IOP-9 Summary of Operations
2 December 2009, 0000 UTC – 03 December 2009 0700 UTC

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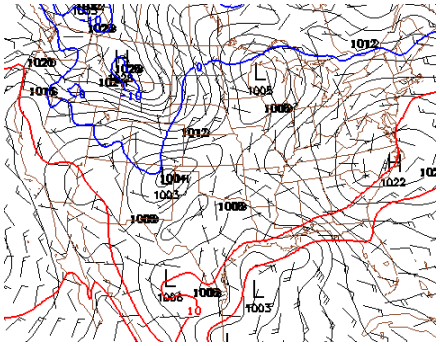
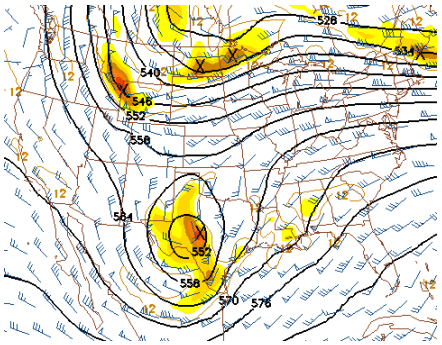
1. Summary of storm evolution

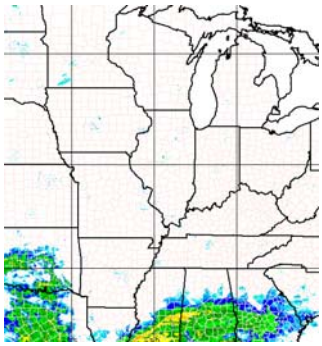
IOP-9 focused on a cyclone that developed along the Gulf Coast. The cyclone was triggered by the eastward advance of a cutoff low which had been anchored for several days over the Baha Peninsula. As the cutoff evolved into an open wave between 0000 UTC and 1800 UTC on 02 December, and progressed toward the Gulf Coast, the cyclone deepened and moved northward into western Tennessee. The precipitation shield associated with the wrap around band progressed slowly northward toward Indiana. PLOWS ground based platforms were located to set up a SW lobe orientation with the Indianapolis, IN WSR-88D, with the MIPS in Amo, Indiana and the MISS in Franklin, IN. Initially, the cloud shield associated with the wrap-around produced only light rain, as the air near the surface was dry and precipitation aloft was evaporating as it fell. The wrap-around band intensified with time, rotating so that it maintained a position just west of, or directly over the MIPS and MAX sites, while remaining just west of the MISS. The MISS remained near the edge of the dry slot for most of the event. Generating cells were evident on the MIPS, MAX RHIs and from the aircraft with the WCR. The flight was targeted at the wraparound band, with a significant stacked pattern across the dual-Doppler lobe at the time when the most intense precipitation passed over the MIPS/MAX within the dual Doppler lobe. The surface precipitation changed to snow during the period of band passage over the MIPS. The cyclone continued to pull northward and eastward, and operations were terminated at about 0600 to 0700 UTC after precipitation ended at all the sites.

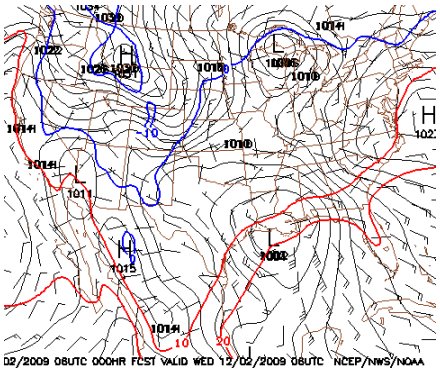
2. Locations of instrumentation platforms

MIPS Location:	39° 41' 41.37"N 86° 36' 56.52"W
Profiler Time of Operation MIPS:	12/2/09 1354 UTC to 12/3/09 0646 UTC
MAX Location:	39° 32' 34.84"N 86° 35' 59.71"W
Radar Time of Operation MAX:	12/2/09 1519 UTC to 12/3/09 0532 UTC
MISS Location:	39°28'58.07"N 86° 1' 9.65"W
Profiler Time of Operation	12/2/09 1100 UTC to 12/3/09 0630 UTC
MO Location:	39° 41' 41.37"N 86° 36' 56.52"W
RF-03 Flight operations:	12/2/09 19:51 UTC - 12/3/09 04:54 UTC

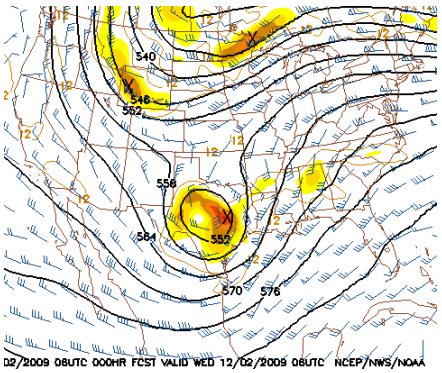

0000 UTC 02 Dec 09 Surface P/T/wind


0000 UTC 02 Dec 09 500 mb Ht/Vort/Wind

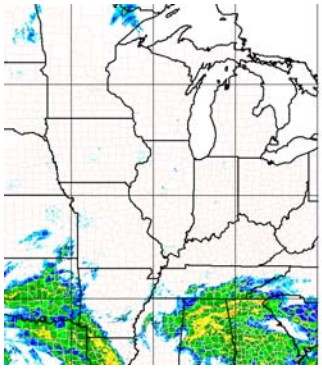

0000 UTC 02 Dec 09 radar

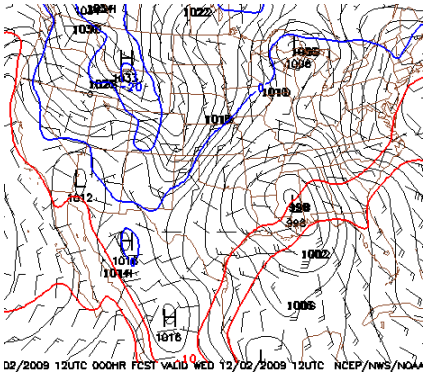


0600 UTC 02 Dec 09 Surface P/T/wind

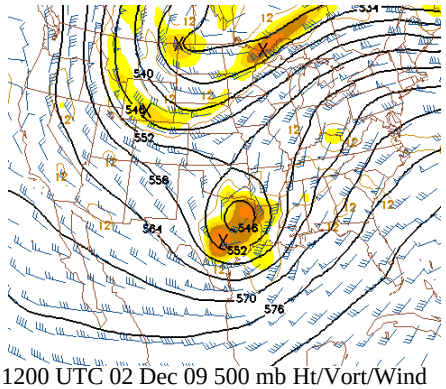


0600 UTC 02 Dec 09 500 mb Ht/Vort/Wind


0600 UTC 02 Dec 09 radar



1200 UTC 02 Dec 09 Surface P/T/wind


1200 UTC 02 Dec 09 500 mb Ht/Vort/Wind

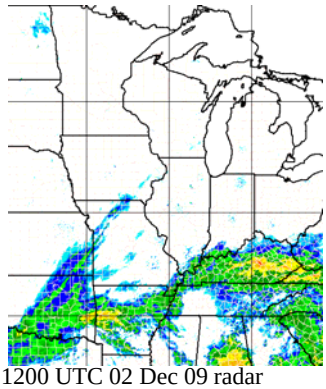

1200 UTC 02 Dec 09 radar

Figure 1: Early evolution of the IOP-9 storm at the surface, 500 mb, and radar echoes from 0000 UTC 02 Dec 09 through 1200 UTC 02 Dec 09.

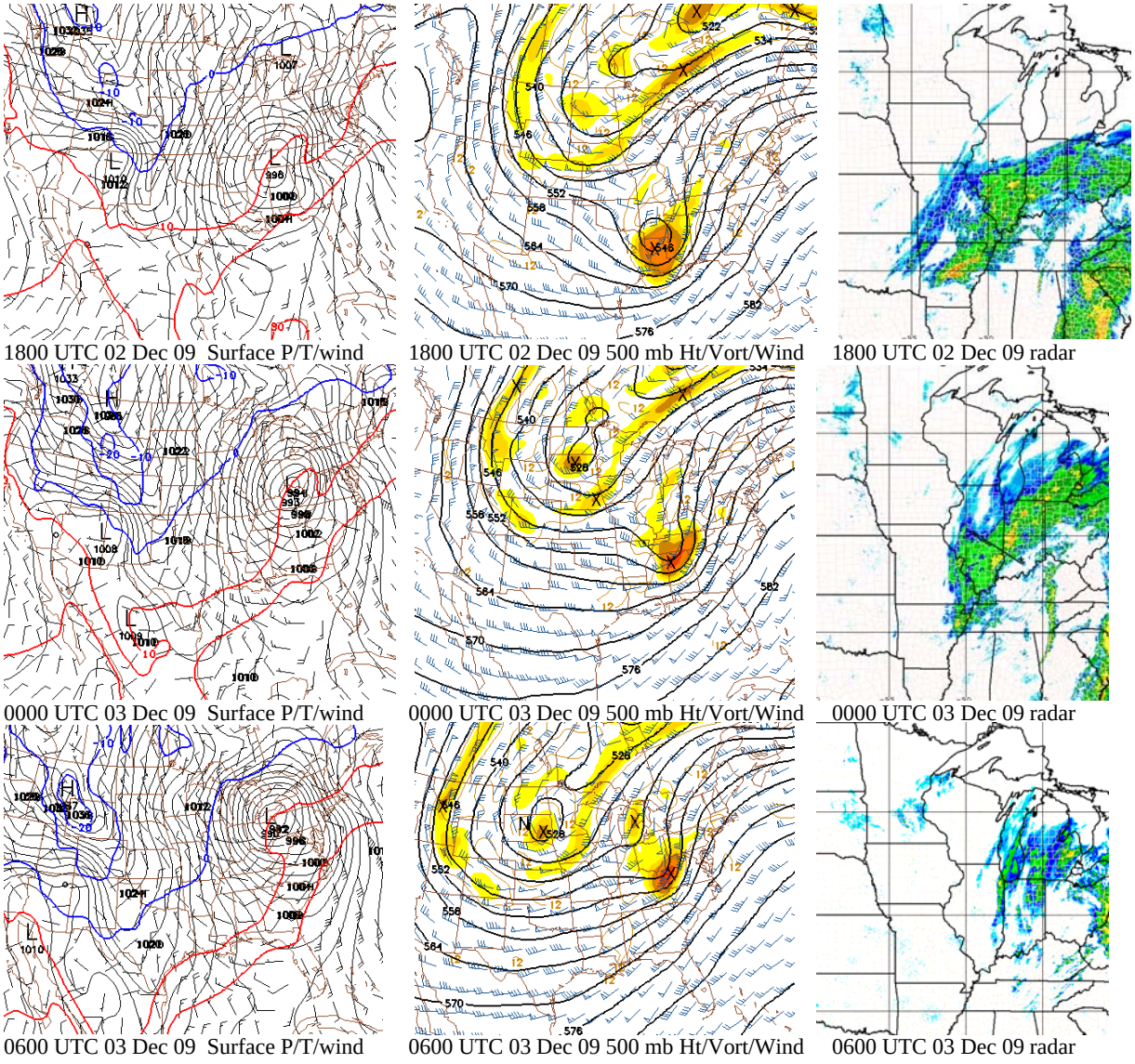


Figure 2: Later evolution of the IOP-9 storm at the surface, 500 mb, and radar echoes from 1800 UTC 02 Dec 09 through 0600 UTC 03 Dec 09.

