IOP-10 Summary of Operations
08 December 2009, 0000 UTC – 09 December 2009 1200 UTC

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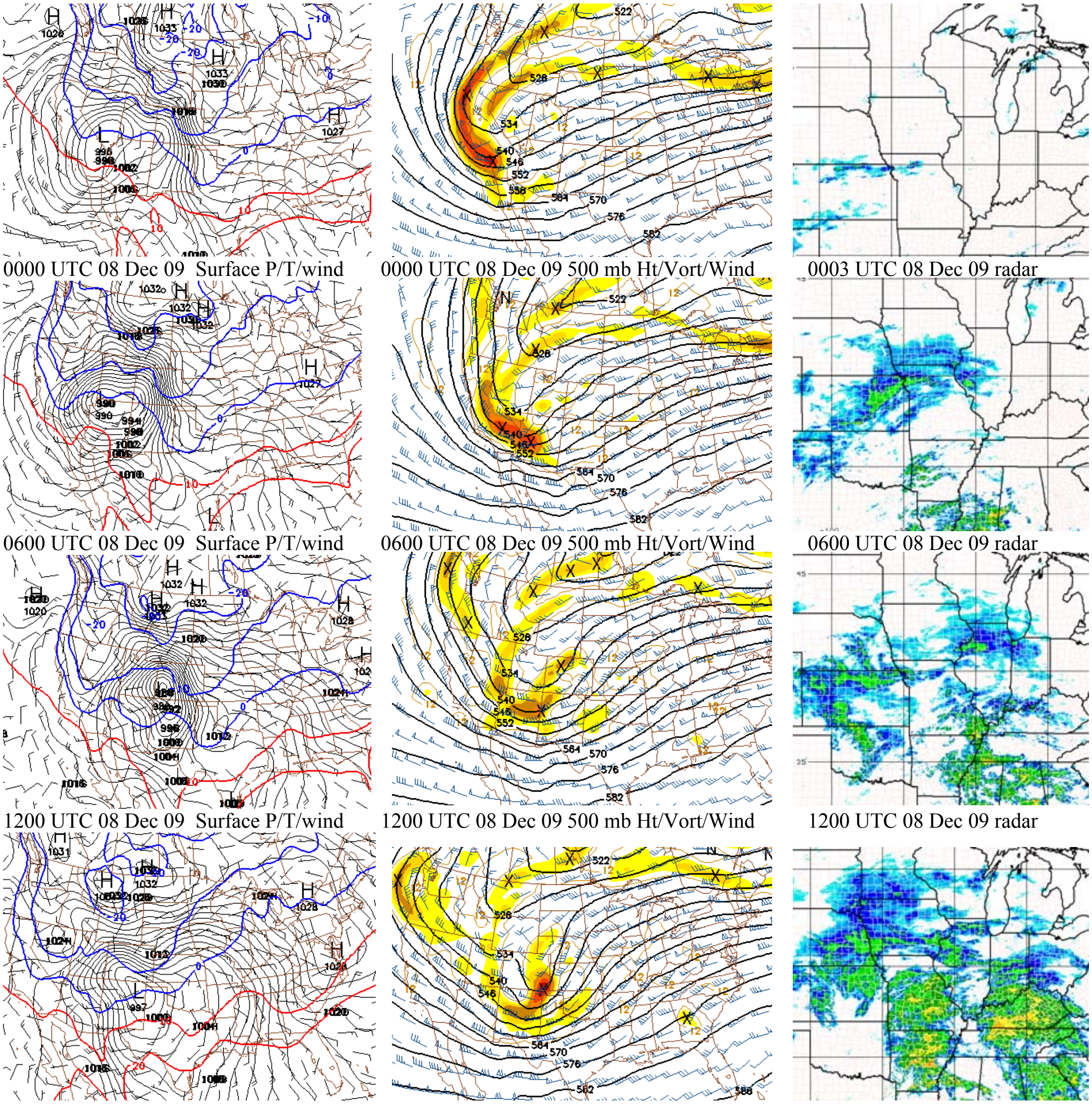
1. Summary of storm evolution

During IOP-10, a large cyclone moved across the Rockies on 8 Dec 09, emerging on to the Plains in Northeast New Mexico by 1800 UTC (Fig. 1). The cyclone was associated with a strong short wave that deepened over eastern Colorado during the day on 8 December. The cyclone's circulation was large and easterly flow was already present at the surface in eastern Iowa at the time the cyclone emerged on to the plains. The first wave of precipitation moved over the ground sites in Clinton and LeClaire, Iowa beginning around 0600 UTC, with about 2 inches of snow accumulating in Clinton. As the cyclone organized and moved eastward, the low pressure center surface position tracked rapidly eastward from northeast New Mexico at 1800 UTC to central Missouri at 0000 UTC to NE Illinois at 0600 UTC to the southern tip of Lake Michigan at 1200 UTC (Fig. 2). The precipitation organized into a distinct comma cloud structure by 0000 UTC 9 December, with the ground sites located right near the leading edge of the dry slot. As a result, snowfall was heavier west and north of the ground sites. Overall, Clinton received about 7.5 inches of snow, with less at Le Claire. To the west, north and northeast, accumulations were more significant, typically 12-16 inches. However, the PLOWS ground facilities were well positioned to study convection near the dry slot/wrap-around interface. As the cyclone propagated northeast, the precipitation shield associated with the wrap-around pulled northeast, with a final band of what looked like dry-slot convection moving over the sites at about 0800 UTC 9 December. The dry slot then moved over the sites between 0900 and 1200 UTC, followed by the very tail of the wrap around between 1200 UTC and 1700 UTC.

2. Locations of instrumentation platforms

MIPS Location:	41° 48' 59.74" N 90° 14' 23.70″ W
Profiler Time of Operation MIPS:	12/07/09 2123 UTC to 12/09/09 1652 UTC
MAX Location:	41° 55' 27.64" N 90° 20' 04.34″ W
Radar Time of Operation MAX:	12/08/09 1418 UTC to 12/09/09 0857 UTC
MISS Location:	41° 35' 19.14" N 90° 21' 48.60″ W
Profiler Time of Operation	12/8/09 0500 UTC to 12/9/09 1030 UTC
MO Location:	41° 48' 59.74" N 90° 14' 23.70″ W
RF-04 Flight operations:	12/09/09 0022 to 0624 UTC



0000 UTC 08 Dec 09 Surface P/T/wind
0000 UTC 08 Dec 09 500 mb Ht/Vort/Wind
0003 UTC 08 Dec 09 radar
0600 UTC 08 Dec 09 Surface P/T/wind
0600 UTC 08 Dec 09 500 mb Ht/Vort/Wind
0600 UTC 08 Dec 09 radar
1200 UTC 08 Dec 09 Surface P/T/wind
1200 UTC 08 Dec 09 500 mb Ht/Vort/Wind
1200 UTC 08 Dec 09 radar
1800 UTC 08 Dec 09 Surface P/T/wind
1800 UTC 08 Dec 09 500 mb Ht/Vort/Wind
1800 UTC 08 Dec 09 radar

Figure 1: Evolution of the IOP-10 storm at the surface, 500 mb, and radar echoes from 0000 UTC 08 Dec 09 through 1800 UTC 08 Dec 09.

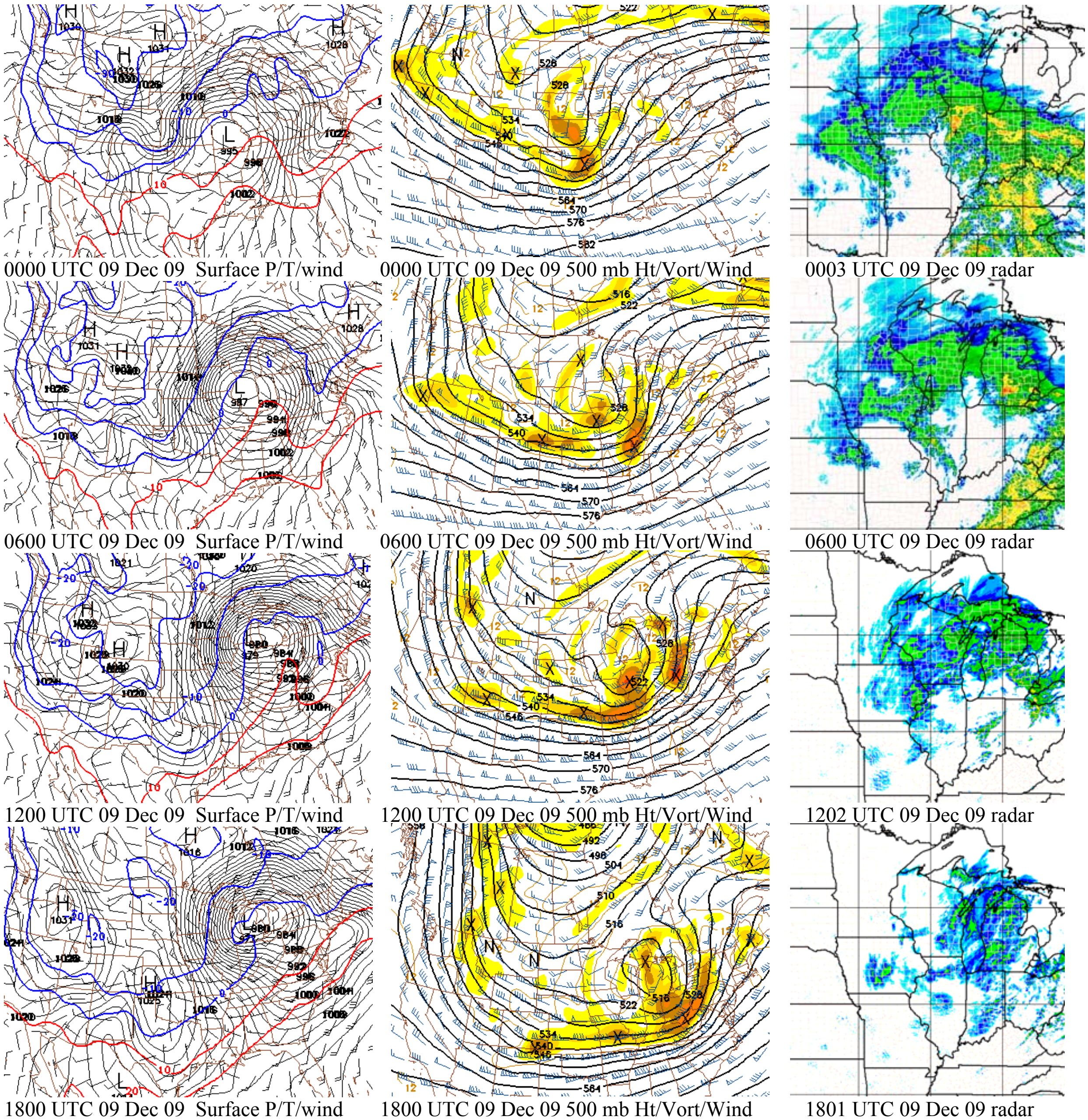


Figure 2: Evolution of the IOP-10 storm at the surface, 500 mb, and radar echoes from 0000 UTC 08 Dec 09 through 1800 UTC 08 Dec 09.

3. Precipitation over research area

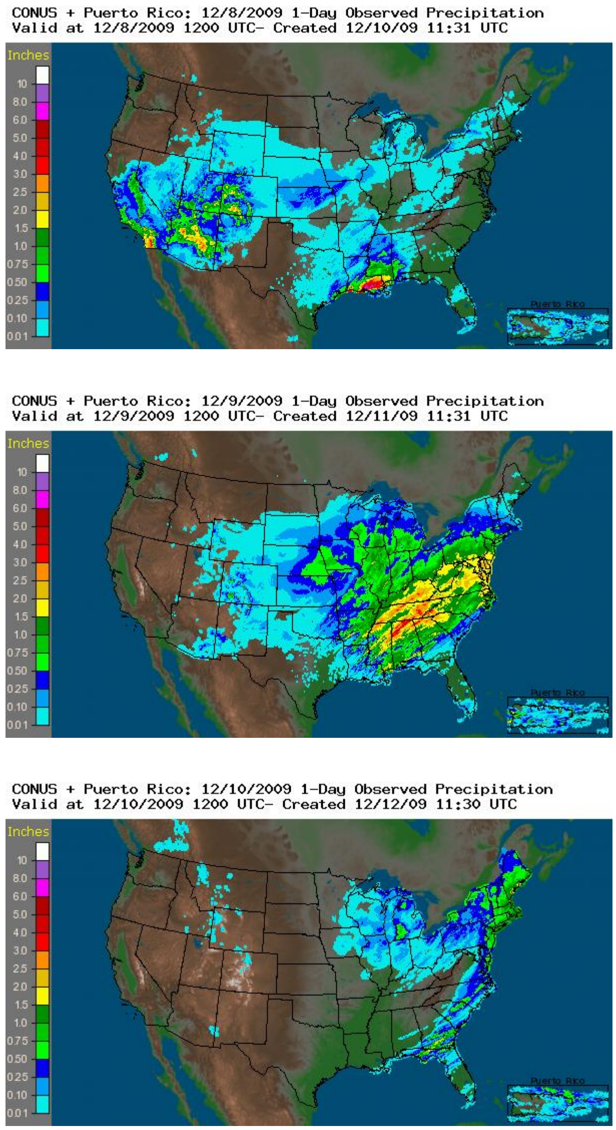


Fig. 3: 24 Hour precipitation ending at 1200 UTC 12/08/09, 1200 UTC 12/09/09, and 1200 UTC 12/10/09 over the United States

