1800 UTC.

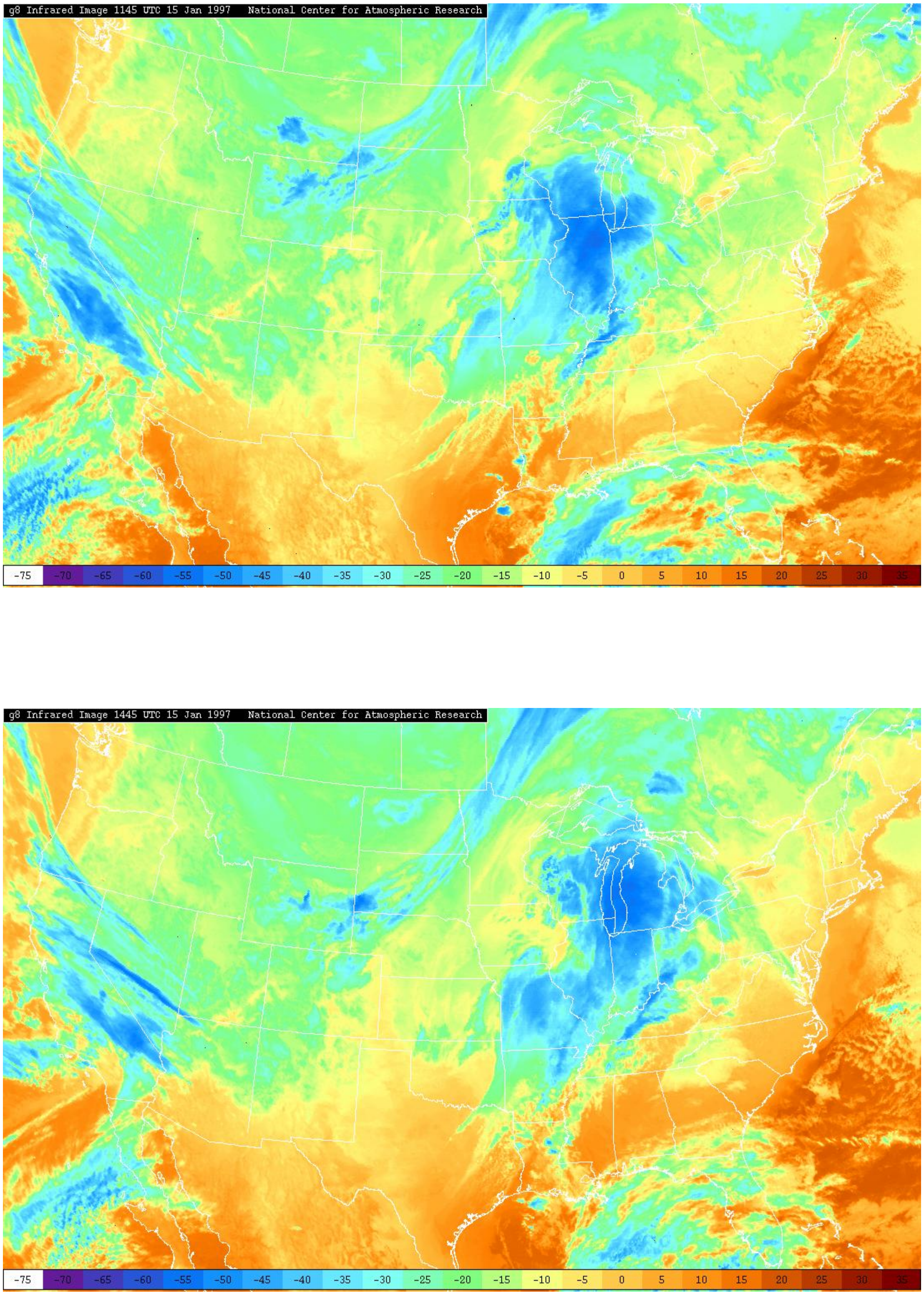
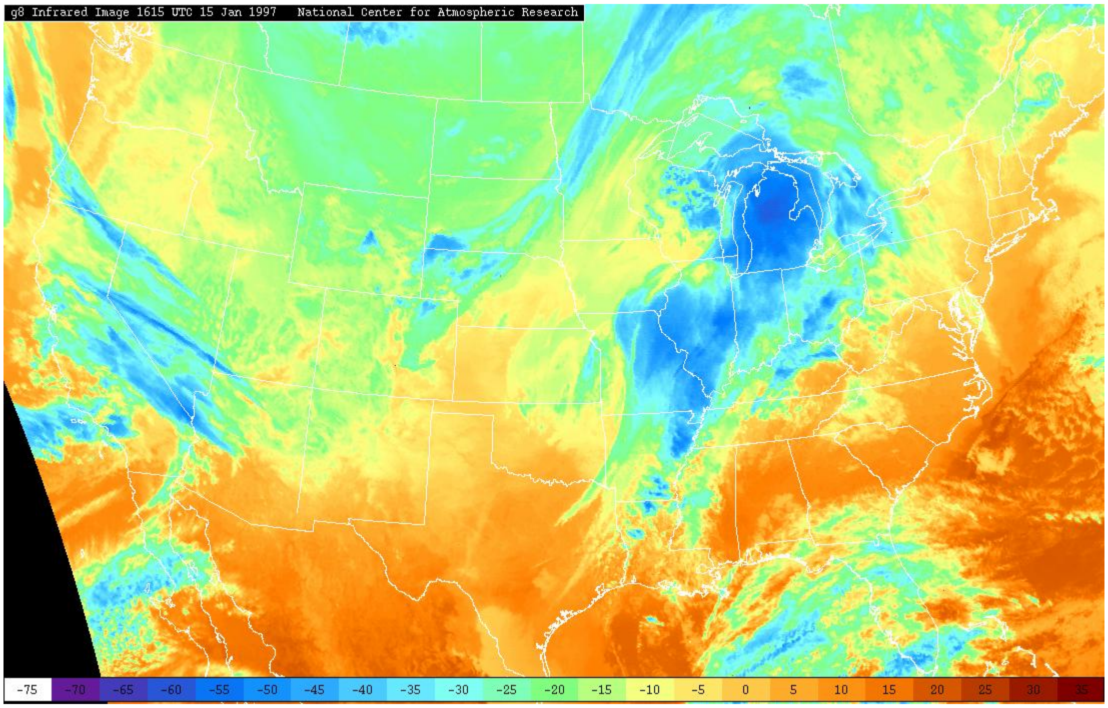


Figure 3 – Infrared satellite imagery for 970115, a) 1145 and b) 1445 UTC.



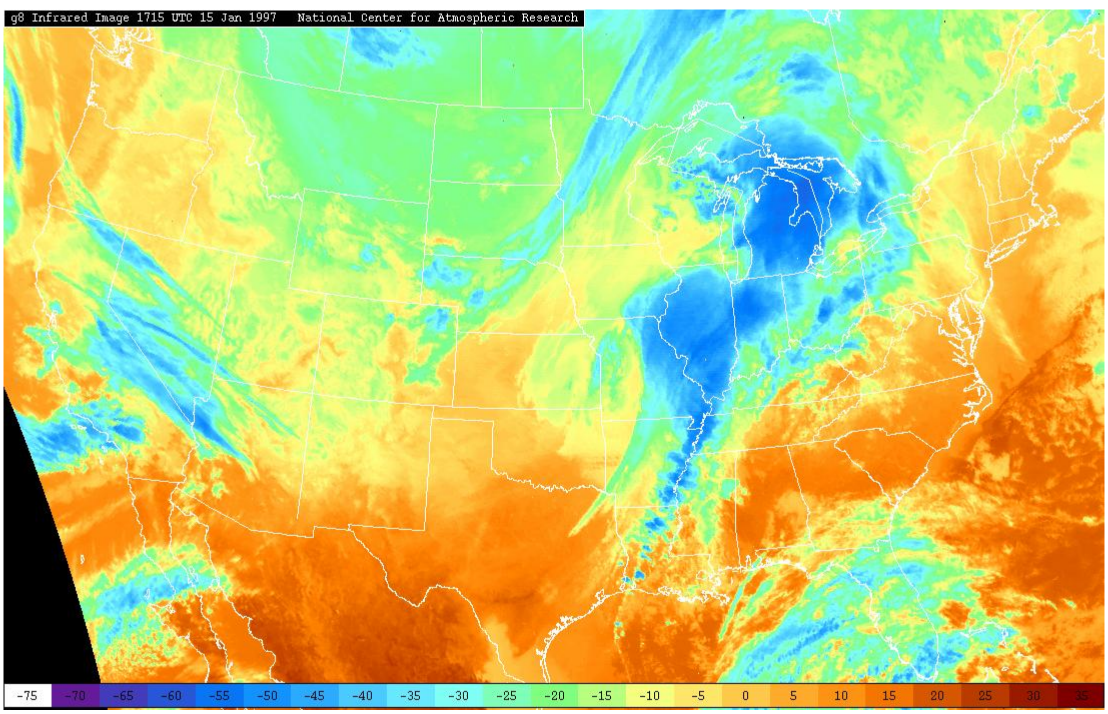
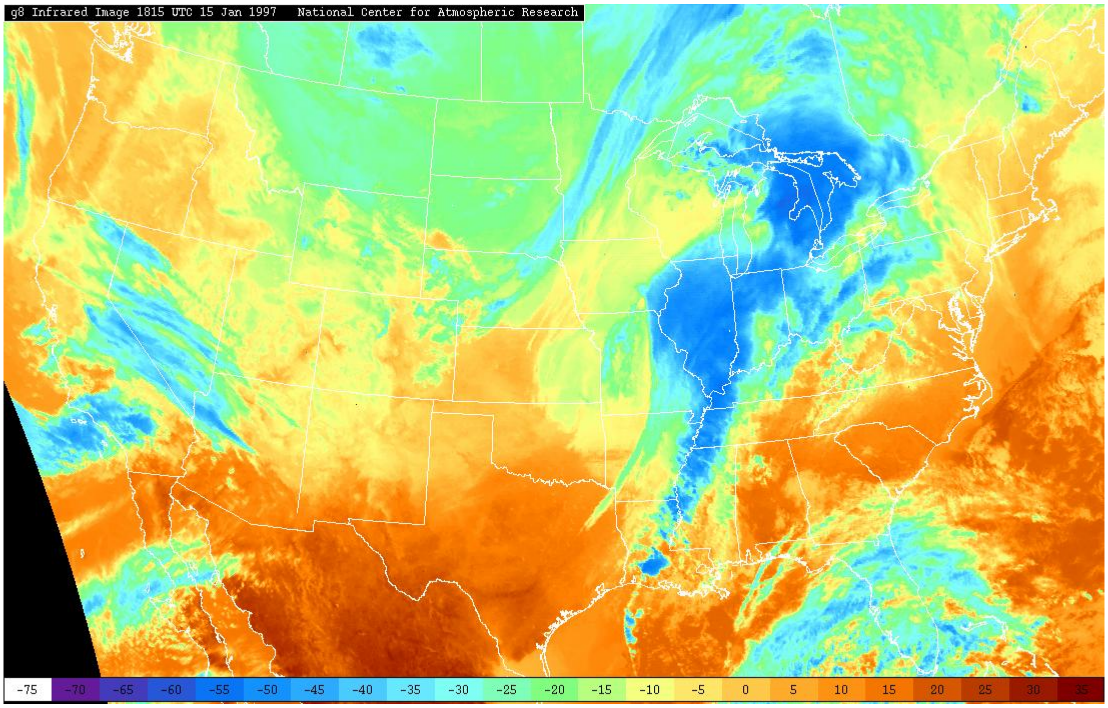


Figure 3 – Infrared satellite imagery for 970115, c) 1615 and d) 1715 UTC.



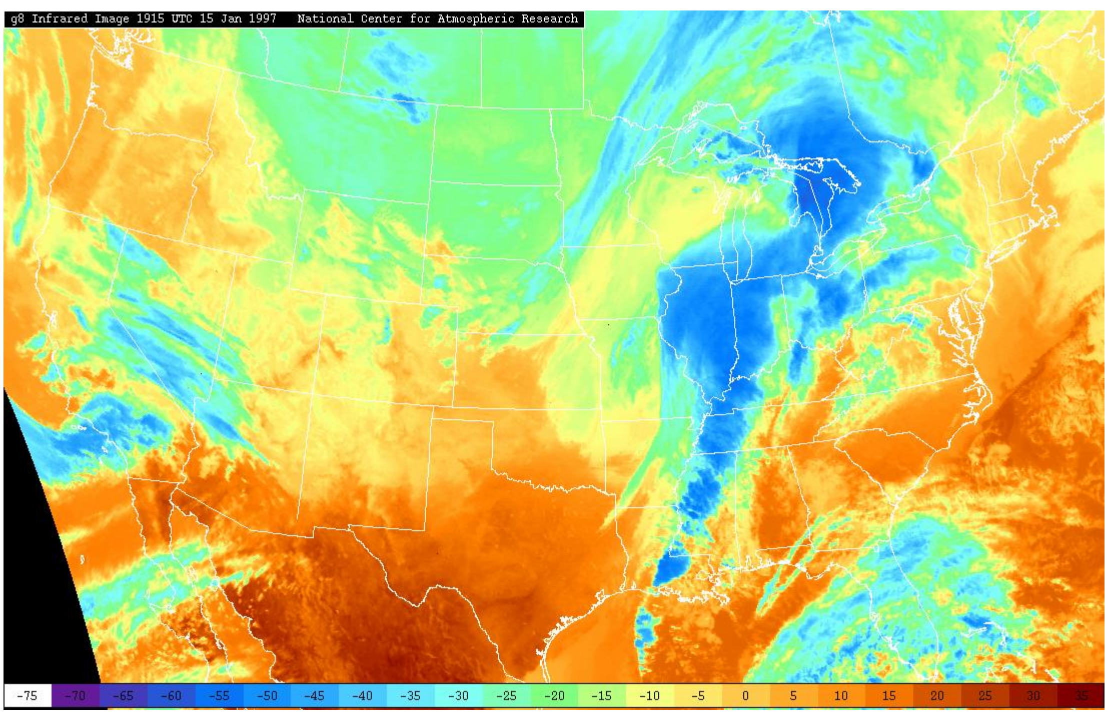
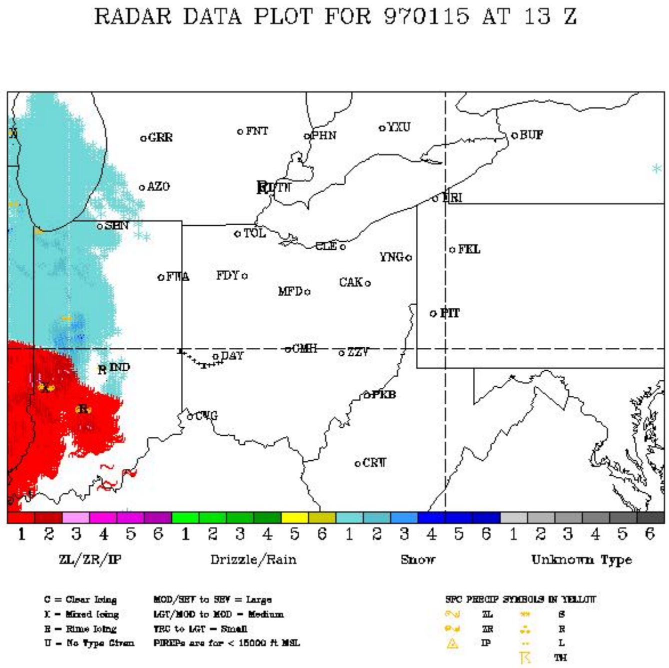


Figure 3 – Infrared satellite imagery for 970115, e) 1815 and f) 1915 UTC.



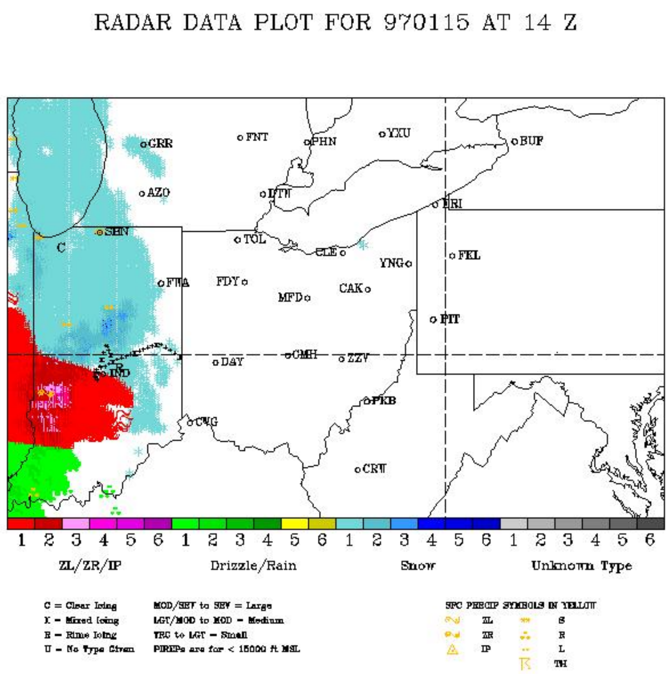
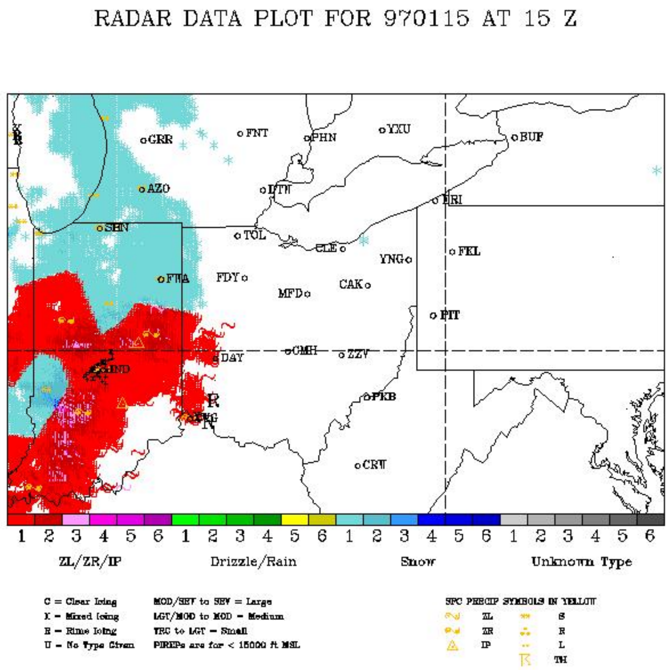


Figure 4 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970115, a) 1300 and b) 1400 UTC.



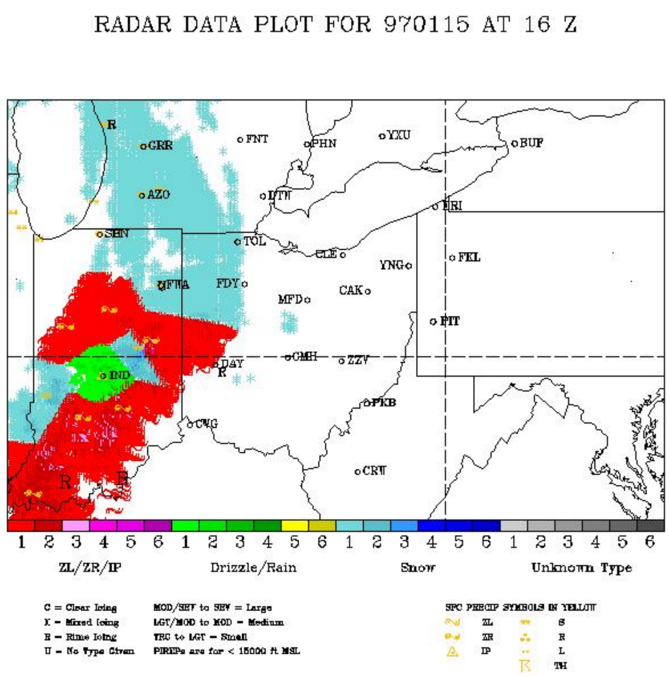
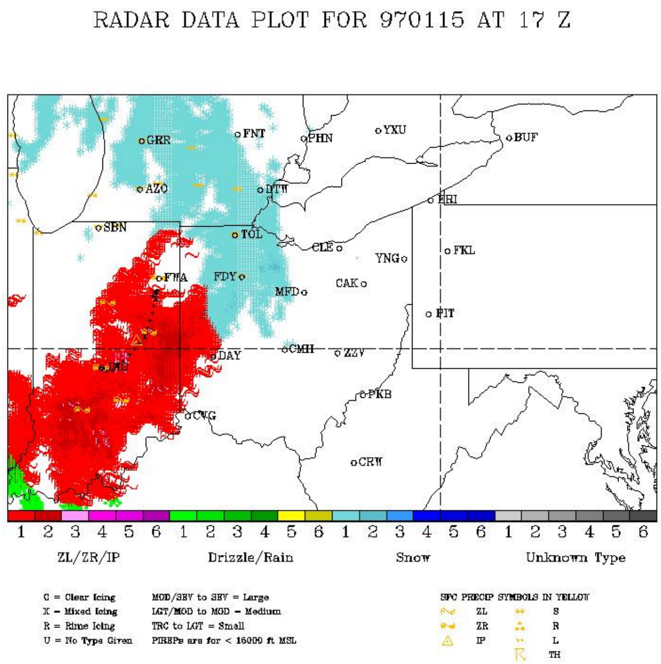


Figure 4 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970115, c) 1500 and d) 1600 UTC.



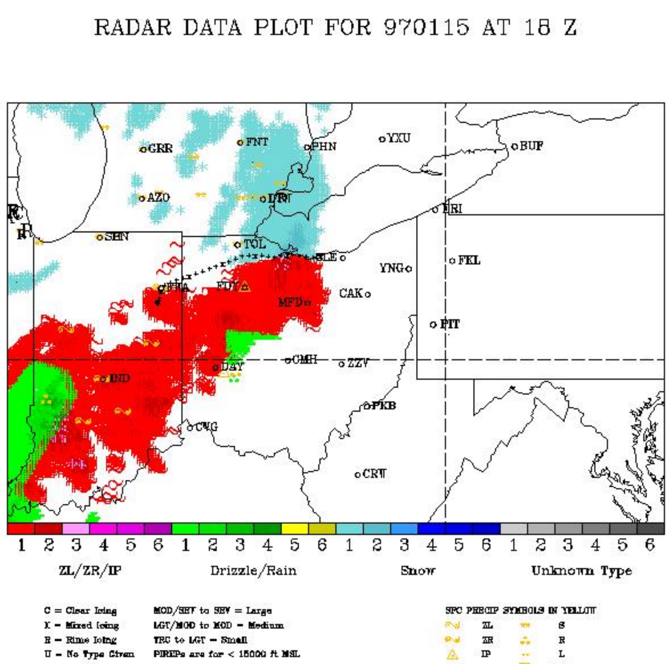


Figure 4 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970115, e) 1700 and f) 1800 UTC.

RADAR DATA PLOT FOR 970115 AT 19 Z

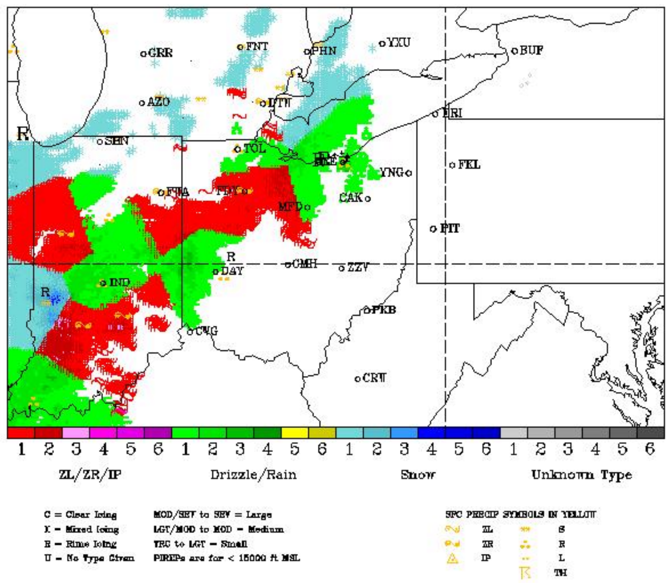


Figure 4 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970115, g) 1900 UTC.

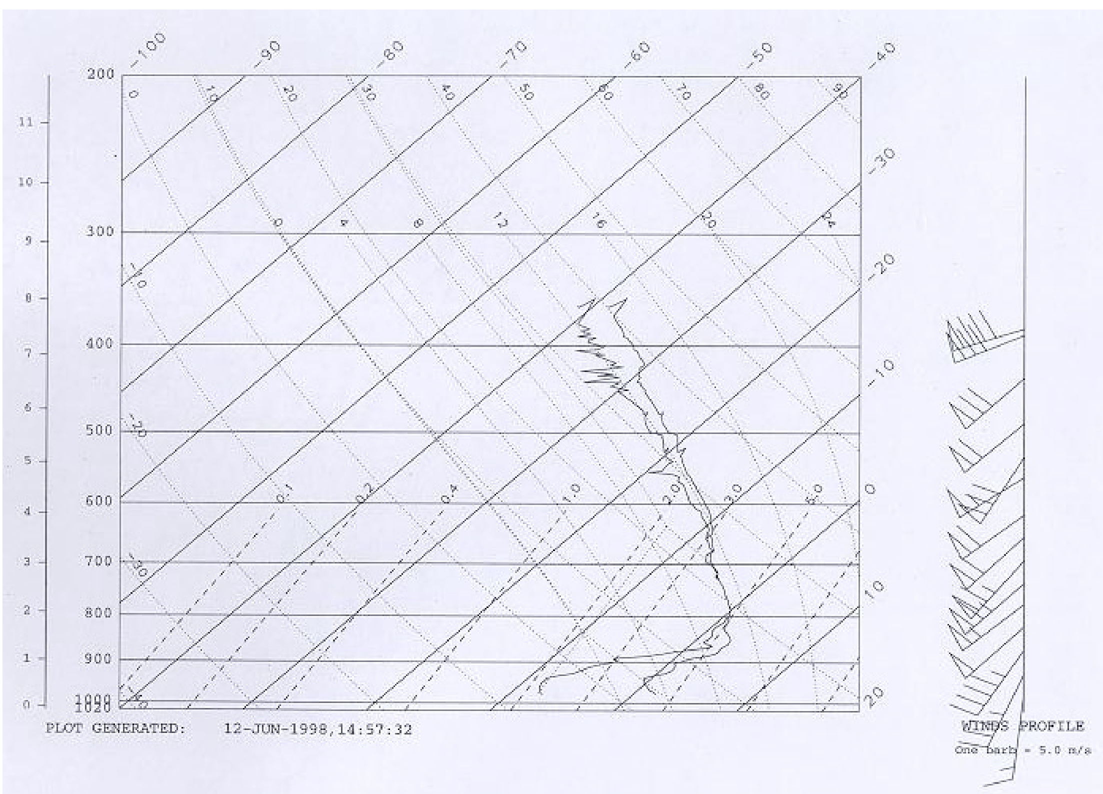
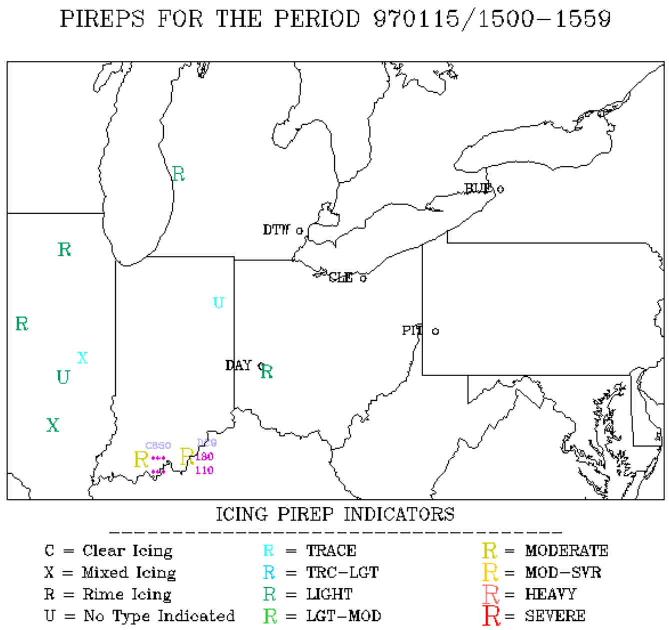


Figure 5 – Balloon-borne NCAR CLASS sounding data for 970115, 2006 UTC at Cleveland.



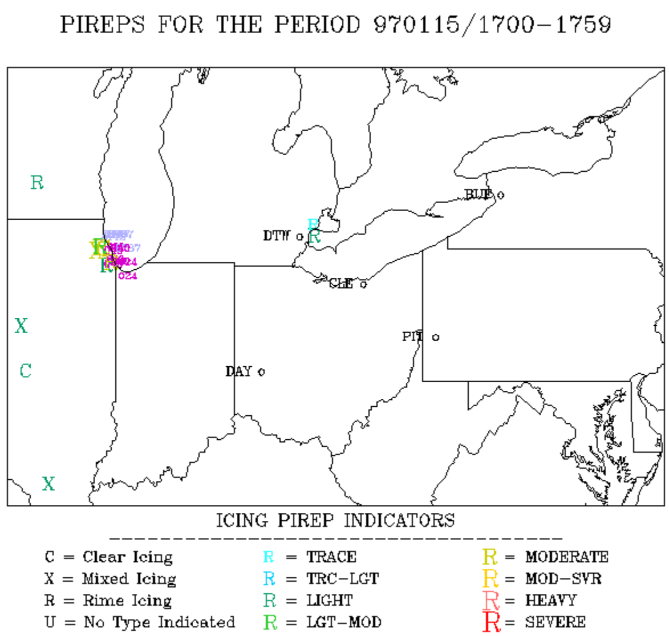


Figure 6 – Pilot reports of icing for 970115, a) 1500-1559 and b) 1700-1759 UTC (1600-1659 UTC PIREPs were not available).

PIREPS FOR THE PERIOD 970115/1800-1859

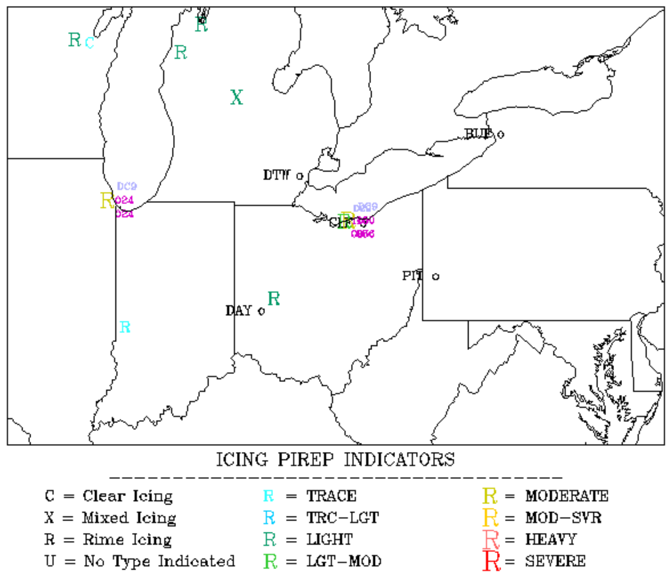


Figure 6 – Pilot reports of icing for 970115, c) 1800-1859 UTC.

January 22, 1997

Flight #1 - Over southeastern Ontario and near Selfridge, Michigan from 1726 to 1929 UTC.

Flight #2 - Over Selfridge, Michigan and southeastern Ontario from 2037 to 2251 UTC.

Brief overview

Two flights were made on this day, both along and within the western edge of a north-south oriented band of precipitation, which tracked eastward across southern Ontario, Lake Erie, and Ohio, and gradually dissipated between 1800 and 2300 UTC. During the first flight, the Twin Otter encountered mostly snow and almost no LWC within the precipitation band, over Lake Erie and southeastern Ontario. The cloud broke into two separate decks on its western edge, with snow above approximately 10000 feet, and all supercooled liquid water below approximately 8000 feet, with LWC up to 0.25. During the second flight, the Twin Otter went southeast from Selfridge, Michigan to Erie, Pennsylvania, catching up to the western end of the precipitation. Near Erie, the aircraft encountered LWC values of 0.2-0.3, with peaks up to 0.4 at temperatures of –3 to –5 Celsius, and a few brief periods of large drops.

Relevant whether features

At 1200 UTC, a disorganized trough was in place across the center of the country at 500 and 700 mb (Fig. 1). Moisture was evident to the east of the trough, across the forecast area, and extended southward to the Gulf of Mexico. The exception to this was a swath of dry air moving into Indiana, Illinois, and Michigan at 700 mb. At 850 mb, the system was well defined, with a closed low over the Upper Peninsula of Michigan and four troughs extending from the low 1) south into Mississippi, 2) southwest into Oklahoma, 3) south into Iowa, and 4) west across Minnesota. The leading trough (#1) separated dry air and cold advection to the west from saturated air and warm advection to the east. The warm advection was associated with southwest flow pushing into a pocket of cool air across an area from eastern Michigan to North Carolina. The moisture was quite deep across the area and a swath of rain at the surface roughly matched the locations where saturated conditions existed at all levels, from 850 to 500 mb.

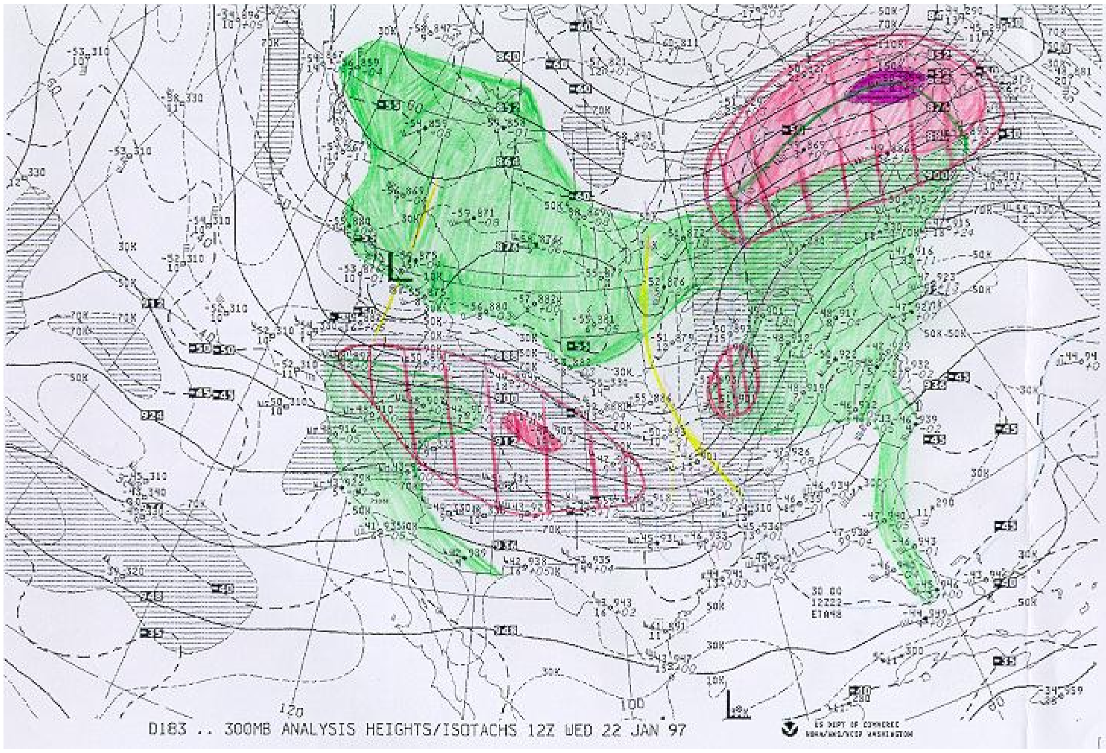
By 0000 UTC, the disorganized trough moved eastward and became oriented from northeast to southwest across the northern Great Lakes at 700 and 850 mb (Fig. 2). At 850 mb, trough #1 was only evident across central Pennsylvania, where it still separated cold advection to the west from warm advection to the east. The cool pocket was no longer evident to the east of the trough and the warm advection had weakened markedly. Although moisture was abundant across the forecast area at 850 mb, dry air at 700 mb had worked its way into much of Pennsylvania and southern Michigan, as well as across Ohio. This dry air helped break up the deeper clouds and precipitation associated with trough #1. An area of saturated air and warm advection was in place across northern Michigan and southeastern Ontario, into New York at 700 mb.

The 1200 and 0000 UTC Detroit and Wilmington (OH) soundings (Figs. 3,4) gave a good indication of the change in structure across trough #1. Ahead of the trough, deep, saturated conditions were present from 850 mb on up (from the surface on up at Detroit). By 0000 UTC, dry air had pushed in aloft, leaving only an approximately 500 foot thick cloud near 850 mb, with CTTs near –6 C over Detroit. The cloud layer was strongly capped with a 4 C inversion between 840 and 800 mb. Conditions also dried out from above at Wilmington, but left an approximately 2000 foot deep, very warm (CTT = + 2 C) cloud there, which was capped by a weaker inversion. At both sites, the lapse rates below the inversion became increasingly unstable with time, providing a profile for capped conviction.

Surface maps for 1500 UTC (Fig. 5) show that a 992 mb surface low was roughly co-located with the 1200 UTC 850 mb low. Two cold fronts extended southwest from the low, across Illinois to Oklahoma and across Wisconsin and Iowa. These cold fronts were the surface reflection of upper-air troughs #2 and #3, respectively, while a surface trough located across Wisconsin and Minnesota is the reflection of upper-air trough #4. Upper-air trough #1 was weakly evident at the surface in the pressure and wind fields, but was mostly marked by the elongated band of rain from Detroit, across eastern Indiana and western Ohio, down to Louisiana. This swath of rain was located to the west of the trough axis, but well ahead of the first cold front. Overcast conditions were present between the rain swath and the cold front, across southeastern Ontario, Michigan, Indiana and Illinois. As the system moved toward the east-northeast over the next several hours, the surface trough fell apart and the northern end of the precipitation band became scattered. This occurred in response to weakening in trough #1 at 850 mb and the push of dry air into the area at 700 mb.

Radar mosaic data for 1800 to 2300 UTC (Fig. 6) showed the eastward progression of the rain and its dissipation as it moved across Ohio and Lake Erie. Pilot reports of icing were indicated within and around the precipitation band between 8000 and 25000 feet (Fig. 7). Much of the icing reported in the vicinity of the flight was moderate rime, but a few reports of moderate mixed and clear icing were given near the eastern end of Lake Erie and the western end of Lake Ontario between 7000 and 11000 feet, and across Michigan between 4000 and 8000 feet.

No satellite data was available for this case.



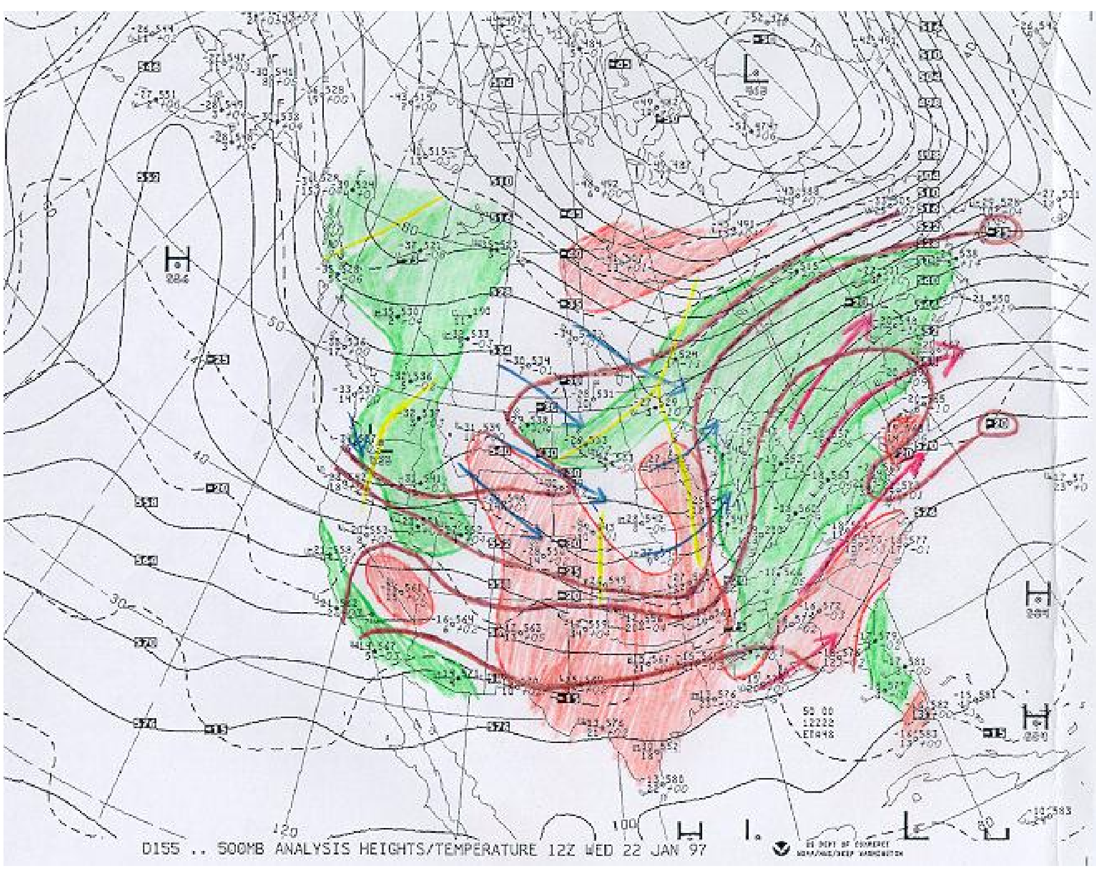


Figure 1 – Upper air charts for 970122, 1200 UTC at a) 300 and b) 500 mb.

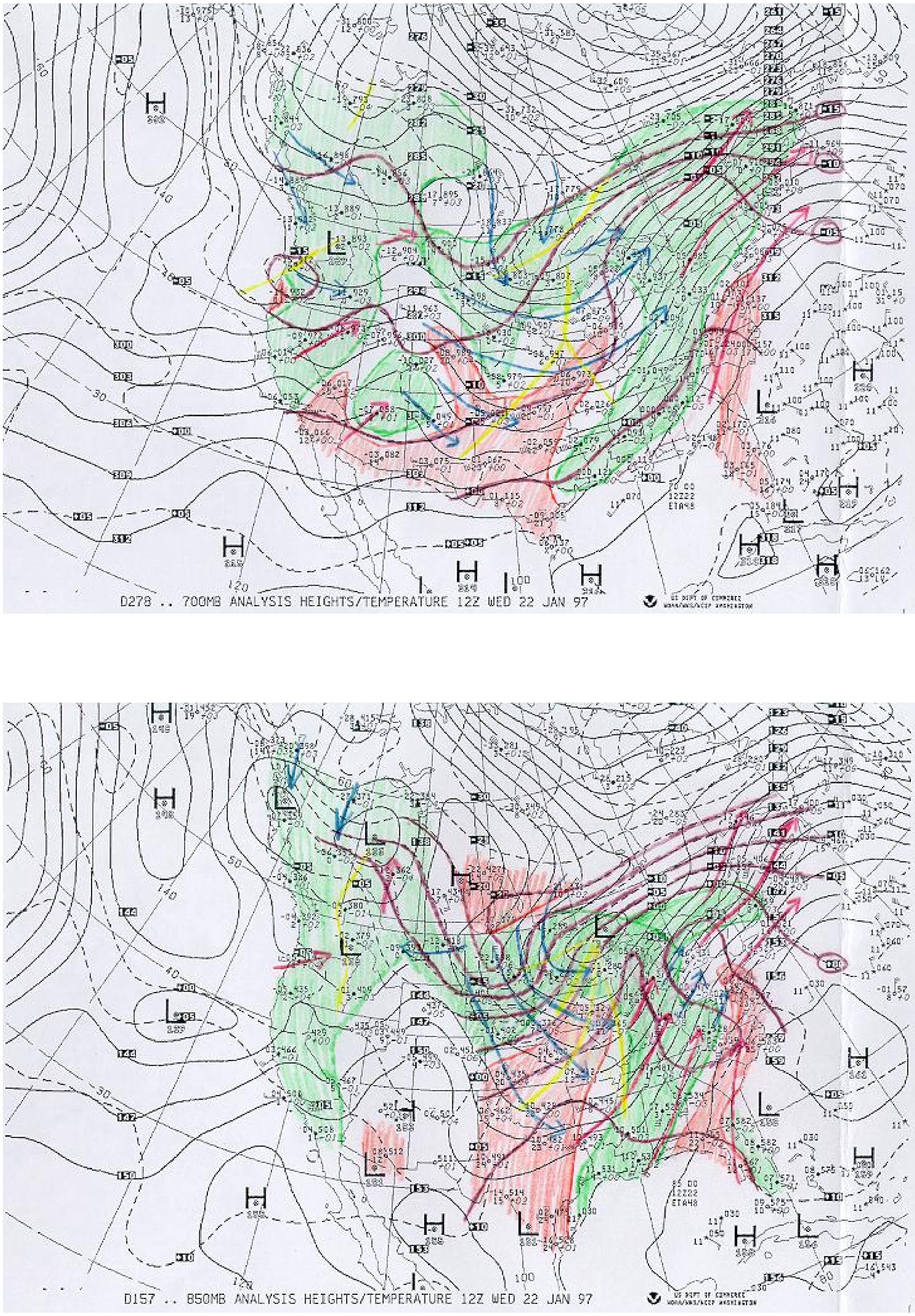


Figure 1 – Upper air charts for 970122, 1200 UTC at c) 700 and d) 850 mb

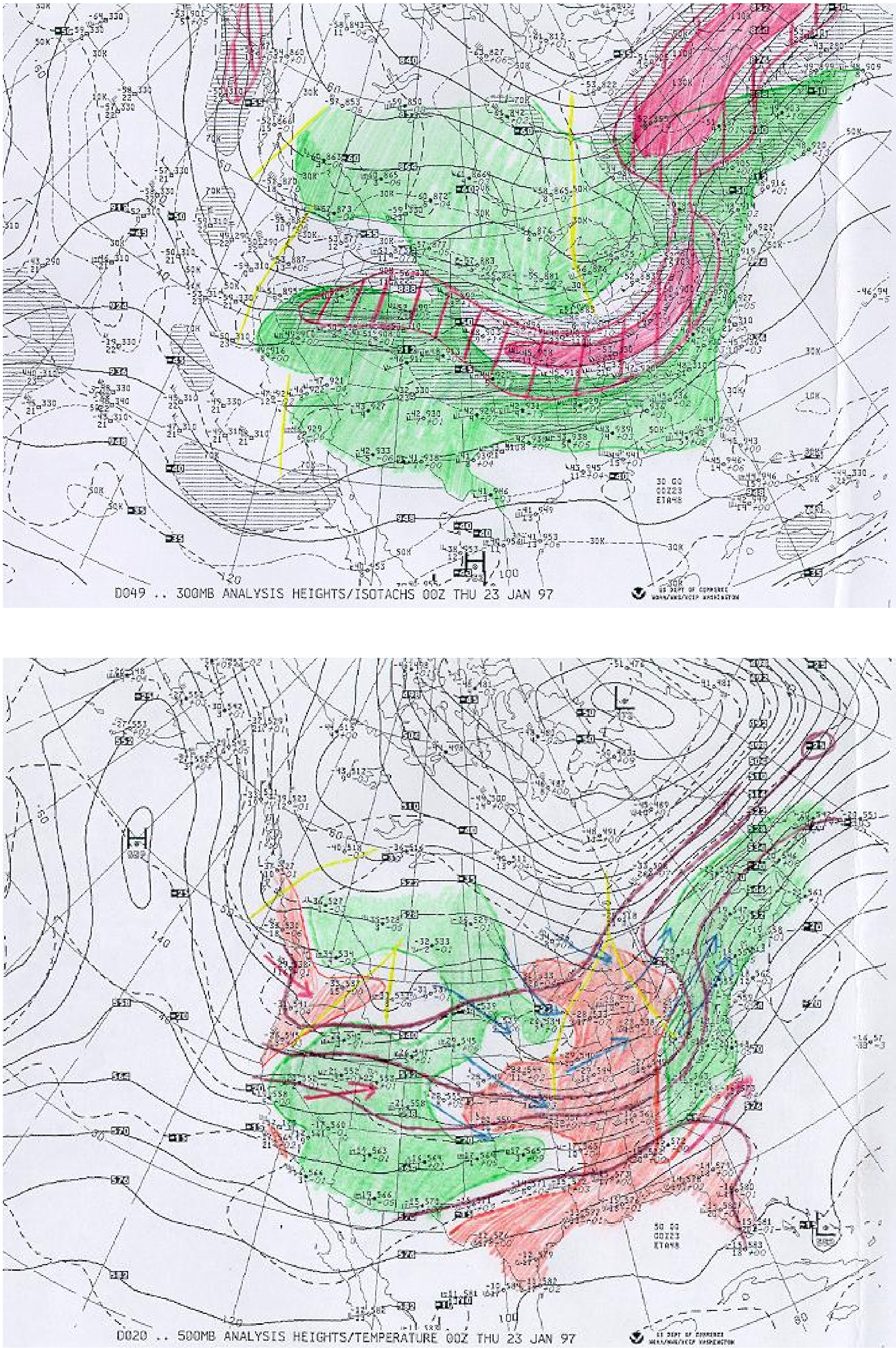


Figure 2 – Upper air charts for 970123, 0000 UTC at a) 300 and b) 500 mb.

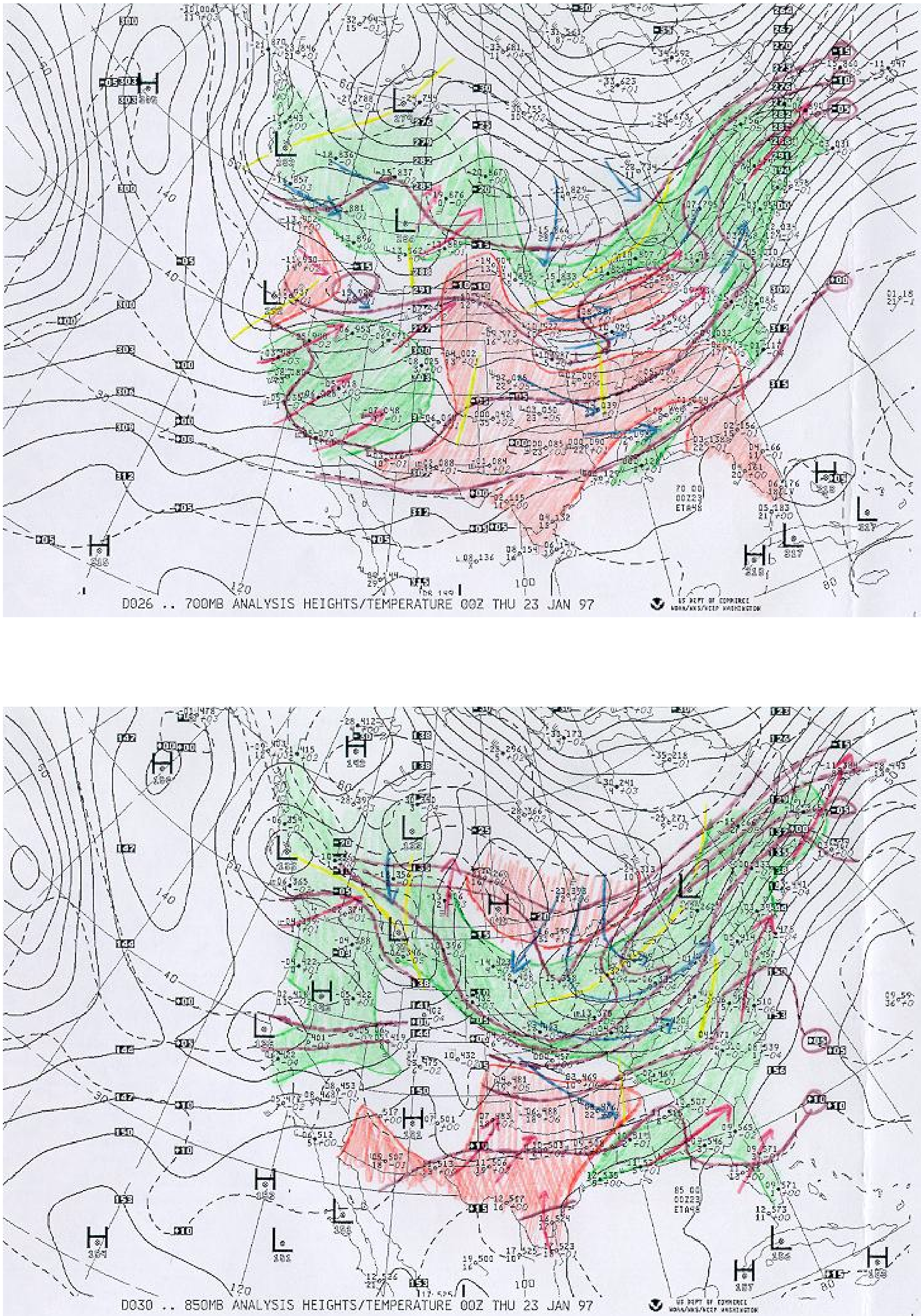
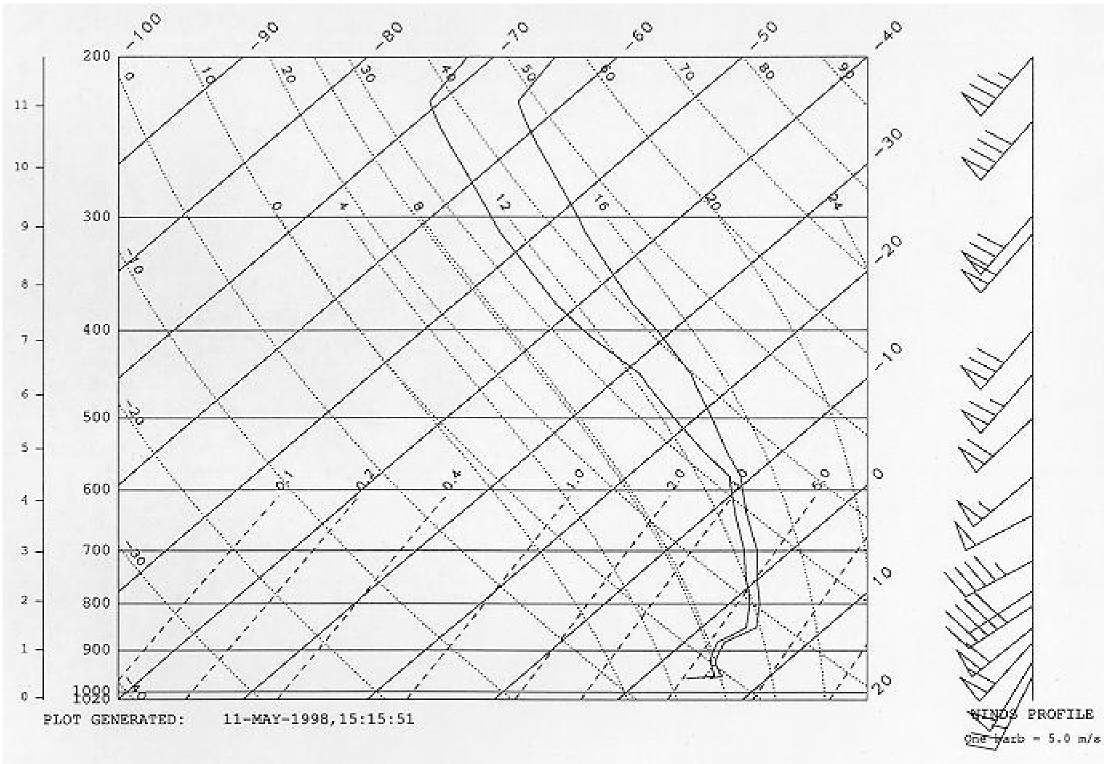


Figure 2 – Upper air charts for 970123, 0000 UTC at c) 700 and d) 850 mb.



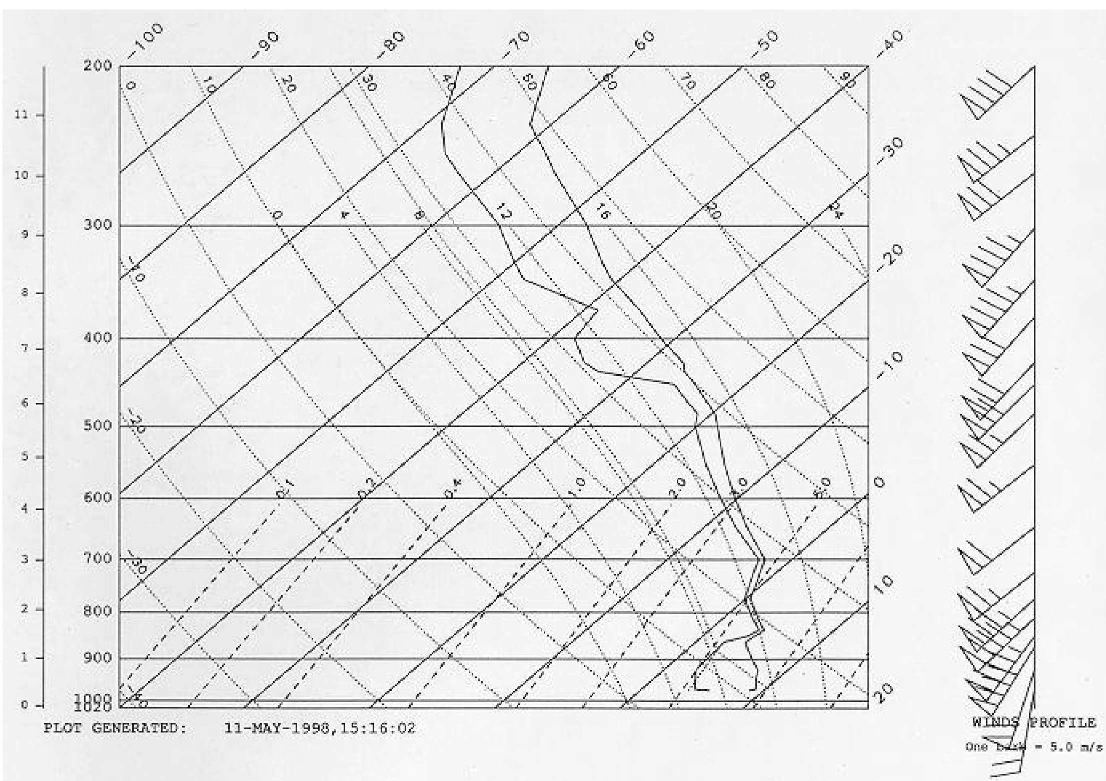


Figure 3 – Balloon-borne soundings for 970122, 1200 UTC at a) Detroit and b) Wilmington.

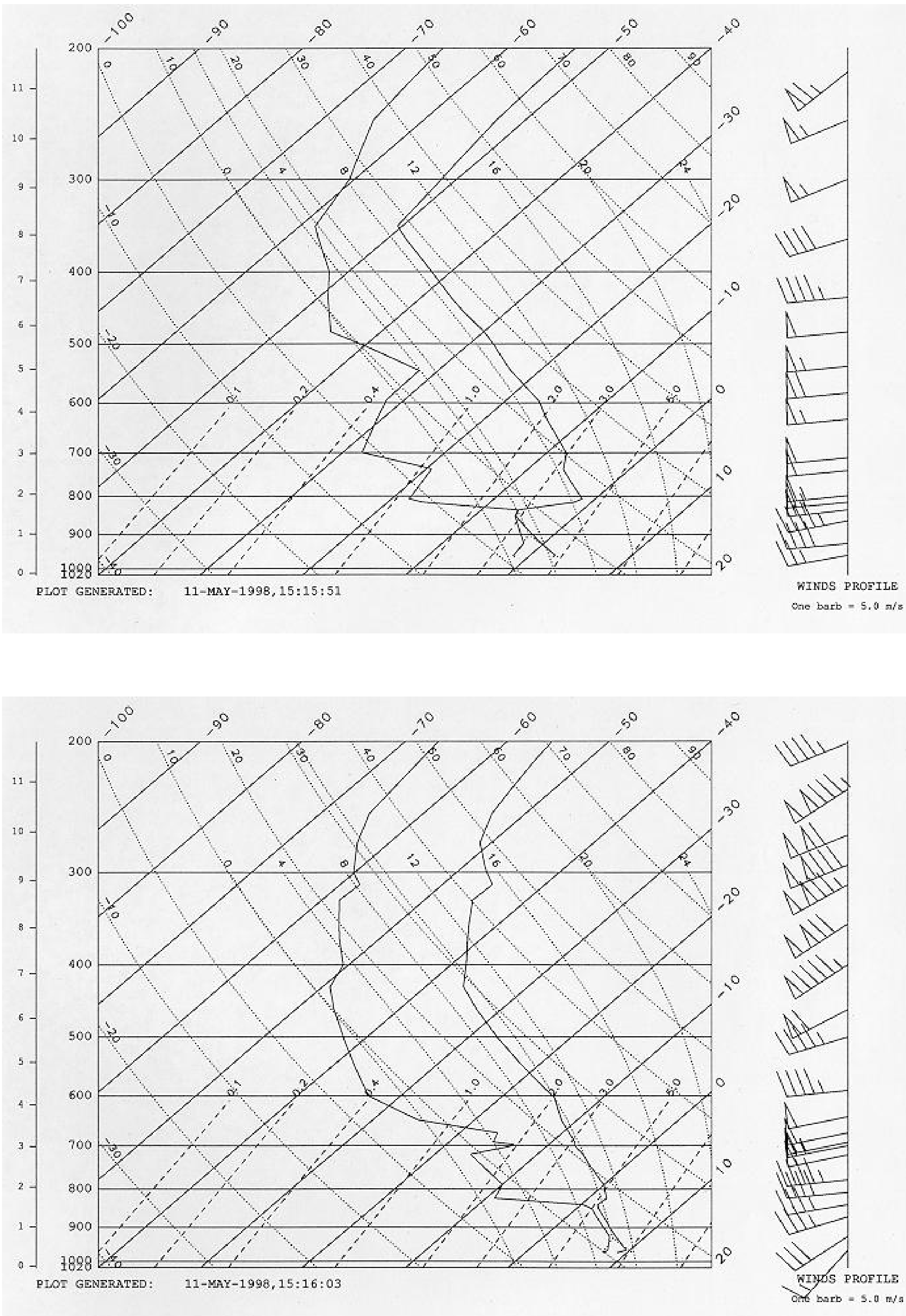


Figure 4 – Balloon-borne soundings for 970123, 0000 UTC at a) Detroit and b) Wilmington

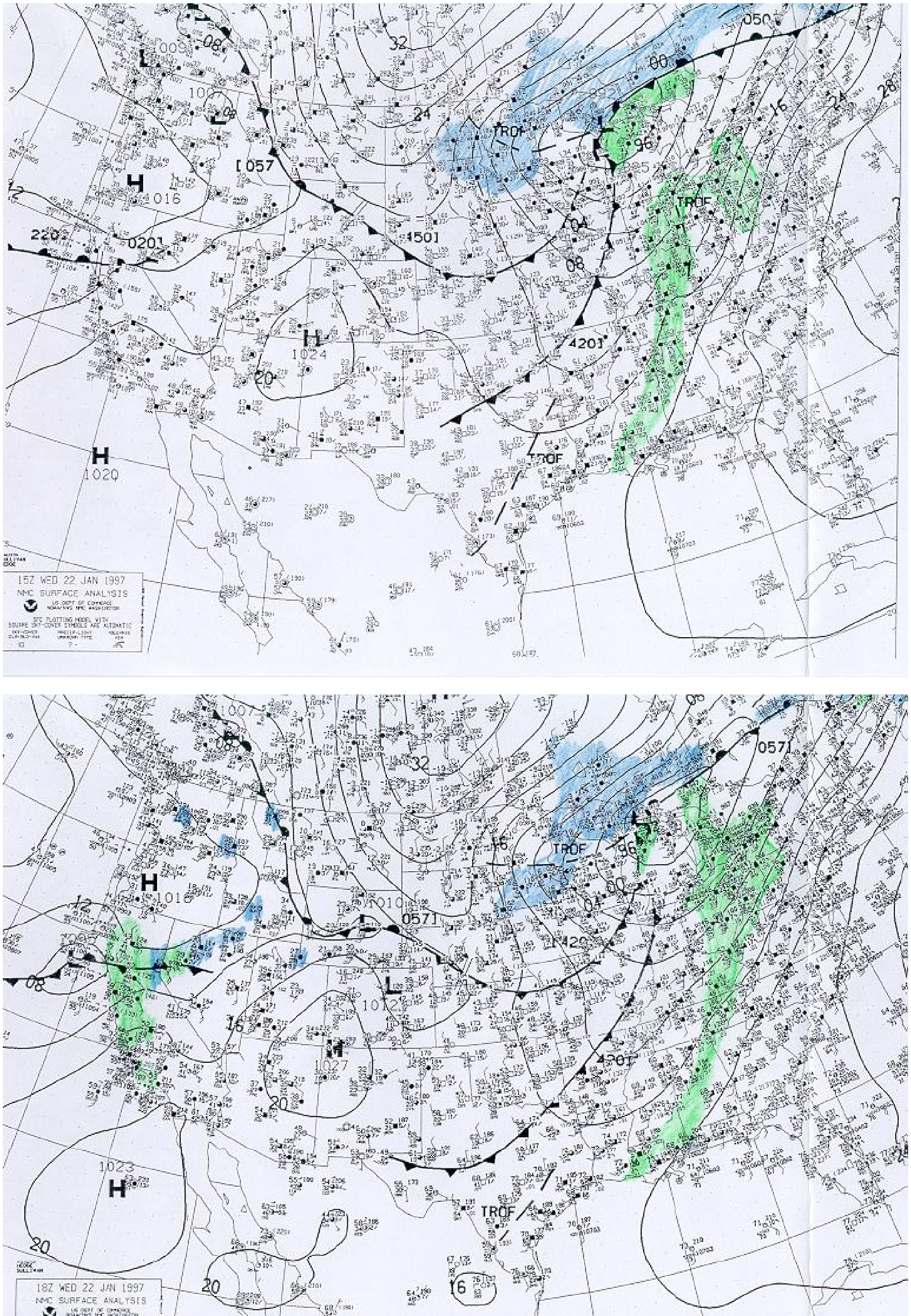


Figure 5 – Surface charts for 970122, a) 1500 and b) 1800 UTC.

