Field Test of Combination Seeding Flares

Report to Ice Crystal Engineering
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Objective

To determine how a new type of flare made of a combination of AgI and $CaCl_2$ material performed during a field test conducted on 1 July 2008 during the Polarimetric Cloud Analysis and Seeding Test 2 **(**POLCAST2) field project.

Aircraft and Research Equipment

During POLCAST2, a Weather Modification Inc. (WMI) Cessna 340 aircraft was used for cloud seeding and airborne measurements. For the 1 July 2008 flight, the Cessna 340 aircraft's flare racks were loaded with a new type of flare manufactured by Ice Crystal Engineering. The new flares are burn-in-place type flares containing a combination of AgI and $CaCl_2$ material.

The Cessna 340 aircraft was instrumented with a Science Engineering Associates (SEA) model M300 data system, a Passive Cavity Aerosol Spectrometer Probe (PCASP), a Forward Scattering Spectrometer Probe (FSSP), and a Cloud Condensation Nuclei (CCN) Counter (Figure 1). The PCASP and CCN counter are used to characterize the cloud base aerosols. The PCASP measures the aerosol size distribution from 0.1 to 3 µm and the CCN counter measures the concentration of aerosols that form cloud droplets at a certain supersaturation. The CCN counter was operated at a single supersaturation of 1%, with supersaturation spectrum measurements (where a range of supersaturations are sampled) taken on the ground before or after aircraft several flights. Aircraft data is recorded with an SEA data acquisition system (M300) and transferred to ground based computers via a PCMCIA data card for post-flight processing and archival. Radar data was recorded using UND's polarimetric radar located at 47 55' 19” N Latitude and 97 5' 11” W Longitude.

Figure 1: Seeding and research equipment deployed on a Cessna 340 and used during POLCAST2.

Synoptic Overview

The overall track of the storms that developed on 1 July 2008 was from the northwest to the southeast. The temperature at the surface at 22:42 UTC was 32° C. The temperature at cloud base averaged 16° C. Cloud bases were at 1650 m above sea level during the seeding interval.

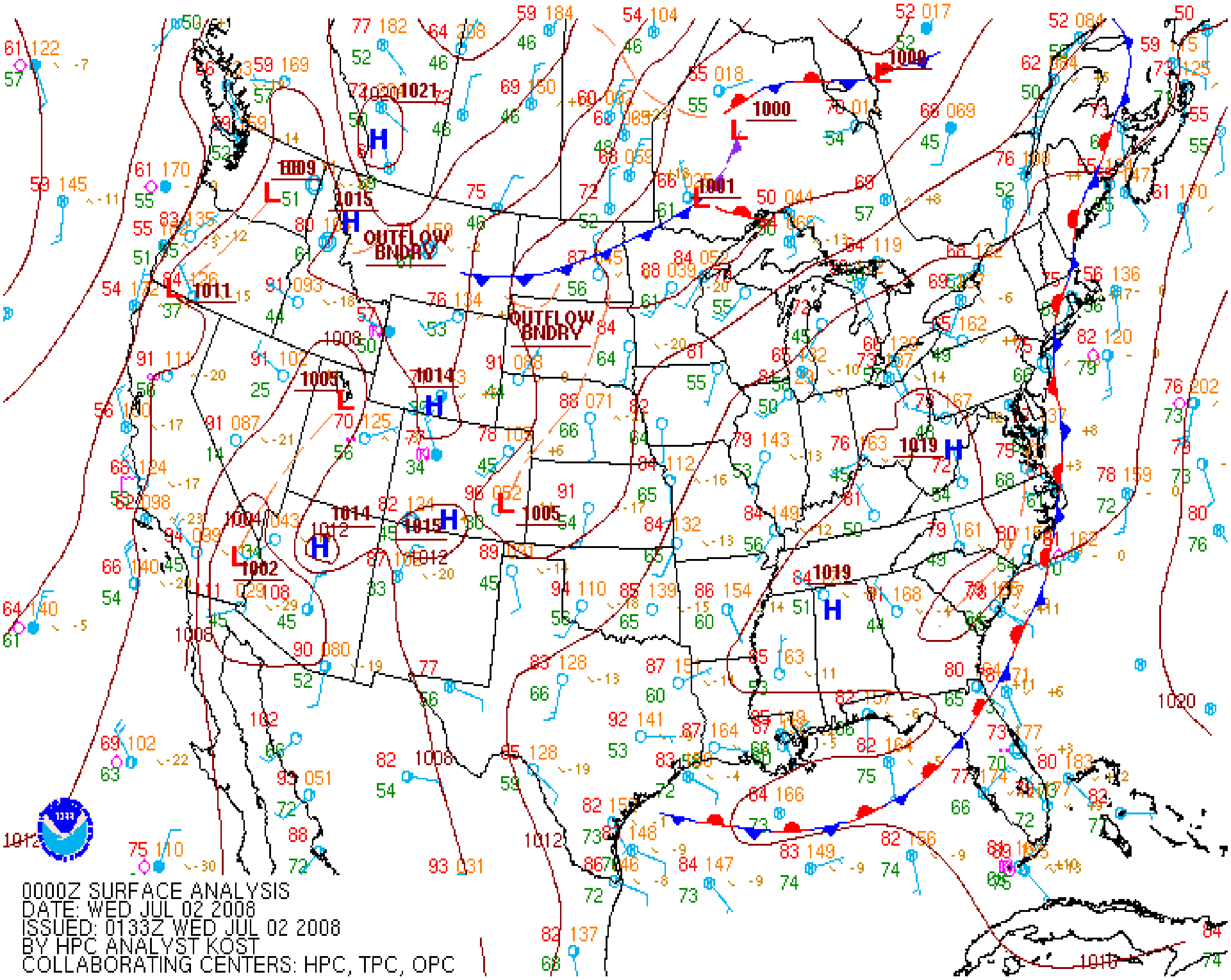

Figure 2: Continental United States surface analysis for 2 July 2010 at 00:00 UTC.

Procedure

On 1 July 2008, the WMI Cessna 340 took off with eight of the special flares on board at 22:47:00 UTC. At 23:26 an appropriate target was noted and the decision to use the new flares was made. The target was located just to the southwest of Grafton's airport. At 23:30:44, 400-500 fpm updrafts were noted and the first two flares were lit. The temperature averaged 16° C at cloud base, which was 5,400 feet MSL. At 23:33:00 rain was noted. The second set of flares were lit at 23:33:49, the third at 23:36:55, and the final set of flares at 23:40:01. All of the flares lit and burned successfully, and at 23:42:00, all flares were burned out and a climb was started for cloud sampling. During the cloud penetrations, 600 – 700 fpm updrafts were noted along with 1000 fpm downdrafts

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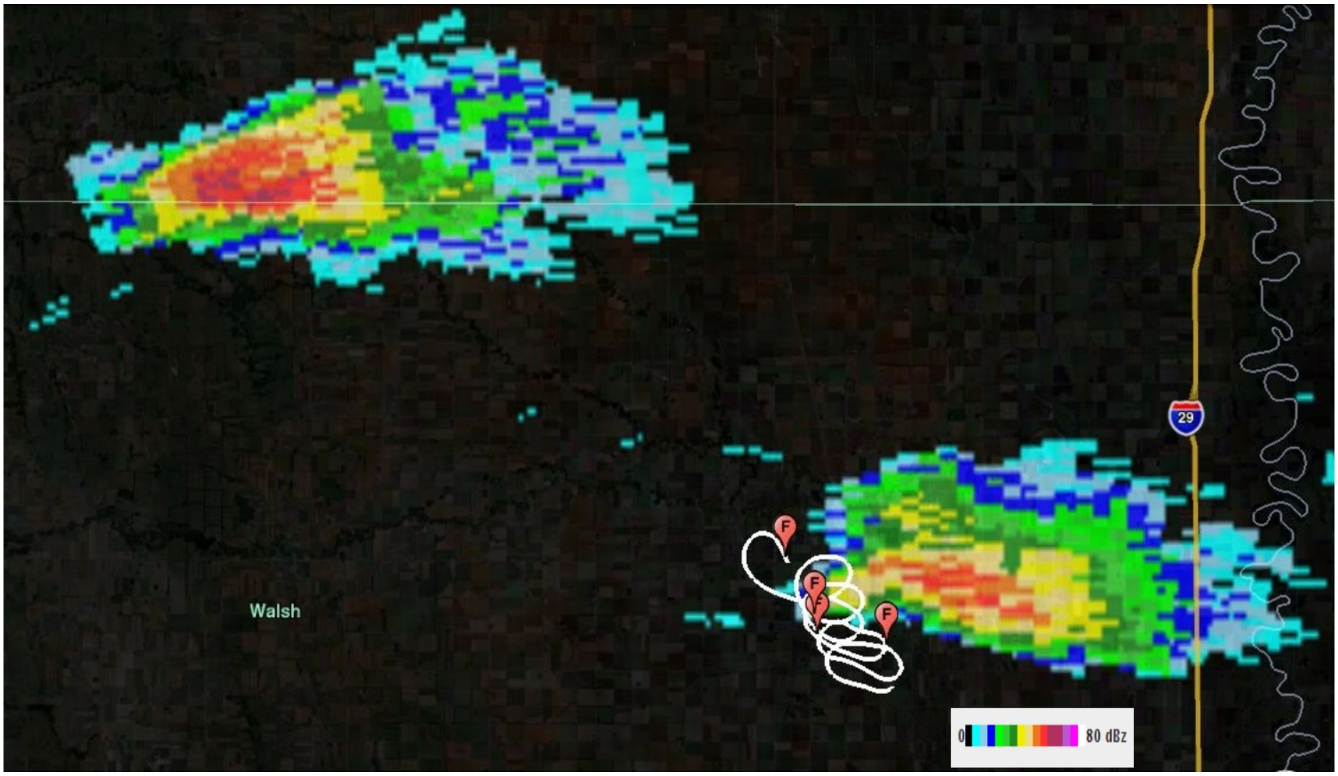

Figure 3: Google Earth image showing the aircraft flight track (white line) on 1 July 2008 from 23:30:44 and 23:41:40 UTC. The red balloons indicate the locations where each set of flares was lit. The color overlay is the level II radar reflectivity at the 0.5 elevation angle from the National Weather Service radar in Mayville, North Dakota.