3. Precipitation over research area

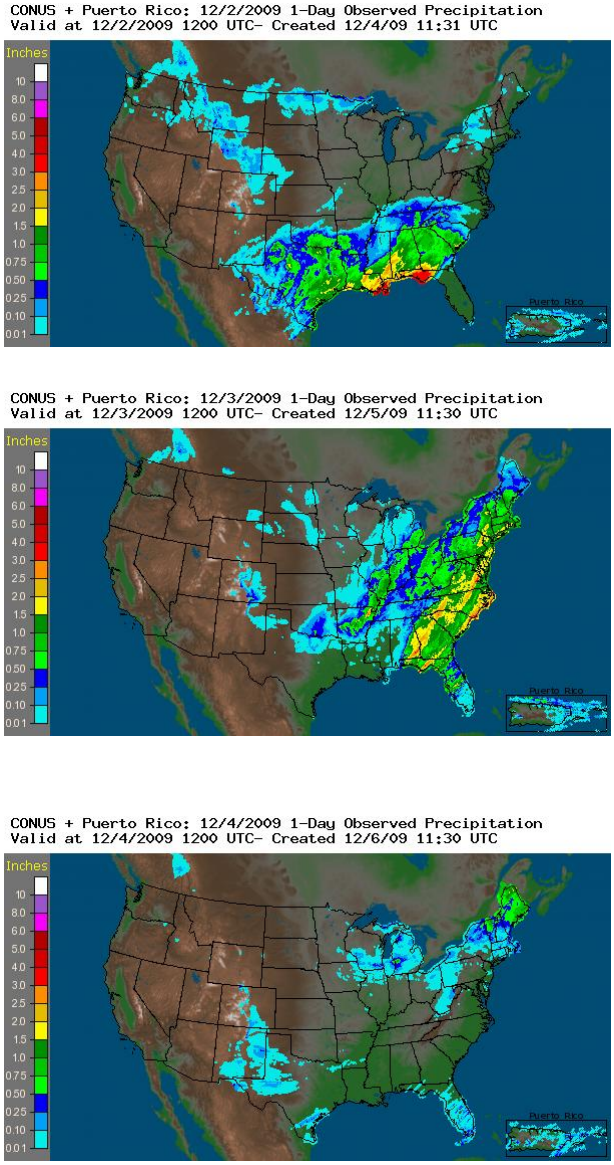


Fig. 3: 24 Hour precipitation ending at 1200 UTC 12/02/09, 12/03/09, 12/04/09 over the United States

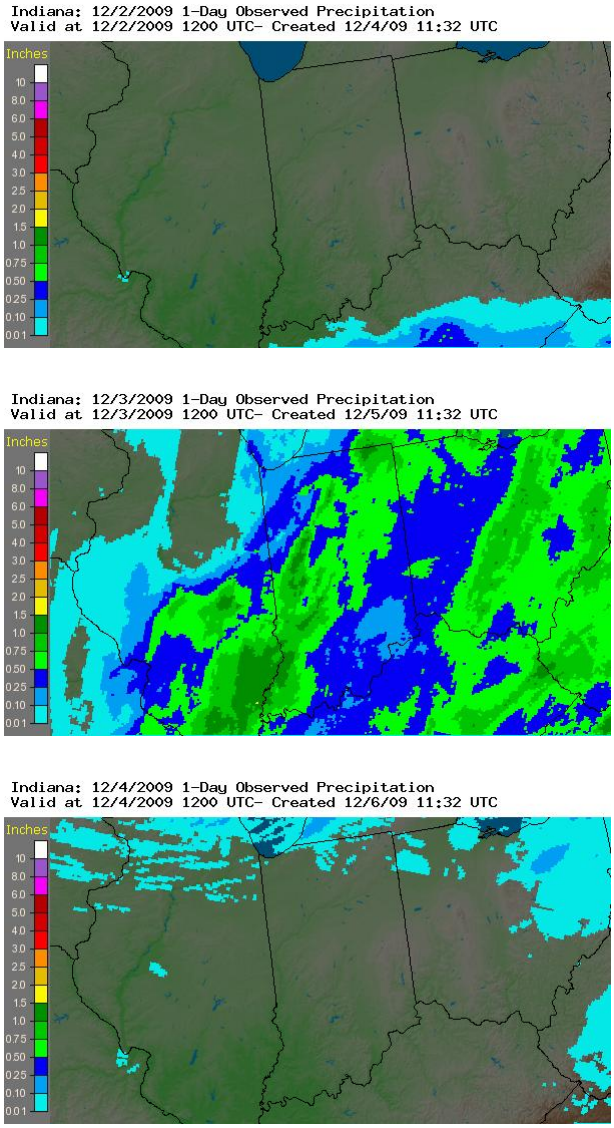


Fig. 4: 24 Hour precipitation ending at 1200 UTC 12/02/09, 12/03/09, 12/04/09 over Illinois and Indiana

4. Flight Summary

C-130 Flight RF-03

The NCAR C-130 took off at around 18:50 UTC (12:50 local) and made measurements in the wrap-around band in Illinois and Indiana as the band moved northwest during the mission. On departure from Peoria, the C-130 headed to VOR ABB at 13 kft. On this leg there were some problems with the INS winds and aircraft vertical velocities. A large generating cell with strong echoes up to 3 km above the C-130 was seen before reaching the dry slot after which echoes up to 1.5 km above and no generating cells were observed. Upon reaching ABB, the C-130 ascended and flew back to Peoria at 16 kft. There were still problems with the INS winds for the first half of this leg, but they were ok after a reboot at 21:15 UTC. On this leg, the C-130 went through the lower part of some large generating cells with strong upward motion that extended 2.5 km above the C-130; large supercooled water droplets were penetrated by the C-130, the lidar attenuated within 100 m of the C-130 and vertical motions of up to 2 m s^{-1} were seen. Near Peoria, Kelvin-Helmholtz waves were seen about 1.5 km above the C-130. Upon reaching Peoria, the C-130 ascended to 19 kft and headed southwest towards Bowman, IN (BQM). For the first part of this leg, the C-130 flew near the tops of the radar echoes, going through a generating cell with motions up to 2 m s^{-1}. There were reports of small activity in generating cells up to 1.6 km above. At other parts of the track the most intense vertical velocities were 2.5 km above the C-130. When the C-130 reached the dry slot shortly before BQM, it ascended to 26 kft for a return leg to Burlington (BRL). On this leg, cloud extended about 1.5 km above the C-130, maximum updrafts were around 2 m s^{-1} and the C-130 flew in a region above which the reflectivities dropped. There was no strong signature of liquid on the lidar.

After exiting the strongest echoes, the clouds were stratiform all the way to the surface so the C-130 turned early and headed back to BQM at 23 kft. On this leg, the lidar showed the C-130 flying in liquid. Tops were 2 km above the C-130 and the reflectivity dropped off rapidly above the C-130. At the latitude of Hoosier Indiana (OOM), echoes started to break below the C-130 with tops decoupled from lower parts, so the C-130 turned and headed northwest to Danville, Illinois (DNV) at 20 kft. Legs flown for the rest of the flight were now shorter, concentrating on the most intense part of the band. On the leg to DNV, two layers were noted by the radar with a break in between (altostratus above, solid looking deck below), with the C-130 about 500 m above the break. No vertical velocities above 0.5 m s^{-1} were sampled with the strongest echoes 1.5 km above. After reaching DNV, the C-130 ascended to 23 kft and returned to OOM. On this leg, a gap between the upper and lower layers with weak echoes up to 2 km above and more intense echoes 2 km below were noted. The next leg from OOM to DNV at 18 kft positioned the C-130 at the top of the lower layer for part of the leg with updrafts just short of 3 m s^{-1} noted by the C-130 when going through part of a generating cell. The two layers were coming together for part of this leg, the C-130 was in liquid layer with the possibility the layer was being seeded by ice crystals from above. The C-130 spent part of this leg near the altitude of maximum reflectivity. The subsequent leg from DNV to OOM at 15 kft still showed a layered structure to the reflectivity pattern, the C-130 flying near the top of the gap with maximum reflectivity 2 km below. On this leg the C-130 encountered some supercooled water and

icing while flying in the upper part of the lower layer. To follow the progression of the highest reflectivity region, the next leg was flown from OOM to Boiler, Indiana (BVT) at 12 kft. Supercooled water was encountered, but not significant vertical motion; temperatures varied from -8 to -12^{o}C. After arrival at BVT, the C-130 descended to 9 kft an went to OOM. On this leg, stratiform cloud was noted up to 5 km above the C-130 and the C-130 passed about 500 m under a layer of significant liquid water seen by the lidar. The CSI ceased operation at the end of this leg (02:35 UTC) due to an empty cylinder. After arrival at OOM, the C-130 ascended to 13 kft and headed north to Knox Starke City, Indiana (OXI). On this leg, time was spent in regions of weaker reflectivity with the cloud layer above having higher reflectivity and possibly turbulence. After passing the maximum reflectivity region on the way to OXI, the C-130 turned south and ascended to 16 kft for the return to OOM. For parts of this leg there were 2 cloud layers, and in other parts the 2 layers merged. Prior to OOM, the C-130 turned north and ascended to 19 kft for a return to OXI. At the start of this leg and on the previous 2 legs, the radar did not detect a lot of turbulence or significant vertical motions; however, some supercooled water and vertical motions of up to 2.5 m s^{-1} were detected at 19 kft. On the subsequent northward leg, the C-130 again turned early to head south to OOM, now at 22 kft. On this leg, the C-130 was near the top of the cloud layer with weaker vertical velocities up to 1.2 m s^{-1} detected. Finally, the C-130 flew at 10 kft on the return leg to Peoria in order to sample some more bands that had estimated tops of between 12 and 15 kft.