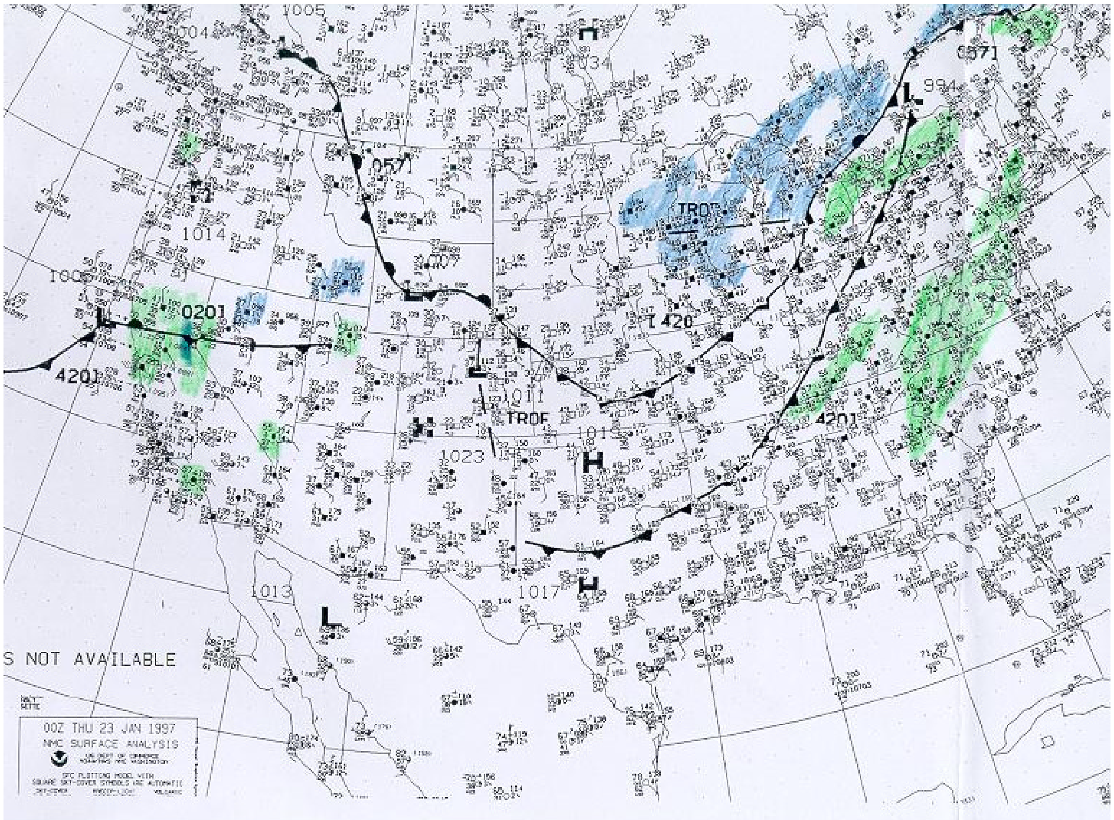
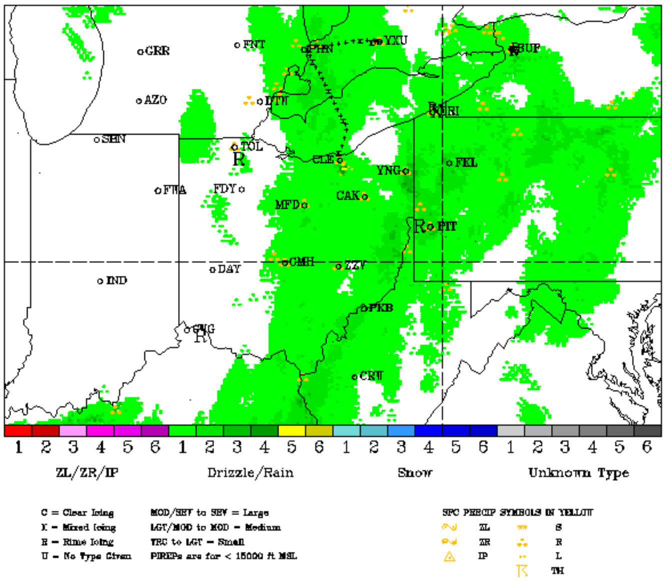


Figure 5 – Surface chart for c) 970123, 0000 UTC.

RADAR DATA PLOT FOR 970122 AT 18 Z



RADAR DATA PLOT FOR 970122 AT 19 Z

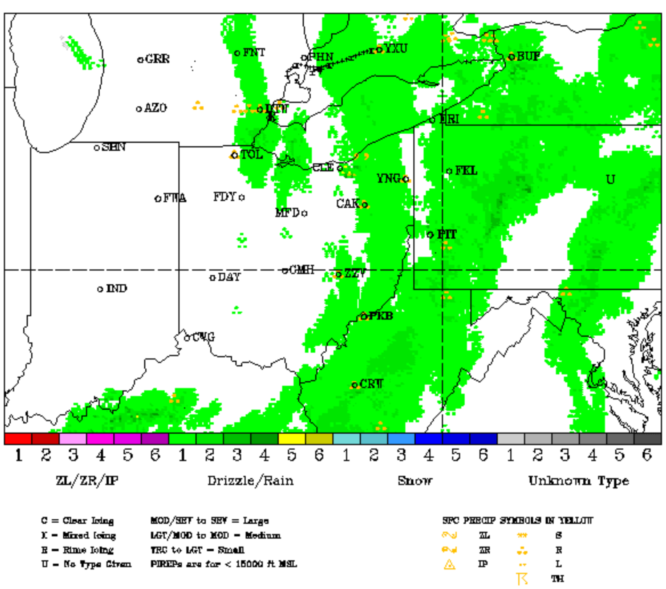
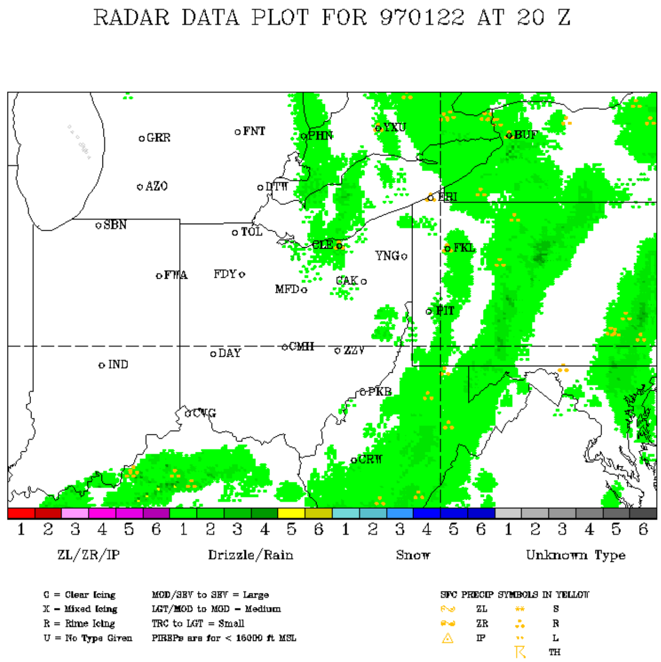


Figure 6 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970122, a) 1800 and b) 1900 UTC.



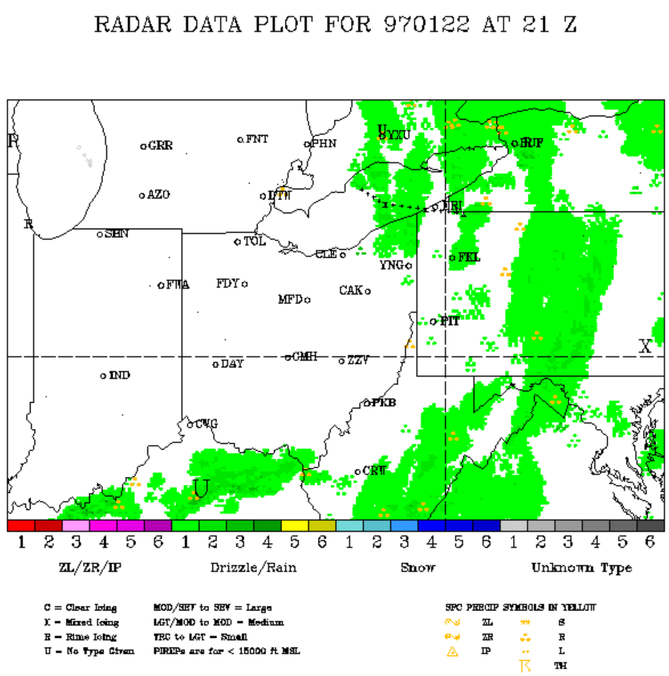
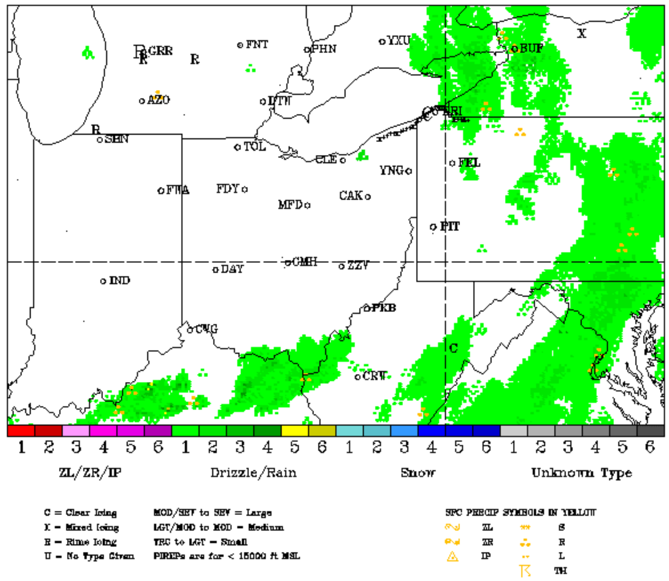


Figure 6 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970122, c) 2000 and d) 2100 UTC.

RADAR DATA PLOT FOR 970122 AT 22 Z



RADAR DATA PLOT FOR 970122 AT 23 Z

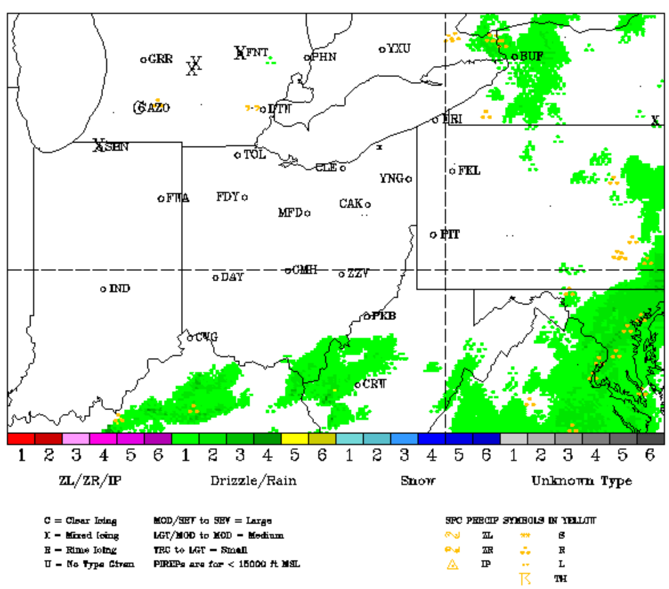
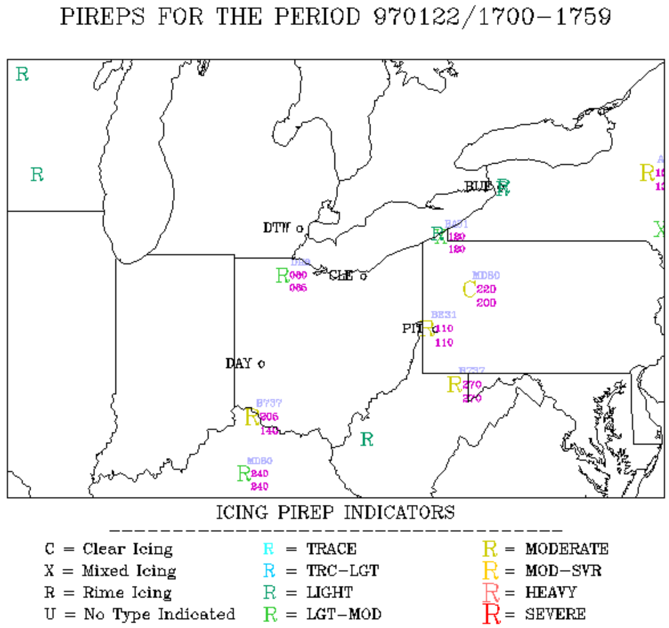


Figure 6 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970122, e) 2200 and f) 2300 UTC.



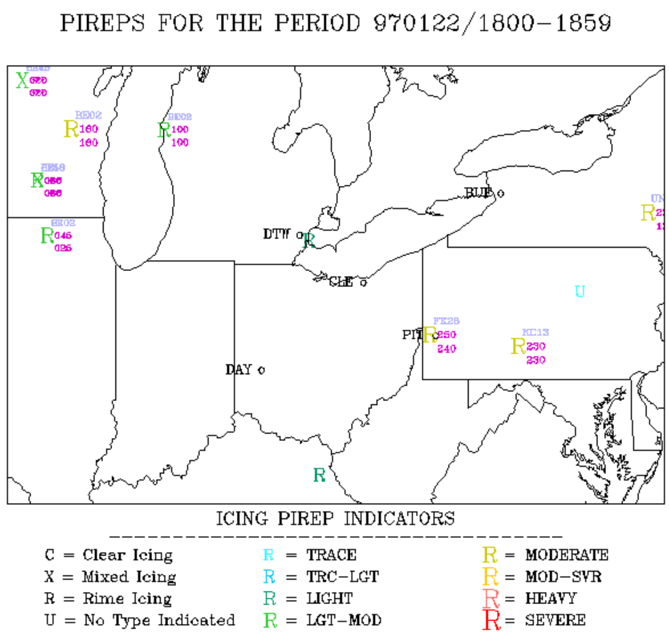
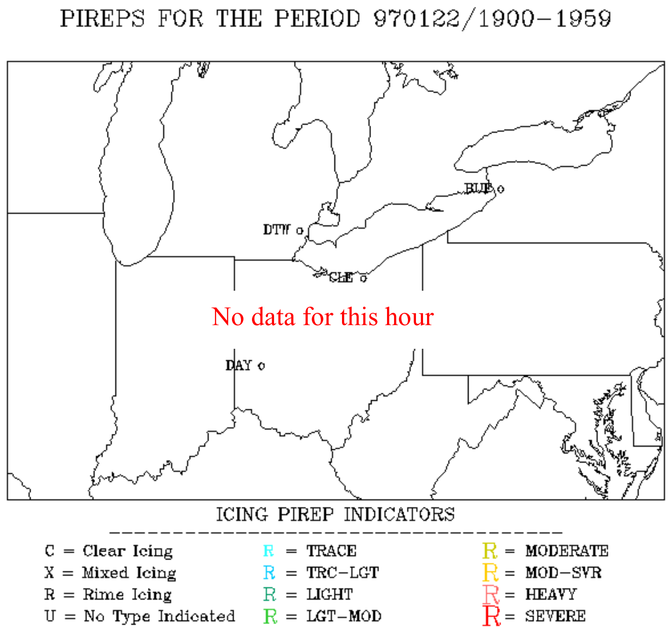


Figure 7 – Pilot reports of icing for 970122, a) 1700-1759 and b) 1800-1859 UTC.



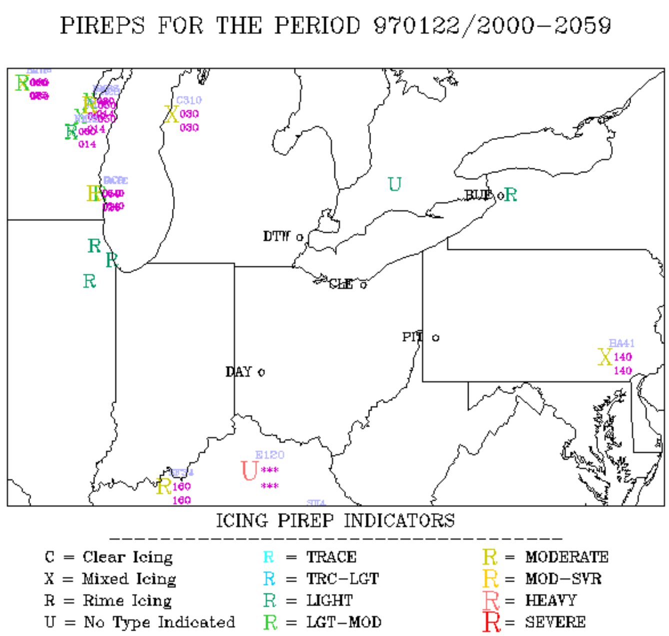
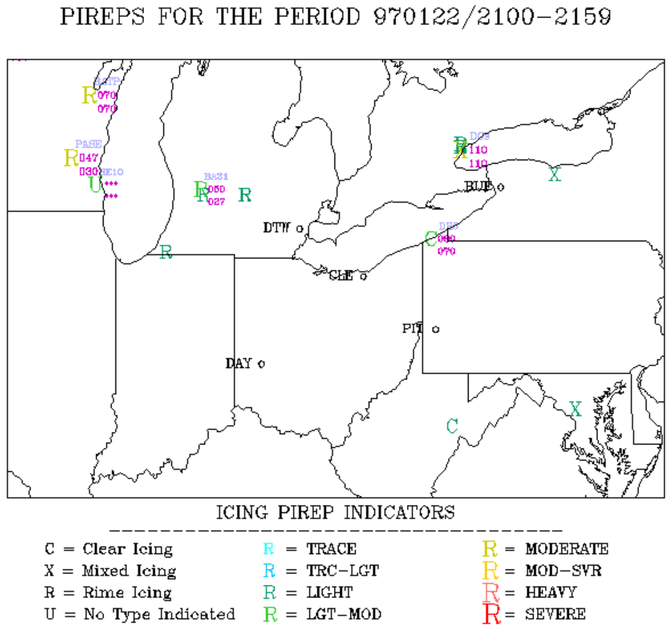


Figure 7 – Pilot reports of icing for 970122, c) 1900-1959 (no data) and d) 2000-2059 UTC



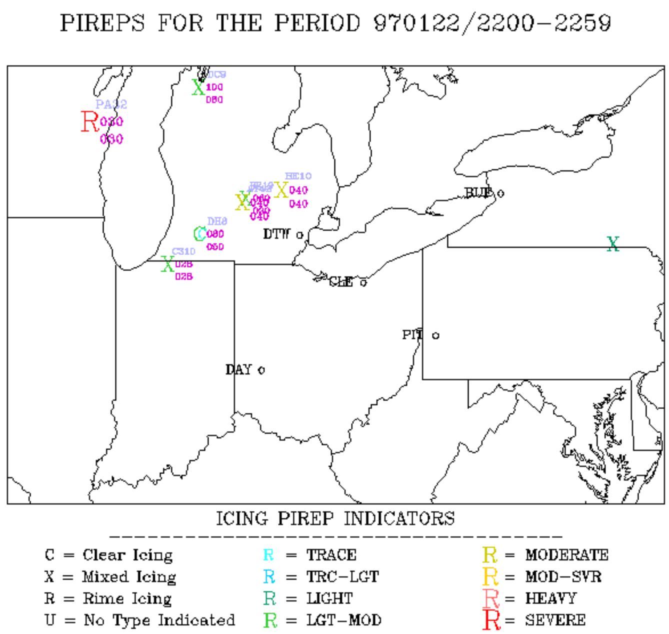


Figure 7 – Pilot reports of icing for 970122, e) 2100-2159 (no data) and f) 2200-2259 UTC.

January 23, 1997

Flight #1 - Over the southeast shore of Lake Erie, near Erie and Bradford, PA from 1432 to 1616 UTC.
Flight #2 - Over Erie, PA and Youngstown, OH from 1709 to 1840 UTC.

Brief overview

Two flights were made on this day. The initial flight was made in an attempt to capture freezing drizzle, as it reached Erie and Bradford. The freezing drizzle was occurring at Buffalo along the leading edge of an area of snow, which was associated with a cold front moving southward across Lakes Erie and Ontario. During the first flight, the Twin Otter sampled LWC up to 0.2 and areas of out-of-focus droplets, which bordered on freezing drizzle sizes, along the southeast shore of Lake Erie. The liquid water content decreased as the aircraft approached Bradford, where the clouds were mostly comprised of ice crystals.

The second flight was essentially a return to Cleveland, but an area of dissipating, pocketed, light snow was sampled along the way, near Erie and Youngstown. Snow crystals were encountered there, and were mixed with small water droplets and low LWC at times. King LWC probe problems were noted during this flight.

Relevant weather features

At 1200 UTC, a trough axis extended south from Hudson's Bay to near Erie, Pennsylvania, and dry conditions were evident across the entire forecast area at 500 mb (Fig. 1). At 700 mb, that trough was oriented from northeast to southwest, along the northern shores of Lakes Erie and Ontario. Cold advection was evident in a narrow swath behind the trough and the only saturated conditions evident across the forecast area were located near Detroit, along the trough axis. At 850 mb, the trough axis/cold front had the same orientation and was draped across the centers of Lakes Erie and Ontario. Cold advection was again present behind the trough, and weak cold advection was occurring ahead of it. Saturated conditions were in place across Michigan, Ohio, Pennsylvania, New York and southeast Ontario.

At the surface, the upper-air trough was reflected as a cold front, which stretched along the south shores of Lakes Erie and Ontario, and reached Youngstown and Bradford by 1500 UTC (Fig. 2). This cold front extended southwest from a 992 mb low centered in the Canadian Maritimes. A 1037 mb high was centered to the north of Lake Superior and was pumping cold, dry air southward behind the front. Temperatures quickly dropped from near 30 F along the front to less than 10 F in southeast Ontario. Snow was occurring immediately behind the front and overcast conditions were prevalent ahead of it. Freezing drizzle was observed at Buffalo between 1000 and 1200 UTC along the leading edge of the snow. According to radar data, the snow appeared to peak in intensity around 1400 UTC (Fig. 3). Moderate snow was reported at Cleveland during this period, but no further observations of freezing drizzle were made across the forecast area after 1200 UTC. The snow decreased in intensity and became patchy in nature by 1600 UTC, while the front pushed further southeast to reach Pittsburgh by 1800 UTC.

The 1200 UTC Buffalo sounding (Fig. 4) was taken during the occurrence of freezing drizzle there, just as the cold front passed. This sounding is somewhat representative of the conditions sampled during the initial flight along the southeast shore of Lake Erie, though the clouds sampled were somewhat deeper, with colder cloud top temperatures. Cold, dry air and northwest winds were evident below 950mb (~2000 feet), while saturated air existed within the frontal zone (~2000 to 4000 feet) and above it to 8000 feet, and very dry conditions existed above that. According to the sounding, cloud top temperatures were approximately –13 C, with cloud tops near 8000 feet. Cold advection and deeper moisture behind the cold front in the surface to 10,000 feet layer is likely to have quickly pushed this sounding into the snow production regime, matching the flight conditions at Bradford. The 1200 UTC Detroit sounding, taken just behind the cold front, indicated that conditions were colder below ~8500 feet and that deeper saturated conditions existed just behind the front. Here, the front was evident near 10,000 feet, and a 3 C inversion was observed near cloud top, with a minimum temperature of –16 C at the base of the inversion.

Twin Otter data taken during initial climbout from Cleveland indicated these colder temperatures (–17 C at 8600 feet) and mixed conditions aloft, just behind the cold front. However, during the flight between Cleveland and Erie, all-water conditions were observed between 8200 and 8600 feet. Snow crystals were more prevalent below these altitudes. The 3 C inversion observed at Detroit was also evident at cloud top in the Twin Otter data.

There were many pilot reports made between 1300 and 1500 UTC in association with this front (Fig. 5). Many of the PIREPs made ahead of the snow area indicated moderate and even some severe icing between 2000 and 9000 feet, most of which was rime or mixed in type. As the precipitation dissipated, the PIREPs died down, becoming lighter in intensity and nearly all rime in type.

No satellite data was available for this case.

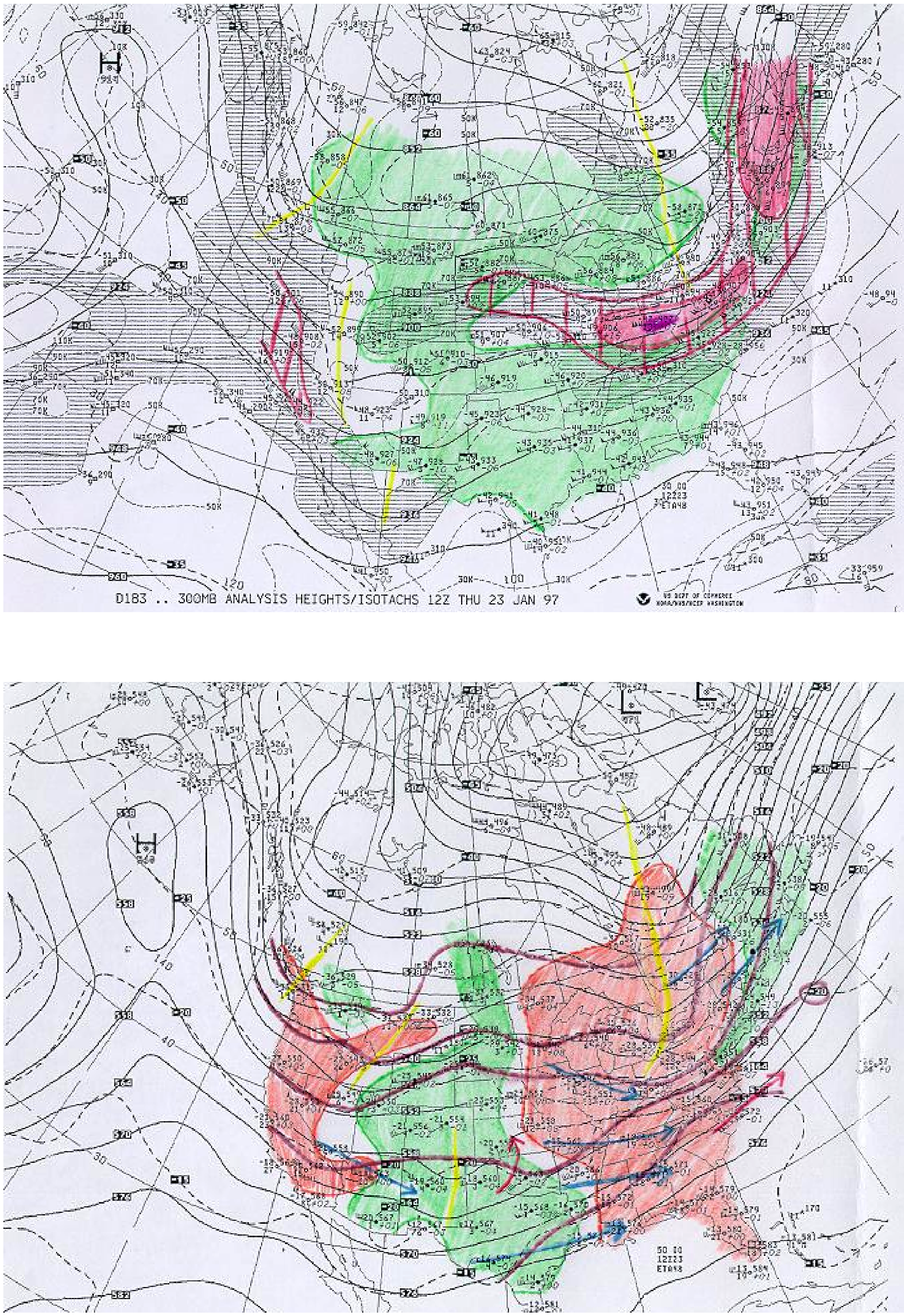


Figure 1 – Upper air charts for 970123, 1200 UTC at a) 300 mb and b) 500 mb.

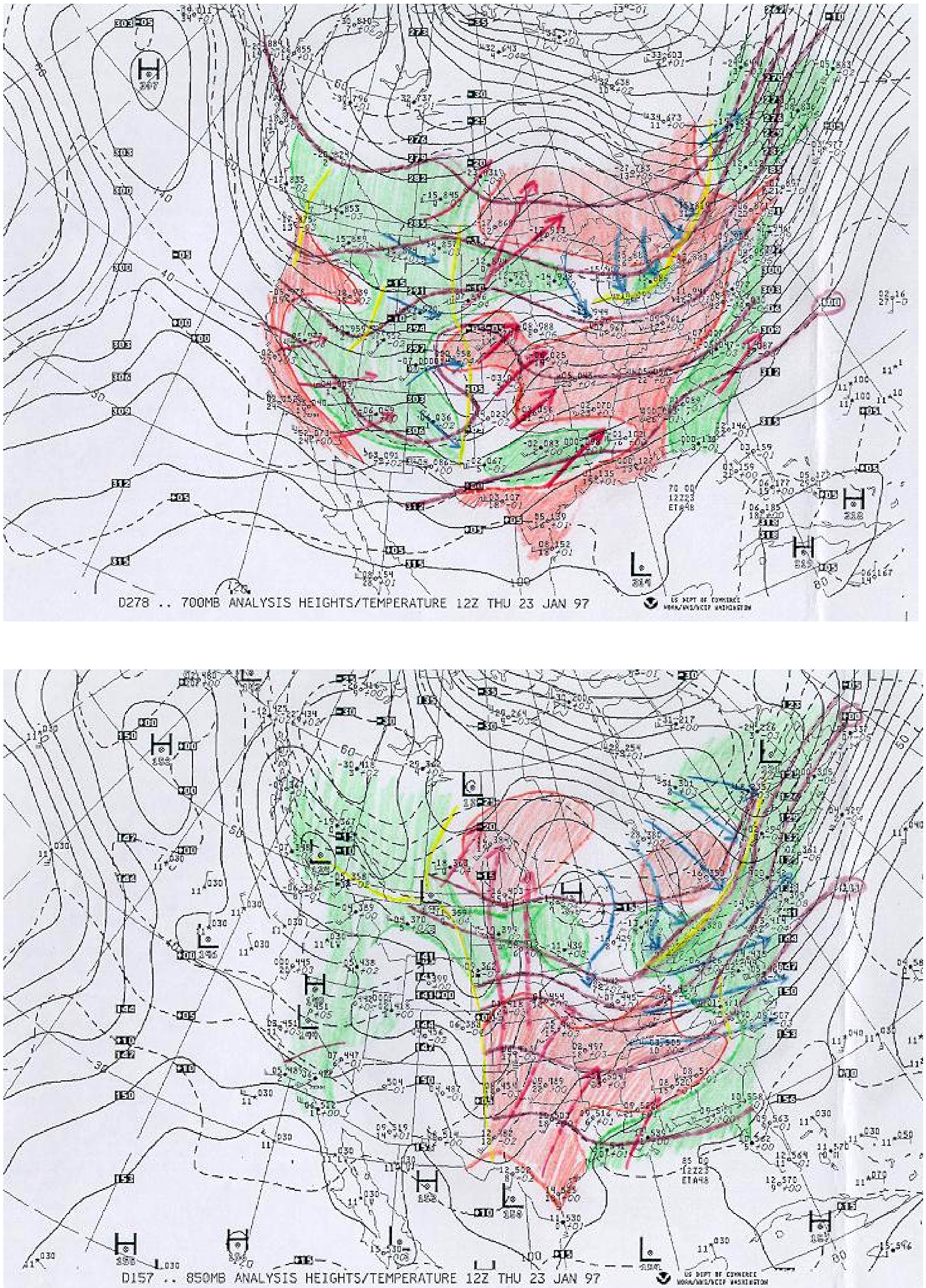


Figure 1 – Upper air charts for 970123, 1200 UTC at c) 700 mb and d) 850 mb.

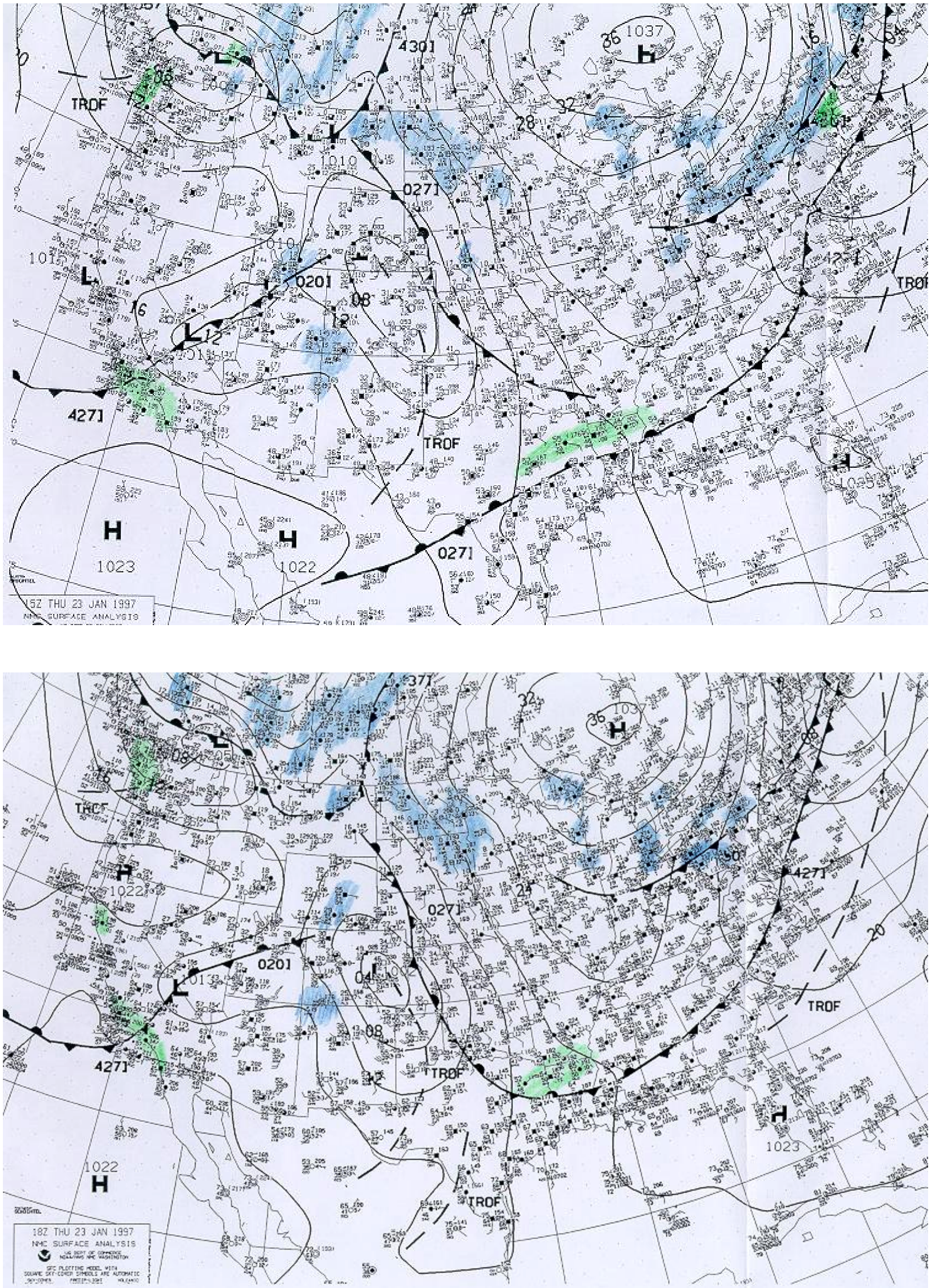
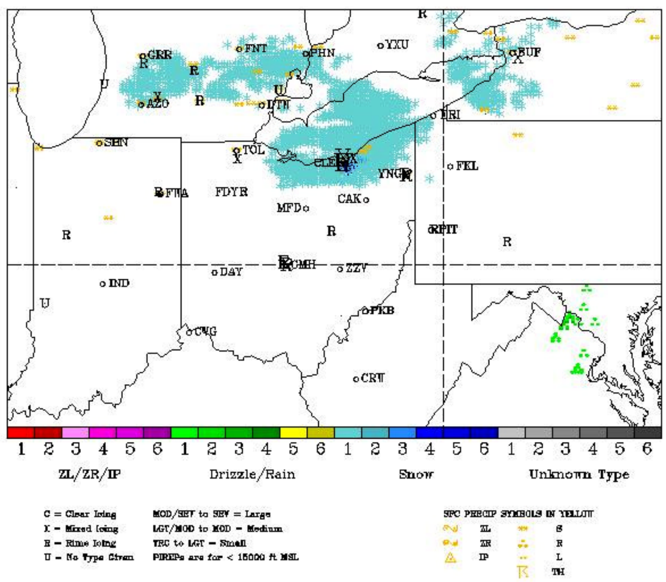


Figure 2 – Surface charts for 970123, a) 1500 and b) 1800 UTC.

RADAR DATA PLOT FOR 970123 AT 14 Z



RADAR DATA PLOT FOR 970123 AT 15 Z

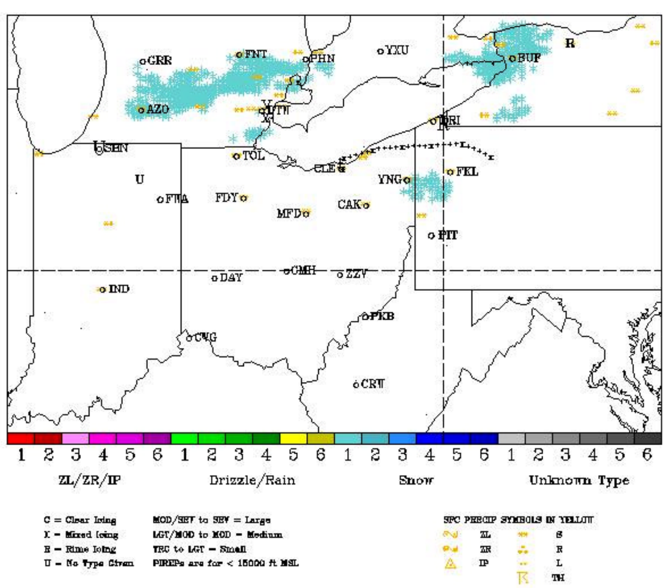
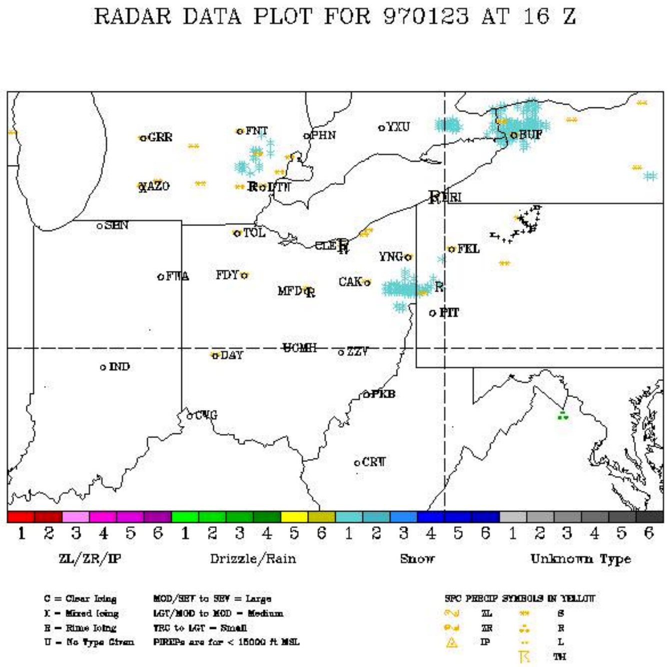


Figure 3 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970123, a) 1400 and b) 1500 UTC.



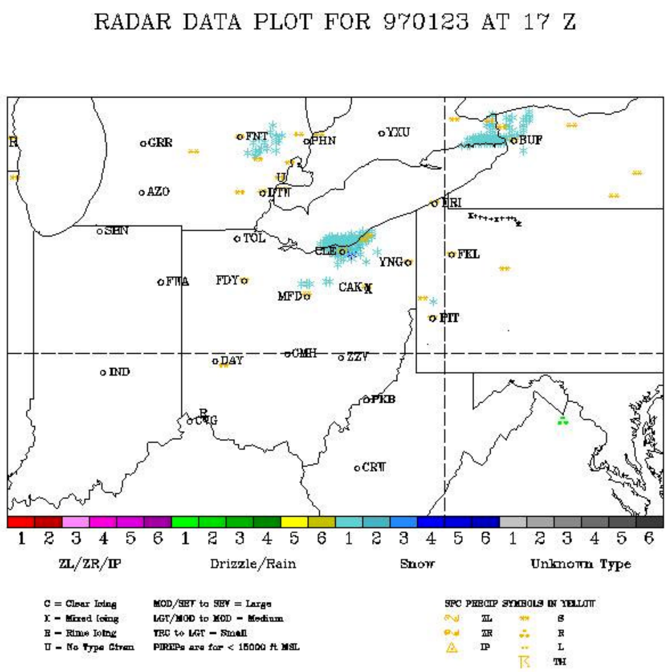
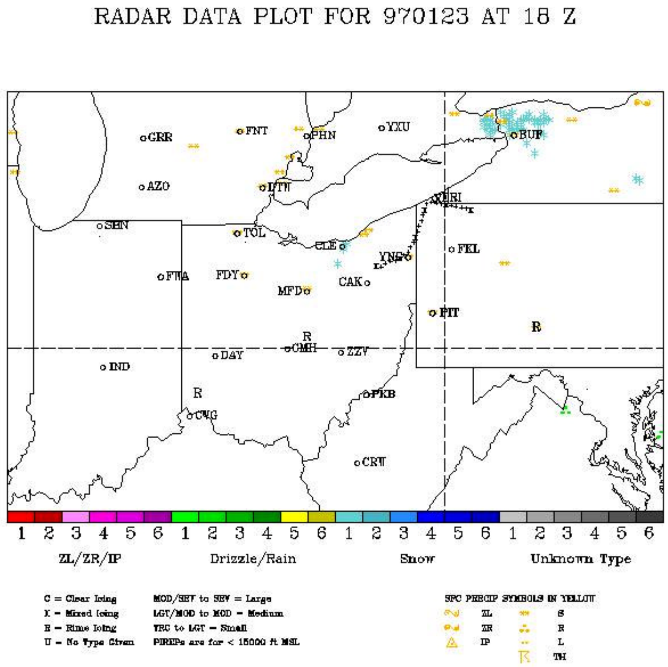


Figure 3 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970123, c) 1600 and d) 1700 UTC.



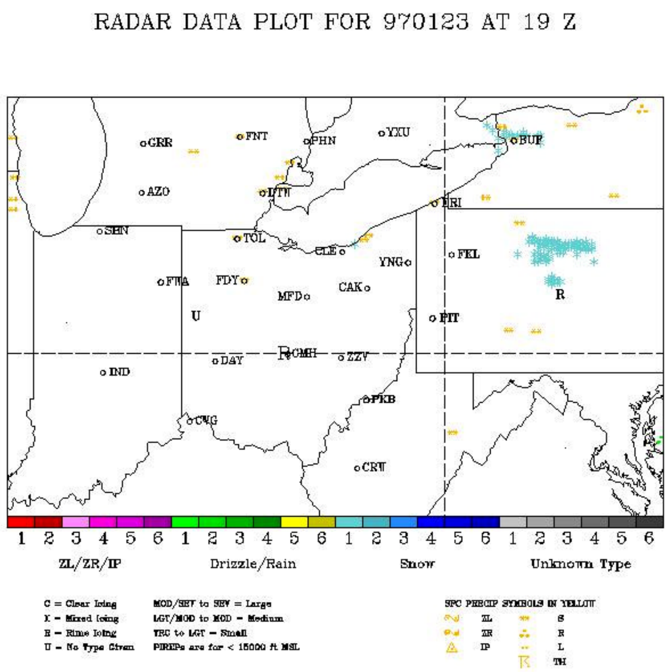
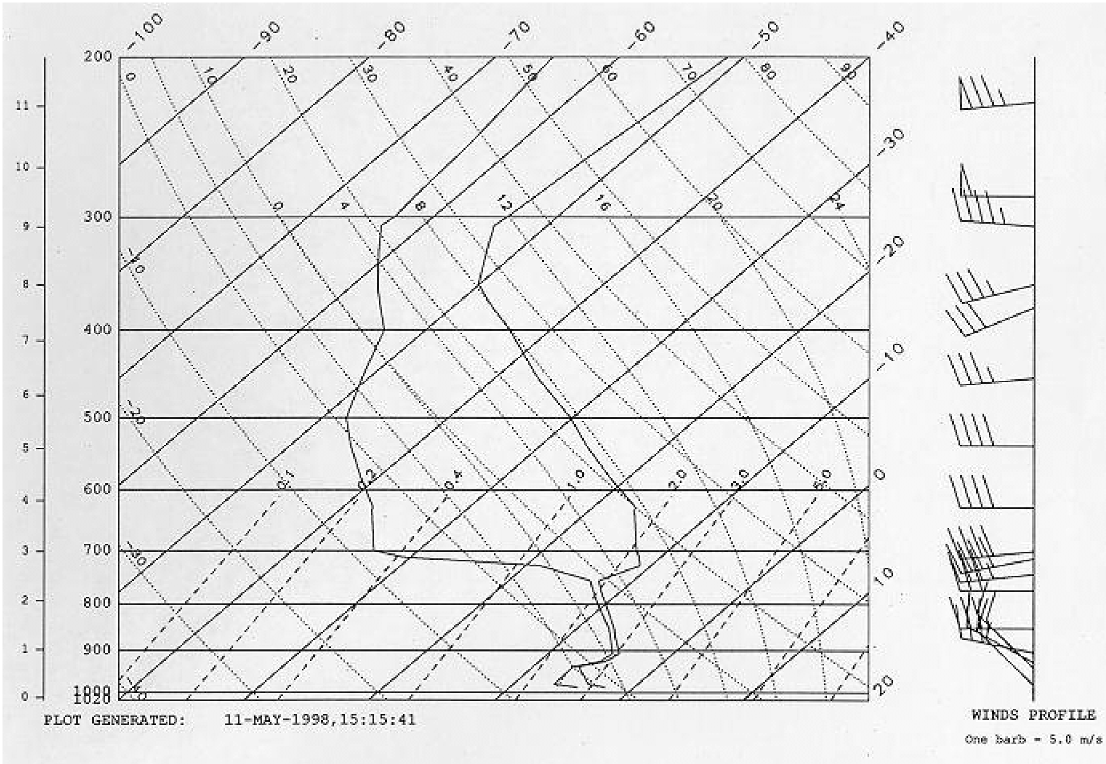


Figure 3 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970123, e) 1800 and f) 1900 UTC.



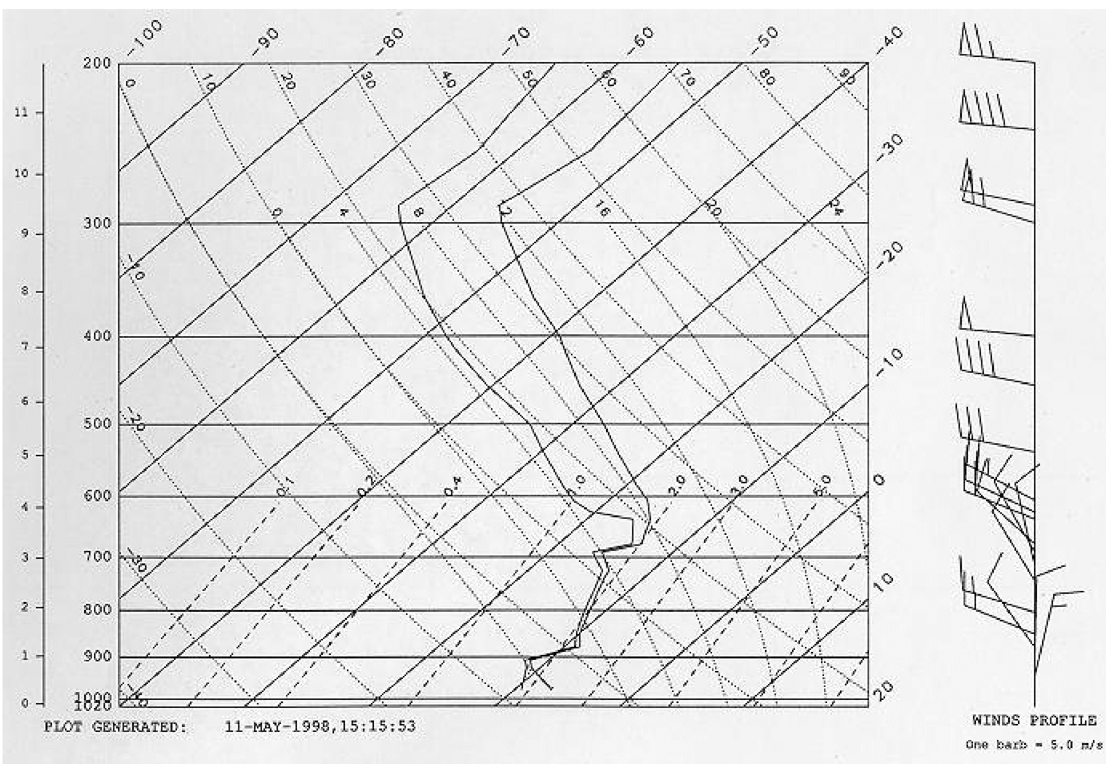


Figure 4 – Balloon-borne soundings for 970123, 1200 UTC at a) Buffalo and b) Detroit.

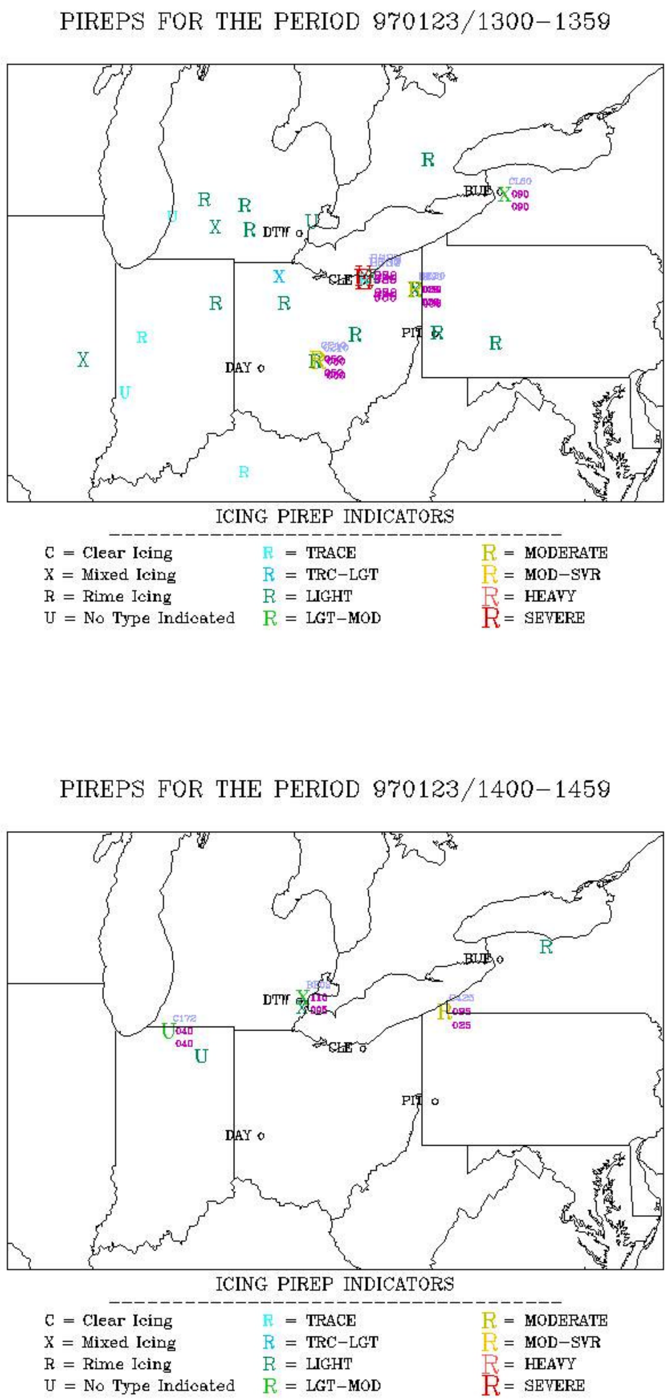
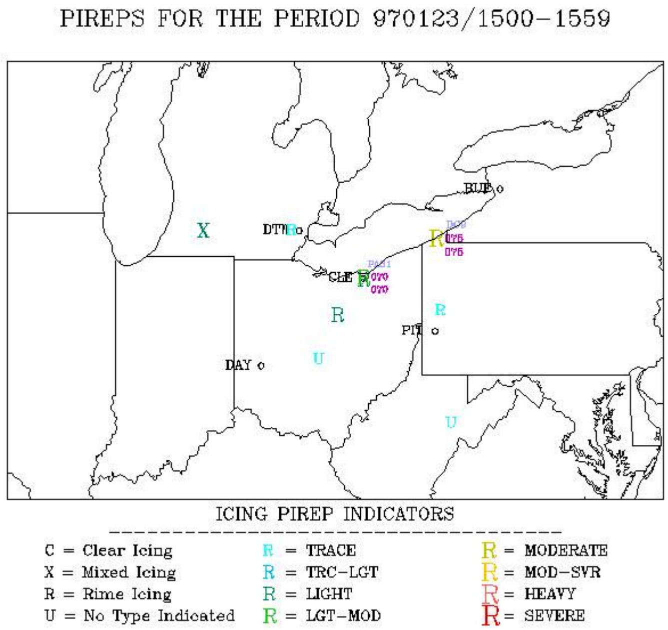


Figure 5 – Pilot reports of icing for 970123, a) 1300-1359 and b) 1400-1459 UTC.



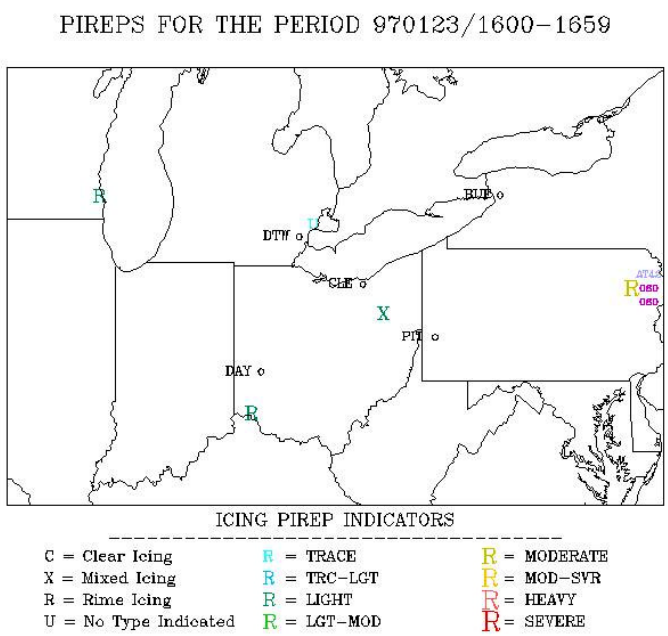
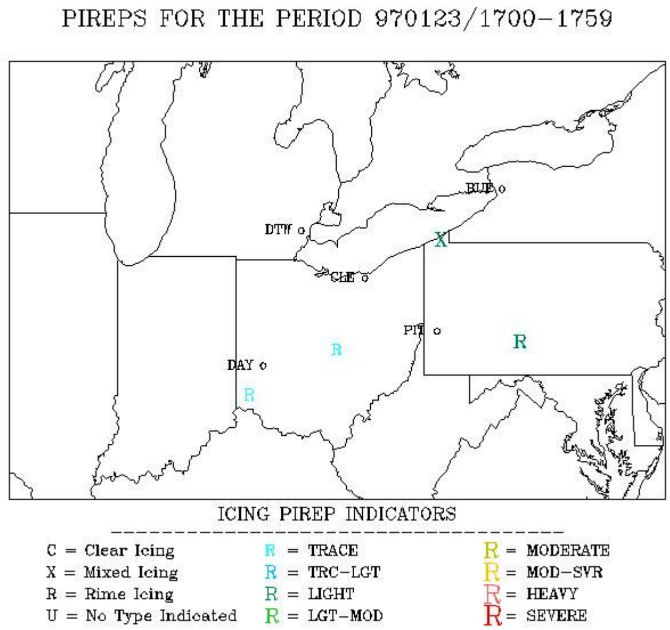


Figure 5 – Pilot reports of icing for 970123, c) 1500-1559 and d) 1600-1659 UTC.



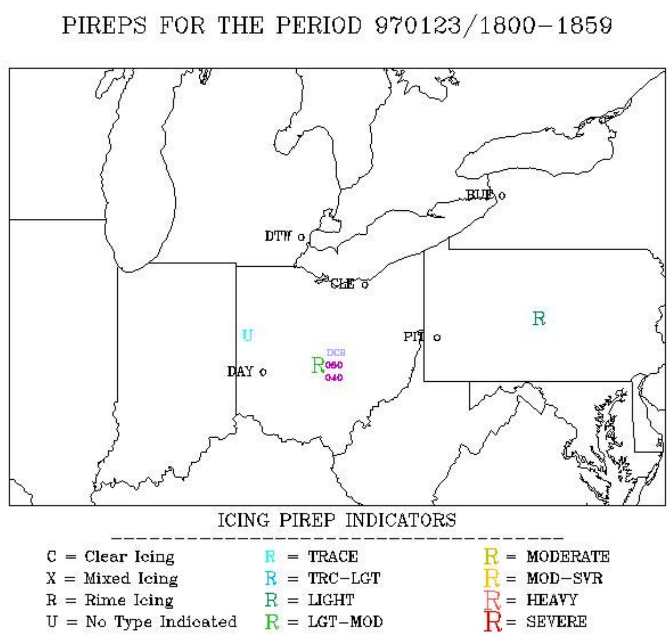


Figure 5 – Pilot reports of icing for 970123, e) 1700-1759 and f) 1800-1859 UTC.

January 27, 1997

Flight #1 - Over Sandusky, Ohio from 1330 to 1552 UTC.

Brief Overview

The Twin Otter made one flight into a stratiform cloud deck between 6000 and 8000 feet over Sandusky, Ohio. This cloud maintained a consistent structure during multiple samples, with LWC increasing from 0.0 at cloud base to 0.25-0.35 near cloud top, and drop sizes gradually increasing from cloud-sized droplets at cloud top to in-focus freezing drizzle within the lowest few hundred feet of the cloud. Freezing drizzle was also observed down to 400 feet below cloud base. This cloud was sampled to the north of a large swath of precipitation approaching from the south. The precipitation area reached the Cleveland area around 1600 UTC, and was first encountered by the Twin Otter at 1540 UTC, when snow crystals were observed at around 9200 feet, well above the liquid cloud top. Soon thereafter, the crystals were observed down to the top of the liquid cloud, then at altitudes as low as 3500 feet.

Relevant weather features

At 1200 UTC, a broad, weak, north-south oriented trough extended from North Dakota to New Mexico at 500 and 700 mb (Fig. 1). Cold advection was present behind this “main” trough. At 500 mb, very dry air was in place across northern Ohio, southeast Michigan, southeast Ontario, New York and Pennsylvania. Saturated conditions approached from the southwest, and had already reached southern Ohio and Indiana. Temperatures were approximately –21 C in the saturated air at this level, and weak, warm advection was present there.

At 700mb, a secondary trough extended from western Wisconsin to central Illinois, and separated dry air to the southwest from saturated air and warm advection to the northeast. The saturated air and warm advection covered the entire forecast area and temperatures within it were near –8 C over Cleveland and –4 C just upstream at Wilmington, Ohio (ILN). At 850 mb, a pocket of dry air was in place across southeast Michigan and northeast Ohio, while saturated conditions were found across the rest of the forecast area. Warm advection was present across Michigan and northern Ohio, to the northeast of the secondary trough.

The 1440 UTC Cleveland sounding data from the NCAR Mobile CLASS (Fig. 2) show the temperature and moisture structure for the location of the Twin Otter flight. Dry air indicated on the 850mb chart is quite evident in the sounding from 820 mb (~6000 feet) to the surface, while saturated conditions (with respect to liquid) and temperatures between –3 and –6 C were present from 820 mb to about 740 mb (~8600 feet). A strong inversion was present from 8600 to 9500 feet. Twin Otter data indicated that cloud top was near the base of the inversion. Although saturated conditions appear to have existed up to 680mb (~11,000 feet) in the sounding data, this may have been due to wetting of the dew point probe, since the Twin Otter data indicated that no cloud was present from approximately 8200 to

11,700 feet (the maximum altitude sampled). A second sounding taken at 1546 UTC indicated that conditions had moistened below cloud base, matching the appearance of snow below 3500 feet at the end of the flight (1552 UTC).

The surface map for 1500 UTC (Fig. 3) shows a weak, 1013 mb low pressure area centered along the western end of the Arkansas/Missouri border. A stationary front extended northeast from the low, across Kentucky. A strong, 1042 mb surface high was centered just north of Vermont and kept relatively cold air in place across the forecast area and the Northeast states. A trough axis was draped across northern Ohio, separating southerly winds to the south of it from southeasterly winds to the north. Rain was mostly occurring to the north of the stationary front, across the southern two-thirds of Ohio, but some freezing rain and ice pellets were observed along the northern edge of the precipitation swath from southwestern Ohio to Kansas City, Missouri. Sounding data from Lincoln, Illinois (ILX – see Fig. 2) indicated that the surface subfreezing layer in the area of the freezing rain was fairly warm (T > -3C) and too shallow to sample on this day. Regional radar data show the northward progression of the precipitation area with time, reaching northern Ohio by 1600 UTC (Fig. 4).

Pilot reports of icing were prevalent within the area of stratiform cloud ahead of the precipitation swath between 5000 and 10000 feet (Fig. 5). The reports included all types of icing and had intensities up to moderate.

No satellite data was available for this case.

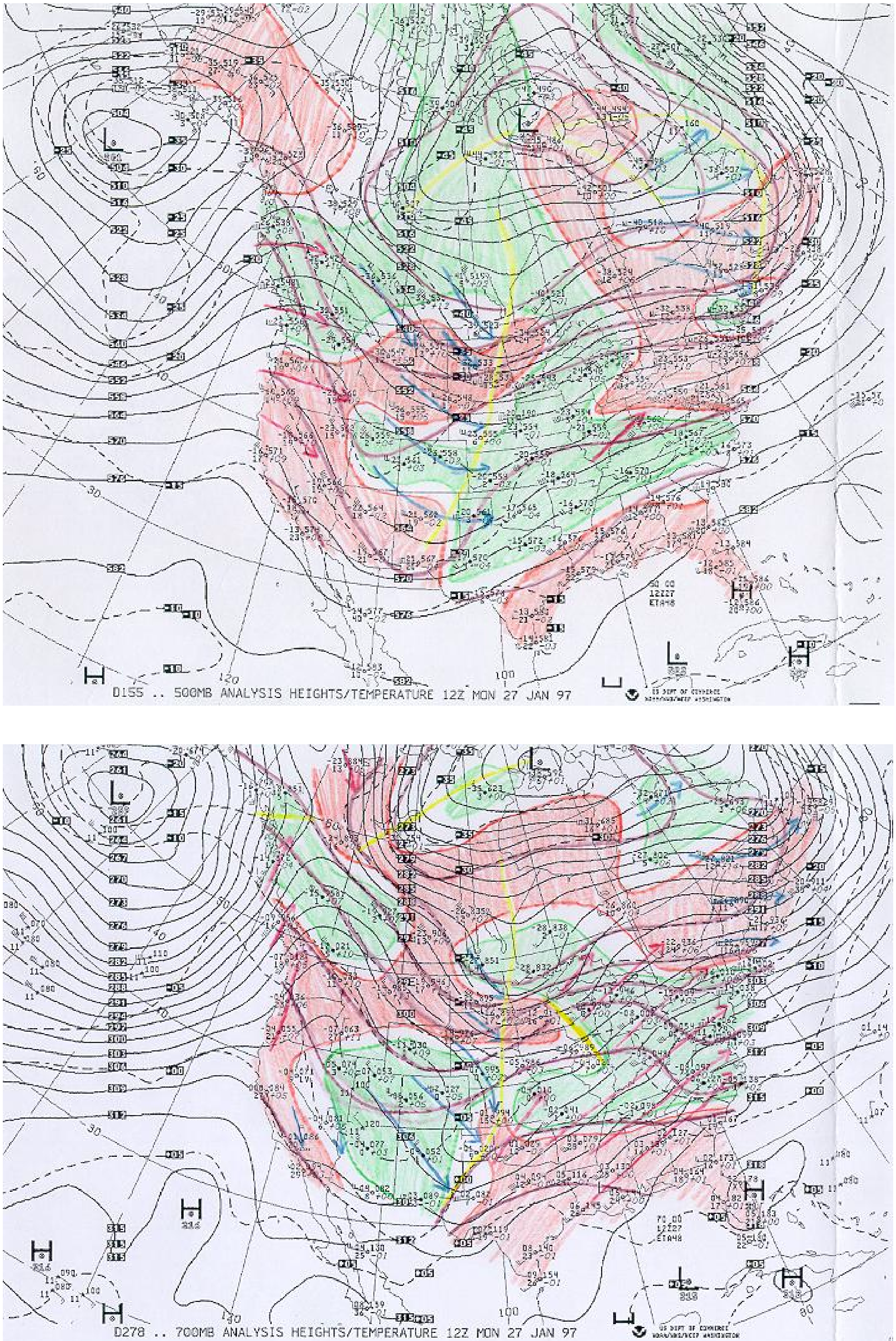


Figure 1 – Upper-air charts for 970127, 1200 UTC at a) 500 and b) 700 mb.