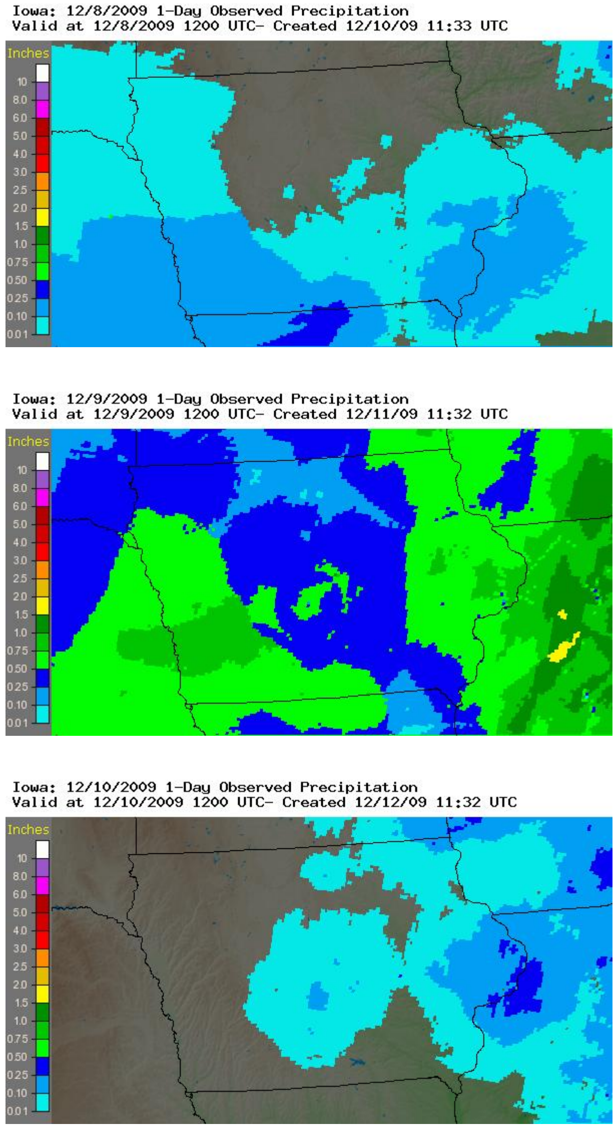


Fig. 4: 24 Hour precipitation ending at 1200 UTC 12/08/09, 1200 UTC 12/09/09, and 1200 UTC 12/10/09 over Iowa

Snowfall totals from HPC

IOWA

ATLANTIC 1 NE	16.0
MOUNT VERNON 3 NW	15.0
WINTERSET	15.0
DANA	14.0
TOLEDO	14.0
WATERFORD 1 E	13.0
DES MOINES 5 WNW	12.7
BELLE PLAINE 1 SSW	12.5
CEDAR RAPIDS 1 NW	11.6

ILLINOIS

FREEPORT	15.0
PEARL CITY	14.0
ROCKFORD 4 NW	6.0
LOVES PARK	5.5
WOODSTOCK	5.5
PORTLAND-RIVERTON	5.0
MOUNT PROSPECT	4.0

MINNESOTA.

ZUMBROTA	13.3
ROCHESTER	11.8
KIESTER	9.0
NEW MARKET	8.5
MANKATO	8.0
MINNEAPOLIS	6.7
LA CRESCENT 1 N	6.5
READS LANDING 1 W	6.5
PRESTON	6.3
CURRIE 4 N	5.0

MISSOURI

ROCKPORT	12.5
TARKIO	12.0
OREGON	10.0
BETHANY	8.0
ALBANY	7.0
MERCER	7.0
UNIONVILLE	7.0
COFFEY 5 W	6.0
GILMAN CITY	6.0
SAVANNAH	5.0

WISCONSIN

MADISON 3 WSW	18.5
ALBANY	18.0
FRENCH ISLAND	17.0
MIDDLETON 4 WSW	17.0
RIO 1 E	16.5
ELKHART LAKE	13.0
LA CROSSE	12.7
STANLEY	12.4
EAU CLAIRE	11.0
LA CROSSE AIRPORT	9.0

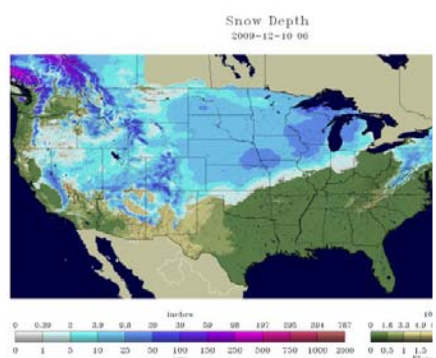
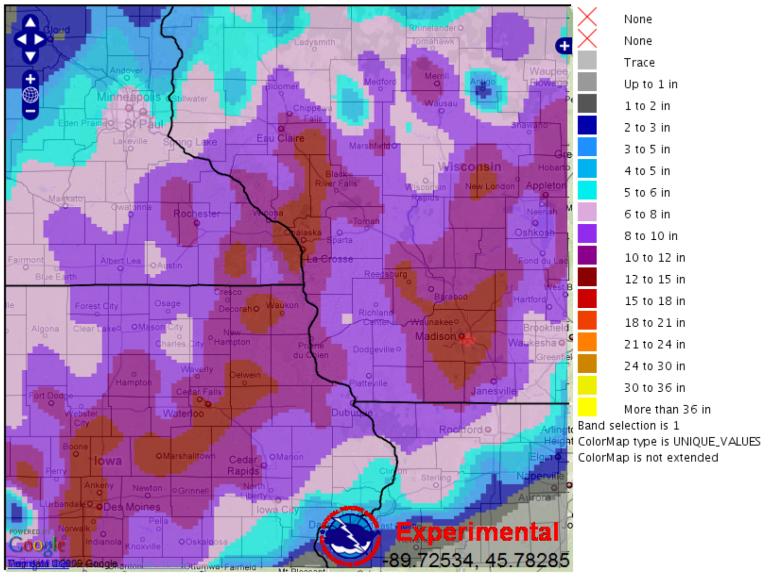
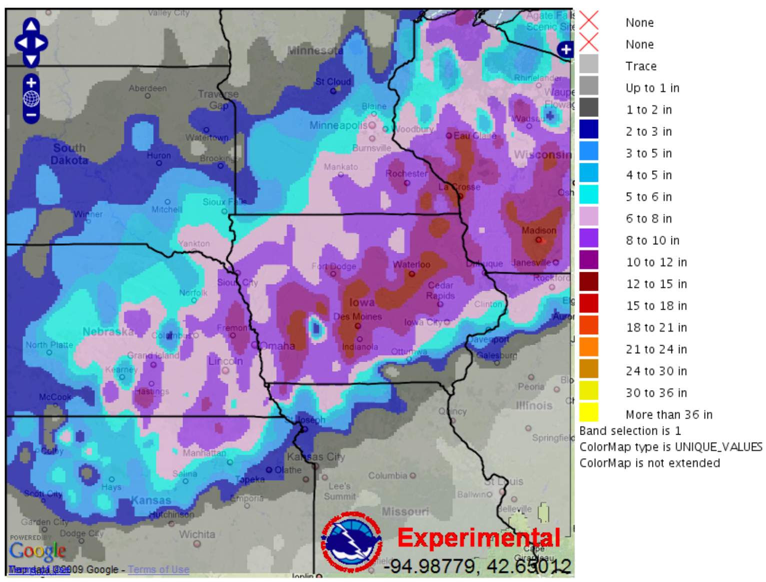


Fig. 5 Snow depth on 10 Dec 09 at 0600 UTC



Local Snowfall Totals Through 1400 UTC 9 Dec 09



Regional Snowfall Totals Through 1400 UTC 9 Dec 09

Fig. 6: Local and regional snowfall totals for IOP-10

4. Flight Summary

C-130 Flight RF-04

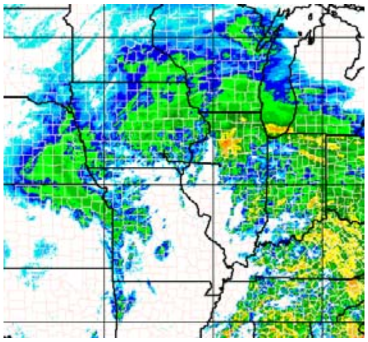
The C-130 departed Peoria at 0024 UTC 9 December. The aircraft proceeded west toward dropsonde track "F", encountering southwest winds of 25-35 m s^{-1} as it ascended and moved into the dry slot. The C130 passed through a cell within the dry slot over Henderson county, IL near 0044 UTC (flight level 6.2 km, temp. -23˚C, wind 210˚ at 24 m s^{-1}; 35 dBZ as seen from KDVN at 0048 UTC), a generating cell with strong vertical velocities (peak 0.5-1.0 km above flight level) and tops indicated by cloud radar over 8 km MSL (see Fig. 7). The WCR indicated generating cells above a stratiform layer.

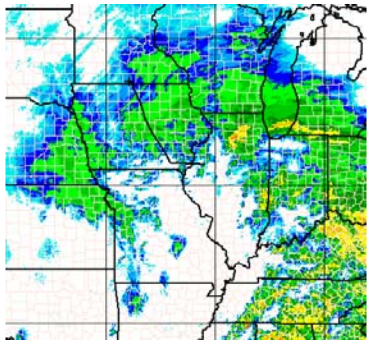
The aircraft flew northwestward along dropsonde track F from approximately 0100 UTC (release of sonde F1) until 0212 UTC at 20.5 Kft, passing through the main precipitation band over Iowa with cloud tops near 9 km MSL. At 0101z one of the C-130 outer front windshield panes cracked but it was determined safe for continued flight. Turbulence was noted at 0108 UTC as the C-130 approached the southern edge of the higher cloud tops, with stronger updrafts as the aircraft flew through cloud with a break below; cloud tops were 1.5-2 km above flight level. Dropsondes were released at 0110 (F2) and 0116 (F3). Vertical motion weakened at/after 0122; cloud tops were 2.5 km above flight level, with strongest ascent from 1km above to cloud top. Dropsonde communication problems were encountered, with data lost on sondes F1-3; F4 and F6 were successful. The strongest echoes on the WCR were observed from 0103-0138 UTC. Dropsonde leg "F" took the C-130 well past the northern extent of the echoes (near 0149 UTC) as seen by KMPX.

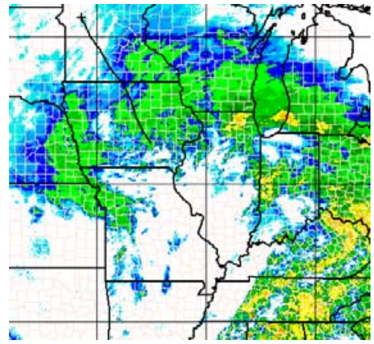
After 0207 the aircraft began climbing to 23 Kft and, finishing the dropsonde leg, turned east (by 0212) towards EAU (Eau Claire, WI). The WCR was unavailable briefly after 0217. The aircraft again entered the precipitation region (seen from MPX) near 0220 UTC. Turbulence was indicated enroute to EAU, from 0.5 km above the aircraft to cloud top (0242, shortly before briefly exiting cloud). The C-130 turned south towards Burlington (BRL) at 0250 UTC. This southbound leg began near the northern edge of precipitation echoes seen by KARX, and WCR cloud tops quickly increased to 9.5 km (0252). Weak vertical velocities (0255), some turbulence, and flight-level winds from 170˚ at 13 m/s (0305 UTC) were noted shortly after entering the band. The C-130 was overflying generating cells at the rate of about 1/minute as it exited cloud near the southern edge of the precipitation band as seen by KARX (0316); raw vertical velocities were again unavailable at this time. Turbulence/vertical velocities accompanying generating cells were noted at 0332, 0335, and 0345. Much lower cloud tops were indicated below the aircraft by the WCR from 0347-0355.

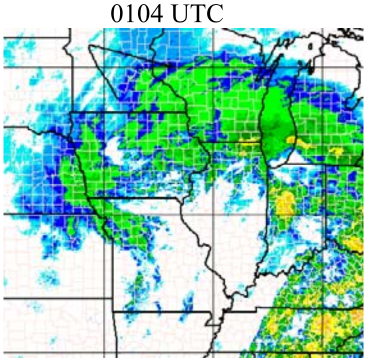
Near 0352 the aircraft turned left to begin a series of NNE-SSW legs from western IL (starting near BRL VOR) to southwest WI (AUW, cut short during leg at latitude of LNR). The first leg (northeastward) started with a descent to 19 Kft. Turbulence was noted at 0359, with tops to 8.5 km and flight level winds 200˚ at 14 m/s, -24˚C. The near-DVN ground sites were ~overflown near 0405 UTC. At 0429 the C-130 reversed course, heading southwest towards MZV, and began descending to 16 Kft. Stronger vertical velocities noted at 0449, 0454 and 0459 (latter near MAX radar position; C-130 at 17 Kft, -19˚C, wind 217˚ at 18 m/s). At 0507 another northeast leg began from MZV to LNR, descending to 13 Kft. Larger drops indicated at 0521 (WCR max reflectivity near flight level, tops to 8.5 km). At 0535, the aircraft turned south towards the Peoria airport on its final flight leg due to weather and time limitations, climbing to 15 Kft. Turbulence was noted at 0556 while passing through a NE-SW band northeast of DVN. Landing at Peoria took place at 0620 UTC 9 Dec.