C-130 Flight RF-03 Flight track

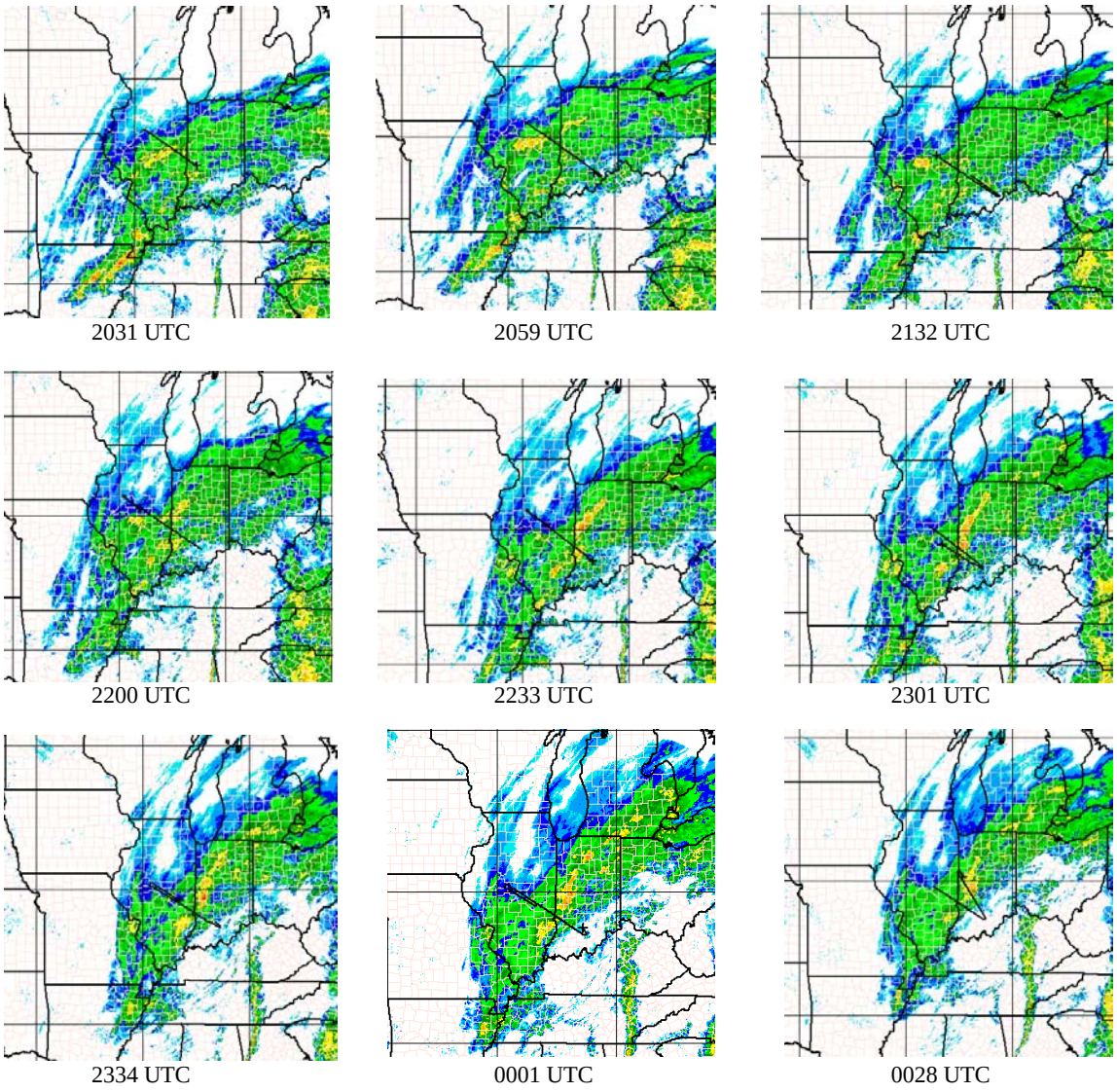


Figure 5: C-130 flight track overlaid on radar composites from 2031 UTC 02 Dec 09 through 0028 UTC 03 Dec 09. Times shown are the times of the radar composites. The flight track for the period just before the composite is shown.

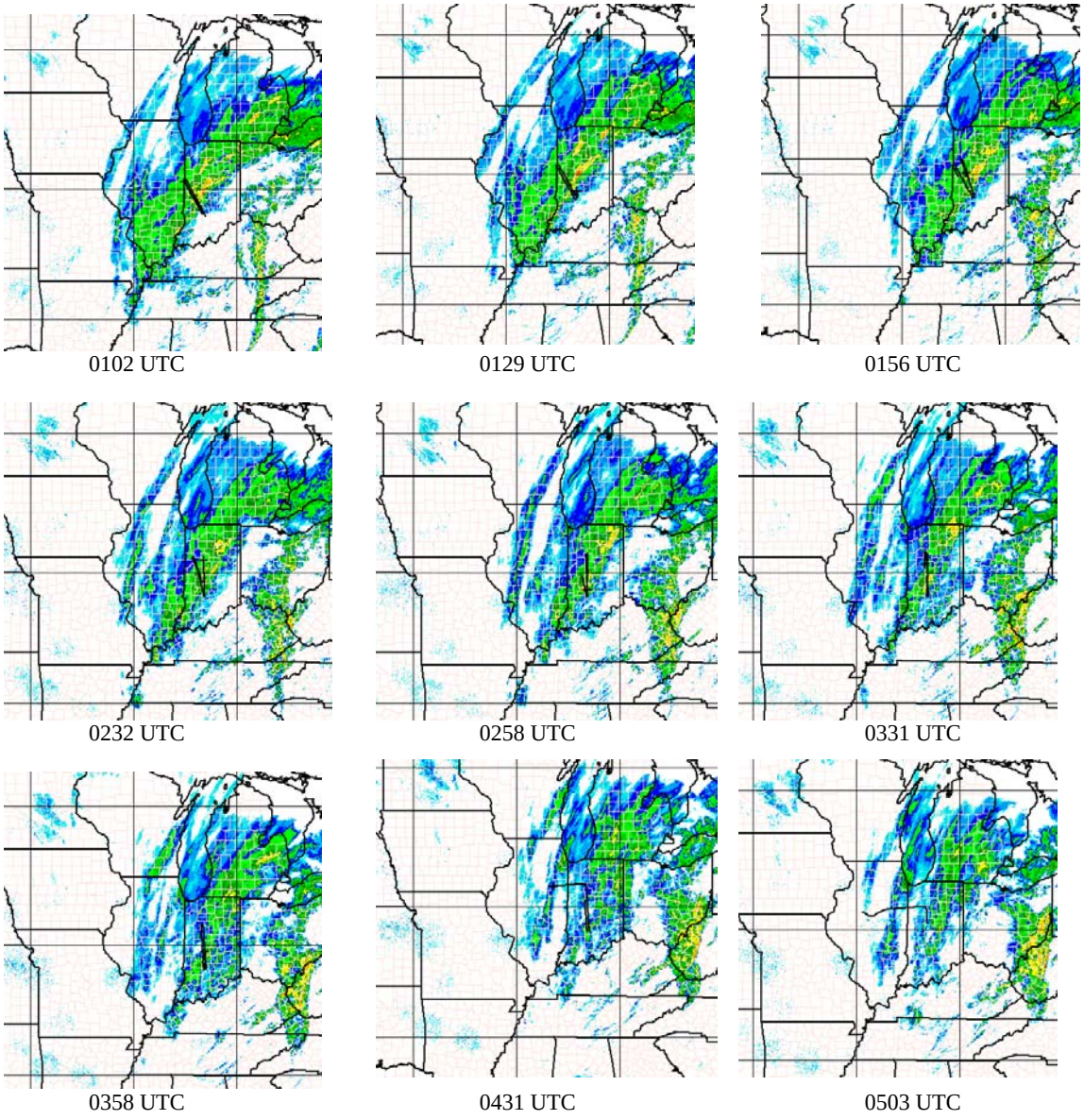
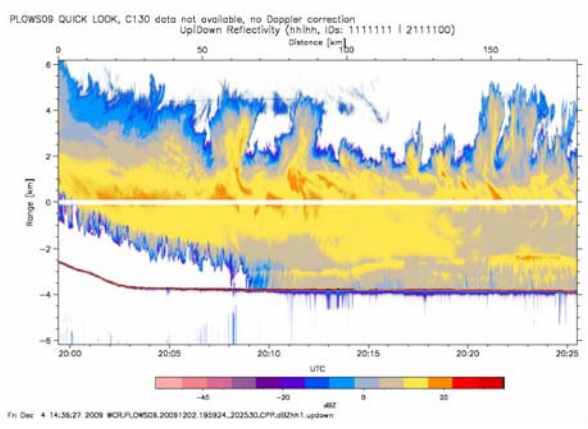
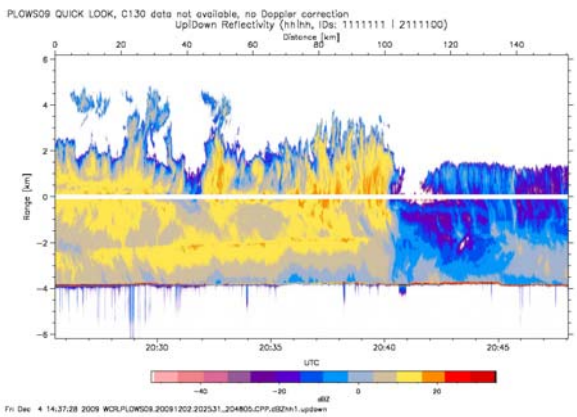


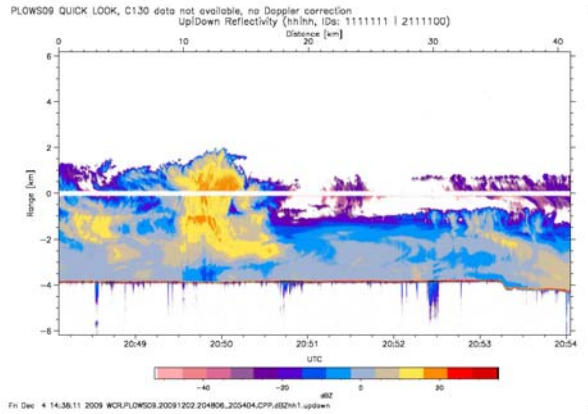
Figure 6: C-130 flight track overlaid on radar composites from 0102 UTC 03 Dec 09 through 0503 UTC 03 Dec 09. Times shown are the times of the radar composites. The flight track for the period just before the composite is shown.