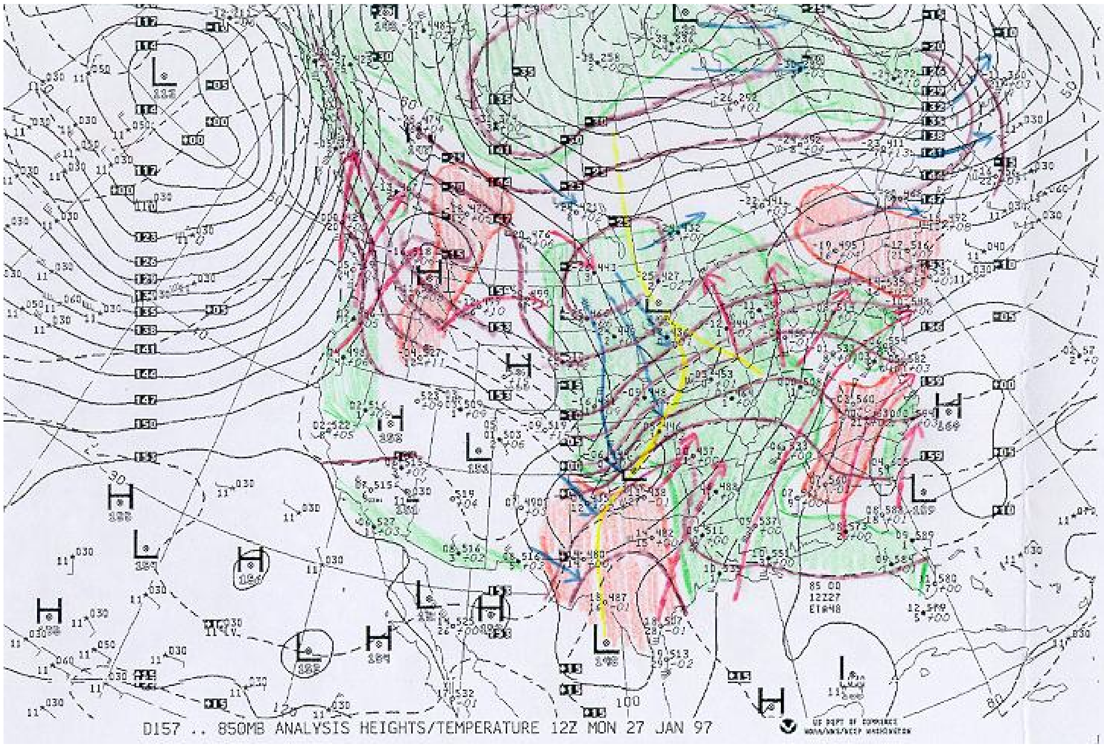


Figure 1 – Upper-air chart for 970127, 1200 UTC at c) 850 mb (300 mb chart was not available).

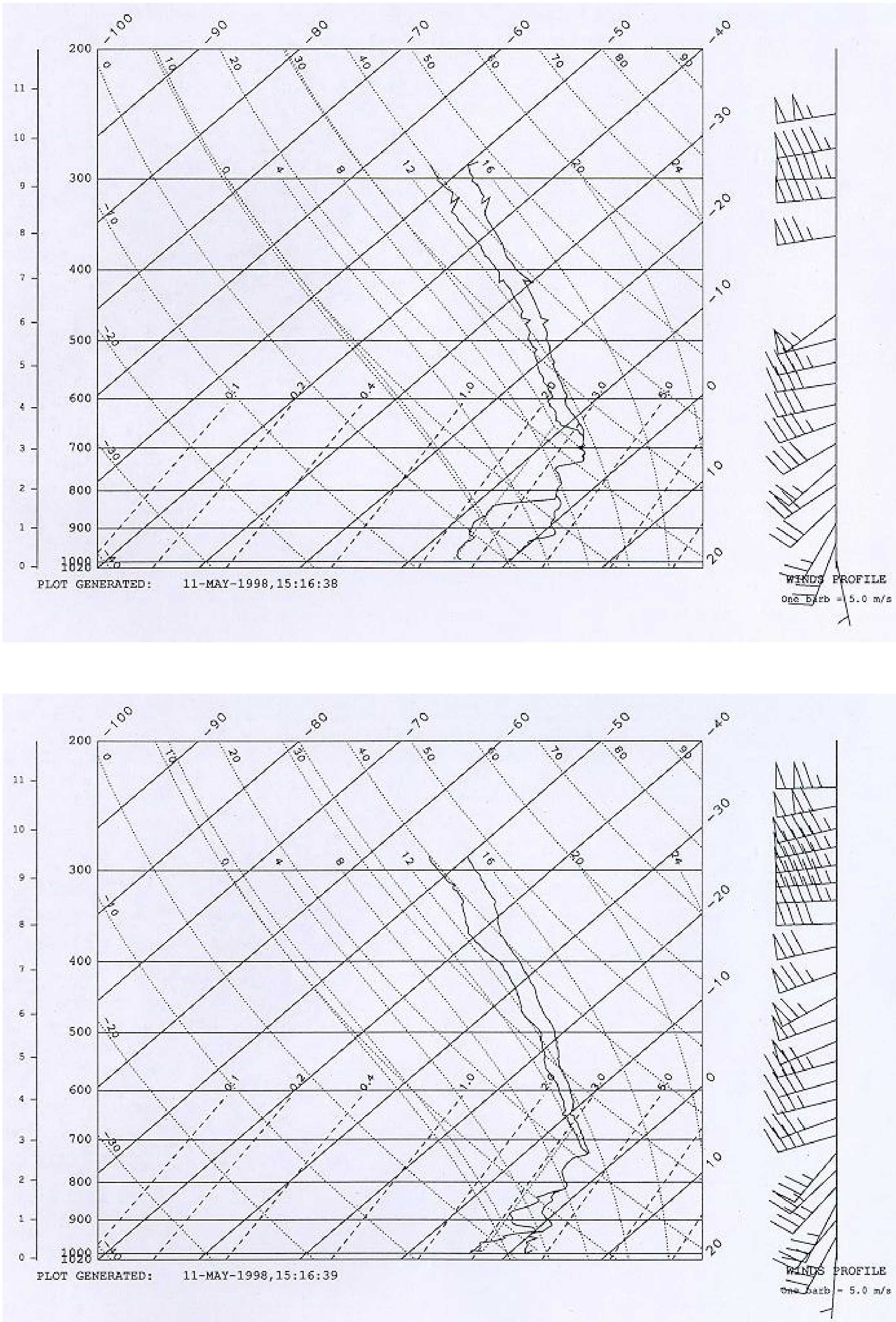


Figure 2 – Balloon-borne soundings from Cleveland for 970127, a) 1440 and b) 1546 UTC.

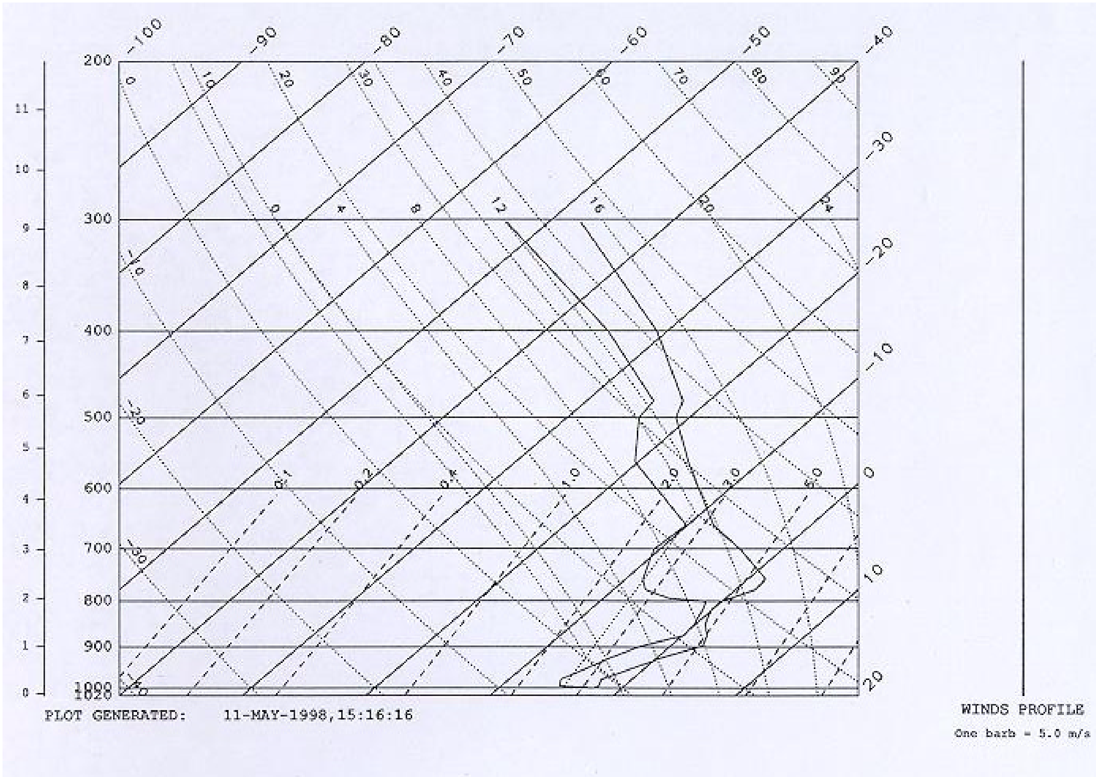


Figure 2 – Balloon-borne soundings for 970127, 1200 UTC at c) Lincoln.

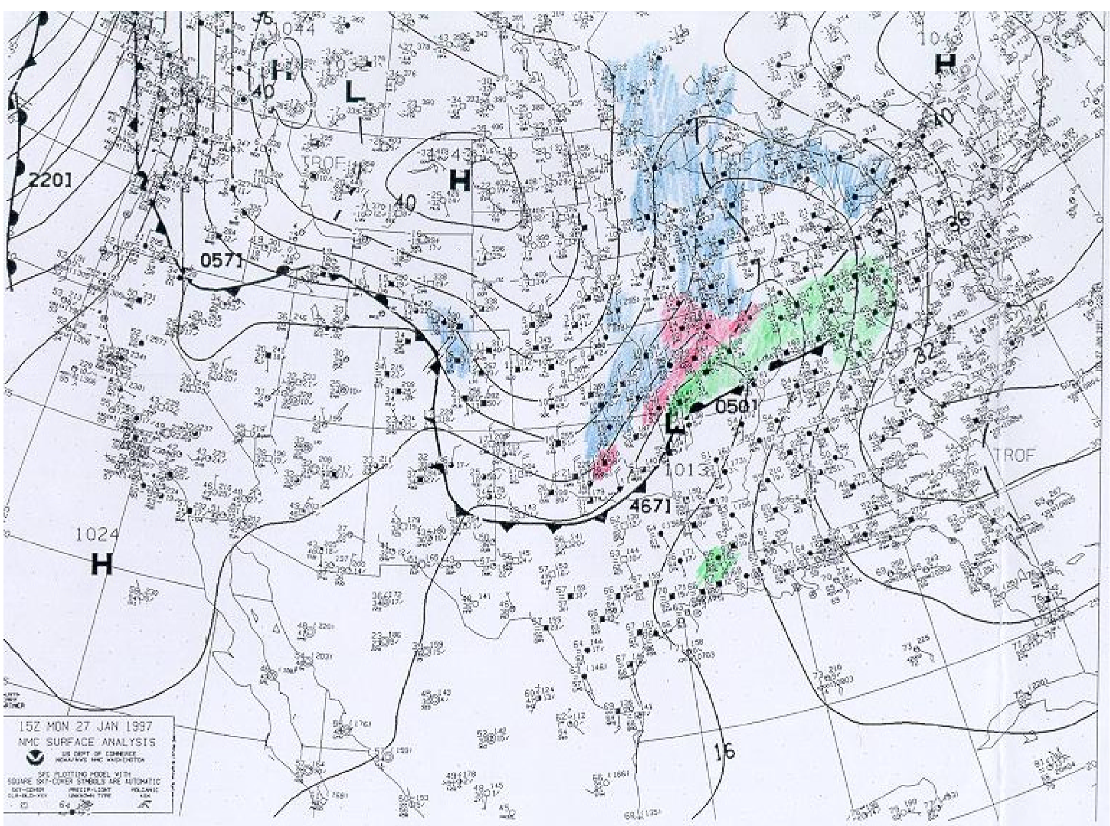
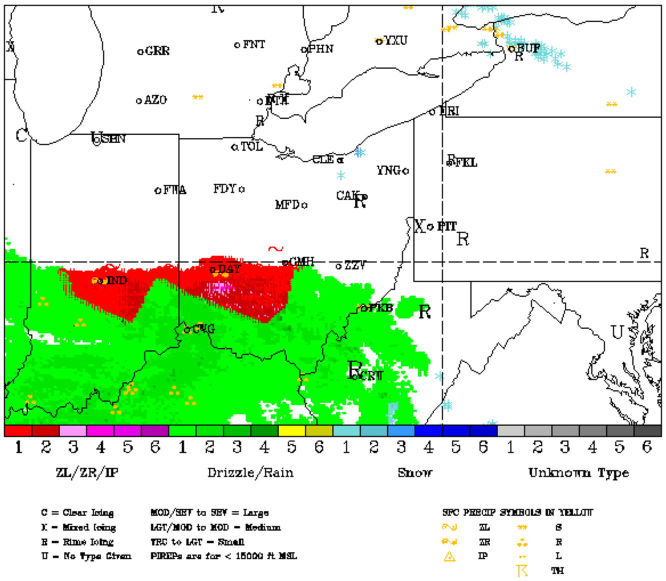


Figure 3 – Surface chart for 970127, 1500 UTC.

RADAR DATA PLOT FOR 970127 AT 13 Z



RADAR DATA PLOT FOR 970127 AT 14 Z

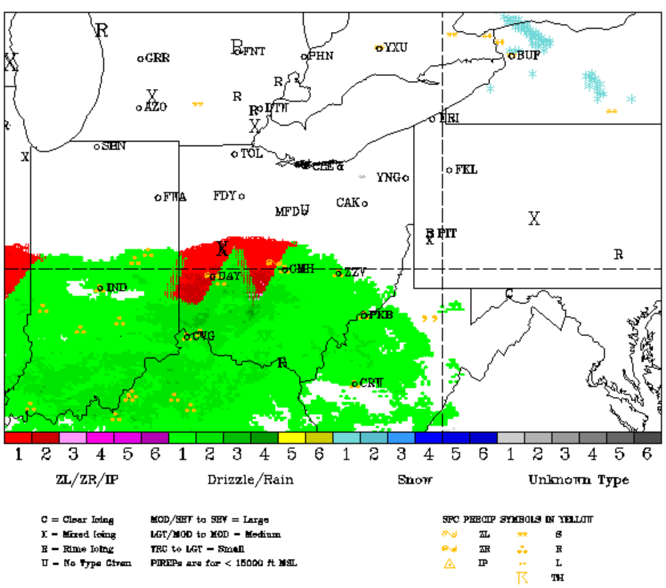
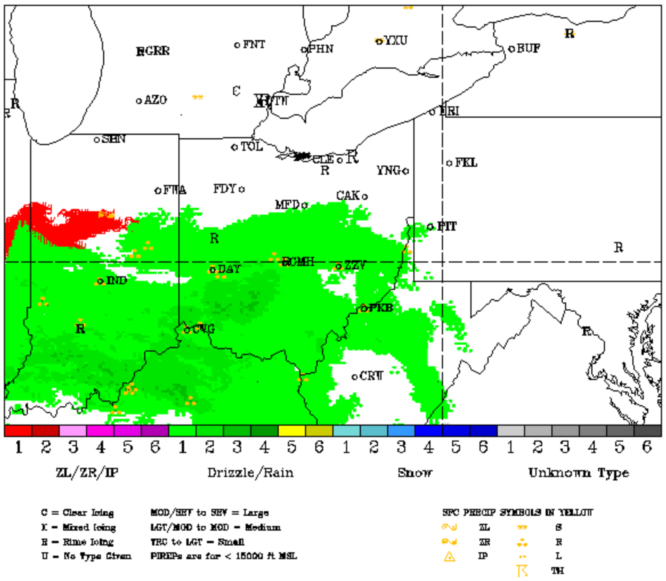


Figure 4 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970127, a) 1300 and b) 1400 UTC.

RADAR DATA PLOT FOR 970127 AT 15 Z



RADAR DATA PLOT FOR 970127 AT 16 Z

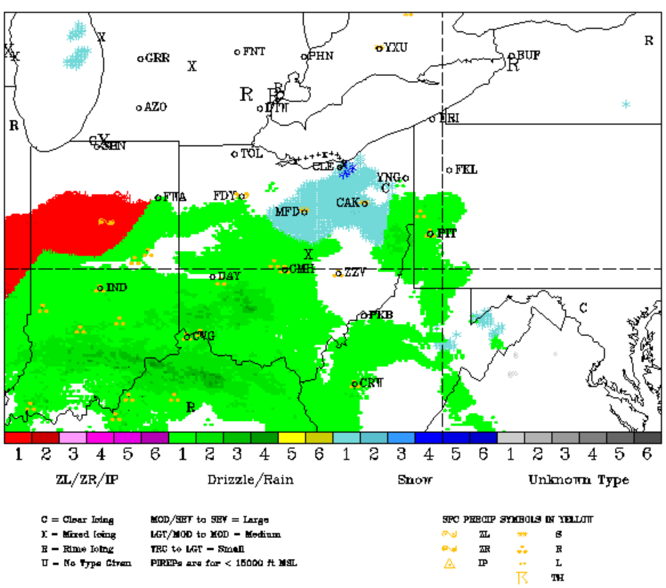
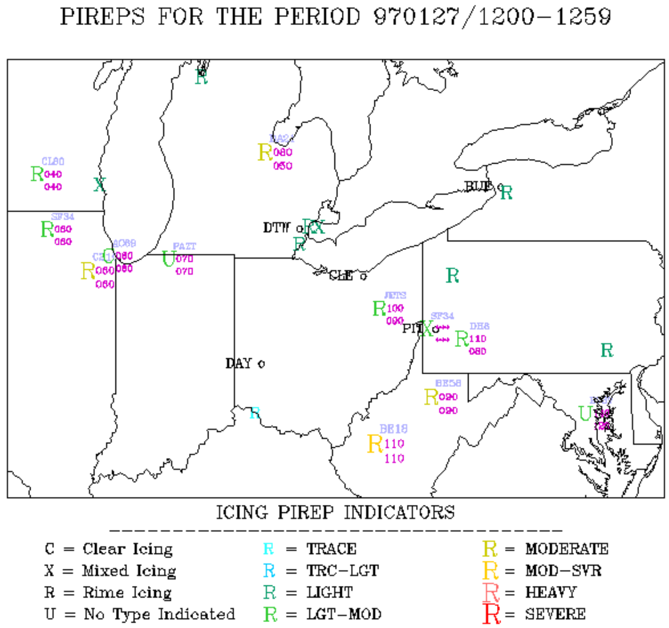


Figure 4 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970127, c) 1500 and d) 1600 UTC.



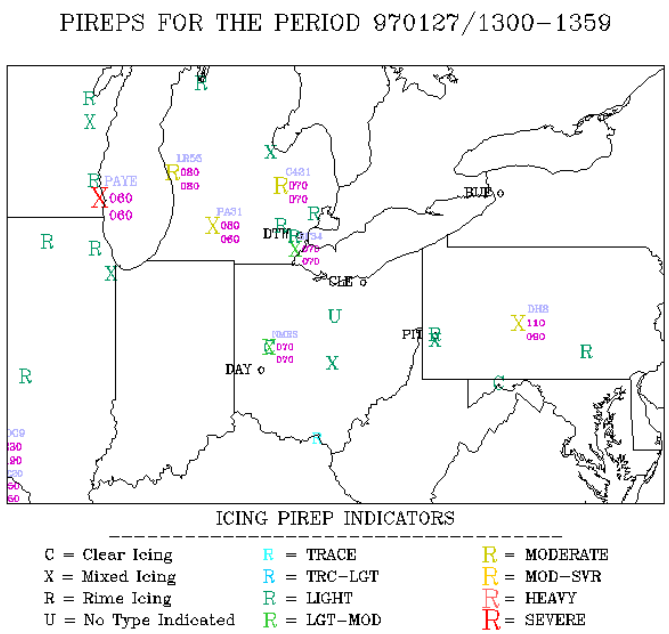
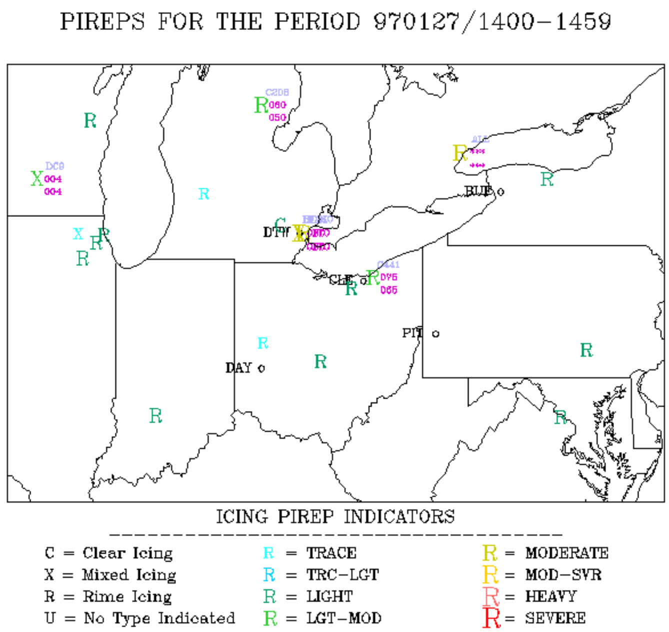


Figure 5 – Pilot reports of icing for 970127, a) 1200-1259 and b) 1300-1359 UTC.



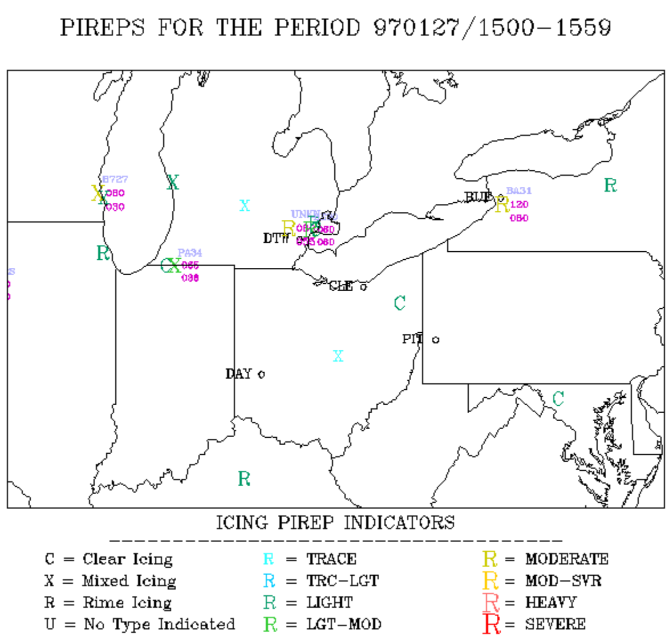


Figure 5 – Pilot reports of icing for 970127, c) 1400-1459 and d) 1500-1559 UTC.

January 31, 1997

Flight #1 - Between Cleveland and Parkersburg (WV), and over Parkersburg from 1558 to 1815 UTC.
Flight #2 - Over Parkersburg and enroute to Cleveland from 1928 to 2103 UTC.

Brief overview

Two flights were made on this day. Flight #1 was made within and ahead of an area of precipitation that was moving southeast across Ohio into Pennsylvania and West Virginia. During the first hour of the flight, the aircraft traversed the precipitation area enroute to Parkersburg. Within the precipitation area, mostly crystals with LWC = 0.0 and possibly a little freezing drizzle were encountered. The aircraft began to break out of the precipitation area to the northwest of Parkersburg at approximately 1700 UTC. To the southeast of the precipitation shield, areas of all-water cloud with pockets of in-focus freezing drizzle and LWC as high as 0.45 were observed between 9600 and 11000 feet. Some pockets of crystals, including columns and aggregates were occasionally encountered. Irregular layers of cloud were present below 9600 feet and crystals were more prevalent at those altitudes, down to 4500 feet.

Flight #2 was simply a return flight from Parkersburg to Cleveland. The microphysical probes were not operable during the first part of this flight, until 1955 UTC, when the aircraft had nearly reached Canton-Akron. Mostly crystals were encountered during that flight, with some pockets of all-water cloud. LWC values were as high as 0.3 at 11300 feet, where temperatures were approximately -7 C.

Relevant weather features

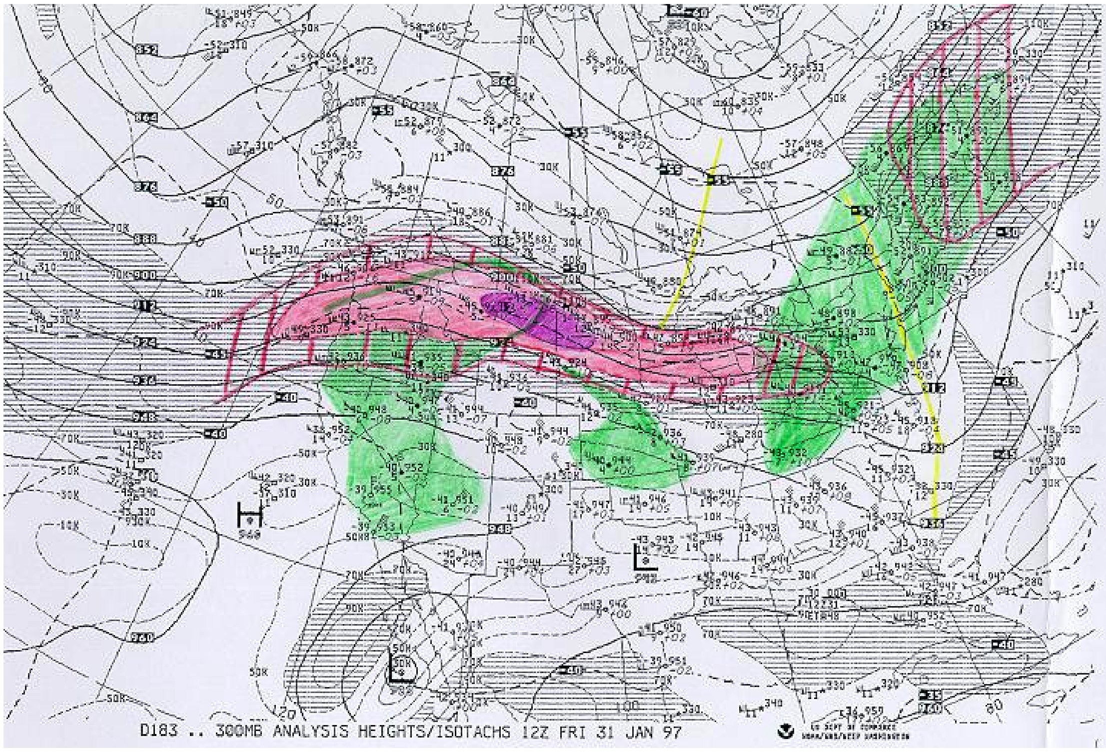
At 1200 UTC, two 500 mb troughs extended into the lower 48 from an upper low centered north of Hudson's Bay (Fig. 1). The eastern trough ran south through central Pennsylvania to the Carolina coast. A pocket of cold air preceded this trough and warm advection was present behind it, across eastern Ohio, West Virginia, Pennsylvania, and New York. Saturated conditions covered most of the forecast area, except Pennsylvania, West Virginia and southeastern Ohio, where dry air was in place. Temperatures were approximately -18 C in the saturated air over Ohio at this level. At 700 mb, a weak trough was in place from Detroit to Georgia, and traversed central Ohio. A lobe of saturated air was present ahead of this trough across western Pennsylvania, eastern Ohio, southeastern Ontario, and Michigan. Warm advection was evident across the entire forecast area. At 850 mb, the trough axis extended southeast from a low over Minnesota to western Pennsylvania, then southwest into Georgia. Dry air and warm advection were found behind this trough, across Ohio, and western West Virginia.

The 1500 UTC surface chart (Fig. 2) shows a 992 mb low centered along the Minnesota-Wisconsin border, with a warm front extending southeast to Cleveland. Snow was falling across northern Ohio, southeastern Ontario, and eastern Michigan, according to both the surface observations and radar mosaic (Fig. 3). By 1800 UTC, the warm front pushed slightly to the northeast, as the low tracked eastward to Green Bay, Wisconsin. The precipitation area moved eastward across Ohio to just north of the Ohio-West Virginia border, covering much of Ohio, northwestern Pennsylvania and western New York.

Twin Otter tracks for 1600-1630 UTC (Fig. 3c) appear to show the aircraft skimming the eastern edge of the precipitation shield. However, since the radar data was for 1600 UTC and the precipitation shield was moving quickly to the southeast, the aircraft was actually well within the precipitation until ~1700 UTC, when it broke out of its southeastern edge (Fig. 3d).

Scattered pilot reports of icing were made around and within the precipitation swath between 13000 and 23000 feet (Fig. 4). Icing types were mostly rime, but some mixed reports were received. Icing intensities were as high as moderate outside and along the edges of the precipitation, but only trace to light PIREPs were made within it.

Satellite data was not available for this case.



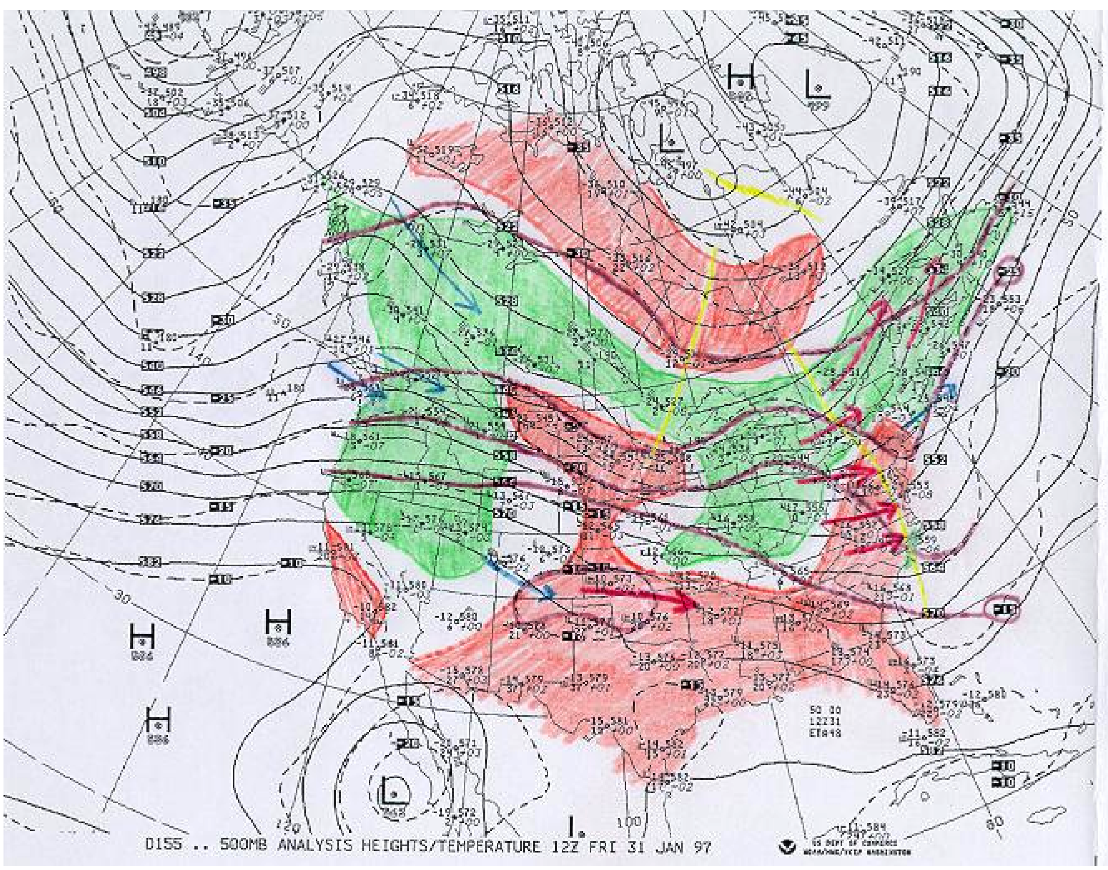
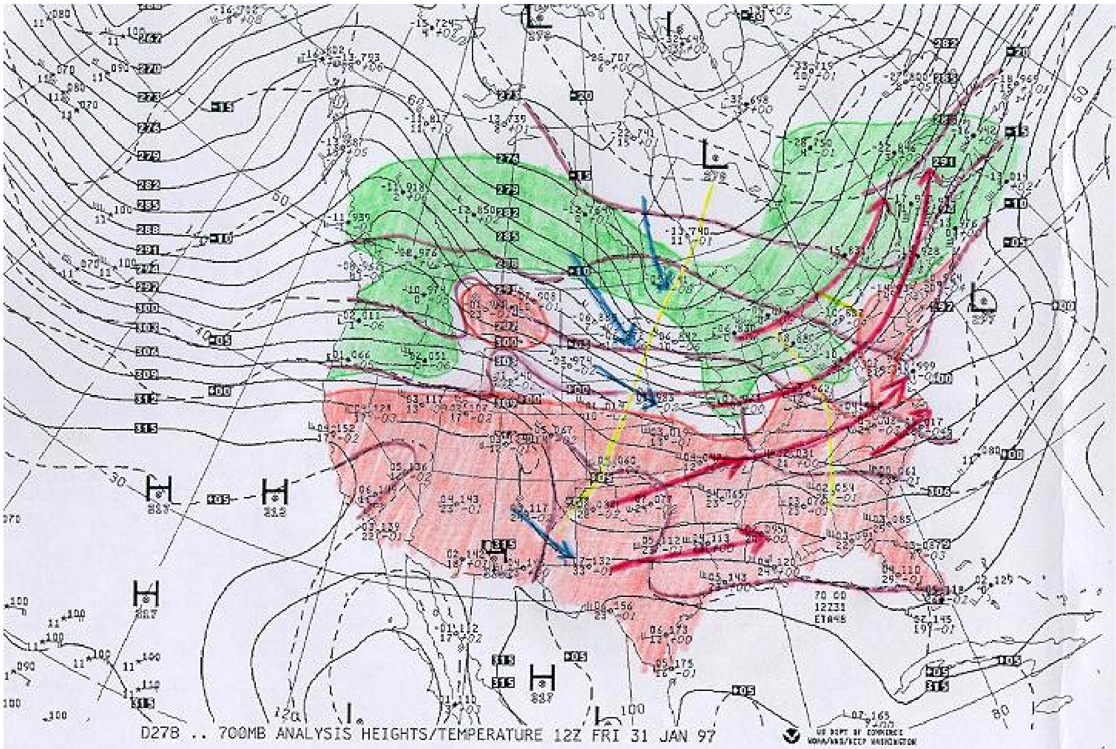


Figure 1 – Upper-air charts for 970131, 1200 UTC at a) 300 and b) 500 mb.



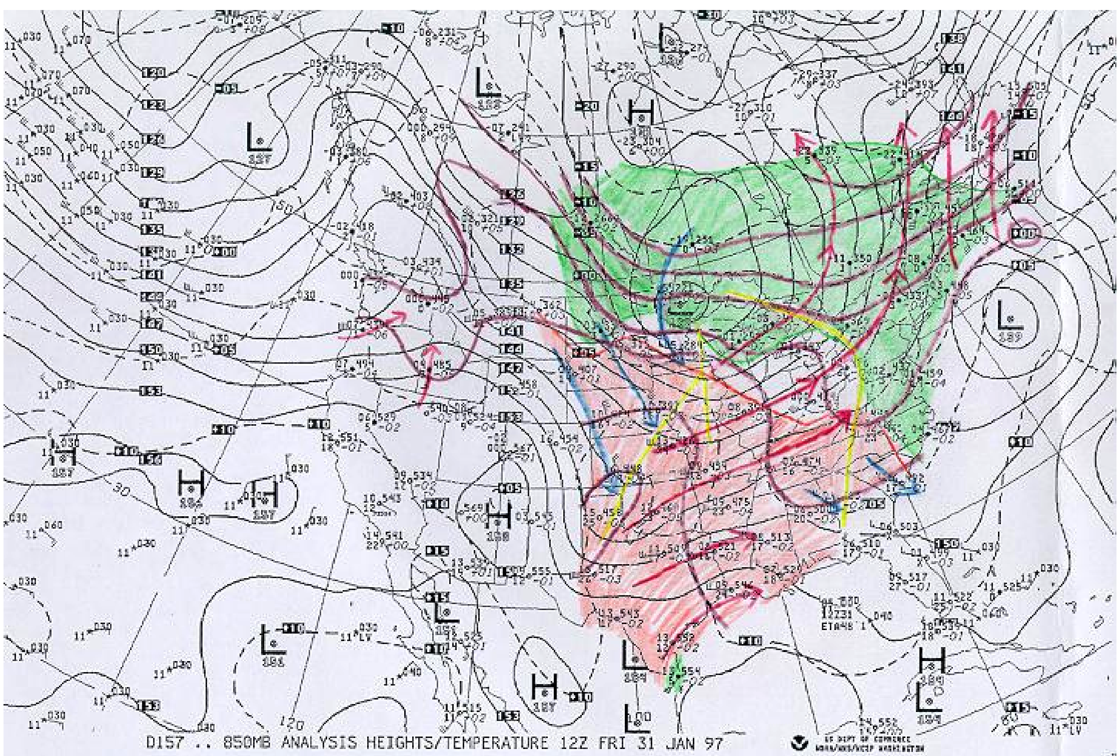


Figure 1 – Upper-air charts for 970131, 1200 UTC at c) 700 and d) 850 mb.

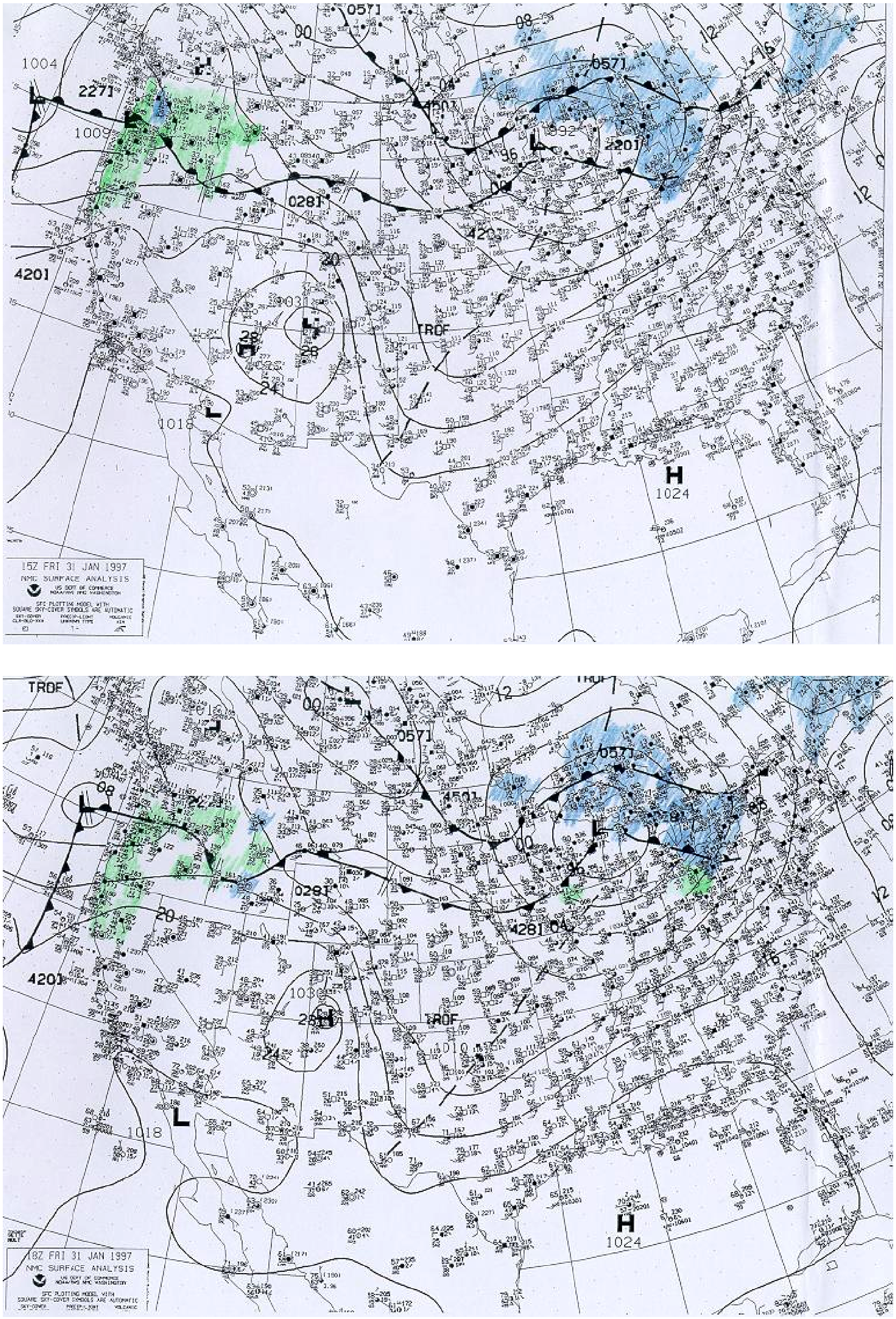


Figure 2 – Surface charts for 970131, a) 1500 and b) 1800 UTC.

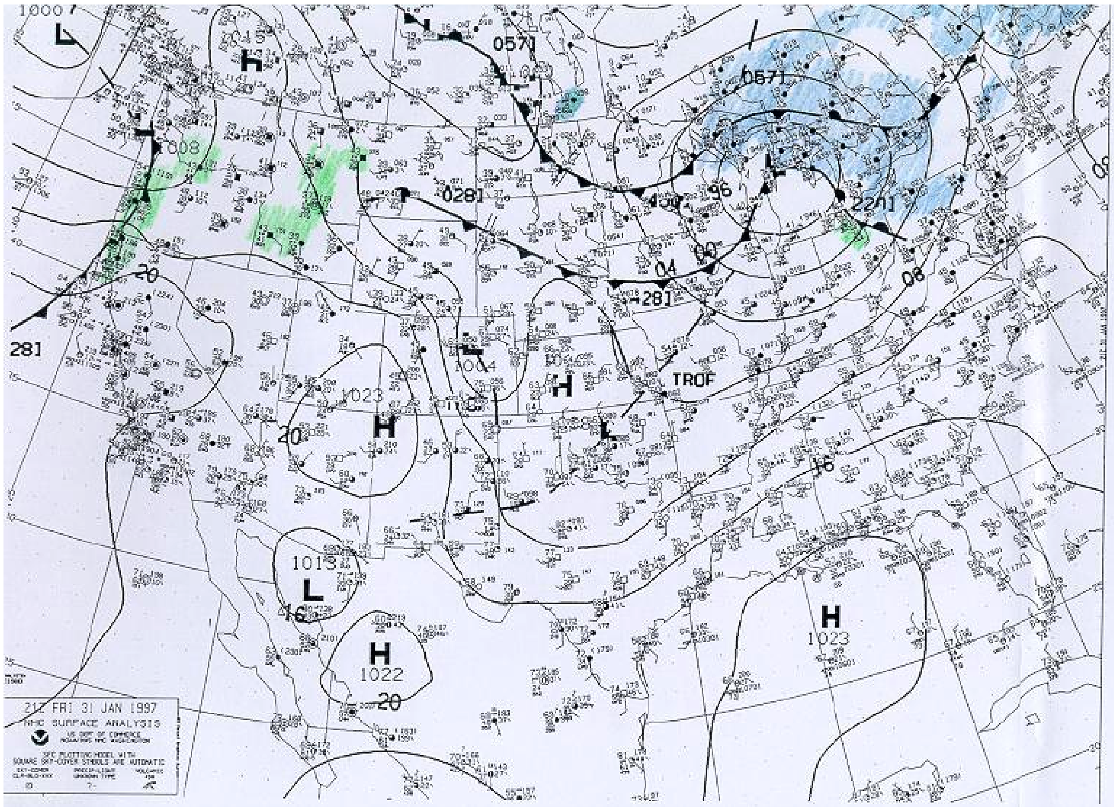
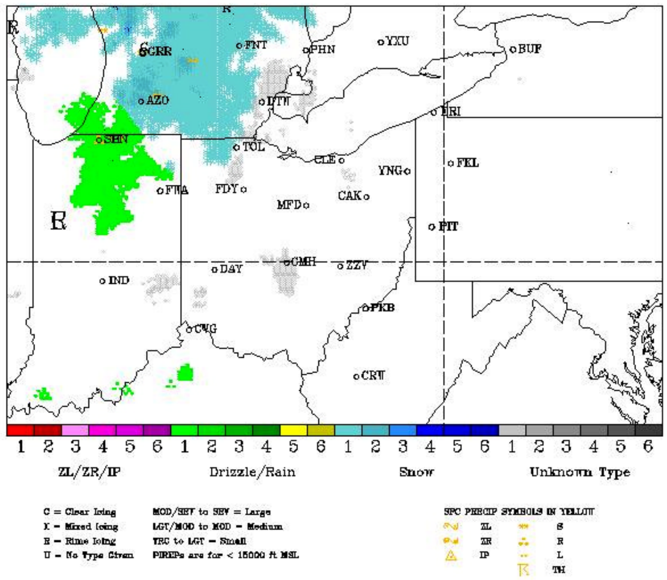


Figure 2 – Surface charts for 970131, c) 2100 UTC.

RADAR DATA PLOT FOR 970131 AT 14 Z



RADAR DATA PLOT FOR 970131 AT 15 Z

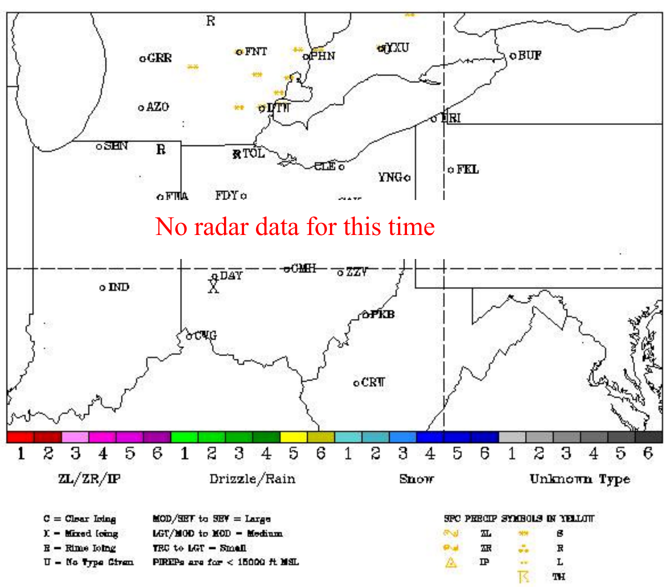
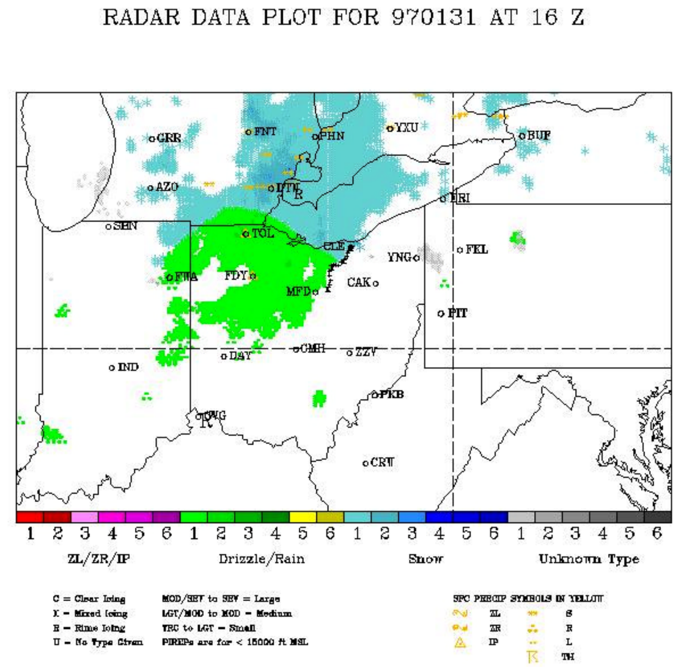


Figure 3 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970131, a) 1400 and b) 1500 UTC (1500 UTC radar data was not available).



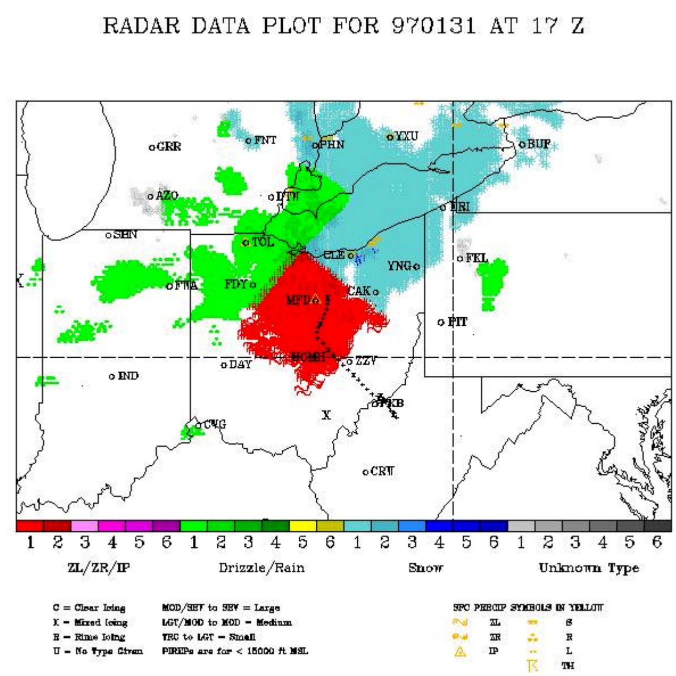


Figure 3 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970131, c) 1600 and d) 1700 UTC.

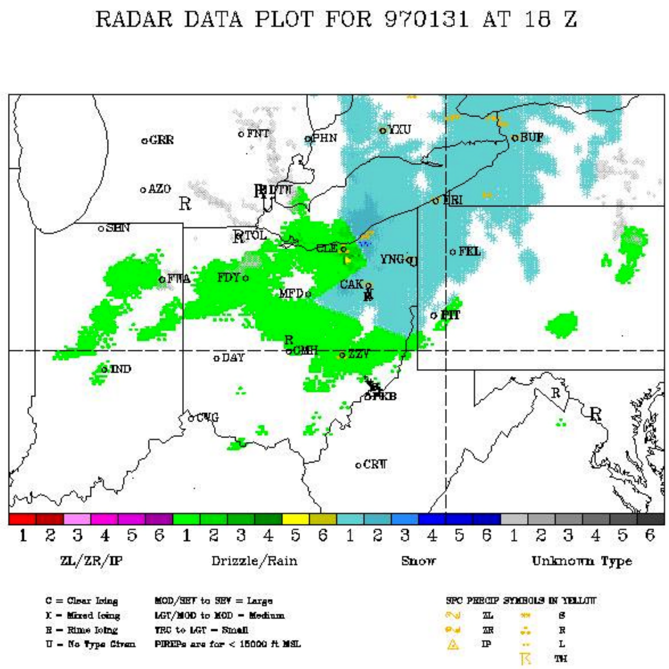


Figure 3 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970131, e) 1800 UTC.

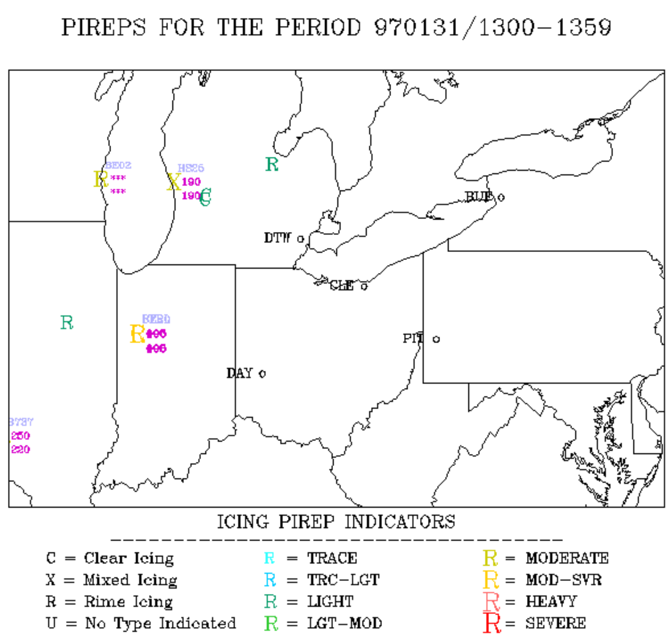
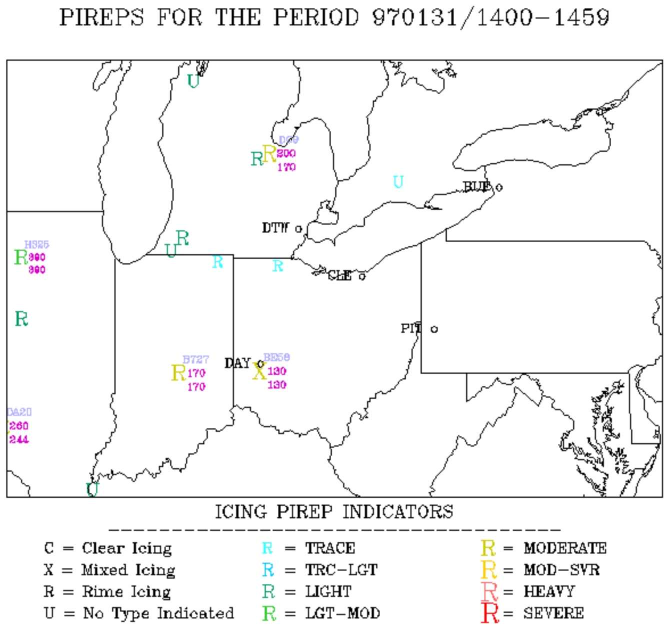


Figure 4 – Pilot reports of icing for 970131, a) 1300-1359 UTC.



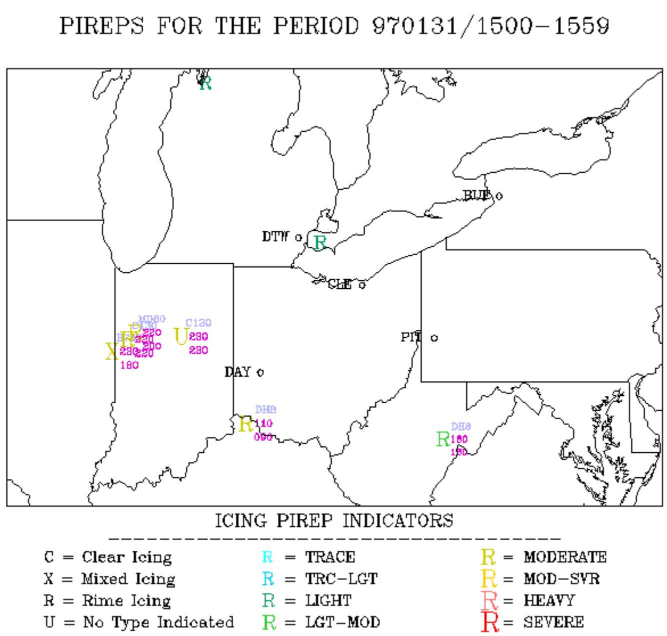
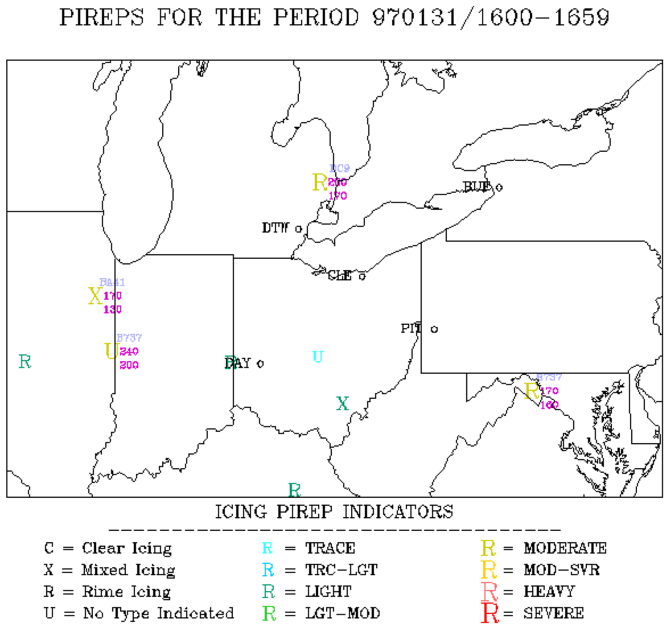


Figure 4 – Pilot reports of icing for 970131, b) 1400-1459 and c) 1500-1559 UTC.



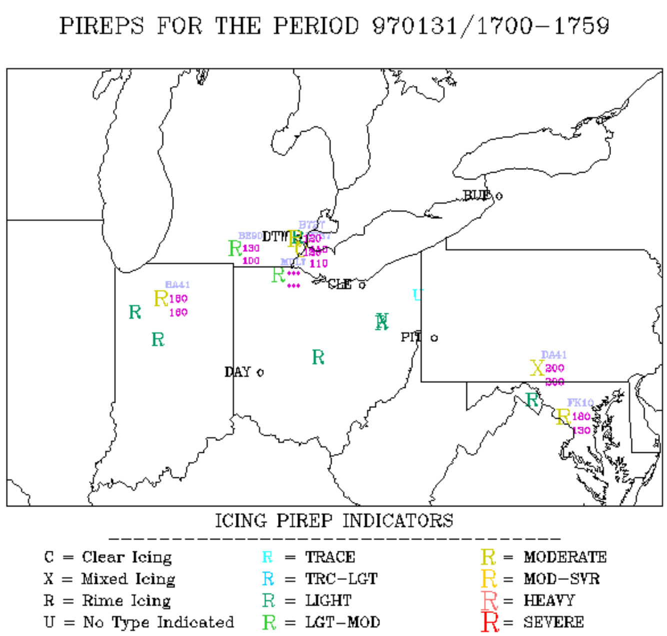


Figure 4 – Pilot reports of icing for 970131, d) 1600-1659 and e) 1700-1759 UTC.

PIREPS FOR THE PERIOD 970131/1800-1859

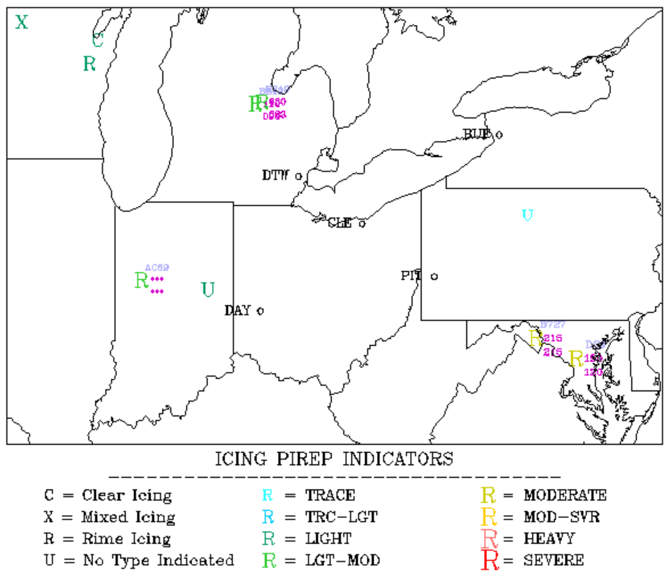


Figure 4 – Pilot reports of icing for 970131, f) 1800-1859 UTC (data for 1900-1959 UTC was not available).

February 4, 1997

Flight #1 – Over northeast Ohio and northwest Pennsylvania from 1312 to 1441 UTC.

Brief overview

Two flights were made on this day. An in depth analysis of the second flight can be found in the "premier cases" document. The first flight was made over northeastern Ohio within a widespread area of precipitation and deep, cold cloud. Rain and drizzle were observed below approximately 7000 feet, and the melting level was near 7500 feet. Snow was observed above the melting level, and consisted of columns, capped columns, plates, needles, irregulars, and aggregates. It is possible that some in-focus and out-of-focus freezing drizzle may have also existed above the freezing level. Occasional pockets of LWC up to 0.1 were observed, but LWC was near 0 during most of the flight.

Relevant weather features

At 1200 UTC, a closed low was centered over the Iowa-Missouri border at 500 and 700 mb (Fig. 1). A number of troughs were attached to the low, including one which ran east across the Michigan-Ohio border and another which ran essentially north-south from Chicago to New Orleans. This second trough separated dry air to the west from saturated air to the east, which nearly all of the forecast area. Temperatures in the saturated air over Ohio were approximately –18 C. The moisture was more extensive at 700 mb, covering as far west as the Illinois-Missouri border, while dry air was present across northern Michigan, southeastern Ontario, New York, and northeastern Pennsylvania, roughly along and northeast of a ridge axis. Warm advection was present ahead of the second trough at both 500 and 700 mb.

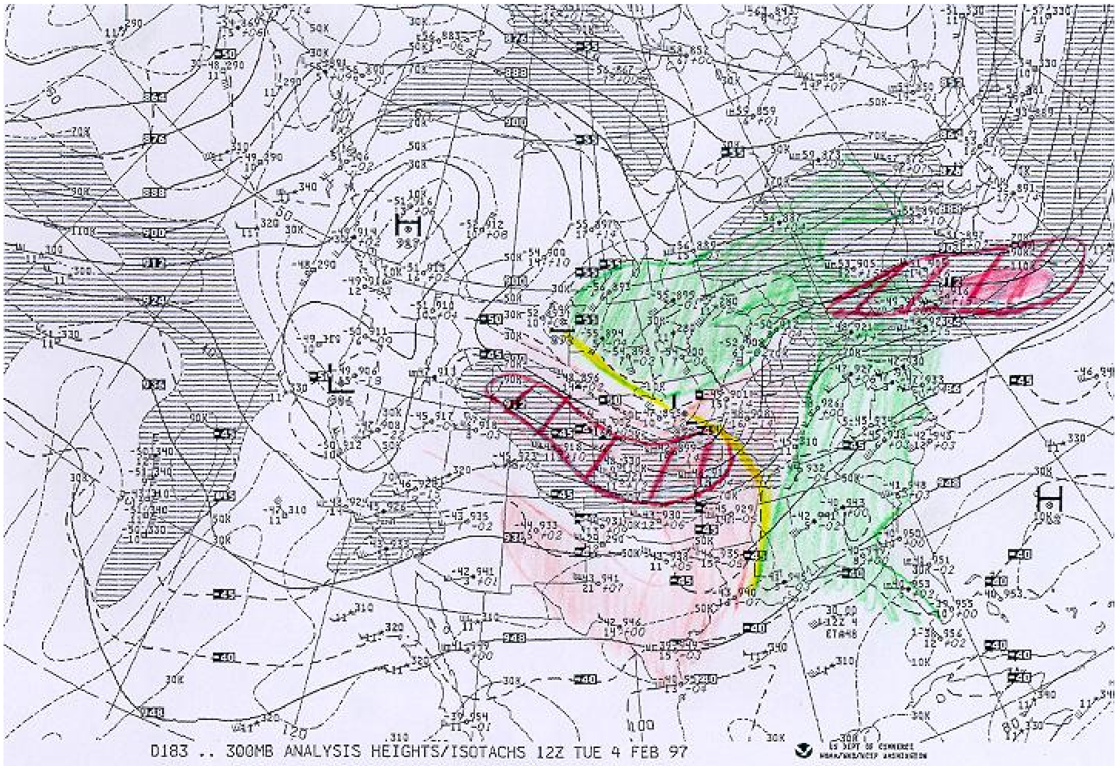
The Missouri-Iowa low was stronger at lower altitudes and had several closed contours at 700 and 850 mb. At 850 mb, saturated conditions and warm advection again covered the forecast area, except for dry air across most of Michigan, southeastern Ontario, New York, and northeastern Pennsylvania. This dry air was in the wake of a high/ridge centered along the East Coast, with a ridge axis extending northwest across New York and southeastern Ontario. Sounding data from Buffalo at 1200 UTC reveal the deep, dry air to the northeast of Cleveland, while the Wilmington sounding indicates deep, saturated conditions over Ohio (Fig. 2).

Surface maps were not available from 0900 to 1500 UTC, but the 0600 UTC surface map (Fig. 3) shows a weak, disorganized, 1013 mb low sprawled across Missouri and Arkansas, with a warm front which extended eastward across Kentucky, and connected to a stationary front in the Carolinas. A strong, 1039 mb high was centered in southwestern Quebec and nosed southward down the East Coast, to the north of the stationary front, as well as westward across the Great Lakes. A broad swath of rain was present along and to the north of the warm front, across Kentucky, southern Ohio and southern Indiana. By 1800 UTC, the surface low became well organized, depend to 1006 mb and moved northeast to Chicago, dragging the warm front with it. The warm front extended southeastward from the low, across southwestern Ohio to the western Carolinas. The broad swath of precipitation also moved northeast into extreme eastern Ohio, western Pennsylvania, southeastern Ontario, and Michigan by 1800 UTC, crossing Ohio during the period of the first flight. Maps of the surface precipitation type for 1400 and 1500 UTC (Fig. 4) confirm that rain was occurring across all of Ohio and was moving into Pennsylvania and Michigan. Some freezing rain was occurring at the leading edge of the rain swath. The first flight took place within and just ahead of the leading portion of this precipitation.

