NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

April 18, 2017

Weather Study

METEOROLOGY

DCA16IA215

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A. INCIDENT

Location: Wood, South Dakota
Date: August 11, 2016
Time: about 2010 central daylight time (0110 UTC[1] on August 12, 2016)
Aircraft: Airbus 320-232; N632JB

B. METEOROLOGIST

Mike Richards
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National Transportation Safety Board

C. DETAILS OF THE INVESTIGATION

The National Transportation Safety Board's meteorological specialist travelled in support of this event and also gathered data for this incident investigation remotely. Unless otherwise noted, all times are in central daylight time (CDT) for August 11, 2016 (based upon the 24-hour clock), directions are referenced to true north, distances are in nautical miles and heights are above mean sea level (msl).

Coordinates used for the incident location in this report: 43.446812° north latitude, 100.47776° west longitude at FL320[2].

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1 UTC – abbreviation for Coordinated Universal Time

2 Flight Level - a standard nominal altitude of an aircraft, in hundreds of feet. This altitude is calculated from the International standard pressure datum of 1013.25 hectopascals (29.92 in Hg), the average sea-level pressure, and therefore is not necessarily the same as the aircraft's true altitude either above msl or agl.

D. FACTUAL INFORMATION

1.0 Synoptic Conditions

The National Weather Service (NWS) Surface Analysis Chart for 1900 CDT is presented in figure 1. The surface analysis chart identified a north/south-oriented trough in eastern South Dakota. Surface temperatures in the incident region ranged between the mid-70's degrees Fahrenheit (°F) and mid-80's°F, with dew point depressions between 5°F and 9°F. A WSR-88D regional radar composite reflectivity mosaic obtained from the National Mosaic and Multi-Sensor (NMQ) Project for 2010 CDT (figure 2) identified numerous areas of convection and high levels of reflectivity across the region.

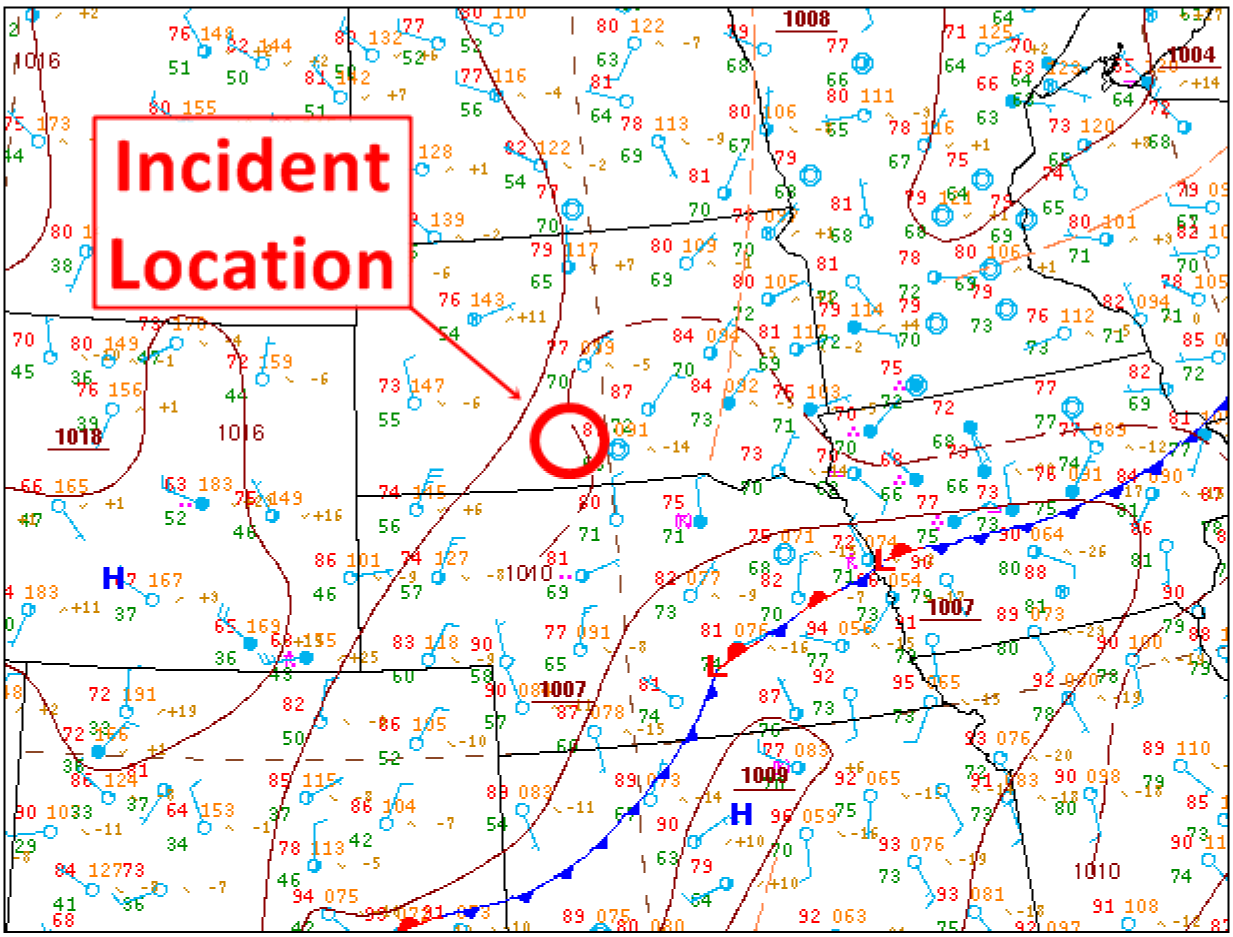

Figure 1 - NWS Surface Analysis Chart for 1900 CDT.

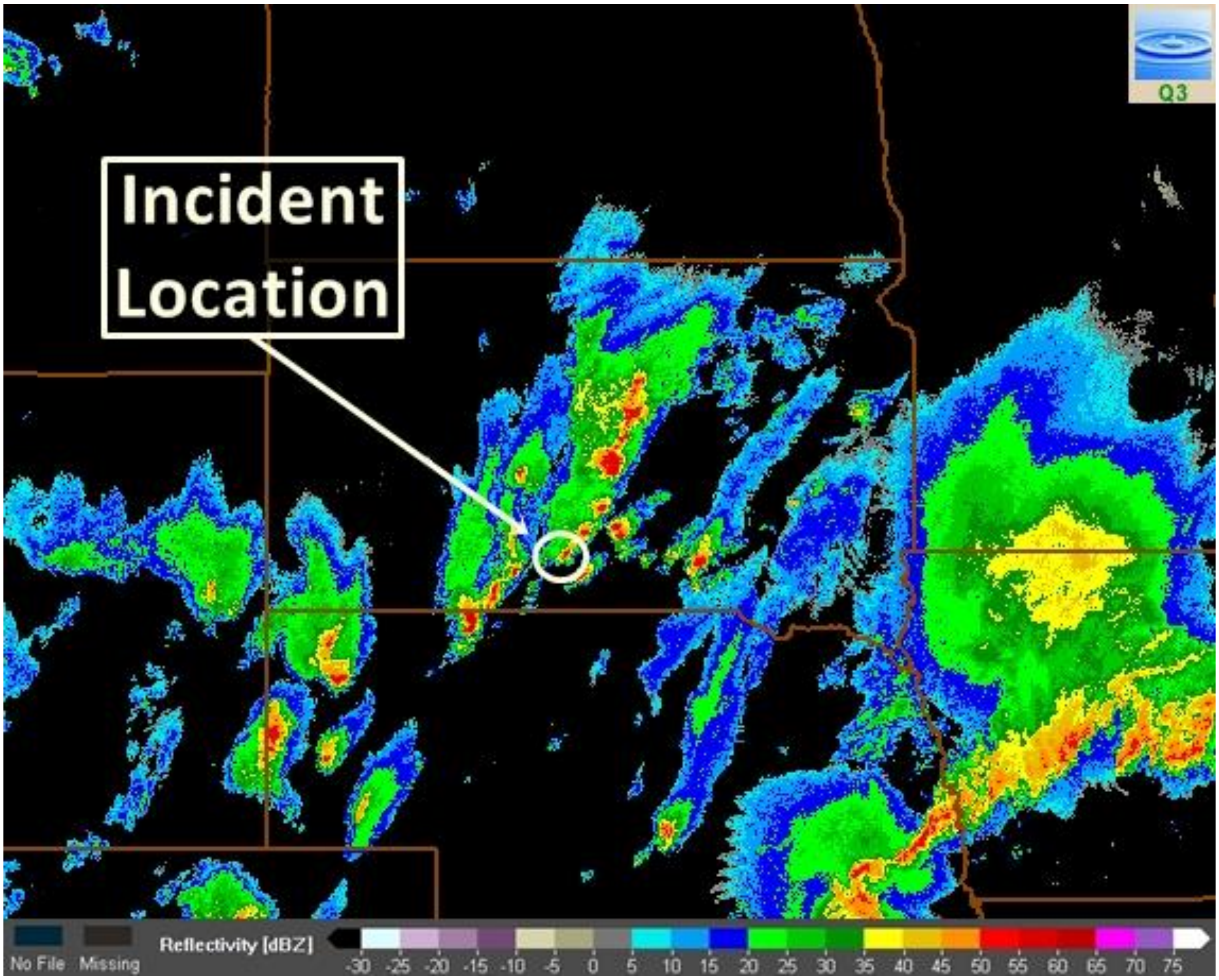

Figure 2 – NMQ NEXRAD mosaic from 2010 CDT.

2.0 Weather Radar

WSR-88D Level-II weather radar imagery from near Thedford, Nebraska (KLNX), is presented in figures 3-11. KLNX was located approximately 90 miles south of the incident site at an elevation of about 2,930 feet. Assuming standard refraction and considering the 0.95° beam width for the WSR-88D radar beam, the KLNX antenna tilts would have "seen" altitudes presented in the following table.

KLNX Antenna Tilts	Approximate Altitudes Observed At Incident Location (msl)
0.48°	8,350 feet – 17,400 feet
0.86°	12,000 feet – 21,050 feet
1.32°	16,350 feet – 25,450 feet
1.81°	21,050 feet – 30,100 feet
2.40°	26,650 feet – 35,700 feet
3.11°	33,400 feet – 42,500 feet

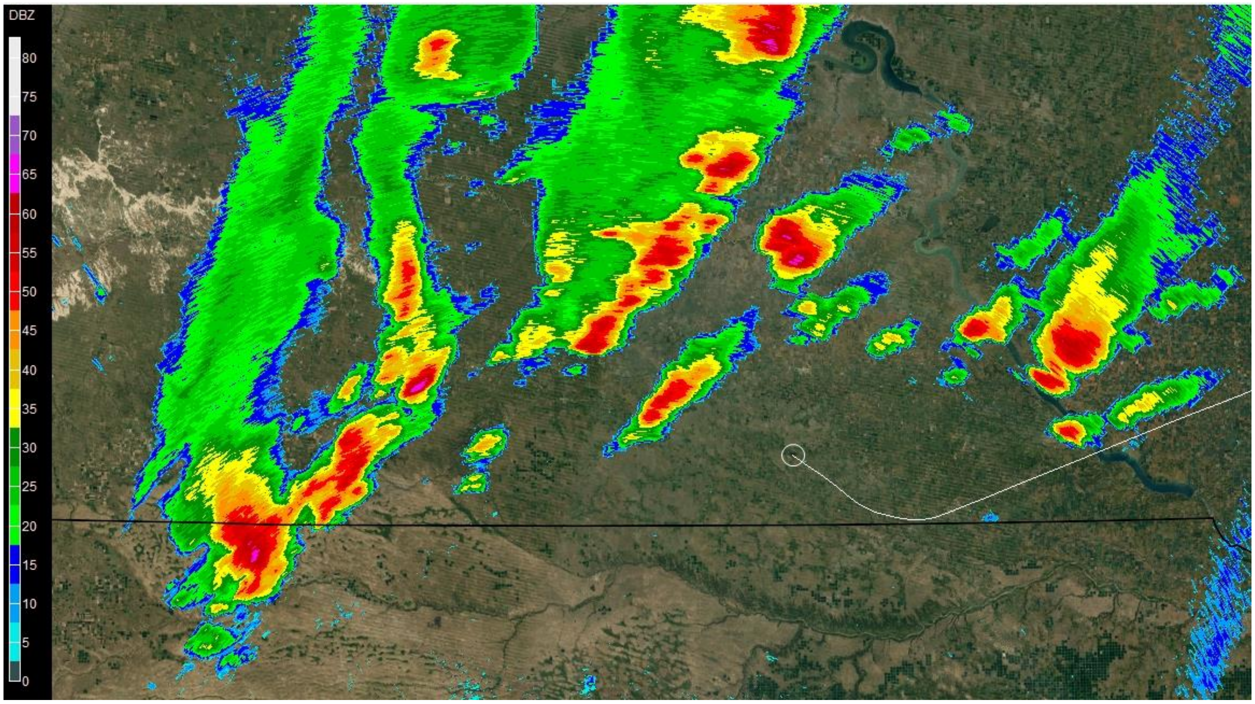

Figure 3 – KLNX 0.48° Level-II reflectivity product from a sweep initiated at 2005:41 CDT. Incident flight path denoted by white line with aircraft location at sweep initiation time identified by white circle.

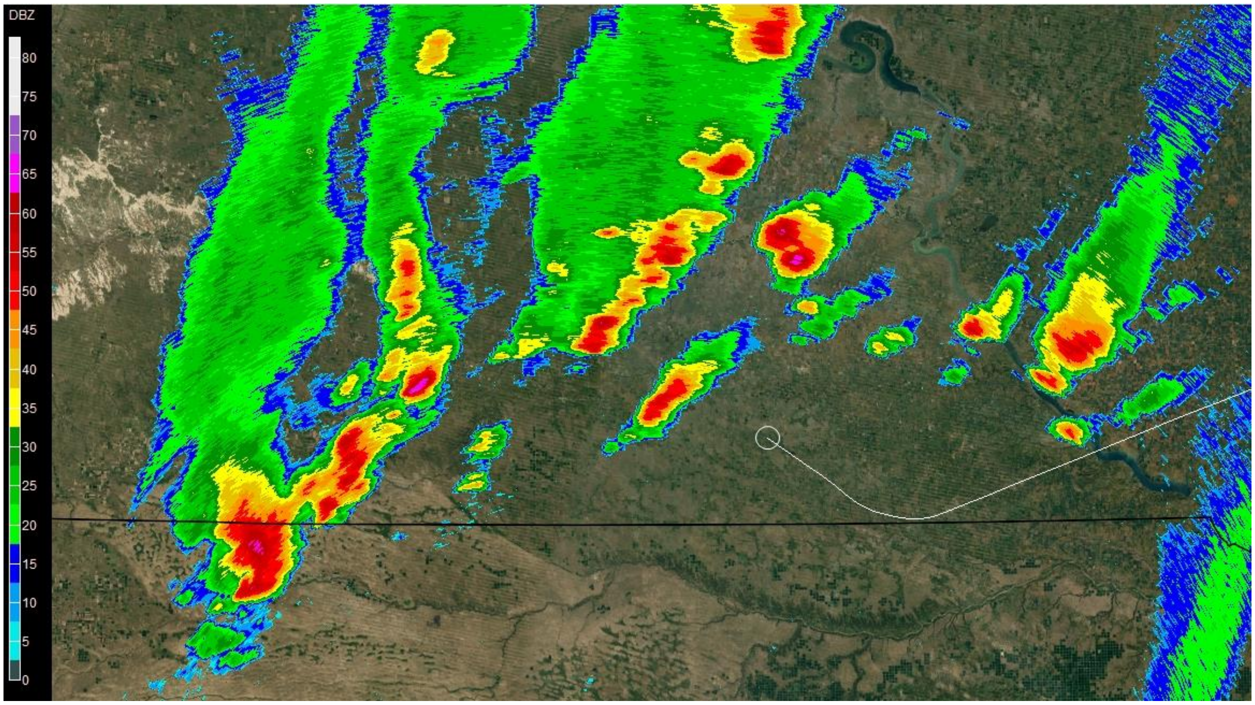

Figure 4 – KLNX 0.86° Level-II reflectivity product from a sweep initiated at 2006:16 CDT. Incident flight path denoted by white line with aircraft location at sweep initiation time identified by white circle.