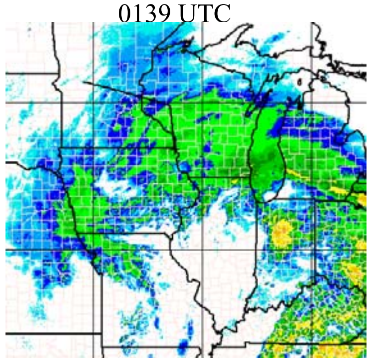
C-130 Flight RF-04 Flight track

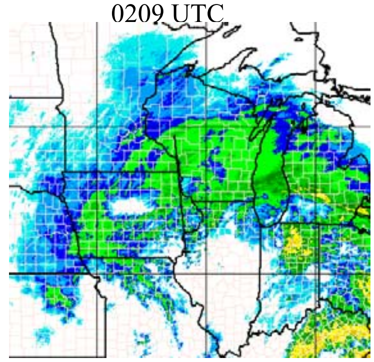

0104 UTC

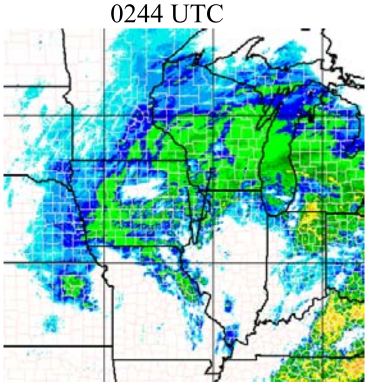

0139 UTC

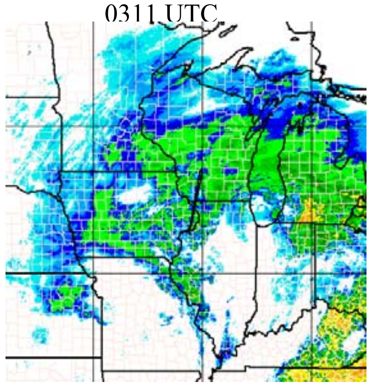

0209 UTC

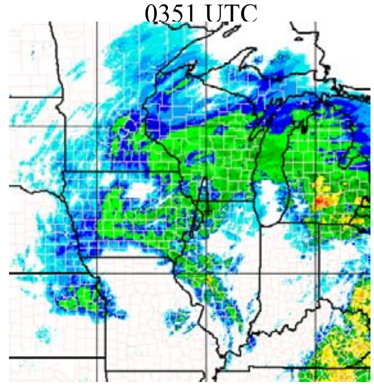

0244 UTC


0311 UTC


0351 UTC


0424 UTC


0504 UTC


0554 UTC

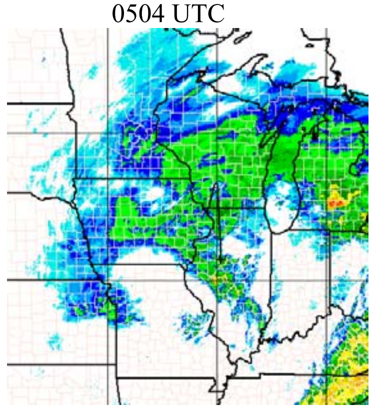
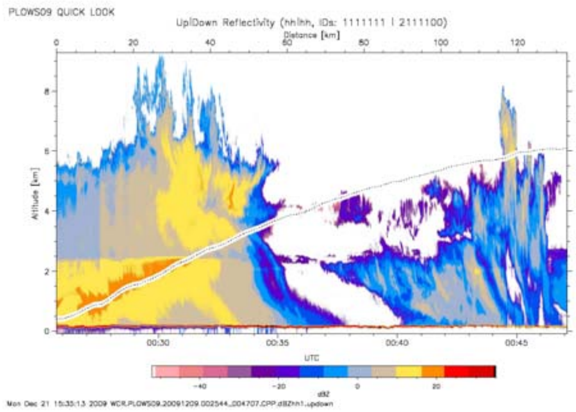
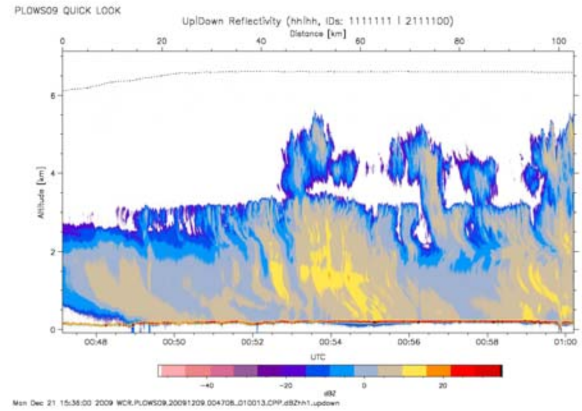

0620 UTC

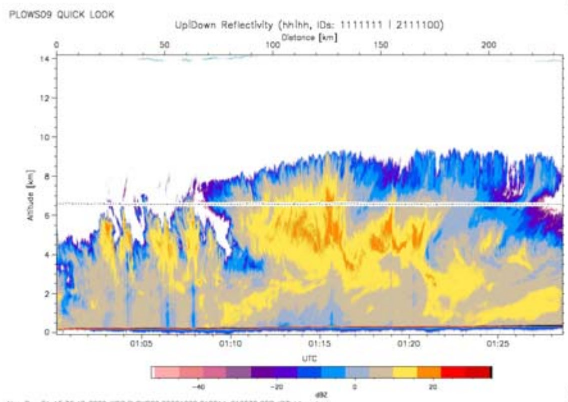
Figure 7: C-130 flight track overlaid on radar composites from 0104 UTC 9 Dec 09 through 0620 UTC 9 Dec 09. Times shown are the times of the radar composites. The flight track for the period just before the composite is shown.



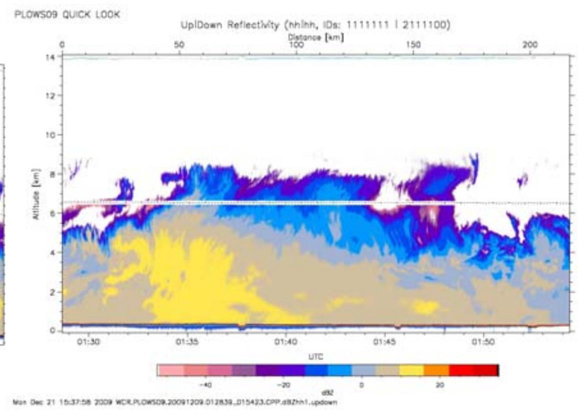
0025 UTC to 0047 UTC



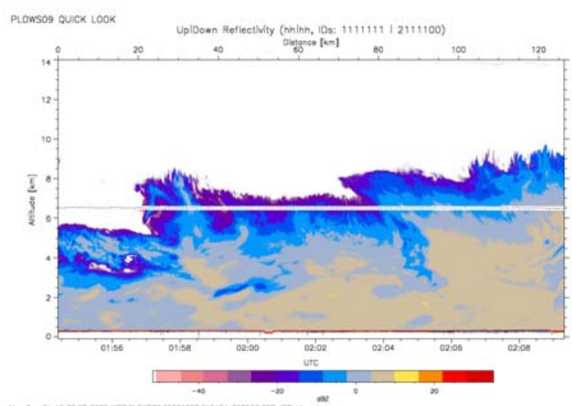
0047 UTC to 0100 UTC



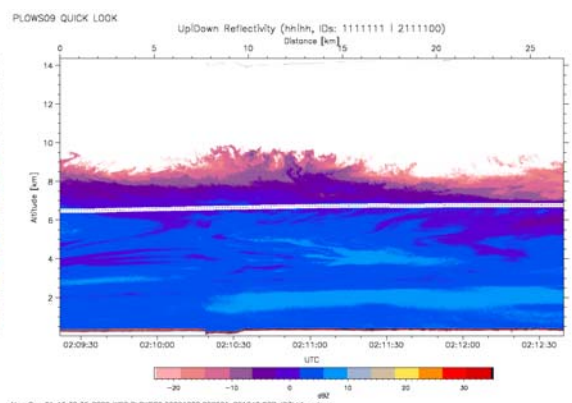
0100 UTC to 0129 UTC



0129 UTC to 0154 UTC

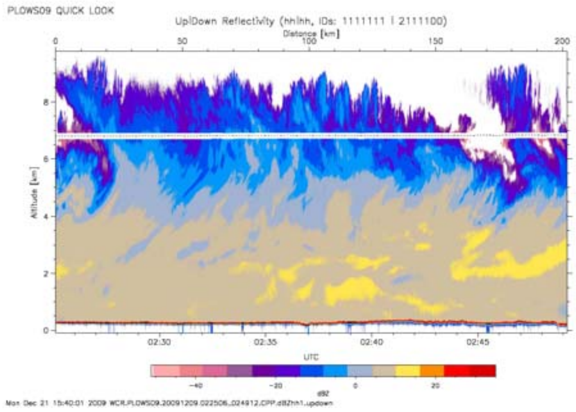


0154 UTC to 0209 UTC

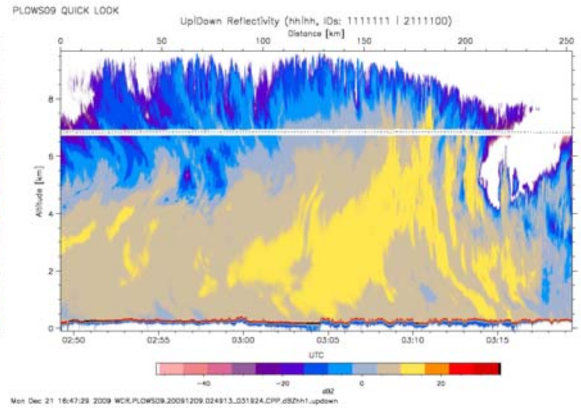


0209 UTC to 0213 UTC

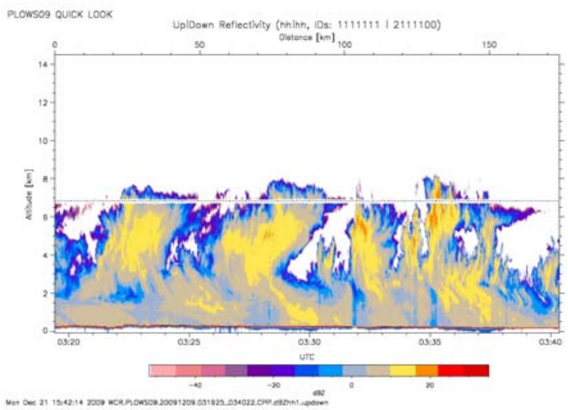
Fig. 8: Wyoming Cloud Radar Quicklook of radar reflectivity between 0025 UTC 9 Dec 09 and 0213 UTC 9 Dec 09.



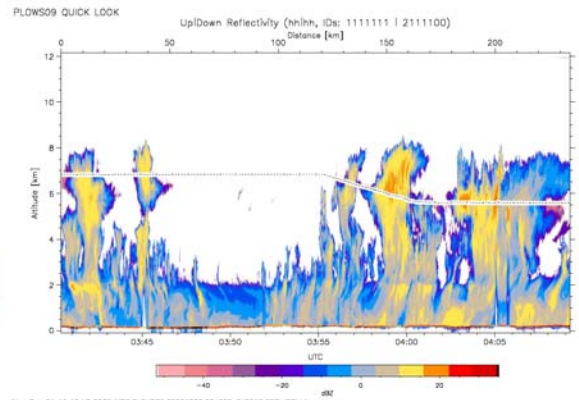
0225 UTC to 0249 UTC



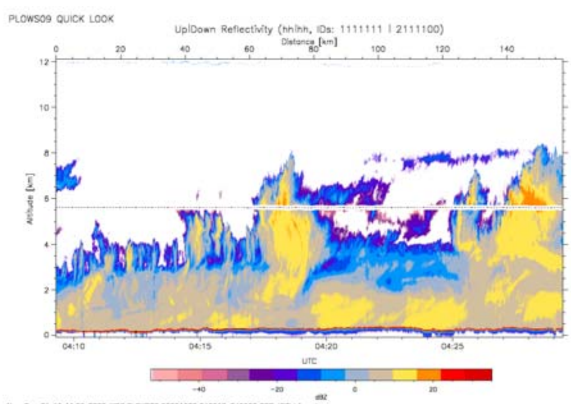
0249 UTC to 0318 UTC



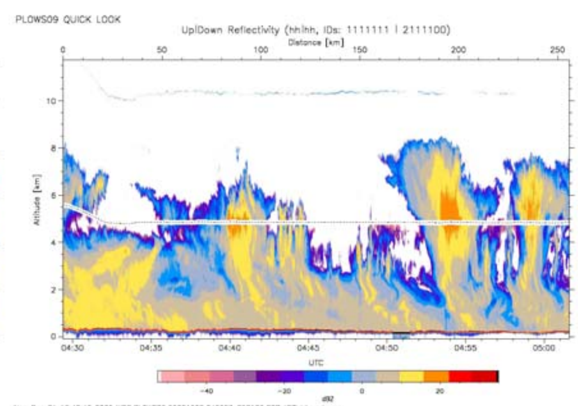
0318 UTC to 0341 UTC



0341 UTC to 0409 UTC

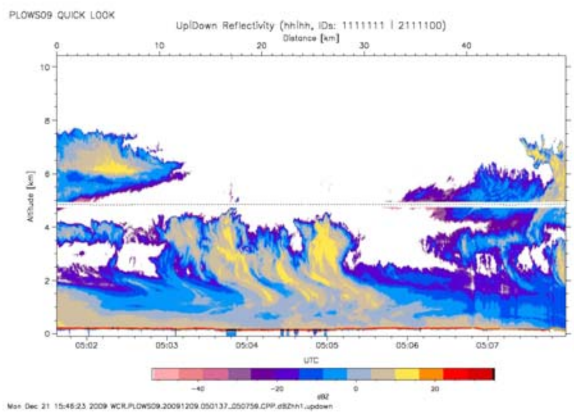


0409 UTC to 0429 UTC

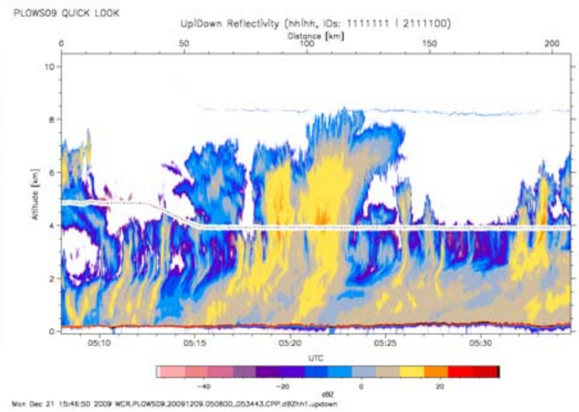


0430 UTC to 0501 UTC

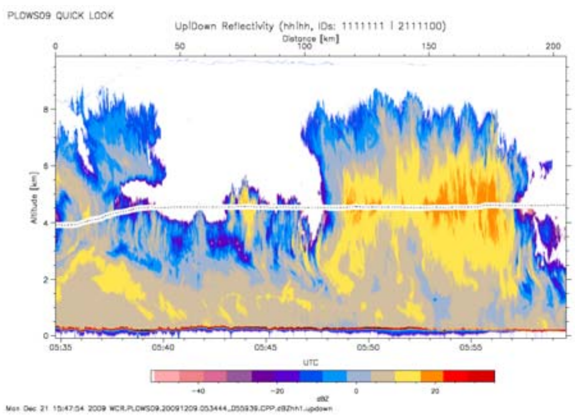
Fig. 9: Wyoming Cloud Radar Quicklook of radar reflectivity between 0225 UTC 9 Dec 09 and 0501 UTC 9 Dec 09.