Satellite data for 1500 UTC (none was available before 1500 UTC) show the area of deep, cold cloud to the east of a line from northern Lake Michigan across Toledo to Cincinnati, with shallower, warmer (-10 C) cloud across western Ohio (Fig. 5). The freezing drizzle observed during the second flight (premier case) occurred with this area of warmer cloud.

Most of the pilot reports of icing were made within the trailing, warmer cloud to the west (Fig. 6). The icing was up to moderate intensity, of all types and at altitudes between 3000 and 16000 feet.

Radar mosaic data was not available for this case.



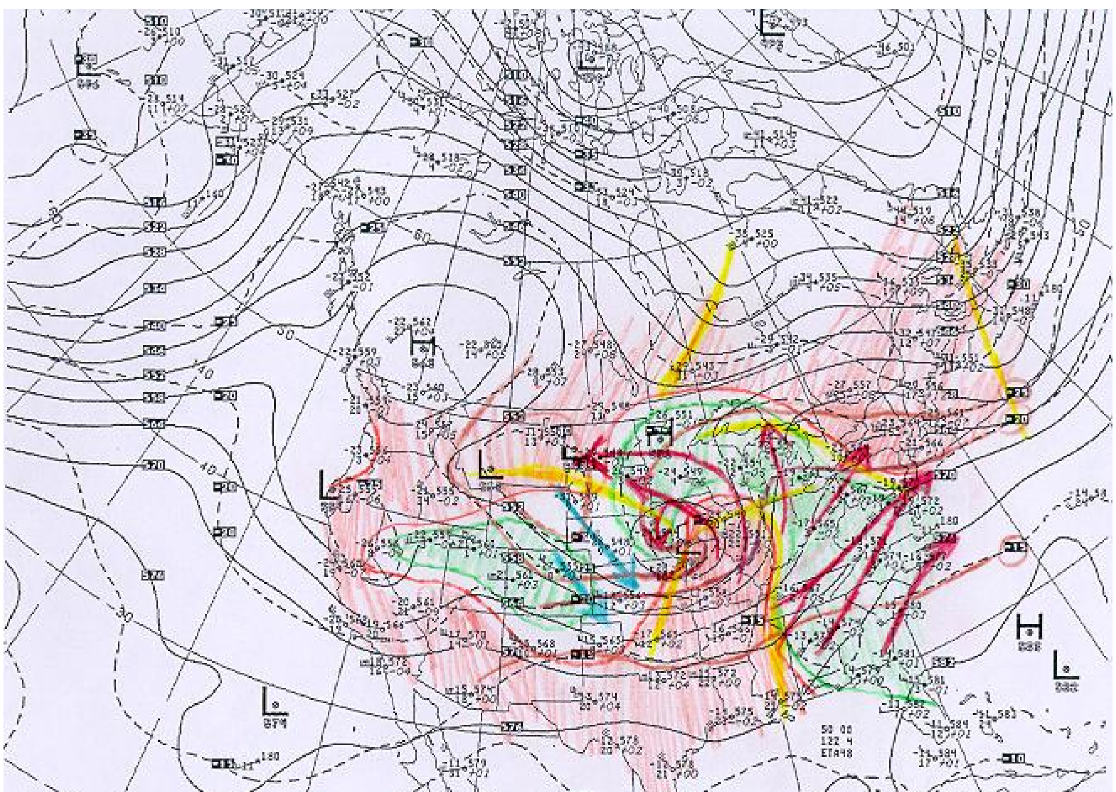
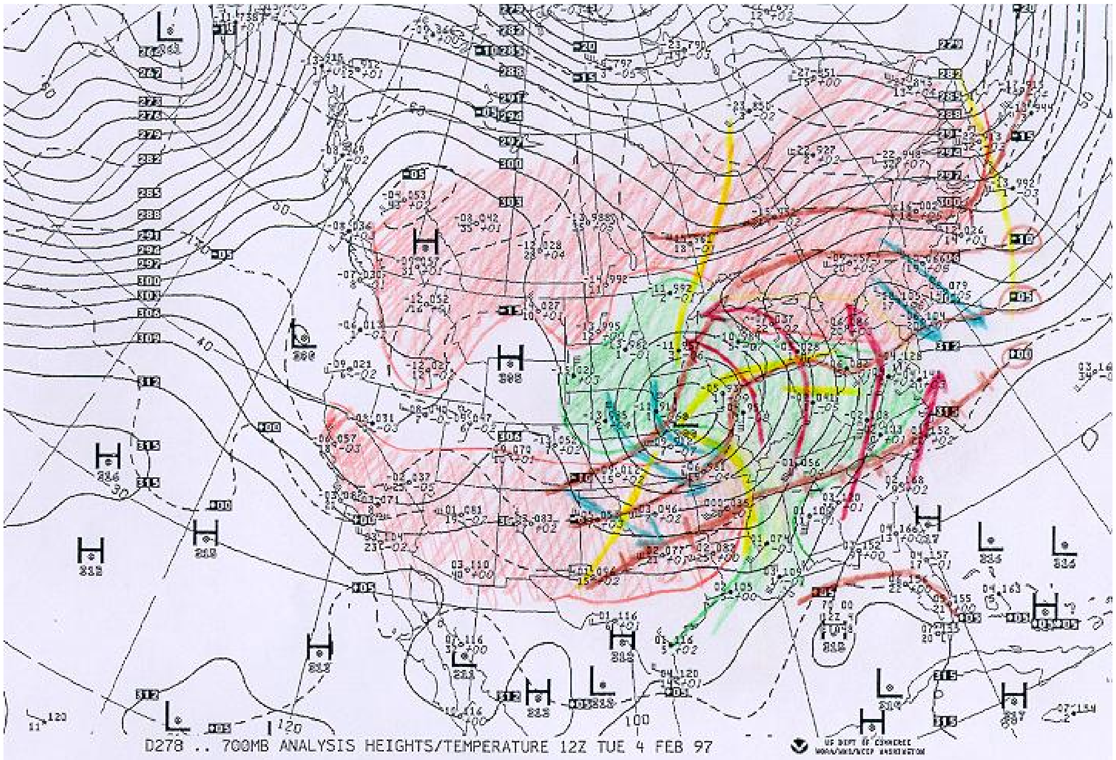


Figure 1 – Upper-air charts for 970204, 1200 UTC at a) 300 and b) 500 mb.



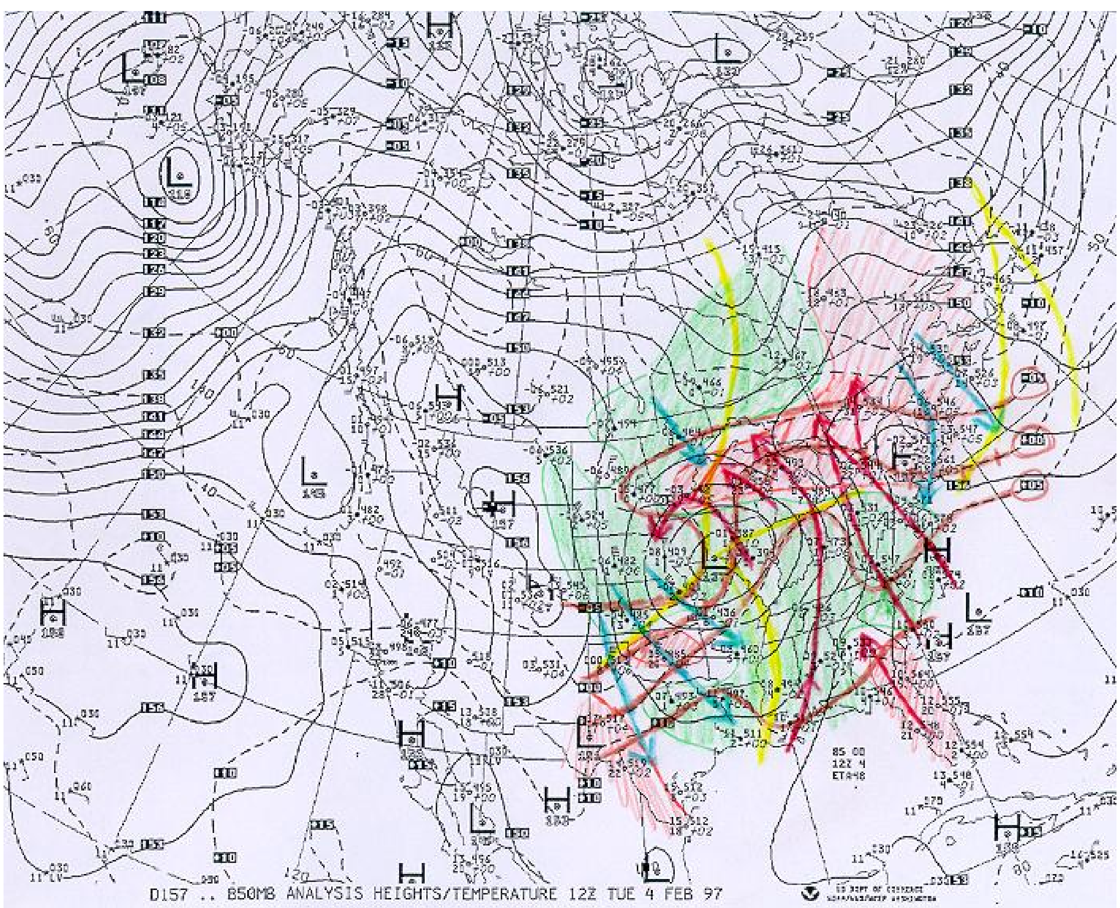
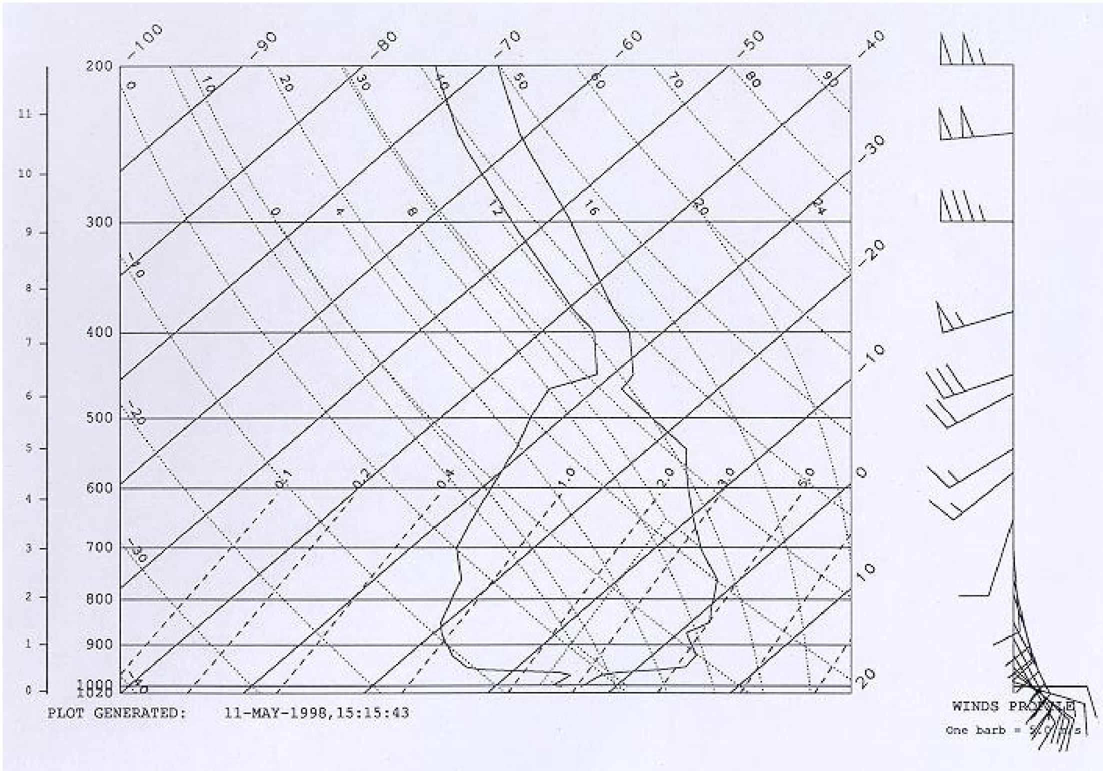


Figure 1 – Upper-air charts for 970204, 1200 UTC at c) 700 and d) 850 mb.



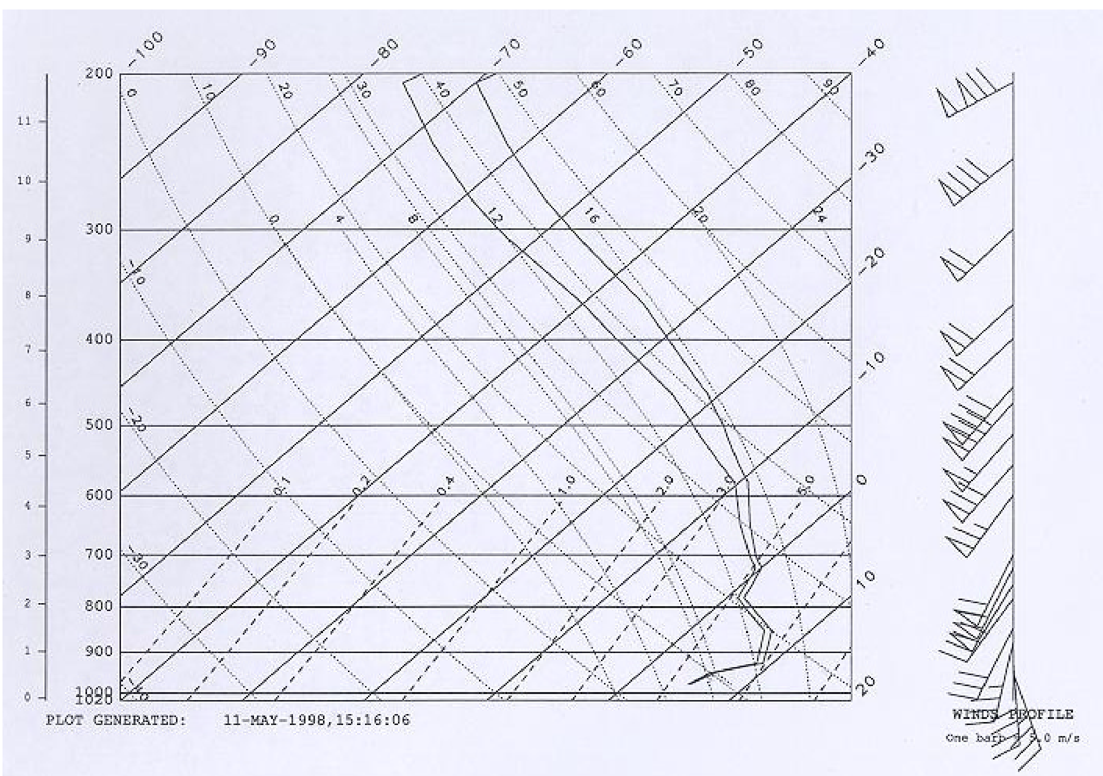


Figure 2 – Balloon-borne sounding data for 970204, 1200 UTC at a) Buffalo and b) Wilmington.

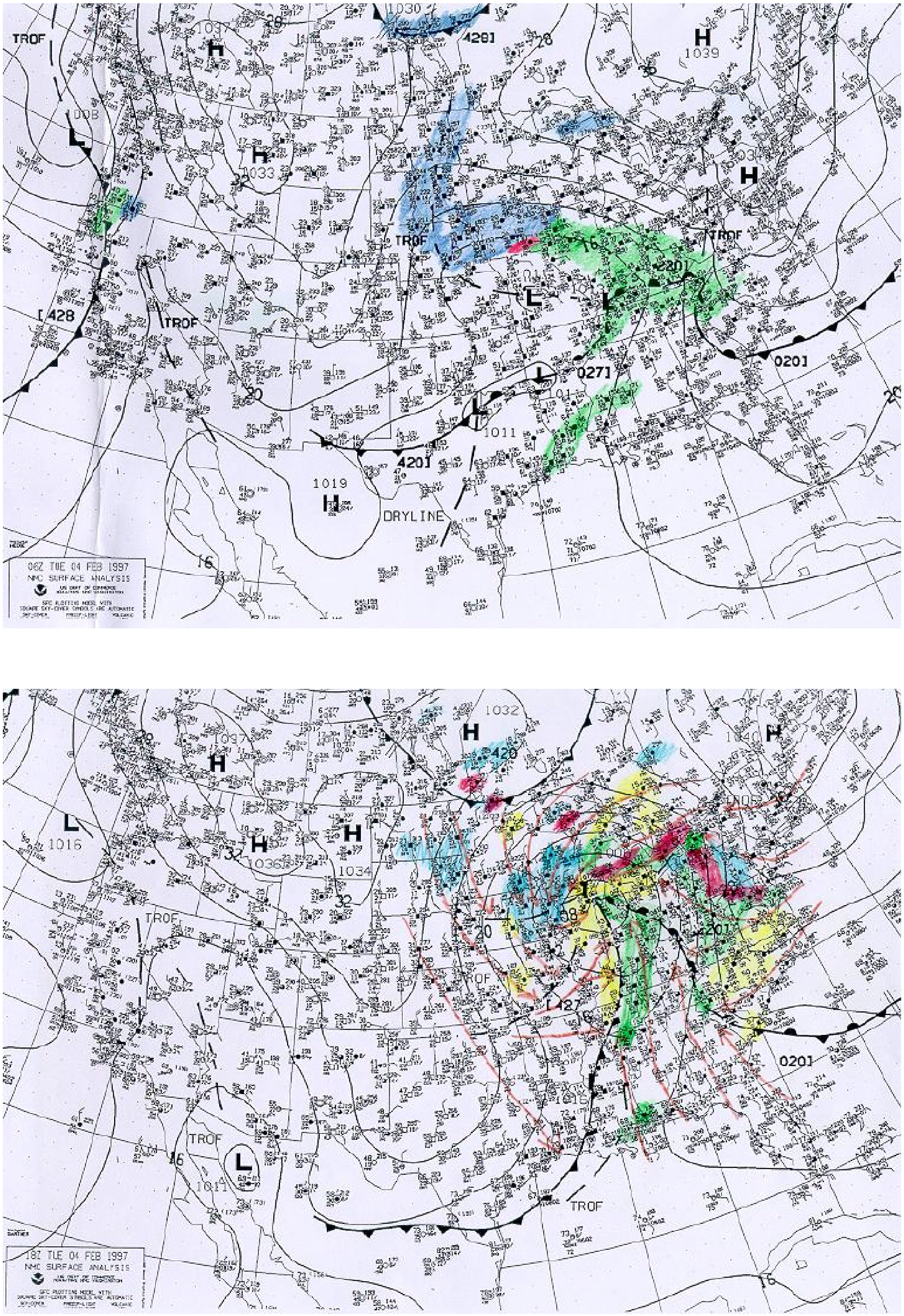


Figure 3 – Surface charts for 970204, a) 0600 and b) 1800 UTC.

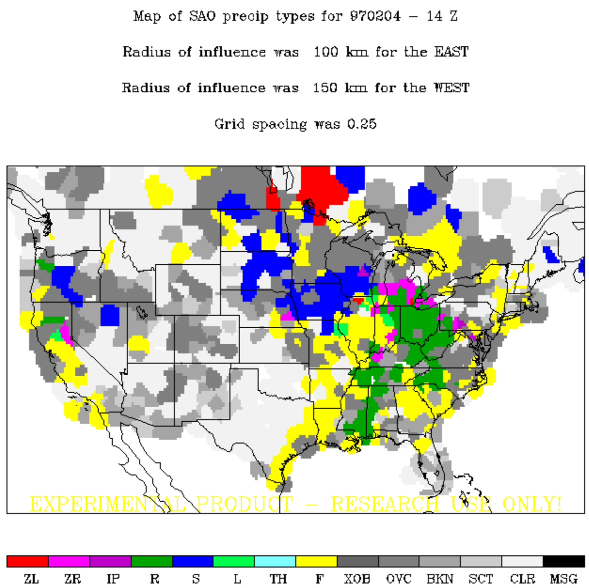


Figure 4 – Observed precipitation type and cloud cover from surface stations for 970204, a) 1400 and b) 1500 UTC.

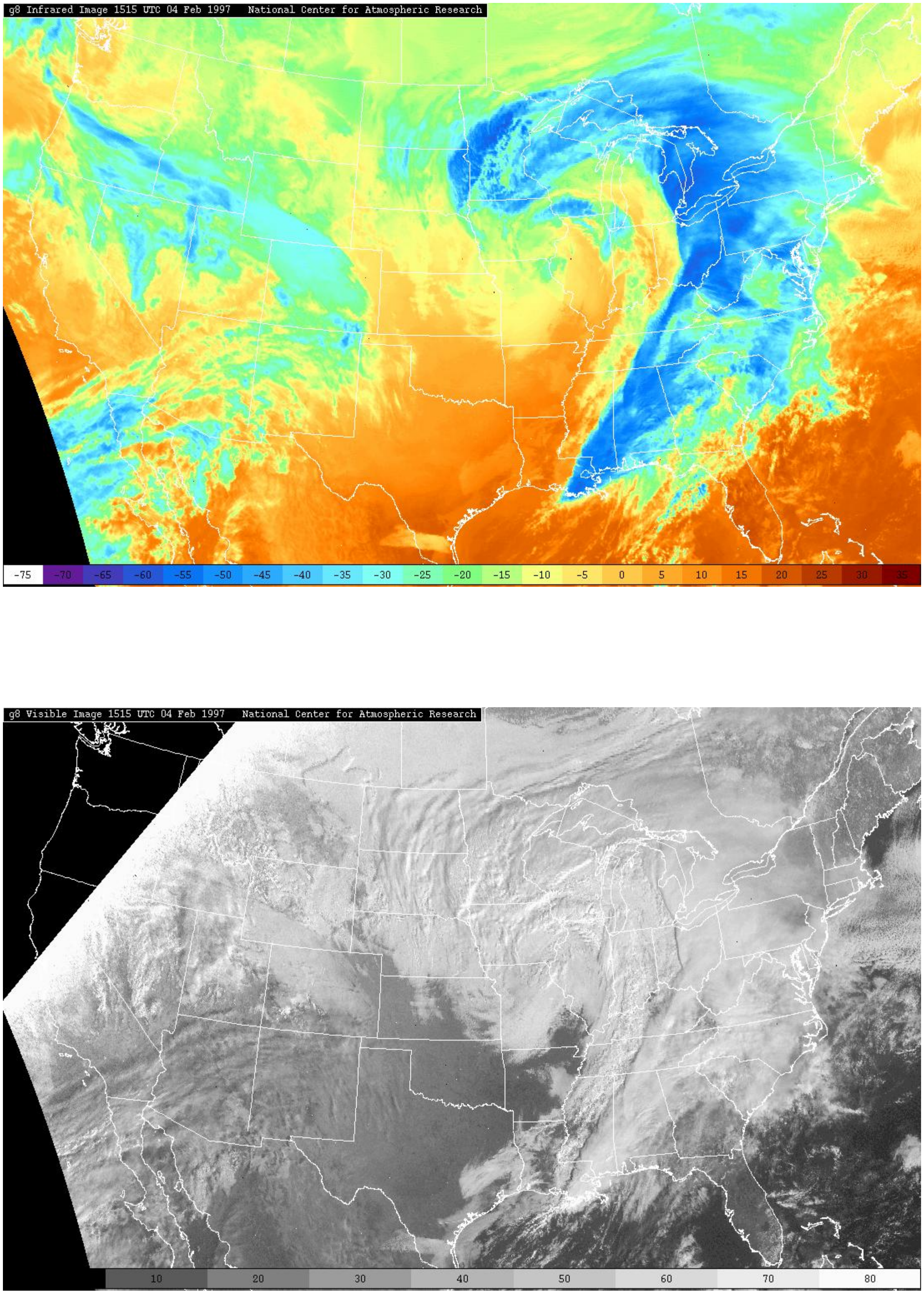


Figure 5 – GOES-8 a) infrared and b) visible satellite imagery for 970204, 1500 UTC.

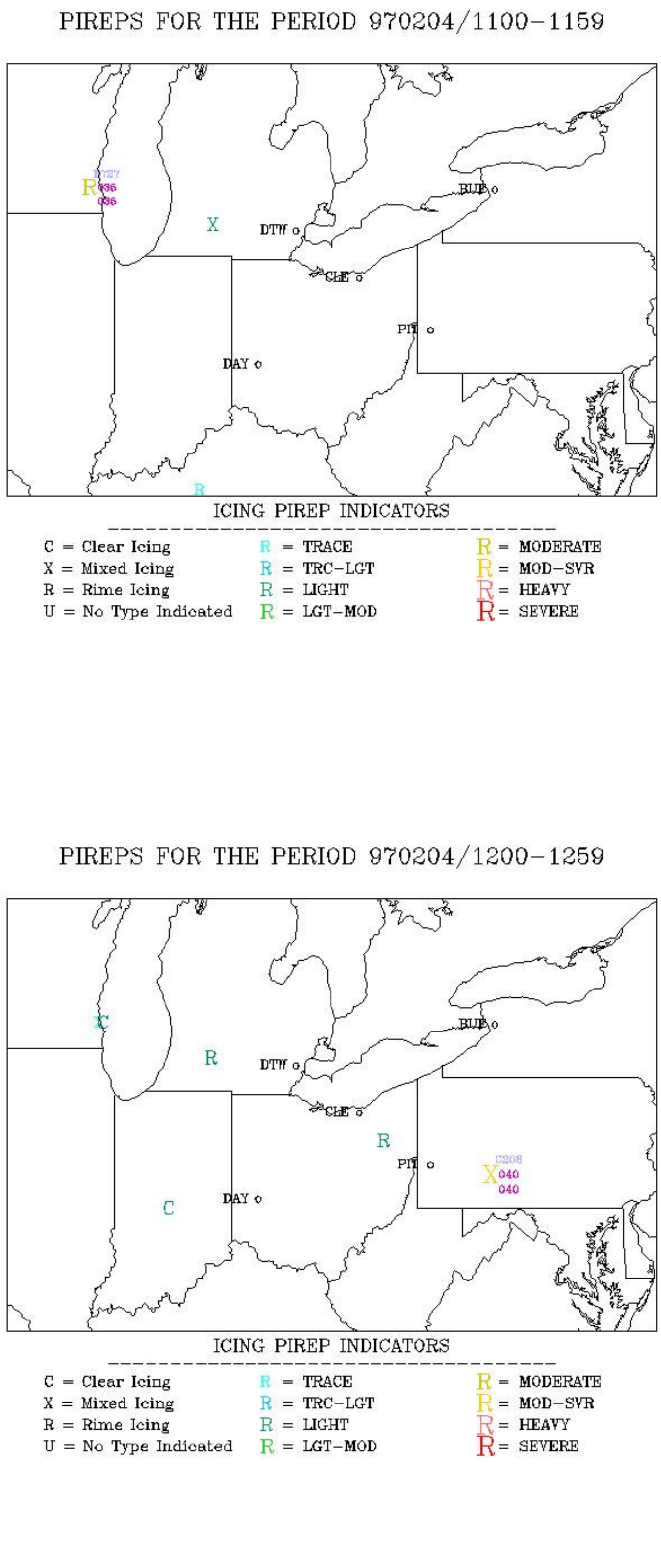
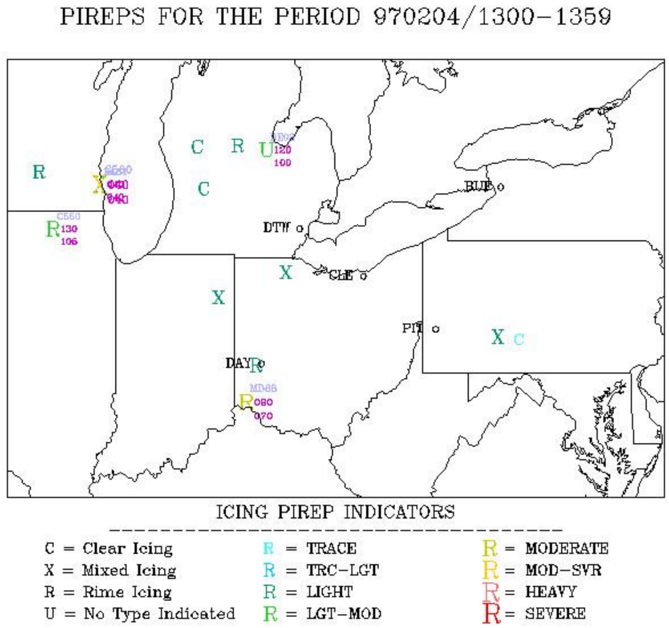


Figure 6 – Pilot reports of icing for 970204, a) 1100-1159 and b) 1200-1259 UTC.



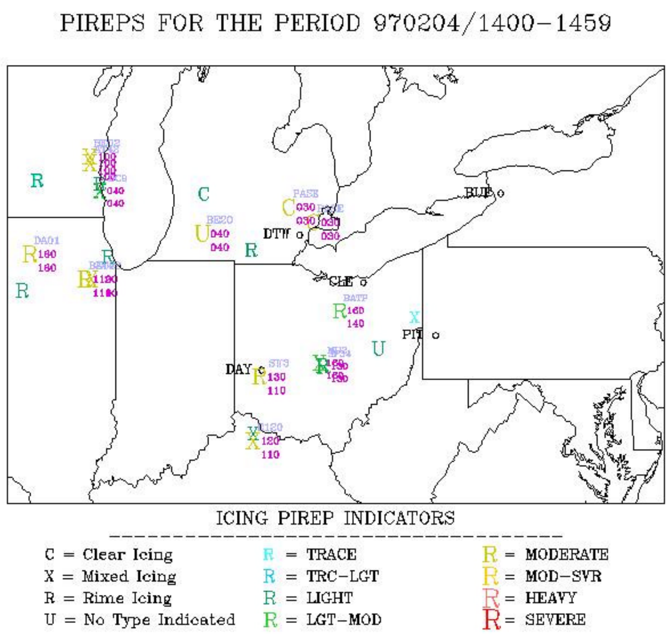


Figure 6 – Pilot reports of icing for 970204, c) 1300-1359 and d) 1400-1459 UTC.

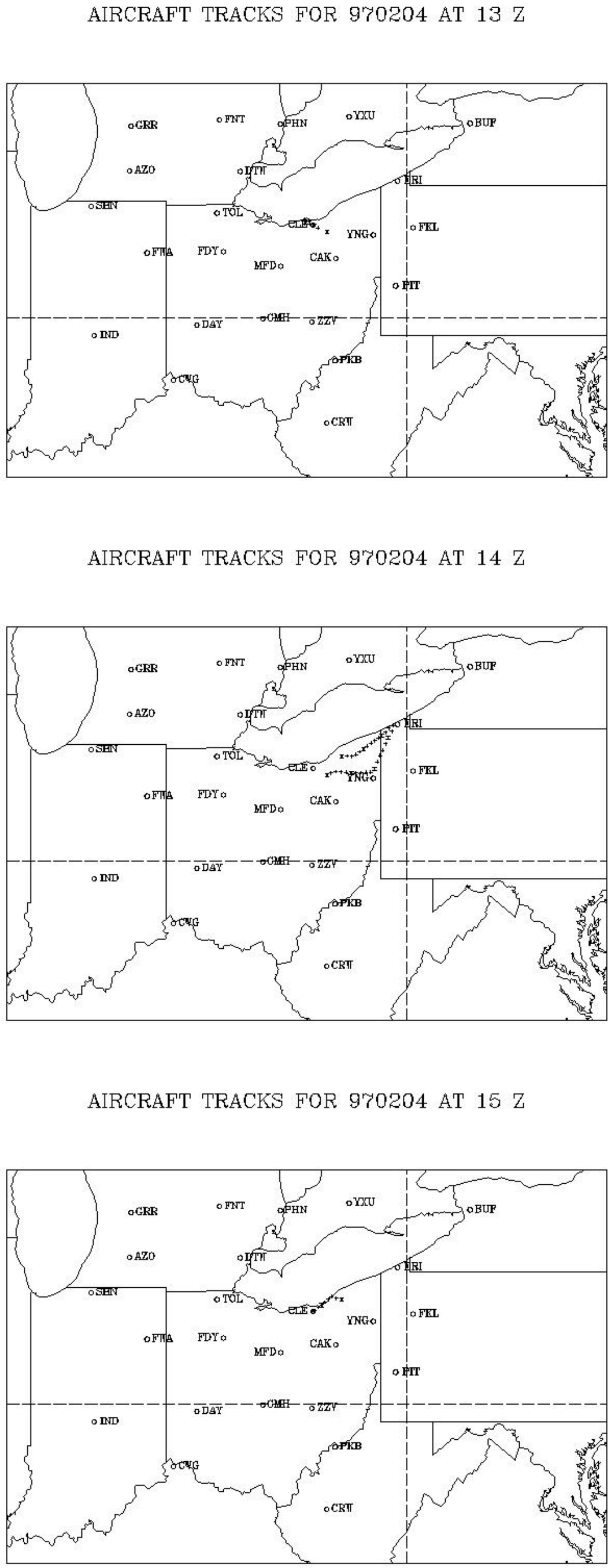


Figure 7 – Twin Otter tracks for 970204, a) 1312-1330, b) 1330-1430 and c) 1430-1441 UTC.

February 5, 1997

Flight #1 - Over northeastern Ohio from 1340 to 1607 UTC.

Brief overview

One flight was made over the northeastern corner of Ohio, within a widespread, fairly deep, stratiform cloud deck. Two distinct cloud layers were present. The lower cloud layer extended from approximately 1300 to 4000 feet, while the upper cloud layer extended from approximately 4500 to 7000 feet. Within both layers, LWC rose from 0.0 to maximum values of 0.5-0.6, and temperatures were subfreezing. The clouds were primarily comprised of liquid water, in the form of small drops. Some freezing drizzle was present, especially within and beneath the bases of both cloud decks. The 2-D Grey probe showed consistent counts in the higher size bins below about 3000 feet. Some in-focus freezing drizzle was clearly visible in the 2-D Grey imagery near cloud base at 1300 feet at the end of the flight, but it was mixed with crystals at that time. The clouds were completely made up of water during the first 90 minutes of the flight, but crystals began to show up near Canton-Akron at 6000 feet around 1520 UTC and were occasionally observed thereafter. It was during the latter part of the flight that several stations around the region began reporting light rain, snow (including snow grains) and "unknown precipitation", all of which was light.

Relevant weather features

At 1200 UTC, a weak, closed low was centered over Lake Huron at 500 mb (Fig. 1). A weak trough extended southwest from the low across northwestern Ohio and cold advection was present behind it. Dry conditions prevailed across the forecast area at 500 mb, with saturated air in place to the east of the Appalachians from Virginia northward. At 700 mb, the low, trough axis, and cold advection became more pronounced, while dry air still covered the forecast area. No significant temperature advection was present over Ohio at this level. At 850 mb, the low/trough setup remained consistent, except that a weak secondary trough extended southward across eastern Ohio. Cold advection was present across New York, Pennsylvania, Ohio, and West Virginia, with the strongest cold advection over the Appalachians and relatively weak cold advection over Ohio. Saturated air was found across the forecast area, except for over Michigan. Temperatures were between -5 and -7 C in the saturated air at 850 mb.

Sounding data from Pittsburgh (Fig. 2) show a solid cloud deck from 920 mb (~3000 feet) to 800 mb (~7000 feet), with a 2 C inversion at cloud top, and a cloud top temperature (CTT) of -8 C. Further to the west at Wilmington, Ohio, a fairly similar cloud extended from 920 mb to 780 mb (~7500 feet), with a strong, 5 C inversion at cloud top and a colder CTT of -11 C. This difference in the character of the stratiform deck is also evident in infrared satellite data from 1215 UTC (Fig. 3). This image shows that CTTs were slightly colder over the southwestern two-thirds of Ohio compared to those over western Pennsylvania, northern Ohio, and Lake Erie. The 1545 UTC infrared image indicates that these slightly colder CTTs had spread across the rest of Ohio, western Pennsylvania and southern Lake Erie, while even colder (near -15 C) CTTs had covered portions of southern Ohio. This change from CTTs which are less often (-10 C) to more often (-15 C) associated with the formation of ice crystals and light precipitation across northeastern Ohio nicely matches the change in character of the clouds from all-water to mixed water and ice crystals, and the development of light precipitation across the area with time. Most of the precipitation reached the surface in the form of snow, but some which fell as light rain may have formed via the collision-coalescence process.

Pilot reports of icing were quite numerous between 1200 and 1600 UTC (Fig. 4). Most were up to moderate intensity, were rime or mixed in type and were at altitudes between 2000 and 8000 feet. Some clear icing was also reported, including one severe PIREP from an ATR-42 over South Bend, Indiana.

No radar mosaic data was available for this case.

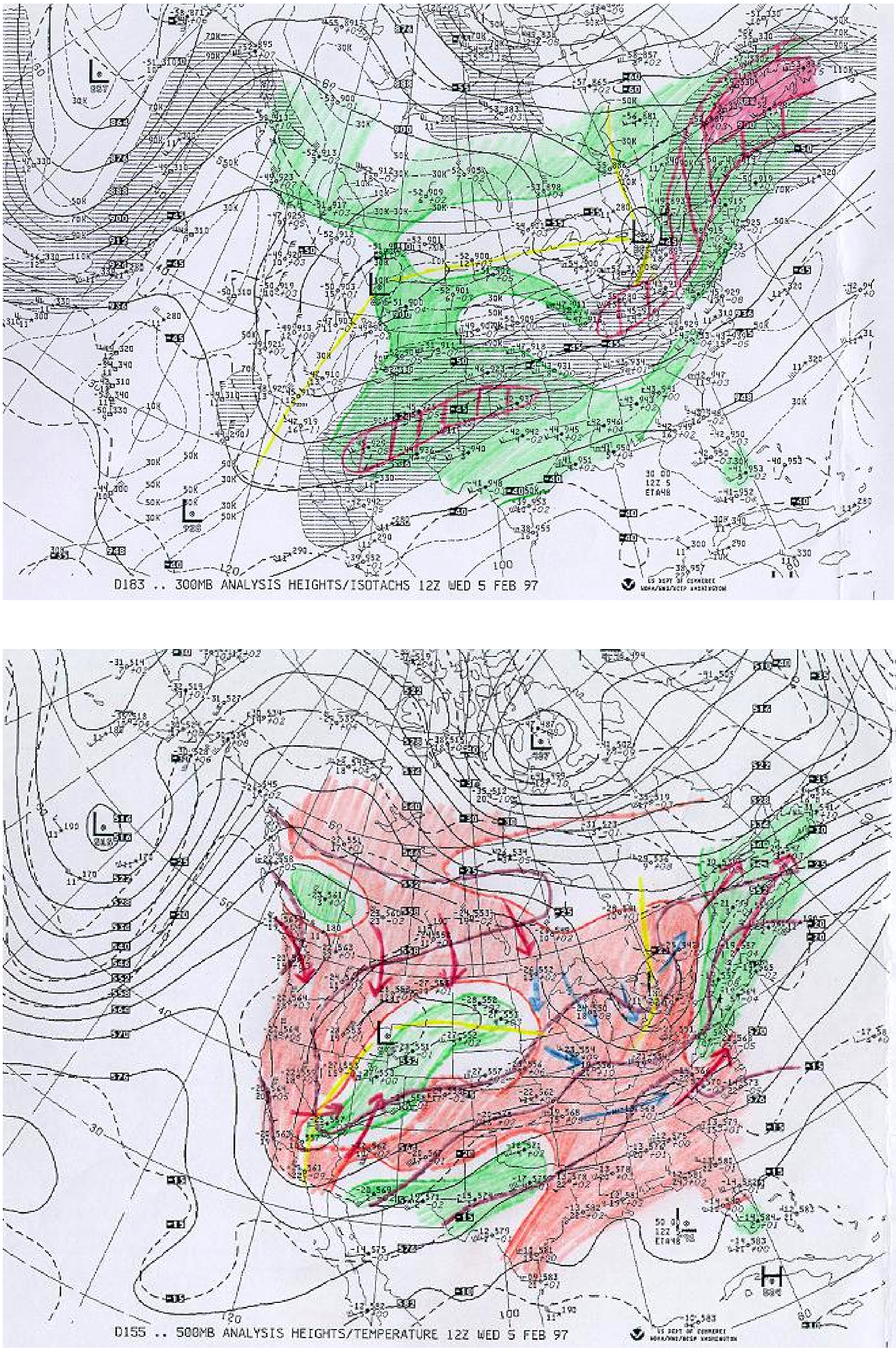


Figure 1 – Upper-air charts for 970205, 1200 UTC at a) 300 and b) 500 mb.

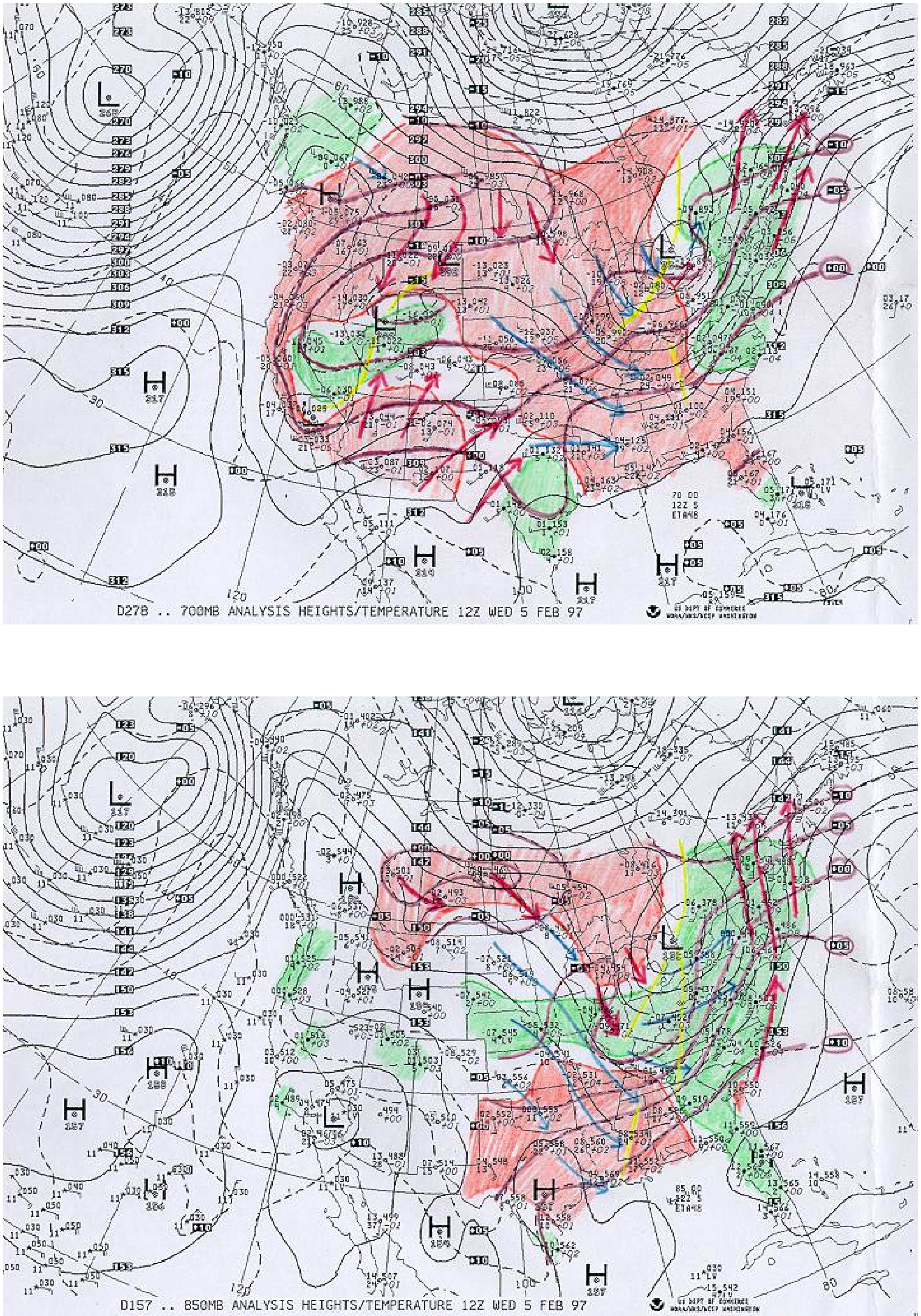
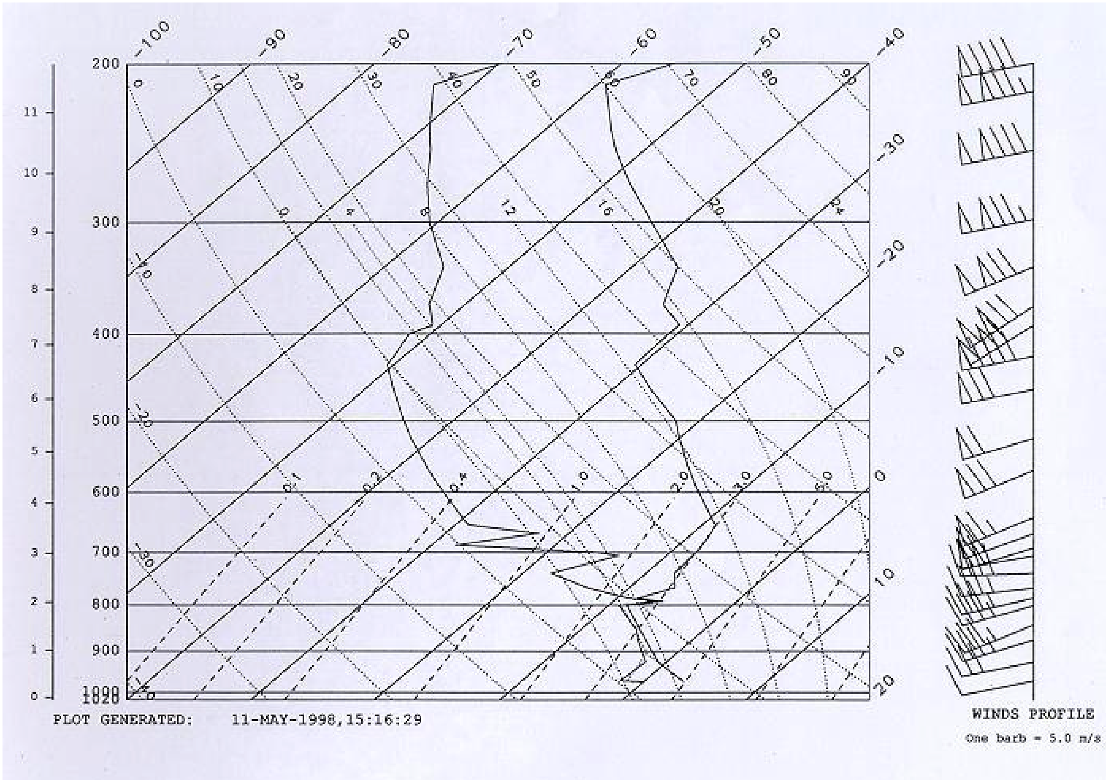


Figure 1 – Upper-air charts for 970205, 1200 UTC at c) 700 and d) 850 mb.



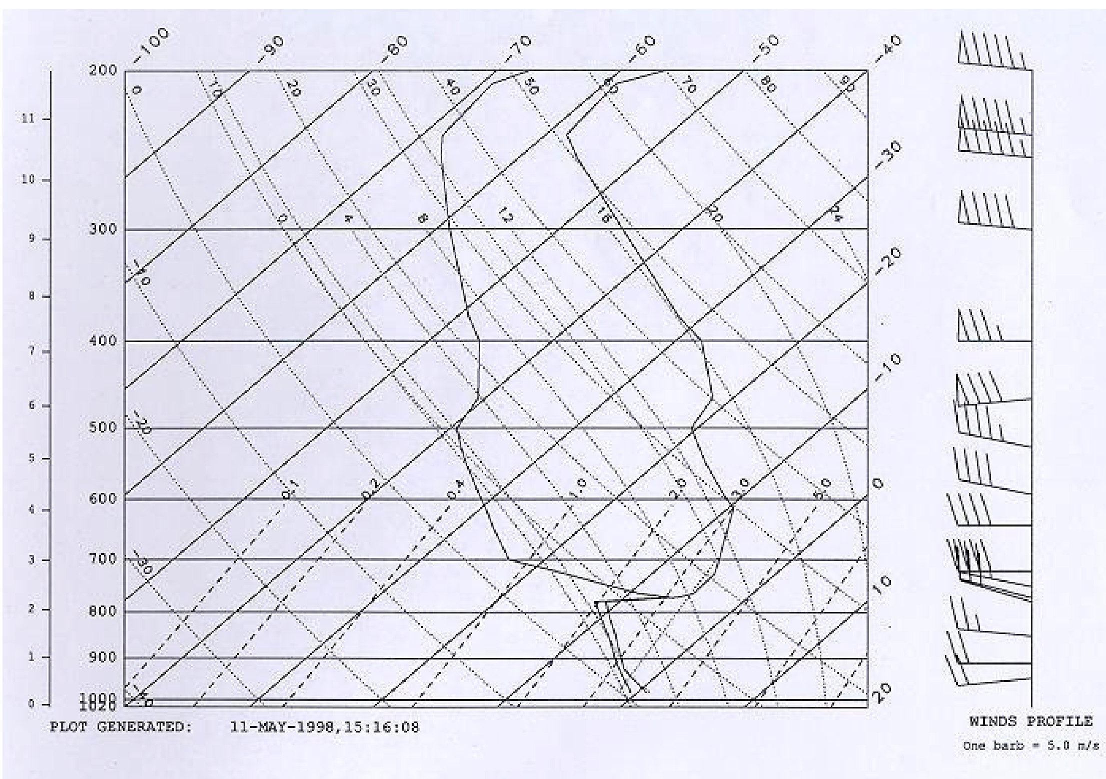
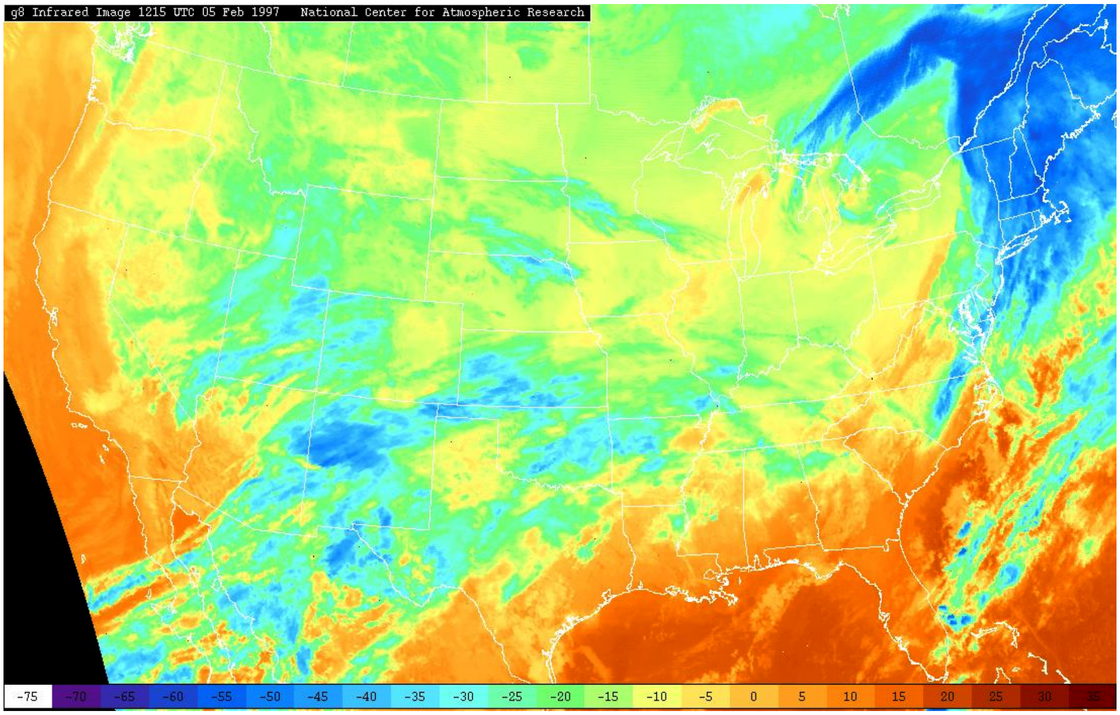


Figure 2 – Balloon-borne soundings for 970205, 1200 UTC from a) Pittsburgh and b) Wilmington.



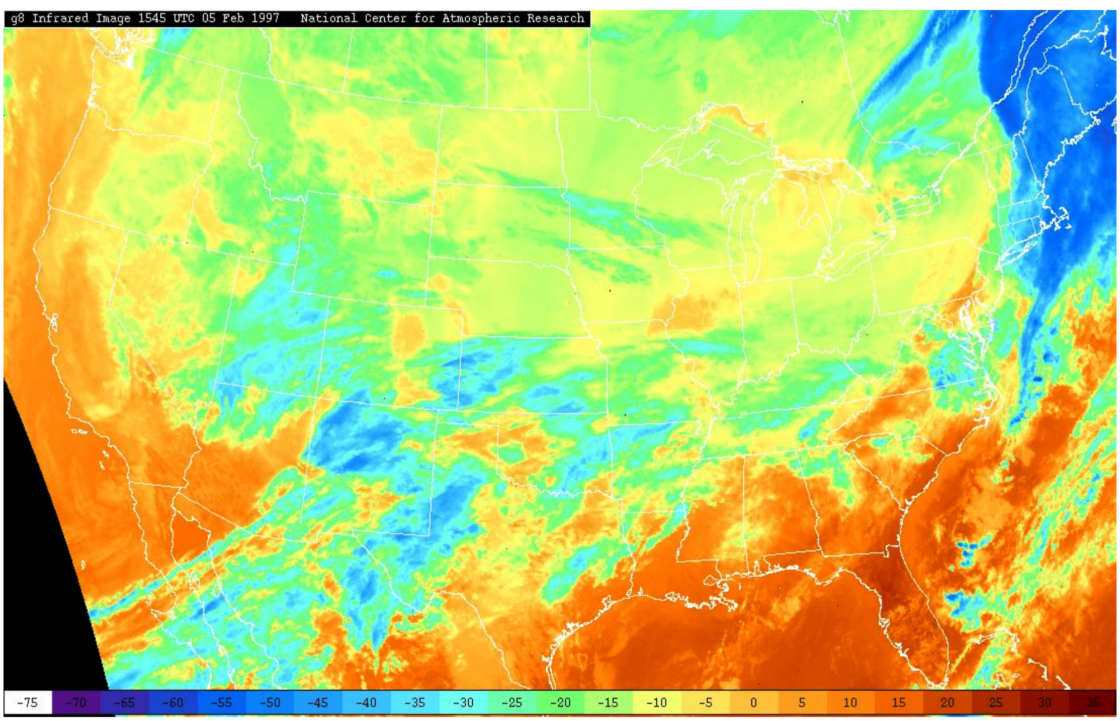
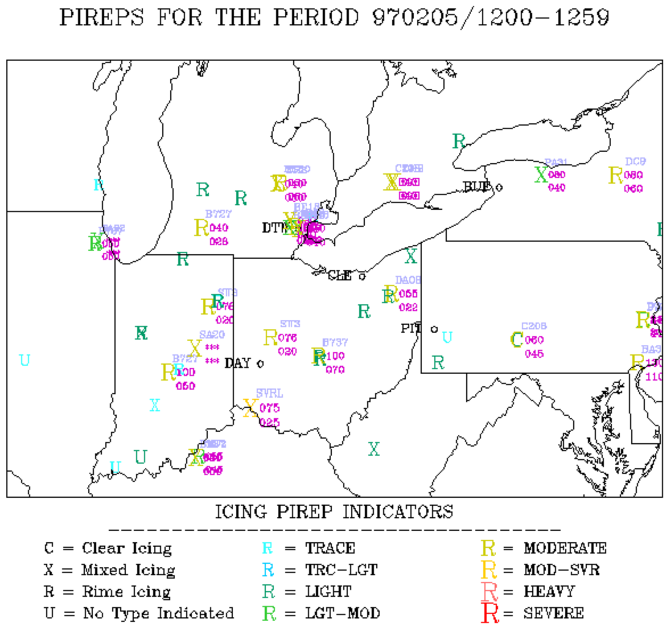


Figure 3 – GOES-8 infrared satellite imagery for 970205, a) 1215 and b) 1545 UTC.



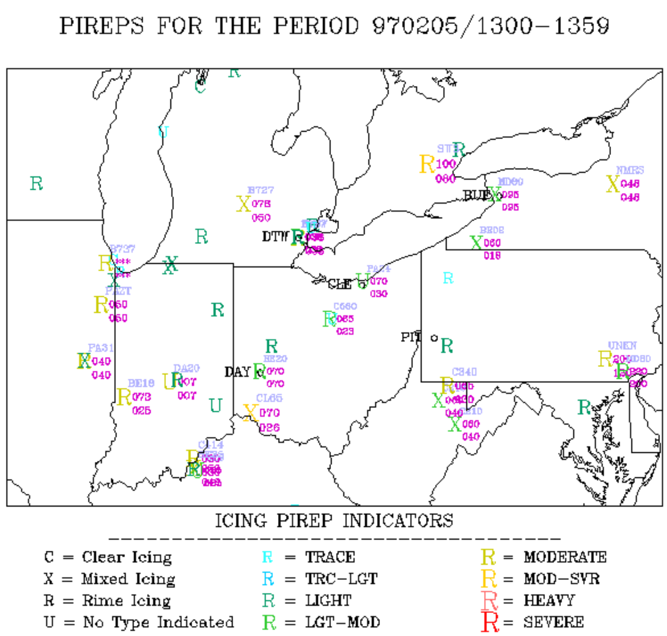
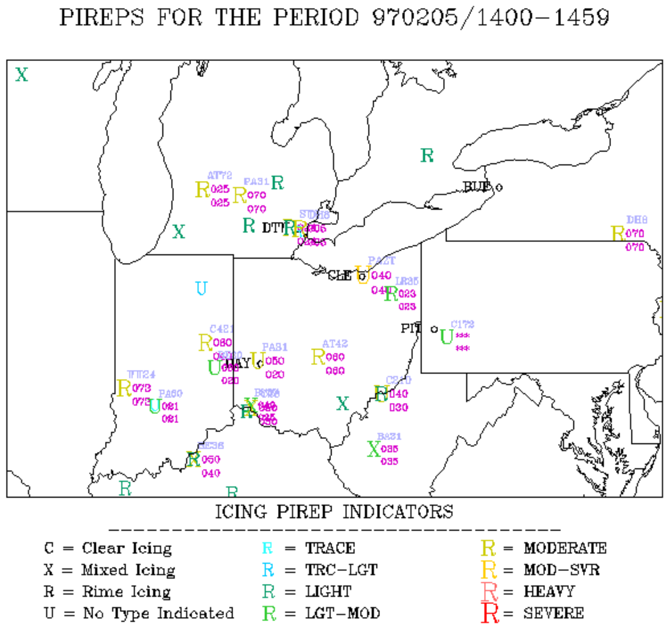


Figure 4 – Pilot reports of icing for 970205, a) 1200-1259 and b) 1300-1359 UTC.



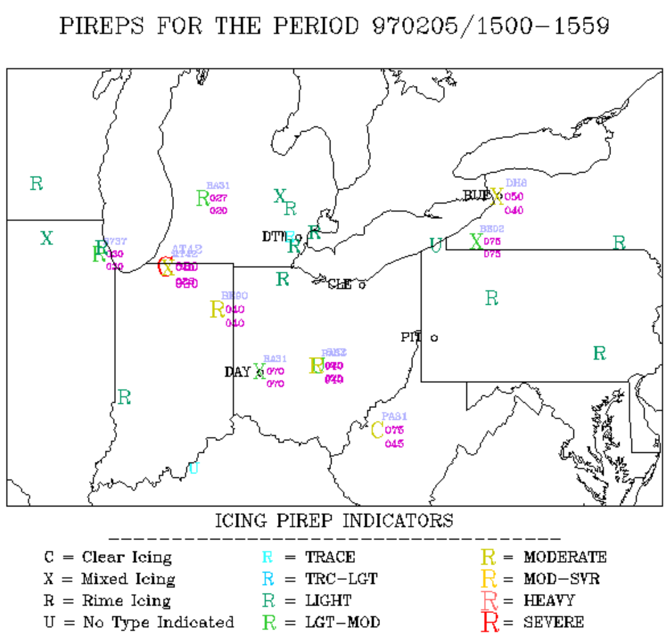


Figure 4 – Pilot reports of icing for 970205, c) 1400-1459 and d) 1500-1559 UTC.

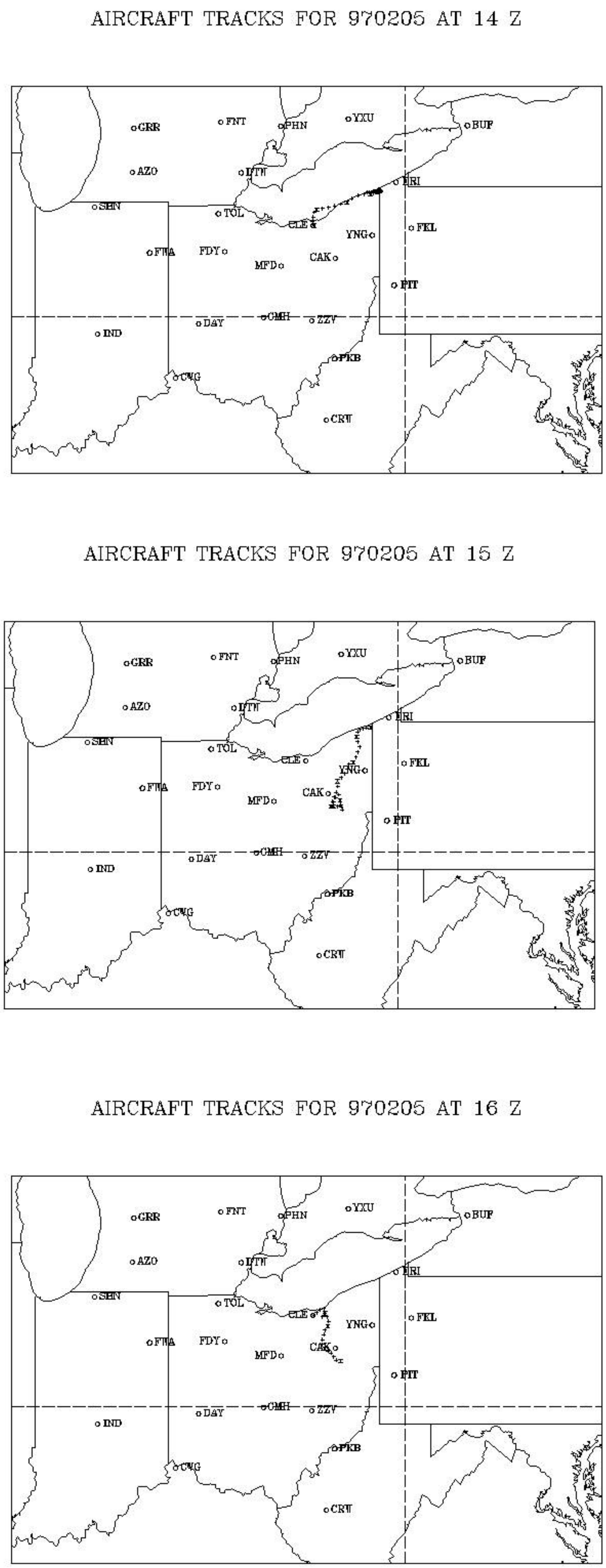


Figure 5 – Twin Otter tracks for 970205, a) 1340-1430, b) 1430-1530 and c) 1530-1607 UTC.

March 6, 1997

Flight #1 - Over northeastern Ohio and northwestern Pennsylvania from 1459 to 1634 UTC.
Flight #2 - Between Erie and Cleveland from 1719 to 1806 UTC.

Brief overview

Two flights were made over the northeastern corner of Ohio and northwestern corner of Pennsylvania, near Youngstown, Franklin (PA), Erie, and along the southeastern shore of Lake Erie. These flights were made within and between a series of northwest-southeast oriented lake effect snowbands. Periods with all-small, supercooled drops with LWC up to 0.5, all ice crystals (pristine, rimed, aggregates) and mixed conditions were observed as the aircraft traversed the bands. Cloud top heights varied between 4000 and 6000 feet.

Relevant weather features

At 1200 UTC, a 500 mb trough extended southward across southeastern Ontario, western New York, and Pennsylvania (Fig. 1). Cold advection was associated with both sides of the trough, and was present across northeastern Ohio and northwestern Pennsylvania. Dry air was present across the forecast area, except for a lobe of saturated air from western New York northward into Canada. At 700 mb, a weak, closed low was present just northeast of Lake Ontario. A trough/cold front extended southward from the low into eastern Pennsylvania (just ahead of the 500 mb trough). Cold advection was again present across eastern Ohio, Pennsylvania, and New York, and moisture at 700 mb covered northeastern Ohio, Pennsylvania, and New York. The temperature was approximately -17 C in the saturated air over eastern Lake Erie at this level. At 850 mb, the low/trough pattern was slightly further east, and cold advection and moisture covered the entire forecast area. Winds were from the west-northwest at 500, 700 and 850 mb over and to the north and east of Ohio.

Surface maps for 0900 UTC (the 1200 UTC map was not available) show a 996 mb surface low over central New York with a cold front running southward along the East Coast (Fig. 2). West-northwest winds were also present at the surface, indicating that cold air was blowing across Lake Erie into northeastern Ohio and northwestern Pennsylvania at all levels. Snow was falling in this area, as well as across western New York, southeastern Ontario, and Michigan. By 1500 UTC, the low tracked to the coast of Maine, while the snow moved out of northeastern Ohio, and was found only in western Pennsylvania and western New York.