Aerosol Measurements

Table 1 showing the average measurements from the PCASP and the University of Wyoming CCN counter. The aircraft flew through the seeding plume while conducting base seeding on 1 July 2008. Figure 4 presents the PCASP measured spectrum and compares the spectrum to natural boundary layer spectrum and the spectrum from hygroscopic flares. The shape of the combination flare spectrum is similar to the shape of hygroscopic flare spectrum. This is to be expected since the AgI aerosol should be small in size and not detectable with the PCASP, while the hygroscopic material should be detectable.

Table 1: PCASP and CCN measurements obtain during the 1 July 2008 aircraft flight.

	Before Seeding (23:30:50 – 23:33:45 UTC)	**Seeding Interval (23:30:50-23:43:20 UTC)**
PCASP Concentration	1555 #/cm^3 at STP	1739 #/cm^3 at STP
UWY CCN Concentration	1995 #/cm^3 at STP	2038 #/cm^3 at STP

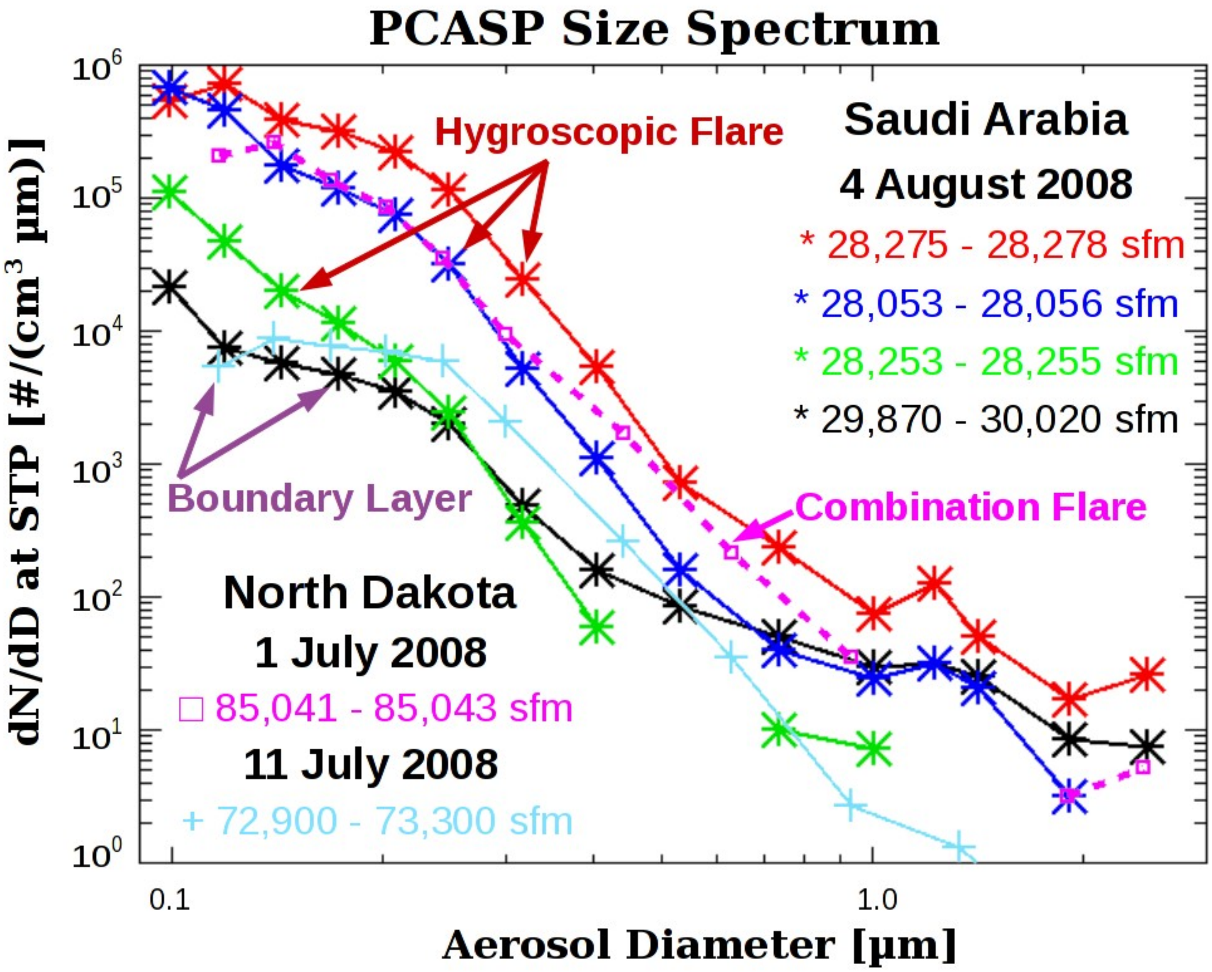

Figure 4: The aerosol size distribution at standard pressure and temperature measured by a Passive Cavity Aerosol Spectrometer Probe (PCASP) during the 4 August 2008 flight in Saudi Arabia and the 1 July 2008 and 11 July 2008 flights in North Dakota. The blue stars are for an in close (~1.5 km) flare sample obtained between 28,053 and 28,056 sfm. The green stars are for a middle (~2.3 km) flare sample obtained between 28,253 and 28,255 sfm. The red stars are for a farther away (~2.8 km) flare sample obtained between 28,275 and 28,278 sfm. All three hygroscopic flare samples were obtained at an altitude of approximately 6,500 m. The black solid line with black stars is a boundary layer natural aerosol obtained between 29,870 and 30,020 sfm at a constant altitude of approximately 3,500 m. The light blue dashed line with light blue plus symbols is a boundary layer natural aerosol obtained between 72,900 and 73,300 sfm on the 11 July 2008 flight in North Dakota. The magenta short dashed line with the square symbols is from a sample of a combination hygroscopic and AgI flare obtained between 85,041 and 85,043 sfm while conducting cloud base seeding during the 1 July 2008 flight in North Dakota.

Radar Observations

The UND radar was used to collect information on the seeded cloud and precipitation characteristics. The fields used from the radar are composite reflectivity, vertically integrated liquid water, and differential reflectivity (ZDR). Overall, the radar data showed two cells that developed around the same time to the northwest of the Grand Forks which moved to the southeast. Figures 5 - 19 shows the composite radar reflectivity, vertically integrated liquid, and differential reflectivity during and after seeding. The northwest cell was not seeded and the southeast cell was seeded. Eventually, the southeast cell dissipated, and the northwest cell lasted a little longer.

The Thunderstorm Identification Tracking Analysis and Nowcasting (TITAN) scripts ctrec, AcTracks2Polygon, and AdvectPolygon were used to look at the ZDR values of the seeded cell. The AdvectPolygon script used wind values calculated by ctrec to advect a polygon that was created using AcTrack2Polygon. The ctrec program uses radar reflectivity to track pattern movement from one scan to the next. AcTrack2Polygon uses the aircraft tracks to create the polygon to be advected. AdvectPolygon calculates the ZDR values within the polygon. Figure 20 shows the advected polygons. Figure 21 shows a time series of differential reflectivity of the seeded cell. The differential reflectivity indicates an initial decrease and then an increase in ZDR which indicates an increase in rain drop size with time.

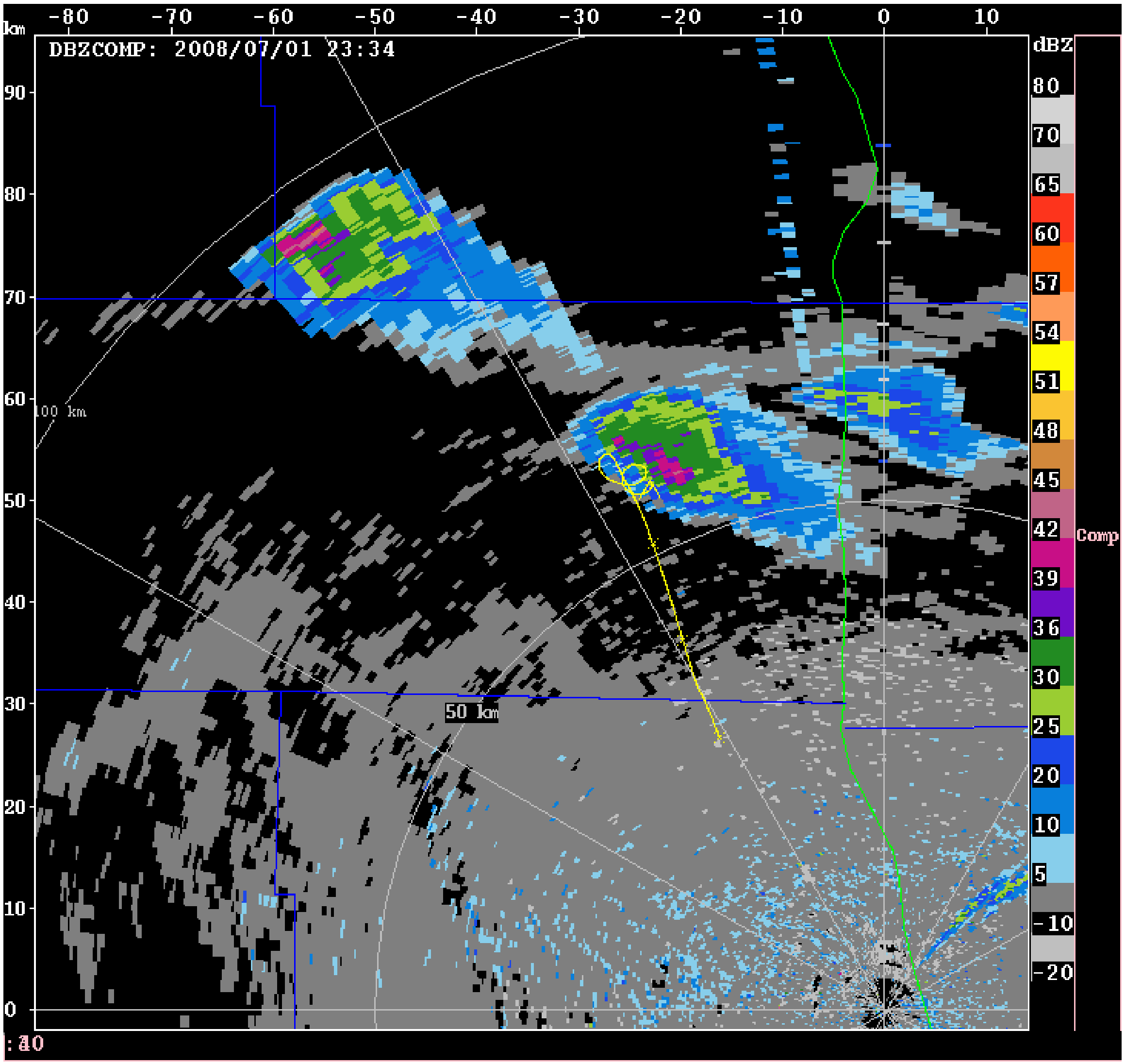

Figure 5: Composite Reflectivity on July 1st, 2008 23:34 UTC. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