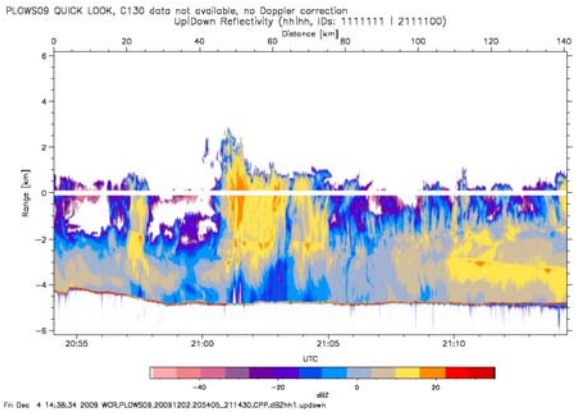
2000 UTC-2025 UTC



2025 UTC to 2048 UTC

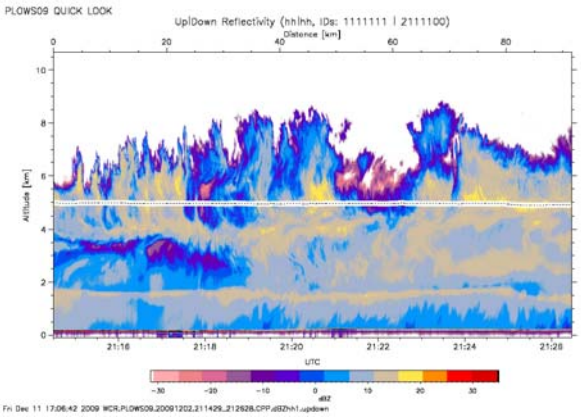


2048 UTC to 2054 UTC

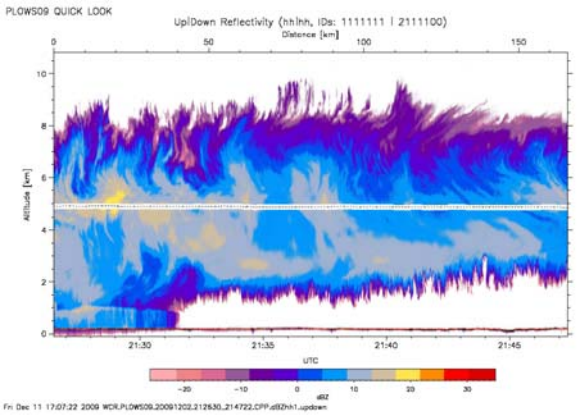


2054 UTC to 2114 UTC

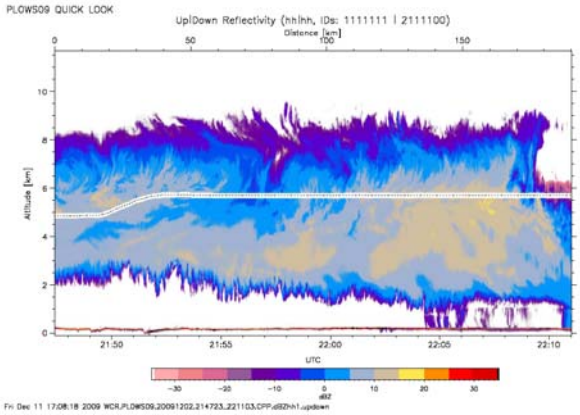
Fig. 7: Wyoming Cloud Radar Quicklook of radar reflectivity between 2000 UTC 2 Dec 09 and 2114 UTC 2 Dec 09. During this part of the flight, the aircraft INS was not functioning. As a result, on these plots, the aircraft height is at the 0 line and the ground (the red line at the bottom) is in negative kilometers. This will be corrected later.



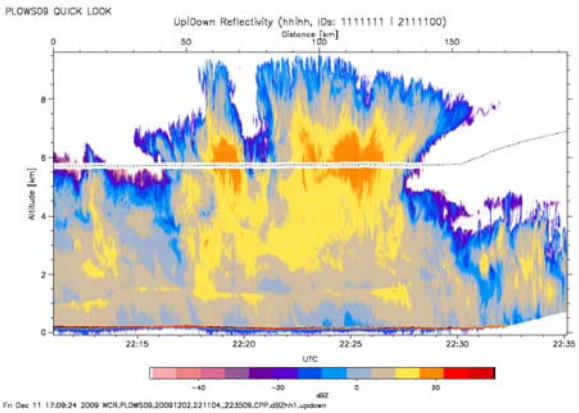
2114 UTC to 2127 UTC



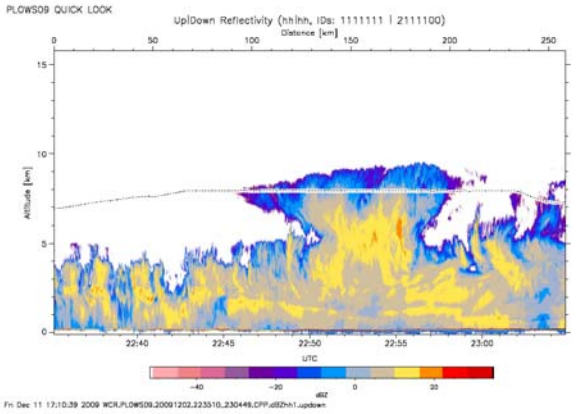
2127 UTC to 2147 UTC



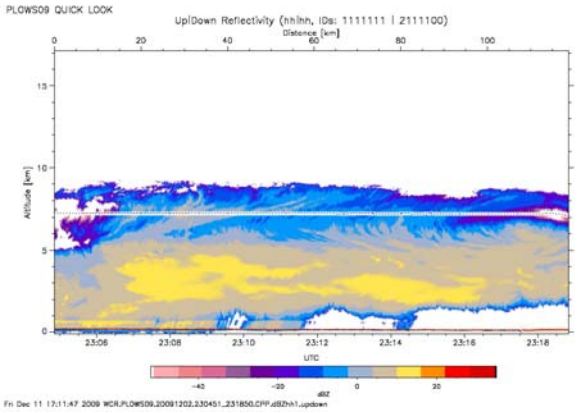
2147 UTC to 2211 UTC



2211 UTC to 2235 UTC

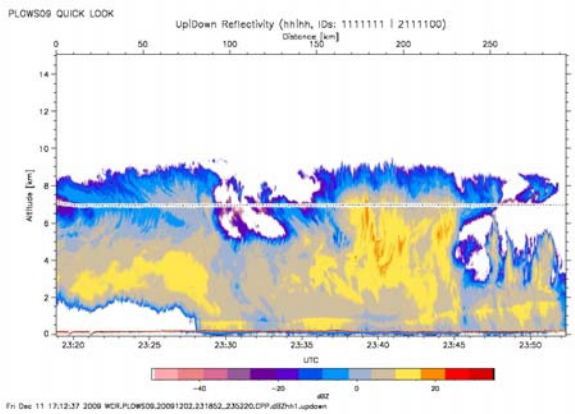


2235 UTC to 2305 UTC

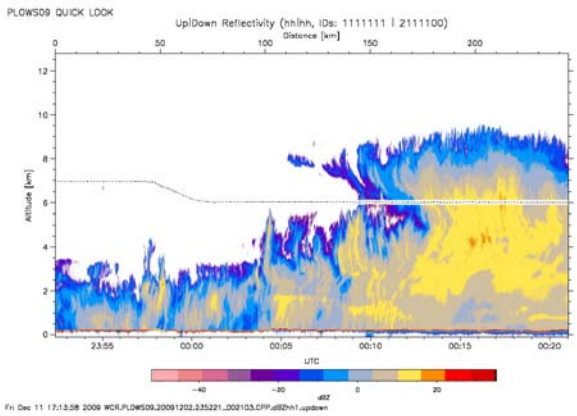


2305 UTC to 2318 UTC

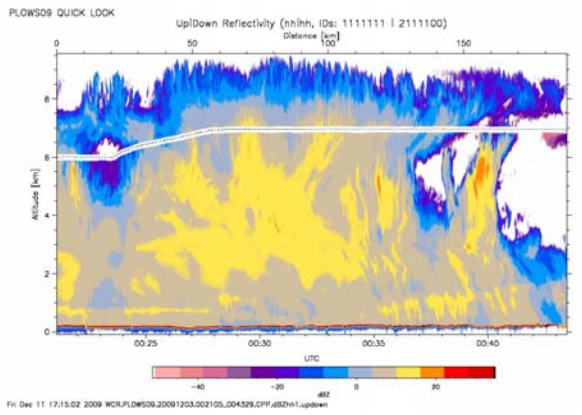
Fig. 8: Wyoming Cloud Radar Quick Look of radar reflectivity between 2114 UTC 2 Dec 09 and 2318 UTC 2 Dec 09.