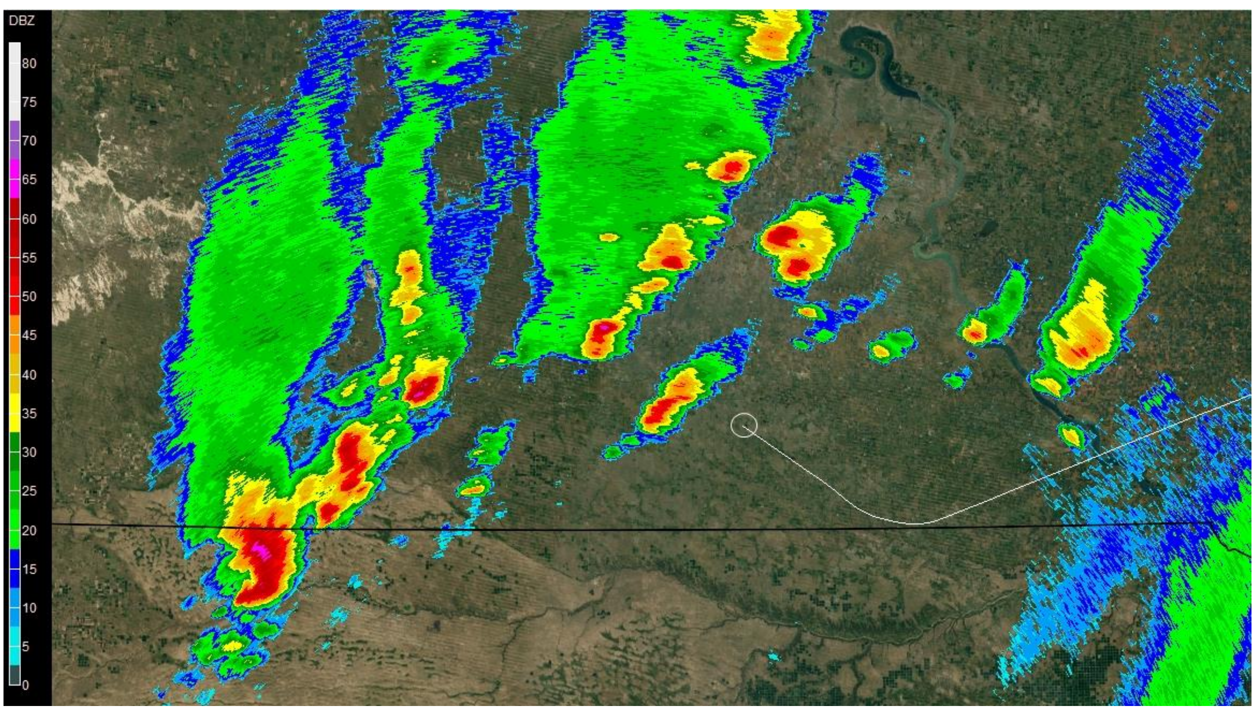

Figure 5 – KLNX 1.32° Level-II reflectivity product from a sweep initiated at 2006:52 CDT. Incident flight path denoted by white line with aircraft location at sweep initiation time identified by white circle.

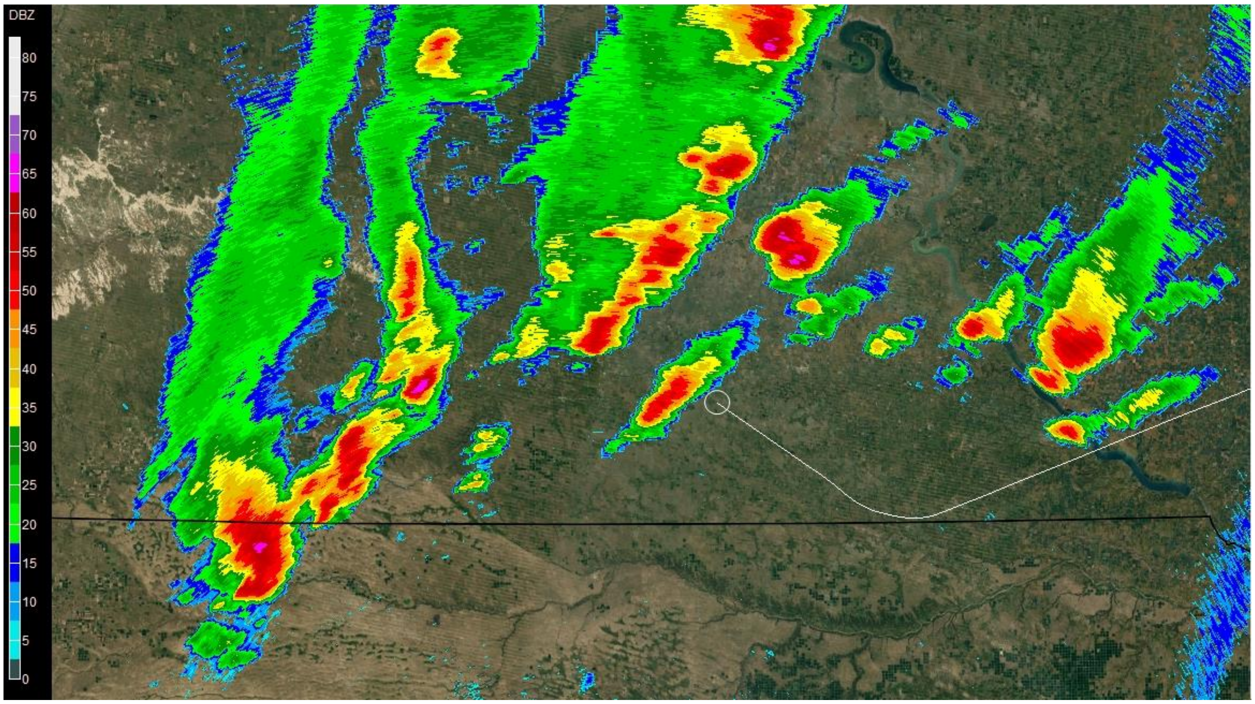

Figure 6 – KLNX 0.48° Level-II reflectivity product from a sweep initiated at 2007:28 CDT. Incident flight path denoted by white line with aircraft location at sweep initiation time identified by white circle.

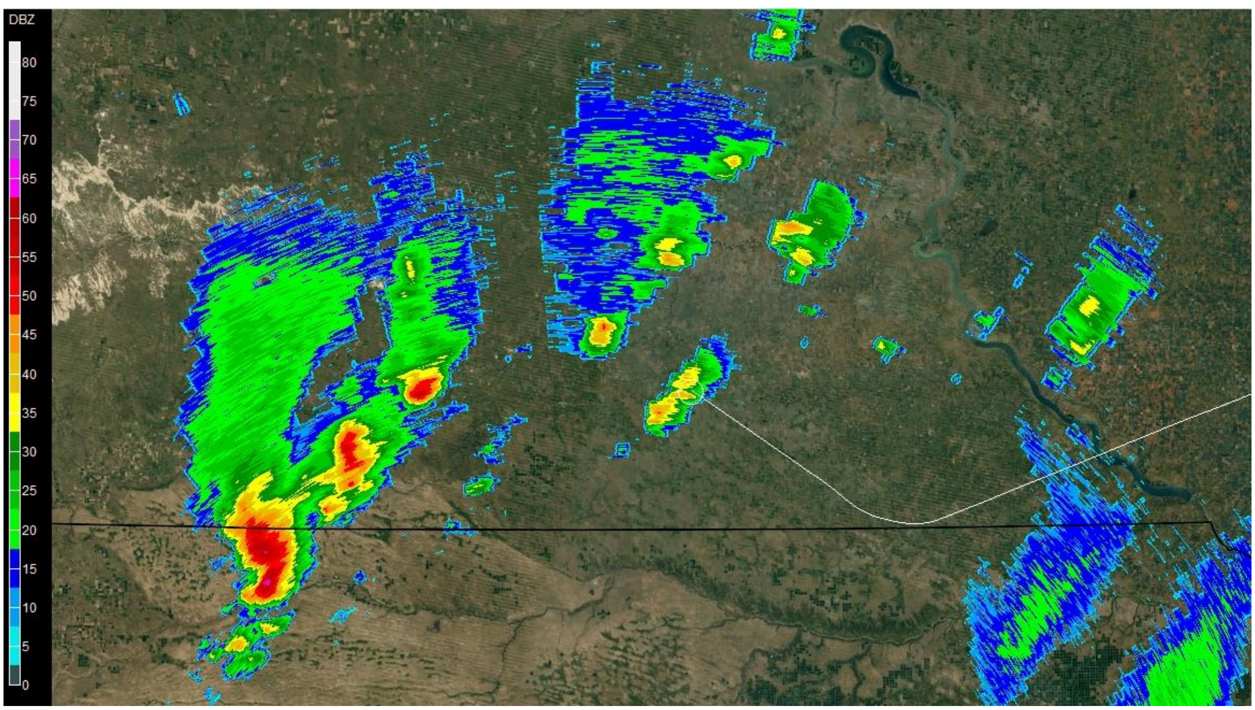

Figure 7 – KLNX 1.81° Level-II reflectivity product from a sweep initiated at 2008:05 CDT. Incident flight path denoted by white line with aircraft location at sweep initiation time identified by white circle.

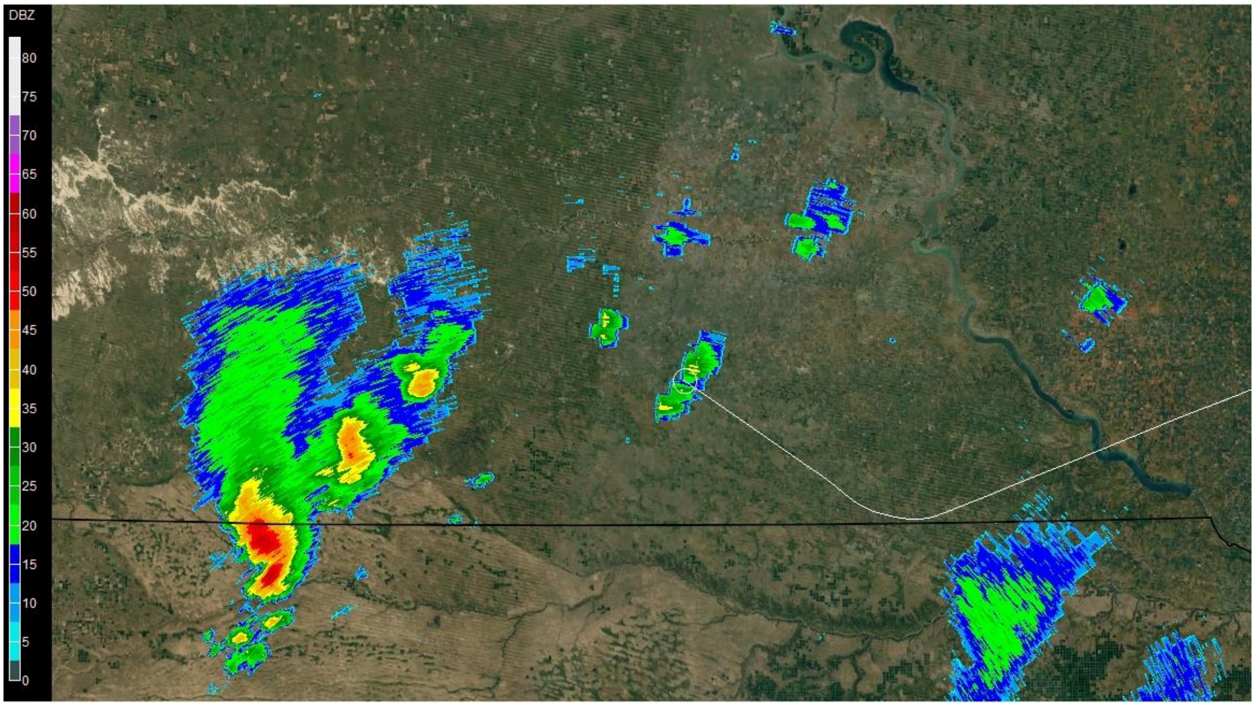

Figure 8 – KLNX 2.40° Level-II reflectivity product from a sweep initiated at 2008:20 CDT. Incident flight path denoted by white line with aircraft location at sweep initiation time identified by white circle.

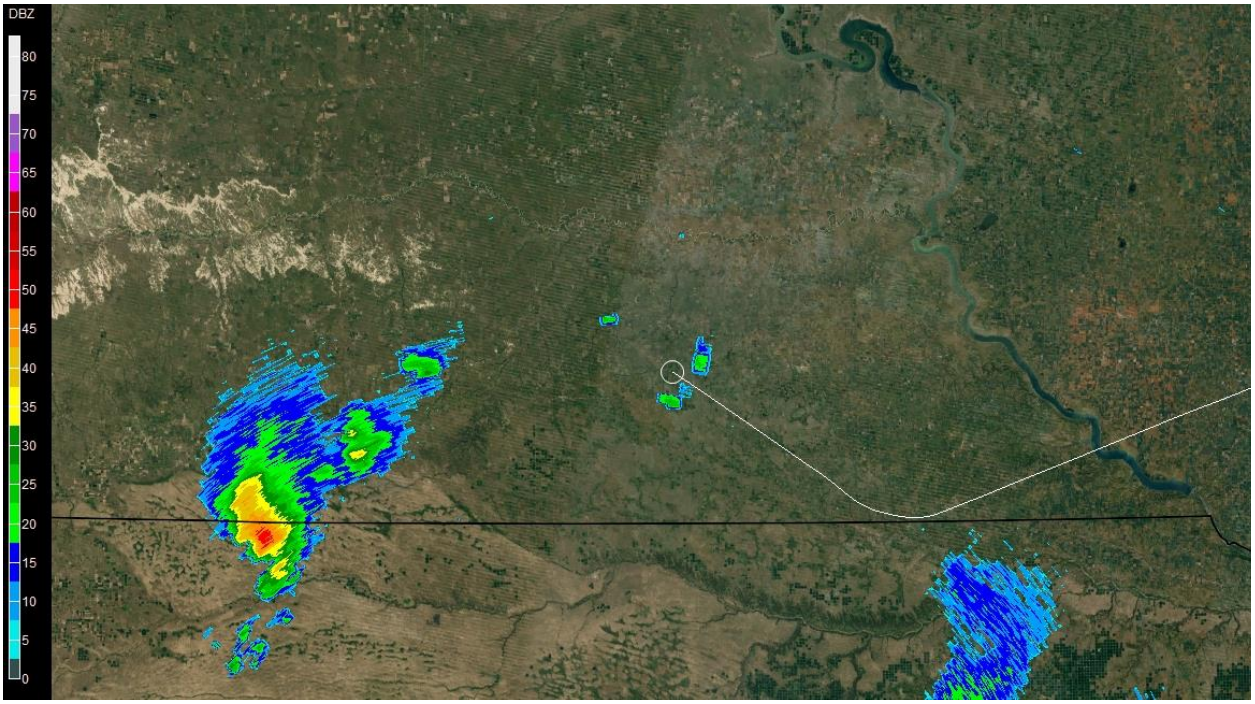

Figure 9 – KLNX 3.11° Level-II reflectivity product from a sweep initiated at 2008:34 CDT. Incident flight path denoted by white line with aircraft location at sweep initiation time identified by white circle.