Sounding data from Pittsburgh, Detroit, and Buffalo (Fig. 3) all indicate west-northwest winds from the surface to at least 10000 feet. Saturated conditions extended from 2000 feet to 10000 feet, with a cloud top temperature of -18 C at Pittsburgh, where snow was reported during most of the event. The same was true at Buffalo, but deeper saturated conditions were present there, while shallower clouds with CTTs of -10 to -15 C were present over Detroit.

Satellite from 1145 UTC (Fig. 4) show the colder cloud from the north just reaching Buffalo, with cloud top temperatures colder than -30 C there, while an area of cloud with CTTs of -15 to -20 C was in place across western Pennsylvania, eastern Ohio, and West Virginia. Pockets of warmer cloud top temperatures were evident over southeastern Michigan and western Lake Erie. By 1445 UTC, the clouds exhibited a variety of cloud top temperatures across northeastern Ohio, from -10 to -20 C or so. Breaks in the clouds were evident in the visible satellite data, in the same locations where the infrared showed temperatures of near 0 C (the temperature of the surface). There were some hints of northwest to southeast oriented bands, as well as some cellular nature in the clouds.

Radar mosaic data also hint at a banded structure in the snow across northeastern Ohio and western Pennsylvania during the period (Fig. 5). This is a common structure in lake effect snow events. Between 1500 and 1800 UTC, the snow shifted eastward into Pennsylvania, but some snow was still evident across the northeastern corner of Ohio at 1800 UTC. Throughout the period, pilot reports of icing were found between 6000 and 7000 feet in the vicinity of the snowbands, but the locations and timing of the reports were not fine enough to determine their location relative to individual bands (Fig. 6). It is likely, however, that most of those pilot reports were probably due to ice accreted within pockets of LWC between and along the edges of the snowbands. Most PIREPs were rime in type and up to moderate in intensity.

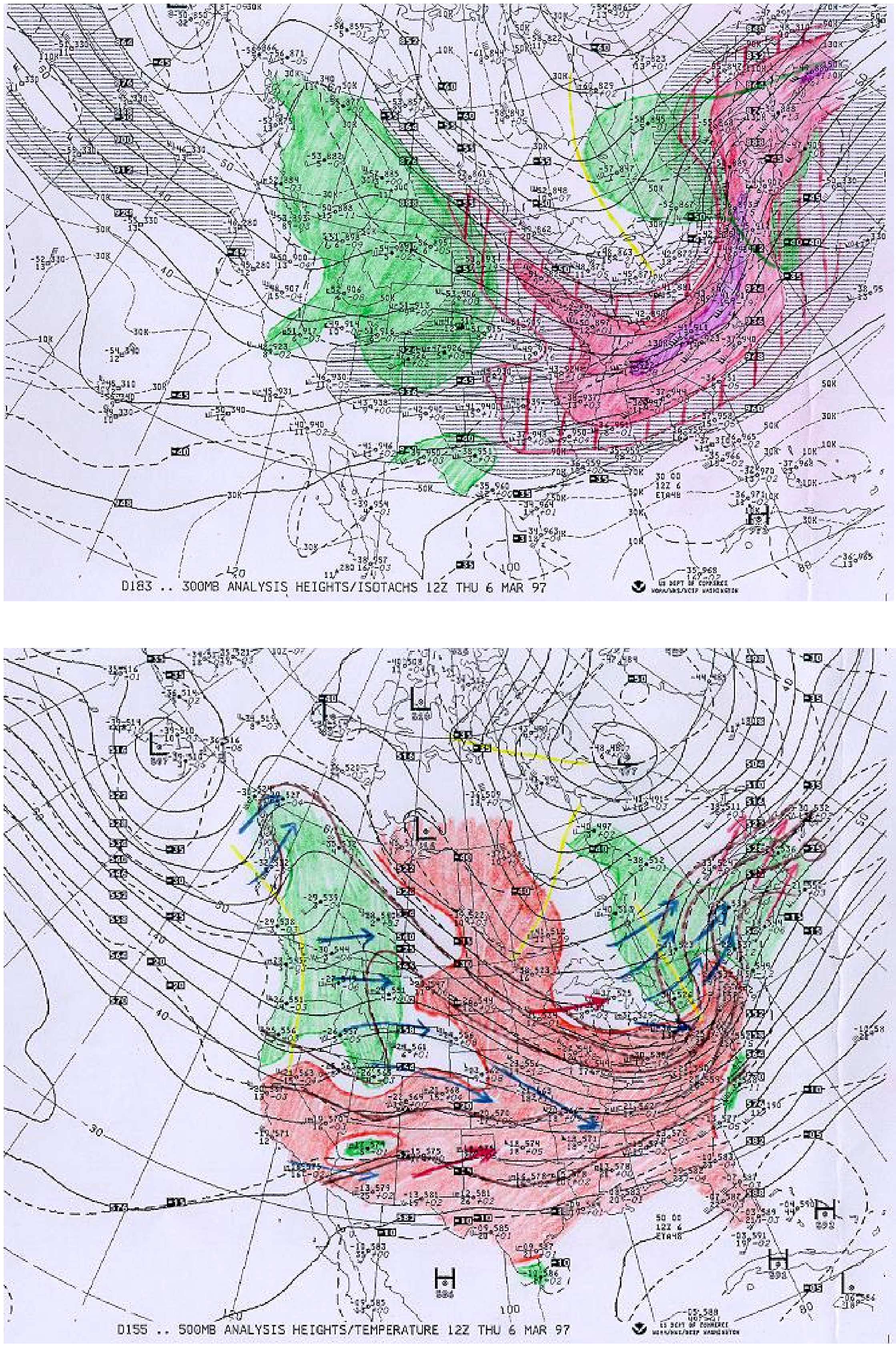
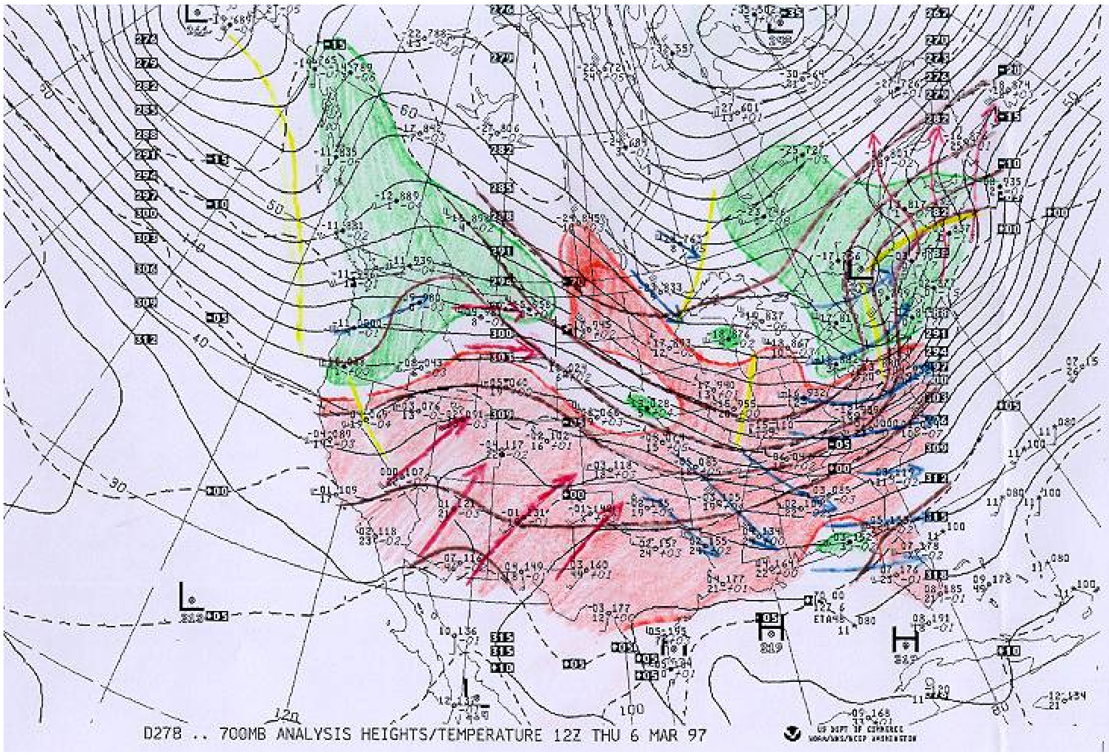


Figure 1 – Upper-air charts for 970306, 1200 UTC at a) 300 and b) 500 mb.



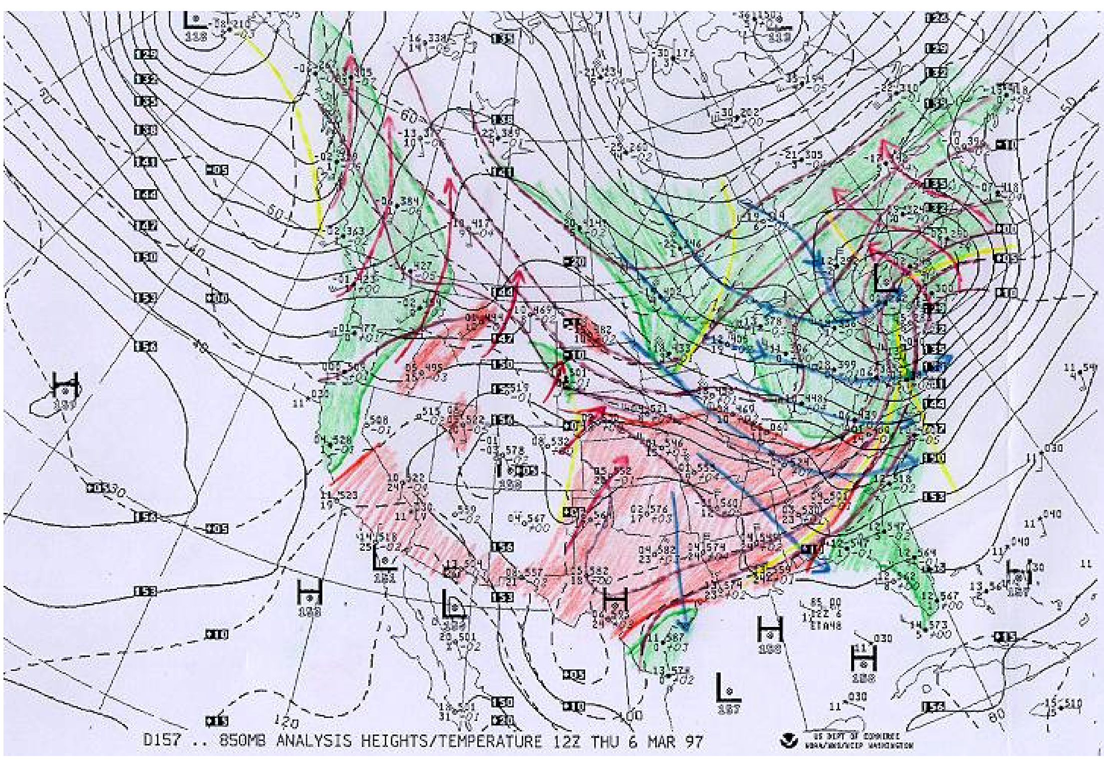


Figure 1 – Upper-air charts for 970306, 1200 UTC at c) 700 and d) 850 mb.

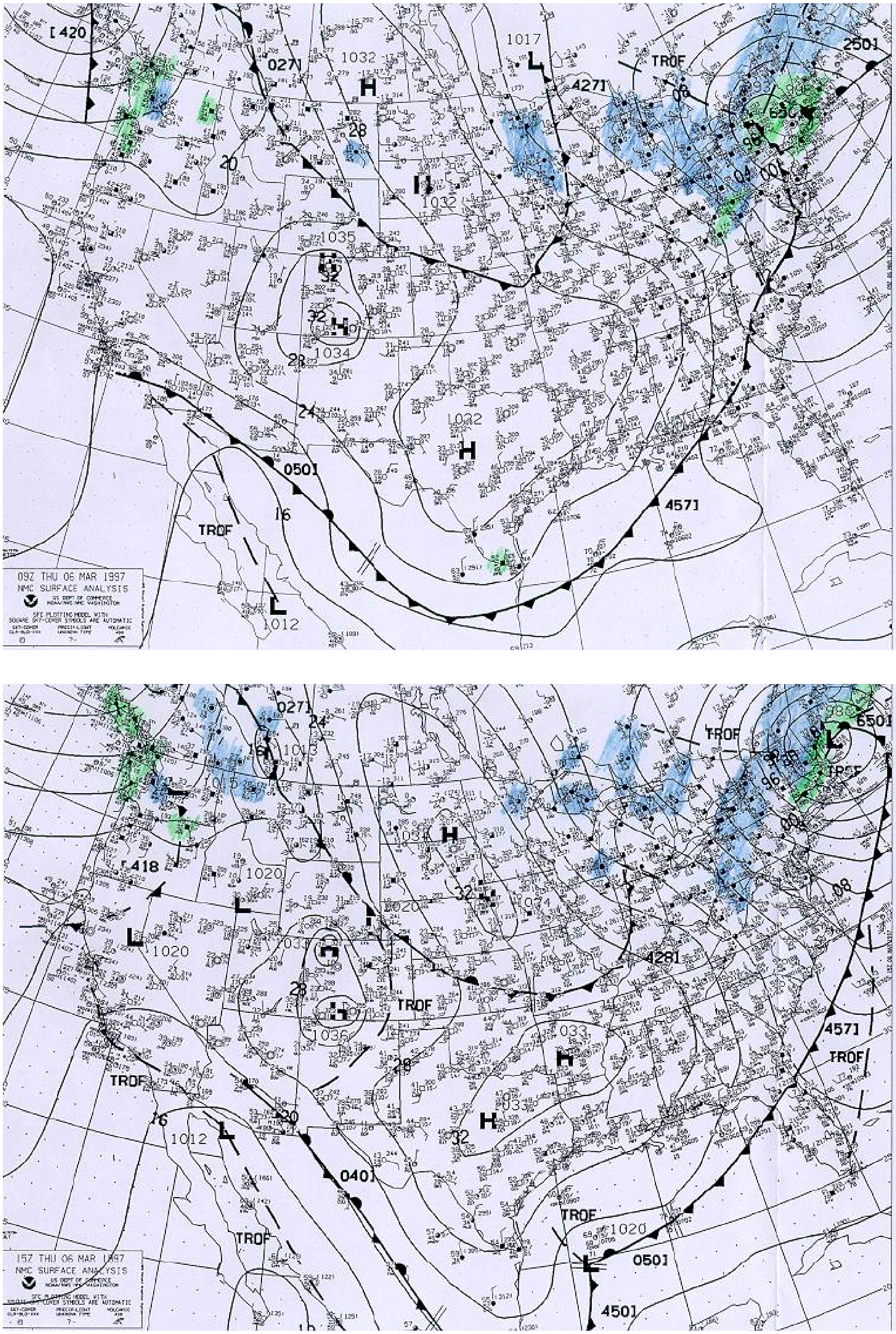
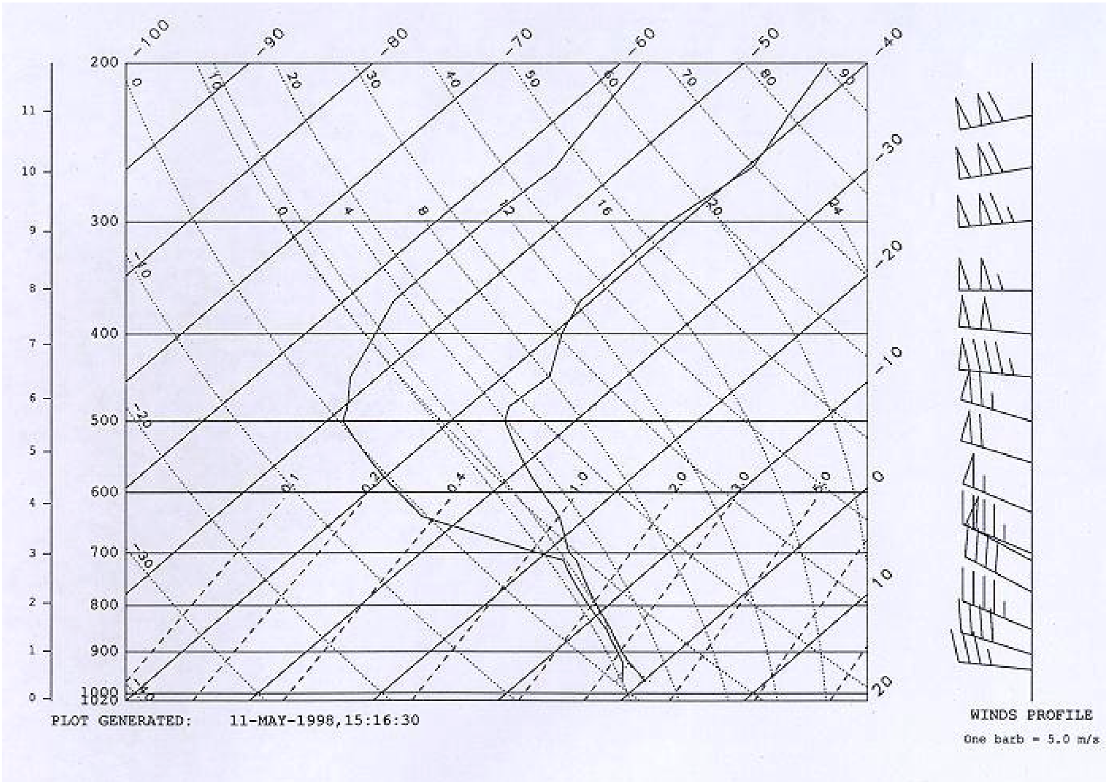


Figure 2 – Surface charts for 970306, a) 0900 and b) 1500 UTC.



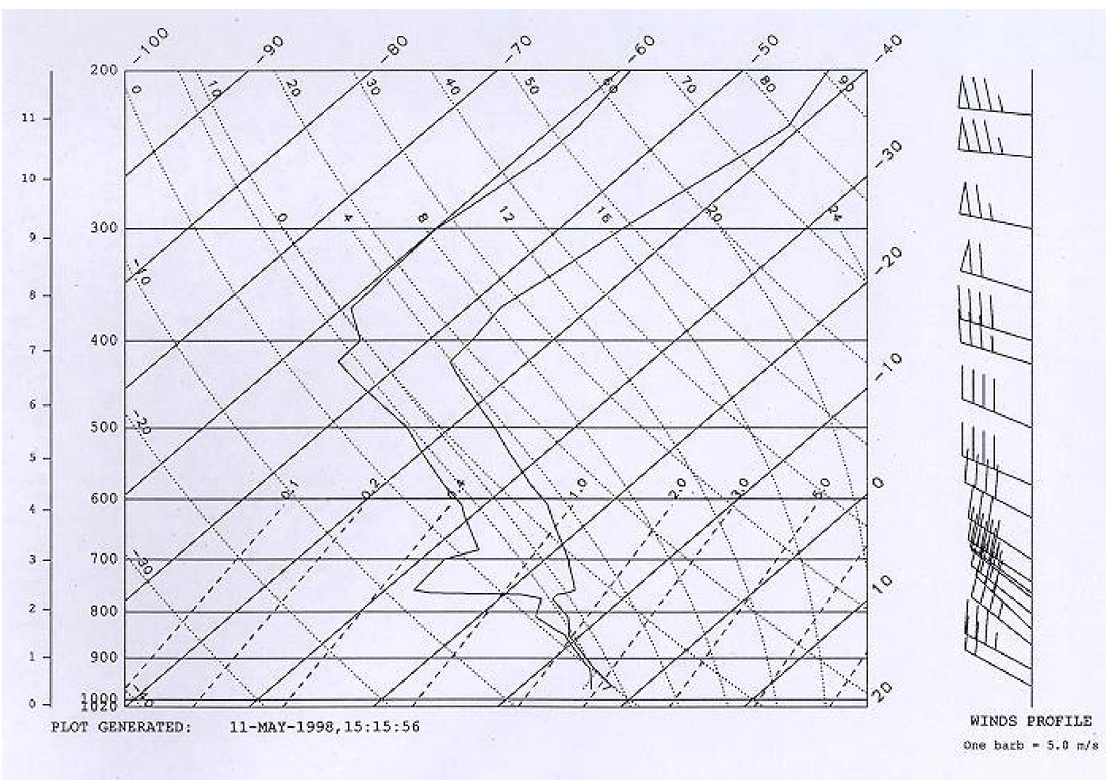


Figure 3 – Balloon-borne soundings for 970306, 1200 UTC at a) Pittsburgh and b) Detroit.

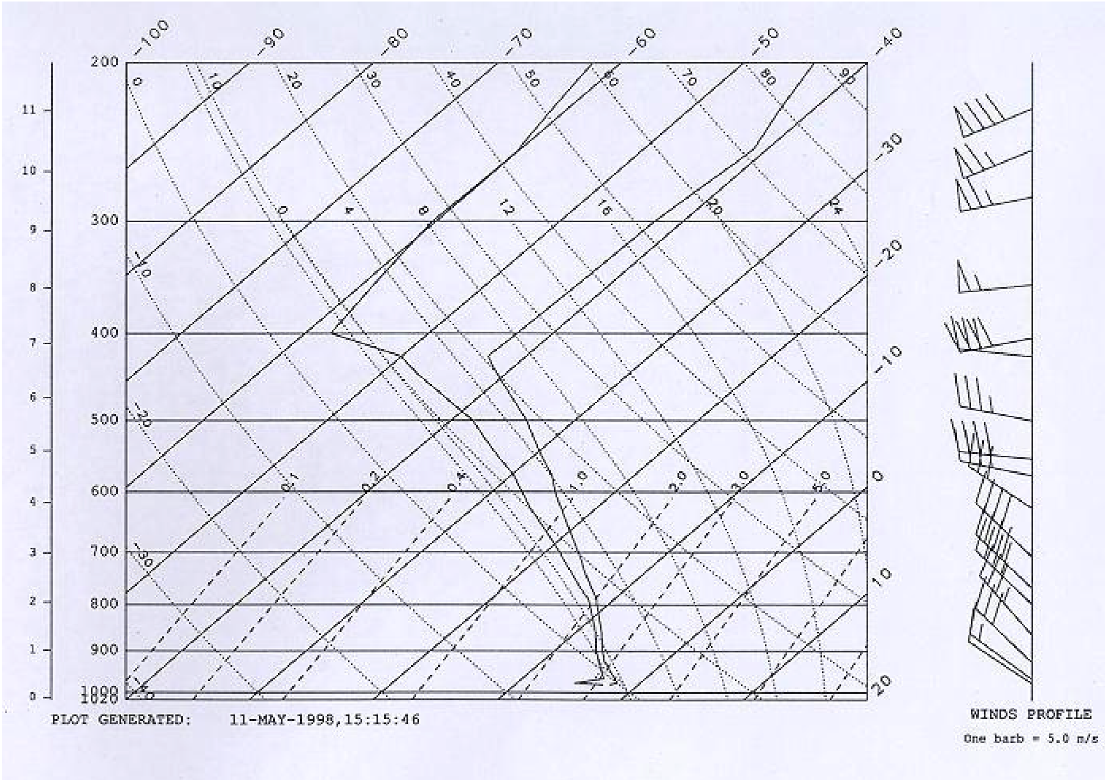


Figure 3 – Balloon-borne soundings for 970306, 1200 UTC at c) Buffalo..

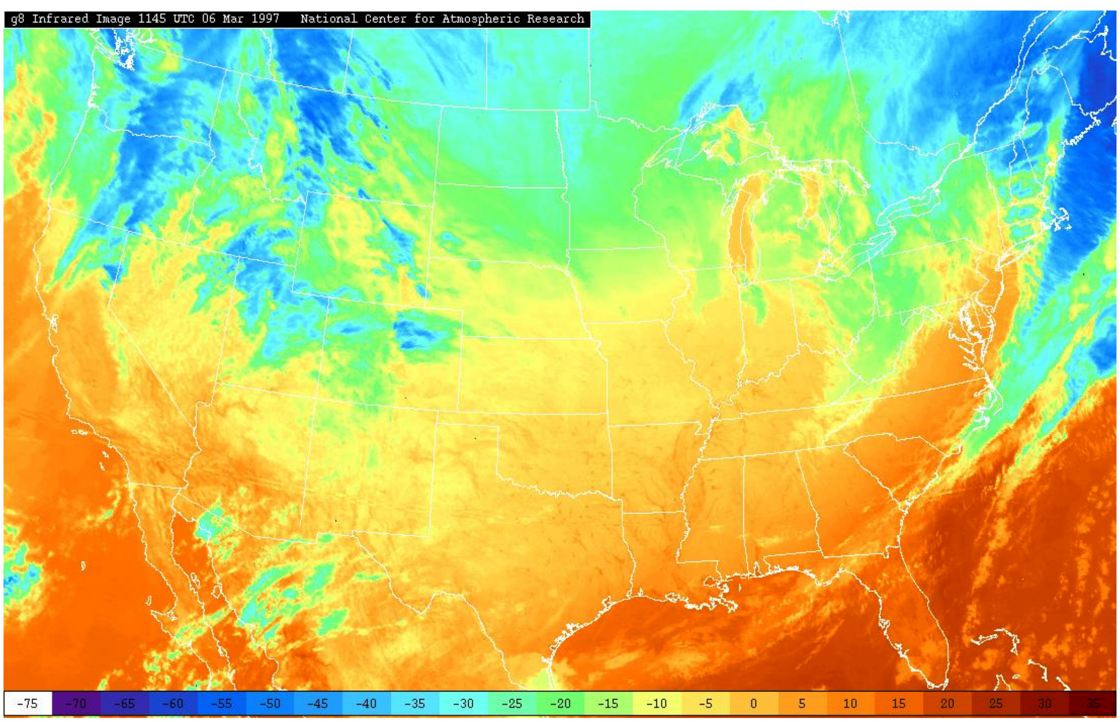
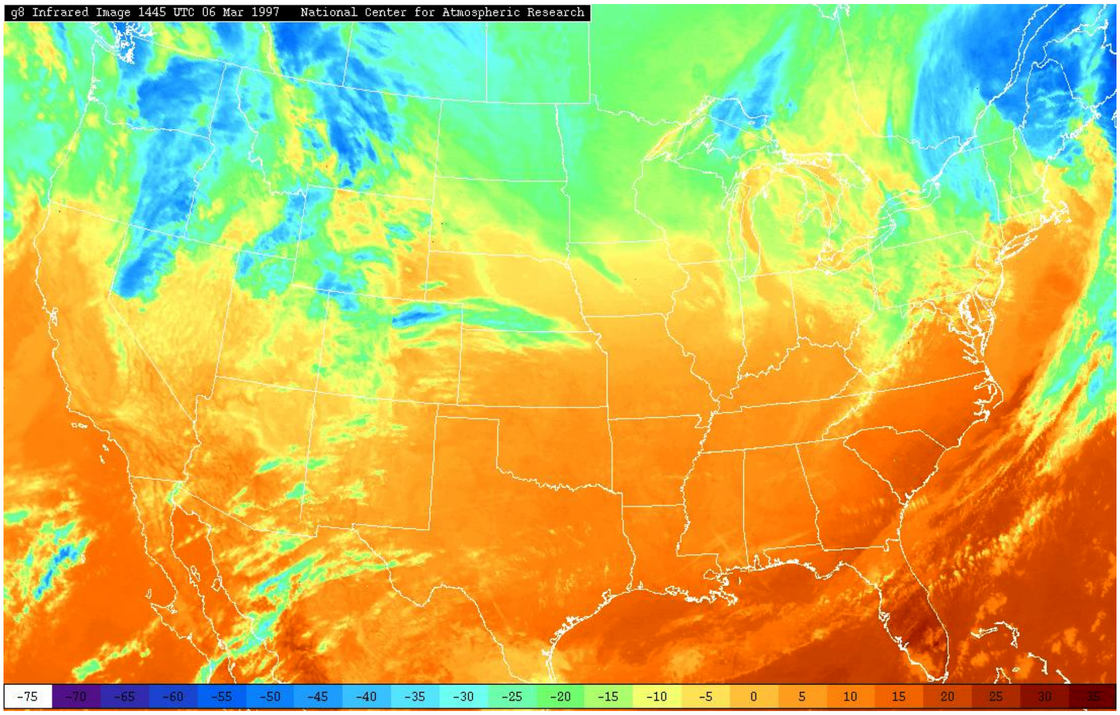


Figure 4 – GOES-8 Infrared satellite image for 970306, a) 1145 UTC.



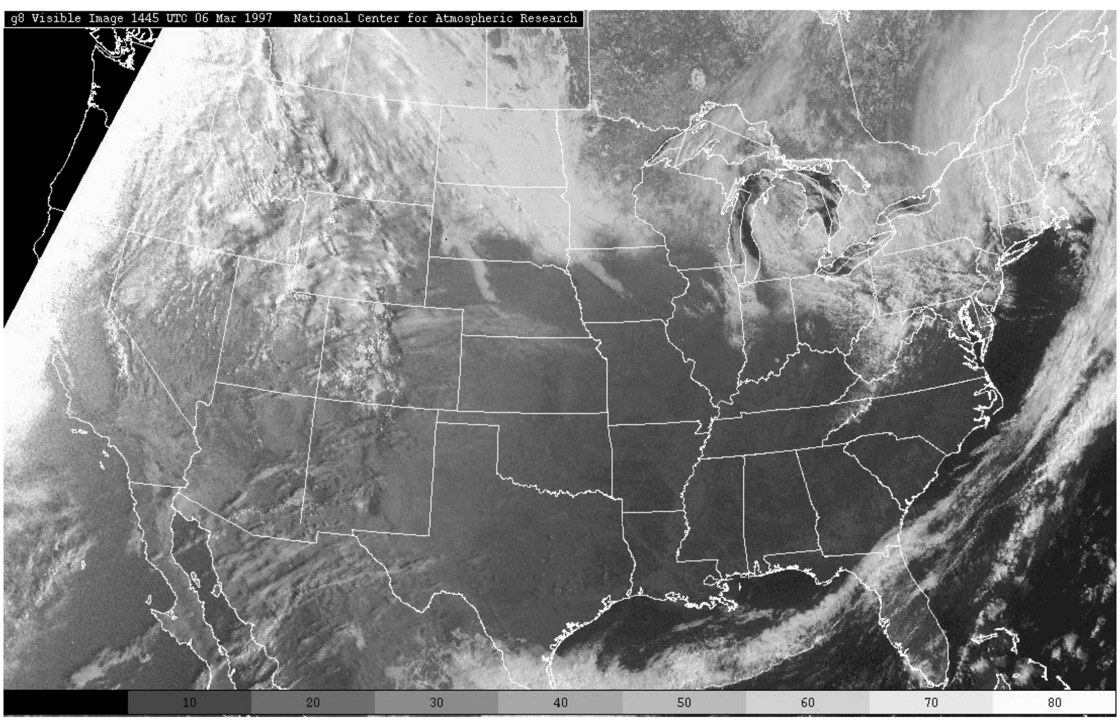
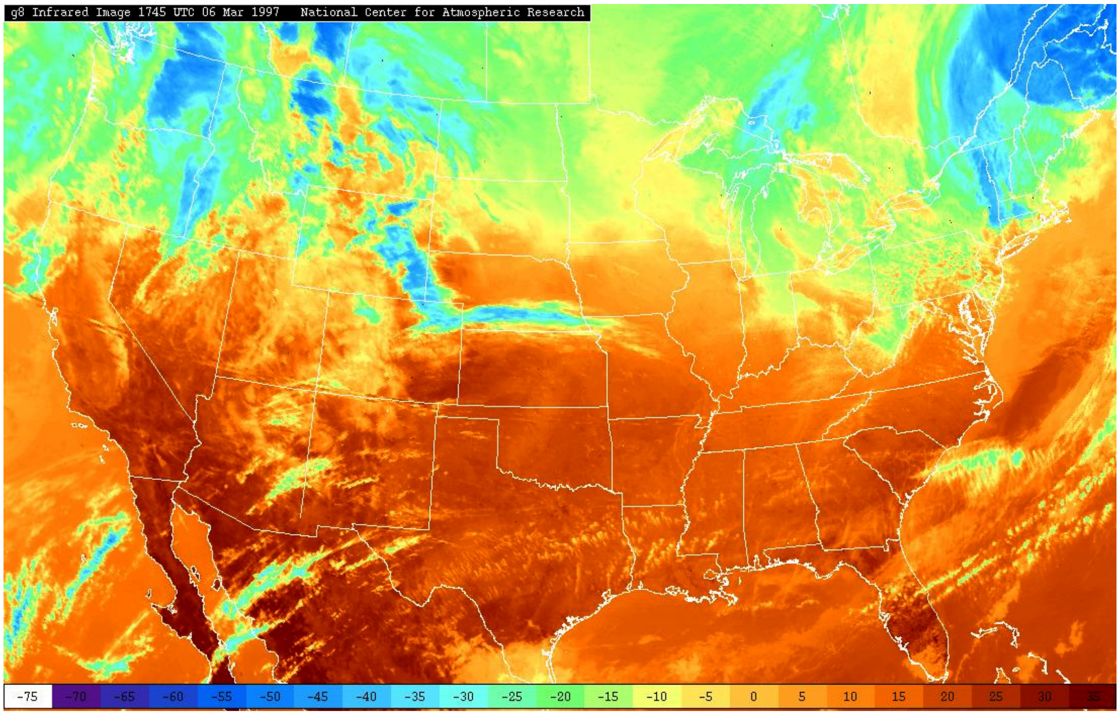


Figure 4 – GOES-8 b) Infrared and c) visible satellite image for 970306, 1445 UTC.



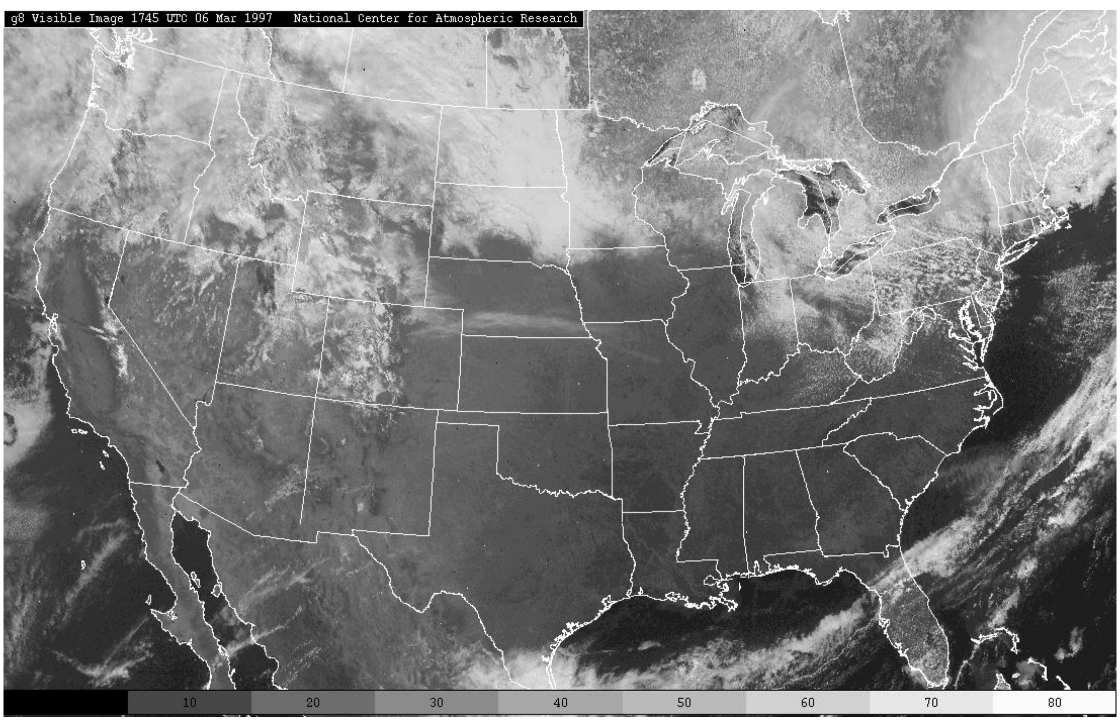
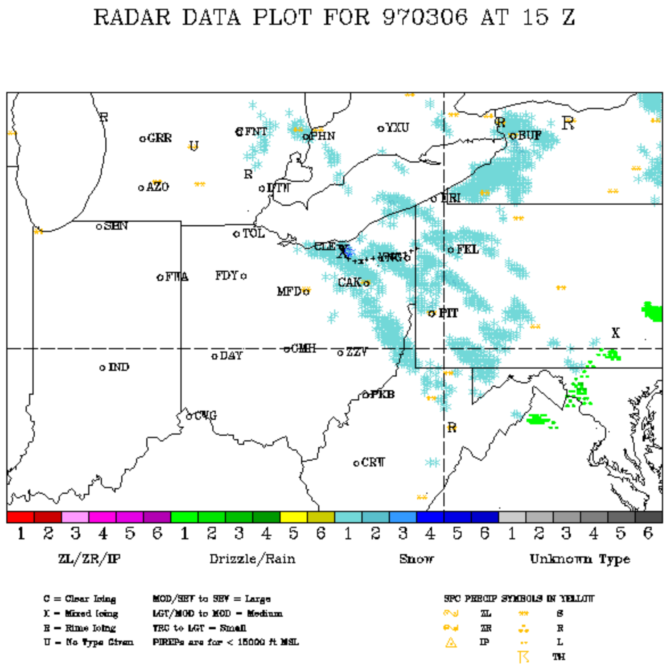


Figure 4 – GOES-8 d) Infrared and e) visible satellite image for 970306, 1745 UTC.



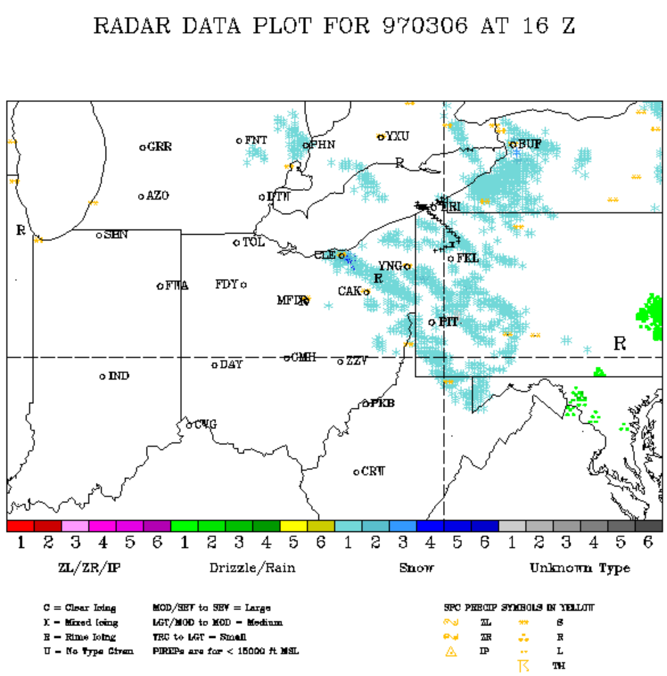


Figure 5 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970306, a) 1500 and b) 1600 UTC.

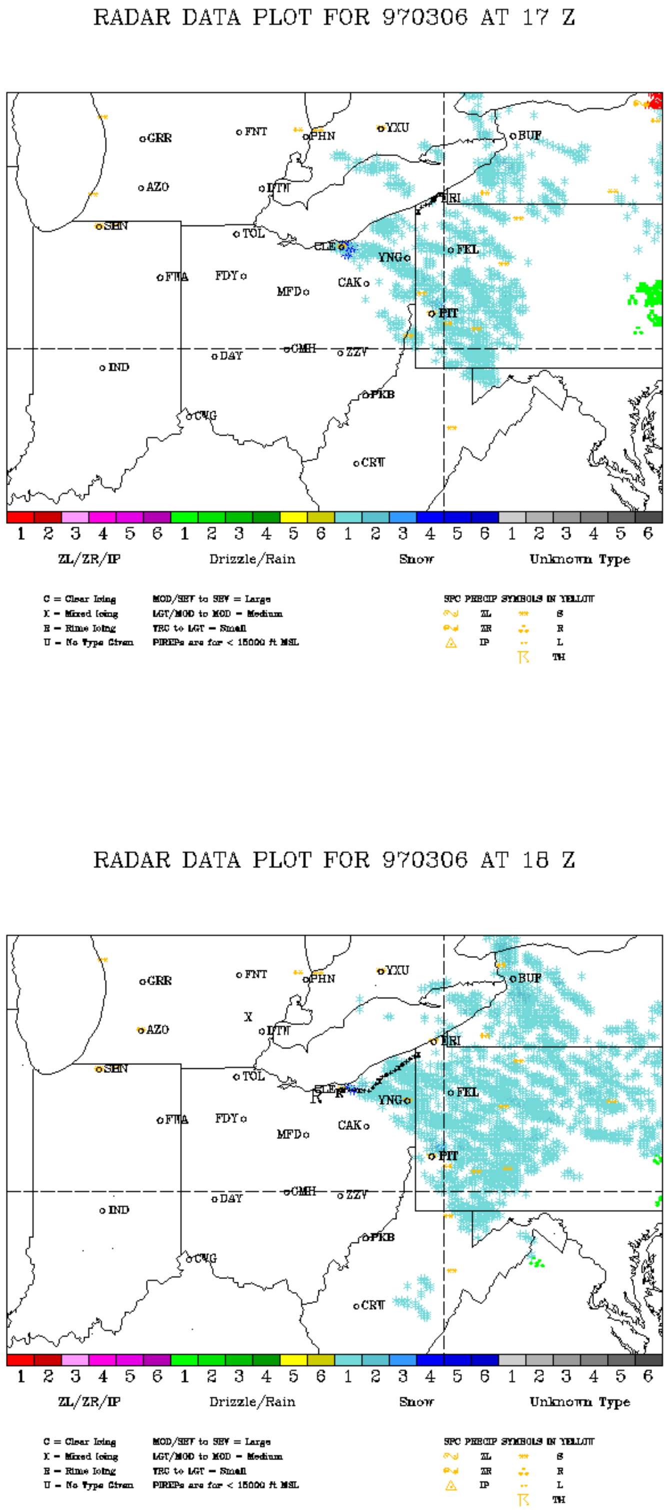
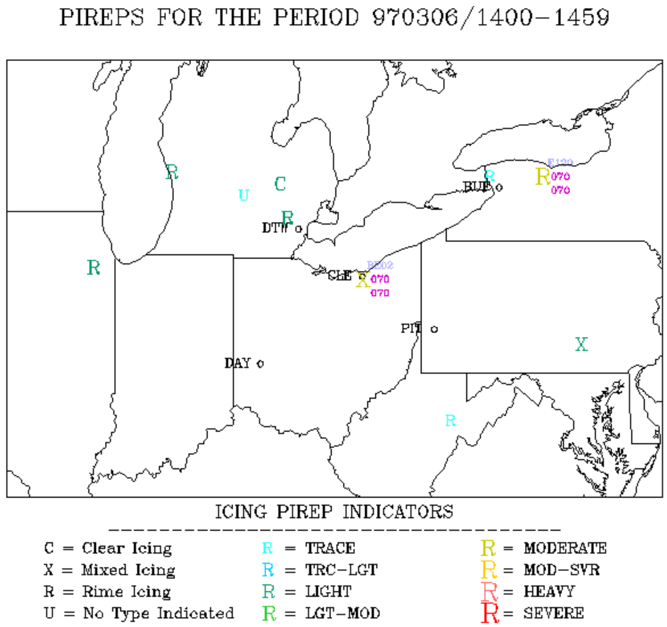


Figure 5 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970306, c) 1700 and d) 1800 UTC.



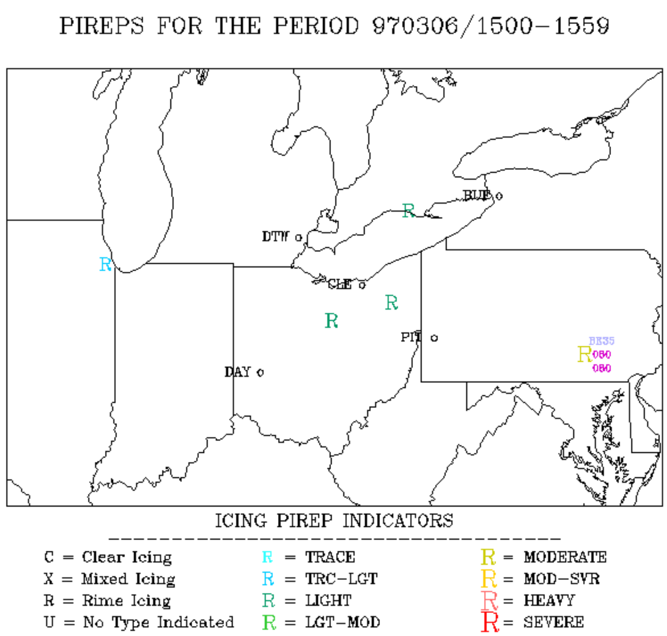
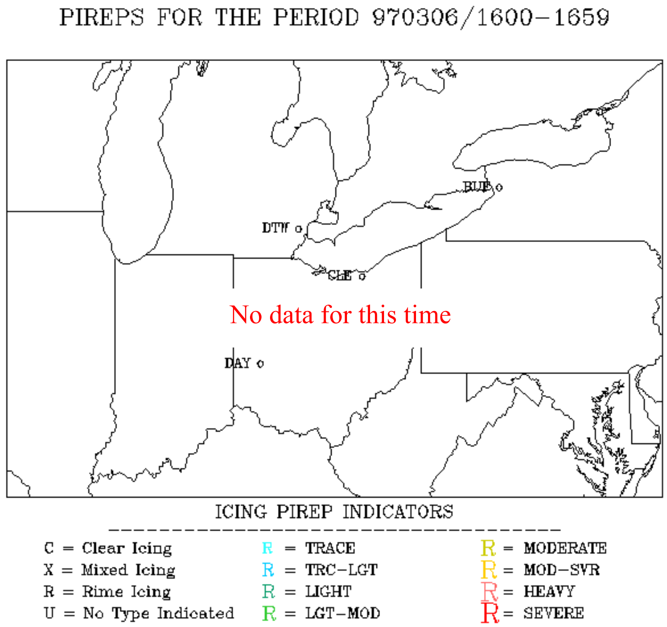


Figure 6 – Pilot reports of icing for 970306, a) 1400-1459 and b) 1500-1559 UTC.



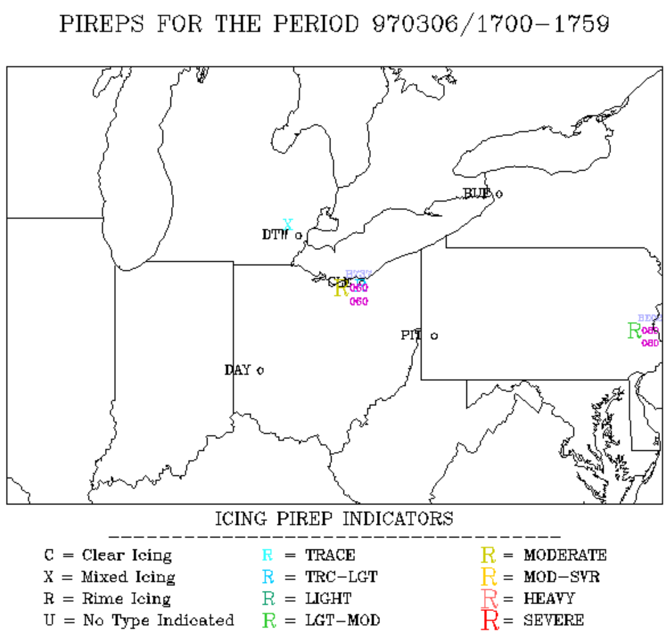


Figure 6 – Pilot reports of icing for 970306, c) 1600-1659 and d) 1700-1759 UTC.

March 11, 1997

Flight #1 - Over northeastern Ohio and northwestern Pennsylvania from 1315 to 1458 UTC.

Flight #2 - Over northeastern Ohio and northwestern Pennsylvania from 1555 to 1714 UTC.

Flight #3 - Over Canton-Akron and Cleveland from 1821 to 2006 UTC.

Brief overview

Three flights were made on this day, all behind a cold front which moved south through Cleveland at 1200 UTC. The first flight was made along the southeastern shore of Lake Erie, between Cleveland and Erie, to the north of an east-west oriented band of precipitation. To the northeast of Cleveland, the aircraft encountered a mixture of ice crystals and small water drops with LWC as high as 0.2 near 6800 feet. Some all-water and some mixed conditions were observed between Erie and Youngstown and Franklin (PA), with temperatures of -3 C and LWC as high as 0.7 at times. A few out-of-focus drops bordering on freezing drizzle sizes were observed on occasion.

The second flight took off from Erie, where colder conditions had arrived (T = -5.6 at 4000 feet). Small drop icing with LWC up to 0.5 was found between Erie and Youngstown at 1600 UTC, and very consistent 0.3-0.4 LWC was observed between Youngstown and Canton-Akron at 4000 feet, where the temperature was -3 C. Cloud tops were near 4500 feet with a cloud top temperature (CTT) near -3 C. Some larger drops were evident over Canton-Akron near the surface, where the temperature was +1 C. This flight took place to the north of precipitation areas that had moved southeast into Pennsylvania.

The third flight took place over Canton-Akron and Cleveland, well to the northwest of all precipitation areas. Things had cooled even further (T = -6.1 at 4000 feet). LWC was typically 0.1-0.4, with lots of droplets bordering on freezing drizzle sizes observed near Canton-Akron between 3000 and 4000 feet at temperatures of approximately -4 C.

Relevant weather features

At 1200 UTC, a weak trough extended southward from a low over Hudson's Bay to the Pennsylvania-Ohio border at 500, 700, and 850 mb (Fig. 1). At 850 mb, the trough clearly continued to the southwest from Erie to Fort Wayne (IN). Dry conditions existed across most of the forecast area at 500 mb, except for some moisture to the east of the trough axis, where weak cold advection was present. At 700 and 850 mb, moisture was clearly evident along and ahead of the trough axis across northeastern Ohio, Pennsylvania, New York, and New England. Cold advection was more evident behind the trough at these levels. Sounding data from Detroit (Fig. 2) show two distinct cloud layers, one from 6000 feet down to just above the surface (with a minimum temperature of -5 C at 3000 feet), and a second cloud deck from 8500 to 10000 feet (CTT = -13 C). A similar structure was in place at Buffalo, though the top of the lower cloud deck was at only 4500 feet and the upper cloud deck was quite thin, existed at 8000 feet and had a warmer CTT of -10 C.

At the surface (see Fig. 3), a weak, cold front extended southwest from a low in central New York, across northern Ohio and central Indiana, at roughly the same position as the 850 mb trough. Light rain and snow was indicated along and just behind the front between Cleveland and Toronto (Figs. 3 and 4). A lobe of high pressure over North Dakota combined with the weak New York low to produce northerly flow behind the cold front. The front and the precipitation progressed southeast across Ohio and Pennsylvania by 1500 UTC, as the low intensified slightly and moved to the New England coast and the lobe of high pressure moved into Minnesota. Winds behind the front became north-northwesterly, blowing across Lake Erie into northeastern Ohio and western Pennsylvania. With cold advection occurring at 850 mb behind the cold front and temperatures remaining surely constant at the surface, the atmosphere became less stable over northeastern Ohio in the lowest 5000 feet during the period from the first to the third flight.

Radar data for 1300-2000 UTC (Fig. 4) show that the precipitation moved southeast into Pennsylvania and dissipated with time. Twin Otter tracks indicate that the first flight (Figs. 4a-c) was made within and near the precipitation, matching the mixed conditions observed. Tracks for the second (Figs. 4d,e) and third (Figs. 4f-h) show that the all-water conditions were observed well to the north of the precipitation swath.

Icing pilot reports of up to moderate intensity and all types were made around the area during the three flights (Fig. 5). Most of these PIREPs were for altitudes between 4000 and 8000 feet, and were found outside of the areas of precipitation. A few were found within or along the edges of the precipitation.

No satellite data was available for this case.

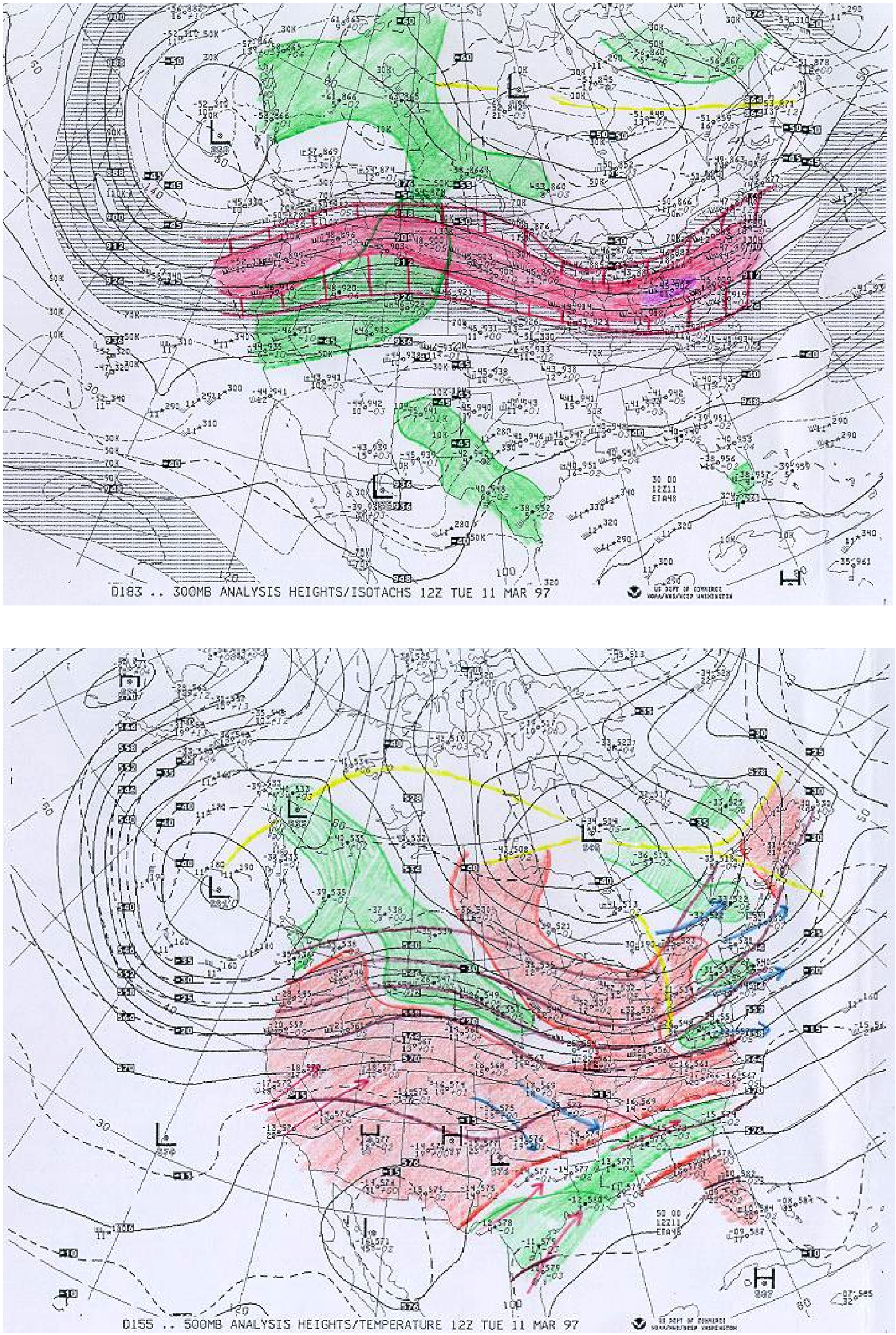


Figure 1 – Upper-air charts for 970311, 1200 UTC at a) 300 and b) 500 mb.

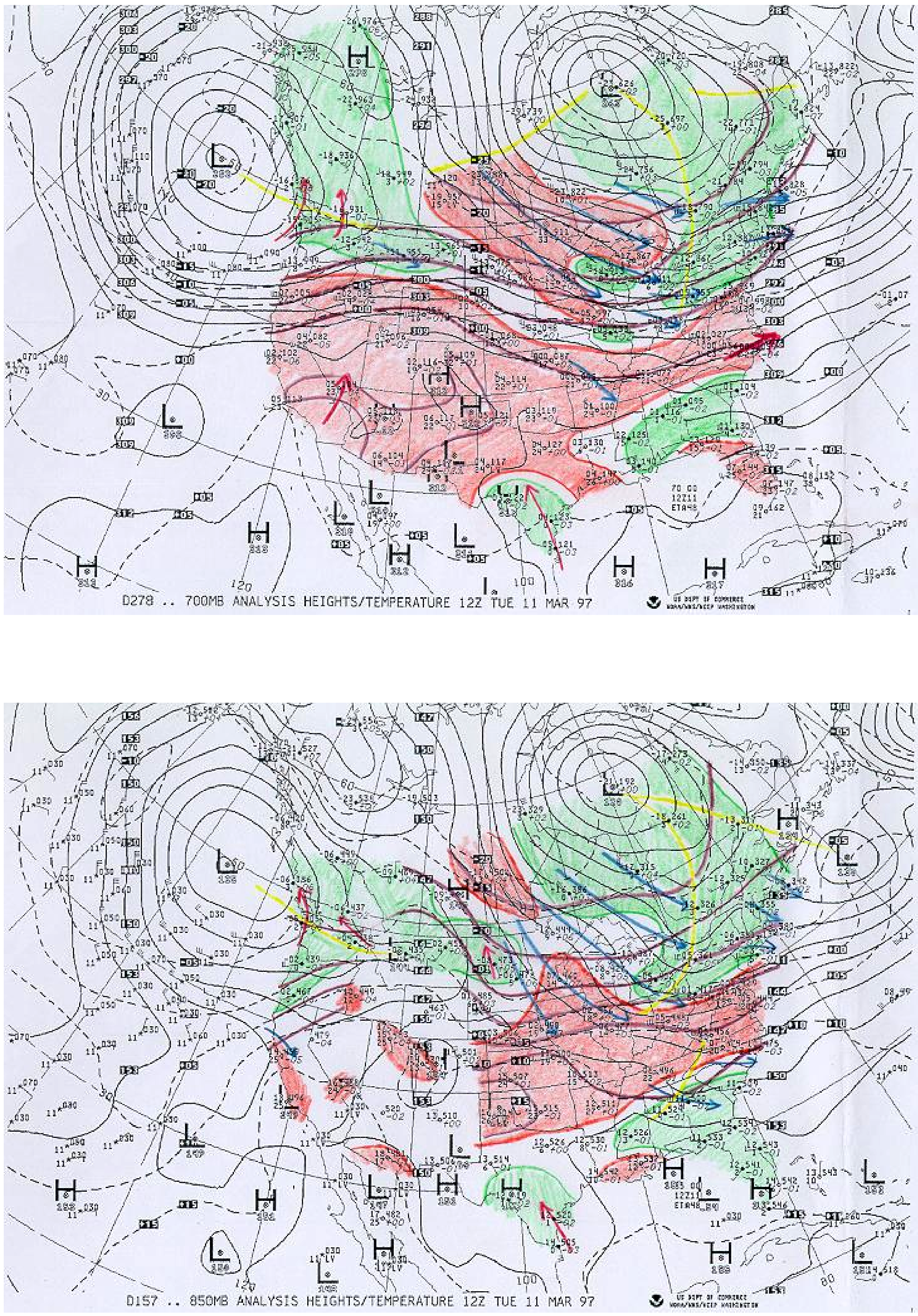
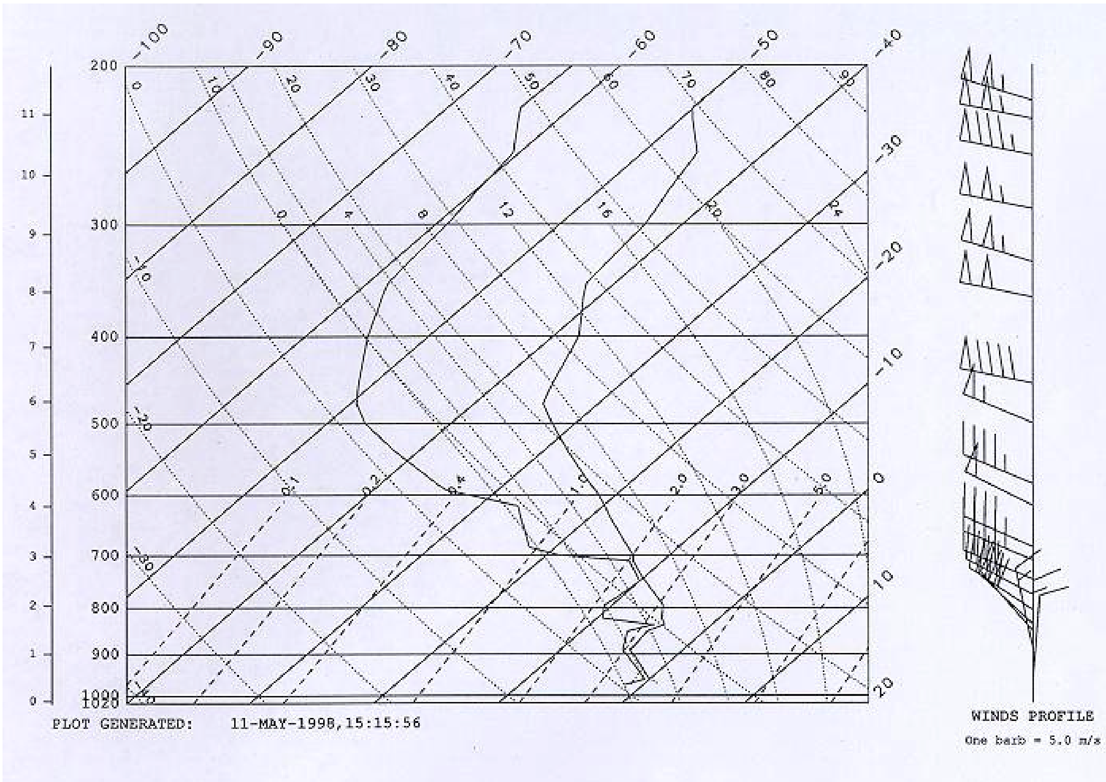


Figure 1 – Upper-air charts for 970311, 1200 UTC at c) 700 and d) 850 mb.



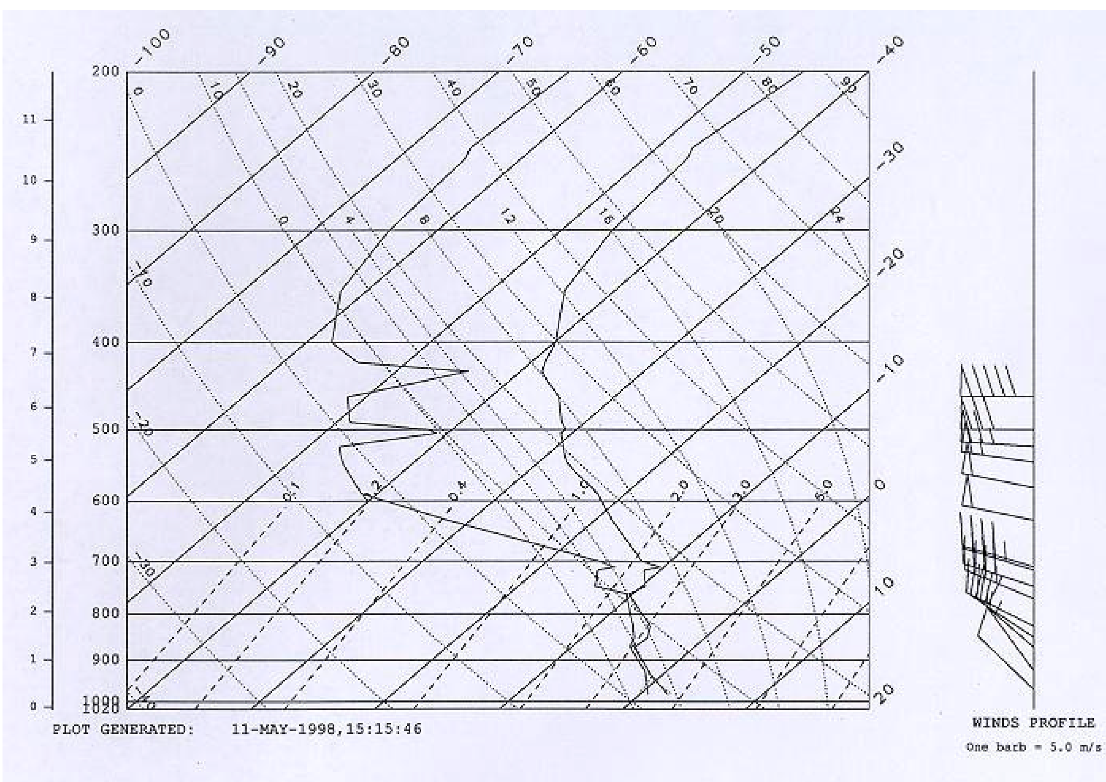


Figure 2 – Balloon-borne soundings for 970311, 1200 UTC at a) Detroit and b) Buffalo.