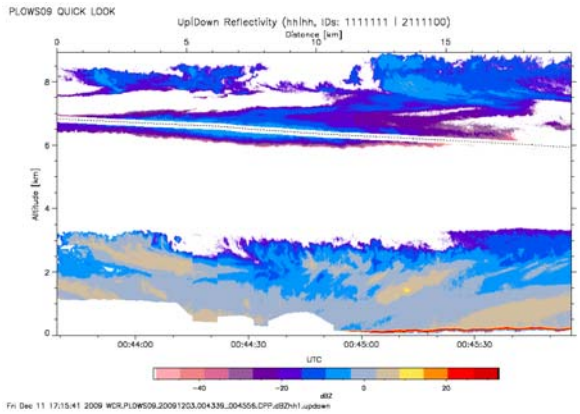
2318 UTC to 2352 UTC



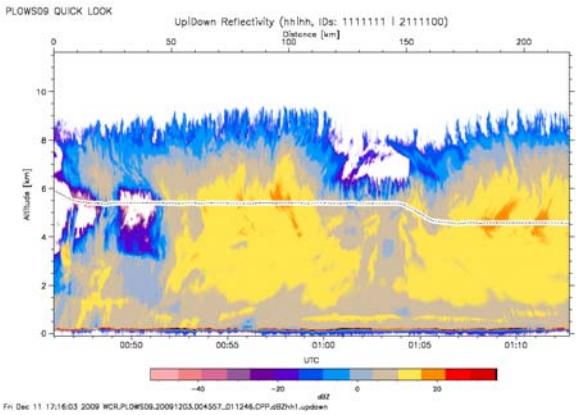
2352 UTC to 0020 UTC



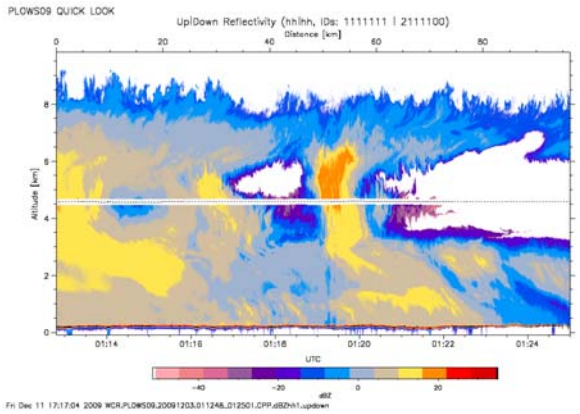
0020 UTC to 0043 UTC



0043 UTC to 0046 UTC

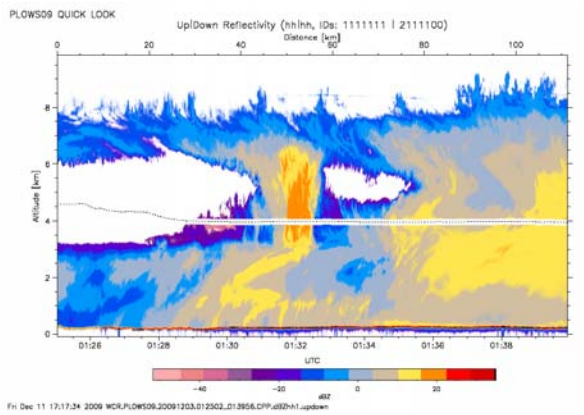


0046 UTC – 0112 UTC

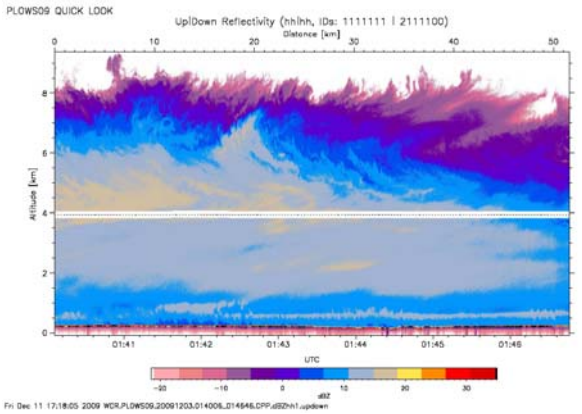


0112 UTC to 0126 UTC

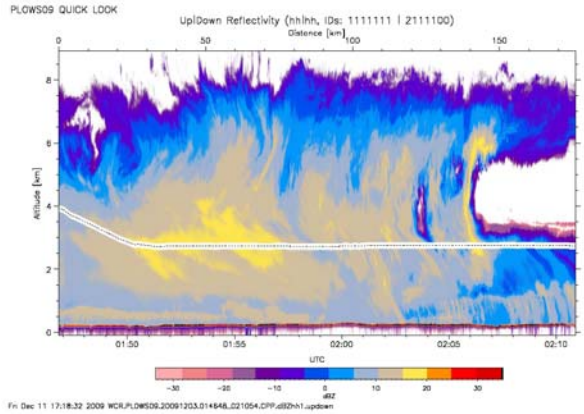
Fig. 9 Wyoming Cloud Radar Quick Look of radar reflectivity between 2318 UTC 2 Dec 09 and 0126 UTC 3 Dec 09.



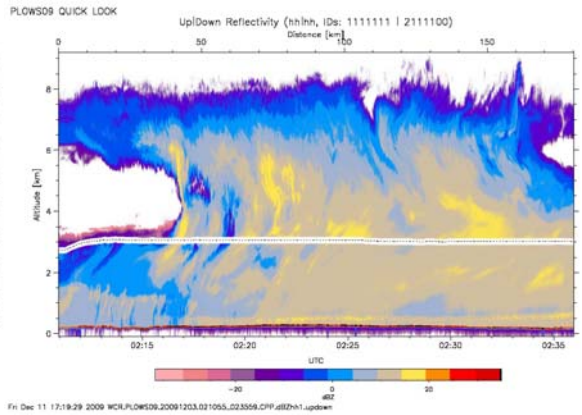
0126 UTC to 0140 UTC



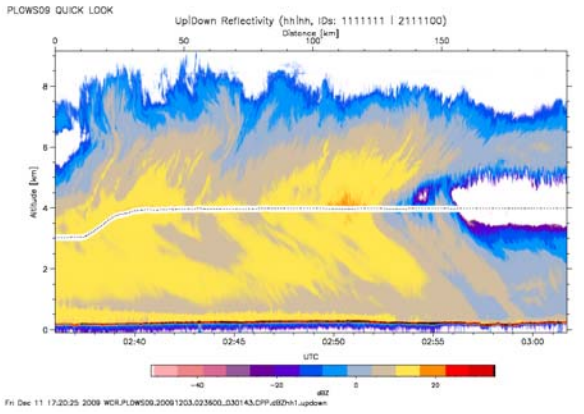
0140 UTC to 0147 UTC



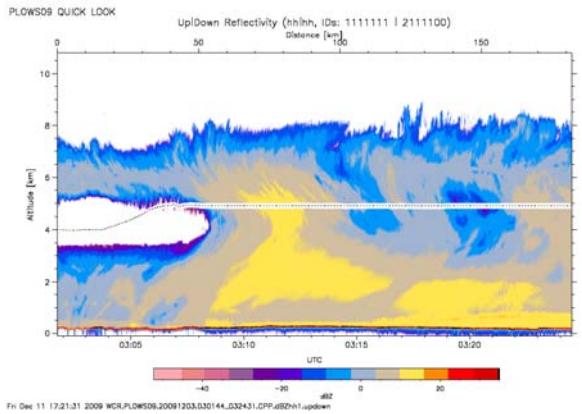
0147 UTC to 0210 UTC



0210 UTC to 0236 UTC



0236 UTC to 0302 UTC



0302 UTC to 0324 UTC

Fig. 10: Wyoming Cloud Radar Quick Look of radar reflectivity between 0126 UTC 3 Dec 09 and 0324 UTC 3 Dec 09.

5. MIPS operations

The MIPS operated in a school parking lot in Amo, Indiana during the event. Details will be provided in a later draft about MIPS operations. Data from the 915 MHz profiler are provided in Figs. 11-12. Two drop-out times occurred early in the event from 1630-1845 UTC and again from 2100 to 2200 UTC on December 2. Convective cells moved over the site during much of the event. Rain changed to snow around 0145 UTC on Dec 3.