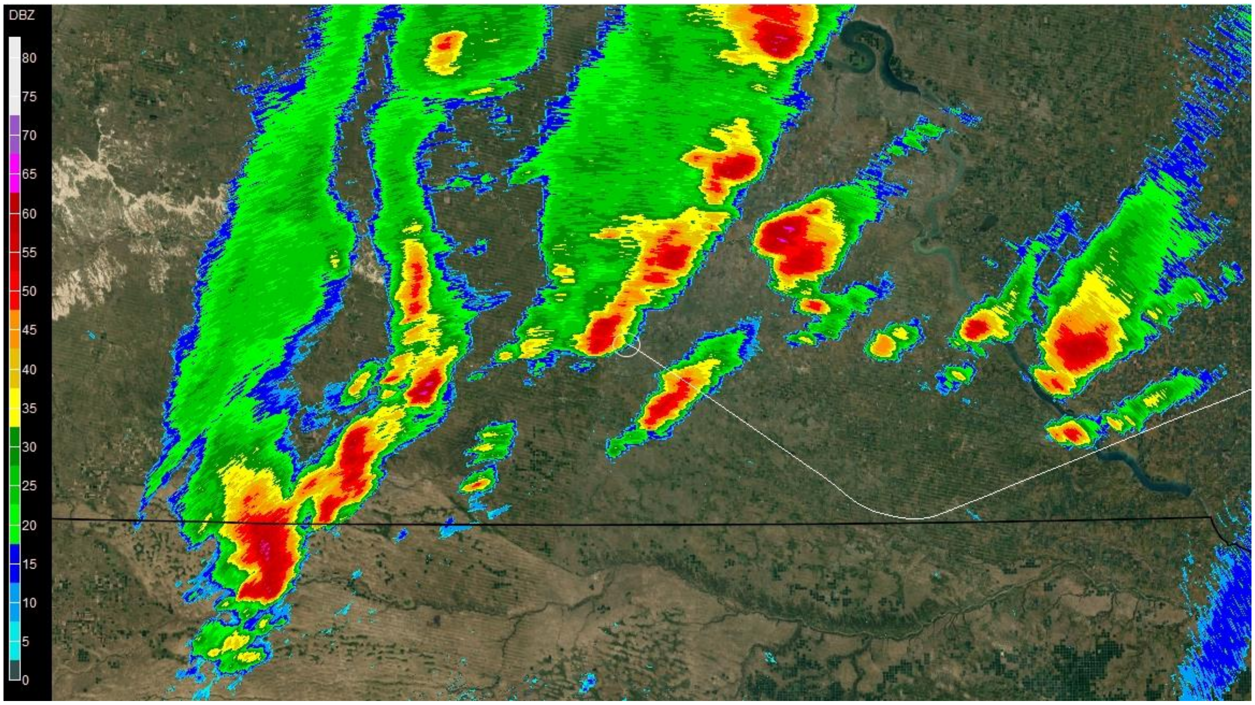

Figure 10 – KLNX 0.48° Level-II reflectivity product from a sweep initiated at 2009:39 CDT. Incident flight path denoted by white line with aircraft location at sweep initiation time identified by white circle.

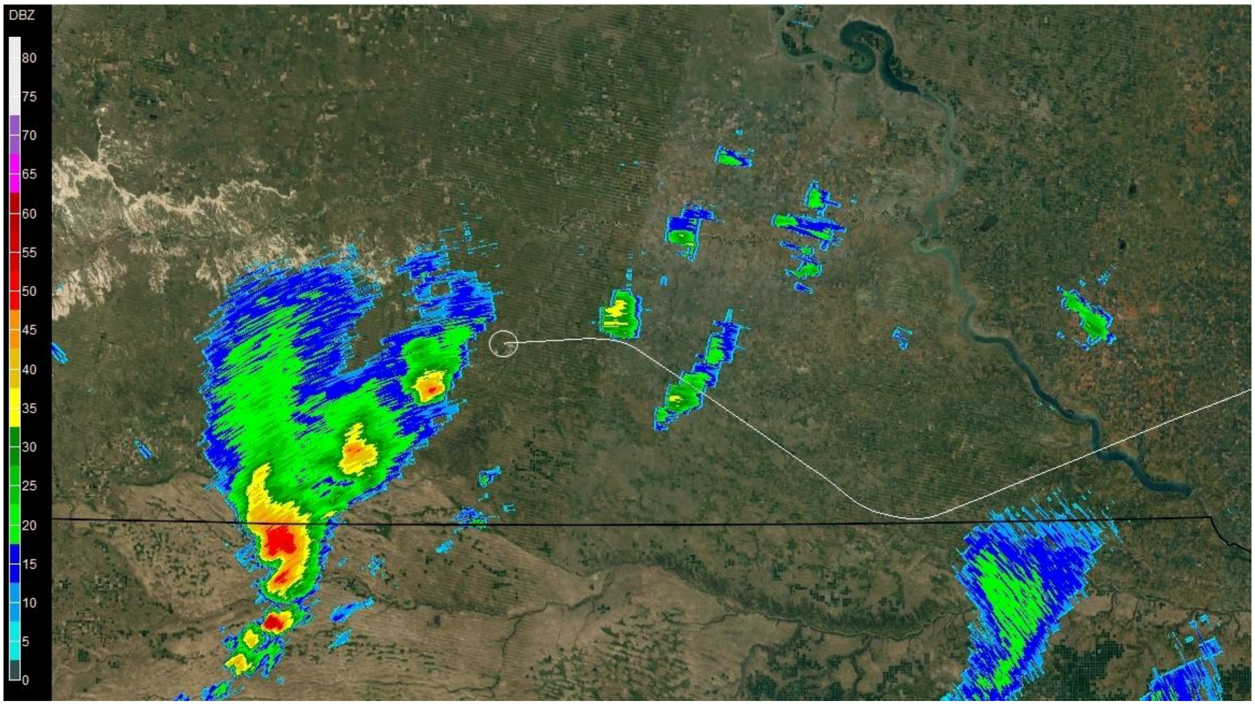

Figure 11 – KLNX 2.40° Level-II reflectivity product from a sweep initiated at 2012:19 CDT. Incident flight path denoted by white line with aircraft location at sweep initiation time identified by white circle.

Figures 12-24 are pictures of a replay of the Denver Air Route Traffic Control Center (ARTCC) Weather and Radar Processor (WARP) radar mosaic applicable to the time surrounding the incident. Timestamps for these WARP mosaics are rounded down to nearest whole minute, and the incident aircraft's (JBU429) location can be identified in these images. "Precipitation" intensities are "moderate" (blue color), "heavy" (green/black "checkerboard" color) and "extreme" (light green color). Altitude composite is not known.

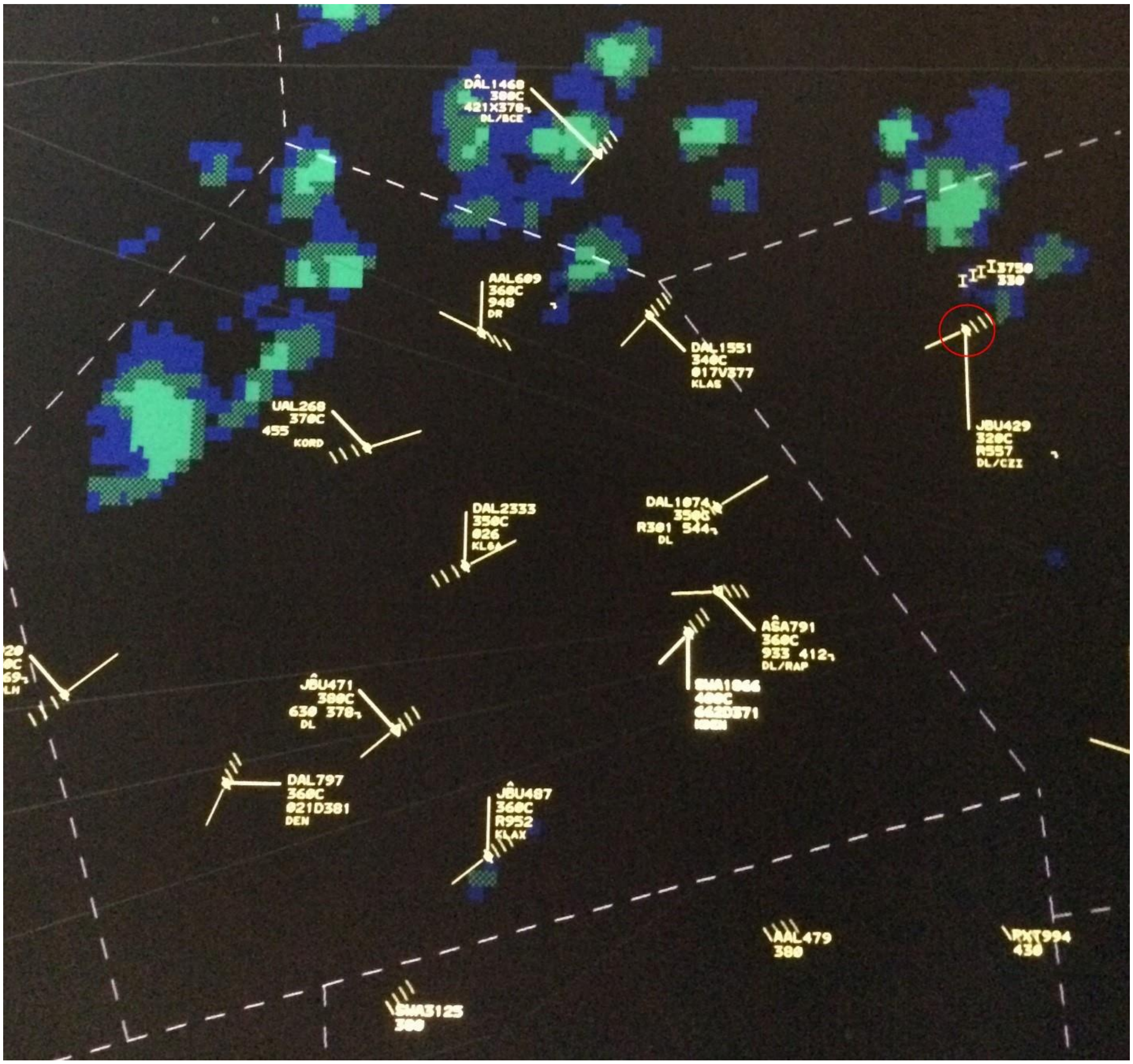

Figure 12 – Screenshot of the Denver ARTCC WARP replay for about 2000 CDT. The incident airplane (highlighted by red circle) is "JBU429."

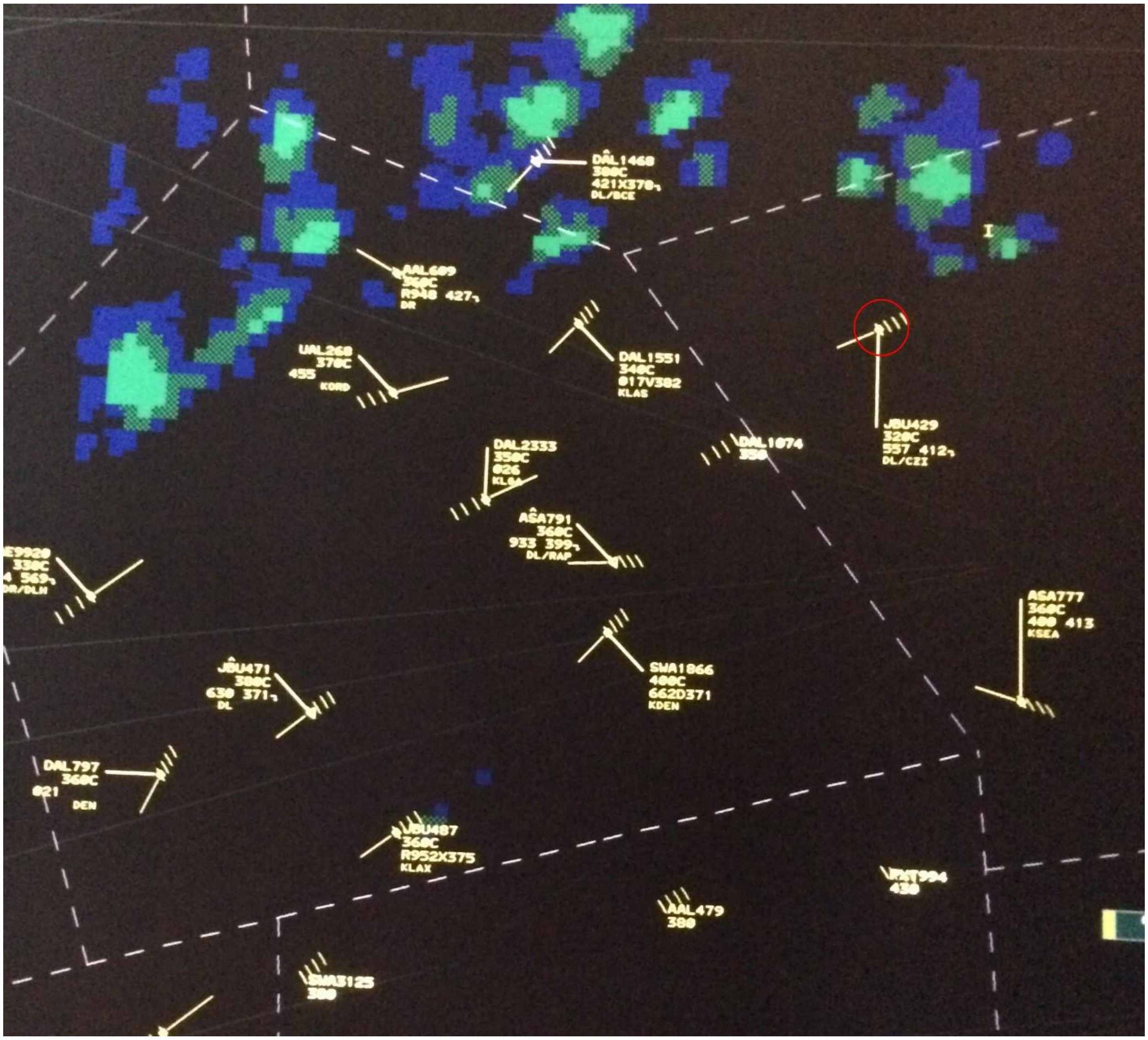

Figure 13 – Screenshot of the Denver ARTCC WARP replay for about 2001 CDT. The incident airplane (highlighted by red circle) is "JBU429."