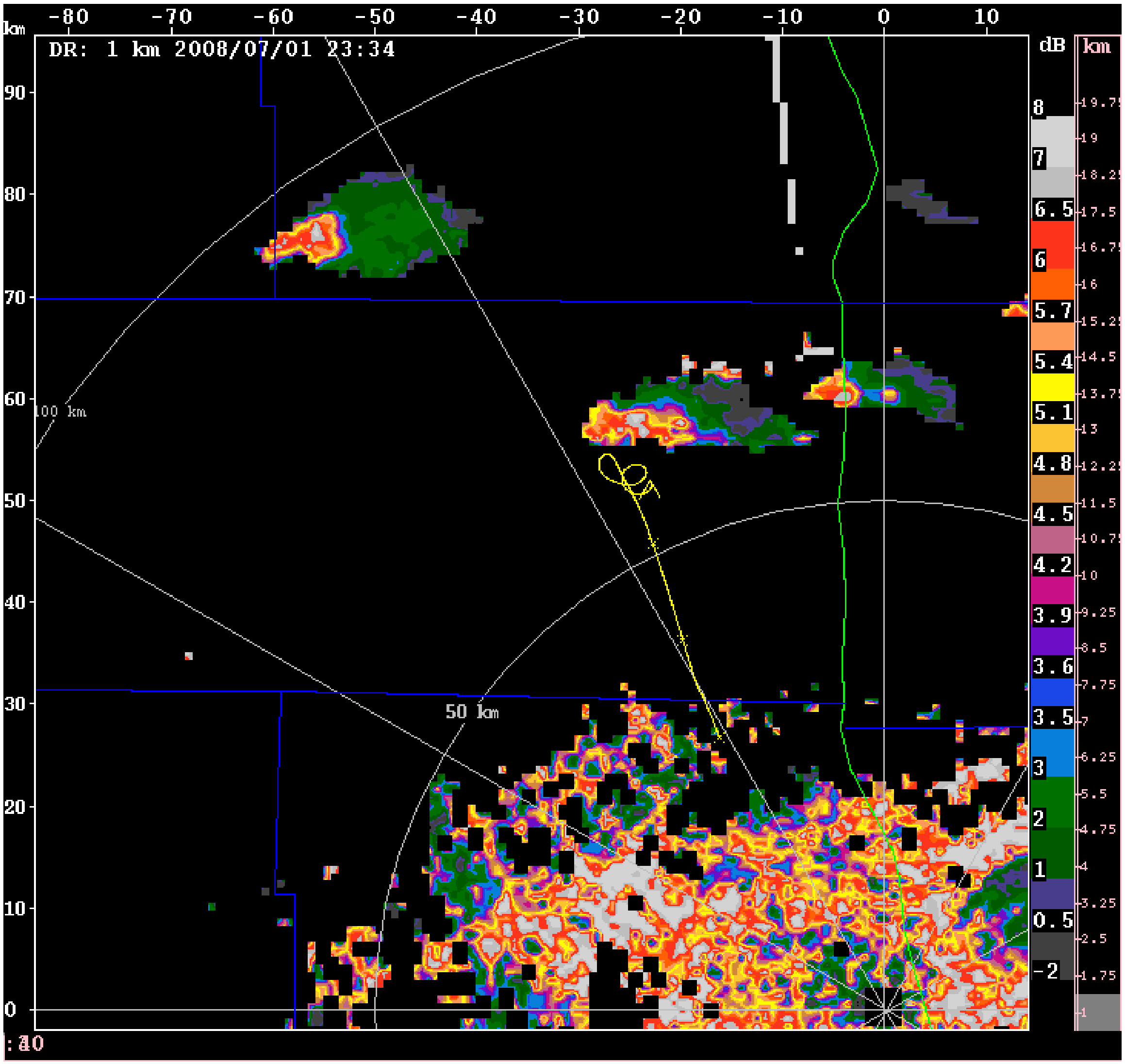

Figure 6: Differential Reflectivity on July 1st, 2008 23:34 UTC at 1 km. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

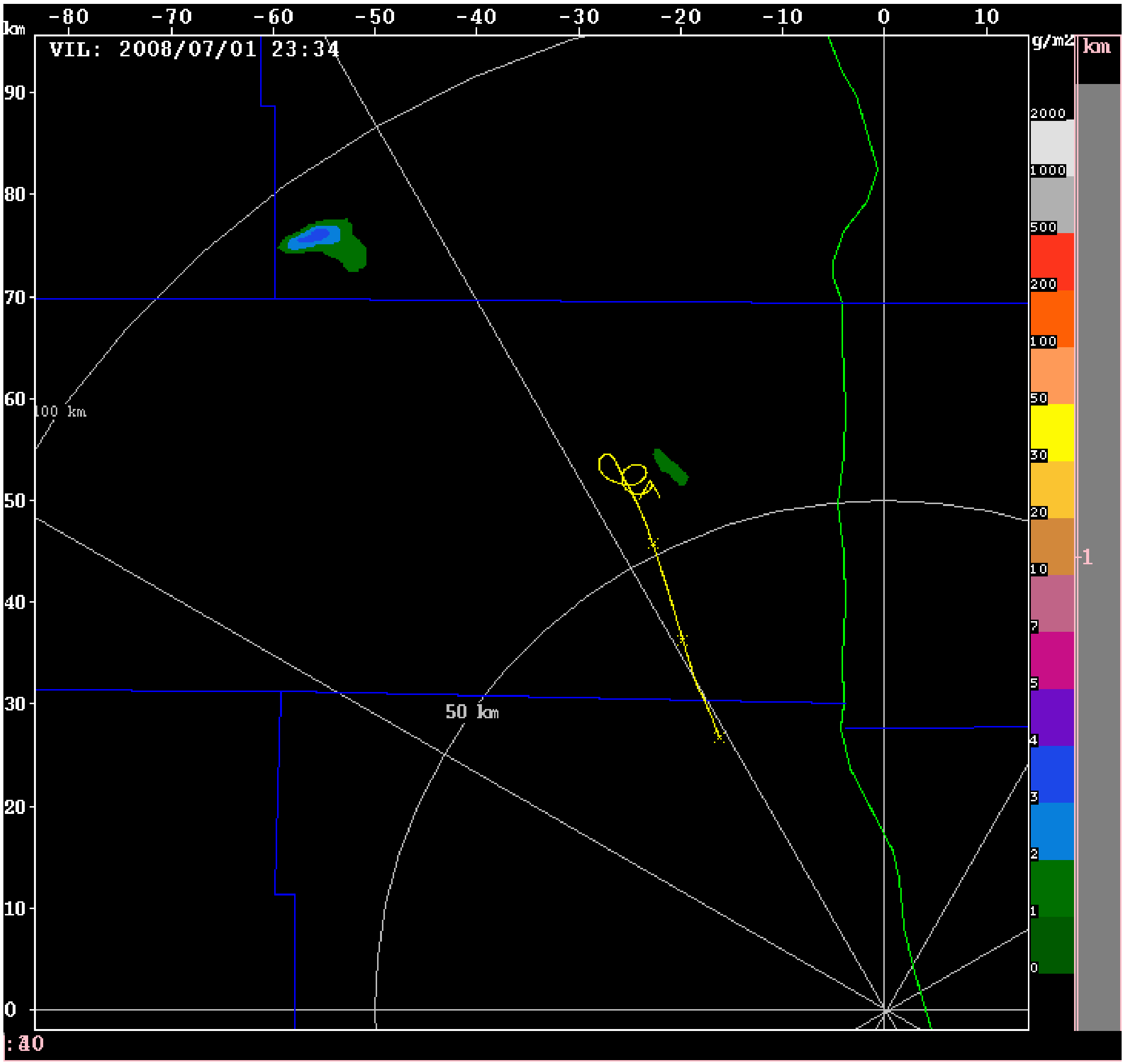

Figure 7: Vertically Integrated Liquid on July 1st, 2008 23:34 UTC. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