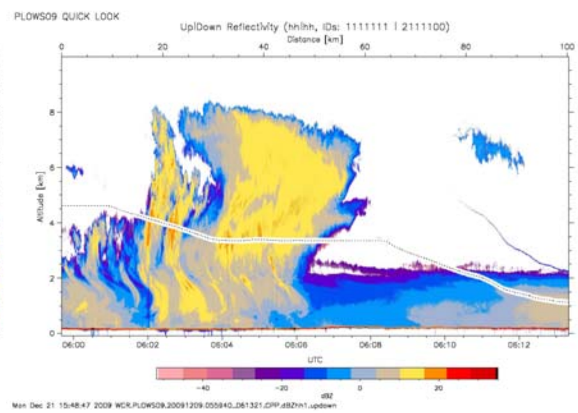
0501 UTC to 0508 UTC



0508 UTC to 0534 UTC



0534 UTC to 0559 UTC



0559 UTC to 0615 UTC

Fig. 10: Wyoming Cloud Radar Quicklook of radar reflectivity between 0501 UTC 9 Dec 09 and 0615 UTC 9 Dec 09.

5. MIPS operations

The MIPS was set up on the northern end of the parking lot between the Country Inn Suites (to the east) and the Best Western Inn (to the west). The orientation (direction in which the van/trailer was pointed) was 115 deg (magnetic north). A stand of trees was located about 200 feet north of the parking lot, and a grass surface extended from the parking lot to the trees. Since the near surface flow was primarily NE to NW during the event, the trees provided a natural wind break that produced a relatively laminar flow over the MIPS site. Both the Parsivel disdrometer and rain gauge / field mill were located about 20 ft north of the MIPS van. Photos looking north (from the MIPS trailer) and south (toward the MIPS are shown in Figs. 11 and 12. Overall, this was a good site for combined MIPS and balloon operations.

MIPS operations started at 2120 UTC on 7 December and ended at 1633 UTC on 9 December (Figs 13,14). All MIPS systems operated quite well during the event. The 915 MHz profiler did show some ground clutter contamination below about 500 m at times, and a coherent external 915 MHz source (radio communications?) was detected during the snow event. This source appeared as a uniform Doppler velocity with fixed values of -2, -8 and about 8 m/s. Since it was far enough removed from the precipitation spectra, this noise should not present any problems in the post analysis. MIPS personnel frequently removed snow accumulations from the 915 MHz radome. The MPR performed well during the snow conditions, as the radome remained mostly snow free. However, the retrieved profiles were often bad (~20% of the time), apparently due to retrieval software issues and not frequency instability or external noise. Post-processing should take care of this issue. It appears that the MPR was not significantly biased by the presence of snow. At times, supercooled water was detected.

Snow was sampled between 0700 UTC 8 December and 1640 UTC 9 December. A total of about 7.5 in was measured at 1630 UTC on 9 December. During the event, a wide range of particles were sampled, including small and large aggregates (up to 1 cm) and sleet. At 0800 UTC, MIPS personnel retired, and the MIPS operated autonomously between 0800 and 1400 UTC. Operations ended at 1633 UTC, 9 December.

An electrical heat wrap was installed on the outside of the tipping bucket rain gage. This appeared to melt the snow quite well most of the time. After 0800 UTC 9 December, the MIPS wind monitor froze and was not spinning at (or after) 1400 UTC.

Fig. 11. Image of the Parsivel disdrometer and rain gauge / field mill looking toward 20 deg from the MIPS trailer.

Fig. 12. Image of the MIPS taken about at 1600 UTC on 9 December. The view is towards 200 deg. The Parsivel disdrometer (right) and rain gauge / field mill (left) are in the foreground.

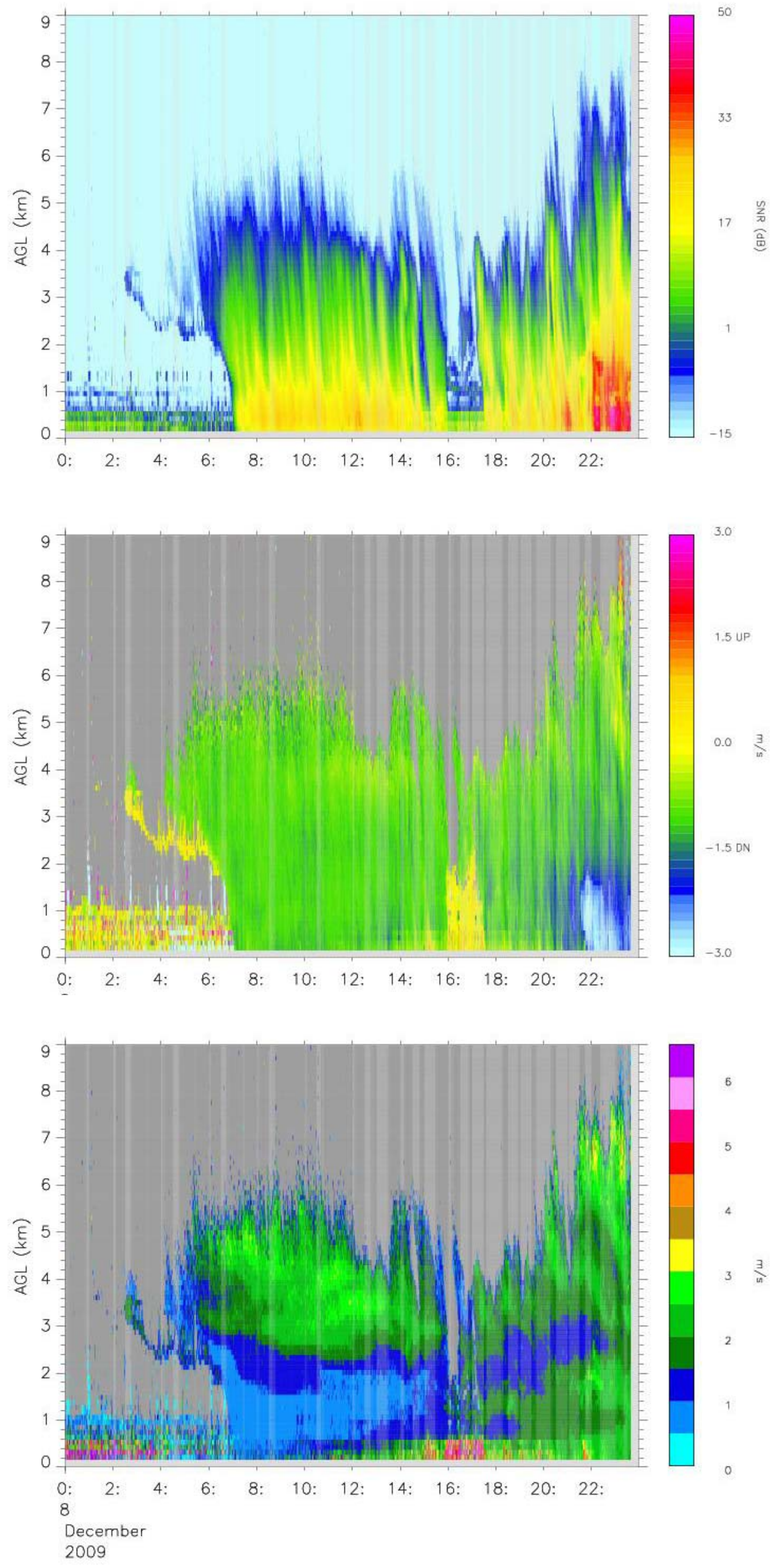


Figure 13: MIPS 915 MhZ Profiler SNR (top), Radial Velocity (center) and Spectral Width (bottom) for the period 0000 UTC 08 Dec 09-0000 UTC 09 Dec 09.

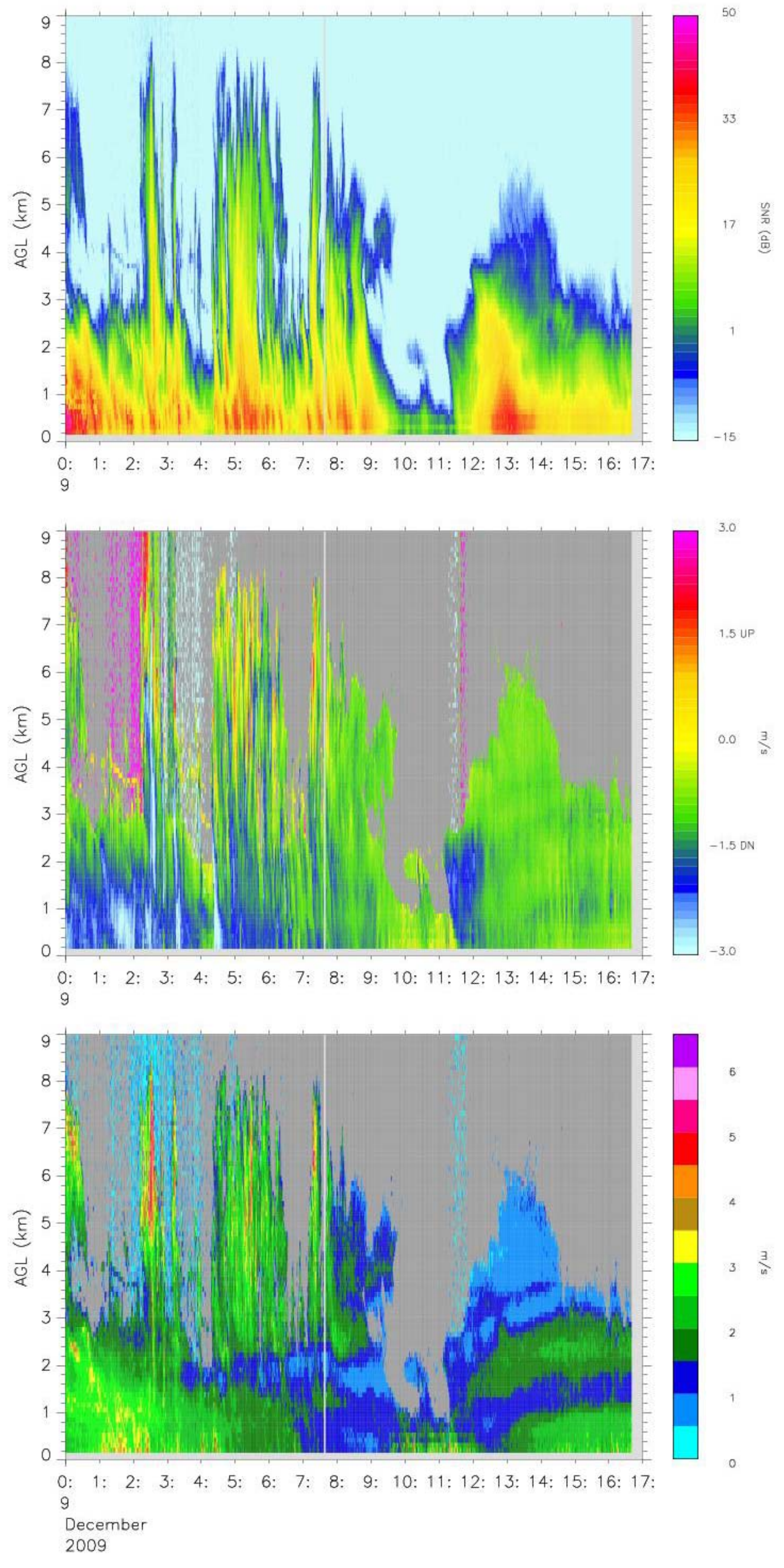


Figure 14: MIPS 915 MhZ Profiler SNR (top), Radial Velocity (center) and Spectral Width (bottom) for the period 0000 UTC 09 Dec 09-1700 UTC 09 Dec 09.