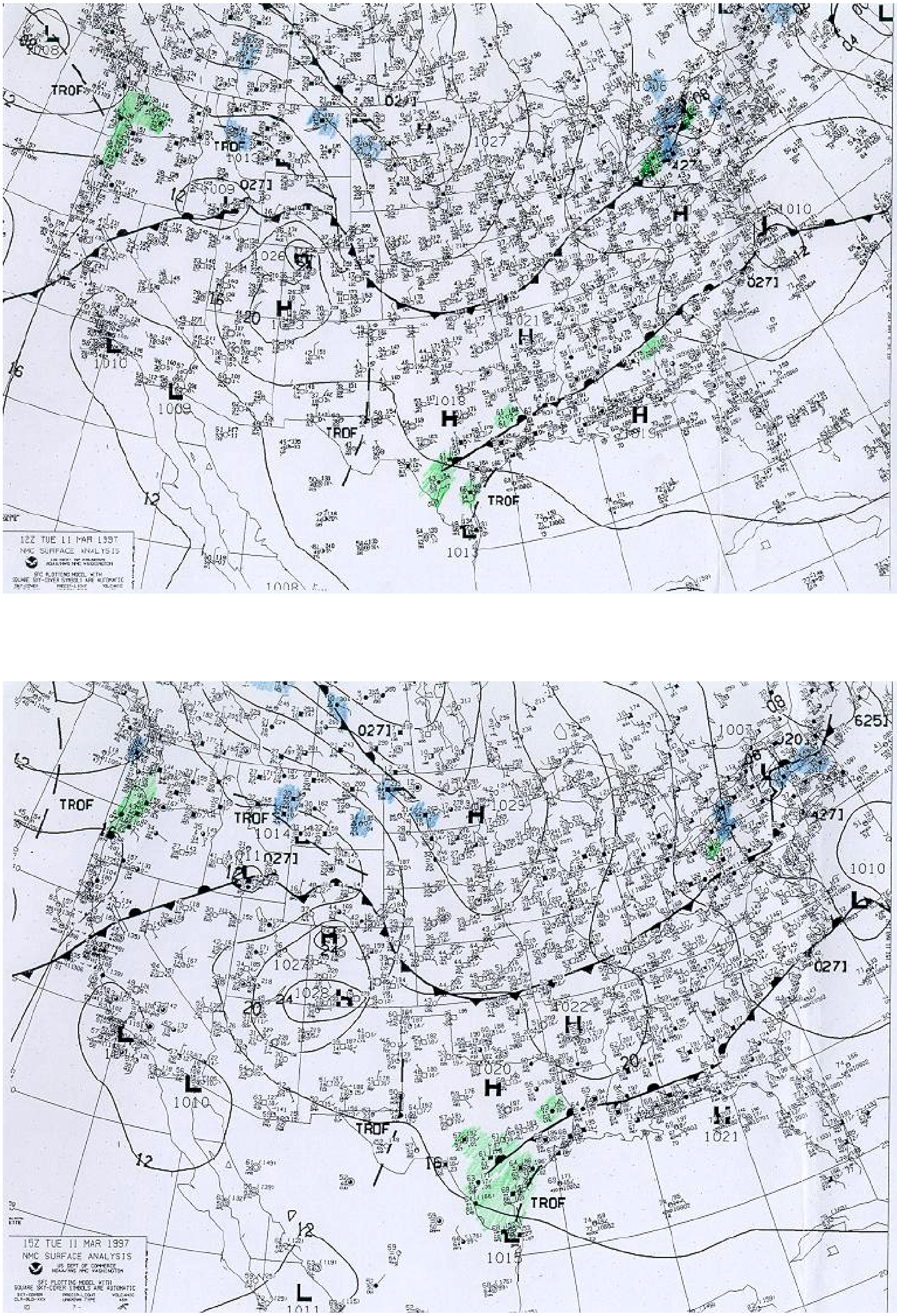
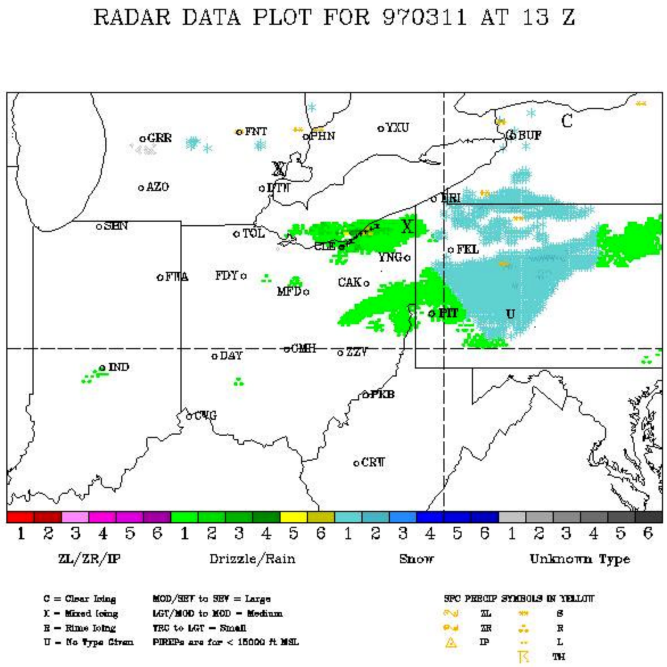


Figure 3 – Surface charts for 970311, a) 1200 and b) 1500 UTC.



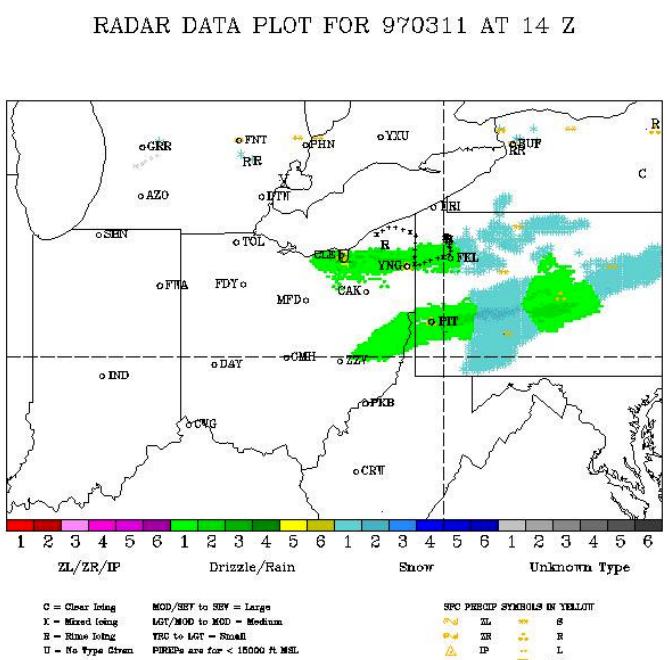
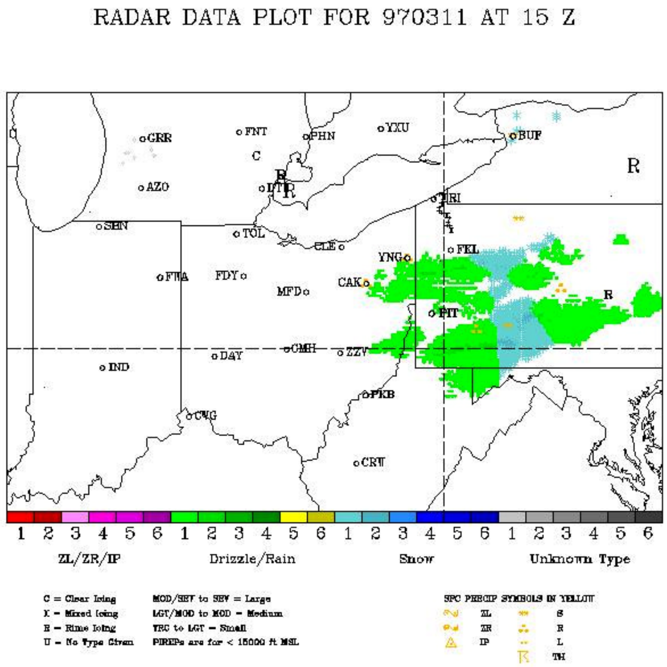


Figure 4 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970311, a) 1300 and b) 1400 UTC.



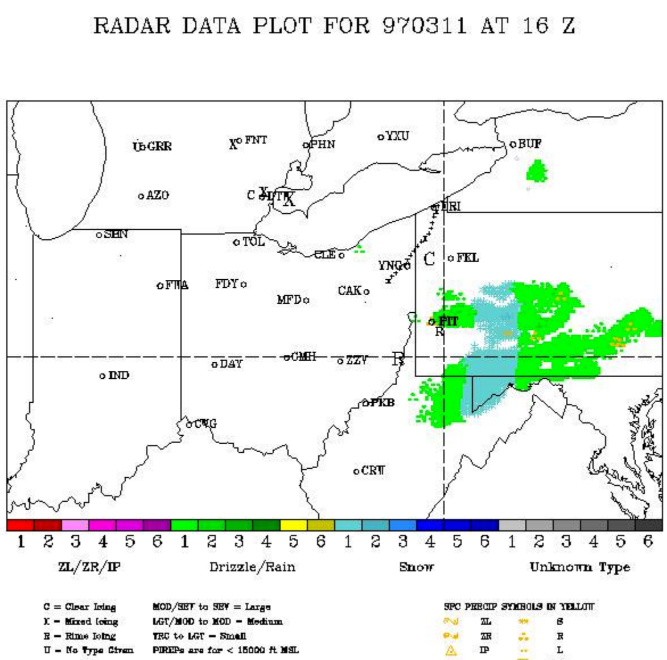
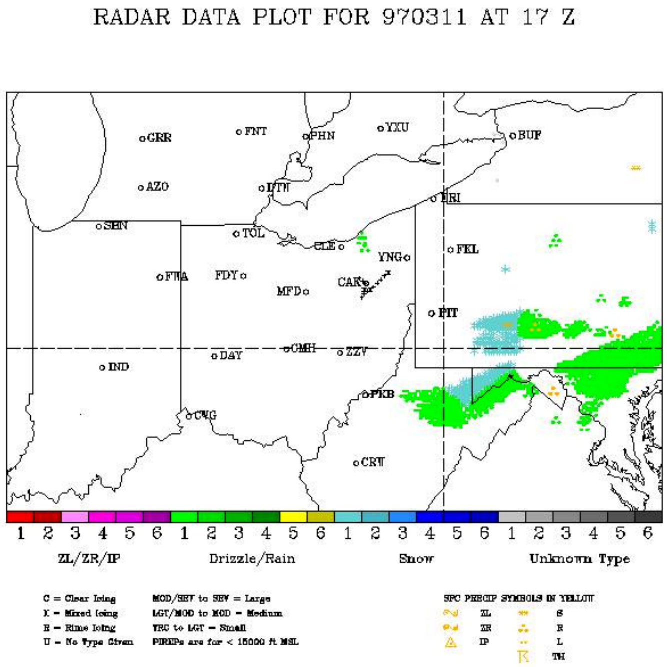


Figure 4 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970311, c) 1500 and d) 1600 UTC.



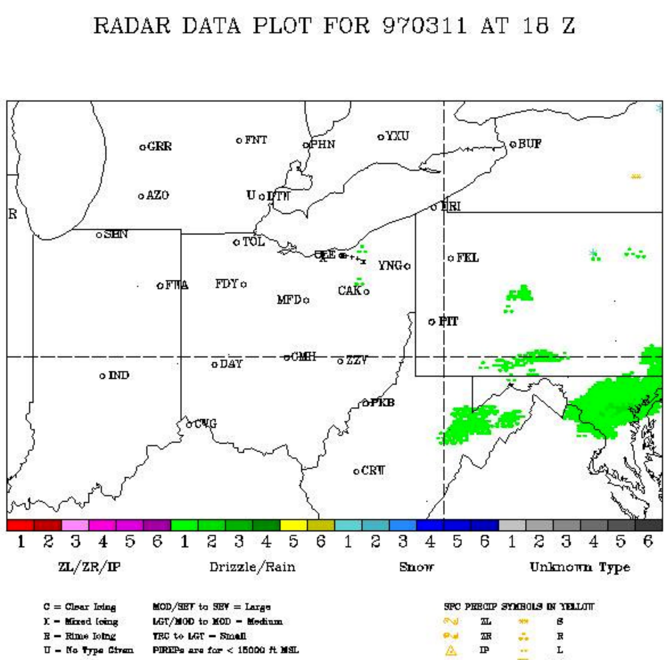
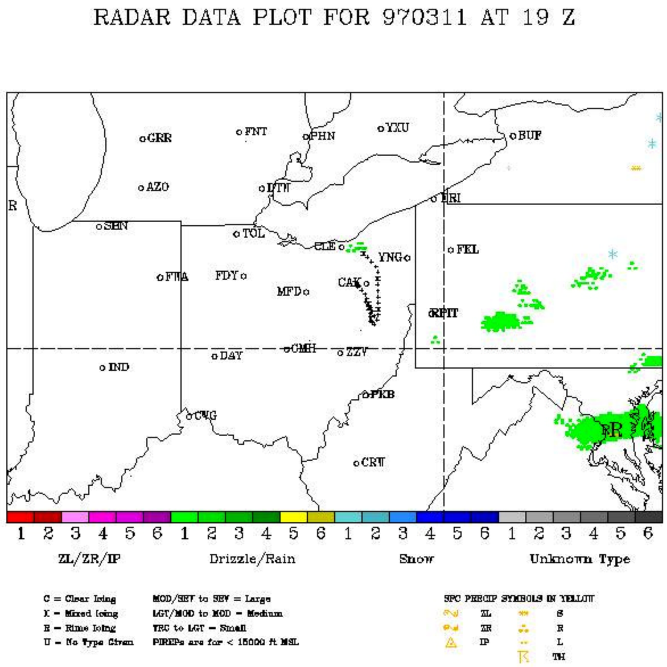


Figure 4 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970311, e) 1700 and f) 1800 UTC.



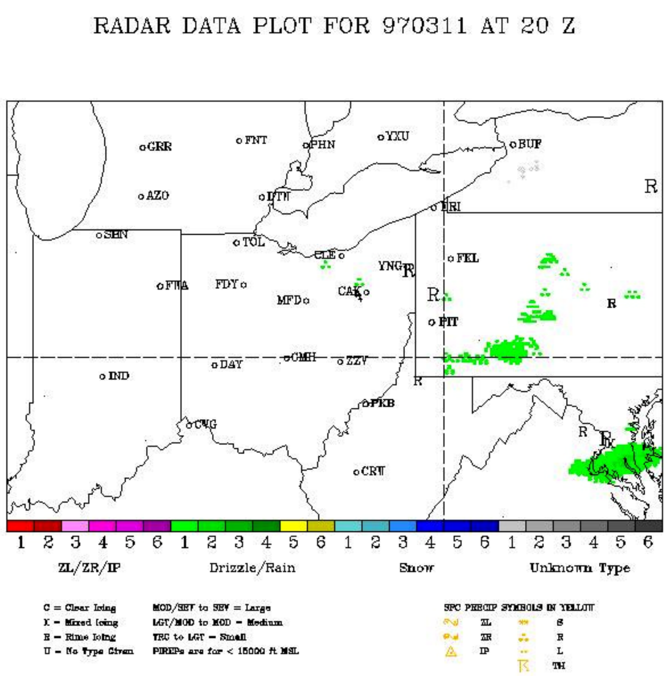
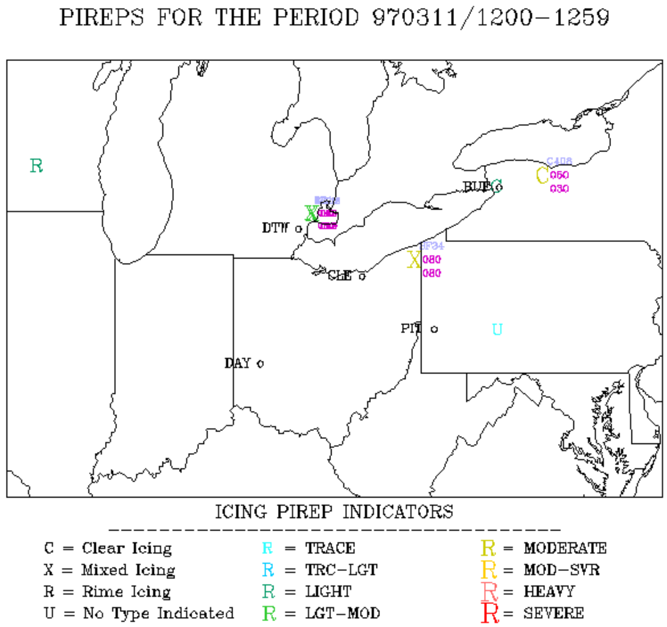


Figure 4 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970311, g) 1900 and h) 2000 UTC.



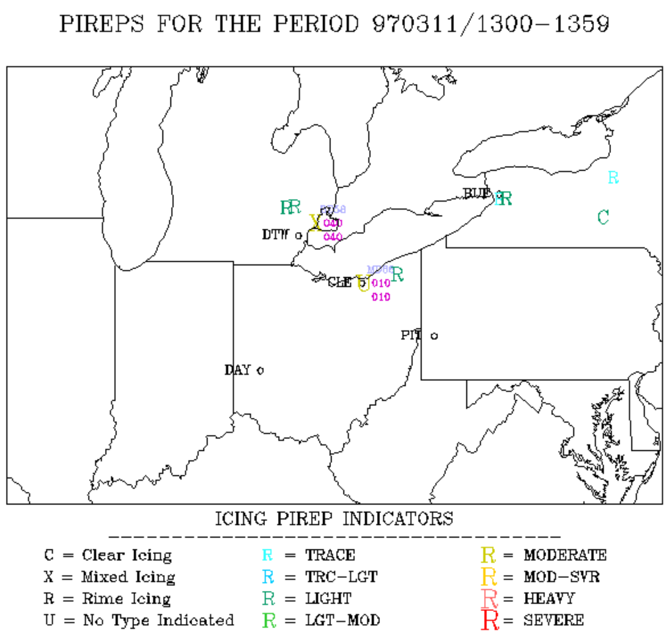
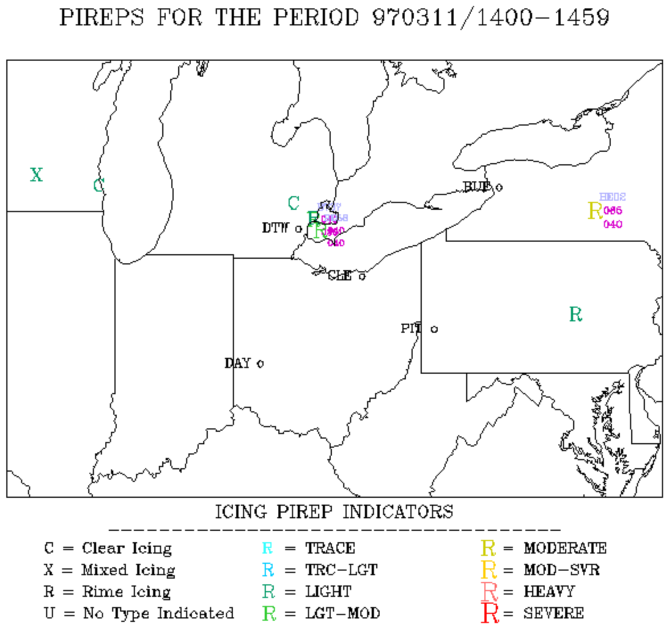


Figure 5 – Pilot reports of icing for 970311, a) 1200-1259 and b) 1300-1359 UTC.



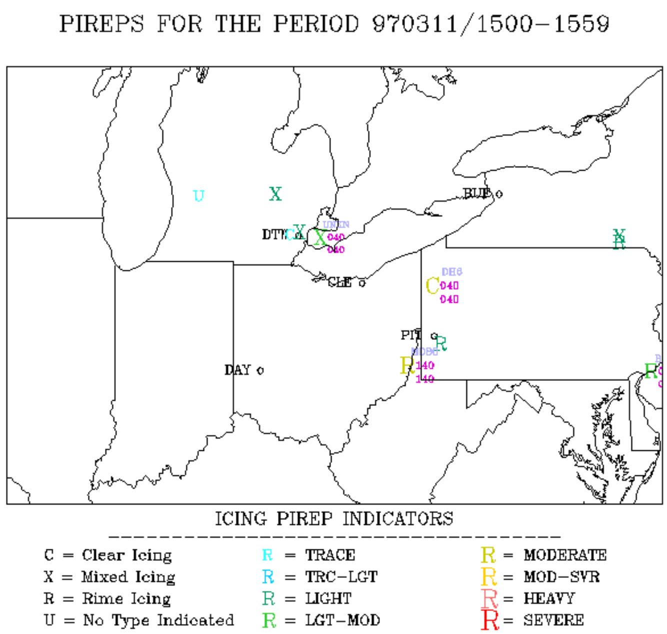
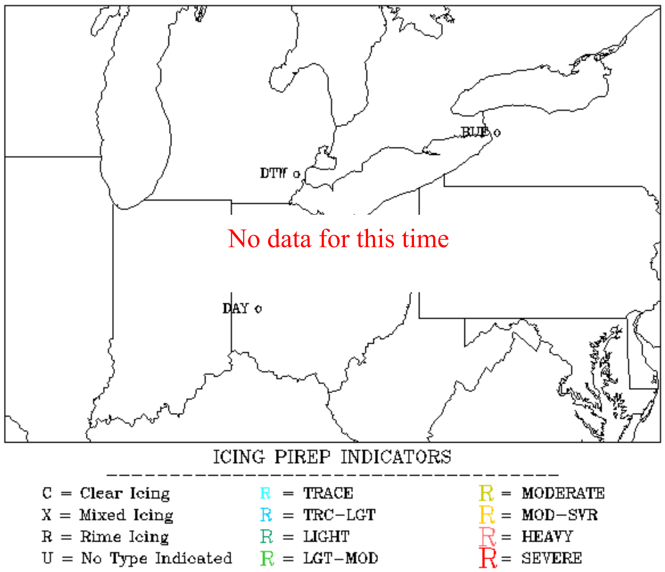


Figure 5 – Pilot reports of icing for 970311, c) 1400-1459 and d) 1500-1559 UTC.

PIREPS FOR THE PERIOD 970311/1600–1659



PIREPS FOR THE PERIOD 970311/1700–1759

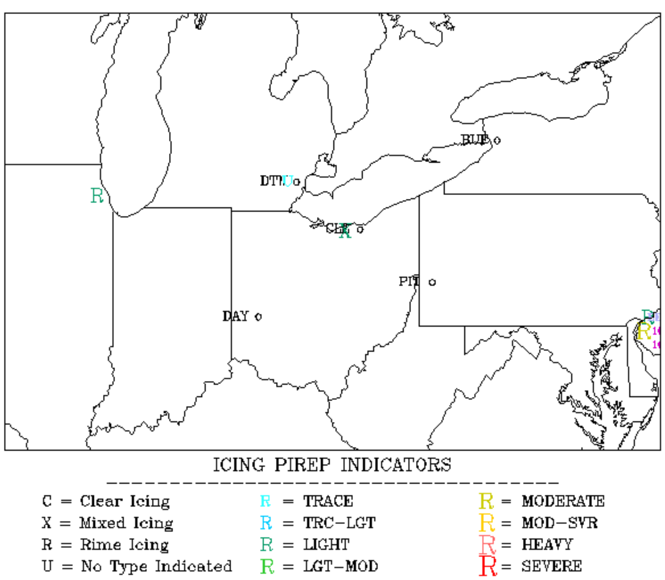
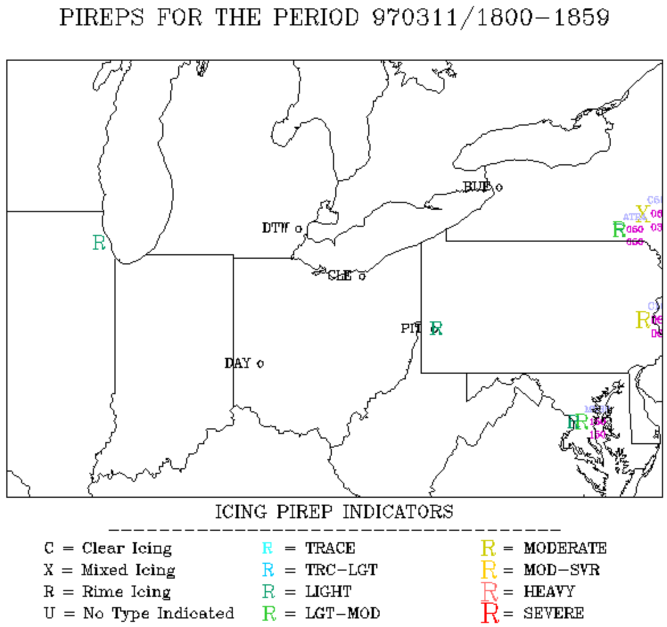


Figure 5 – Pilot reports of icing for 970311, e) 1600-1659 and f) 1700-1759 UTC.



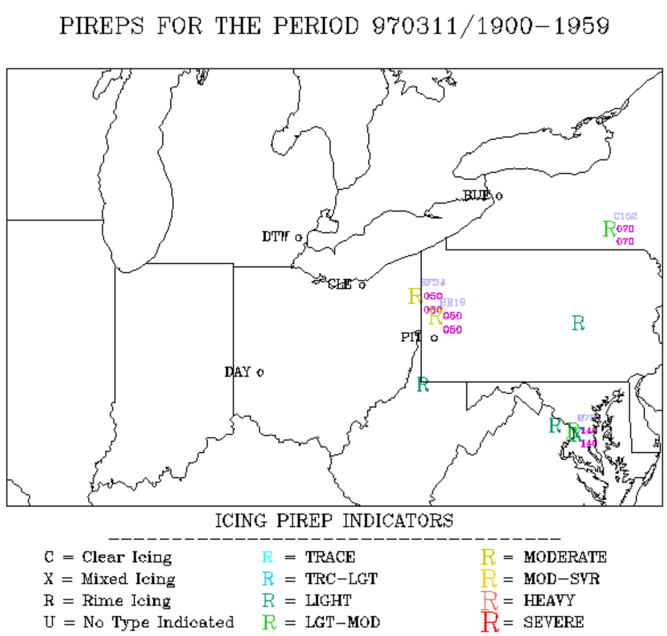


Figure 5 – Pilot reports of icing for 970311, g) 1800-1859 and h) 1900-1959 UTC.

March 13, 1997

Flight #1 - Over southeast Ontario, Selfridge AFB and Flint, Michigan from 1848 to 2036 UTC.
Flight #2 - Over Flint, Sarnia (Ontario) and southeastern Ontario from 2129 to 2252 UTC.

Brief overview

Two fights were made on this day. During the first flight, the aircraft flew to Selfridge, encountering an all-liquid cloud layer between 7500 and 9500 feet. This cloud contained LWC up to 0.25 and some out-of-focus droplets which bordered on freezing drizzle sizes. Between Selfridge and Flint, the cloud continued to be nearly all-water in composition and extended up to 11800 feet. More borderline freezing drizzle was encountered, and some heavily rimed crystals/graupel began showing up near the end of the flight. Ice pellets and graupel were reported at both Selfridge and Sarnia between 2000 and 2200 UTC, matching these in-flight observations. Similar conditions were observed during the second flight, but with more mixed conditions, including graupel and stellar crystals. Some periods of all-liquid were still observed with sporadic LWC values as high as 0.5. Some clean, in-focus freezing drizzle was observed near Sarnia at 10000-11000 feet and other pockets of out-of-focus near-ZL sized drops were found in that vicinity.

These flights were made at the southern end of an area of strong convergence and warm advection that was moving northward through the area. This convergence area was marked by a band of patchy, light precipitation just north of the flight area at 1800 UTC. The Flint/Selfridge area was located within a break in the precipitation shield at 1800 and 1900 UTC, but by 2000 UTC, some light snow grains and pellets, as well as some radar echo began to show up there.

Relevant weather features

At 1200 UTC, a weak trough was in place across the southern Plains at 500 mb (Fig. 1). Weak warm advection and saturated conditions existed across the Southeast states, ahead of this trough. A swath of dry air was in place across Illinois, Indiana, and southwestern Ohio, while saturated air existed across Michigan, northeastern Ohio, and southwestern Pennsylvania at 500 mb. The moisture pattern was very similar at 700 mb, but shifted a little to the southwest, with saturated conditions in place just south of Detroit. Warm advection extended further to the north at 700 mb, reaching northern Indiana and central Ohio, while weak cold advection was evident in northern Michigan. At 850 mb, the cold advection was stronger and covered all of Michigan, as well as northeastern Ohio, Pennsylvania, and New York. The cold advection to the north and strong warm advection from the south met in a line across southern Michigan and northeastern Ohio, which nicely matched the swath of moisture at 700 mb. This swath of saturated air was still evident over Wisconsin and Michigan at 850 mb, but did not continue to the southeast across Ohio, as very dry conditions were evident at Pittsburgh and Buffalo.

The 1200 UTC Detroit sounding (Fig. 2) shows a layer of cloudiness to from about 7000 feet on up, with fairly dry air below. Strong stability was in place within the cloud deck from 7000 to 8500 feet, then more unstable conditions were present from 8500 to 10000 feet, capped by a 1 C inversion from 10000 to 11500 feet. Ice saturated or nearly-ice saturated conditions were present up to approximately 400 mb, where temperatures were around -35 C, roughly matching the CTTs indicated on the 1445 infrared image.

By 0000 UTC, the Plains trough strengthened at all levels and a low center developed over western Minnesota at 700 mb, and over Missouri at 850 mb (Fig. 3). Saturated air from the south pushed quickly northward and combined with warm advection to eliminate the dry air that was in place across Indiana and Ohio at these levels earlier. Saturated conditions covered the forecast area at 500, 700, and 850 mb. The area of strongest warm advection and the tightest temperature gradient pushed into northern Michigan at 700 mb and over lower Michigan at 850 mb, while the cold, which was evident over Michigan at 1200 UTC, retreated to New York and New England by 0000 UTC.

Satellite imagery from 1445 UTC (Fig. 4) indicate the existence of deep clouds over most of Michigan and northeastern Ohio, and breaks in these clouds over Ohio and Indiana, matching the moisture patterns on the 1200 UTC upper air charts. These were slightly north of the location of the dry air at 1200 UTC, due to its northward movement over 3 hours. With time, the breaks became filled in, as deep moisture continued to move northward. National and regional radar data (Figs. 5, 6) reflect this progression. The 1300 UTC national radar mosaic shows a swath of snow across central Michigan, a gap in the precipitation across Ohio, Indiana, and northern Illinois, and an area of rain to the southwest. By 1800 UTC, the entire precipitation pattern shifted to the north and the gap had shrunk. This trend continued through the period of flight (1900-2300 UTC). Some ice pellets and snow grains were reported at Selfridge and Sarnia by 2000 UTC, within some patchy reflectivity on the south side of the central Michigan precipitation swath. Pilot reports of moderate icing occurred between 9000 and 12000 feet, along the southern edge of the Michigan precipitation swath early on, but became sparse as the deep, cold cloud shield filled in (Fig. 7).

At the surface, a 1038 mb high that was centered just north of Michigan nosed southeastward into Pennsylvania at 1500 UTC (Fig. 8). Relatively clear skies were present to the northeast of this ridge axis, while clouds and precipitation were occurring to the southwest of it. A weak low/trough was strengthening over eastern Nebraska and a stationary front extended southeast from the low across Missouri, then eastward across the Tennessee-Kentucky border. Snow and freezing rain were occurring to the north of the low, across the upper Midwest, with the aforementioned swath of snow protruded southeast from the main snow area across central Michigan. Rain was occurring to the northeast of another weak low over southwestern Arkansas, reaching southern Illinois and southwestern Indiana. By 2100 UTC, the Arkansas low strengthened slightly and began to merge with the Nebraska low over the Arkansas-Missouri region, while rain from the south moved northeast into western Ohio and nearly all of Indiana.

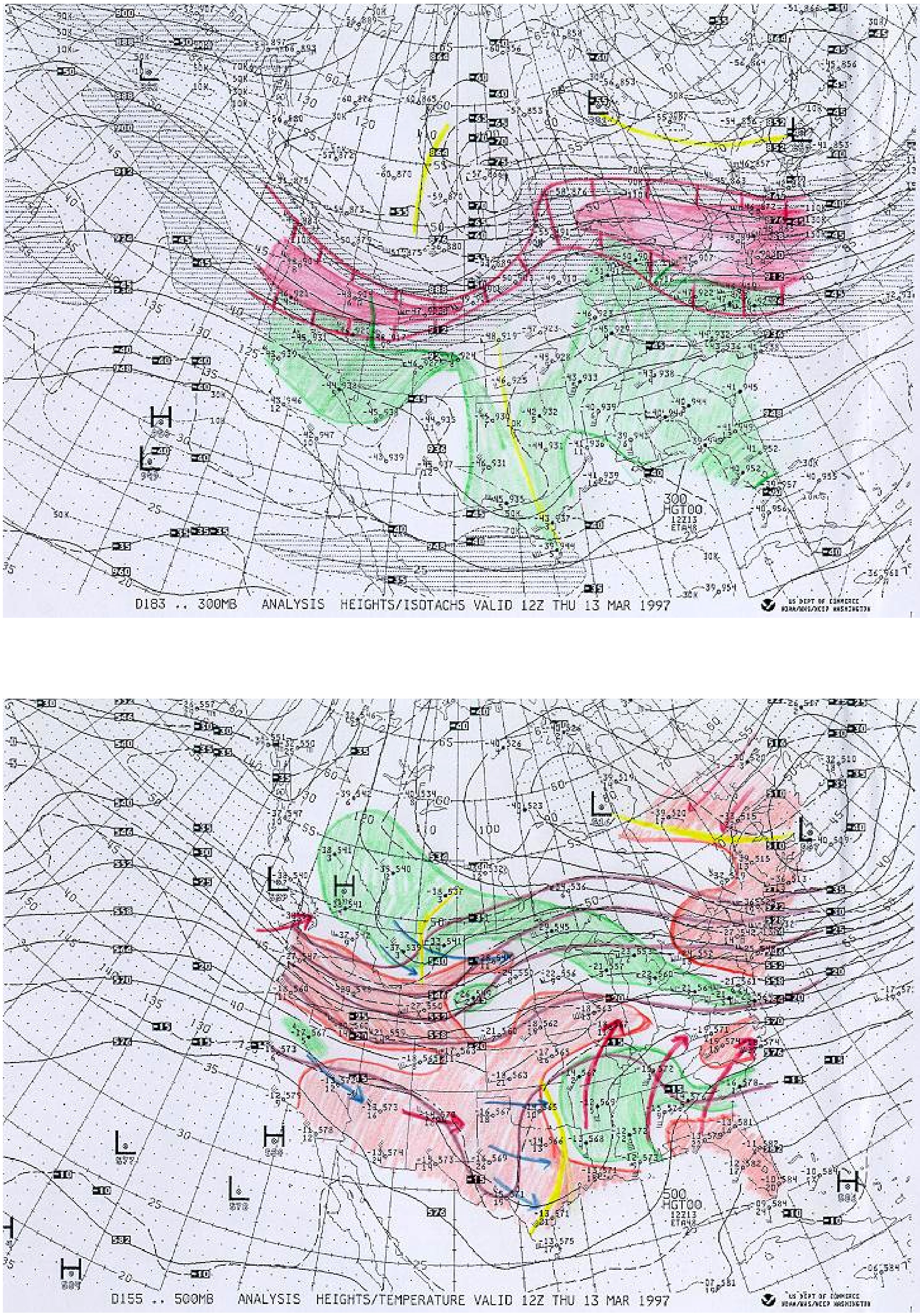


Figure 1 – Upper-air charts for 970313, 1200 UTC at a) 300 and b) 500 mb.

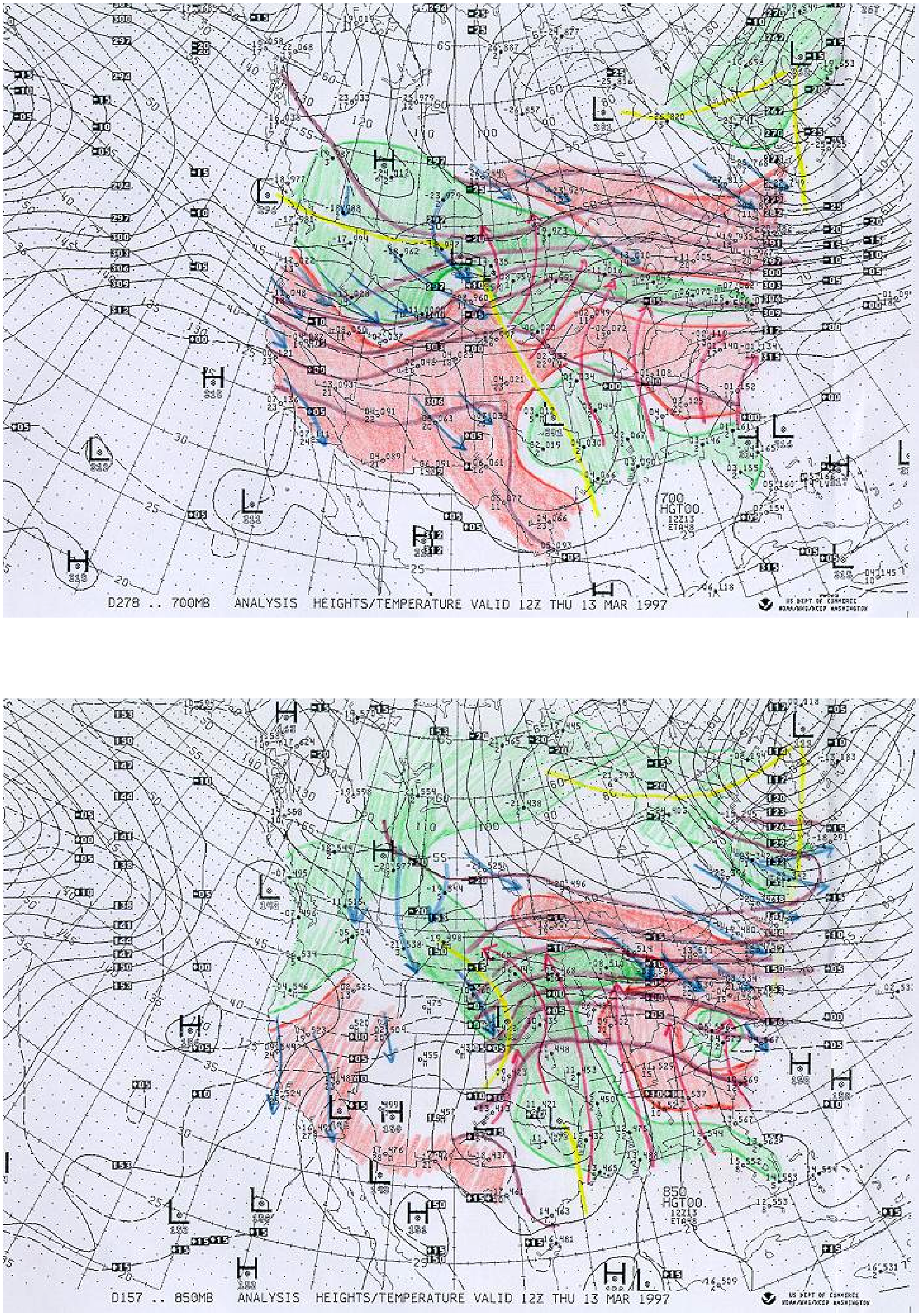


Figure 1 – Upper-air charts for 970313, 1200 UTC at c) 700 and d) 850 mb.

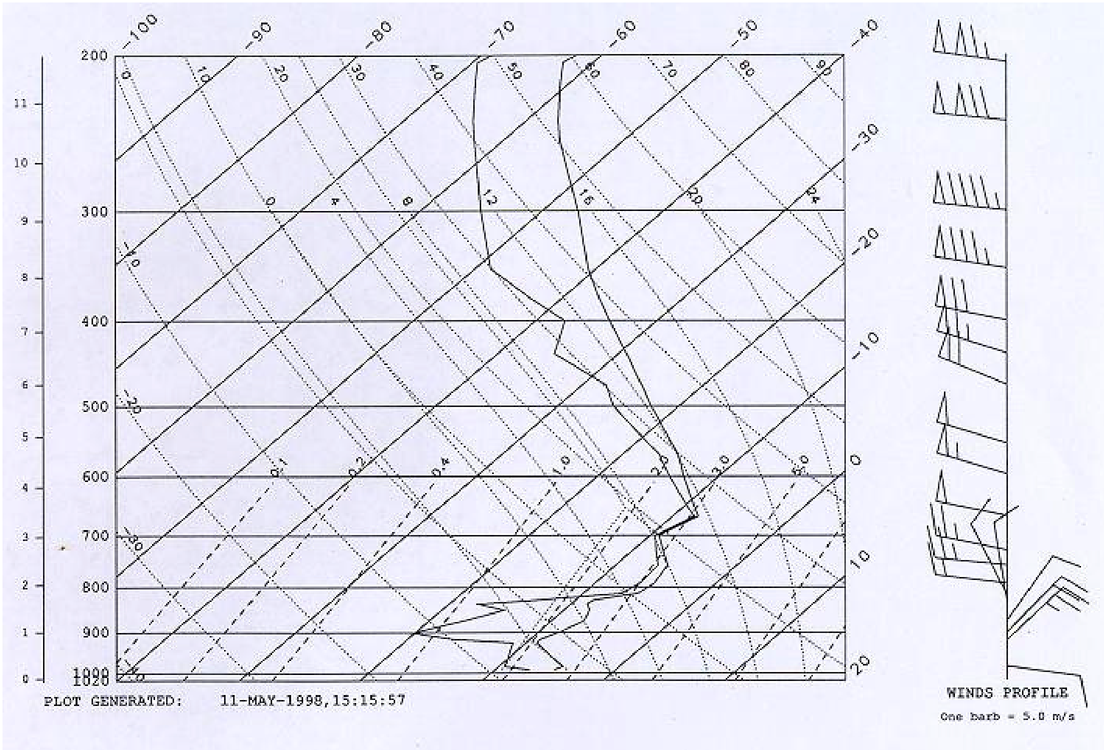
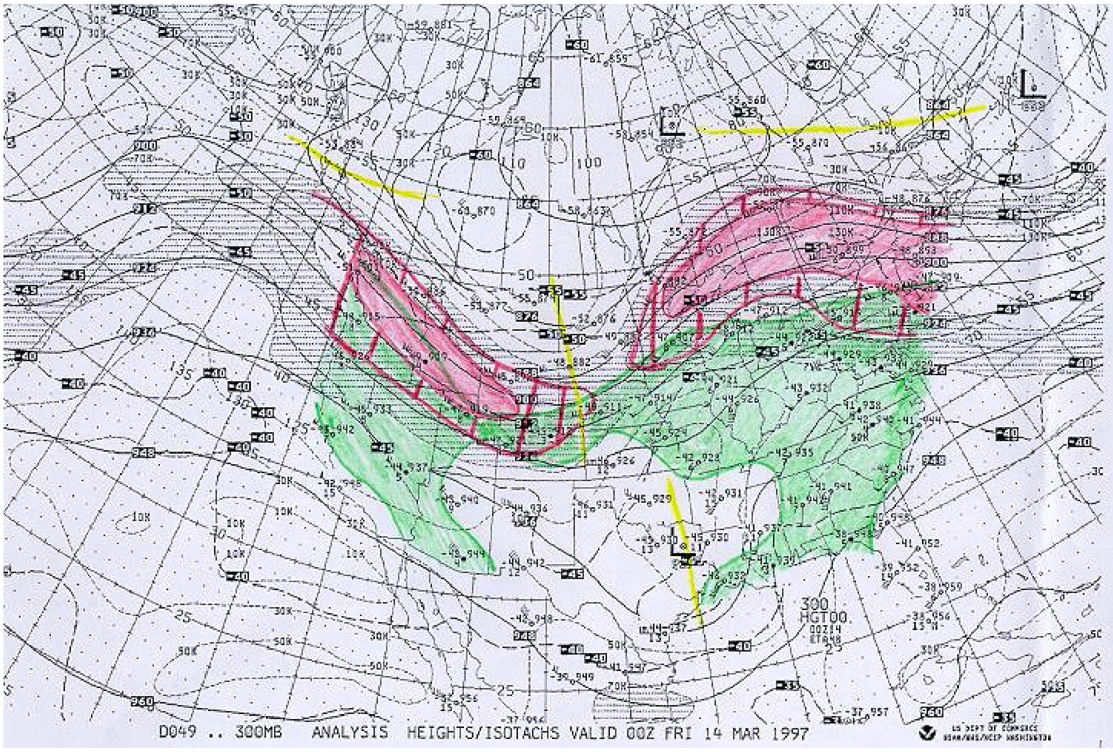


Figure 2 – Balloon-borne sounding for 970313, 1200 UTC at Detroit.



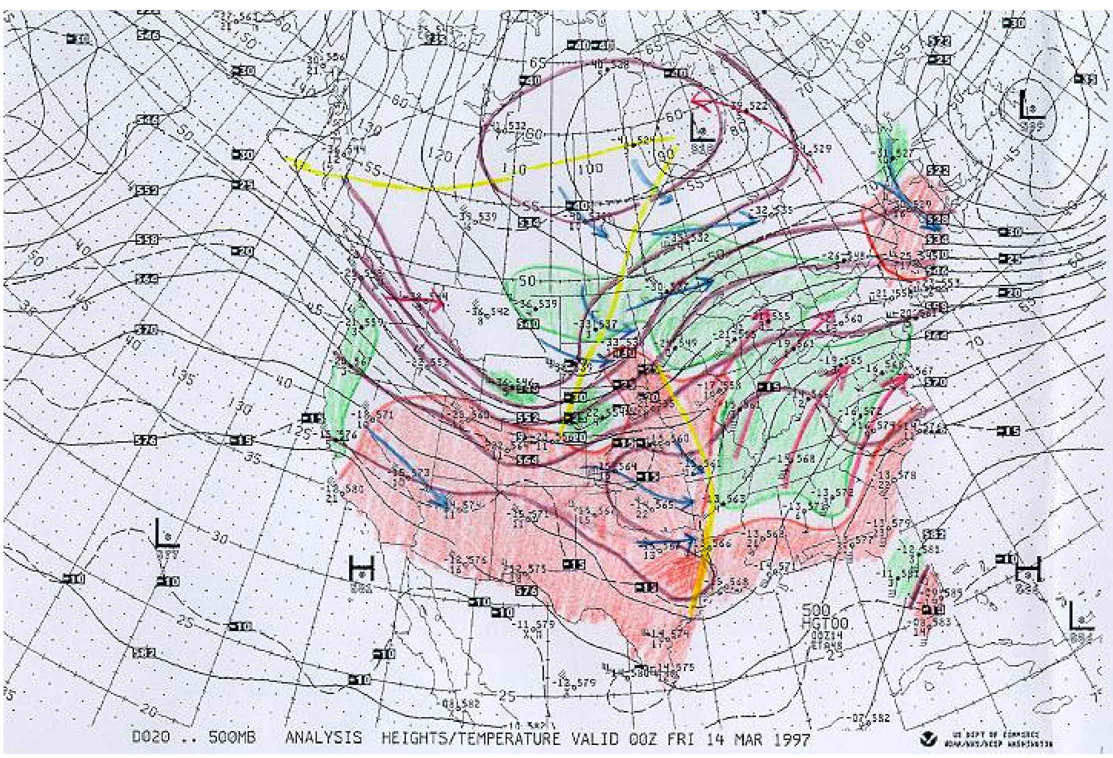
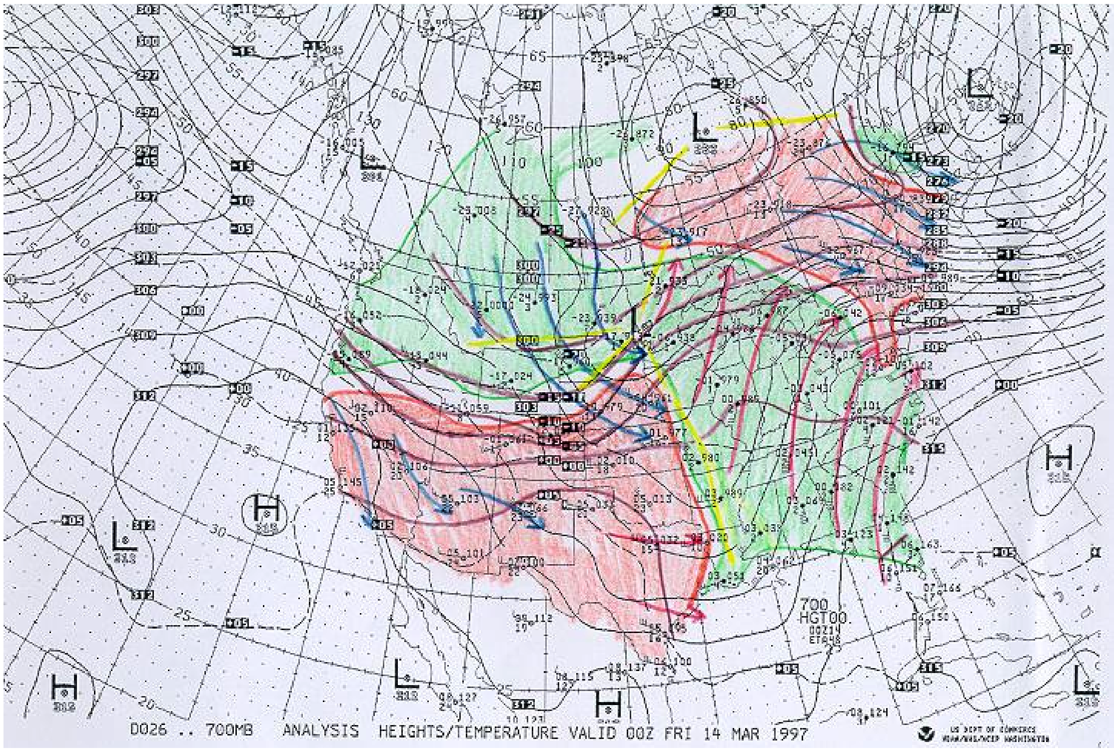


Figure 3 – Upper-air charts for 970314, 0000 UTC at a) 300 and b) 500 mb.



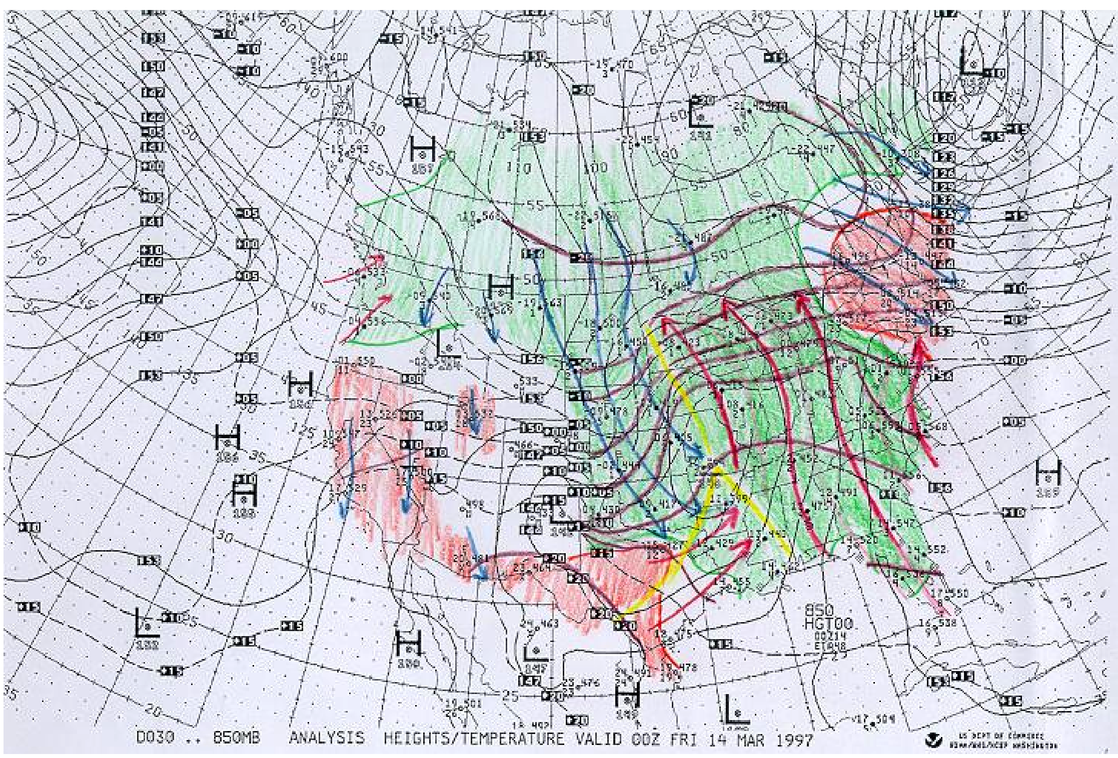


Figure 3 – Upper-air charts for 970314, 0000 UTC at c) 700 and d) 850 mb.

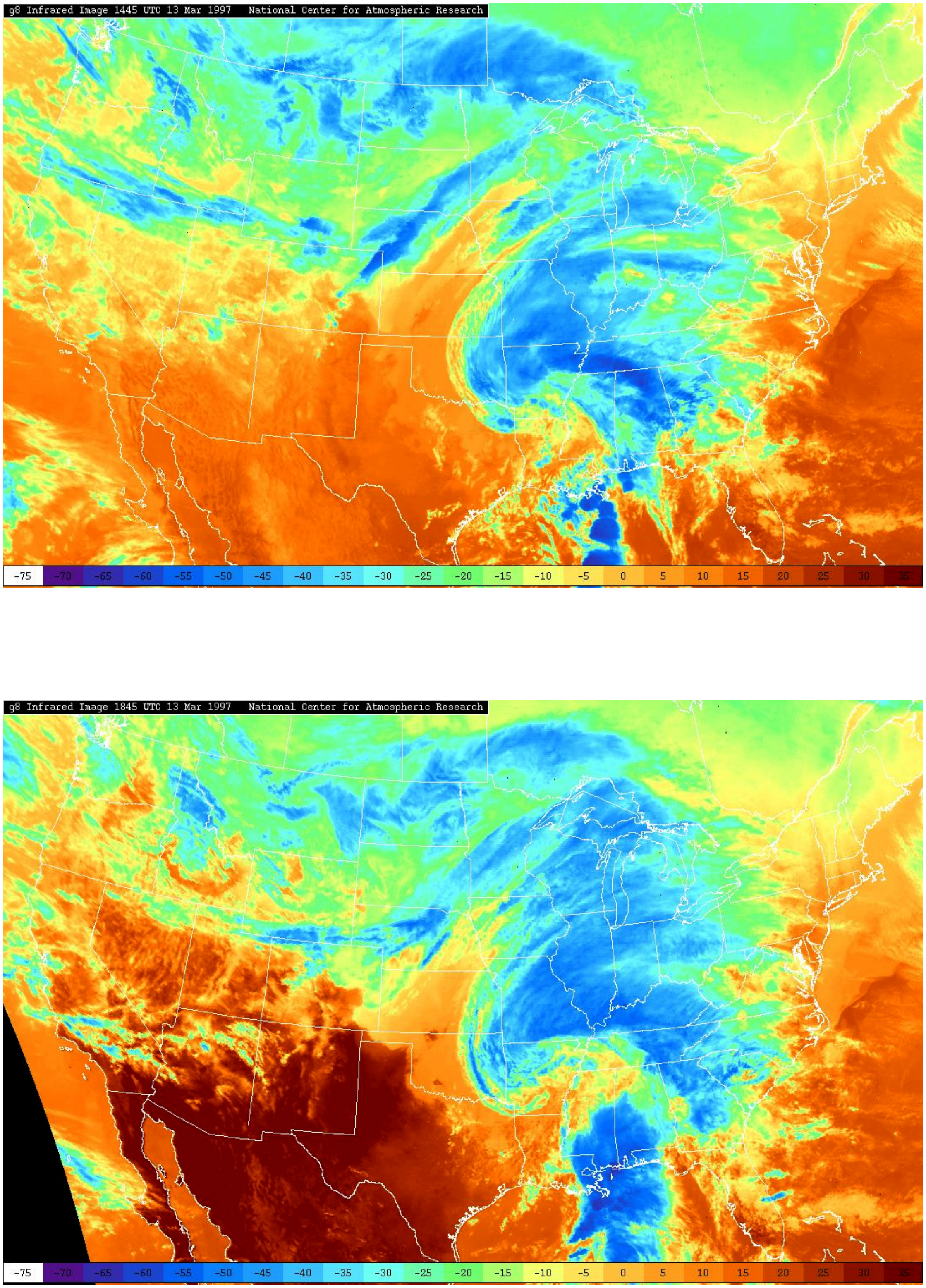
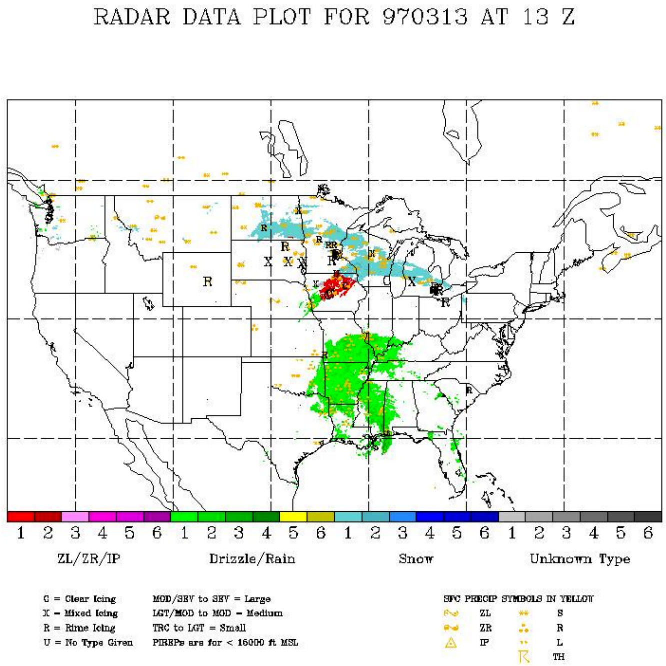


Figure 4 – GOES-8 infrared satellite imagery for 970313, a) 1445 and b) 1845 UTC.



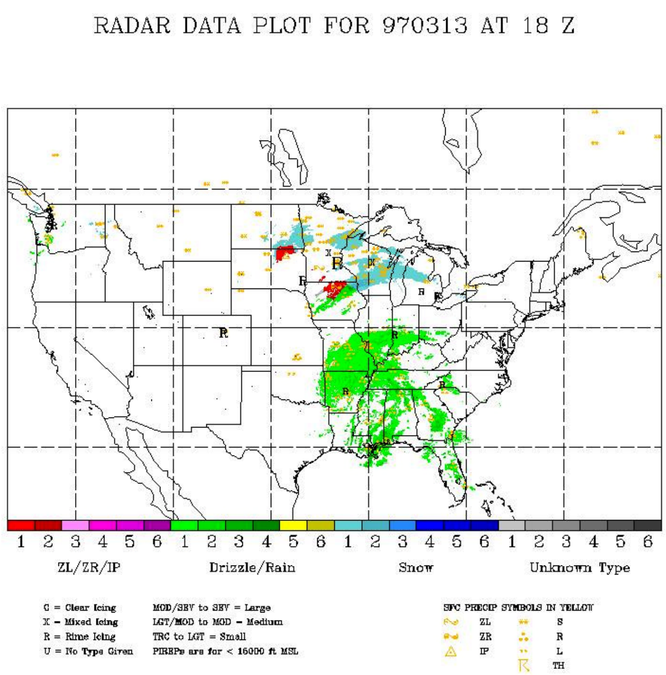
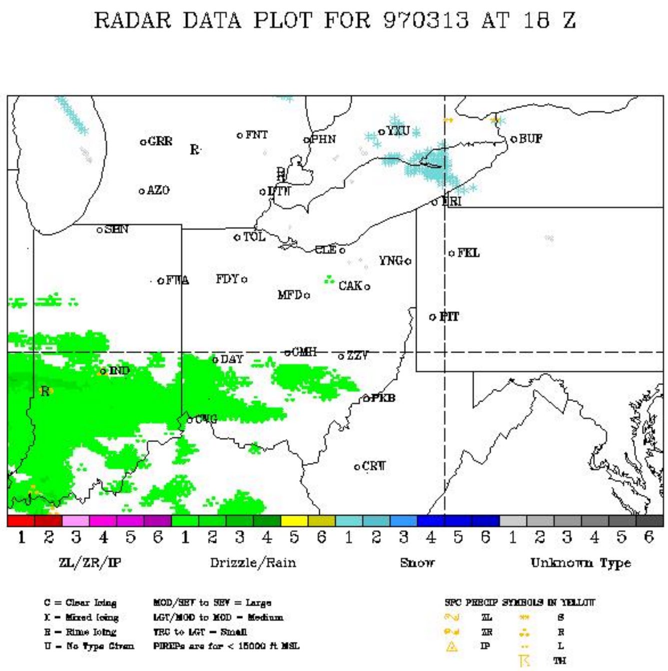


Figure 5 – National radar data, surface observations and icing PIREPs for 970313, a) 1300 and b) 1800 UTC.



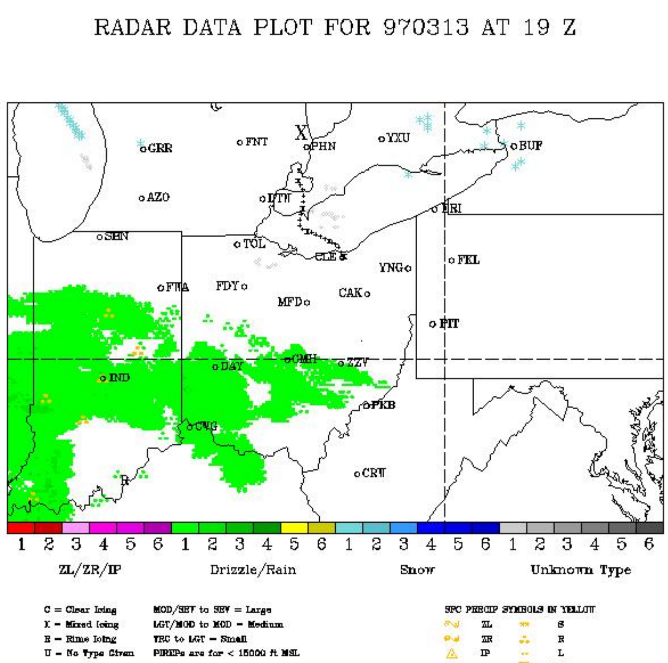
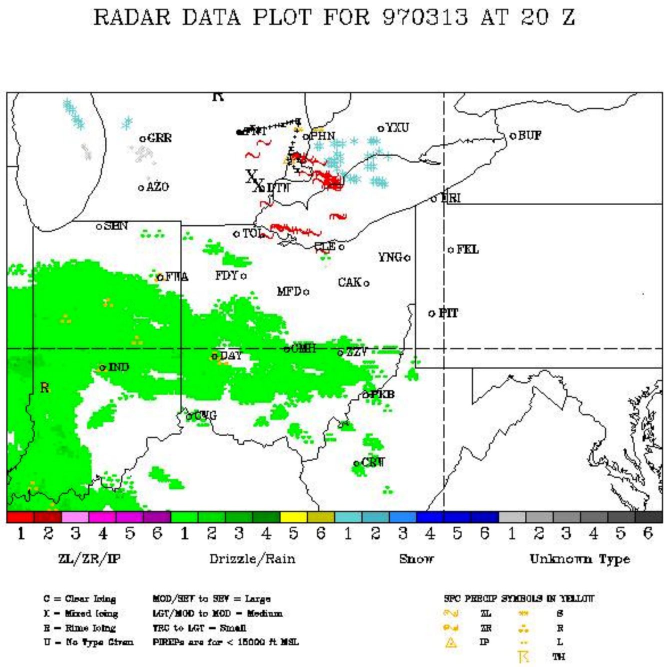


Figure 6 – Regional radar data, surface observations, icing PIREPs and Twin Otter tracks for 970313, a) 1800 and b) 1900 UTC.



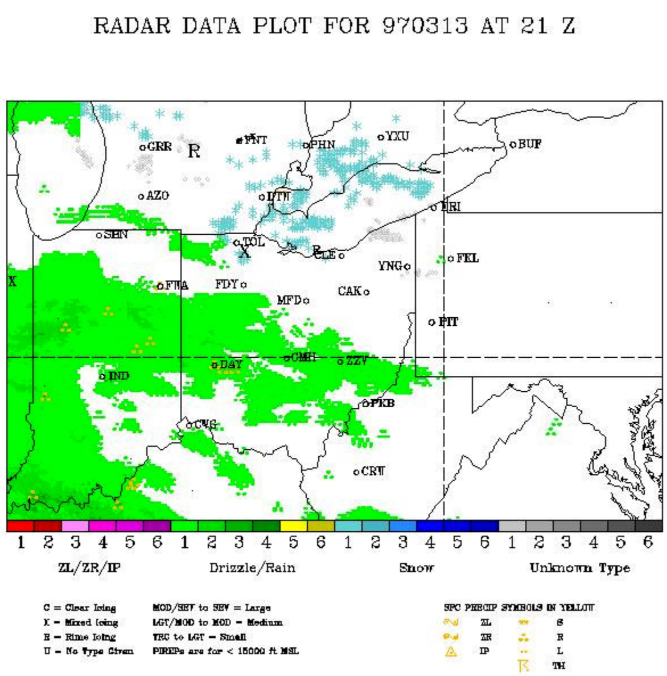
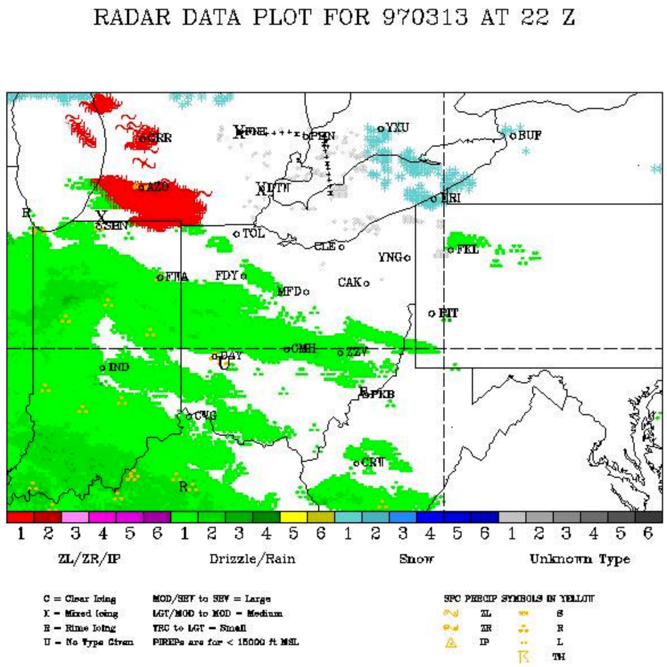


Figure 6 – Regional radar data, surface observations, icing PIREPs and Twin Otter tracks for 970313, c) 2000 and d) 2100 UTC.