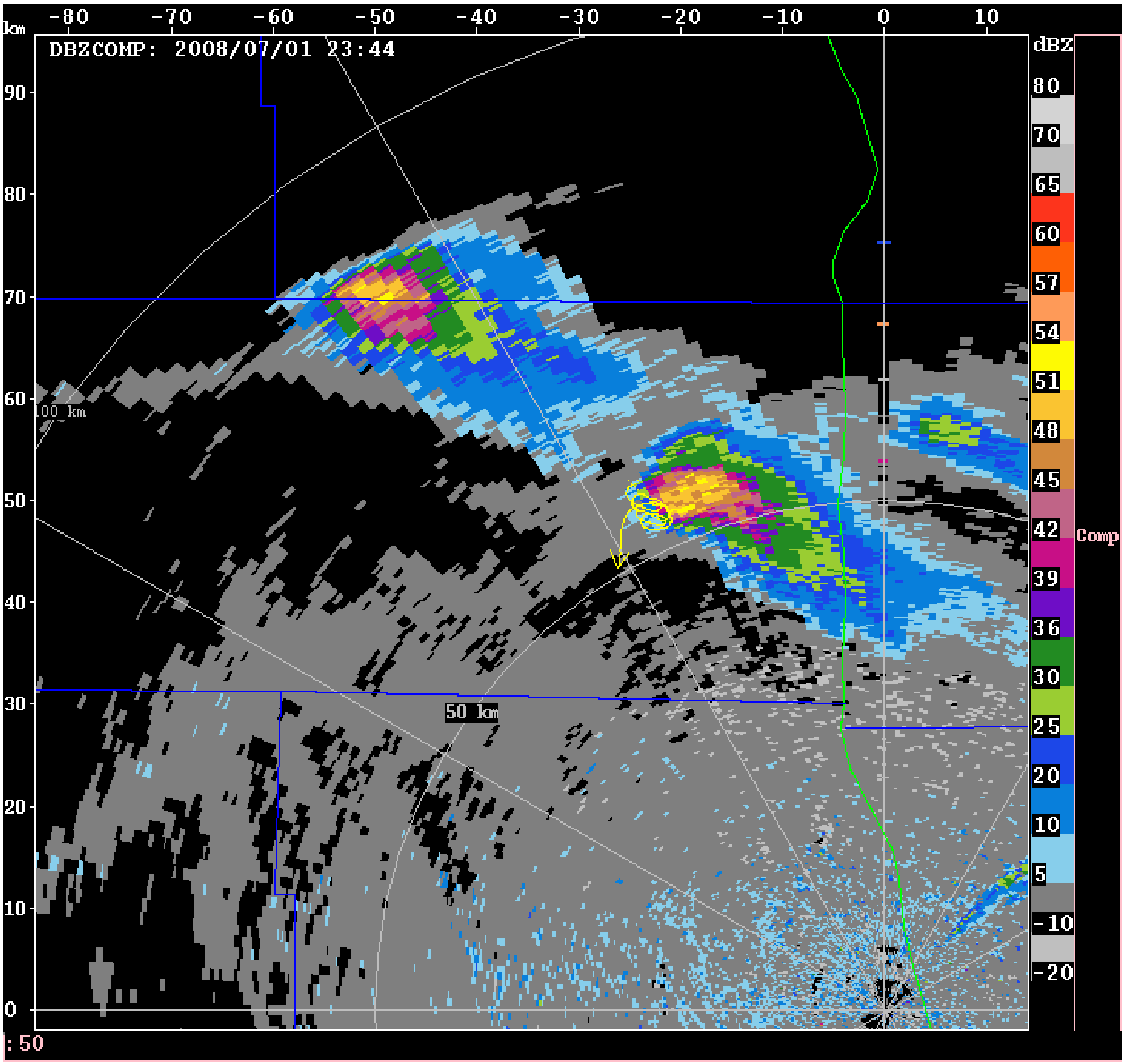

Figure 8: Composite Reflectivity on July 1st, 2008 23:44 UTC. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

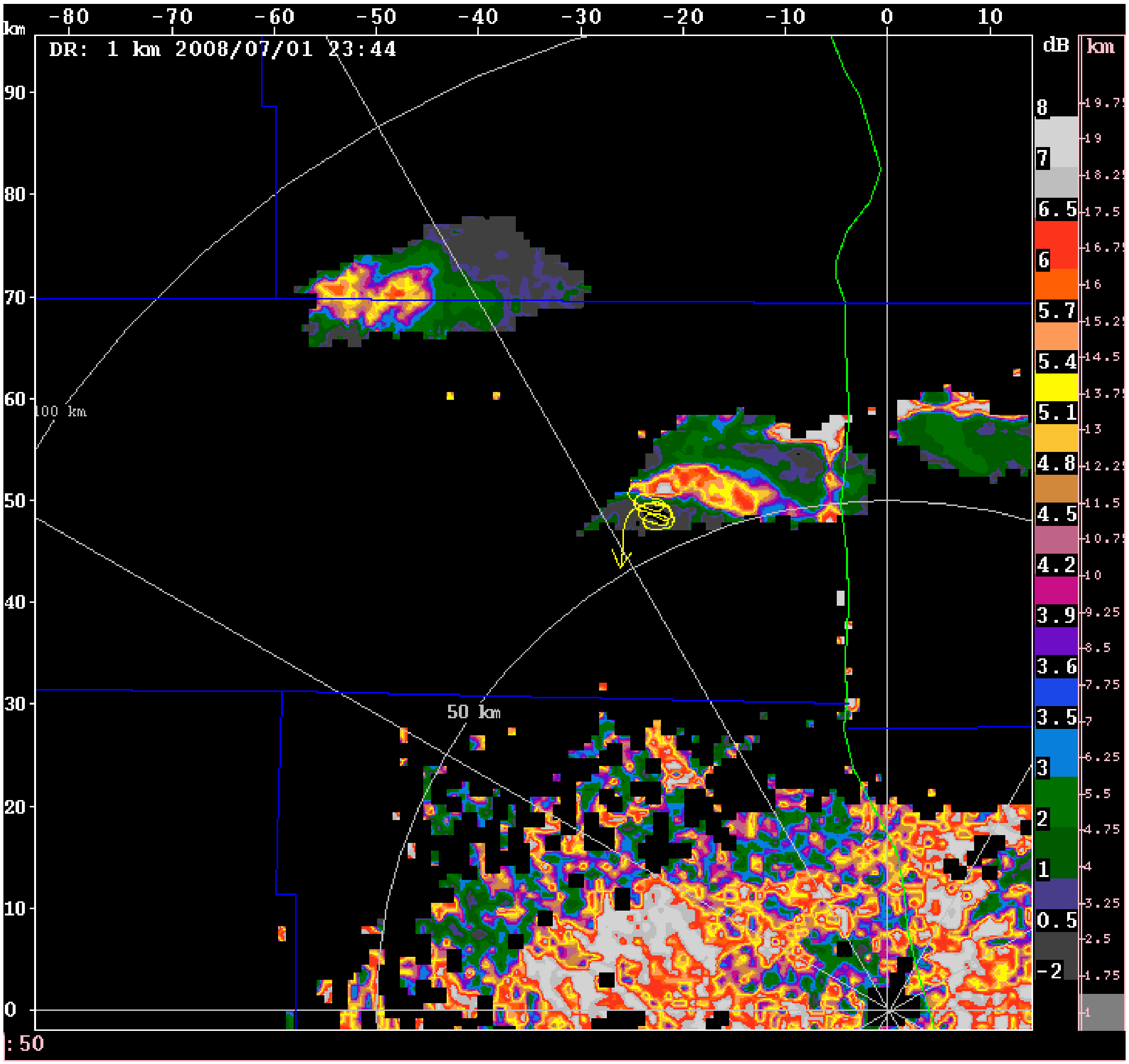

Figure 9: Differential Reflectivity on July 1st, 2008 23:44 UTC at 1 km. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

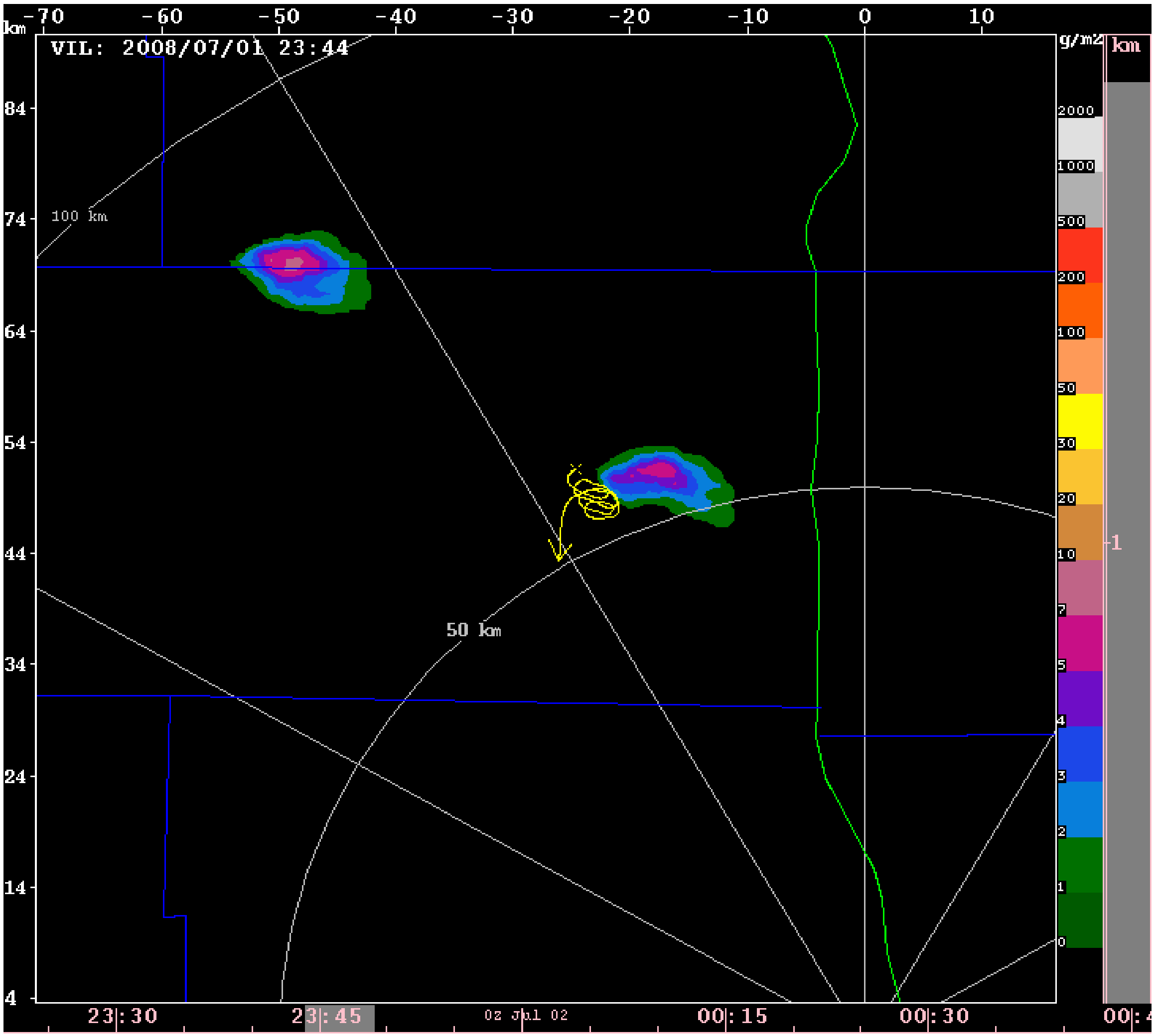

Figure 10: Vertically Integrated Liquid on July 1st, 2008 23:44 UTC. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