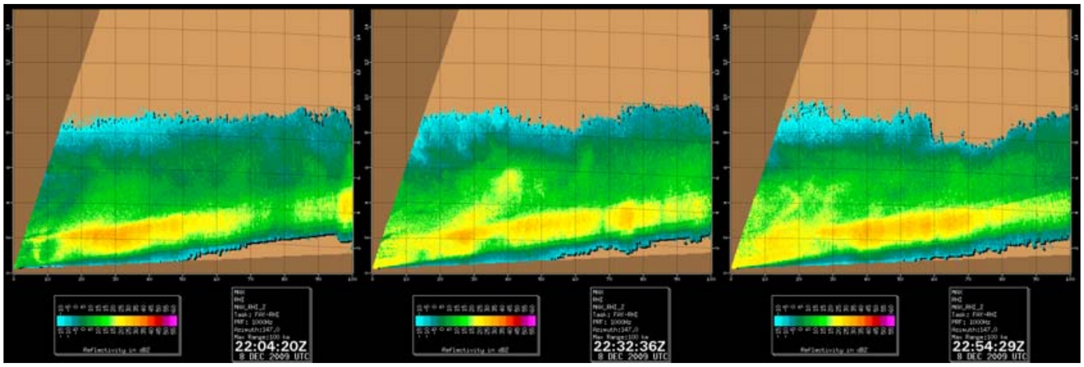
6. MAX operations

MAX operations

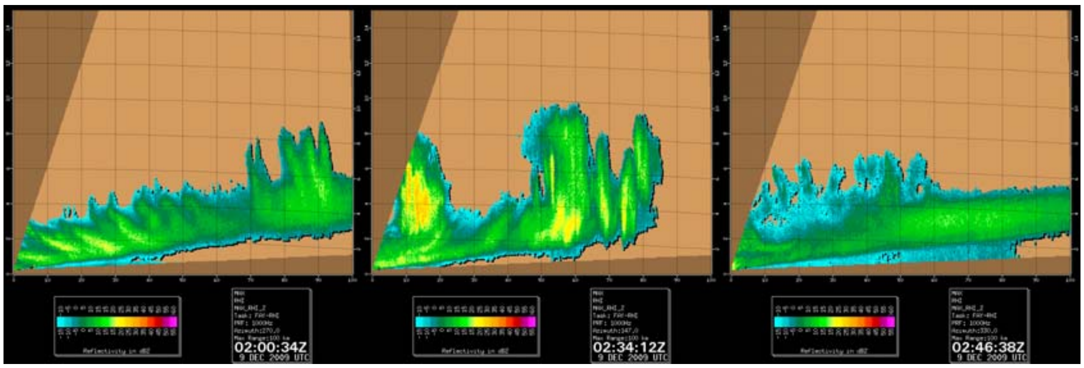
The MAX location was moved further north from the previous site used during IOP 7 (March 2009) in order to place the MIPS at a distance of ~15 km from the MAX. This area is hilly farmland, and a high quality site was difficult to find. The actual site had good view of the horizon over the SW semicircle, and some blocking up to 2 deg elevation by elevated topography towards the NE (along the dual Doppler baseline, oriented along 210-30 deg with a 40 km separation). The MIPS azimuth/range from this location was 147 deg / 14.3 km.

The MAX conducted full volume VAD scans followed by RHI scans over the MIPS site and towards other areas of interest. The cycle time was approximately 6 min. Operations were conducted continuously from 1418 UTC (12/8/09) to 0857 UTC (12/9/09).

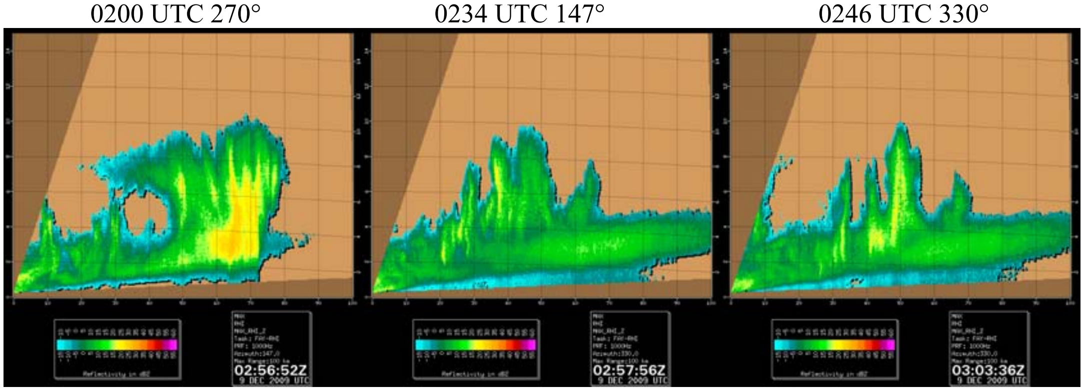
MAX images from the event are shown on Figs. 15-18.



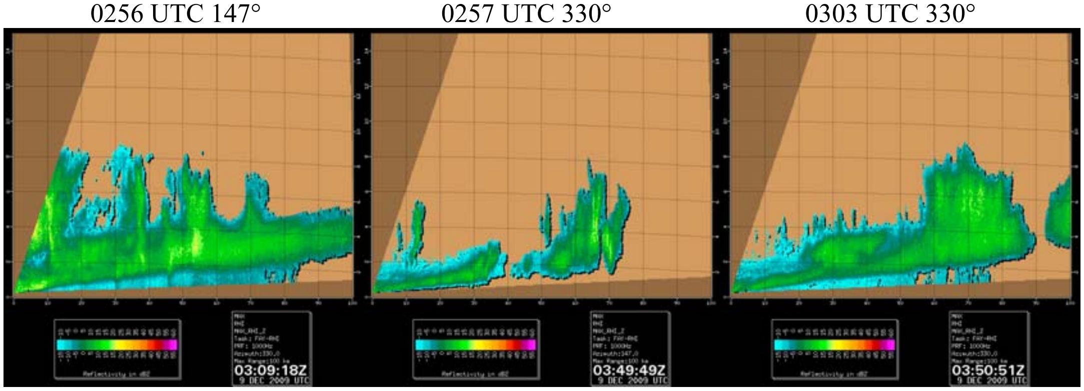
2204 UTC 147°　　2232 UTC 147°　　2254 UTC 147°



0200 UTC 270°　　0234 UTC 147°　　0246 UTC 330°

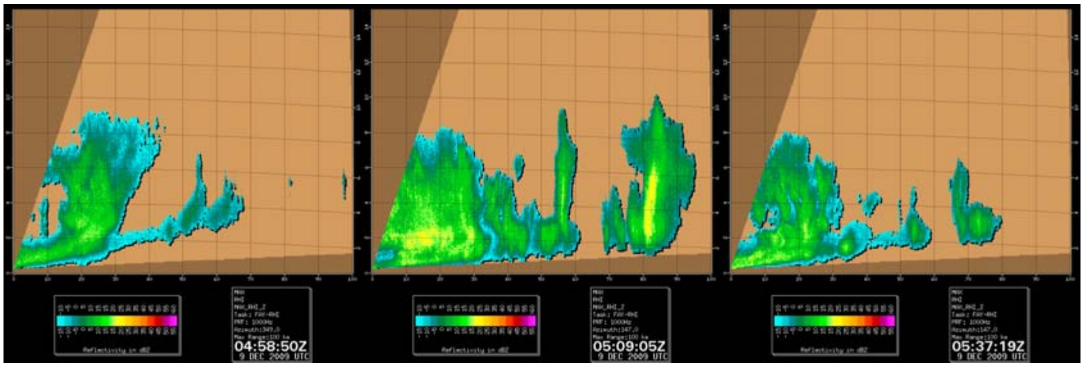


0256 UTC 147°　　0257 UTC 330°　　0303 UTC 330°

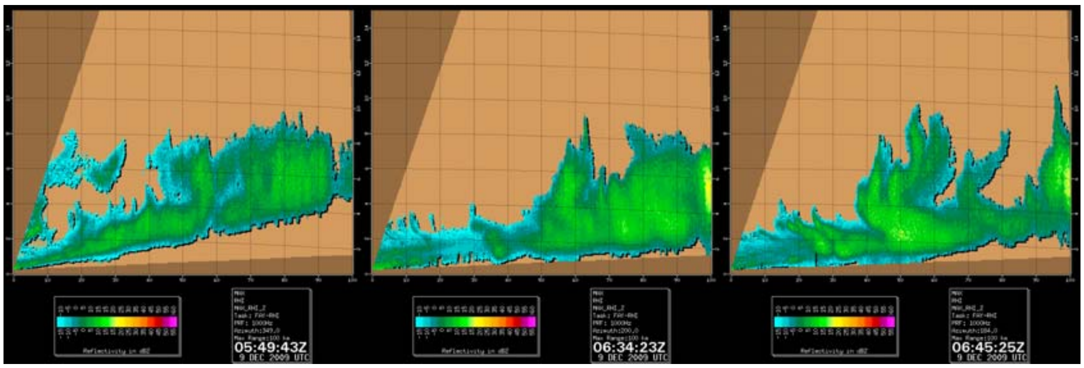


0309 UTC 330°　　0349 UTC 147°　　0350 UTC 330°

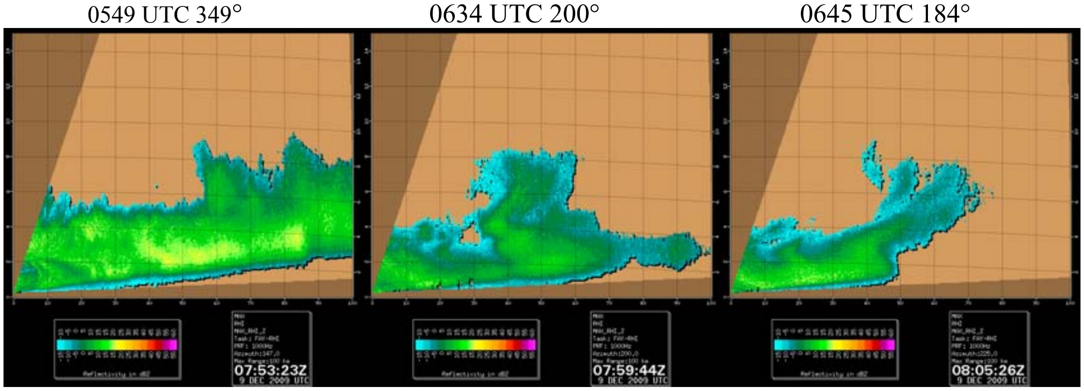
Fig. 15: MAX radar RHI images of Z_H from the period 0200 through 0700 UTC 9 December 09



0458 UTC 349° 0509 UTC 147° 0537 UTC 147°

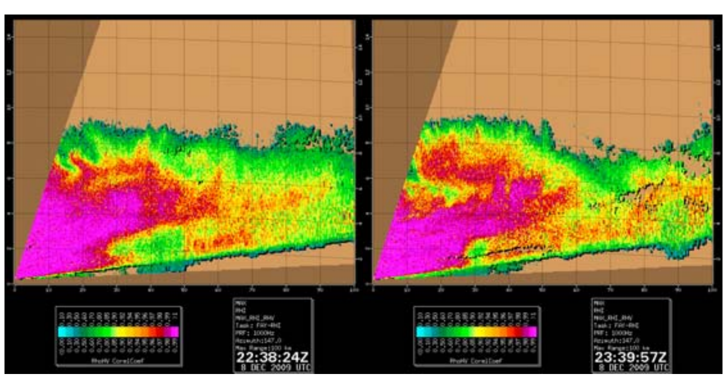


0549 UTC 349° 0634 UTC 200° 0645 UTC 184°



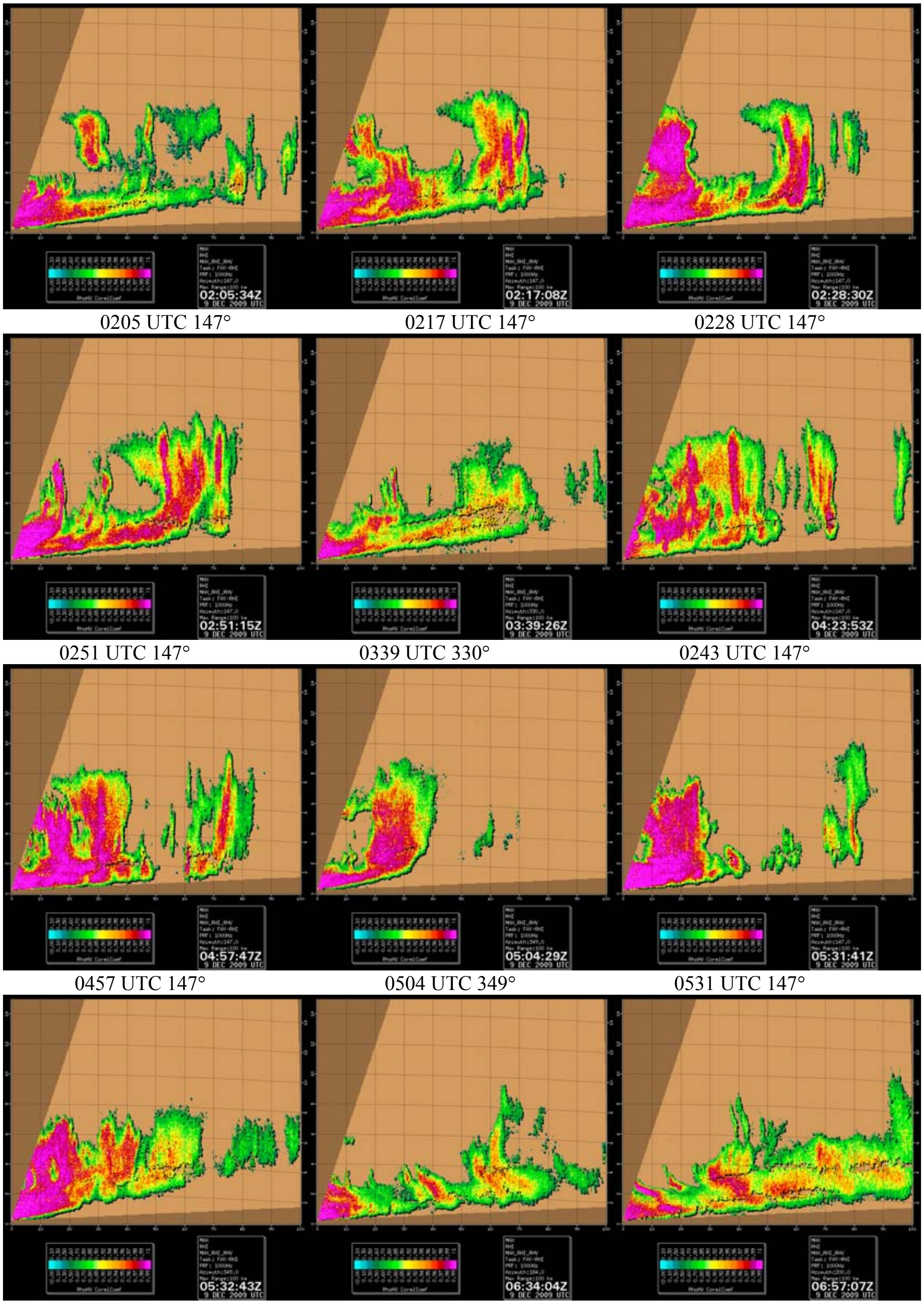
0753 UTC 147° 0759 UTC 200° 0805 UTC 225°

Fig. 16: MAX radar RHI images of Z_H from the period 0500 through 0800 UTC 9 December 09



2238 UTC 147° 2339 UTC 147°

Fig. 17: MAX radar RHI images of ρ_{HV} from the period 2200 8 Dec 09 through 0000 UTC 9 Dec 09



0205 UTC 147° 0217 UTC 147° 0228 UTC 147°

0251 UTC 147° 0339 UTC 330° 0243 UTC 147°

0457 UTC 147° 0504 UTC 349° 0531 UTC 147°

0532 UTC 349° 0634 UTC 184° 0657 UTC 200°

Fig. 18: MAX radar RHI images of ρ_{HV} from the period 0200 through 0700 UTC 9 December 09

7. MISS 915 MHz Profiler

The MISS operated in the southeastern dual Doppler lobe. The MISS was in the gradient of the snowfall, and was positioned to observe convection developing near the leading edge of the dry slot. The convective cells are evident in the images below.