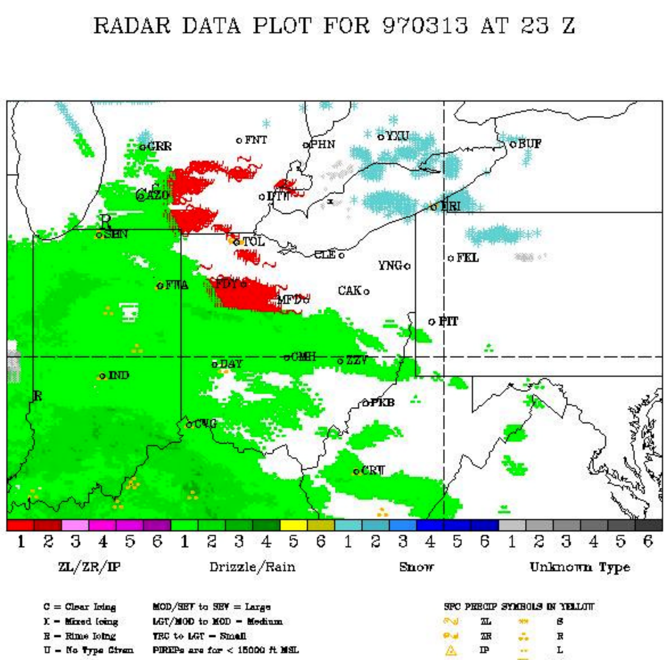
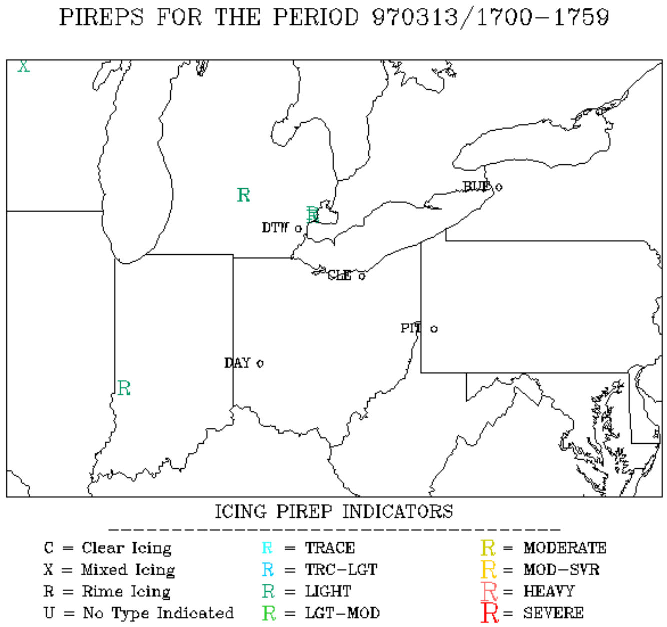


Figure 6 – Regional radar data, surface observations, icing PIREPs and Twin Otter tracks for 970313, e) 2200 and f) 2300 UTC.



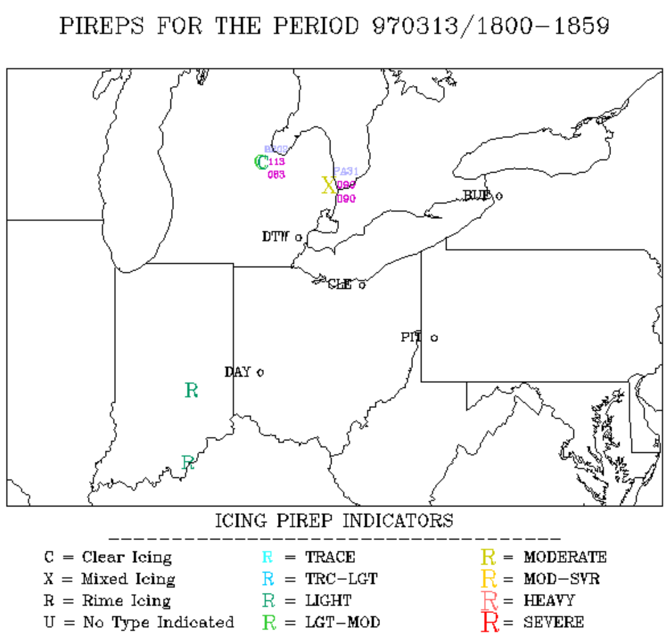
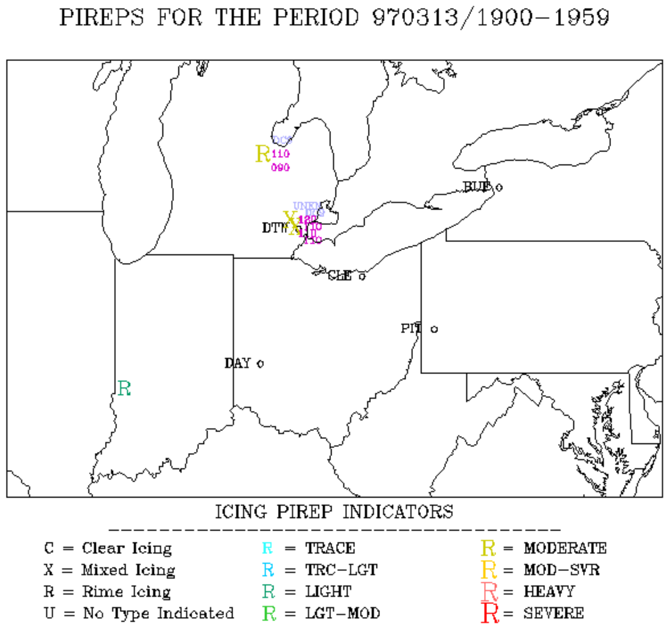


Figure 7 – Pilot reports of icing for 970313, a) 1700-1759 and b) 1800-1859 UTC.



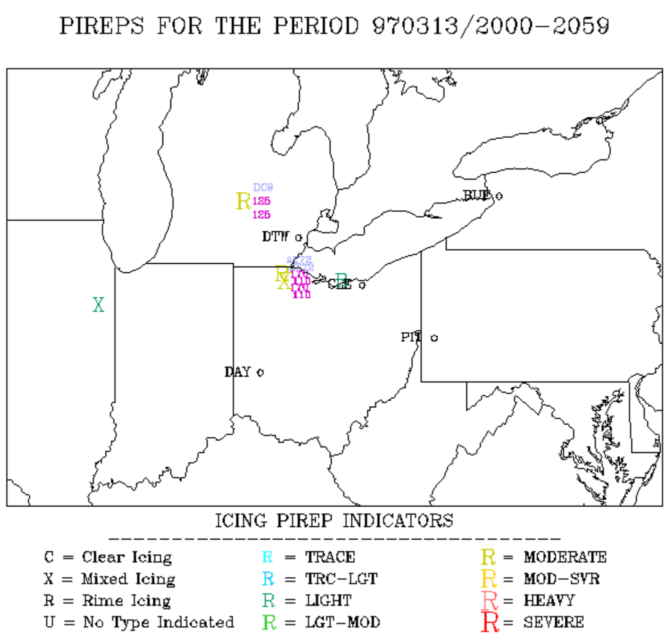
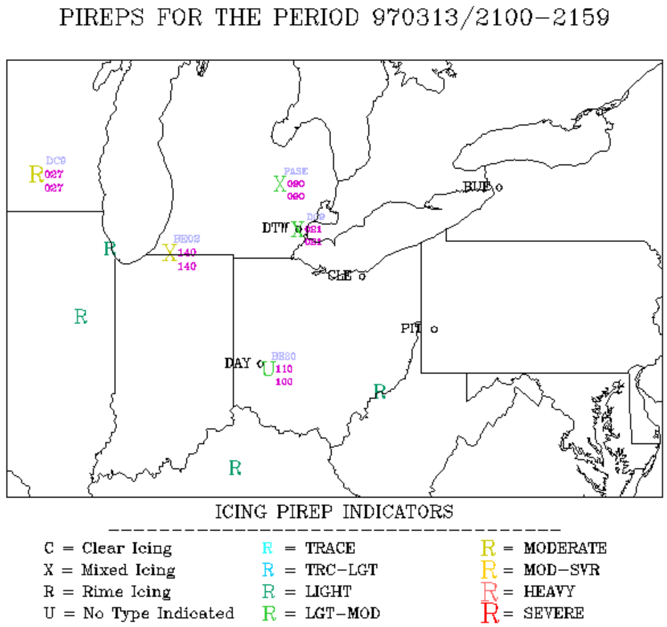


Figure 7 – Pilot reports of icing for 970313, c) 1900-1959 and d) 2000-2059 UTC.



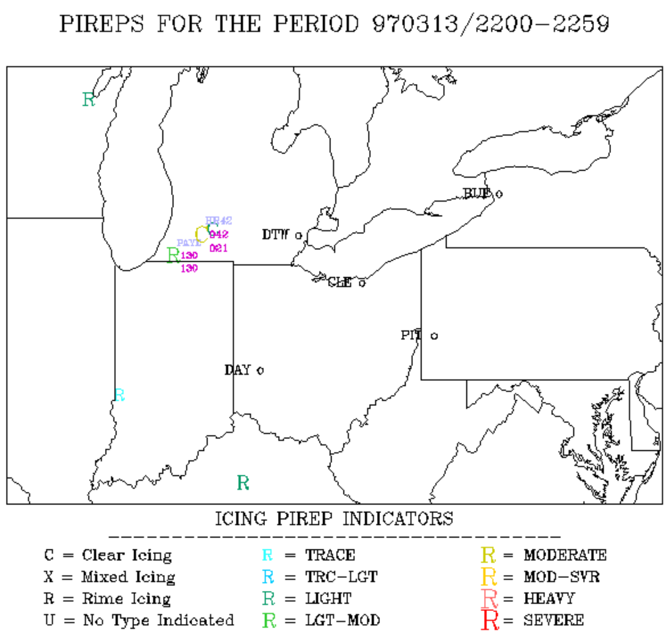


Figure 7 – Pilot reports of icing for 970313, e) 2100-2159 and f) 2200-2259 UTC.

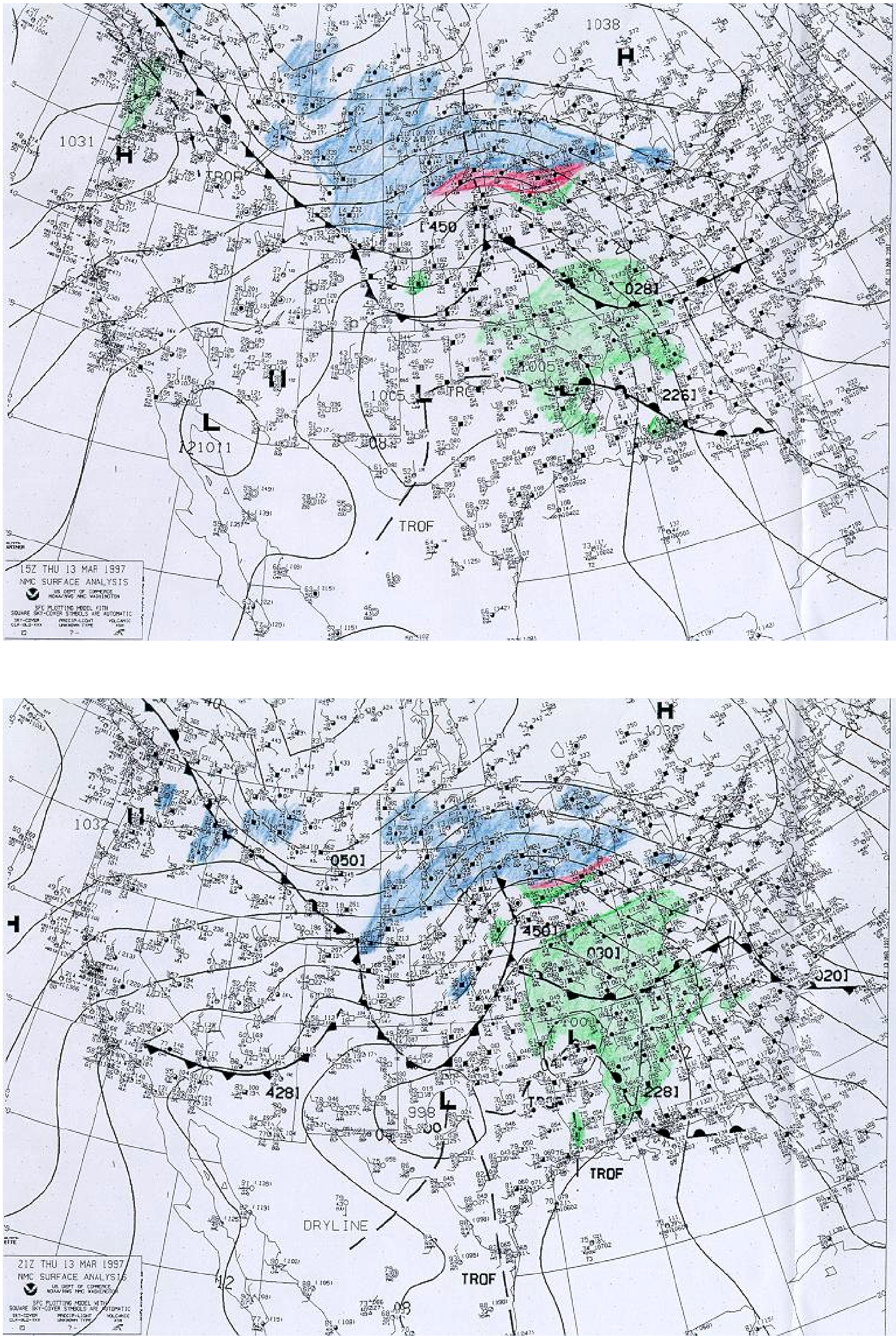


Figure 8 – Surface charts for 970313, a) 1500 and b) 2100 UTC.

March 14, 1997

Flight #1 - En-route to and over Toledo and Fort Wayne from 1744 to 1946 UTC.
Flight #2 - Over Fort Wayne, Toledo, Detroit and southeastern Ontario from 2058 to 2250 UTC.

Brief overview

Two flights were made on this day. During the first flight, the Twin Otter headed west to meet up with the leading portion of an area of stratiform cloud that was advancing eastward across Indiana. The leading portion of this cloudy area had cloud top temperature (CTT) values near -10 C and no precipitation was observed beneath it, while CTTs < -15 C and light snow were observed to the west of the leading edge. Consistent LWC of 0.4 and temperatures near -6 C were found between Toledo and Fort Wayne above 3900 feet, and LWC gradually decreased to 0 at cloud base (1600 feet). A strong, 5 C inversion was in place from 4800 feet to cloud top at 6800 feet. Some brief pockets of out-of-focus droplets bordering on freezing drizzle sizes at temperatures of -4 C were found just west of Toledo near 1859 UTC, while consistent LWC of 0.3-0.5 with T = -7 C was observed after 1900 UTC between Toledo and Fort Wayne near 4500 feet.

The second flight began at Fort Wayne in a mixture of snow and possibly a little ZL below 4000 feet. A layer of mixed water and some crystals with LWC values of 0.2-0.4 was observed between 4000 and 6000 feet, as the aircraft tracked to the northeast. The development of snow in the Fort Wayne area matched the advancement of colder air toward the east, cooling the atmosphere at the base of the inversion from -9 C at 1930 UTC to -12 C at 2100 UTC. This cooling pushed the cloud into a temperature range where crystals were more likely to form. The change from the obvious appearance of crystals below 4000 feet to relatively few crystals and mostly water drops from 4000 to 6000 feet may be due to the overwhelming number of small droplets in the 2D-Grey buffer (concentration > 10000) above 4000 feet compared to the very low concentrations to of snow crystals alone (concentration < 200) below 4000 feet. The aircraft continued northward into Michigan in an attempt to sample some freezing drizzle reported at Jackson before snow moved in from the west. However the aircraft could not reach Jackson in time and only snow was observed there, along the eastern edge of a patch of echo on the radar. Continuing to the east over Detroit, en-route to Cleveland, the Twin Otter observed supercooled liquid water and some out-of-focus, borderline ZL-sized drops to the east of Detroit. Steady 0.2-0.4 LWC, with a little snow and possibly a little ZL at times, was observed between Detroit and Cleveland at temperatures between -6 and -11 C in the 4000 to 6000 feet altitude band.

Relevant weather features

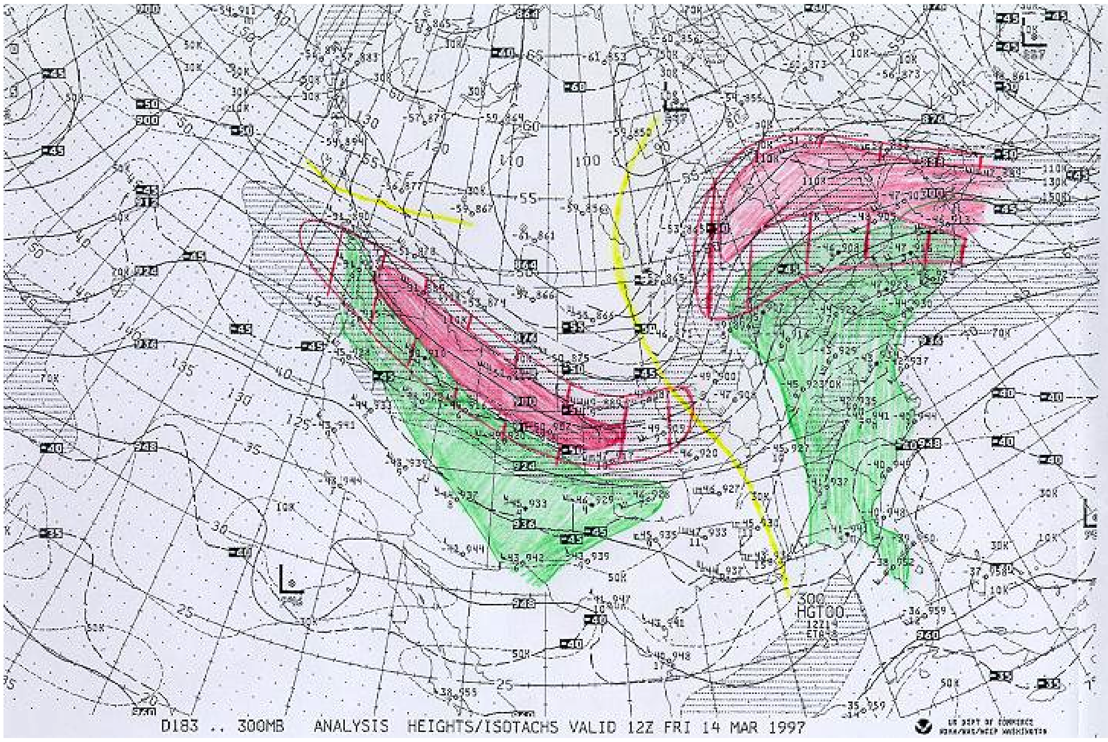
At 1200 UTC, a weak, closed low at 700 mb was centered over northern Wisconsin (Fig. 1). This low featured two troughs, one of which extended southeast into Indiana, then south to the Gulf Coast, while the other extended southwest across eastern Iowa, then down to Oklahoma. Cold advection was evident behind both troughs, but was strongest along and behind trough #2. Dry air was in place behind trough #2 and saturated conditions to were found ahead of it. At 850 mb, a strong closed low was centered over Michigan and had a strong trough/cold front to which extended south across western Ohio then southwest to Mississippi. Strong cold advection was evident behind this trough/front from Canada to Texas, while strong warm advection was evident ahead of it across eastern Michigan, eastern Ohio, New York, and the mid-Atlantic states. A weak trough/warm front extended east from the low across southeastern Ontario and northern New York. Saturated conditions were present across the entire forecast area at this level.

A strong, 994 mb surface low was centered over western Lake Erie at 1500 UTC (Fig. 2). A cold front running south from the low across central Ohio to the Texas Gulf Coast was the surface reflection of upper-air trough #1. Rain was occurring along and ahead of the cold front, where deep moisture was evident at 1200 UTC. Dry air pushing in aloft (see 500 mb chart for 1200 UTC) left only warm, non-precipitating cloud in place behind the cold front. Light snow was occurring across Illinois and Wisconsin at 1500 UTC, and gradually moved eastward across Indiana and Michigan by 2100 UTC. The eastward progression of this snow was clearly reflected in surface observations.

Infrared satellite data from 1145 UTC (Fig. 3) show deep, patchy cloudiness east of a line from Lake Michigan to New Orleans, and a lack of deep cloud to the west of that line. These cloud locations roughly match the moisture patterns at 500 mb. A swath of clouds was advancing eastward across Illinois to around Fort Wayne by 1745 UTC. The location and movement of this cloudy area during this period is similar to that of trough #2 at 700 mb, but precedes it, and fairly closely matches the advance of a lobe of moisture and the T = -10 C contour at 850 mb. The –10 C temperature is approximately the same as the CTT at the top of the inversion at 6000 feet (~820 mb).

For the most part, the advancing snow was too light to be picked up in the radar mosaic data (Fig. 4). Tracks for flight #1 indicate that it took place ahead of the snow (as reported in surface observations). Tracks for flight #2 show that the Twin Otter intercepted an area of snow (visible in the mosaic data) upon entering Michigan, but that the aircraft got ahead of the snow as it flew east over Detroit. It was at this point that the significant LWC and some freezing drizzle was observed.

Numerous pilot reports of moderate mixed and rime icing were made between 2000 and 6000 feet in the area of warm cloud top temperatures just ahead of the advancing snow (Fig. 5). This is where the aircraft spent most of its flight time on this day.



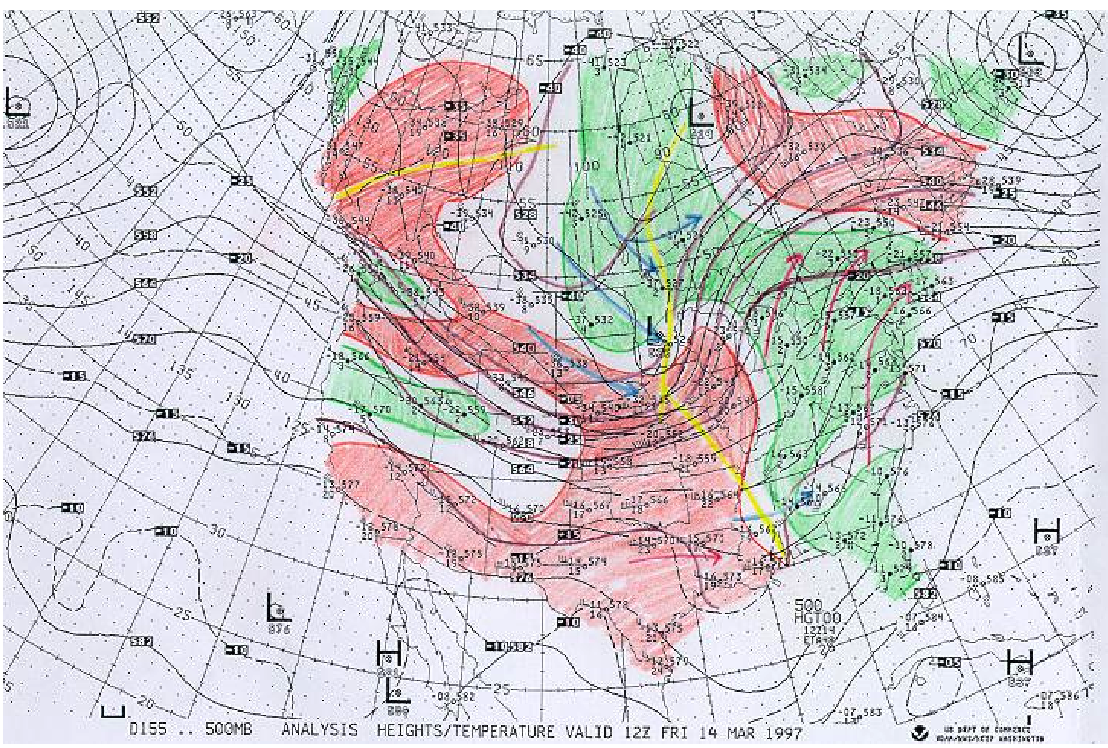
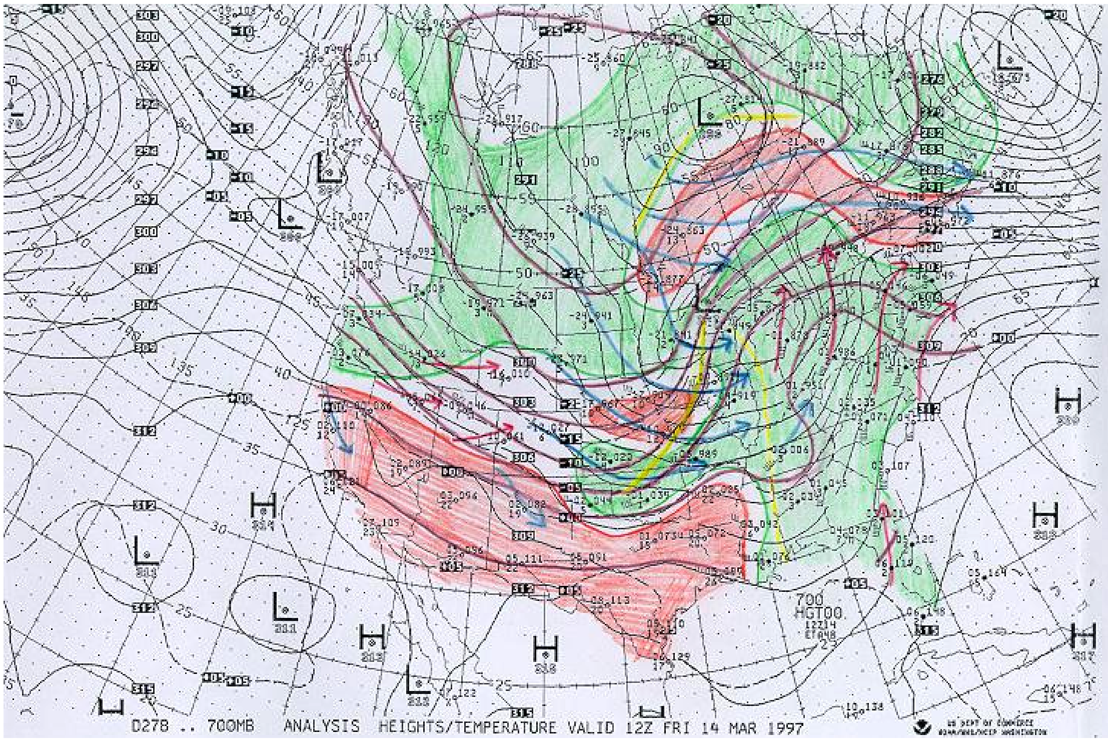


Figure 1 – Upper-air charts for 970314, 1200 UTC at a) 300 and b) 500 mb.



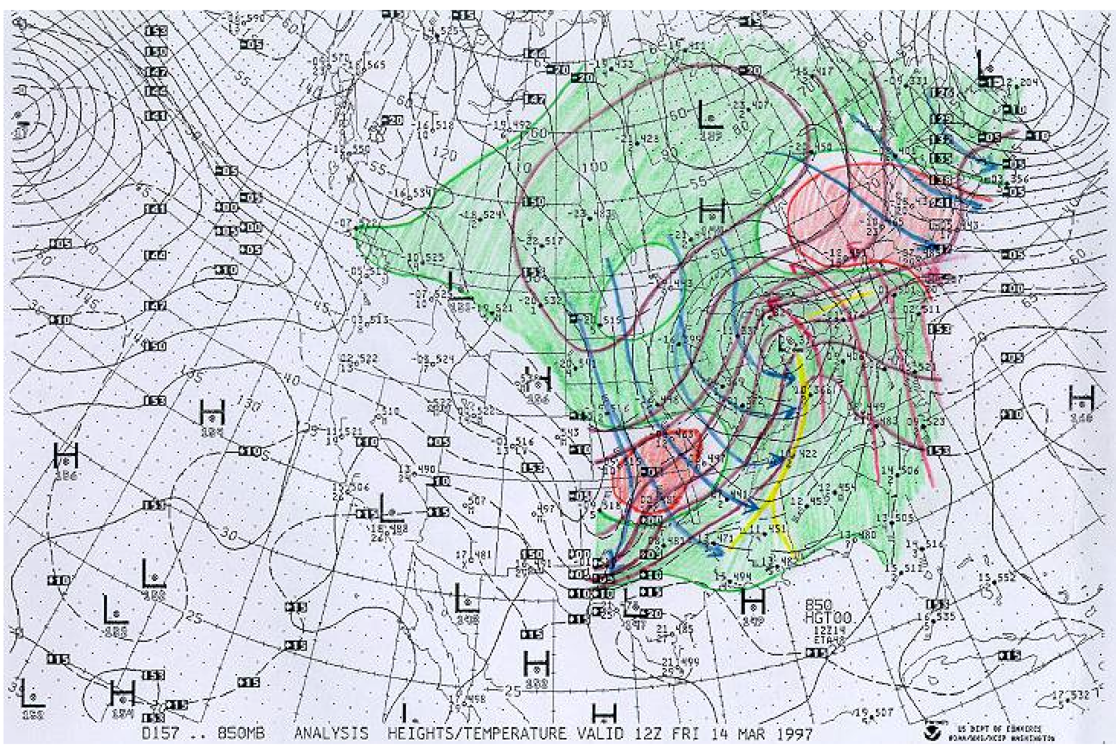


Figure 1 – Upper-air charts for 970314, 1200 UTC at c) 700 and d) 850 mb.

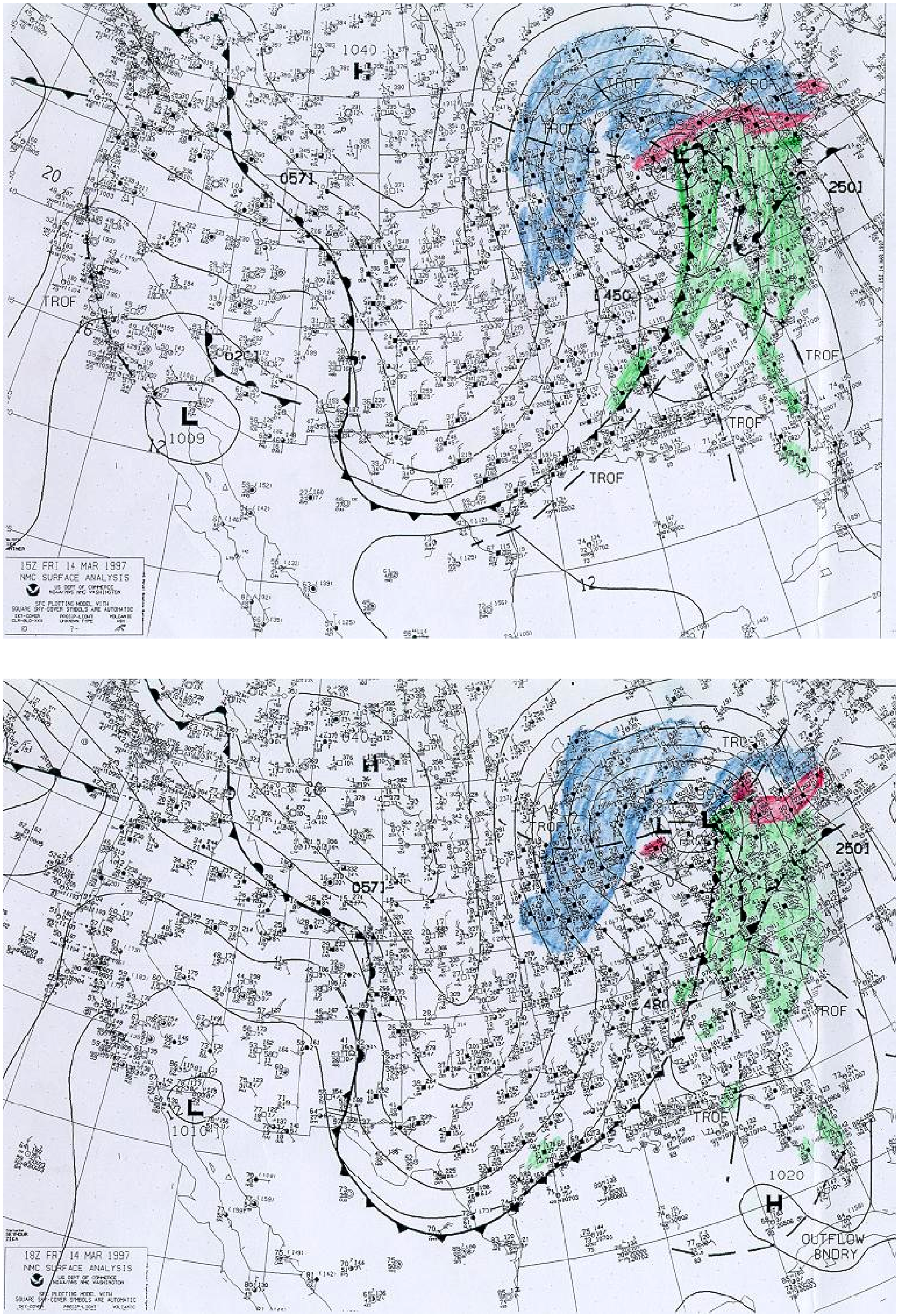


Figure 2 – Surface charts for 970314, a) 1500 and b) 1800 UTC.

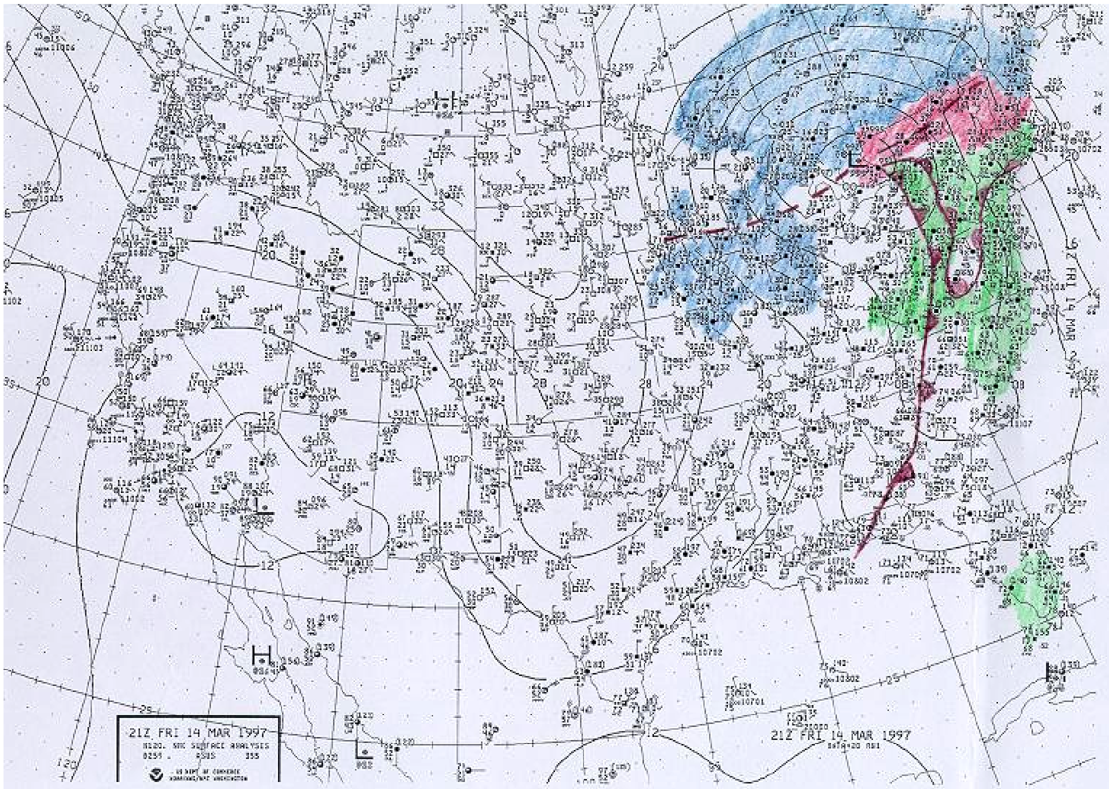
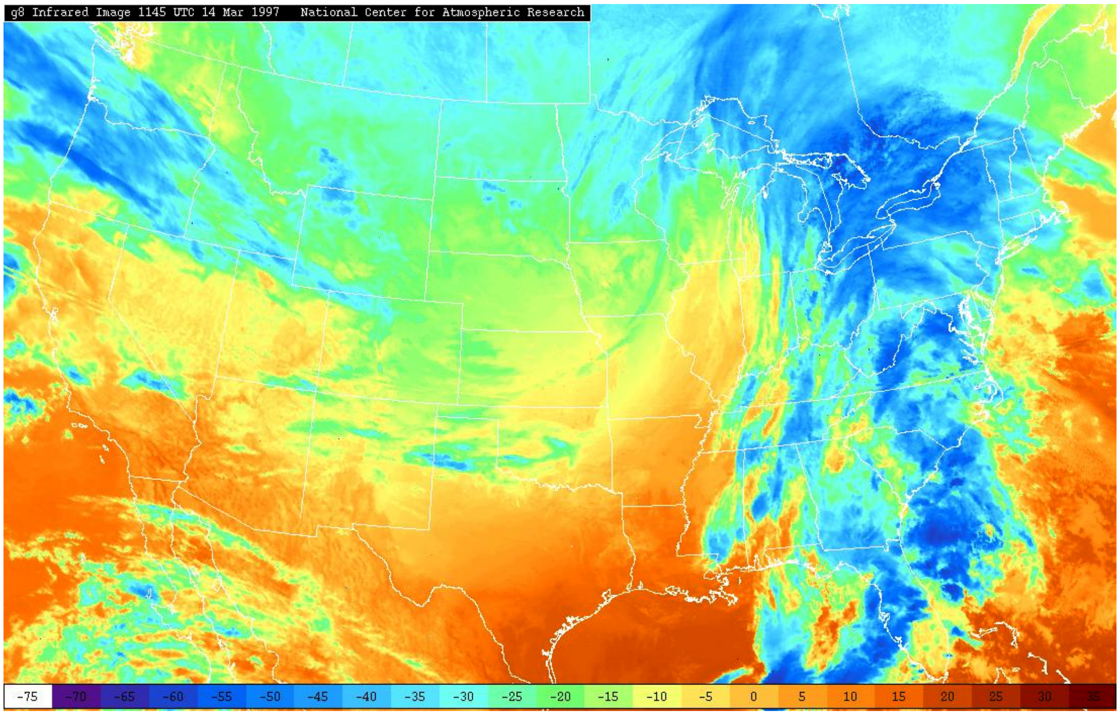


Figure 2 – Surface charts for c) 970314, 2100 UTC.



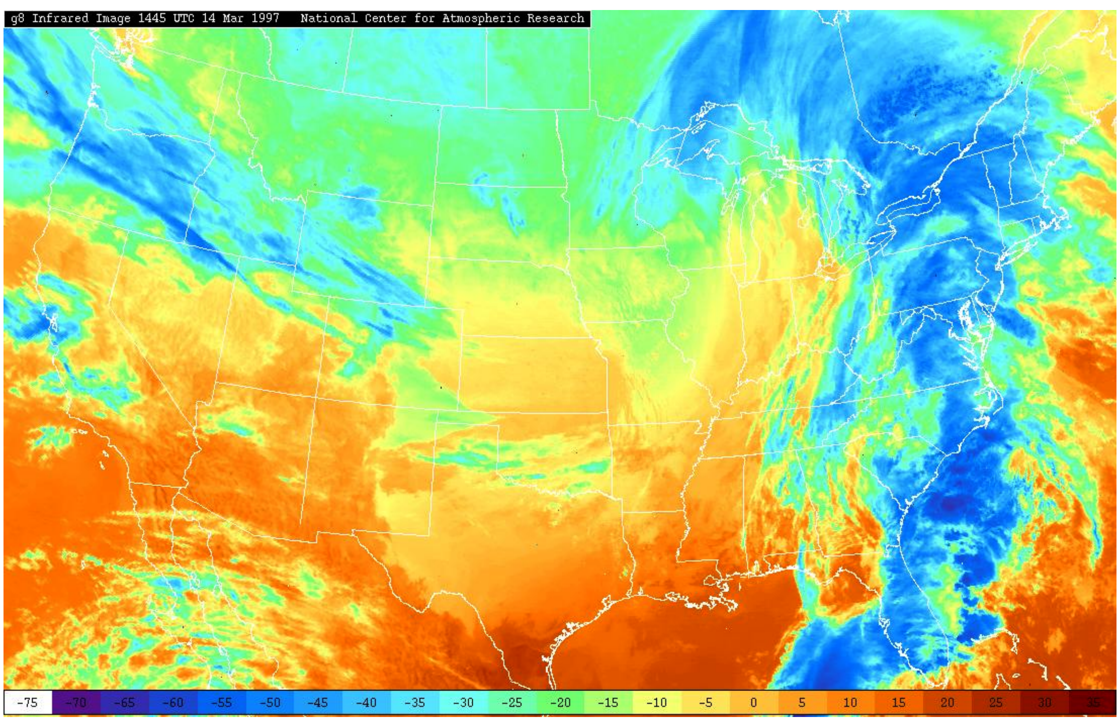
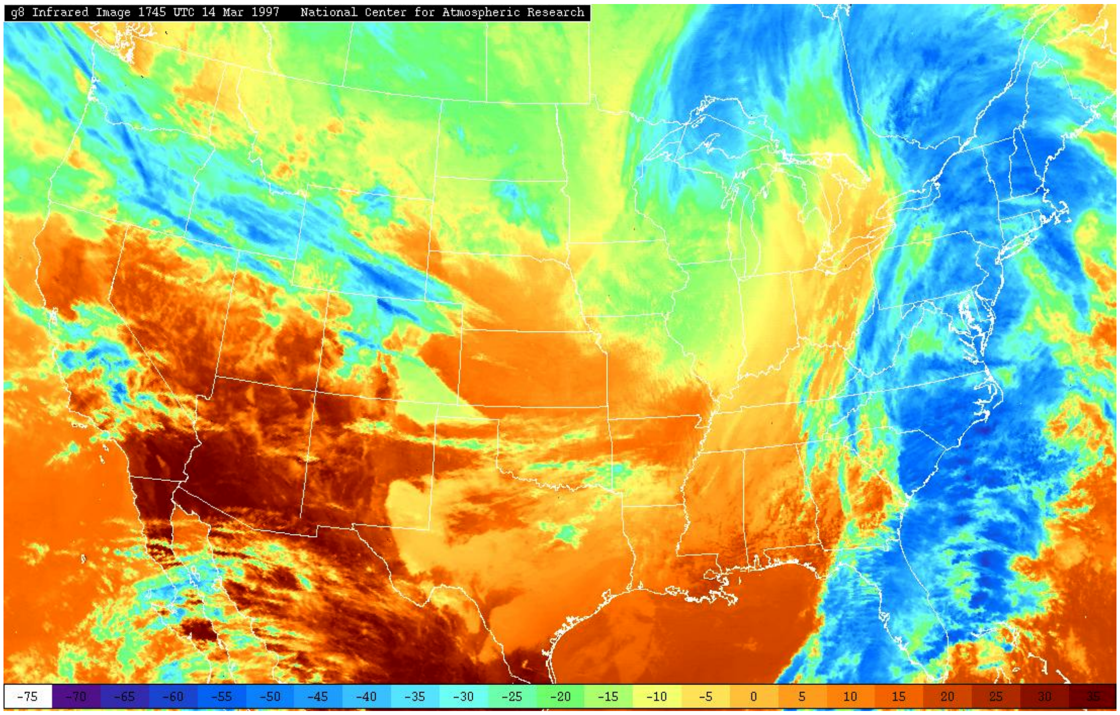


Figure 3 – Infrared satellite imagery for 970314, a) 1145 and b) 1445 UTC.



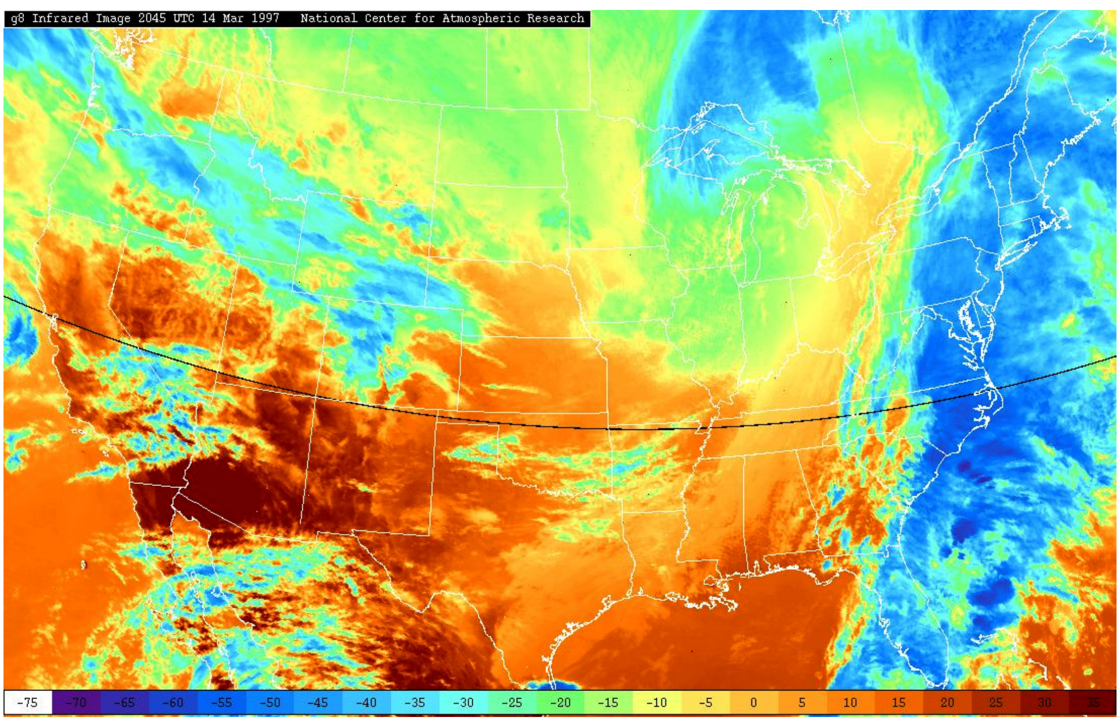
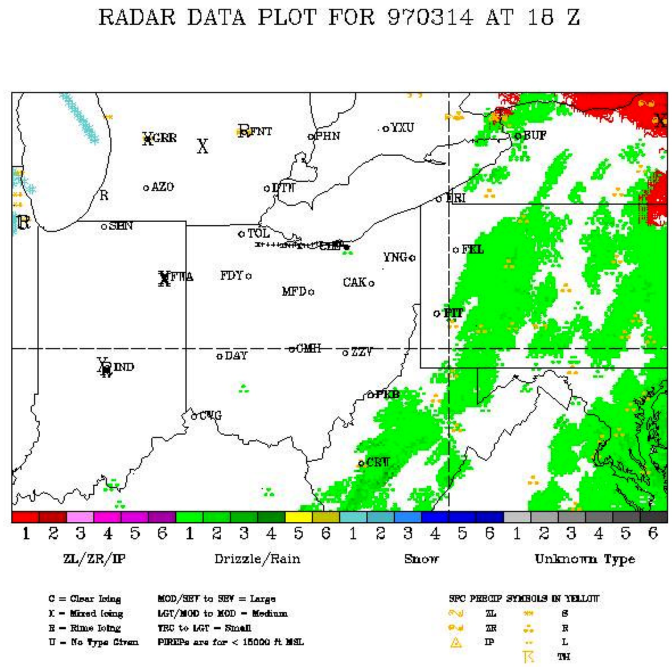


Figure 3 – Infrared satellite imagery for 970314, c) 1745 and d) 2045 UTC.



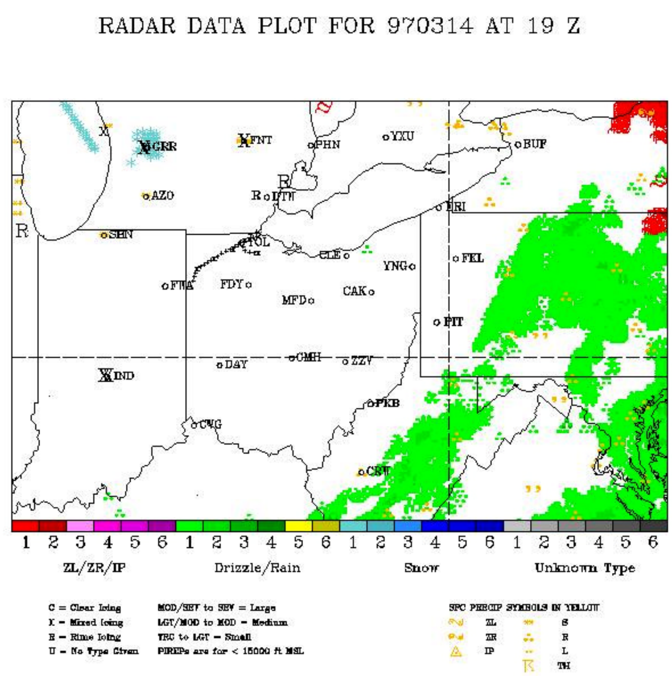
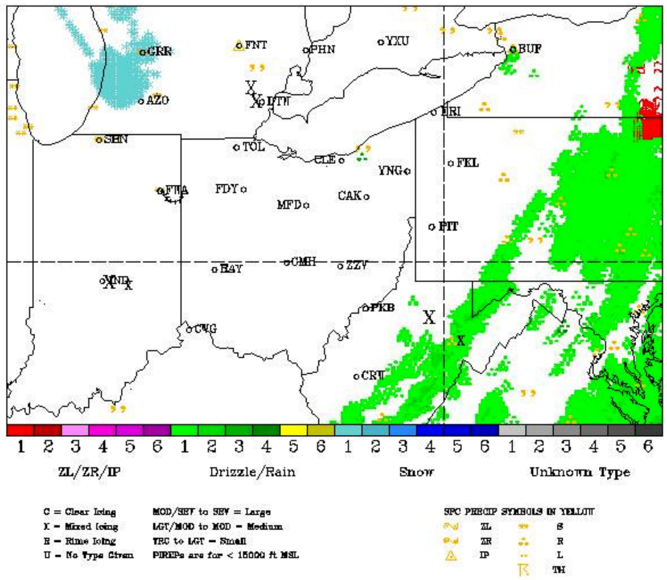


Figure 4 - Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970314, a) 1800 and b) 1900 UTC.

RADAR DATA PLOT FOR 970314 AT 20 Z



RADAR DATA PLOT FOR 970314 AT 21 Z

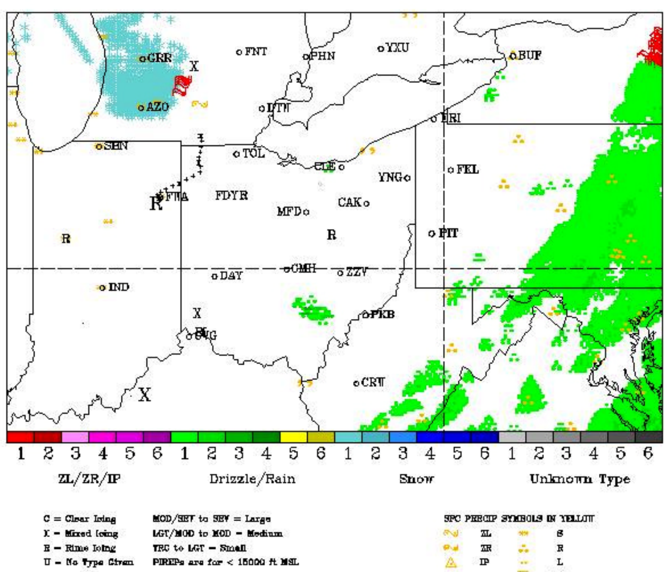
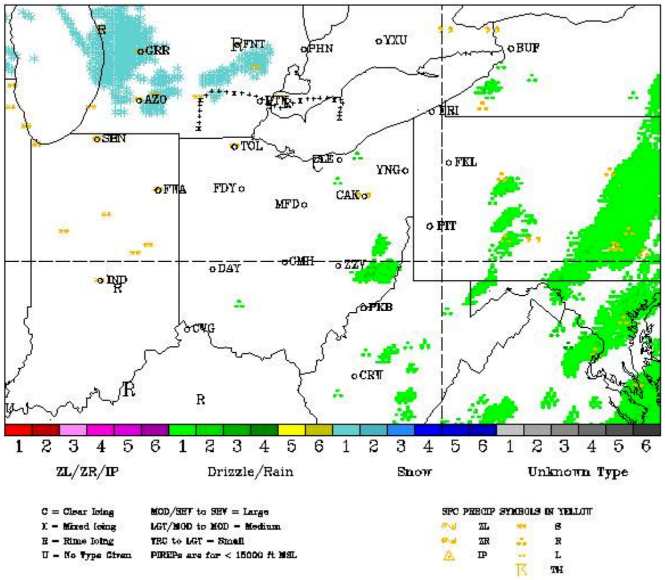


Figure 4 - Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970314, c) 2000 and d) 2100 UTC.

RADAR DATA PLOT FOR 970314 AT 22 Z



RADAR DATA PLOT FOR 970314 AT 23 Z

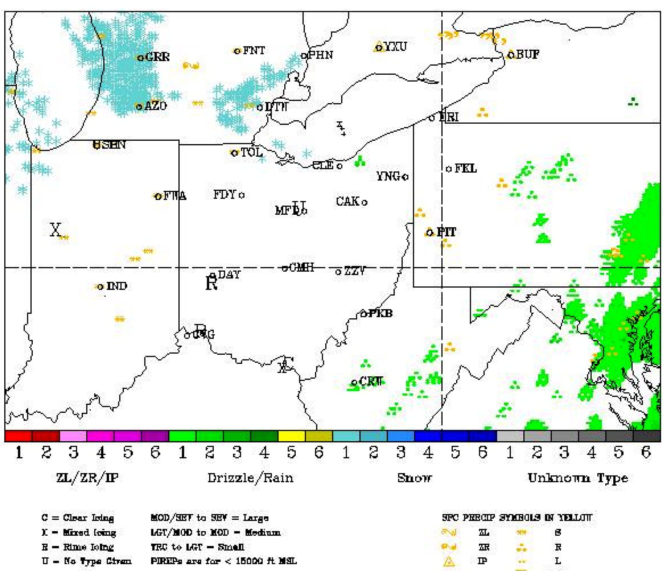
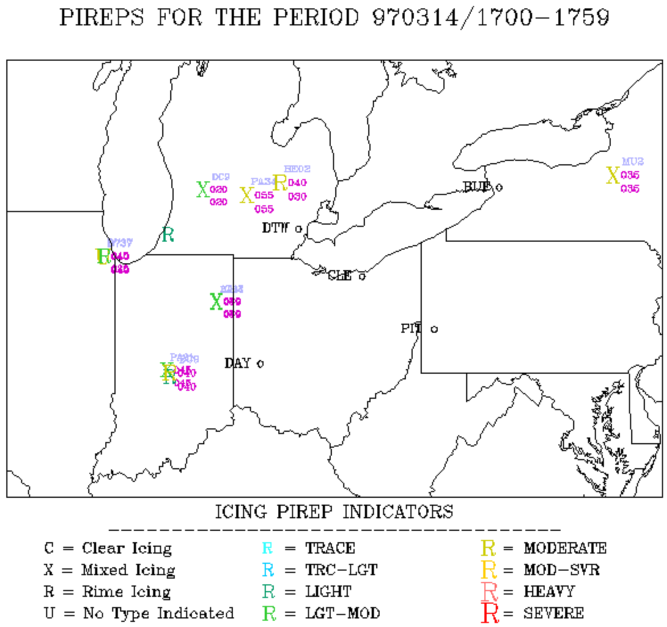


Figure 4 - Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970314, e) 2200 and f) 2300 UTC.



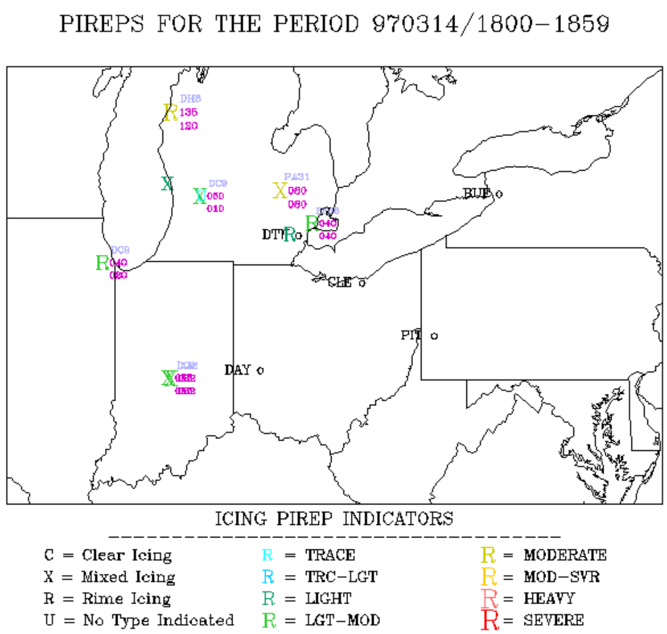
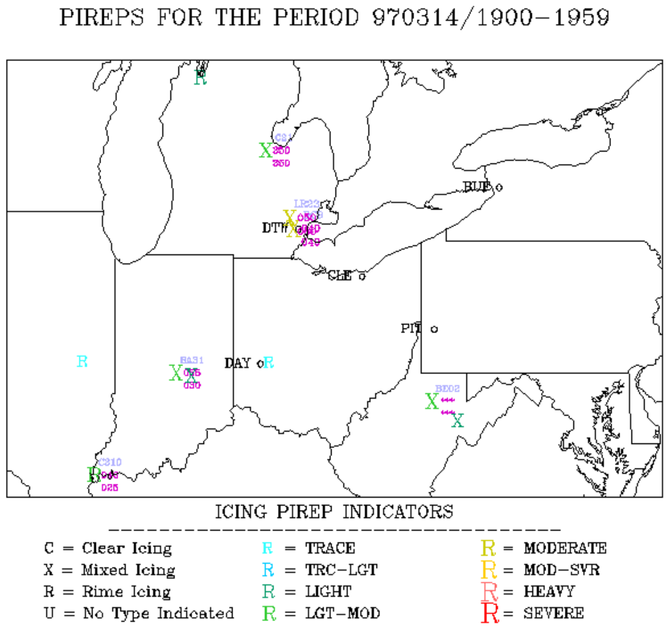


Figure 5 – Pilot reports of icing for 970314, a) 1700-1759 and b) 1800-1859 UTC.



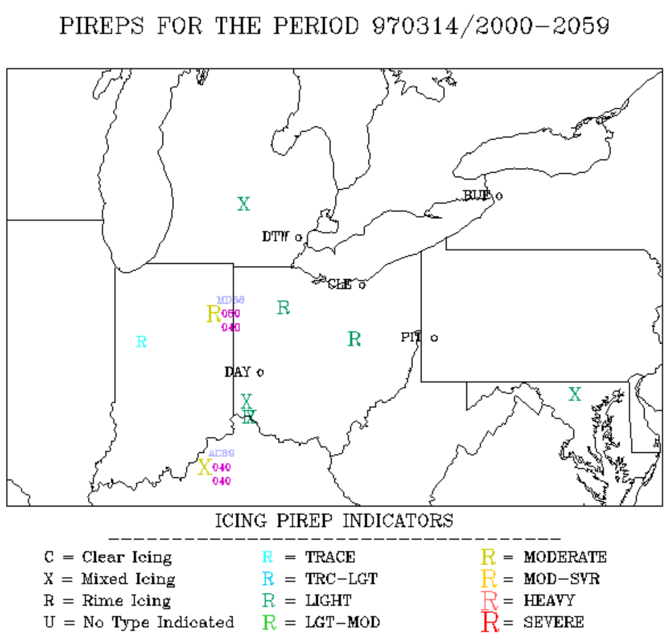
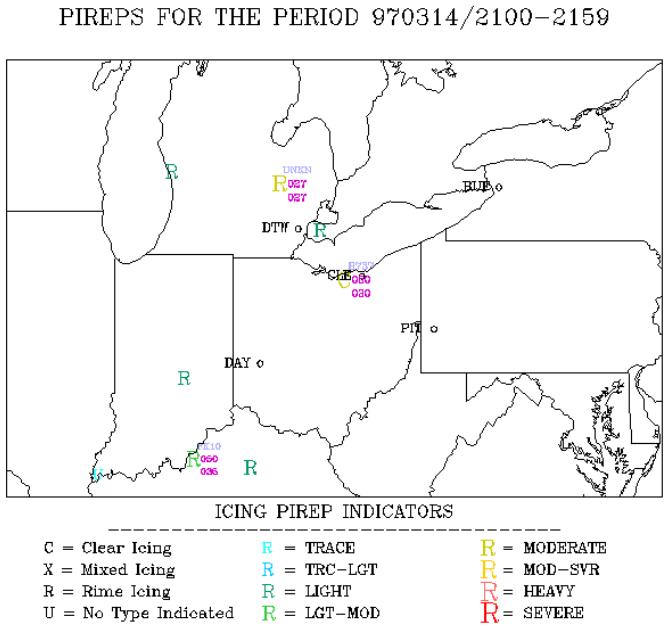


Figure 5 – Pilot reports of icing for 970314, c) 1900-1959 and d) 2000-2059 UTC.



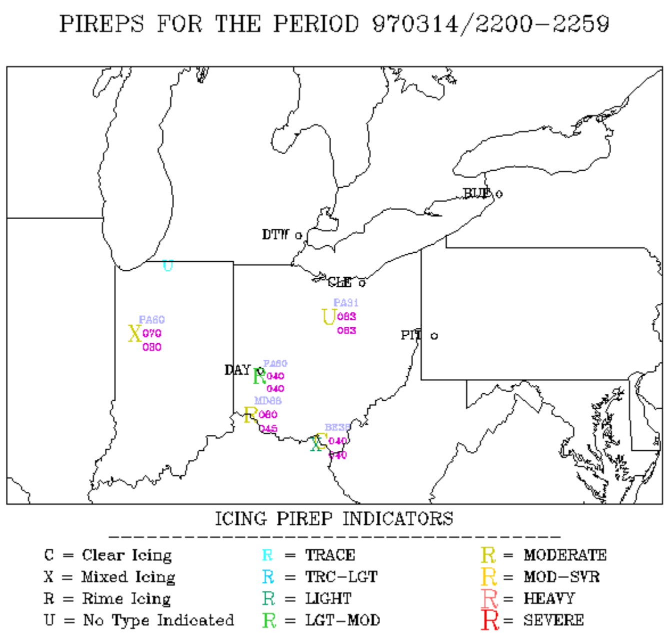


Figure 5 – Pilot reports of icing for 970314, e) 2100-2159 and f) 2200-2259 UTC.

March 20, 1997

Flight #1 - Over Lake Erie, near Pelee Point, Ontario from 1249 to 1442 UTC.

Brief overview

One flight was made into a stratiform cloud deck over Lake Erie, between Cleveland and Pelee Point. With the exception of some graupel and heavily rimed crystals that were encountered during initial climbout, the clouds and precipitation sampled were entirely made up of supercooled liquid water drops, including freezing drizzle. The cloud were lower and warmer toward the west. On initial climbout from Cleveland, a 2 C inversion was present at cloud top and LWC values reached a maximum of 0.5 at 7500 feet. At 1300 UTC, cloud tops just northwest of Cleveland were near 8200 feet and the minimum temperature within the cloud deck was -7 C. By 1400 UTC, the cloud tops near Pelee Point were down to 6600 feet with CTT = -5.2 C. Drop sizes gradually increased with decreasing altitude, going from all cloud-sized drops above 7000 feet to in-focus freezing drizzle from 6000 to 4000 feet. Similar patterns were observed throughout the flight, with the largest drops encountered below 6000 feet, where the temperature was -4 C or warmer. No precipitation was reported at the surface and no radar echo was present in the mosaic data in the vicinity of the flights. The Twin Otter accreted glaze ice shapes with nodules, horns and ridges, according to flight notes.

Relevant weather features

At 1200 UTC, a north-south oriented trough extended from a Hudson's Bay low to the west end of Lake Ontario, then southwest across Lake Erie and central Indiana at 500, 700 and 850 mb (Fig. 1). At 500 mb, deep moisture and light precipitation was in place ahead of the trough, across New York and Pennsylvania. Dry air was observed west of the Pennsylvania-Ohio order, including over Lake Erie. At 700 mb, the air was saturated across Ohio and Lake Erie, with dry air as nearby as Detroit. At 850 mb, saturated air was in place across Michigan, Lake Erie, and southeast Ontario, but it was dry across much of Ohio. Overall, this combination produced a stratiform cloud deck over northern Ohio, Lake Erie, and southeastern Michigan, with the cloud deck sloping downward and warming toward the west. This cloud was clearly evident on infrared and visible satellite imagery for 1345 UTC (Fig. 2). CTTs were slightly colder on the eastern and of Lake Erie, compared to the western end. Sounding data for 1200 UTC from Detroit (Fig. 3) show dry air down to 780 mb (~7000 feet) and a cloud deck from approximately 4000 to 7000 feet with CTT of -6 C. This structure was very similar to that observed by the Twin Otter.