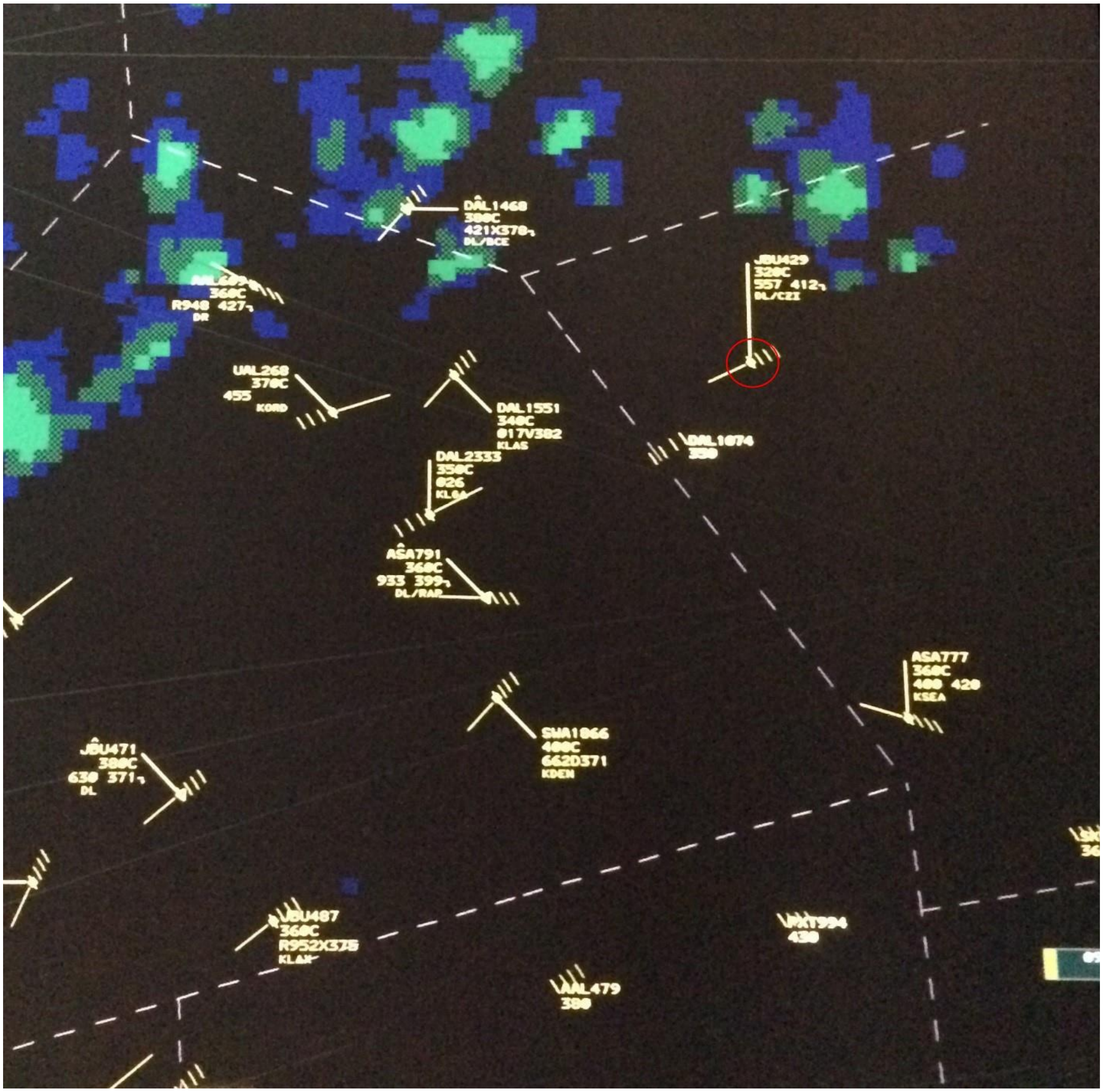

Figure 14 – Screenshot of the Denver ARTCC WARP replay for about 2002 CDT. The incident airplane (highlighted by red circle) is "JBU429."

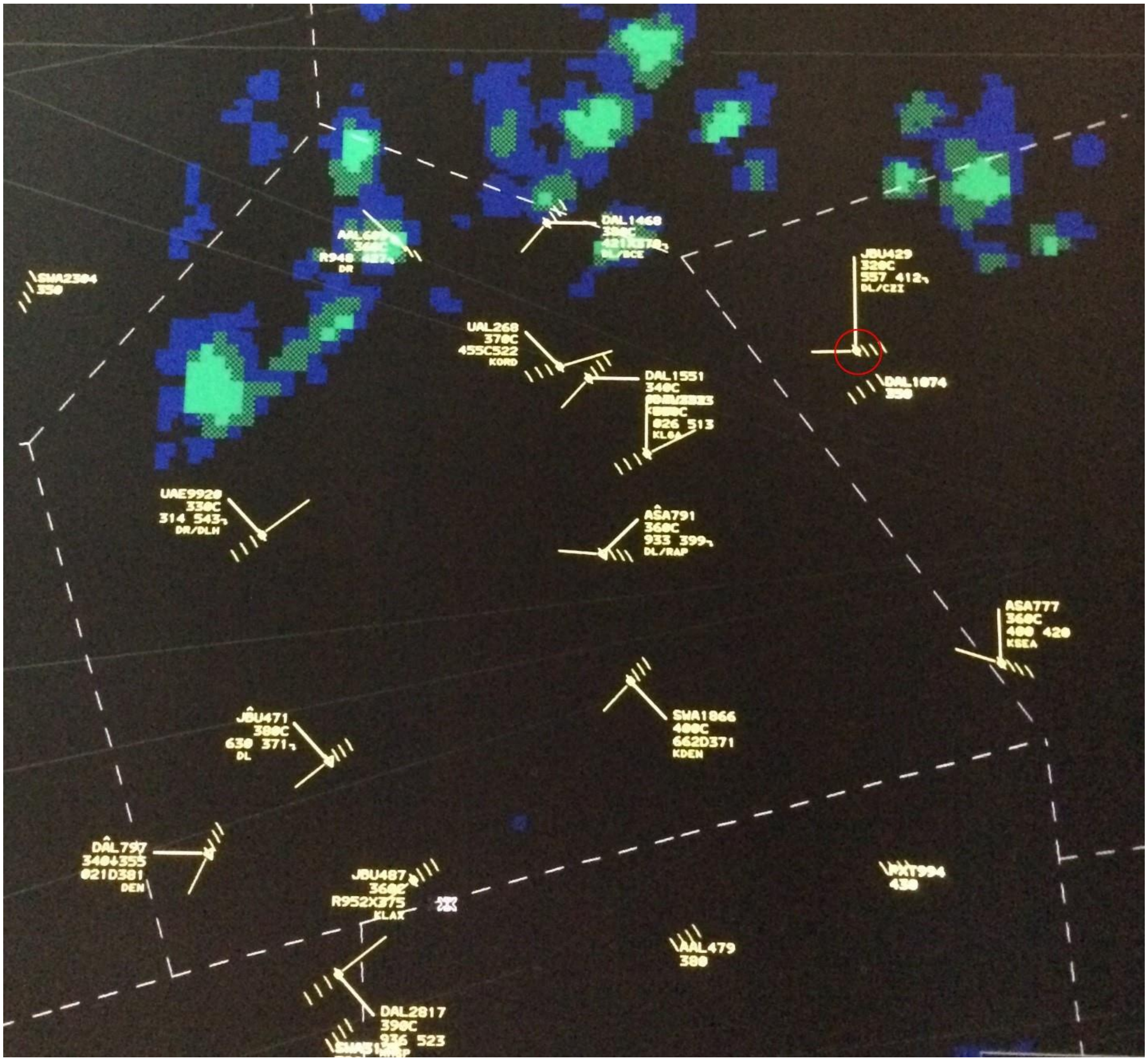

Figure 15 – Screenshot of the Denver ARTCC WARP replay for about 2003 CDT. The incident airplane (highlighted by red circle) is "JBU429."

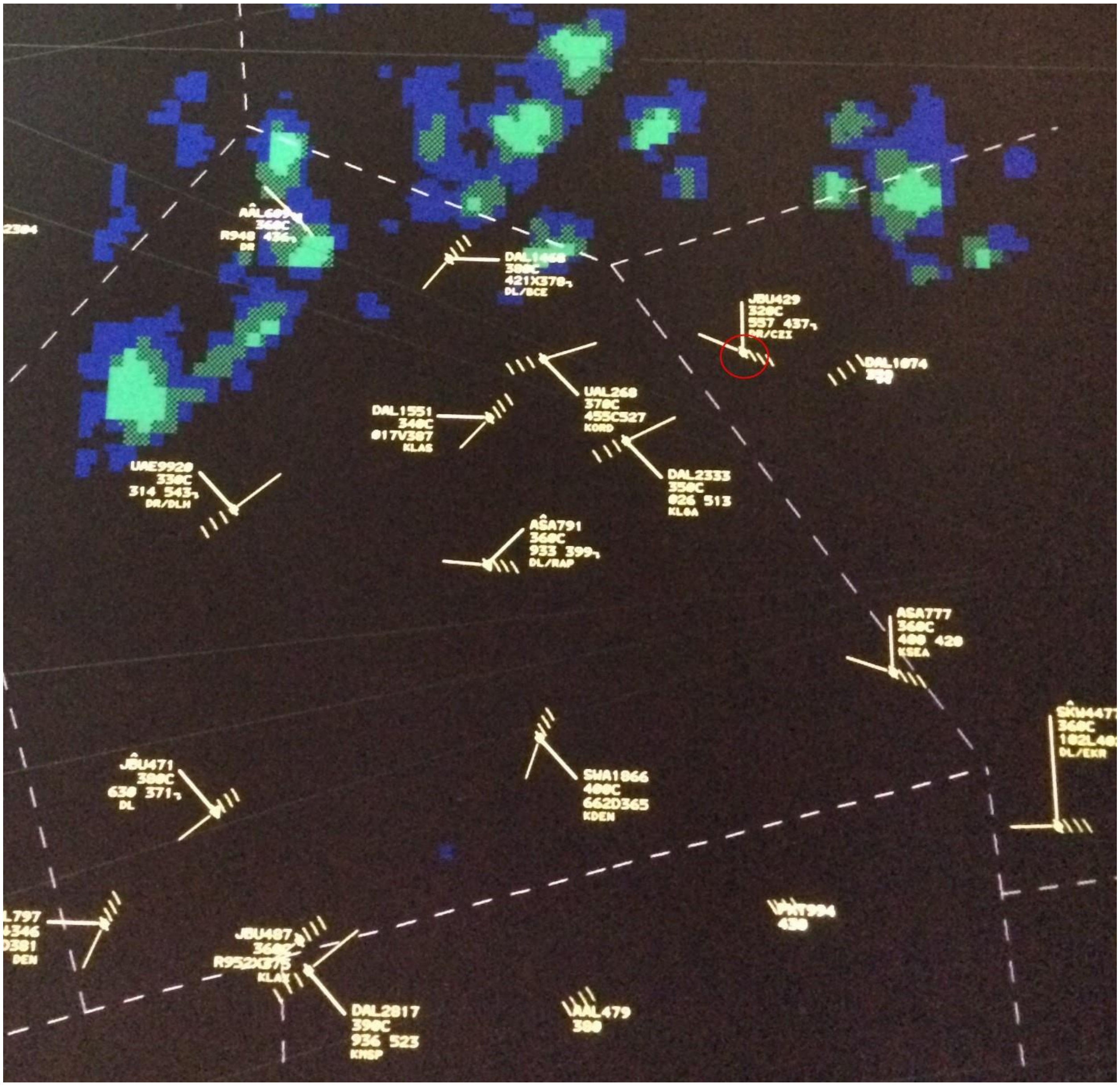

Figure 16 – Screenshot of the Denver ARTCC WARP replay for about 2004 CDT. The incident airplane (highlighted by red circle) is “JBU429.”

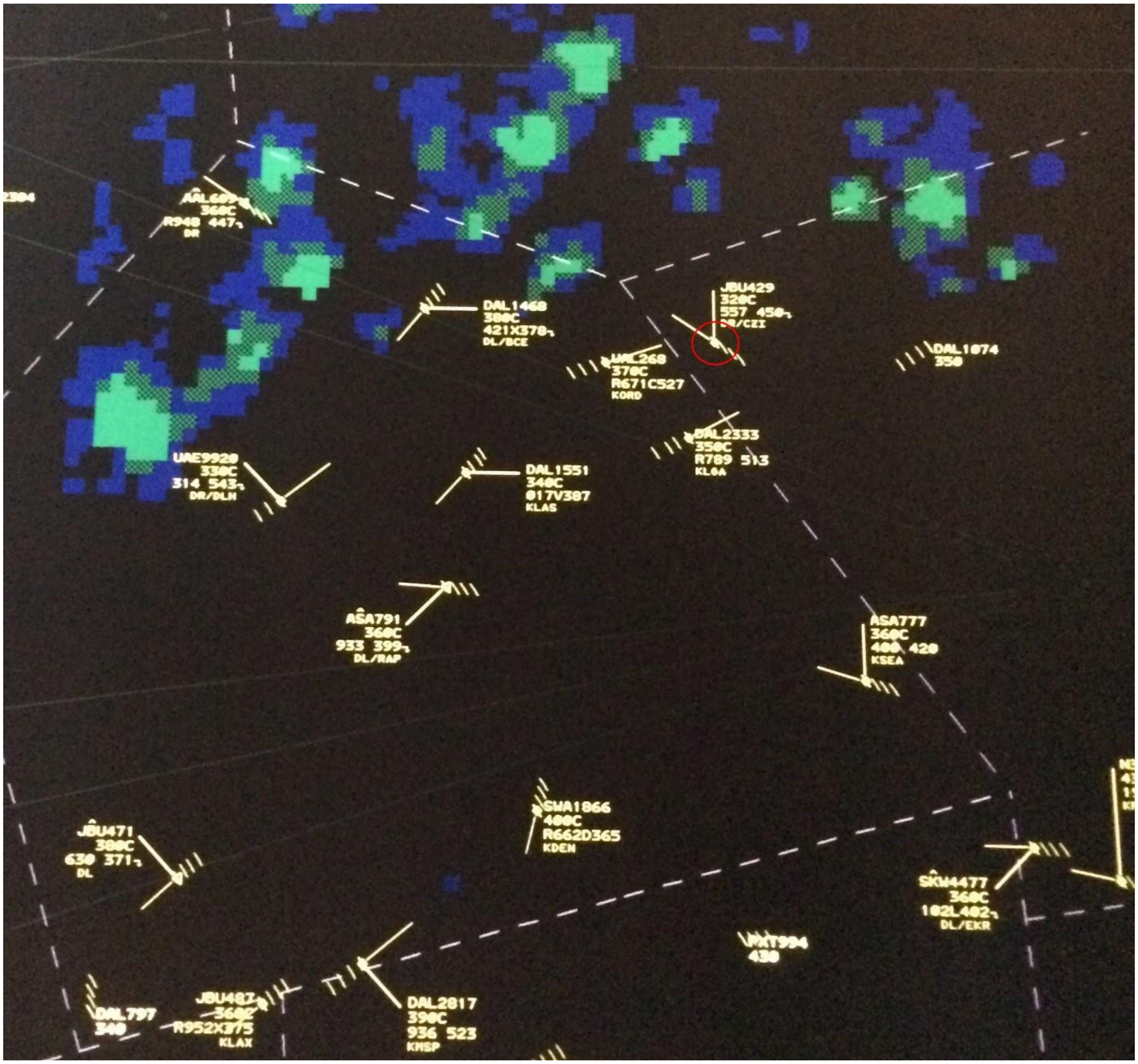

Figure 17 – Screenshot of the Denver ARTCC WARP replay for about 2005 CDT. The incident airplane (highlighted by red circle) is “JBU429.”