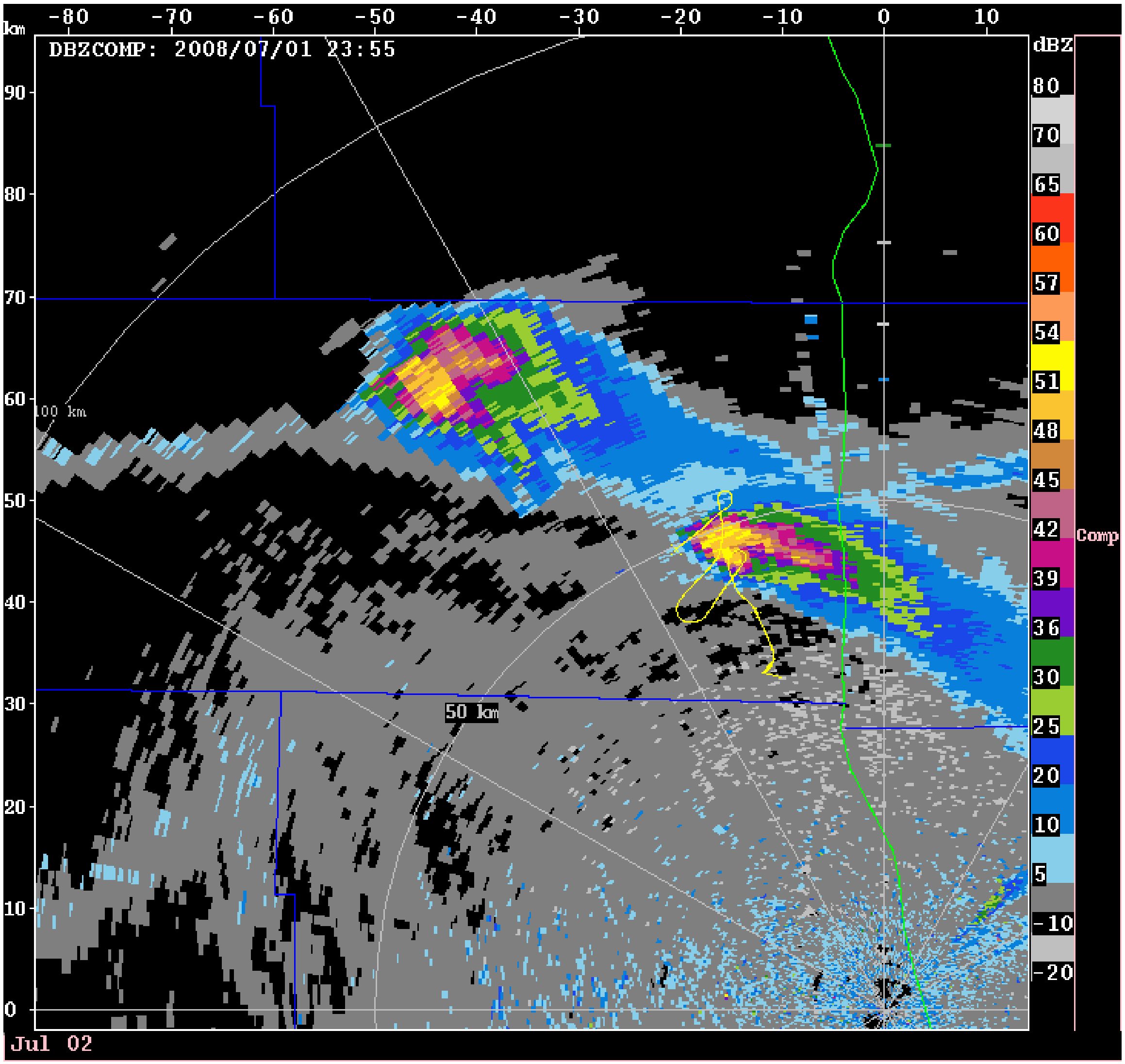

Figure 11: Vertically Integrated Liquid on July 1st, 2008 23:55 UTC. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

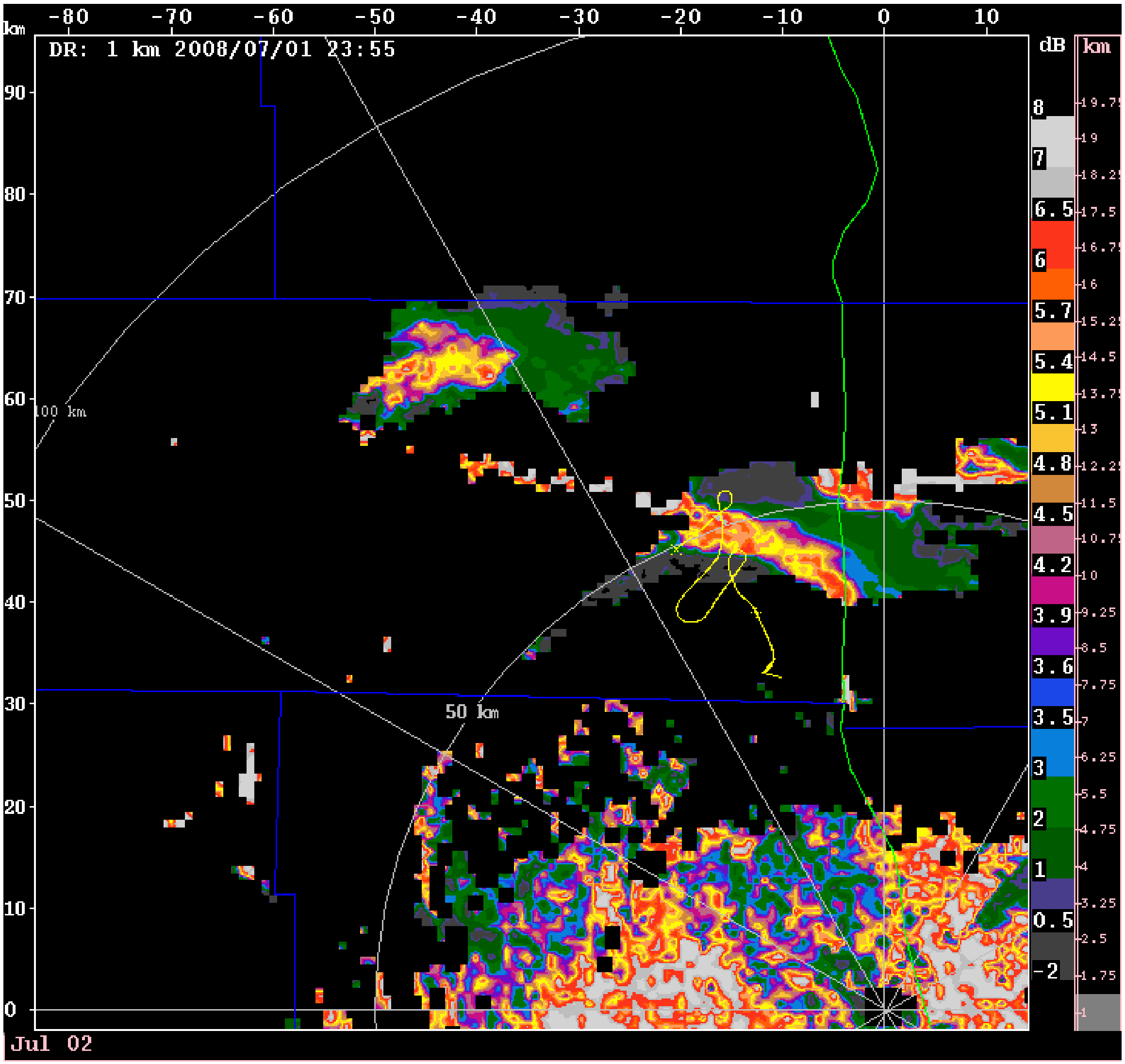

Figure 12: Differential Reflectivity on July 1st, 2008 23:55 UTC at 1 km. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

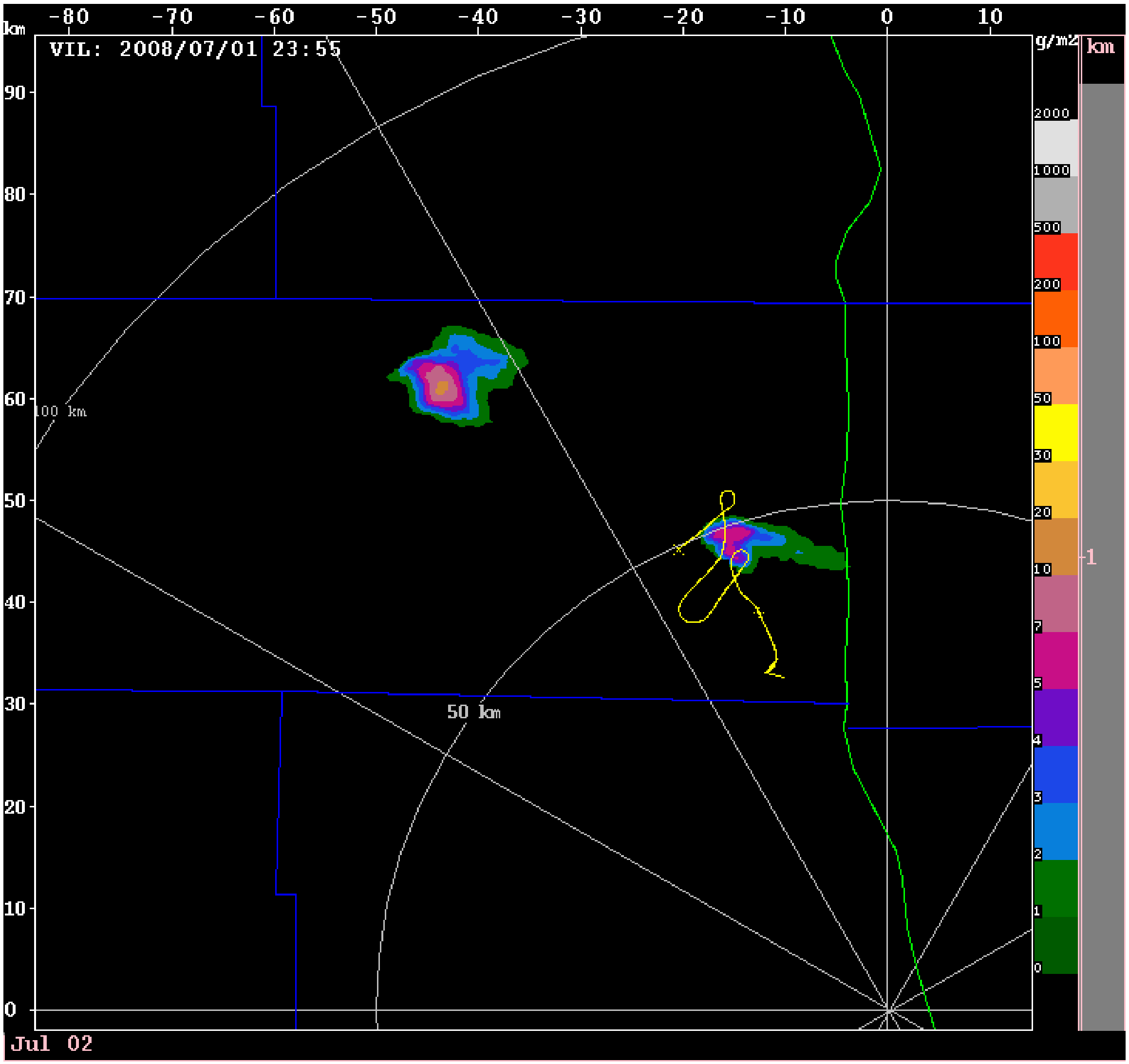

Figure 13: Vertically Integrated Liquid on July 1st, 2008 23:55 UTC. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