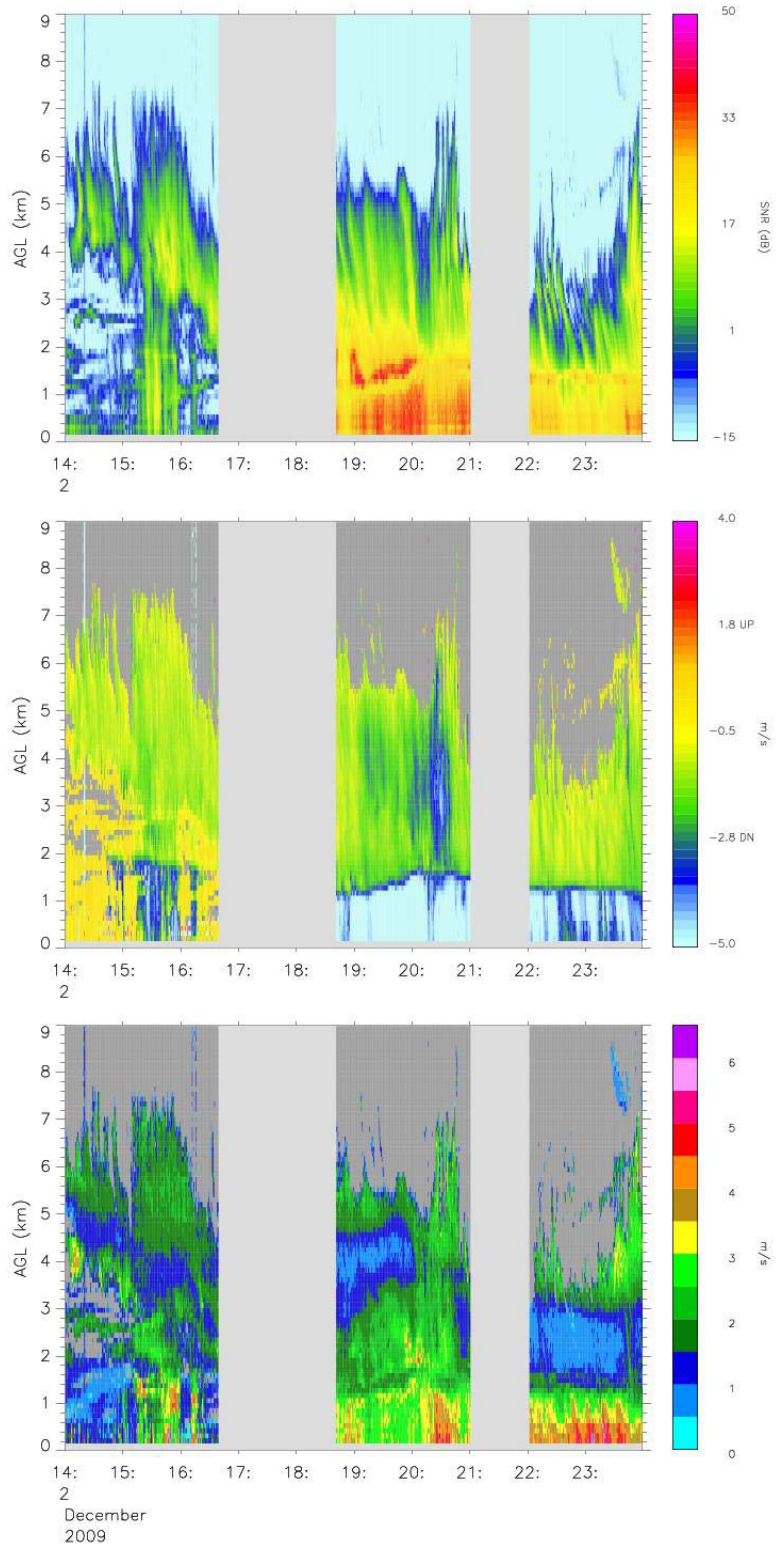


Figure 11: MIPS 915 MhZ Profiler SNR (top), Radial Velocity (center) and Spectral Width (bottom) for the period 1400 UTC 02 Dec 09-0000 UTC 03 Dec 09.

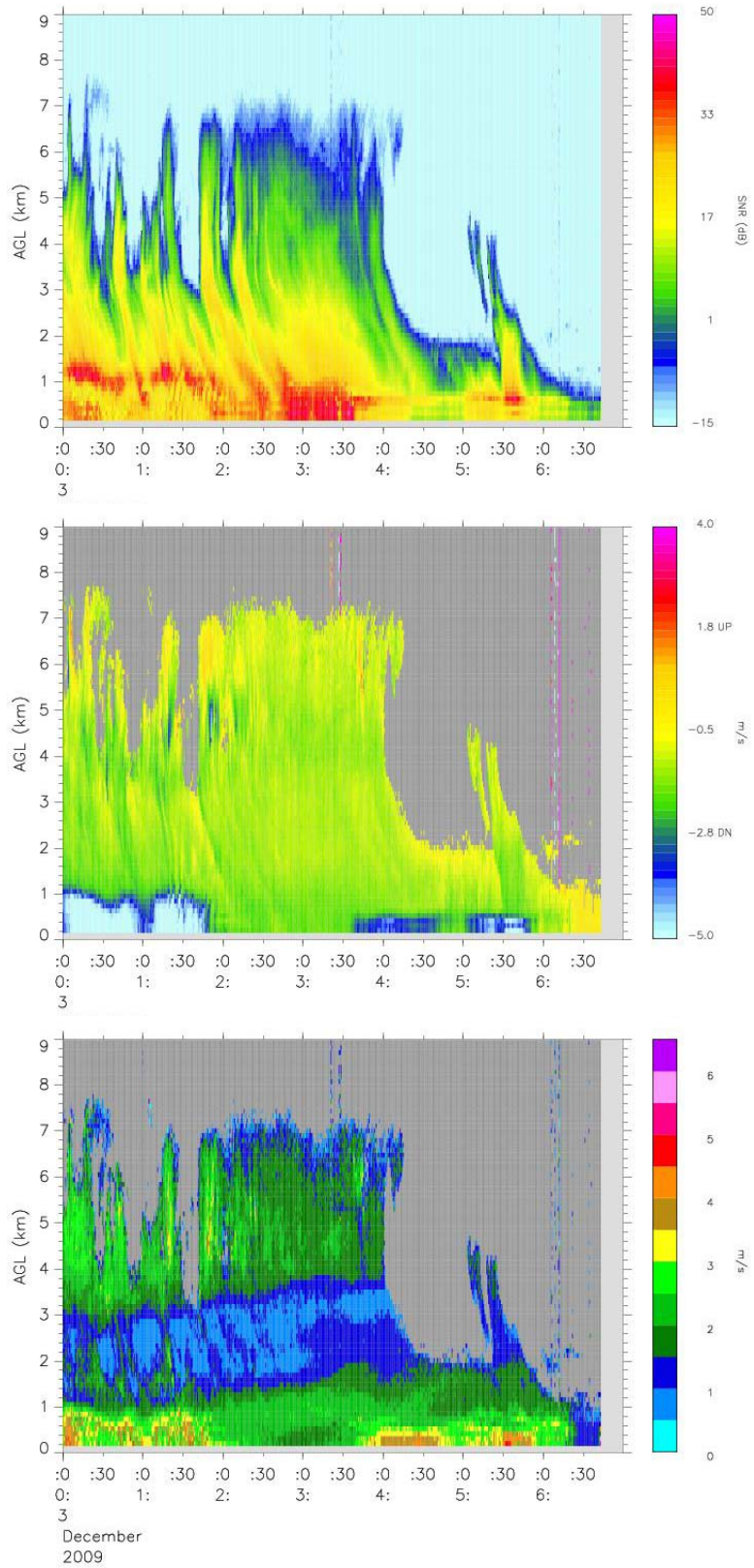


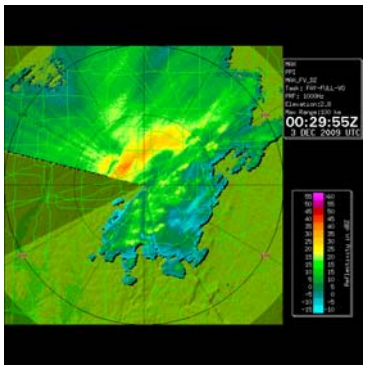
Figure 12: MIPS 915 MhZ Profiler SNR (top), Radial Velocity (center) and Spectral Width (bottom) for the period 0000 UTC 03 Dec 09-0630 UTC 03 Dec 09.

6. MAX operations

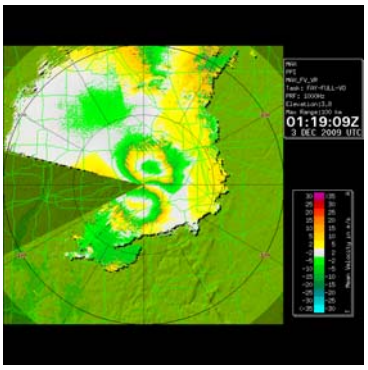
The MAX conducted cycles of full volume VAD and RHI scans over the MIPS site MISS sites. The total scan cycle time was about 6 min. The Indianapolis WSR-88D remained in VCP-11 model throughout the event.

MAX Scanning Angles: ?
MAX radar parameters ?

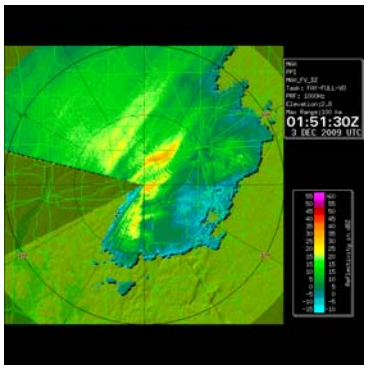
Images from the MAX are included below as Figs. 13-