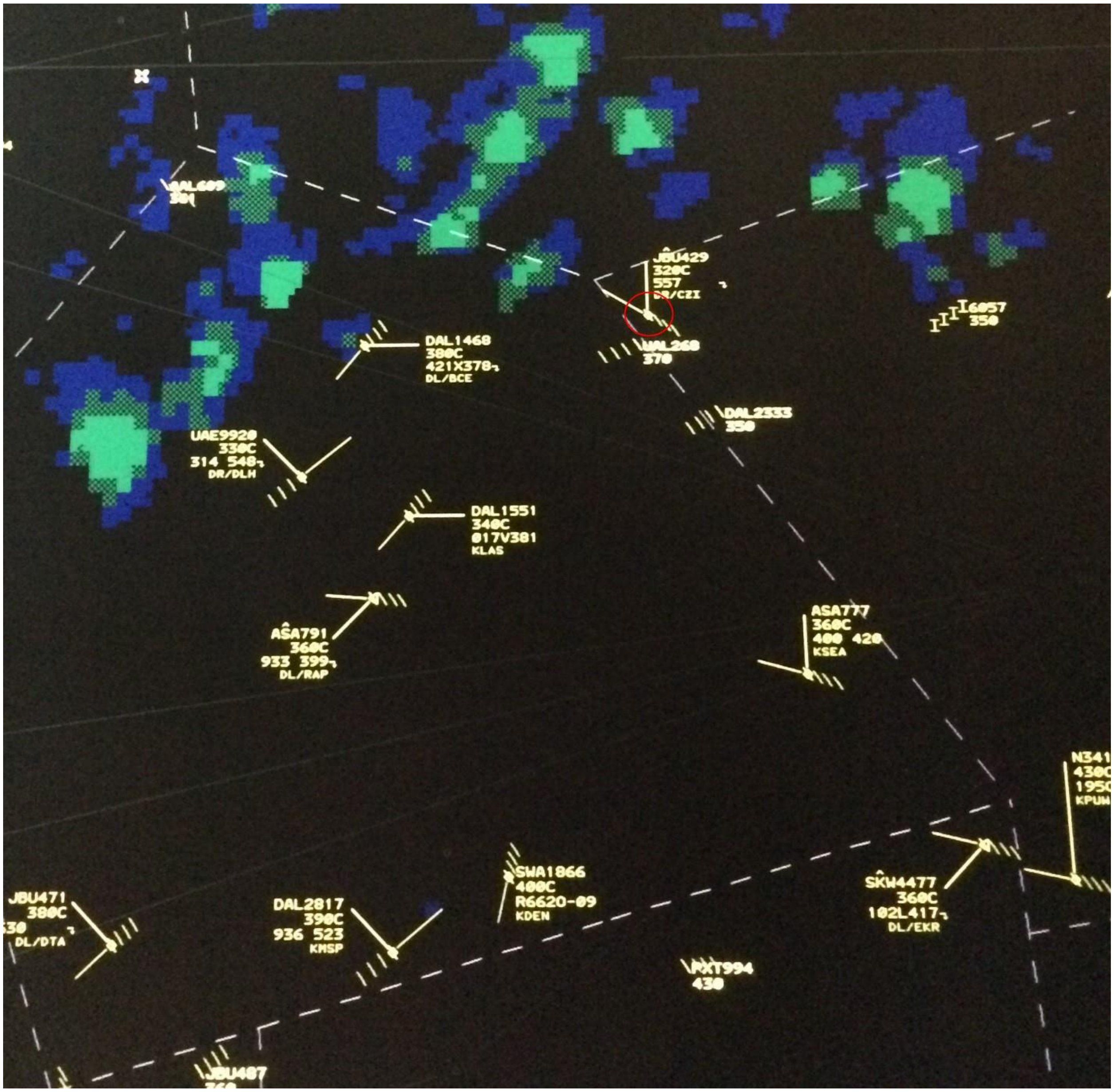

Figure 18 – Screenshot of the Denver ARTCC WARP replay for about 2006 CDT. The incident airplane (highlighted by red circle) is “JBU429.”

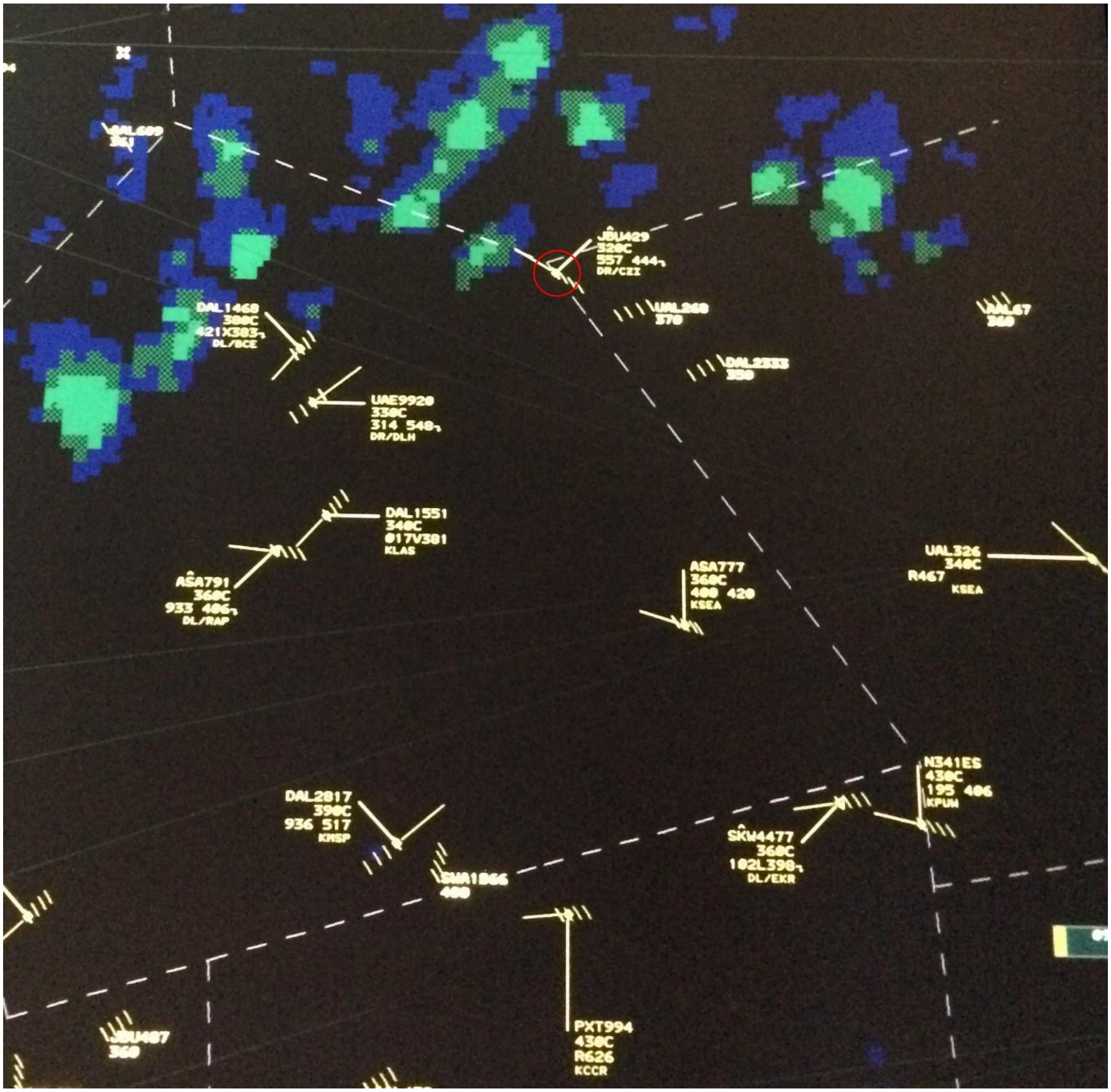

Figure 19 – Screenshot of the Denver ARTCC WARP replay for about 2007 CDT. The incident airplane (highlighted by red circle) is "JBU429."

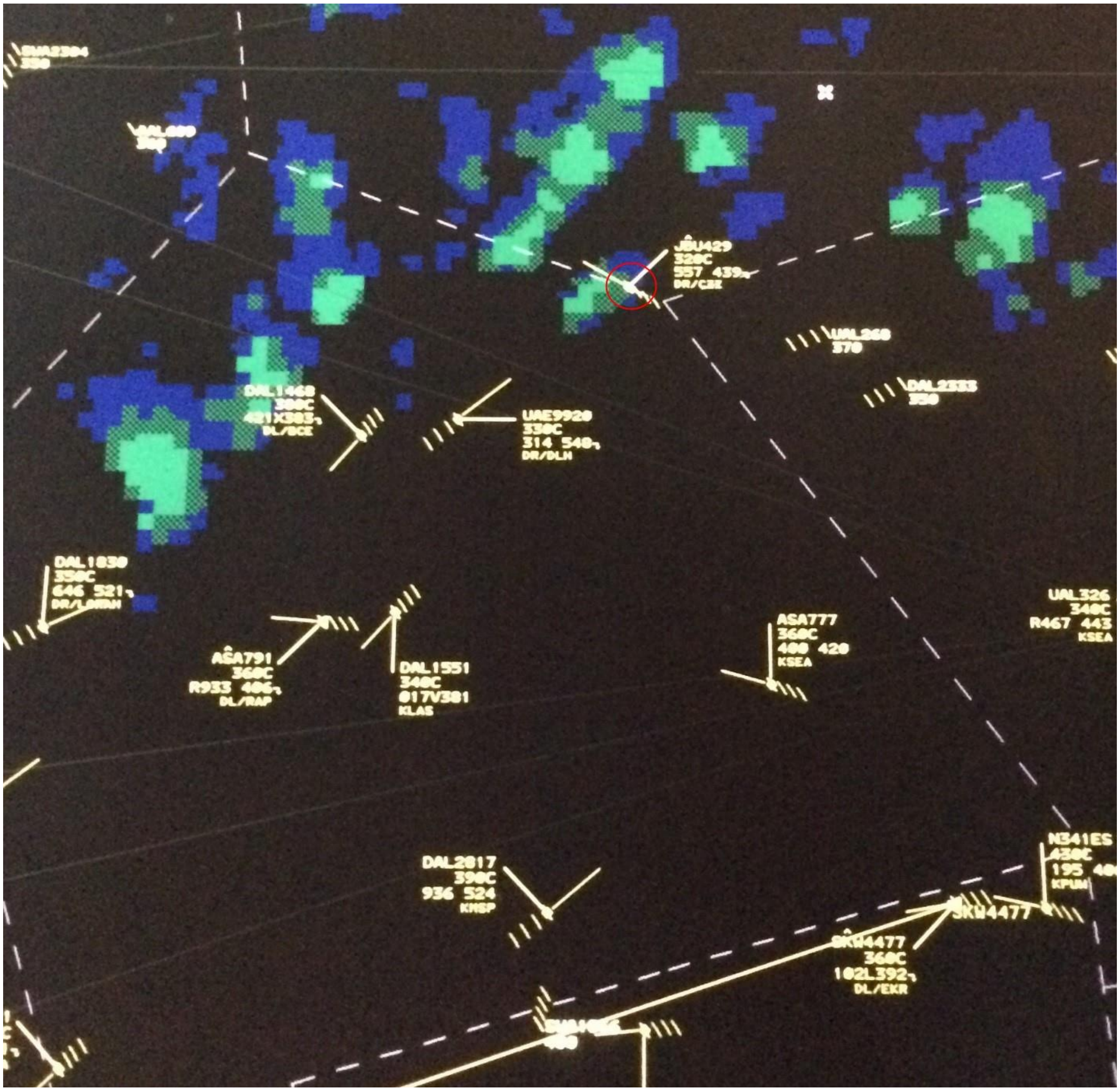

Figure 20 – Screenshot of the Denver ARTCC WARP replay for about 2008 CDT. The incident airplane (highlighted by red circle) is “JBU429.”