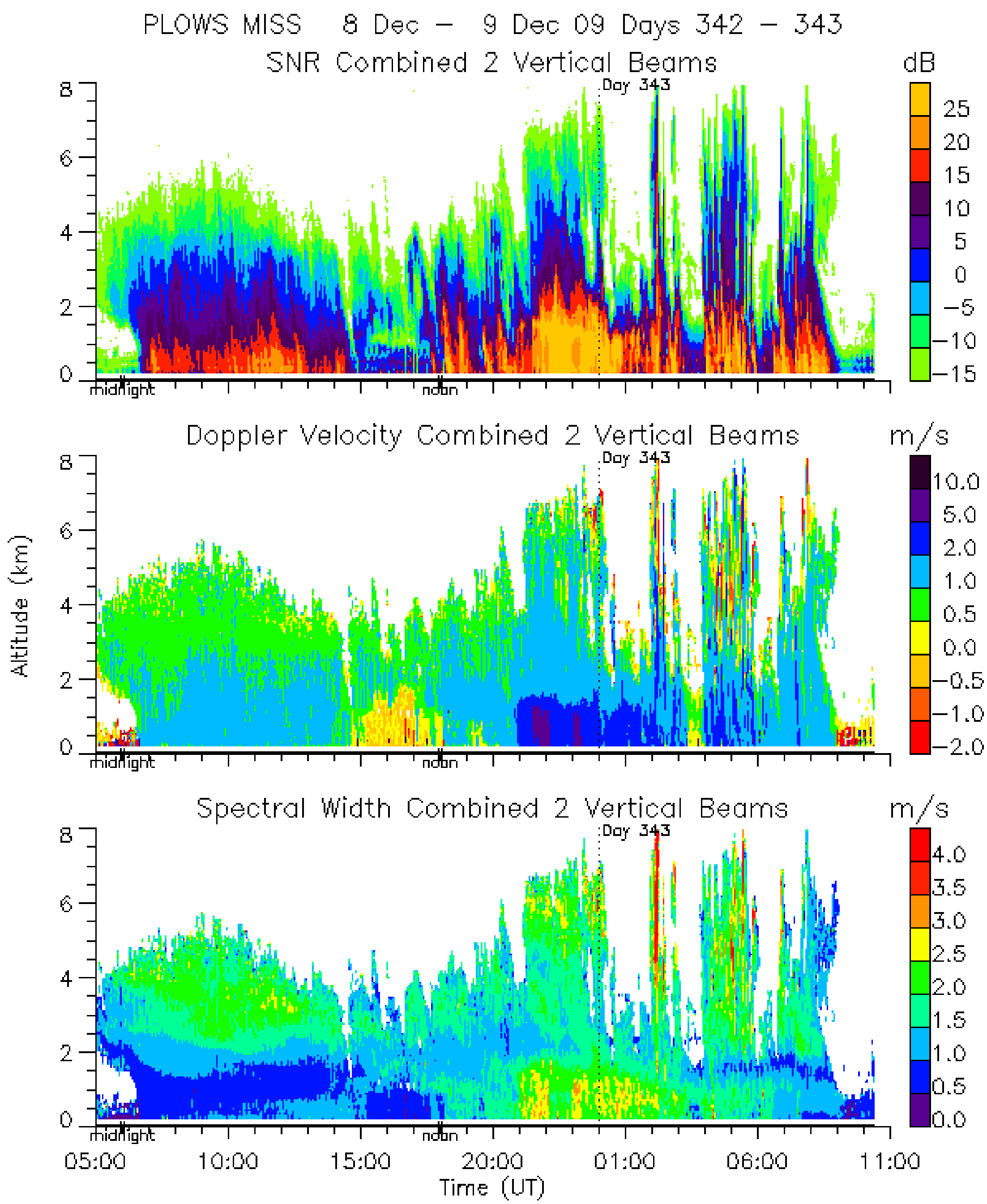


Figure 19: MISS 915 MHz Profiler SNR (top), Radial Velocity (center) and Spectral Width (bottom) for the period of operation 0500 UTC 8 Dec 09 through 1030 UTC 9 Dec 09

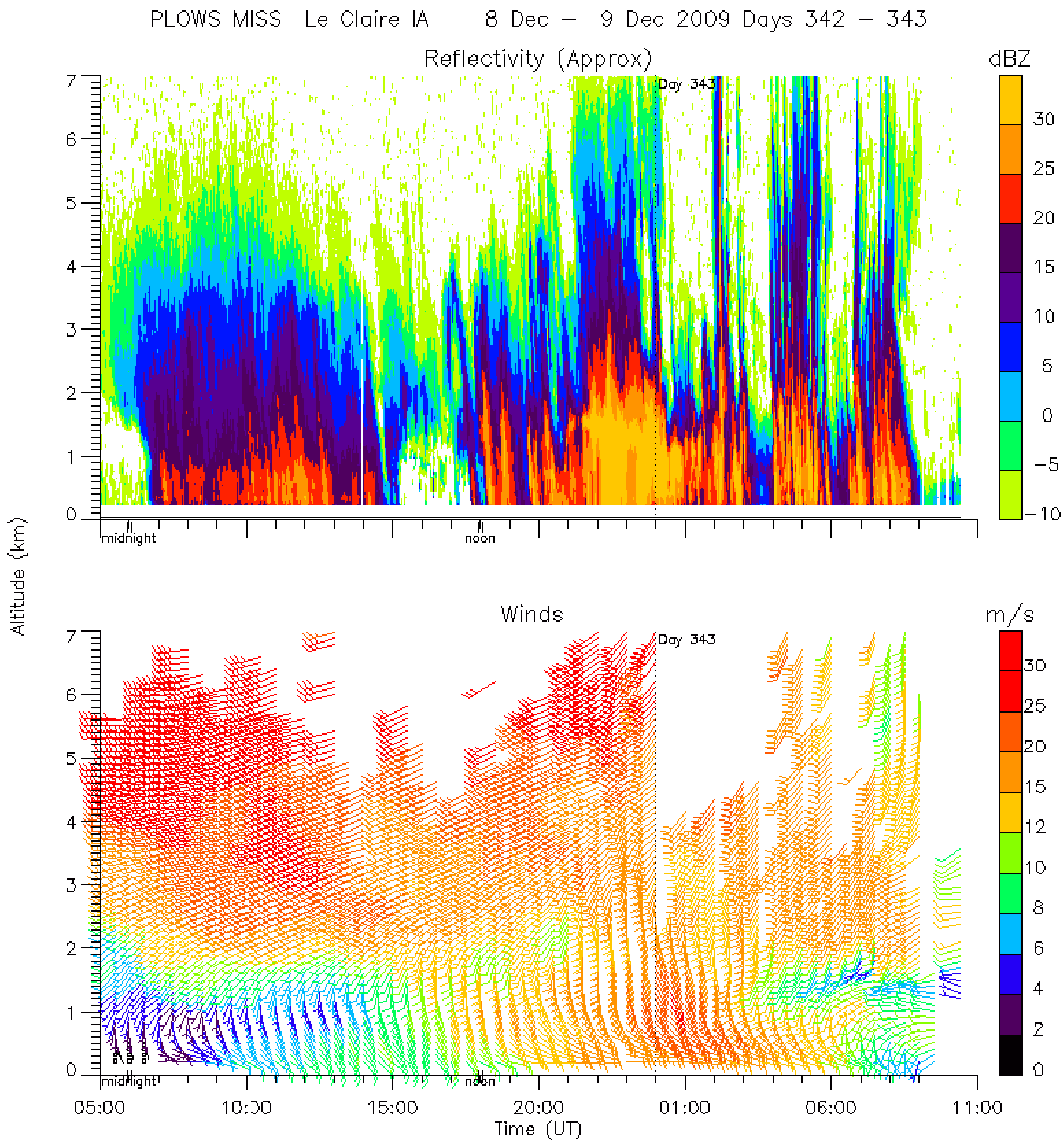


Figure 20: MISS 915 MHz Profiler SNR (top), and winds
for the period of operation 0500 UTC 8 Dec 09 through 1030 UTC 9 Dec 09

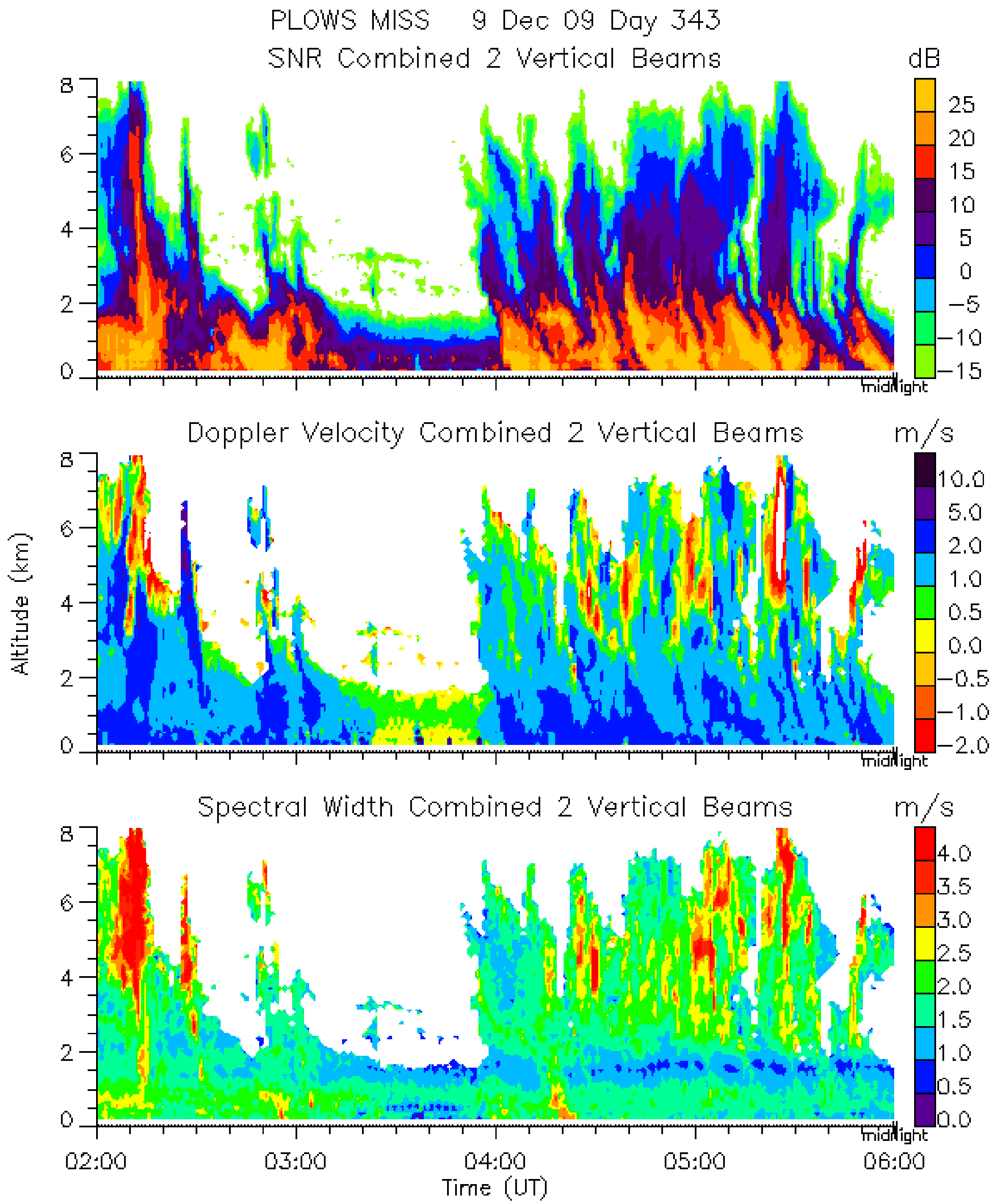


Figure 21: MISS 915 MHz Profiler SNR (top), Radial Velocity (center) and Spectral Width (bottom) for the most convective period from 0200 to 0600 UTC 9 Dec 09