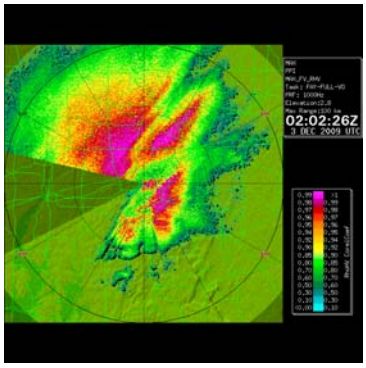
MAX PPI 0029 UTC 03 Dec 09



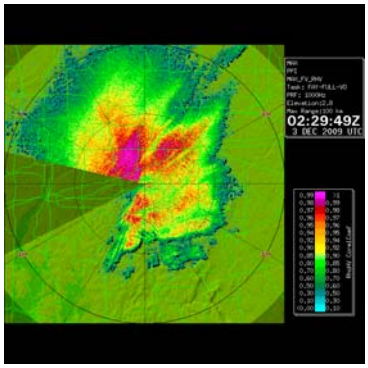
MAX PPI Vel 0119 UTC 03 Dec 09



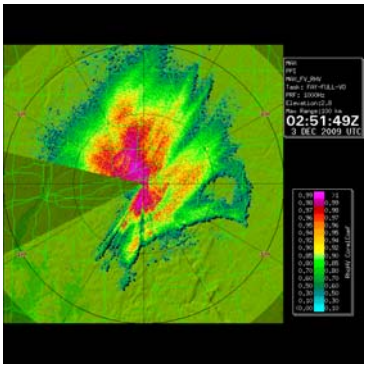
MAX PPI 0151 UTC 03 Dec 09



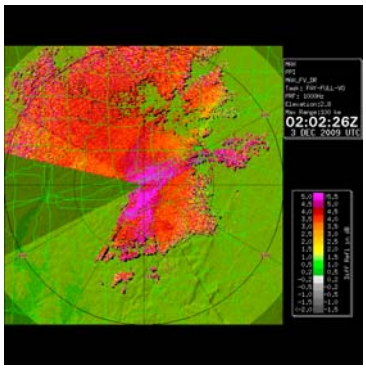
MAX PPI 0202 UTC 03 Dec 09



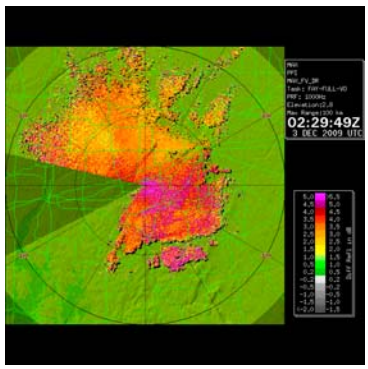
MAX PPI 0229 UTC 03 Dec 09



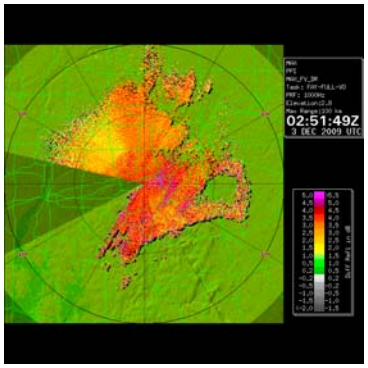
MAX PPI 0251 UTC 03 Dec 09



MAX PPI ZDR 0202 UTC 03 Dec 09

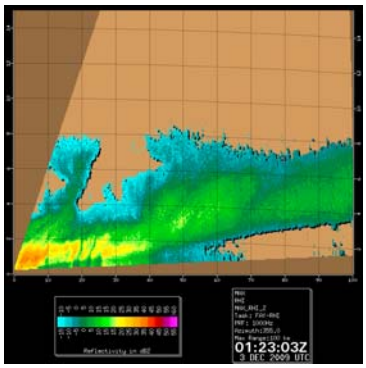


MAX PPI ZDR 0229 UTC 03 Dec 09

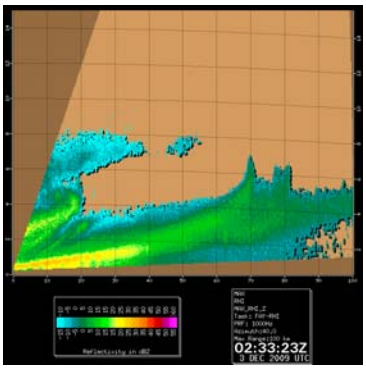


MAX PPI ZDR 0251 UTC 03 Dec 09

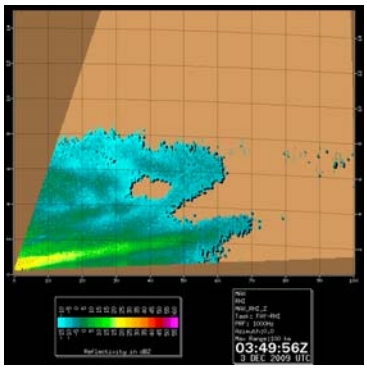
Figure 13: MAX PPI images during the passage of the major band between 0000 and 0300 UTC 03 Dec 09.



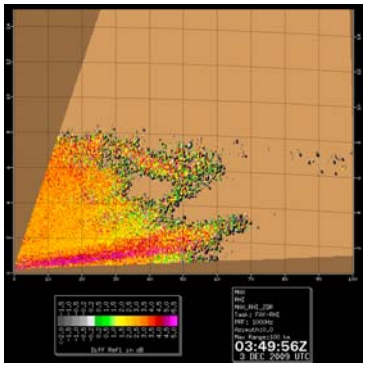
MAX RHI Z 0123 UTC 03 Dec 09



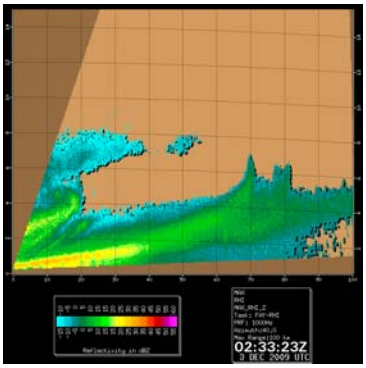
MAX PPI Z 0233 UTC 03 Dec 09



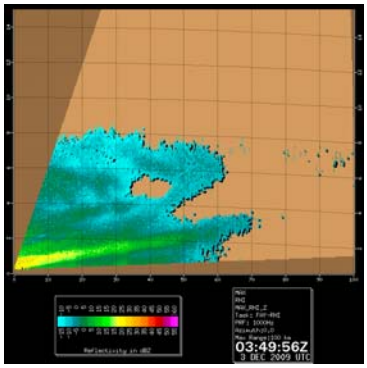
MAX PPI Z 0349 UTC 03 Dec 09



MAX RHI ZDR 0349 UTC 03 Dec



MAX PPI RHOHV 0233 UTC 03 Dec 09



MAX PPI RHOHV 0349 UTC 03 Dec 09

Figure 14: MAX PPI images during the passage of the major band between 0100 and 0400 UTC 03 Dec 09.

7. MISS 915 MHz Profiler

The MISS operated in the eastern dual Doppler lobe. Because of the path of the storm, the wrap-around band moved over the MISS between about 1400 UTC 2 Dec 09 and 0000 UTC 3 Dec 09. The MISS then moved into the dry slot and remained near the edge of the band for the remainder of the IOP.

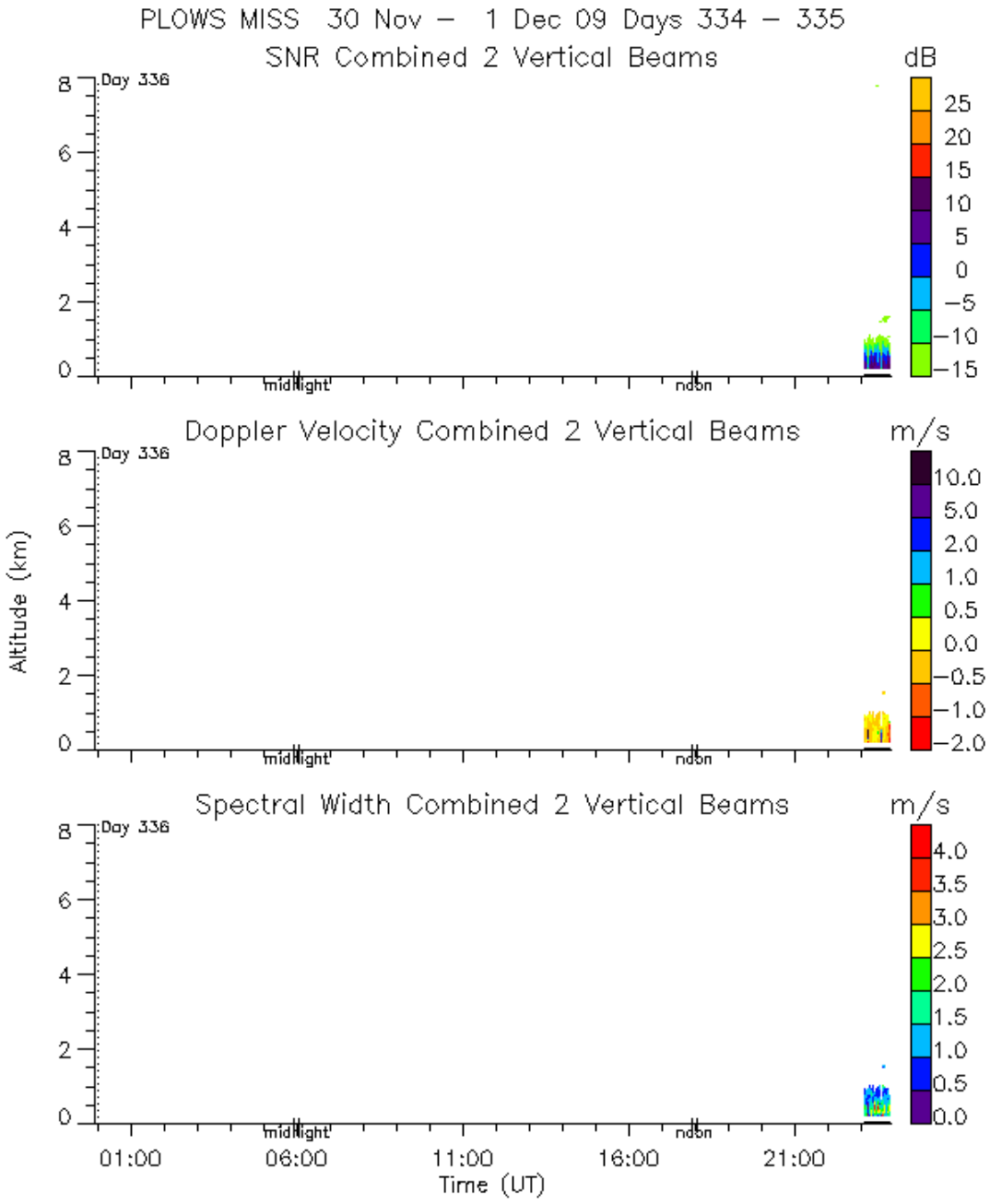


Figure 15: MISS 915 MHz Profiler SNR (top), Radial Velocity (center) and Spectral Width (bottom) for the period 0000 UTC 30 Nov 09 through 0000 UTC 1 Dec 09