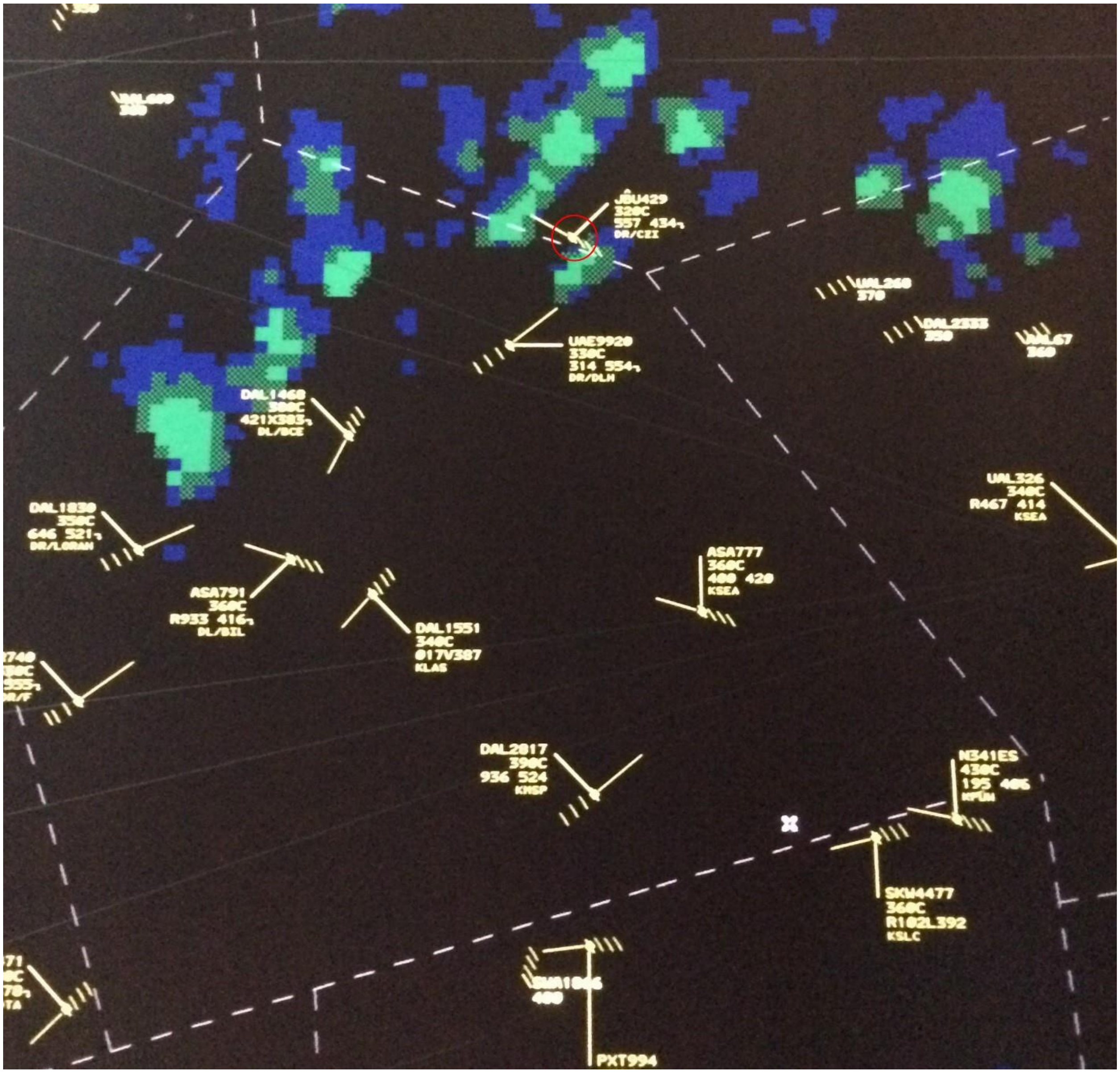

Figure 21 – Screenshot of the Denver ARTCC WARP replay for about 2009 CDT. The incident airplane (highlighted by red circle) is “JBU429.”

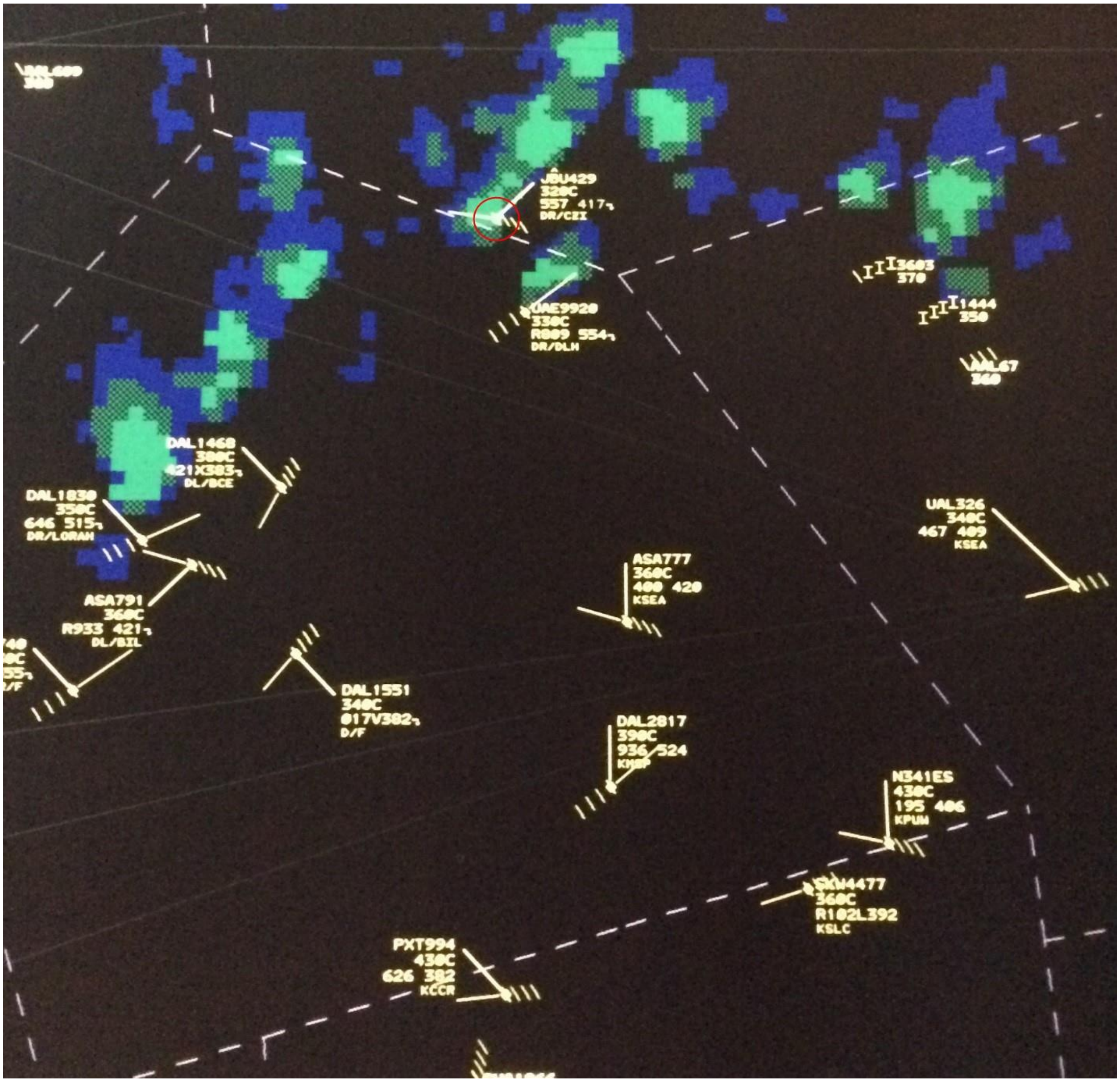

Figure 22 – Screenshot of the Denver ARTCC WARP replay for about 2010 CDT. The incident airplane (highlighted by red circle) is "JBU429."

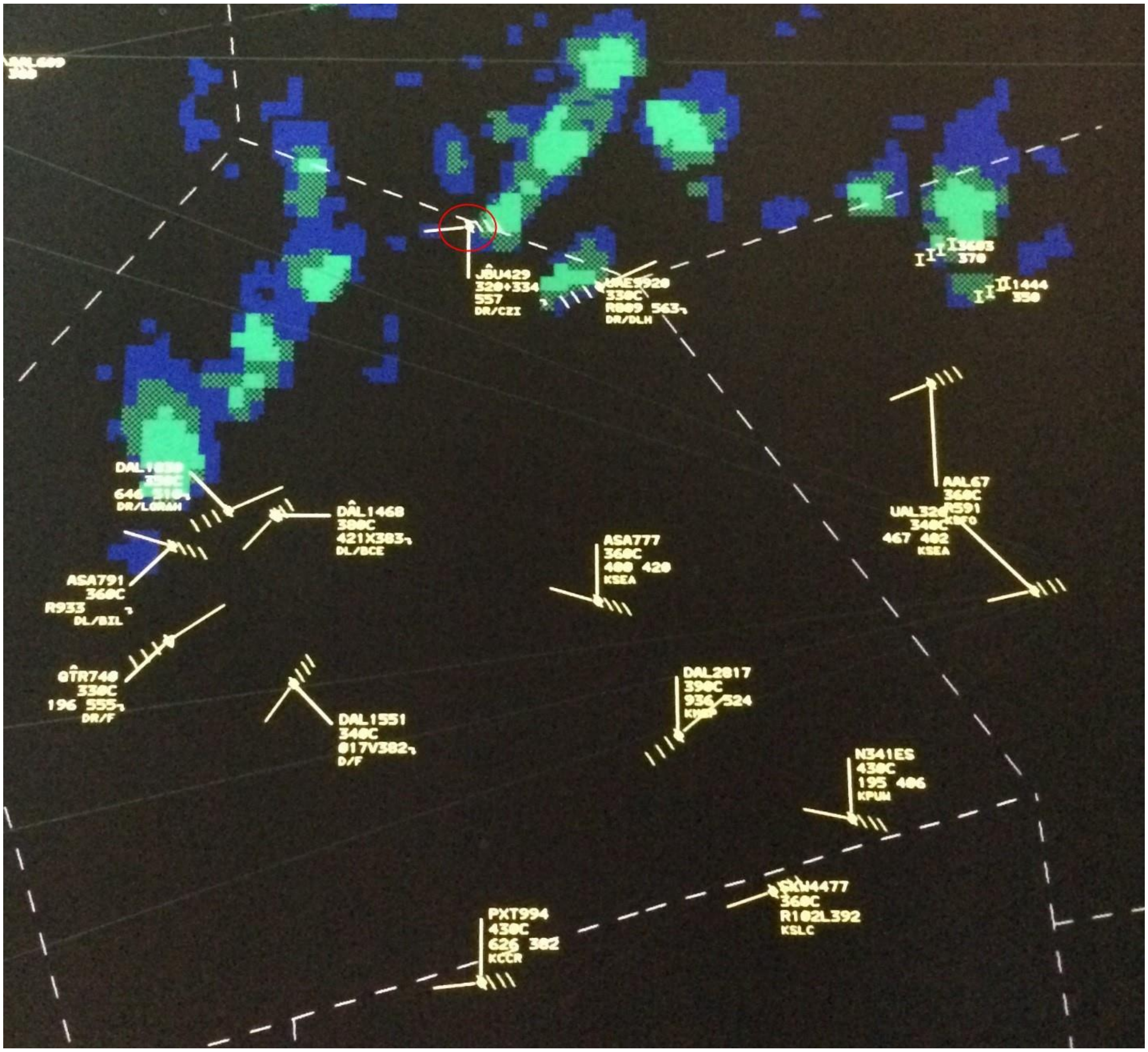

Figure 23 – Screenshot of the Denver ARTCC WARP replay for about 2011 CDT. The incident airplane (highlighted by red circle) is "JBU429."

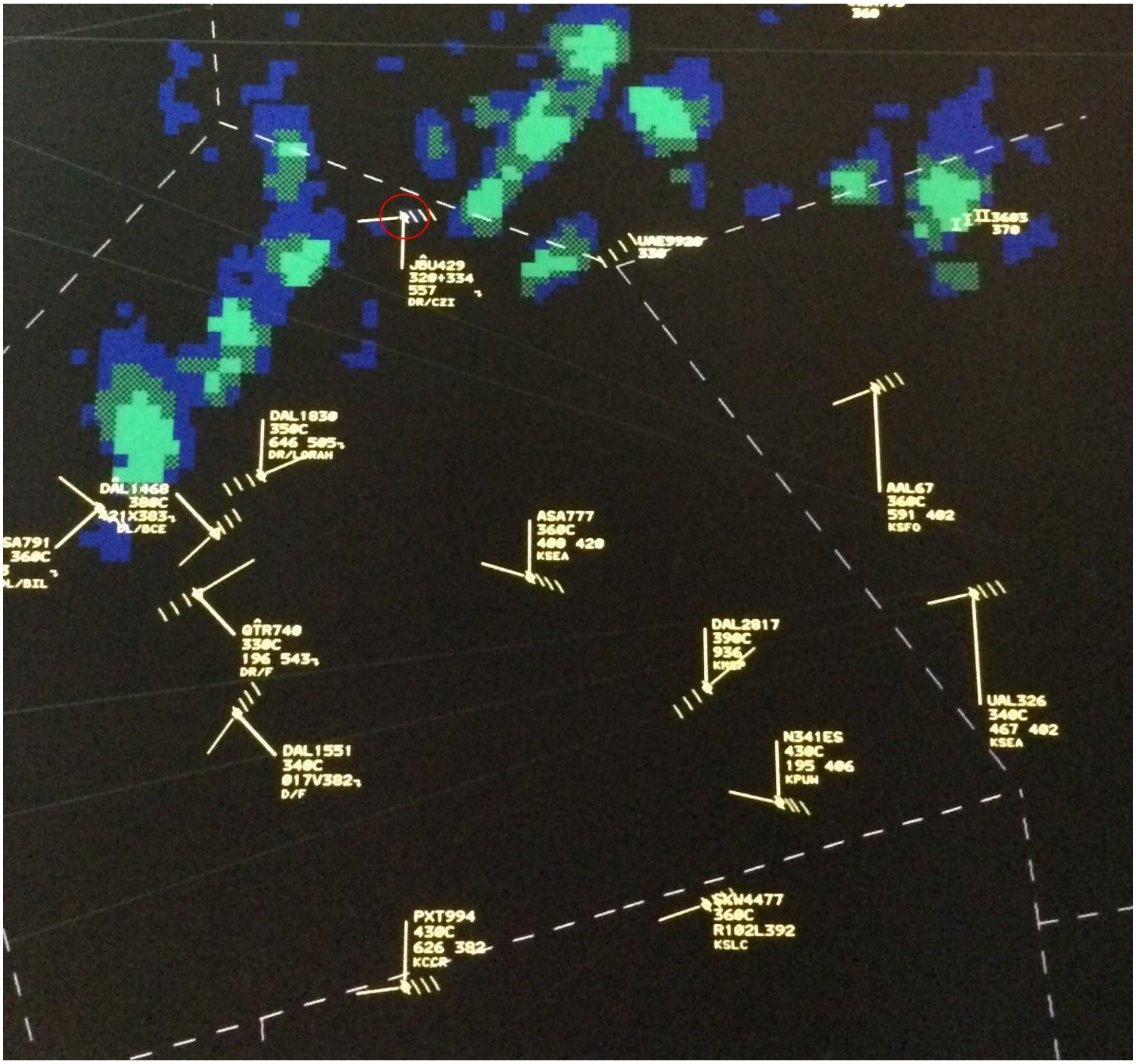

Figure 24 – Screenshot of the Denver ARTCC WARP replay for about 2012 CDT. The incident airplane (highlighted by red circle) is "JBU429."

At the request of the NTSB, scientists from the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS)[3] reviewed weather radar data from the region and provided additional data, as well as an analysis of the scene using their "Z_{dr} column" identification algorithm.[4] A general description of this algorithm, and a presentation of their analysis for this event, is available in a

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[3] The Cooperative Institute for Mesoscale Meteorological Studies is a research organization created in 1978 by a cooperative agreement between the University of Oklahoma and the National Oceanic and Atmospheric Administration.

[4] The differential reflectivity (Z_{dr}) WSR-88d radar product shows the difference in returned energy between the horizontal and vertical pulses of the radar. Z_{dr} is defined as the difference between the horizontal and vertical reflectivity factors in dBZ units.

video file in the docket for this incident. Presentation of echo tops[5], 10-kilometer height reflectivity[6], severe hail index[7] and vertically integrated liquid[8] data may be found in Attachments 1, 2, 3 and 4, respectively.

3.0 Lightning

Figure 25 depicts the total lightning activity detected by the Earth Networks Total Lightning Network (ENTLN) in the incident region between 1955 and 2011 CDT. Attachment 5 presents these data and other lightning strike parameters in tabular form.