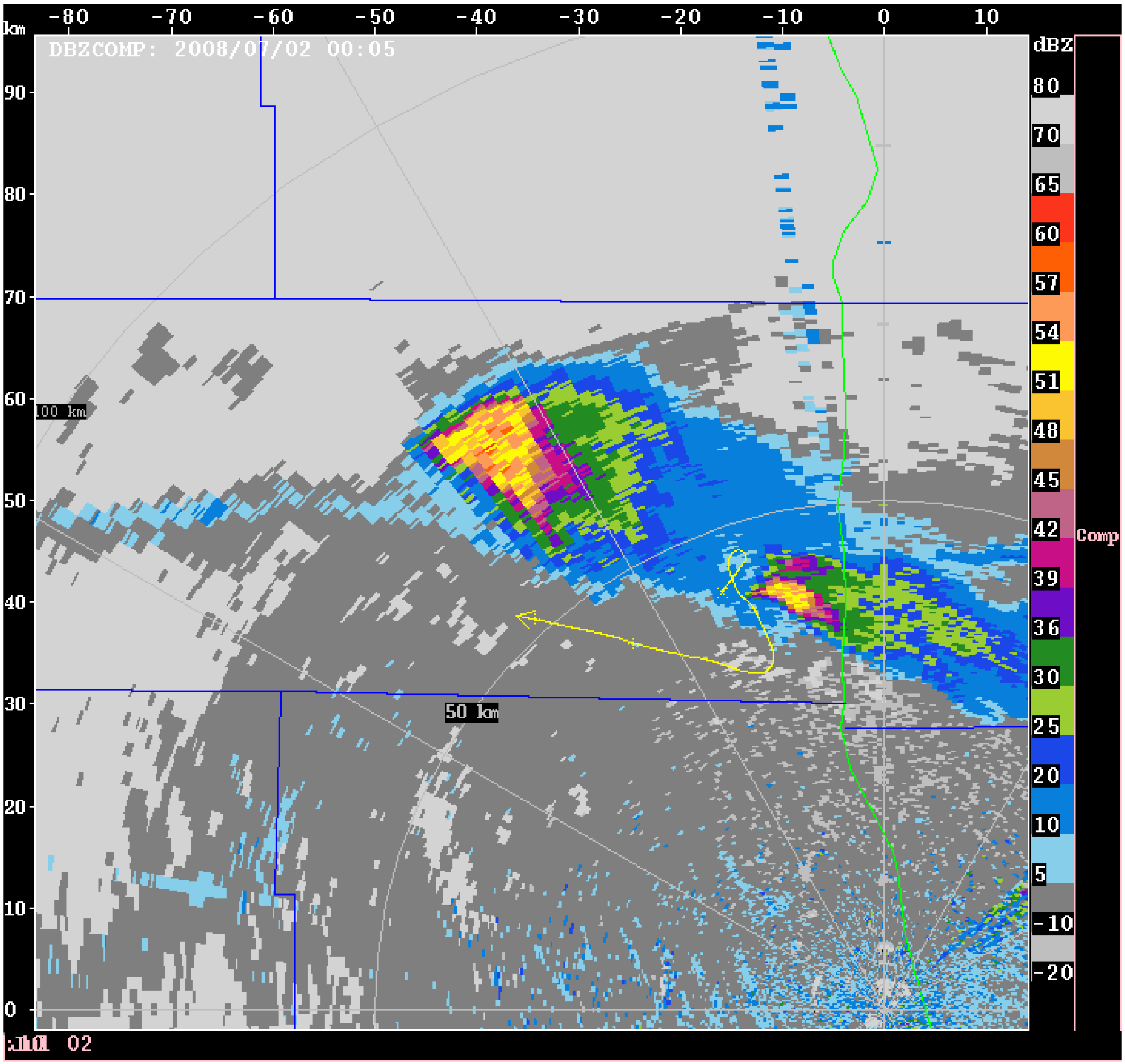

Figure 14: Composite Reflectivity on July 2nd, 2008 00:05 UTC. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

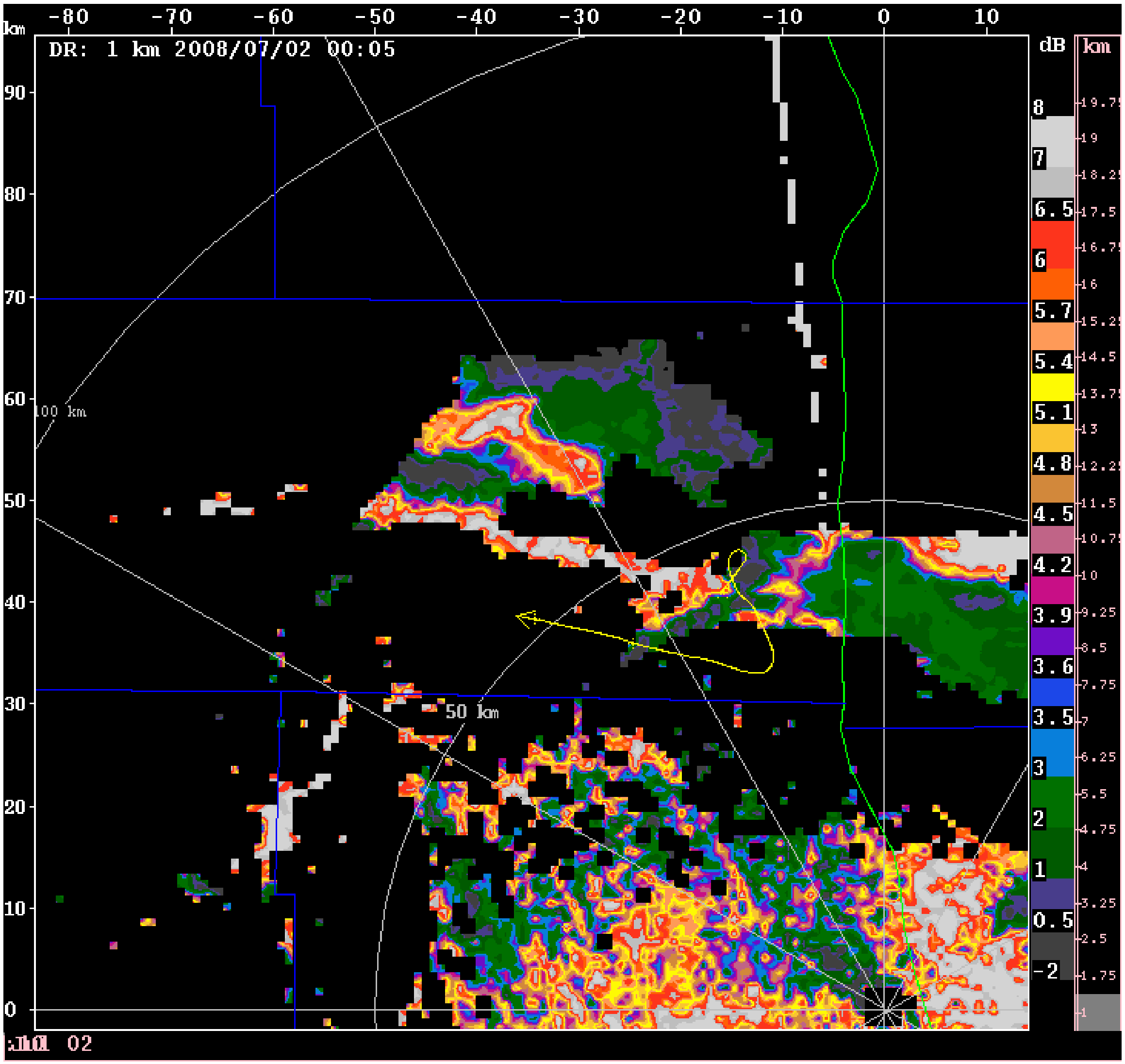

Figure 15: Differential Reflectivity on July 2nd, 2008 00:05 UTC at 1 km. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