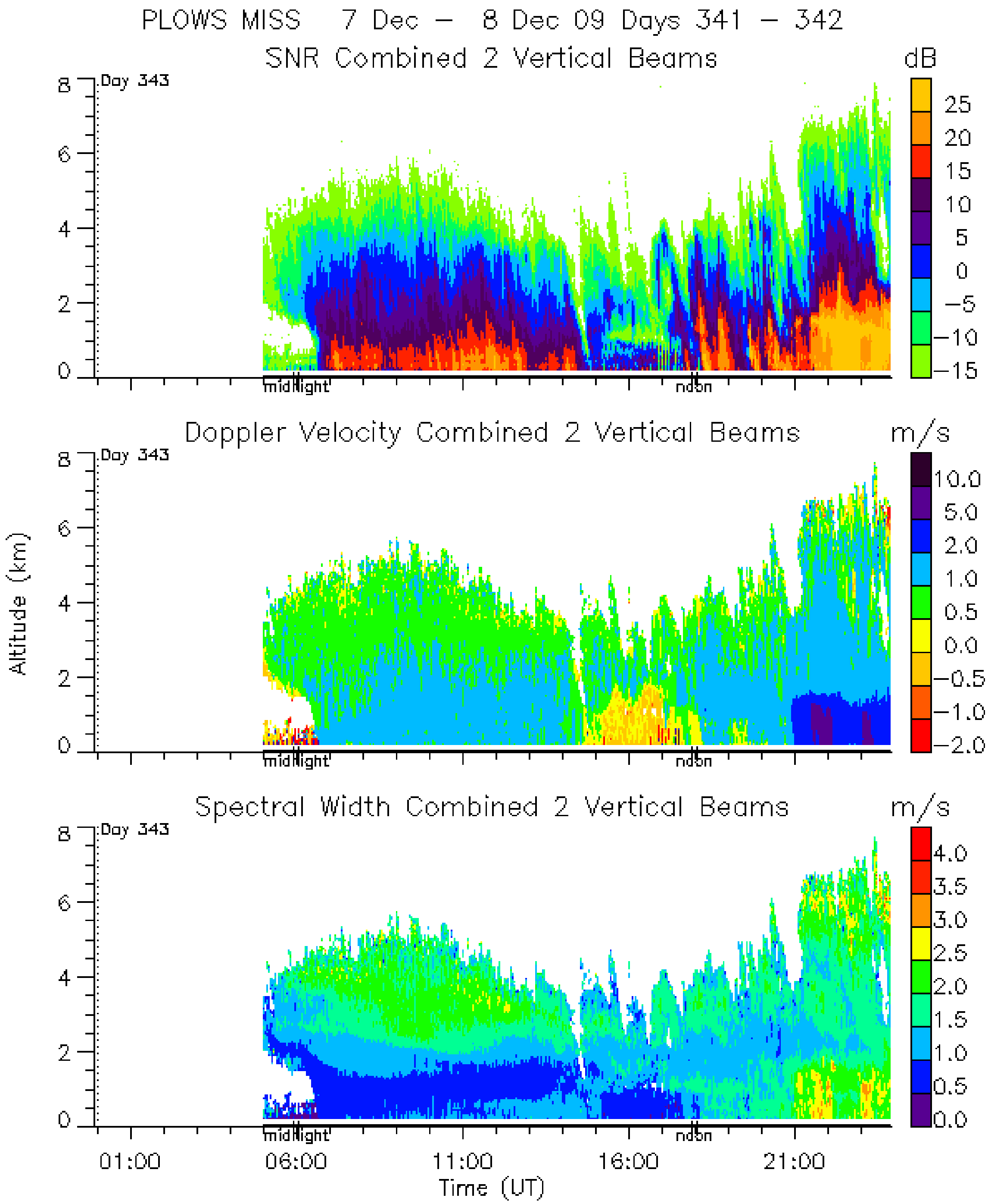


Figure 22: MISS 915 MHz Profiler SNR (top), Radial Velocity (center) and Spectral Width (bottom) for the most convective period from 0000 to 2359 UTC 8 Dec 09

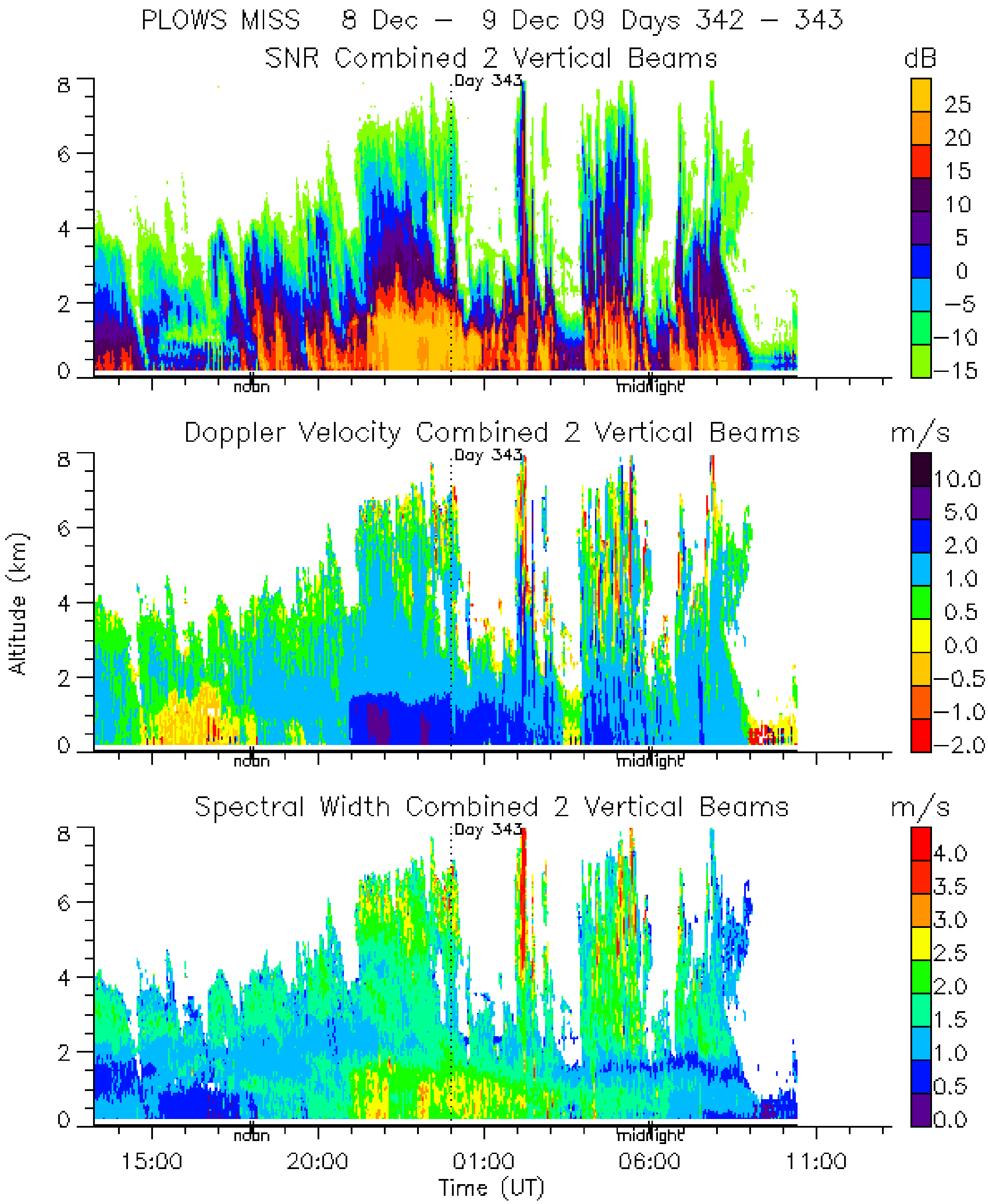


Figure 23: MISS 915 MHz Profiler SNR (top), Radial Velocity (center) and Spectral Width (bottom) from 1300 8 Dec 09 to 1030 UTC 9 Dec 09

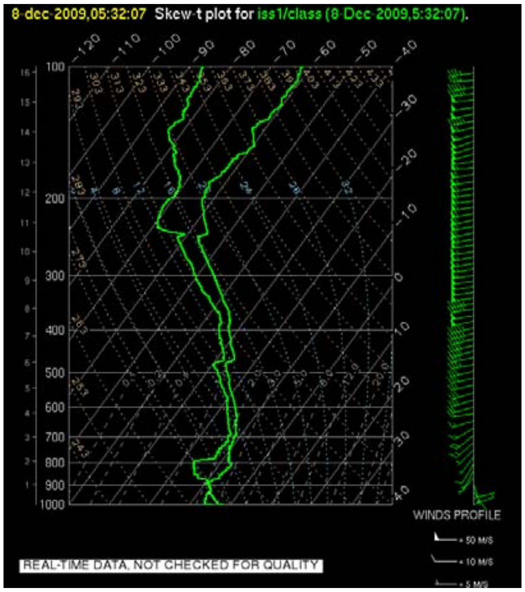
8. Rawinsondes

Rawinsondes were launched at the MISS site on a 2 hourly schedule. The following soundings were launched

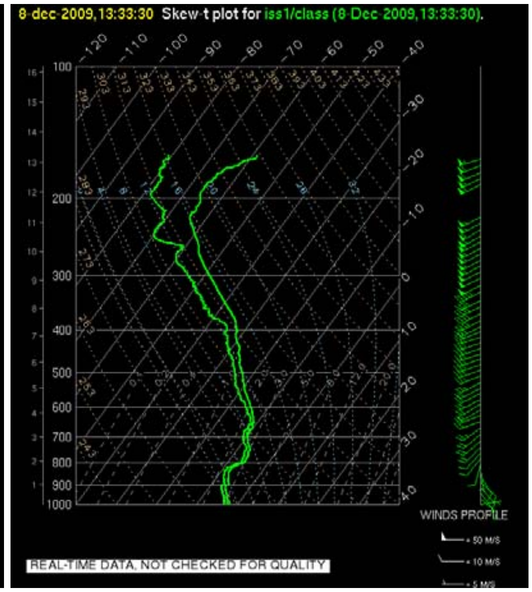
DATE	Launch	Nominal Date and time		Status
2009 12 08	**0532 UTC**	**2009 12 08**	**0600 UTC**	**Good**
2009 12 08	**1333 UTC**	**2009 12 08**	**1400 UTC**	**Good**
2009 12 08	**1531 UTC**	**2009 12 08**	**1600 UTC**	**Good**
2009 12 08	**1733 UTC**	**2009 12 08**	**1800 UTC**	**Good**
2009 12 08	**1934 UTC**	**2009 12 08**	**2000 UTC**	**Good**
2009 12 08	**2144 UTC**	**2009 12 08**	**2200 UTC**	**Good**
2009 12 08	**2346 UTC**	**2009 12 09**	**0000 UTC**	**Good**
2009 12 09	**0134 UTC**	**2009 12 09**	**0200 UTC**	**Good**
2009 12 09	**0334 UTC**	**2009 12 09**	**0400 UTC**	**Good**
2009 12 09	**0526 UTC**	**2009 12 09**	**0600 UTC**	**Good**
2009 12 09	**0908 UTC**	**2009 12 09**	**0900 UTC**	**Good**

Rawinsondes were launched at the MIPS site at Clinton, Iowa, by the University of Missouri on a primarily 3-hourly schedule. The following soundings were obtained

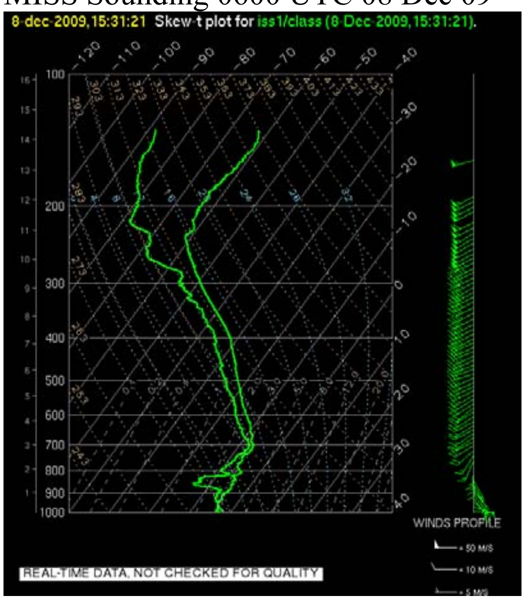
DATE	Launch	Nominal Date and time		Status
2009 12 08	**1341 UTC**	**2009 12 08**	**1400 UTC**	**Good**
2009 12 08	**1634 UTC**	**2009 12 08**	**1700 UTC**	**Good**
2009 12 08	**1931 UTC**	**2009 12 08**	**2000 UTC**	**Good**
2009 12 08	**2134 UTC**	**2009 12 08**	**2200 UTC**	**Good**
2009 12 08	**2334 UTC**	**2009 12 09**	**0000 UTC**	**Good**
2009 12 09	**0139 UTC**	**2009 12 09**	**0200 UTC**	**Good**
2009 12 09	**0339 UTC**	**2009 12 09**	**0400 UTC**	**Good**
2009 12 09	**0538 UTC**	**2009 12 09**	**0600 UTC**	**Winds lost above 550 mb**
2009 12 09	**0732 UTC**	**2009 12 09**	**0800 UTC**	**Good**