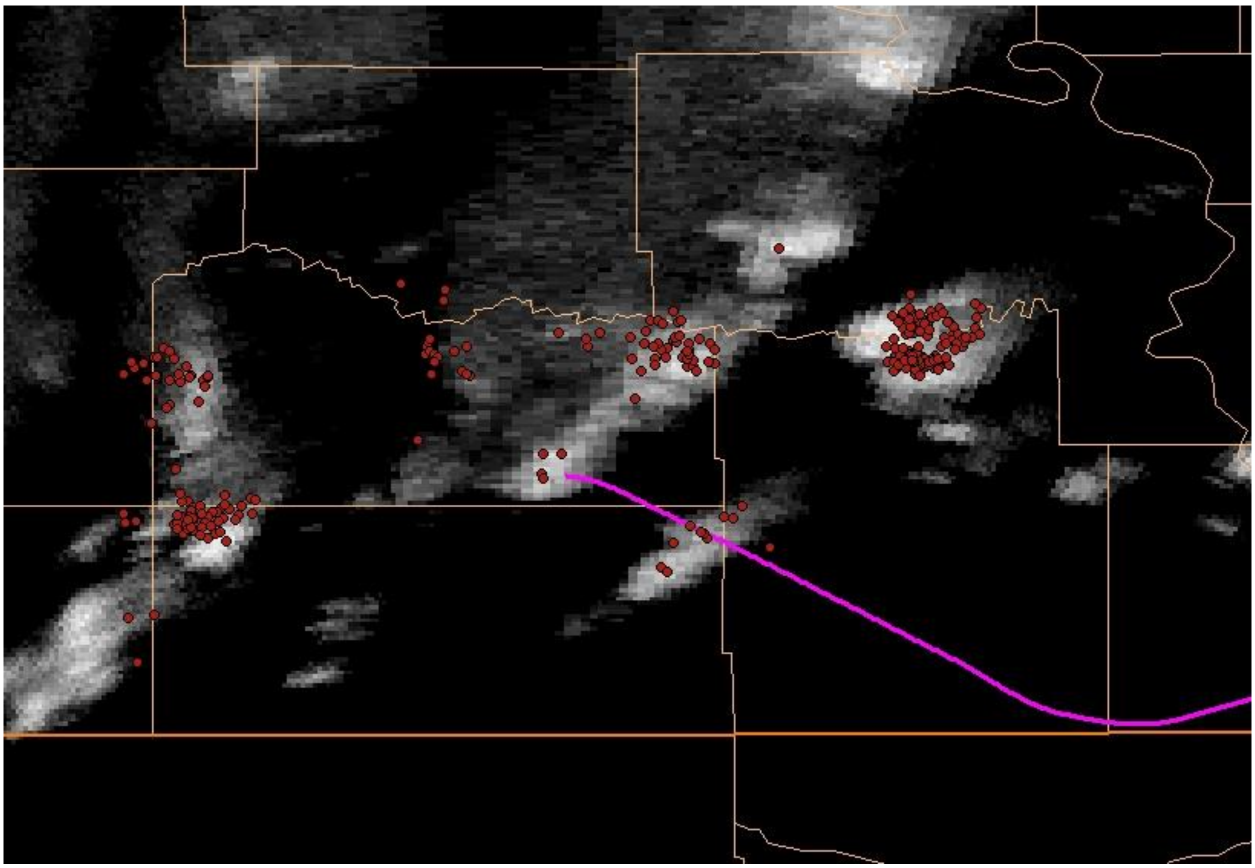

Figure 25 - Total lightning activity (red dots) detected by the ENTLN between 1955 and 2011 CDT. Incident aircraft flight path through incident time is shown as a pink line. Background is a grayscale depiction of the radar imagery from figure 10.

[5] An echo top is the radar indicated top (i.e., height) of an area of precipitation. Once the precipitation intensity drops below a threshold value (18 dBZ in Attachment 1) as the radar beam samples higher elevations of a storm or precipitation region, then the echo top is located. The cloud top will often extend above the echo top since clouds are more difficult to detect by radar.

[6] A presentation of reflectivity values at a constant height of 10 kilometers (approximately)

[7] Severe hail index is a radar-derived parameter that can be a good indicator of strong vertical updrafts. Technical details may be found here: http://www.wdtb.noaa.gov/courses/MRMS/ProductGuide/SevereWeather/severe-hail-index.php

[8] Vertically integrated liquid is an estimate of the total mass of precipitation in a column.

4.0 Pilot Reports

The following urgent pilot report (PIREP)[9] was made in the area of the incident site and publicly-disseminated.

> PIR UUA /OV PIR165055/TM 0112/FL320/TP A320/TB SEV TURB/RM CLIMBED 1800 FT=

At 2012 CDT an Airbus A320 aircraft 55 nautical miles away on the 165° radial from the Pierre VORTAC in Pierre, South Dakota, reported severe turbulence and remarked that the aircraft climbed 1,800 feet.

5.0 Upper Air Data

A High-Resolution Rapid Refresh (HRRR) model sounding (figure 26) for the incident location at 2000 CDT was retrieved from the National Oceanic and Atmospheric Administration's Air Resources Laboratory. The wind at the incident altitude was approximately 45 knots from the west-southwest. Calculations made by the Rawinsonde OBservation Program did not yield any significant areas of non-convective turbulence for this atmosphere. The freezing level was at about 16,000 feet.

The most-unstable Convective Available Potential Energy (CAPE)[10] parameter was 1,715 Joules/kilogram (from 928 hectopascals [hPa]). The Lifting Condensation Level (LCL)[11] and Level of Free Convection (LFC)[12] were calculated to be 5,555 feet and 5,814, respectively. Maximum vertical velocity (MVV) for this atmosphere was calculated as 58 meters/second (about 11,417 feet per minute).[13] Downdraft CAPE (DCAPE; 6 kilometers agl)[14] was measured at 1,134 Joules/kilogram.

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9 Only pilot reports with the WMO header UBSD** were considered.

10 Convective Available Potential Energy - A measure of the amount of energy available for convection. CAPE is directly related to the maximum potential vertical speed within an updraft; thus, higher values indicate greater potential for severe weather.

11 Lifting Condensation Level - The level at which a parcel of moist air lifted dry-adiabatically would become saturated.

12 Level of Free Convection - The level at which a parcel of air lifted dry-adiabatically until saturated and saturation-adiabatically thereafter would first become warmer than its surroundings in a conditionally unstable atmosphere. On a thermodynamic diagram the level of free convection is given by the point of intersection of the process curve, representing the process followed by the ascending parcel, and the sounding curve, representing the lapse rate of temperature in the environment.

13 MVV is not usually considered a realistic estimate for maximum vertical velocity in a storm. Anecdotes suggest considering a value of MVV/2, however it is not well understood when or where such a half-value should be applied.

14 The DCAPE can be used to estimate the potential strength of rain-cooled downdrafts within thunderstorm convection, and is similar to CAPE. Larger DCAPE values are associated with stronger downdrafts.

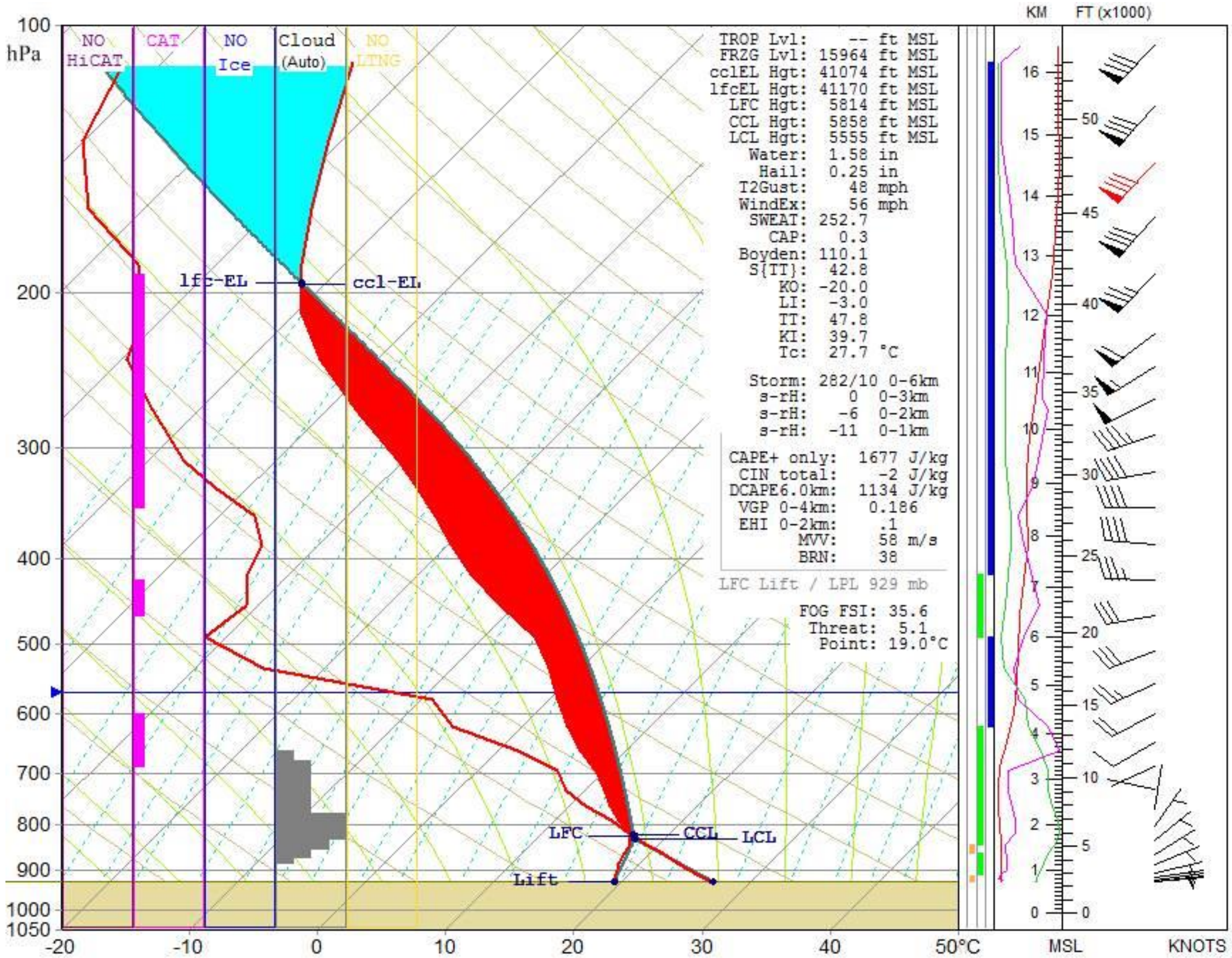

Figure 26 – HRRR model sounding data in SkewT/LogP format for 2000 CDT at the incident site, surface to 100 hPa.

6.0 Satellite Imagery

Geostationary Operational Environmental Satellite (GOES)-13 visible (0.63µm) and infrared (10.7µm) data were obtained from an archive at the Space Science Engineering Center at the University of Wisconsin-Madison. Imagery from 2000 CDT is presented in figures 27 and 28. The GOES-13 infrared cloud-top temperatures varied between -9°C and -25°C in the immediate area of the incident location. When considering the HRRR model sounding, -9°C corresponded to cloud top heights of about 20,800 feet and -25°C was about 28,500 feet. It should be noted that the clouds in these figures have not been corrected for any parallax error; however, the aircraft's position has been adjusted from its ground position to reflect its height of approximately 32,000 feet.

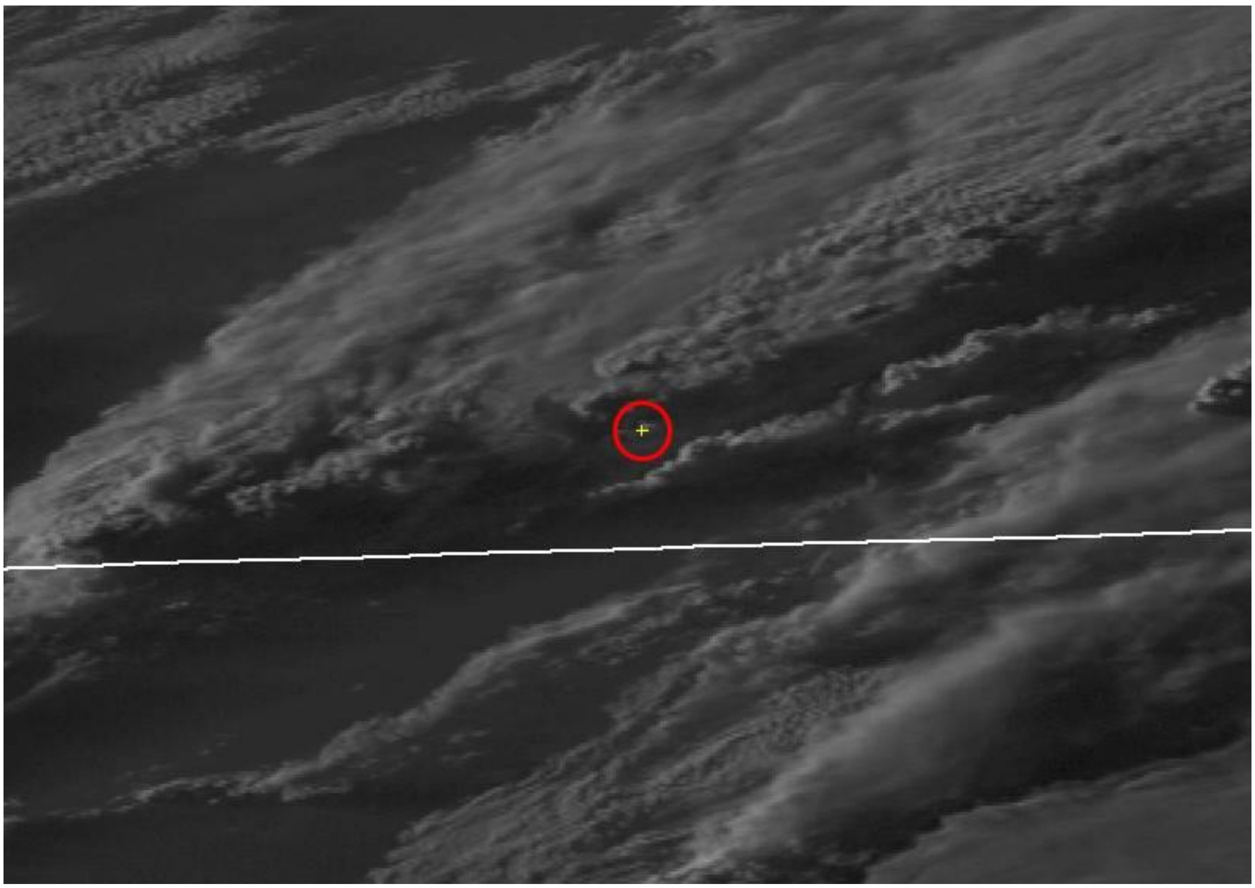

Figure 27 – GOES-13 visible imagery from 2000 CDT. Incident location denoted by yellow "+" symbol inside the red circle.