The earliest surface map available for this case was for 1800 UTC (3 hours after the flight was completed; Fig. 4). It shows a weak cold front draped across the southern borders of Indiana, Ohio, and Pennsylvania, and a trough running from southwest to northeast across eastern Ohio. Northwest winds were occurring across Ohio, Michigan, and southeast Ontario, bringing air across Lakes Erie and Huron. The 1200 UTC Detroit sounding showed that this northwest flow extended through a very deep layer, from the surface to the tropopause.

Radar data and Twin Otter tracks for 1300-1500 UTC (Fig. 5) indicate that this flight took place in a location where no precipitation was reaching the ground.

Numerous pilot reports of light to moderate mixed, rimed, and clear (light only) icing were made between 3000 and 8000 feet within this stratiform cloud deck (Fig. 6). These observations match the glaze/mixed agreements and significant performance hits experienced by the Twin Otter.

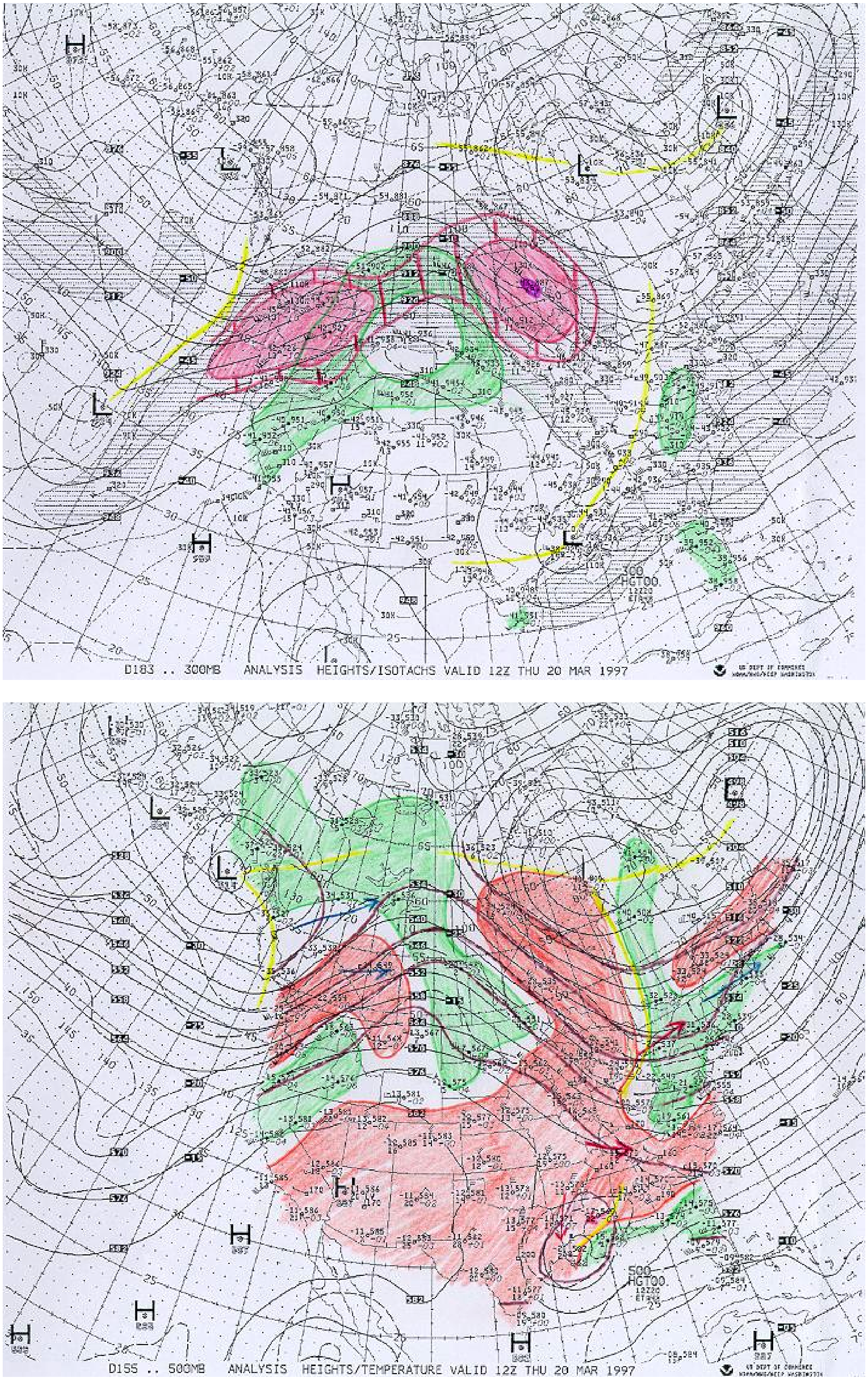


Figure 1 – Upper-air charts for 970320, 1200 UTC at a) 300 and b) 500 mb.

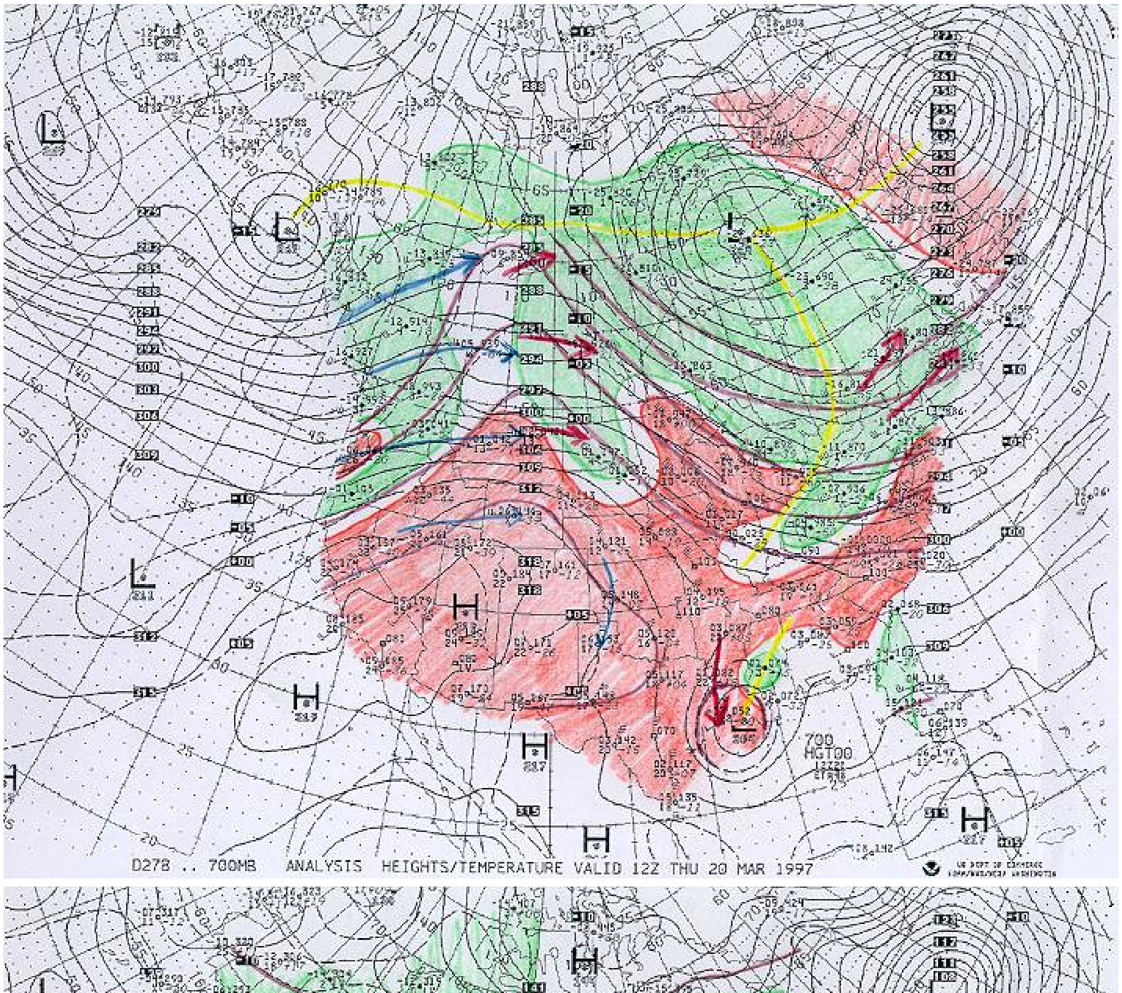
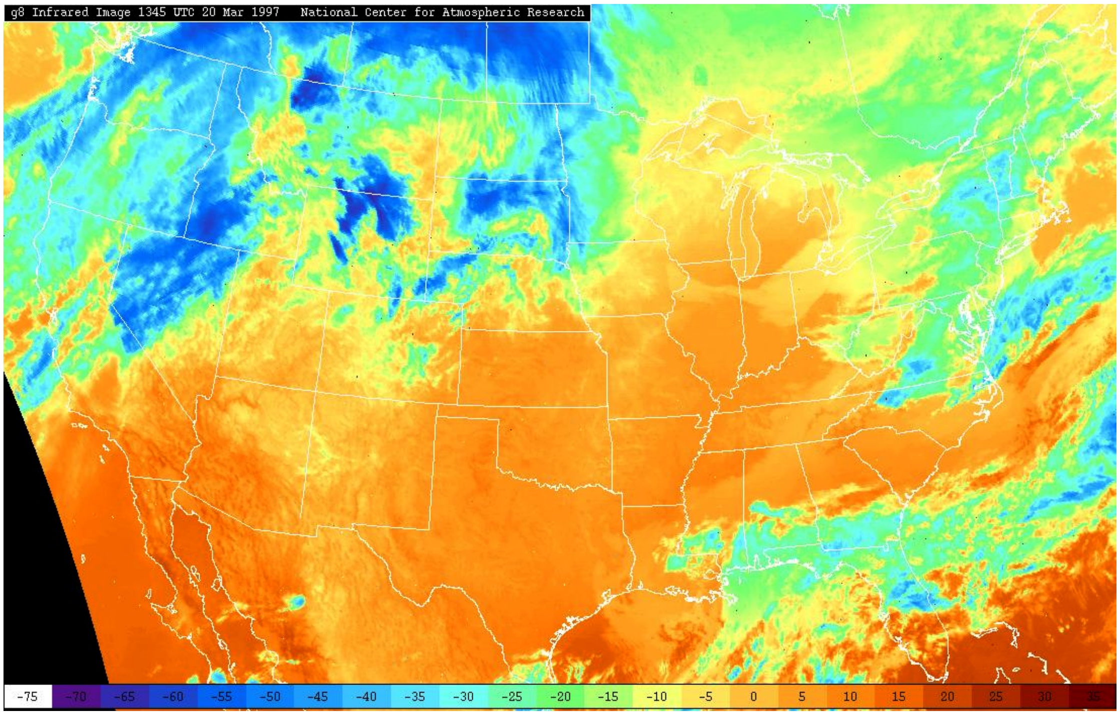


Figure 1 – Upper-air charts for 970320, 1200 UTC at c) 700 and d) 850 mb.



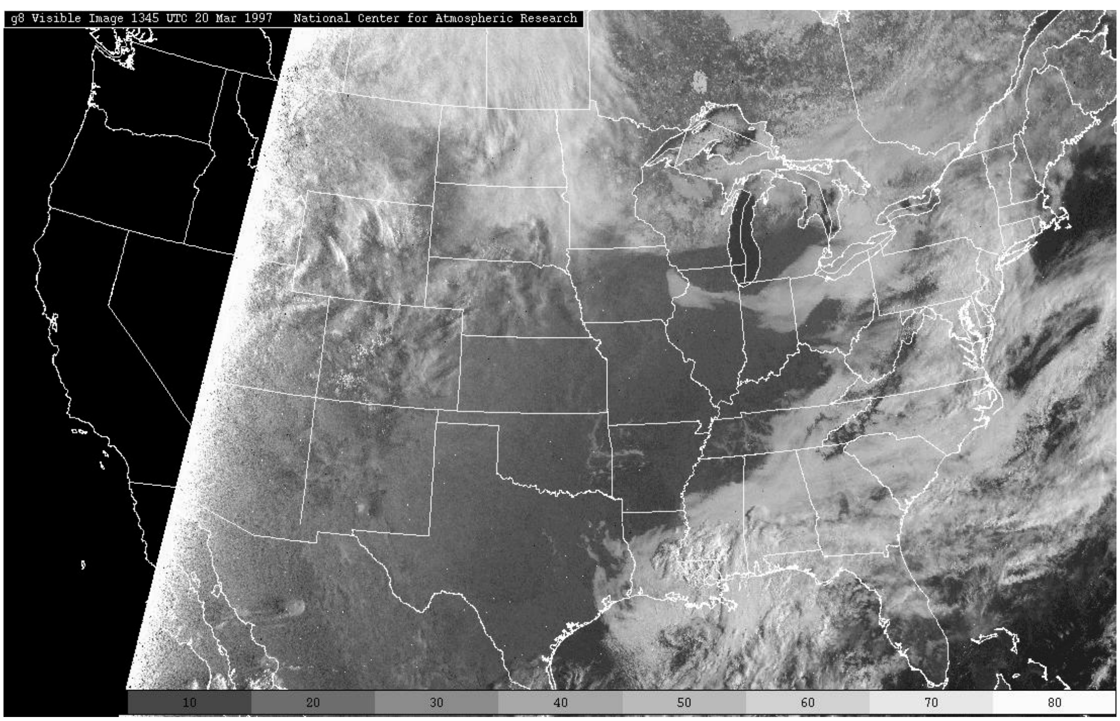


Figure 2 – a) Infrared and b) visible satellite imagery for 970320, 1345 UTC.

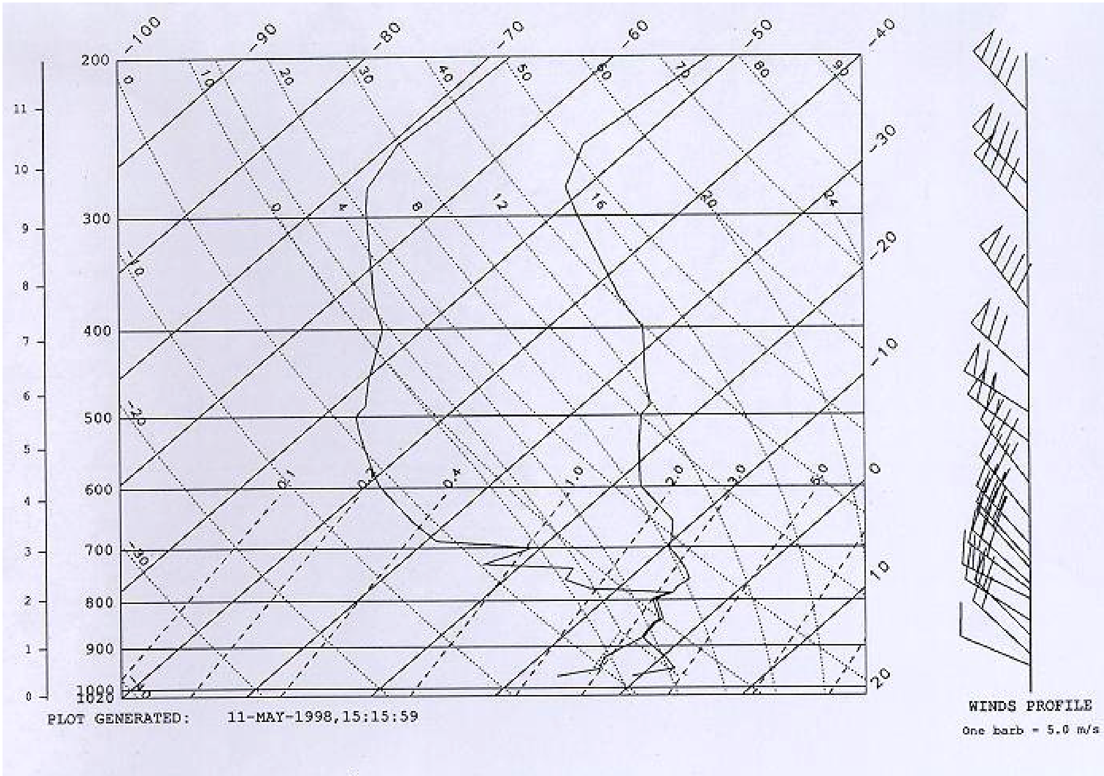


Figure 3 – Balloon-borne sounding data for 970320, 1200 UTC from Detroit.

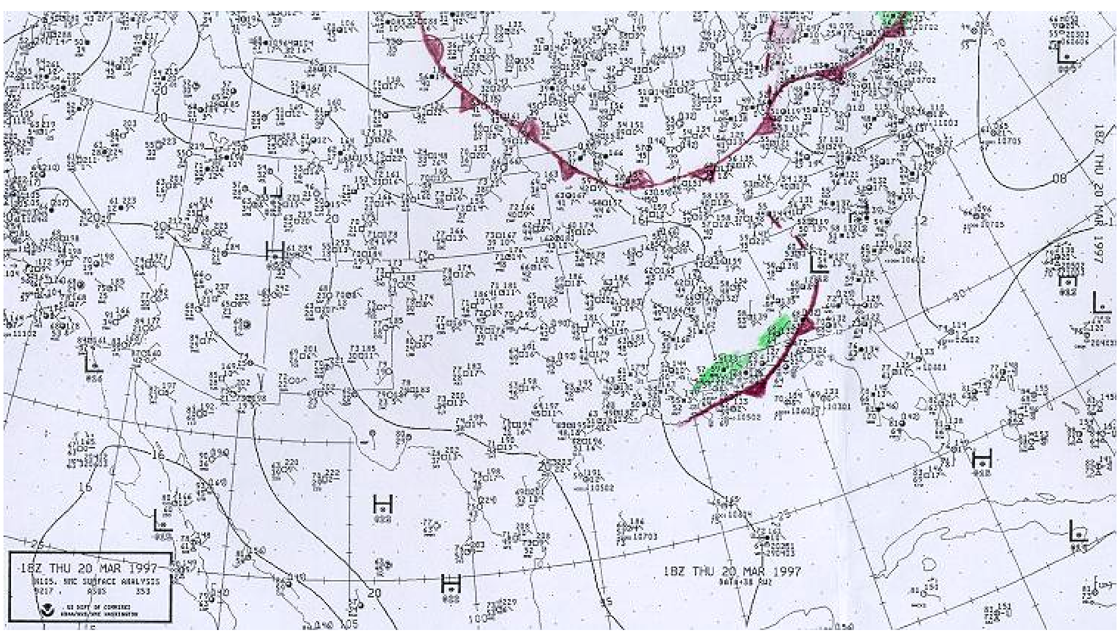
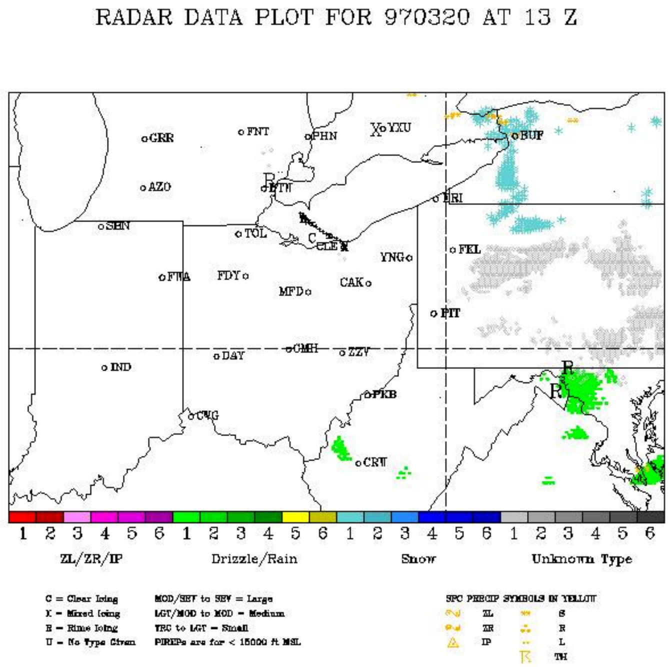


Figure 4 – Surface chart for 970320, 1800 UTC.



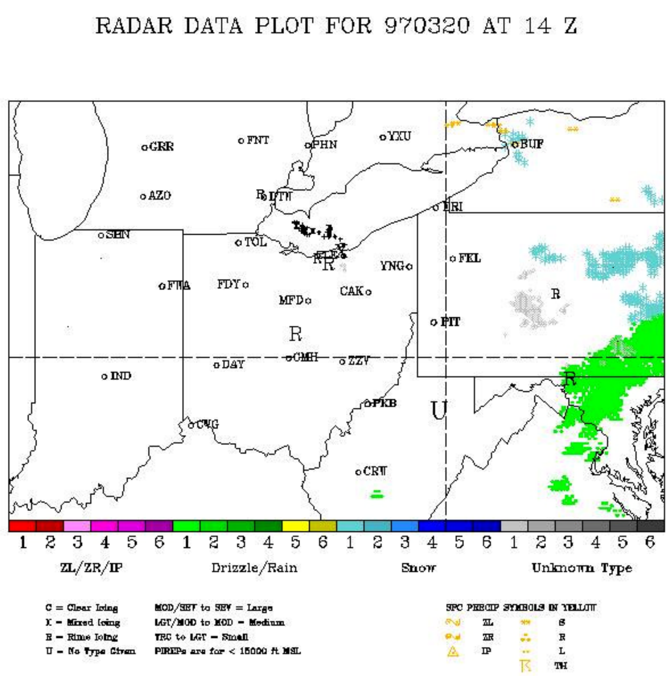


Figure 5 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970320, a) 1300 and b) 1400 UTC.

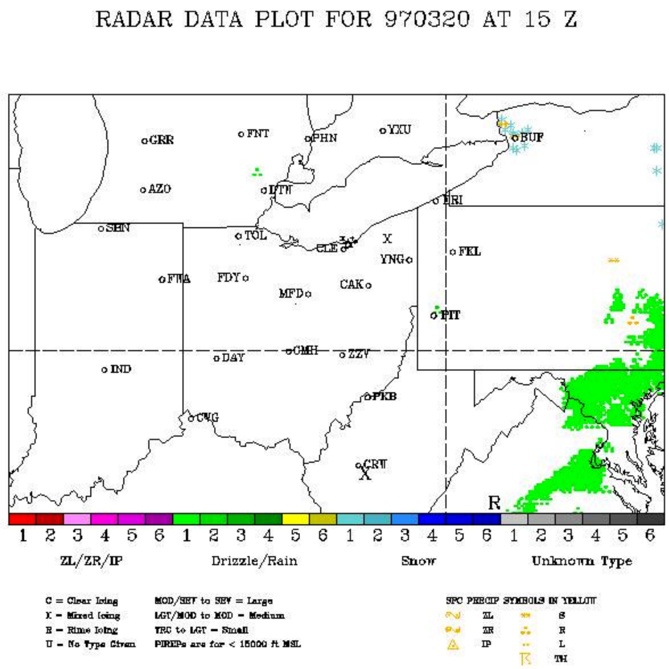
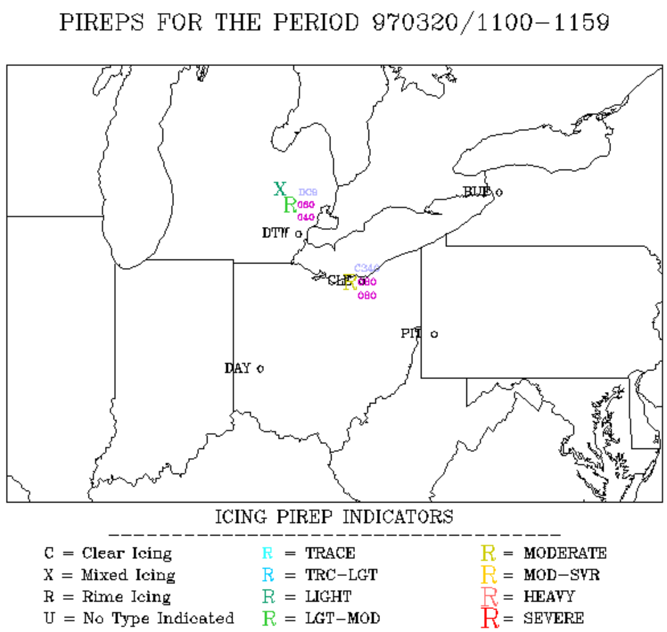


Figure 5 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970320, c) 1500 UTC.



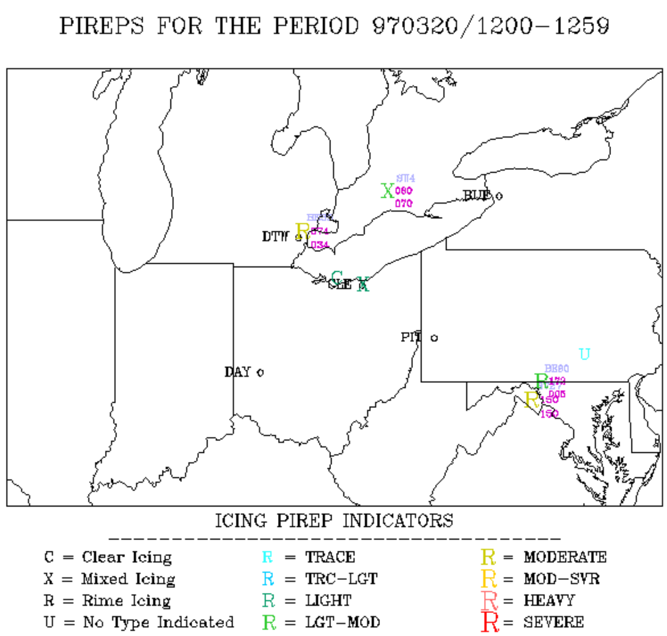
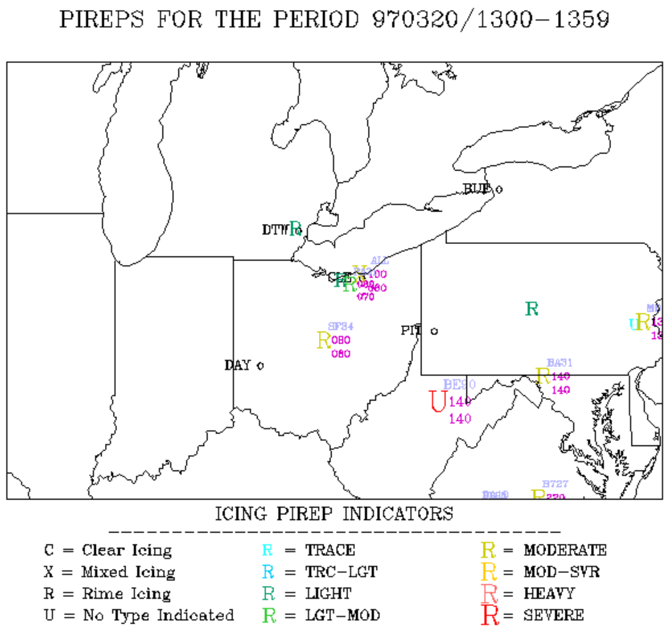


Figure 6 – Pilot reports of icing for 970320, a) 1100-1159 and b) 1200-1259 UTC.



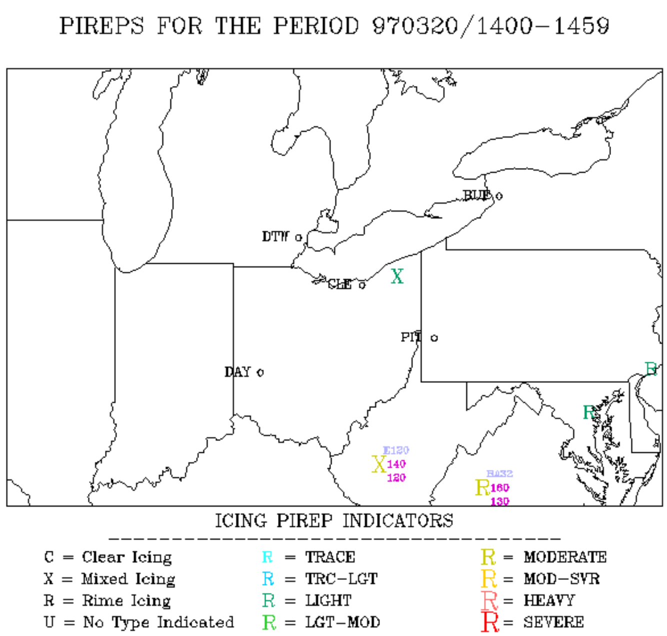


Figure 6 – Pilot reports of icing for 970320, c) 1300-1359 and d) 1400-1459 UTC.

March 25, 1997

Flight #1 - Over Sandusky, Ohio from 1355 to 1529 UTC.

Brief overview

One flight was made near Sandusky, Ohio into clouds on the south side of a northward moving area of precipitation. Deep clouds associated with the precipitation were thinning out on their southern end, with pockets of CTTs as warm as -10 to -15 C. During this flight, the 2D-Grey probe had a great deal of noise, and it was difficult to discern what was being sampled. The aircraft encountered LWC of 0.1-0.3, with pockets of LWC as high as 0.5. Cloud base was near 8300 feet, while cloud tops were quite variable and as high as 15000 feet in places. Breaks were occasionally found within the cloud decks. The 1D-260X probe data showed that particles larger than 100 microns in diameter were present during portions of the flight, but the nature of these particles is unknown due to the 2D-Grey problems.

Relevant weather features

At 1200 UTC, a sharp, northeast-southwest oriented trough was in place from Minnesota to New Mexico at 500 mb (Fig. 1). A second trough ran northeast to southwest from southern Wisconsin to southwestern Missouri. A ribbon of saturated air was in place ahead of trough #2, from Texas to Michigan and western Ohio, while dry air was found from Louisiana to Kentucky, and over an area from the Pennsylvania-Ohio border to Quebec. At 700 mb, a closed low was located over northeastern Minnesota, with a trough/cold front extending south into Iowa, then southwest to New Mexico. Cold advection was occurring behind the trough, while warm advection was occurring ahead of it, northeast of a line from Green Bay to Pittsburgh. Again, saturated air was in place ahead of the trough, covering most of the forecast area, but dry air from the southwest had already reached central Ohio. At 850 mb, the trough/cold front was slightly further east and the moisture was mostly found behind it, except for a swath across Michigan, Lake Erie and southeastern Ontario. Dry air was in place ahead of the trough and reached as far north as central Ohio. Warm advection was occurring ahead of the trough across the forecast area. Soundings taken at 1200 UTC at Detroit and Wilmington (Ohio) show the transition from deep, saturated conditions (Detroit) to rather dry conditions with a thin layer of residual moisture near 700 mb (10000 feet; Wilmington) across the warm front (Fig. 2).

At 1200 UTC, an elongated surface low was in place from the Upper Peninsula of Michigan to Chicago (Fig. 3). A cold front extended southwest from the Chicago low to Texas, and featured a narrow band of light rain and thundershowers along it. A warm front extended southeast from the Chicago low across southwestern Ohio then southward into Georgia. High pressure (1036 mb) anchored to the east of New Jersey left cold air in place across the Great Lakes, mid-Atlantic and New England states, which warm air from the south was trying to push out. Light rain showers and even some thunder (at Mansfield) were reported across northern Ohio and southern Michigan, while light snow was occurring further to the north.

By 1500 UTC, the warm front moved northeast to the southwest end of Lake Erie, and a broad swath of rain was in place to the north of Ohio. Overcast skies were reported just behind the warm front in northwestern Ohio and northeastern Indiana.

Satellite data from 1145 UTC (Fig. 4) reveal deep, cold cloud along the trough/cold front, as well as across northern Indiana, northern Ohio, Michigan, southeastern Ontario, and Pennsylvania, closely matching the moisture patterns on the upper-air charts. Areas of warmer CTTs and breaks in the deeper clouds across northern Ohio mark the intrusion of dry air and the pocketed nature of the moisture there. This scenario continues to be evident in the 1445 UTC infrared image, which shows larger areas of CTT warmer than -25 C over northern Ohio.

Radar mosaic data (Fig. 5) match this pattern quite well, with precipitation across northern Ohio at 1300 UTC moving northward into Michigan and southeastern Ontario by 1500 UTC, leaving non-precipitating cloud behind over the southwestern end of Lake Erie by 1500 UTC. Twin Otter tracks show that the aircraft initially sampled the southern portion of the precipitation swath, then areas to the south of it. Scattered icing PIREPs of all types and up to moderate intensity were made between 10000 and 15000 feet along the edges of and within holes in the precipitation shield (Fig. 6).

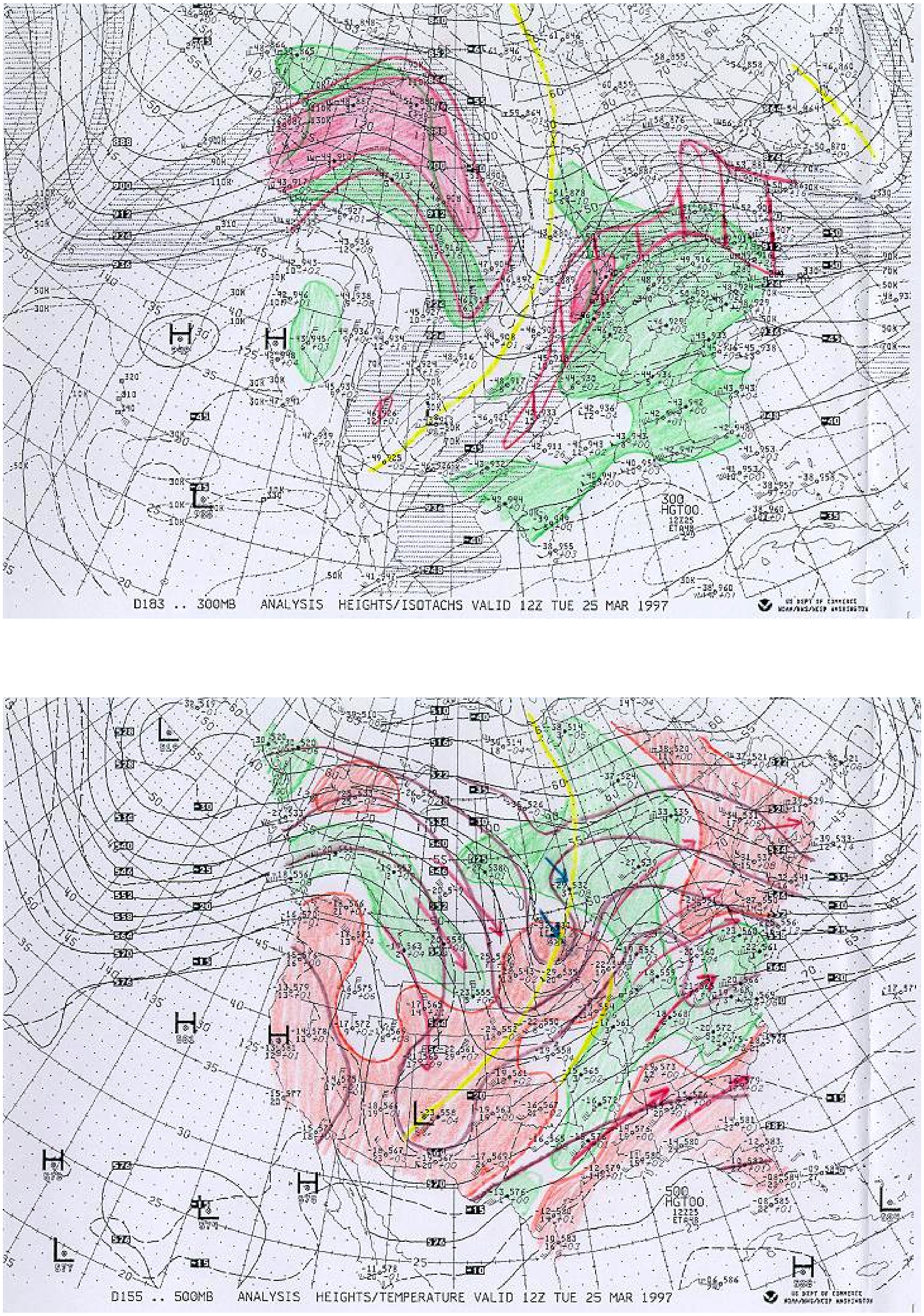


Figure 1 – Upper-air charts for 970325, 1200 UTC at a) 300 and b) 500 mb.

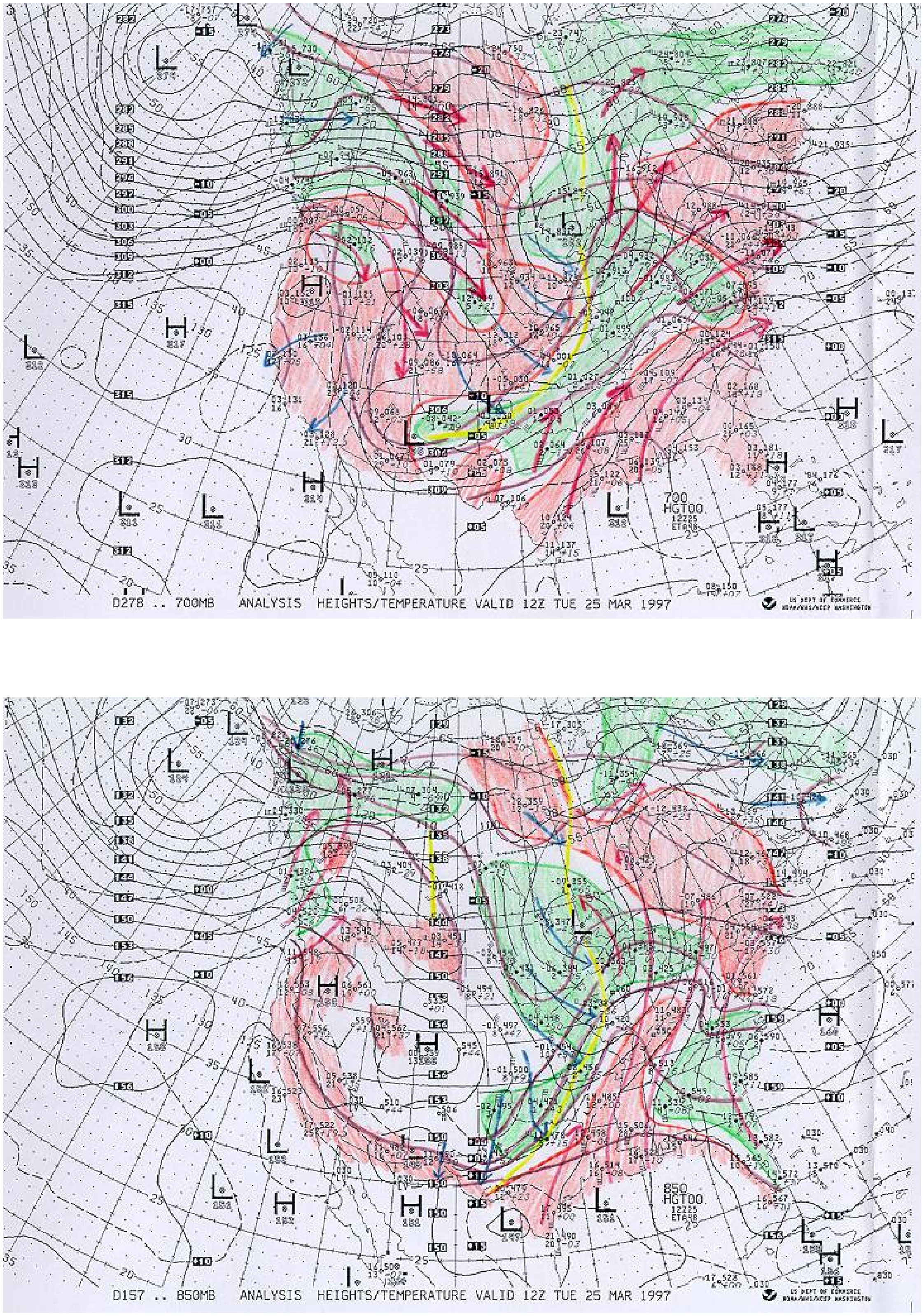


Figure 1 – Upper-air charts for 970325, 1200 UTC at c) 700 and d) 850 mb.

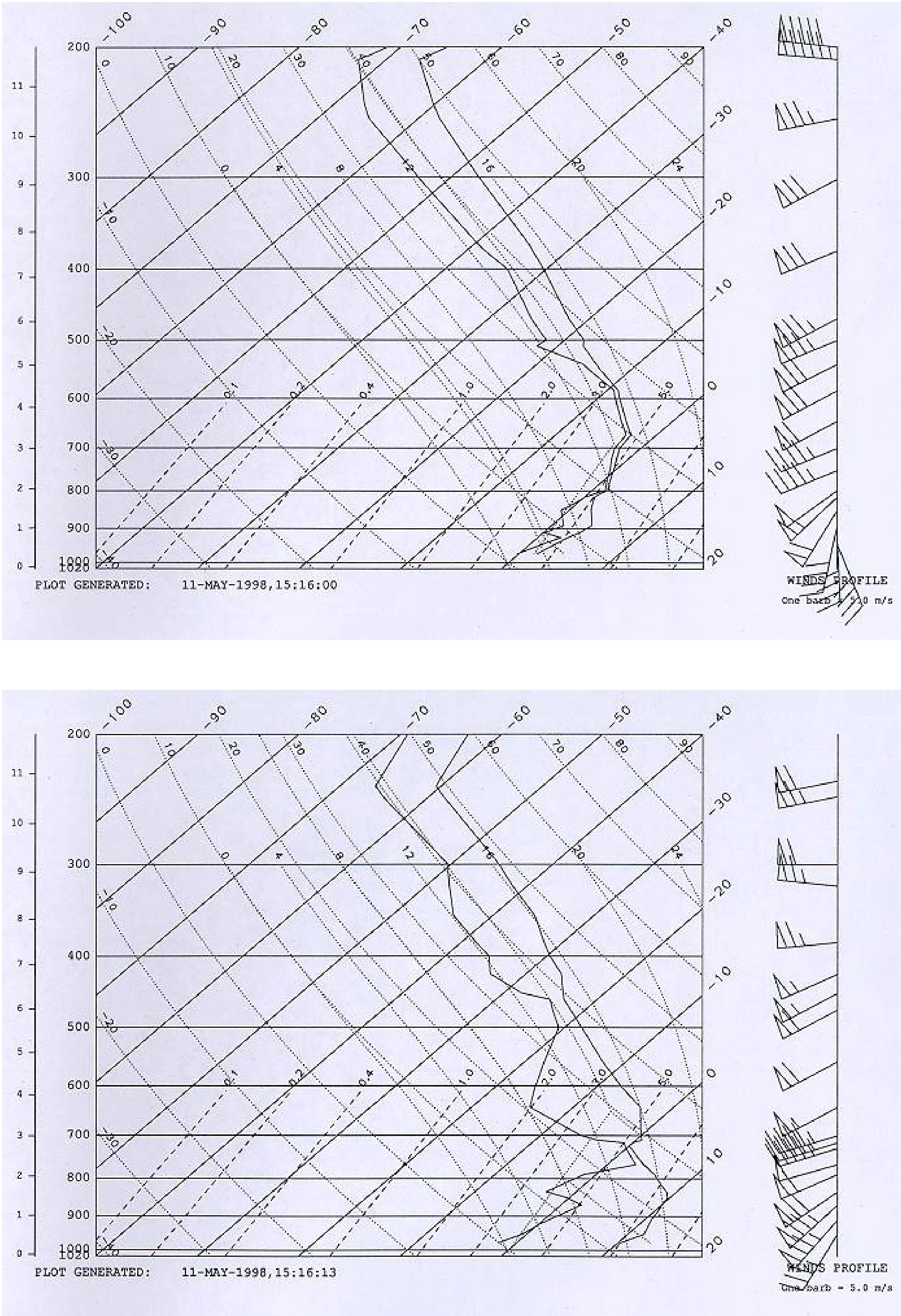
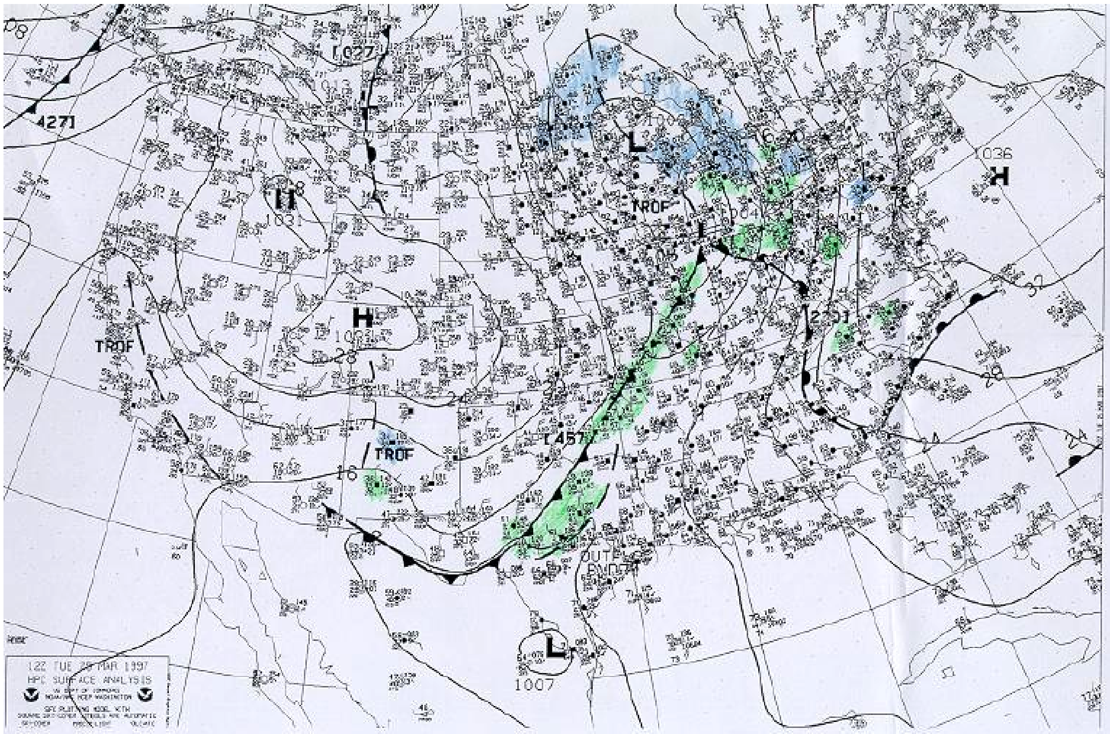


Figure 2 – Balloon-borne sounding data for 970325, 1200 UTC at a) Detroit and b) Wilmington.



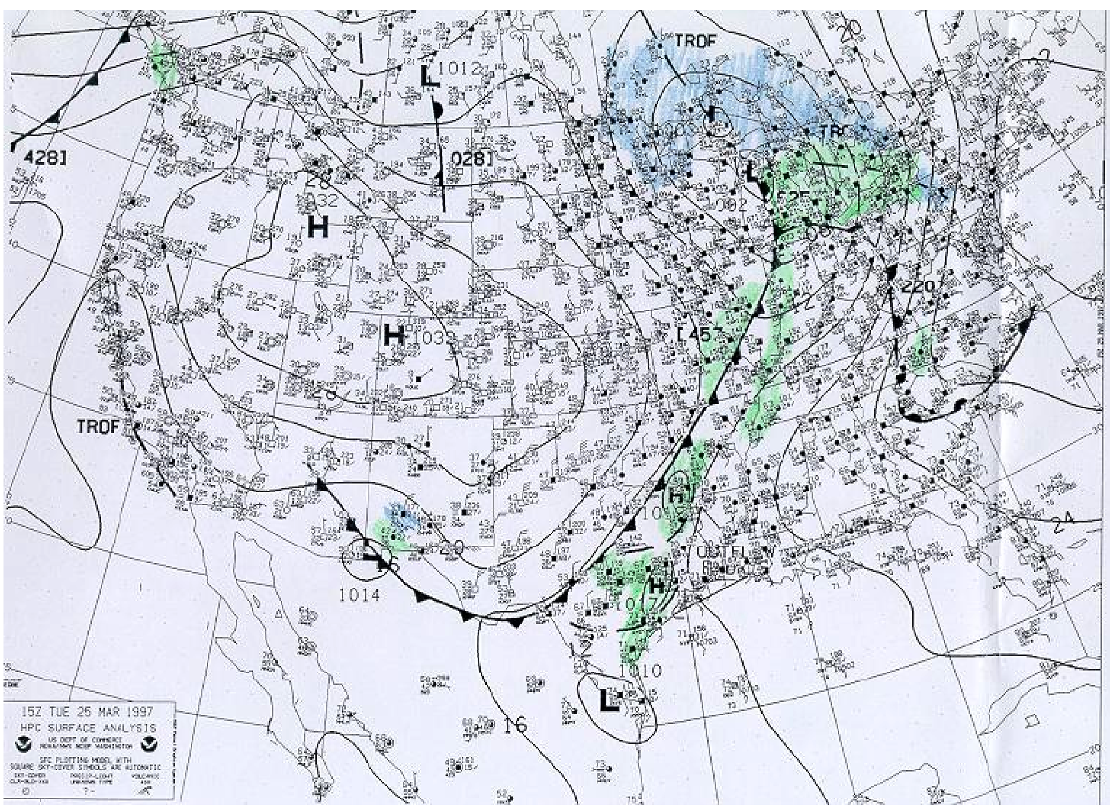


Figure 3 – Surface charts for 970325, a) 1200 and b) 1500 UTC.

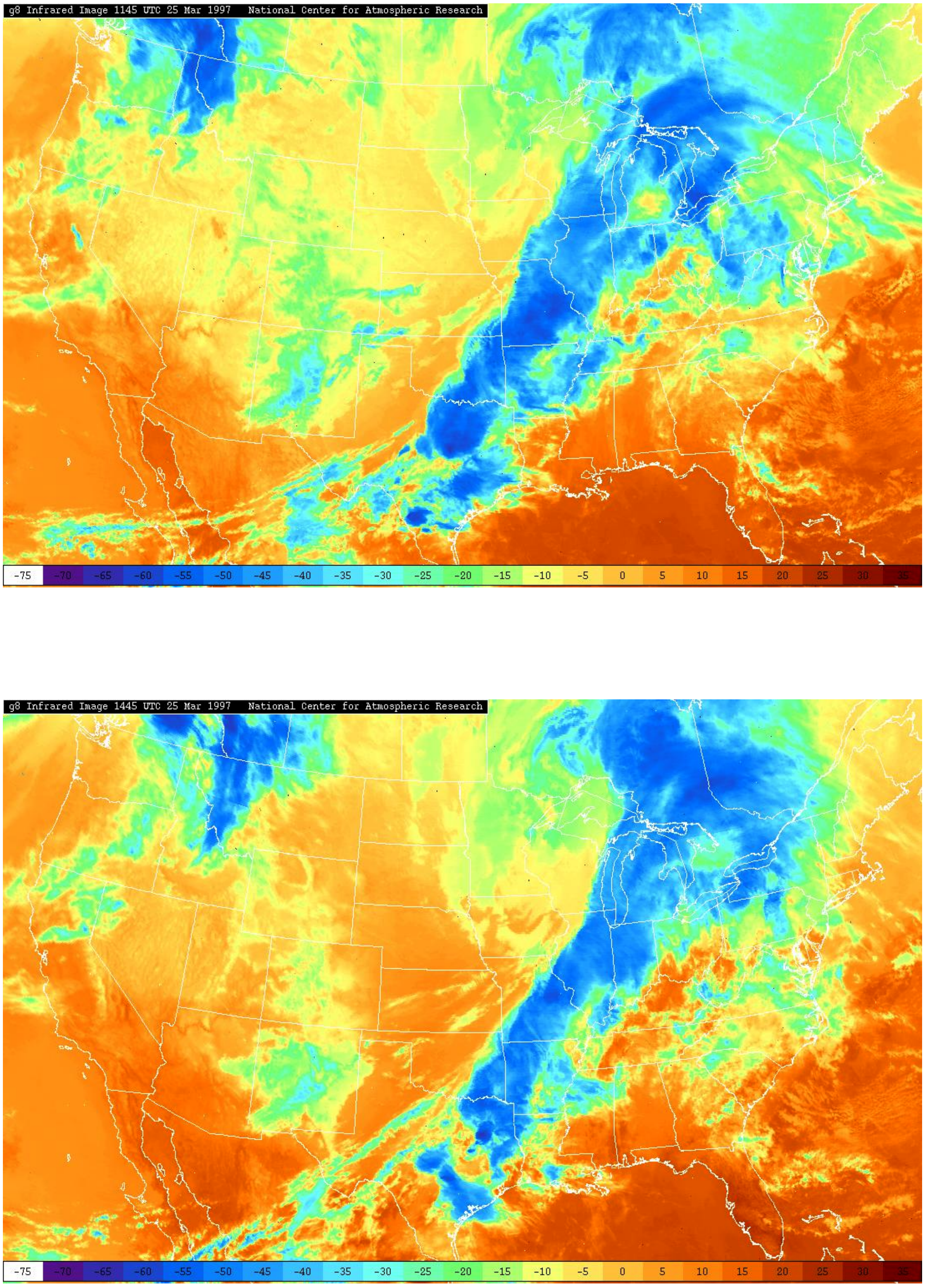
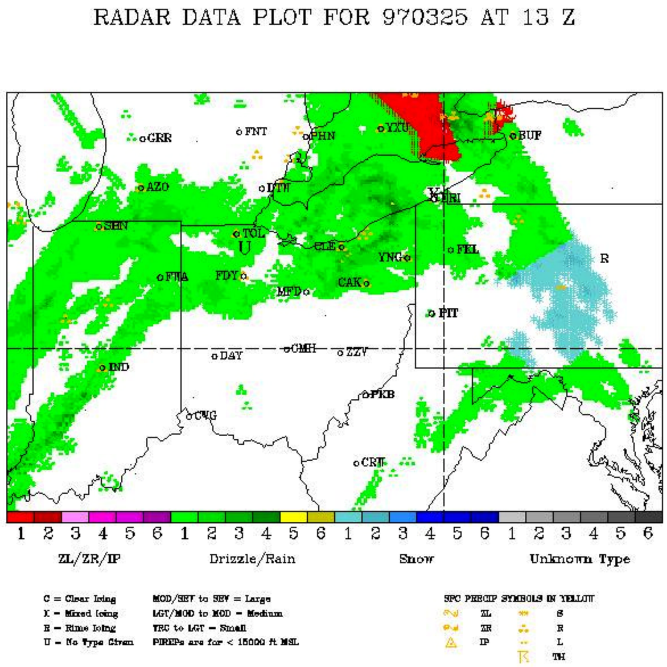


Figure 4 – Infrared satellite data for 970325, a) 1145 and b) 1445 UTC.



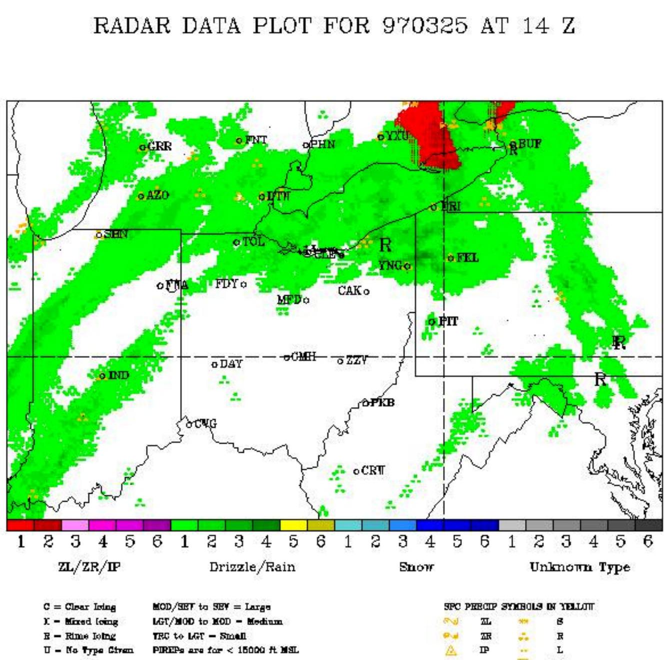
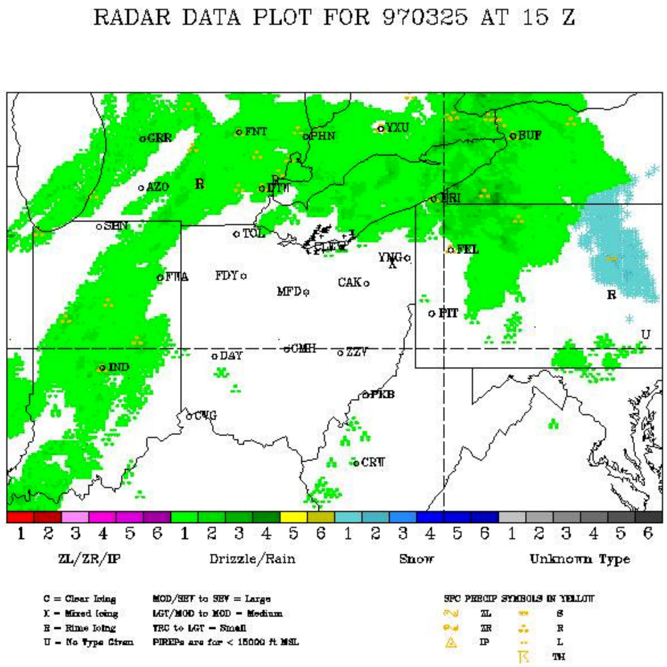


Figure 5 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970325, a) 1300 and b) 1400 UTC.



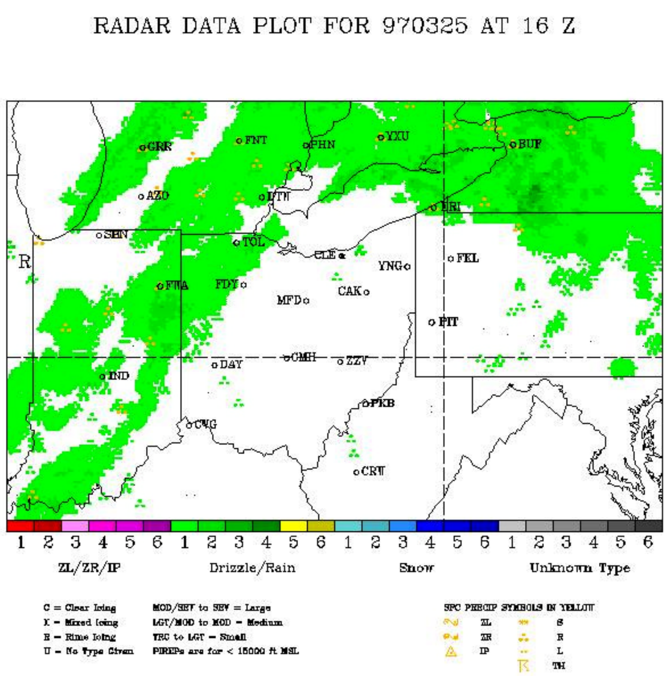
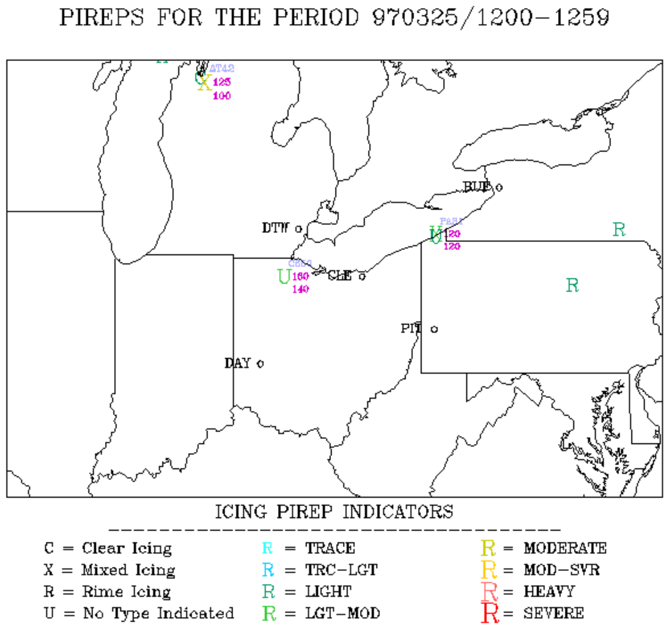


Figure 5 – Radar data, surface observations, icing PIREPs and Twin Otter tracks for 970325, c) 1500 and d) 1600 UTC.



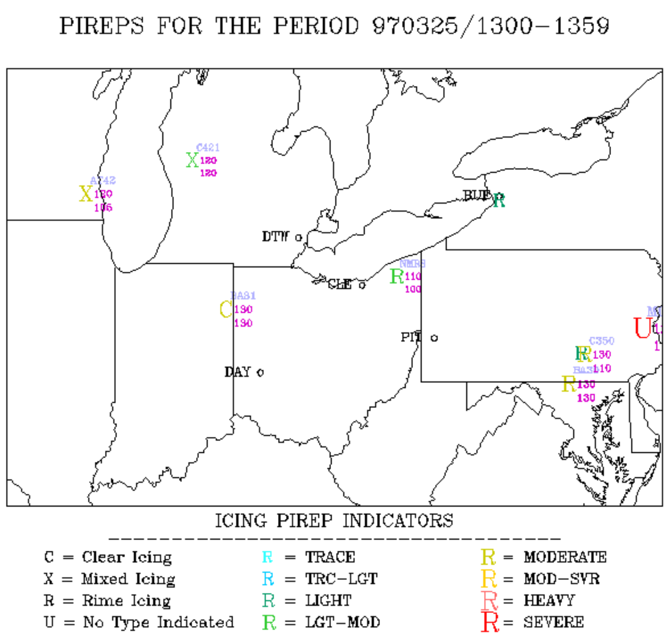
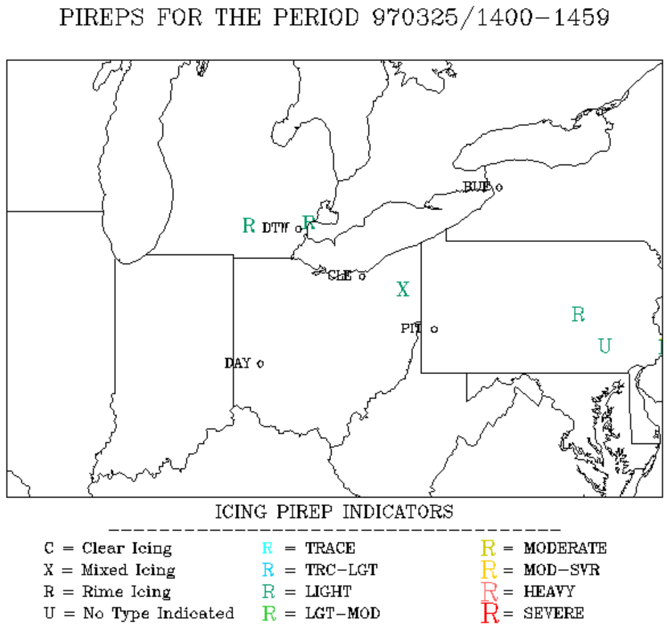


Figure 6 – Pilot reports of icing for 970325, a) 1200-1259 and b) 1300-1359 UTC.



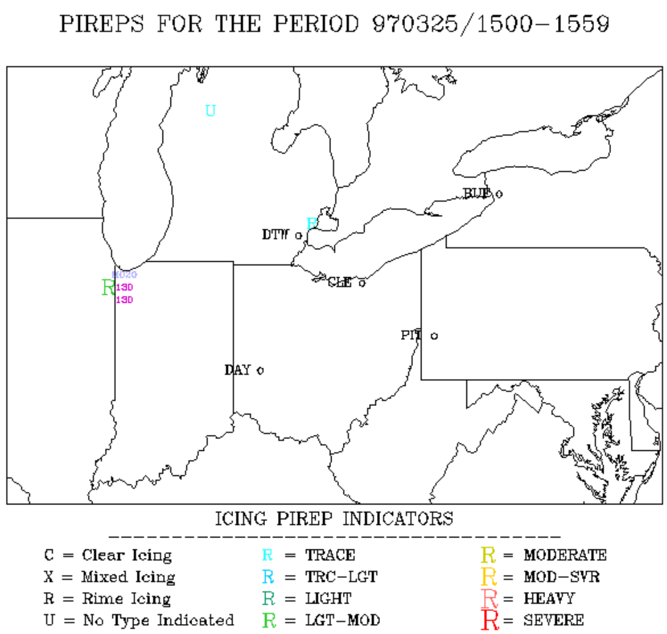


Figure 6 – Pilot reports of icing for 970325, c) 1400-1459 and d) 1500-1559 UTC.

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13. ABSTRACT ***(Maximum 200 words)***

This part of the document contains an analysis of the meteorology associated with the premier icing encounters from the January-March 1997 NASA Twin Otter dataset. The purpose of this analysis is to provide a meteorological context for the aircraft data collected during these flights. For each case, the following data elements are presented: (1) A detailed discussion of the Twin Otter encounter, including locations, liquid water contents, temperatures and microphysical makeup of the clouds and precipitation aloft, (2) Upper-air charts, providing hand-analyzed locations of lows, troughs, ridges, saturated/unsaturated air, temperatures, warm/cold advection, and jet streams, (3) Balloon-borne soundings, providing vertical profiles of temperature, moisture and winds, (4) Infrared satellite data, providing cloud locations and cloud top temperature, (5) 3-hourly surface charts, providing hand-analyzed locations of lows, highs, fronts, precipitation (including type) and cloud cover, (6) Hourly plots of icing pilot reports, providing the icing intensity, icing type, icing altitudes and aircraft type, (7) Hourly, regional radar mosaics, providing fine resolution of the locations of precipitation (including intensity and type), pilot reports of icing (including intensity and type), surface observations of precipitation type and Twin Otter tracks for a one hour window centered on the time of the radar data, and (8) Plots of data from individual NEXRAD radars at times and elevation angles that have been matched to Twin Otter flight locations. Outages occurred in nearly every dataset at some point. All relevant data that was available is presented here. All times are in UTC and all heights are in feet above mean sea level (MSL).

14. SUBJECT TERMS

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