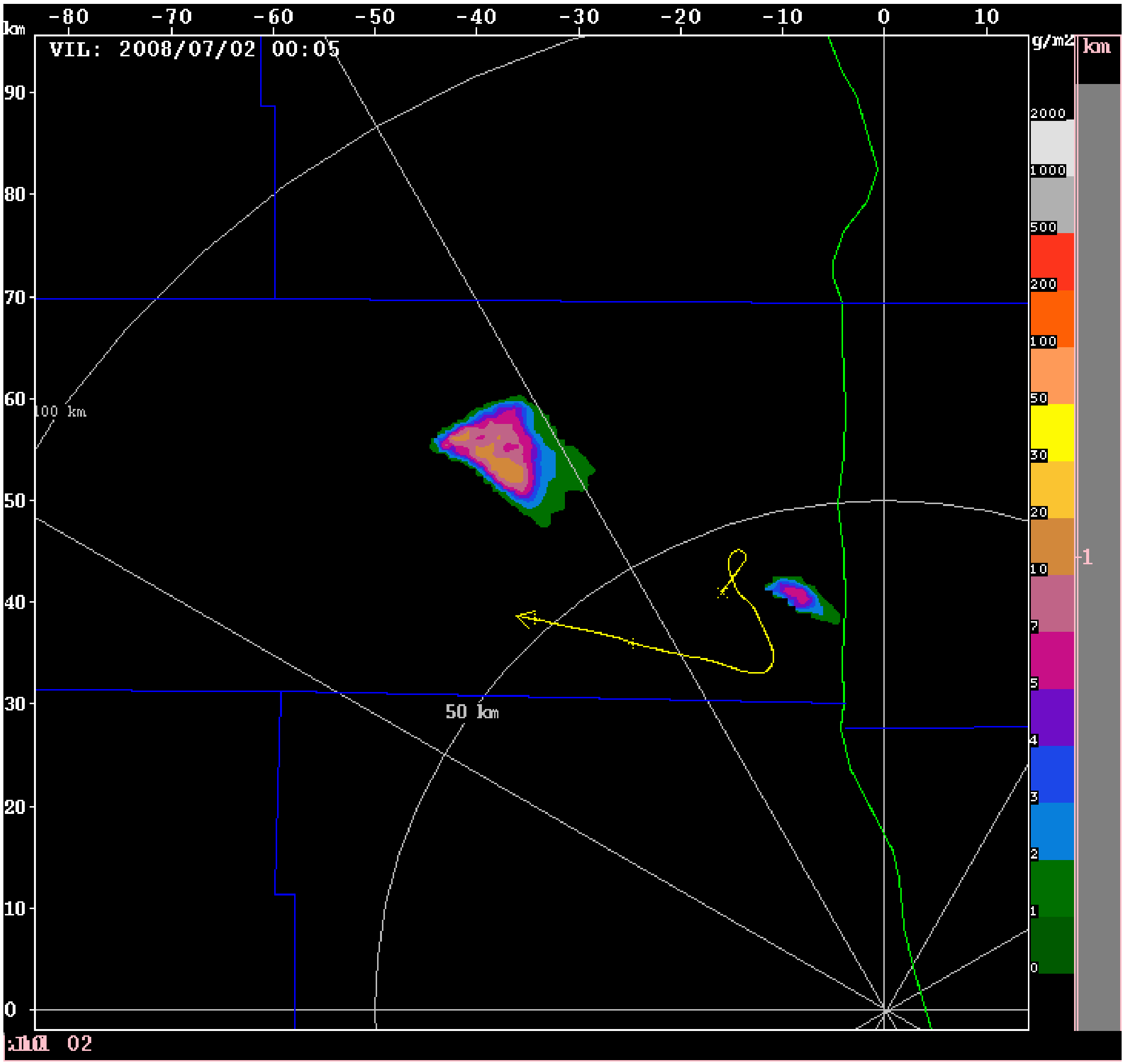

Figure 16: Vertically Integrated Liquid on July 2nd, 2008 00:05 UTC. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

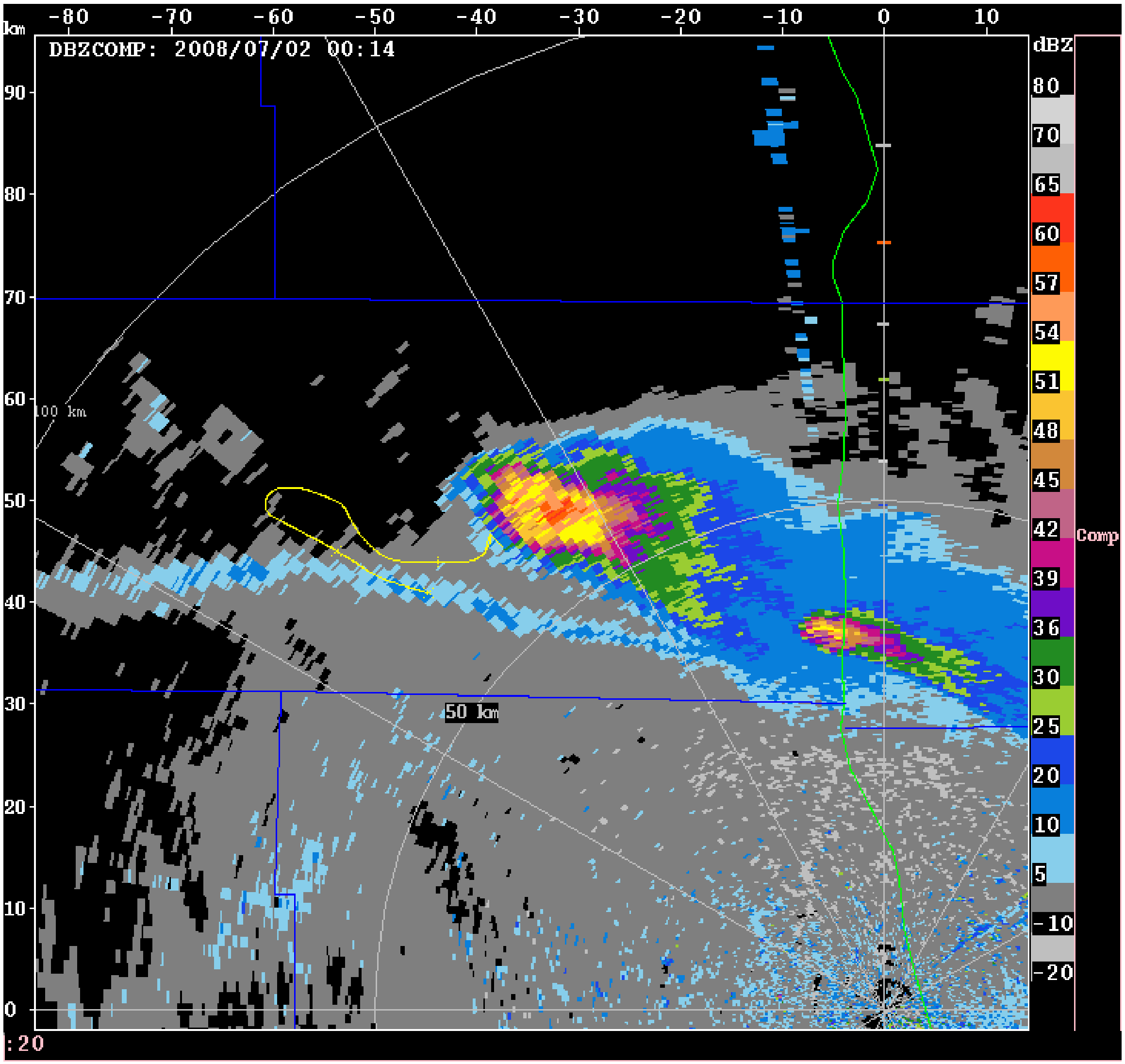

Figure 17: Composite Reflectivity on July 2nd, 2008 00:14 UTC. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

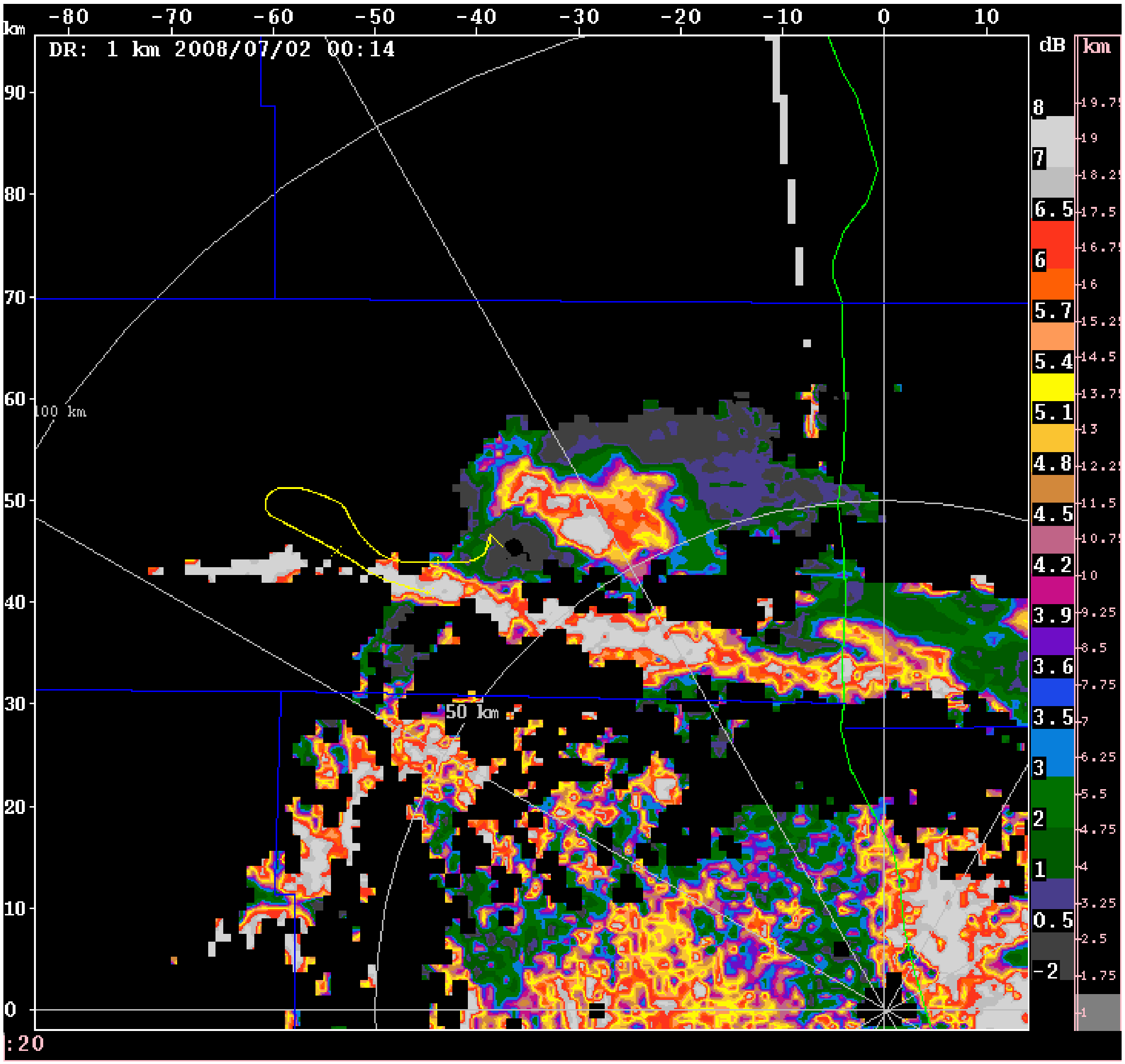

Figure 18: Differential Reflectivity on July 2nd, 2008 00:14 UTC at 1 km. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