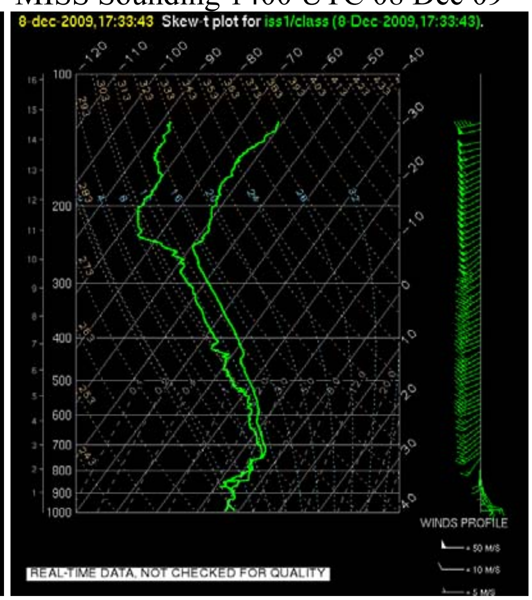
MISS Sounding 0600 UTC 08 Dec 09



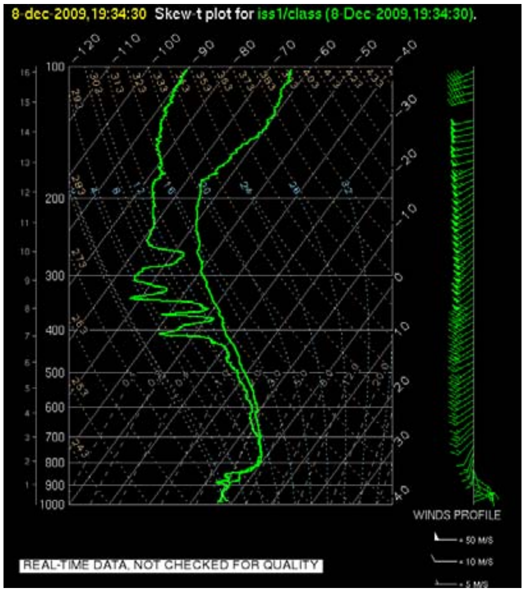
MISS Sounding 1400 UTC 08 Dec 09



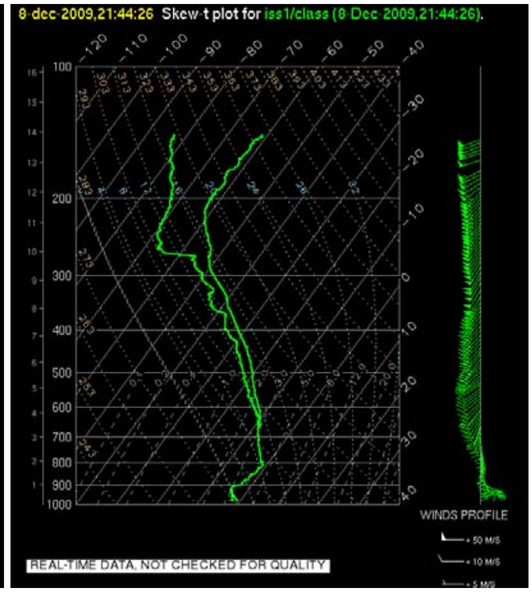
MISS Sounding 1600 UTC 08 Dec 09



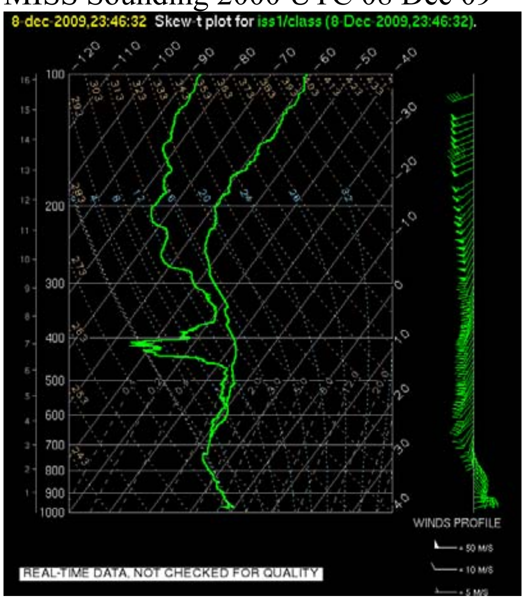
MISS Sounding 1800 UTC 08 Dec 09



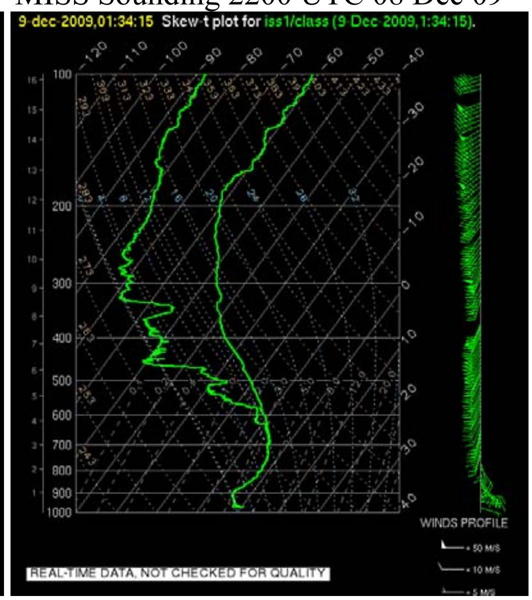
MISS Sounding 2000 UTC 08 Dec 09



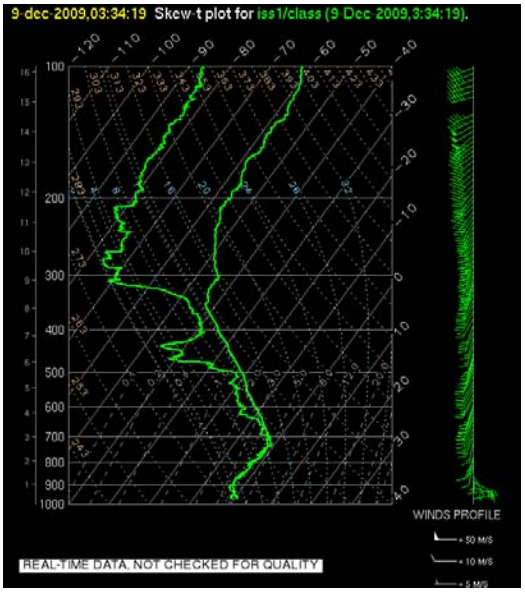
MISS Sounding 2200 UTC 08 Dec 09



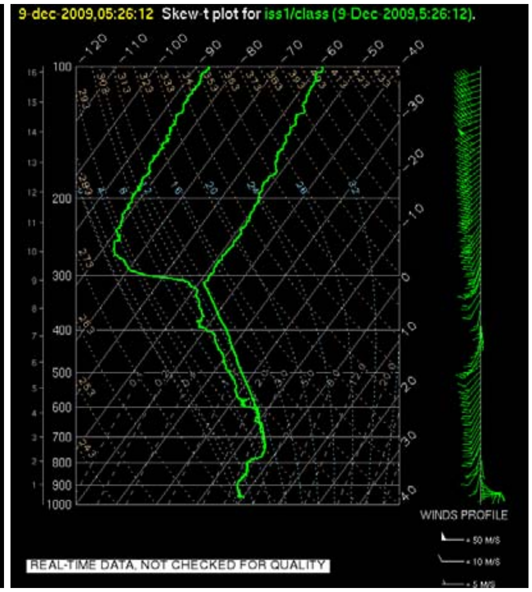
MISS Sounding 0000 UTC 09 Dec 09



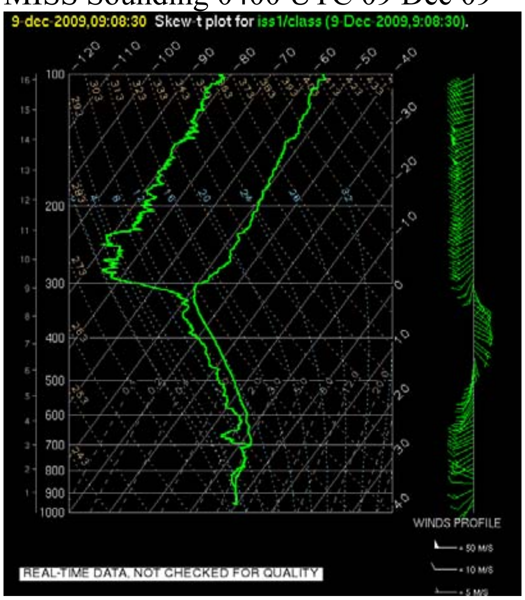
MISS Sounding 0200 UTC 09 Dec 09



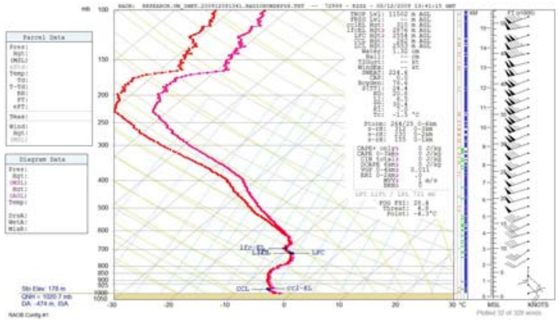
MISS Sounding 0400 UTC 09 Dec 09



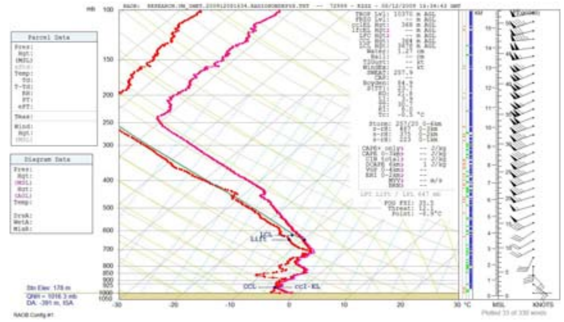
MISS Sounding 0600 UTC 09 Dec 09



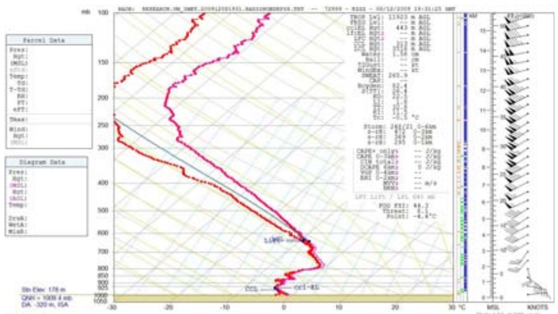
MISS Sounding 0900 UTC 09 Dec 09



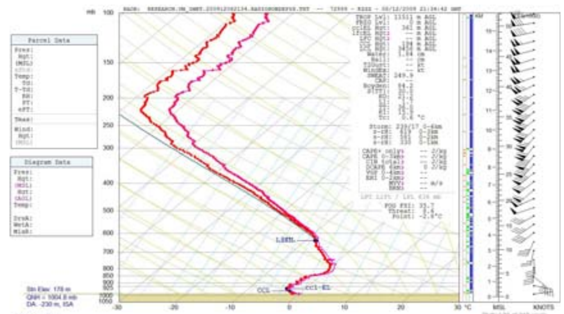
UM sounding 1400 UTC 08 Dec 2009



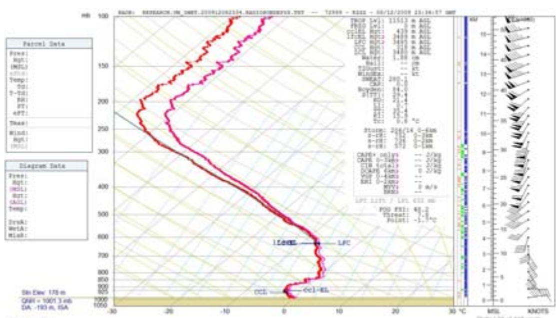
UM sounding 1700 UTC 08 Dec 2009



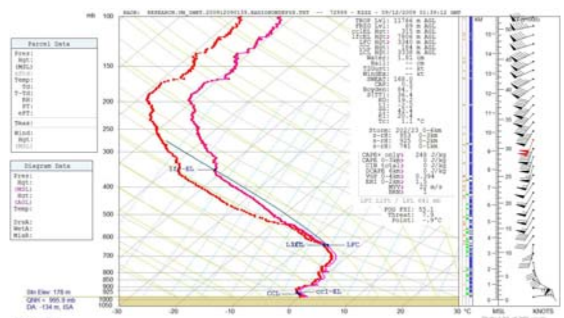
UM sounding 2000 UTC 08 Dec 2009



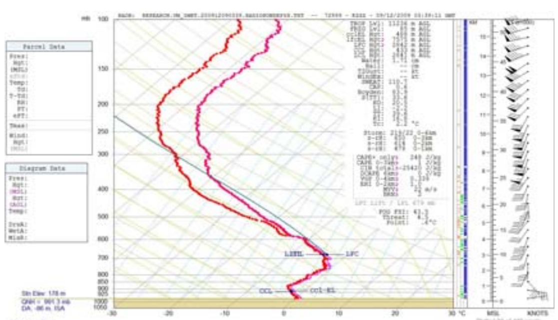
UM sounding 2200 UTC 08 Dec 2009



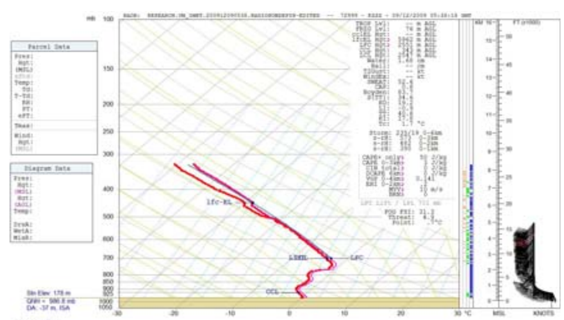
UM sounding 0000 UTC 09 Dec 2009



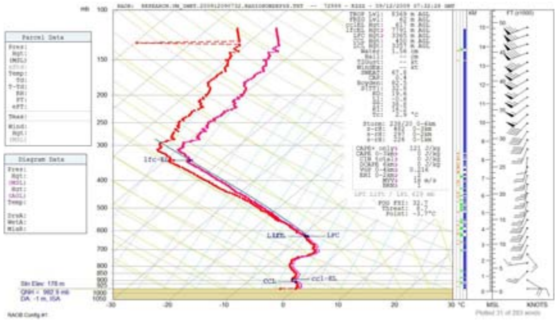
UM sounding 0200 UTC 09 Dec 2009



UM sounding 0400 UTC 09 Dec 2009



UM sounding 0600 UTC 09 Dec 2009



UM sounding 0800 UTC 08 Dec 20099