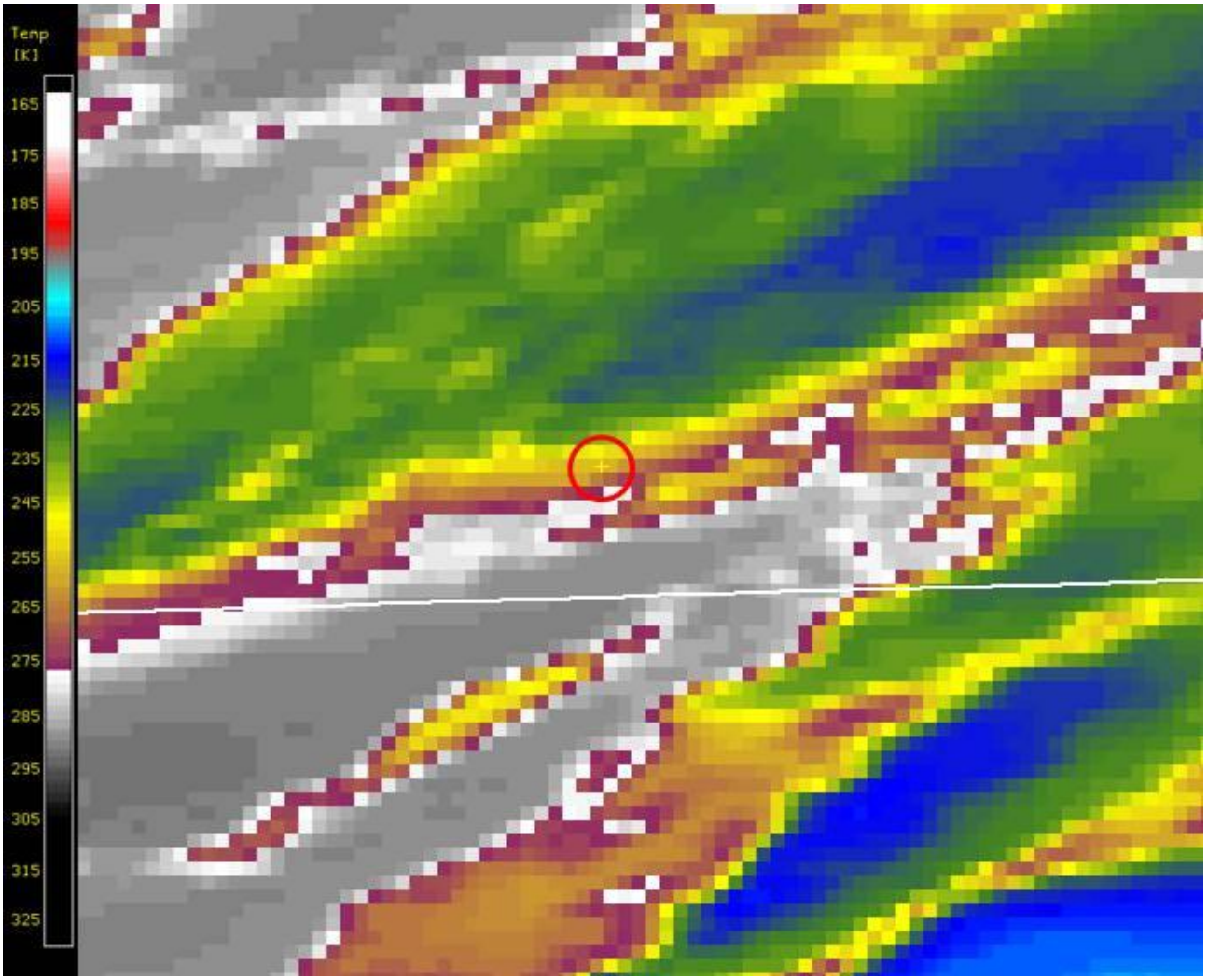

Figure 28 – GOES-13 infrared imagery from 2000 CDT. Incident location denoted by yellow "+" symbol inside the red circle.

7.0 SIGMETs

There were no non-convective Significant Meteorological Information (SIGMET) advisories active for the incident location at the incident time.

There were convective SIGMET advisories active for the incident location at the incident time. Presented here are convective SIGMETs that included the state of South Dakota issued within two hours prior to the incident time (also see figures 29 and 30).

WSUS32 KKCI 112355
SIGC
MKCC WST 112355

CONVECTIVE SIGMET 07C

VALID UNTIL 0155Z
WI IL MN IA NE SD
FROM 50ESE PIR-40WSW ODI-20ESE DBQ-40ENE DSM-40W LBF-50ESE PIR
AREA SEV TS MOV FROM 26030KT. TOPS ABV FL450.
HAIL TO 2 IN...WIND GUSTS TO 60KT POSS.

CONVECTIVE SIGMET 12C
VALID UNTIL 0155Z
NE SD
FROM 50NE DPR-30E PIR-60ENE BFF-20SW RAP-50NE DPR
AREA SEV TS MOV FROM 26025KT. TOPS ABV FL450.
HAIL TO 2 IN...WIND GUSTS TO 55KT POSS.

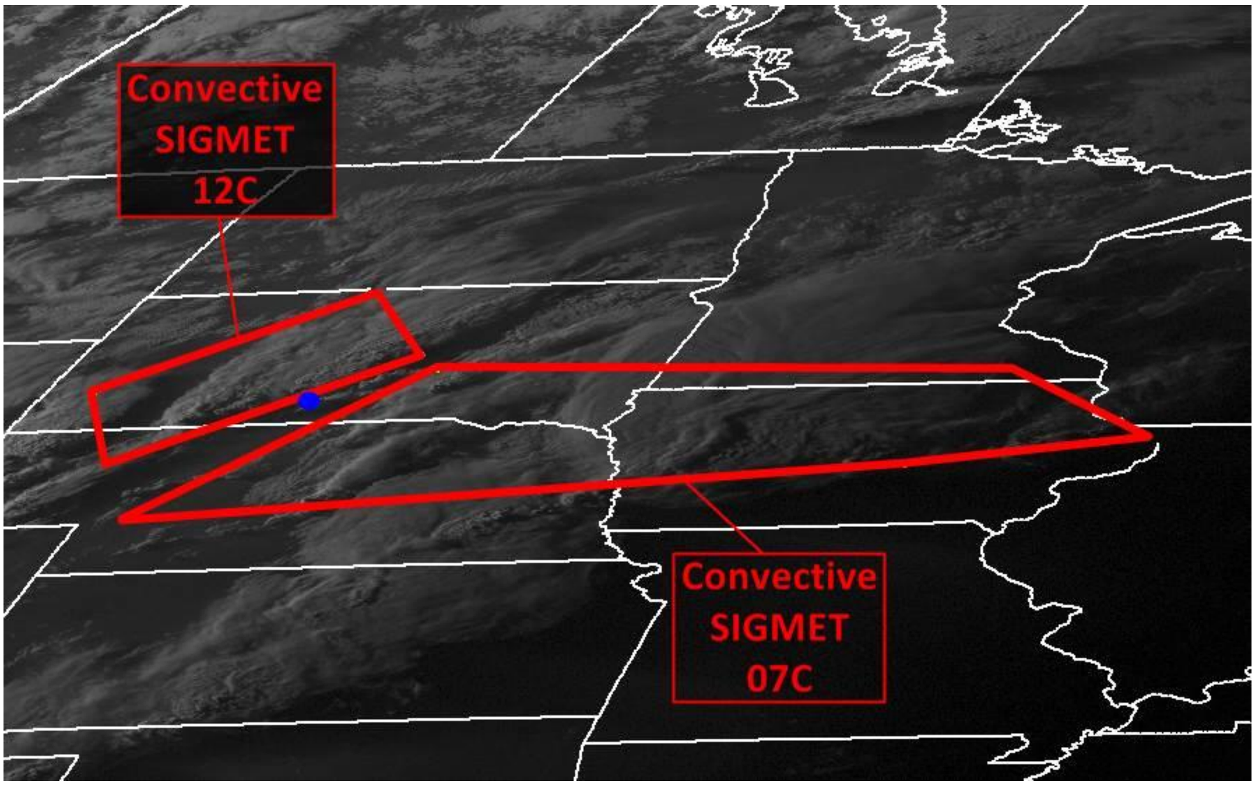

Figure 29 – Convective SIGMETs affecting South Dakota issued at 1855 CDT and valid for two hours. Incident location is denoted by the blue dot.

WSUS32 KKCI 120055
SIGC
MKCC WST 120055

CONVECTIVE SIGMET 6C
VALID UNTIL 0255Z
NE SD

FROM 60WNW ABR-50SSW ABR-60SSE PIR-70ENE BFF-30SSE RAP-60WNW ABR
AREA SEV TS MOV FROM 28025KT. TOPS ABV FL450.
HAIL TO 2 IN...WIND GUSTS TO 55KT POSS.

CONVECTIVE SIGMET 9C
VALID UNTIL 0255Z
SD
70N ONL
ISOL EMBD TS D30 MOV LTL. TOPS ABV FL450.

WSUS33 KKCI 120055
SIGW
MKCW WST 120055

CONVECTIVE SIGMET 2W
VALID UNTIL 0255Z
NE SD CO WY
FROM 60E CZI-60NNE BFF-10N SNY-20SSW DEN-20SSE CZI-60E CZI
AREA TS MOV FROM 25025KT. TOPS ABV FL450.

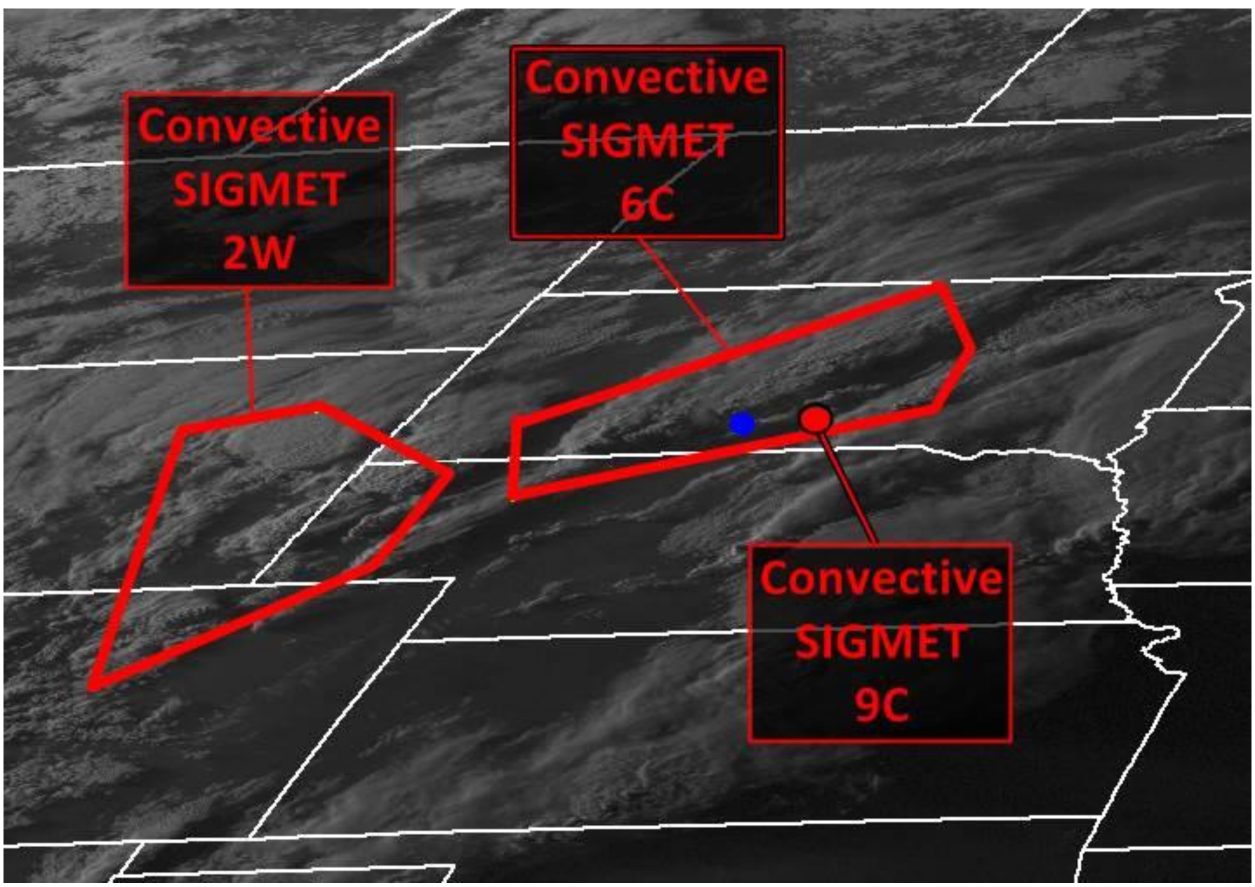

Figure 30 – Convective SIGMETs affecting South Dakota issued at 1955 CDT and valid for two hours. Incident location is denoted by the blue dot.

8.0 CWSU Products

There were no Center Weather Advisories or Meteorological Impact Statements issued by the Center Weather Service Units (CWSUs) at the Denver or Minneapolis ARTCCs that were active within the incident region at the incident time.

9.0 Collaborative Aviation Weather Statement

The following Collaborative Aviation Weather Statement (CAWS) was issued at 1223 CDT.

> FAUS11 KKCI 111723
> AWSTS
> Collaborative Aviation Weather Statement 003
> NWS Aviation Weather Center Kansas City MO
> 1723 UTC Thu 11 Aug 2016
> Weather: Thunderstorms
> Valid: 2300-0100Z
> ARTCCs affected: ZDV, ZKC, ZMP
> Terminals affected:
> CCFP: 17Z Issuance - Coverage/confidence too high
> SUMMARY: Broken line TS over NE/KS
> DISCUSSION: This CAWS refines CCFP from 23Z to 01Z for broken lines of TS over NE and KS. Current CCFP depicts a large area of medium coverage across the region where broken lines of TS are expected. Expecting convection to continue east and southeast beyond the valid period.
> Operations Note - CCFP areas that are not displayed in the CAWS graphic for the valid times posted are deemed to be accurate unless otherwise stated.
> BOUNDING BOX: 44.72,-103.86 34.61,-103.19 34.05,-90.38
> 44.38,-88.79 44.72,-103.86

10.0 Astronomical Data

The astronomical data obtained from the United States Naval Observatory for 43° 27' north latitude and 100° 29' west longitude, indicated the following:

SUN	
Sunset	2050 CDT
End Civil Twilight	2121 CDT

MOON	
Moonrise	1522 CDT
Moonset	0135 CDT (August 12, 2016)

E. LIST OF ATTACHMENTS

Attachment 1 - Echo tops data provided by the Cooperative Institute for Mesoscale Meteorological Studies.

Attachment 2 - 10-kilometer height reflectivity data provided by the Cooperative Institute for Mesoscale Meteorological Studies.

Attachment 3 - Severe hail index data provided by the Cooperative Institute for Mesoscale Meteorological Studies.

Attachment 4 - Vertically integrated liquid data provided by the Cooperative Institute for Mesoscale Meteorological Studies.

Attachment 5 - Total lightning activity detected by the Earth Networks Total Lightning Network in the incident region between 1955 and 2011 CDT.

Submitted by:

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Mike Richards
Senior Meteorologist

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