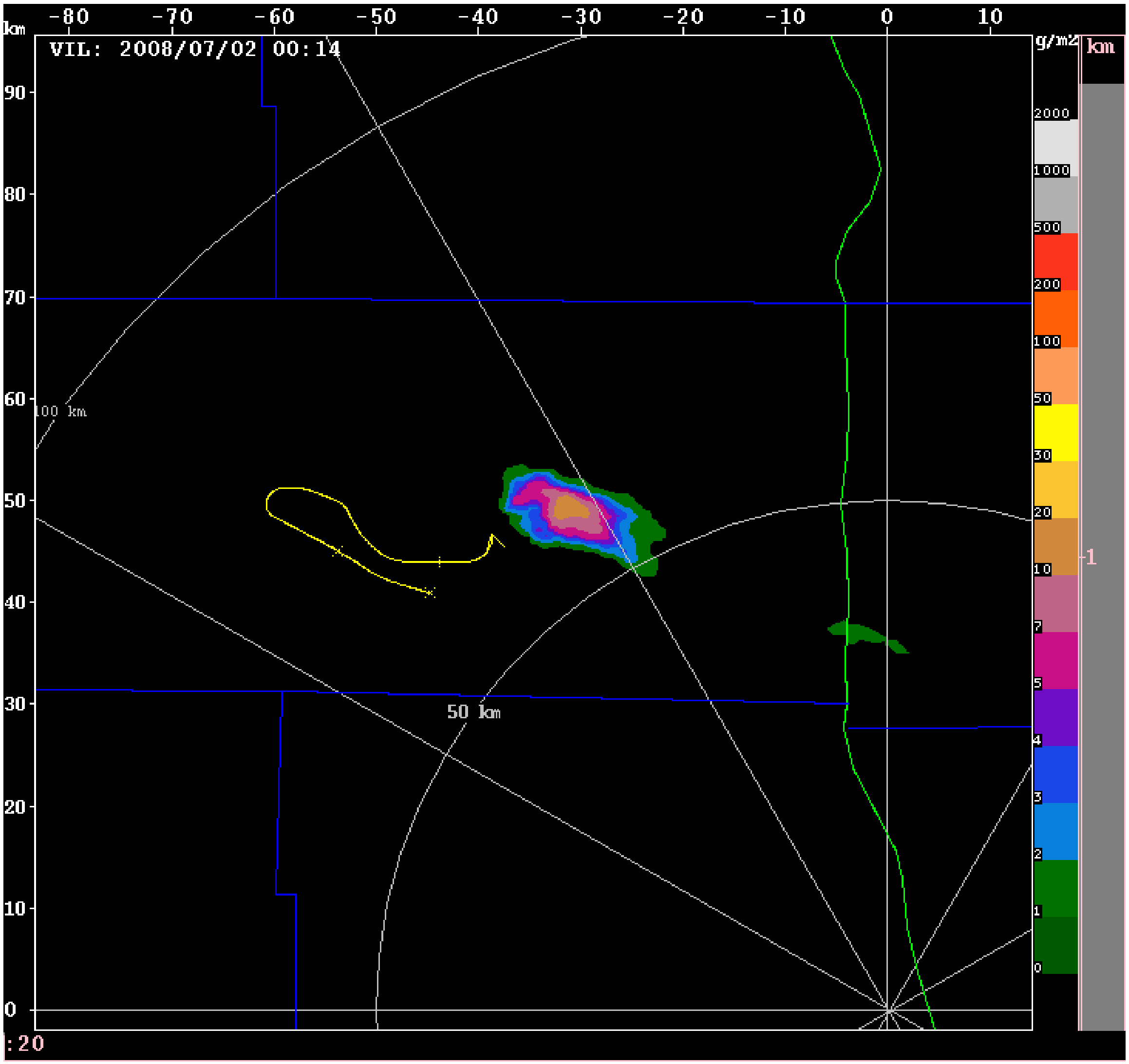

Figure 19: Vertically Integrated Liquid on July 2nd, 2008 00:14 UTC. The aircraft's tracks are overlaid on the image in yellow. The aircraft tracks include the location of the aircraft at the time of the scan to ten minutes before the scan.

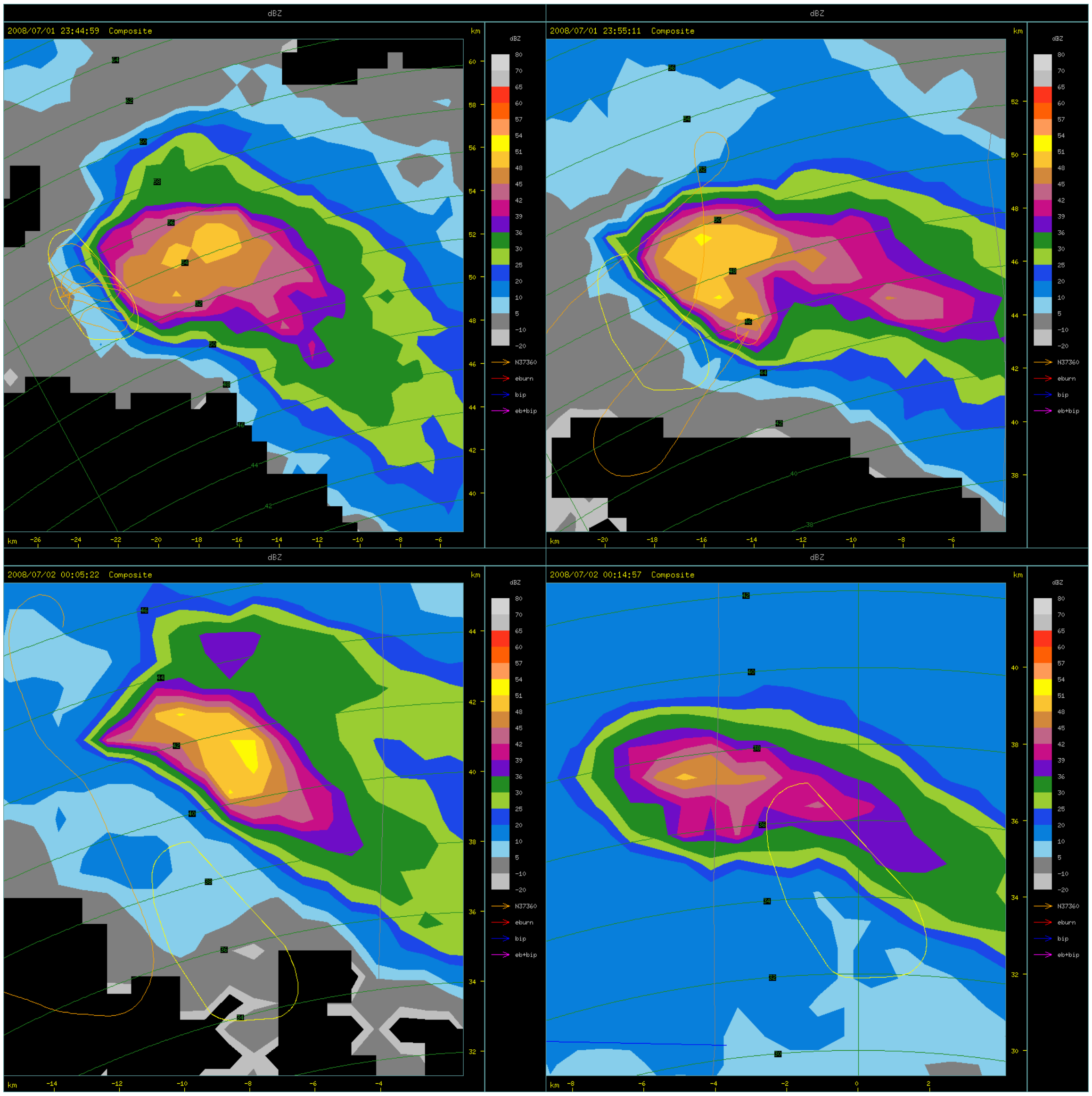

Figure 20: Four plots showing the cell that was seeded and where the polygon from the aircraft tracks was advected. The aircraft tracks are shown in orange, the polygons are shown in yellow, and composite reflectivity is also shown. The times of each image are 23:44:59 (upper left), 23:55:11 (upper right), 00:05:22 (lower left), and 00:14:57 (lower right)

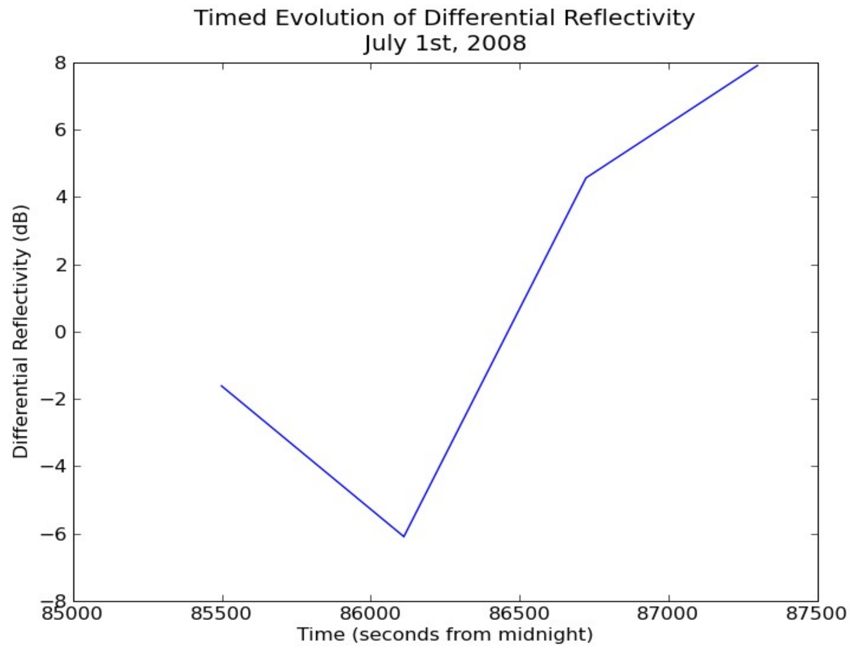

Figure 21: Differential Reflectivity values found within advected polygons using the Titan software AdvectPolygon. The values are shown as they occur in time.

Conclusions

With one only one test case, it is impossible to prove the effectiveness of the combination flares; however, this case did show an increase in radar derived drop size after seeding. The aerosol size spectrum was sampled and had a spectrum similar to hygroscopic flares in the 0.1 to 3.0 μm diameter size range as would be expected. All the flares tested lit and burned successfully.