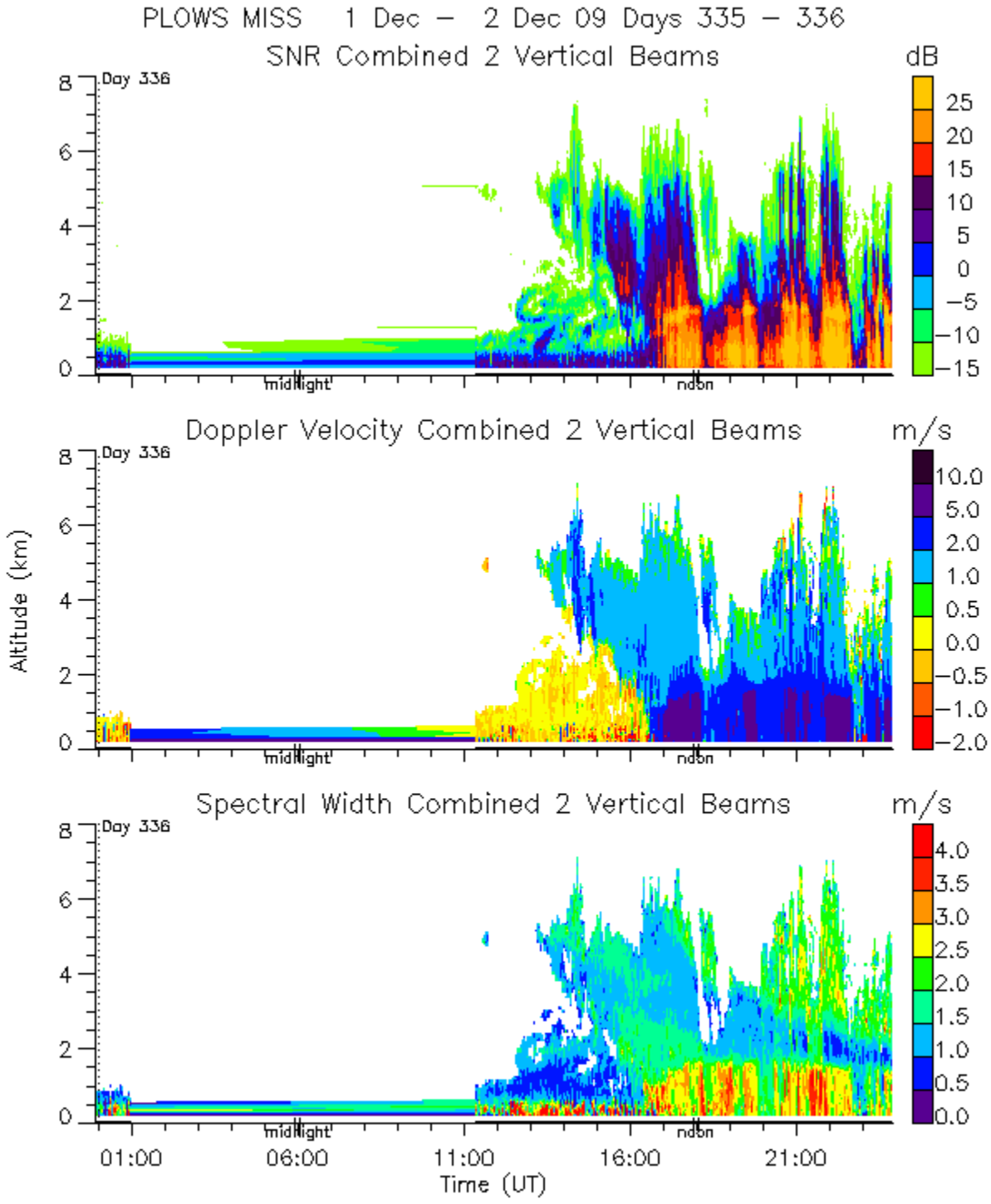


Figure 16: MISS 915 MHz Profiler SNR (top), Radial Velocity (center) and Spectral Width (bottom) for the period 0000 UTC 1 Dec 09 through 0000 UTC 2 Dec 09

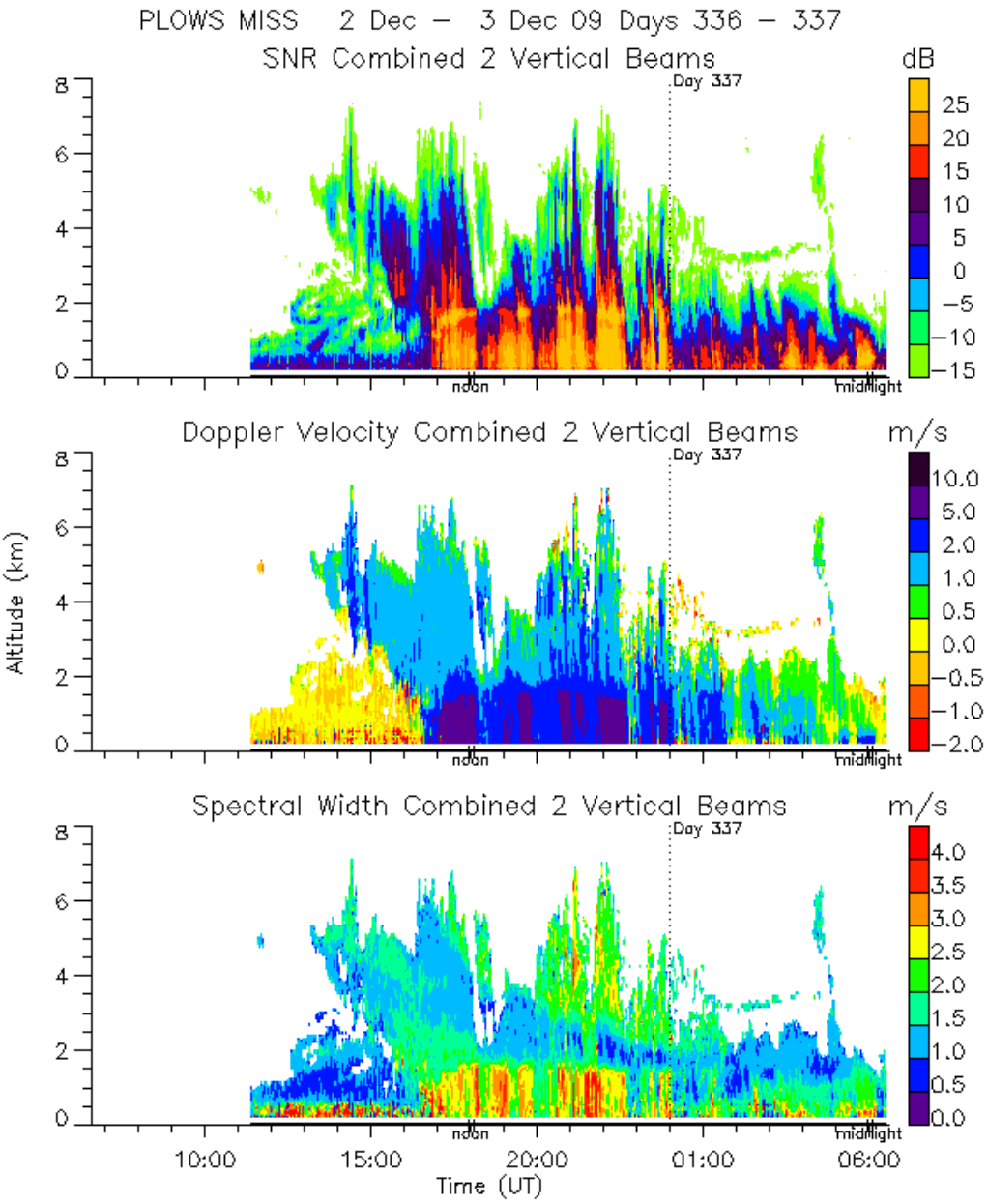


Figure 17: MISS 915 MHz Profiler SNR (top), Radial Velocity (center) and Spectral Width (bottom) for the period 0000 UTC 2 Dec 09 through 0000 UTC 3 Dec 09

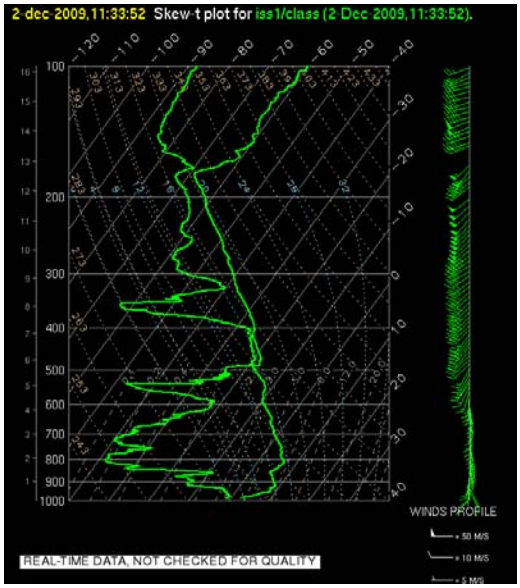
8. Rawinsondes

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

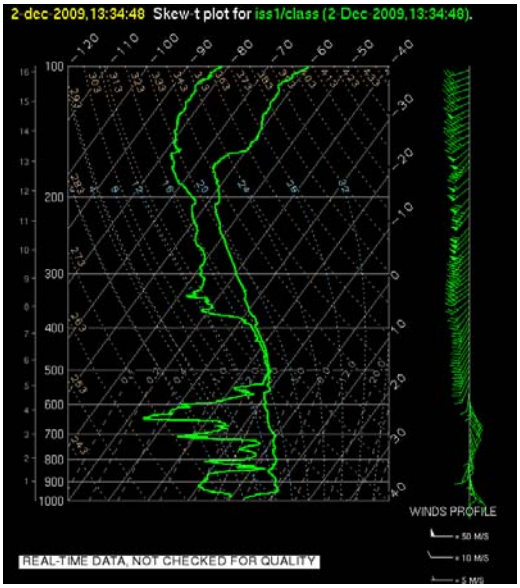
DATE	Launch	Nominal Date and time		Status
2009 12 02	**1133 UTC**	**2009 12 02**	**1200 UTC**	**Good**
2009 12 02	**1344 UTC**	**2009 12 02**	**1400 UTC**	**Good**
2009 12 02	**1536 UTC**	**2009 12 02**	**1600 UTC**	**Good**
2009 12 02	**1744 UTC**	**2009 12 02**	**1800 UTC**	**Good**
2009 12 02	**1935 UTC**	**2009 12 02**	**2000 UTC**	**Good**
2009 12 02	**2135 UTC**	**2009 12 02**	**2200 UTC**	**Good**
2009 12 02	**2332 UTC**	**2009 12 03**	**0000 UTC**	**Good**
2009 12 03	**0142 UTC**	**2009 12 03**	**0200 UTC**	**Good**
2009 12 03	**0330 UTC**	**2009 12 03**	**0400 UTC**	**Good**
2009 12 03	**0551 UTC**	**2009 12 03**	**0600 UTC**	**Data issues below 500 mb**

Rawinsondes were launched at the MIPS site in Amo, Indiana, by the University of Missouri on a two hourly schedule. The following soundings were obtained

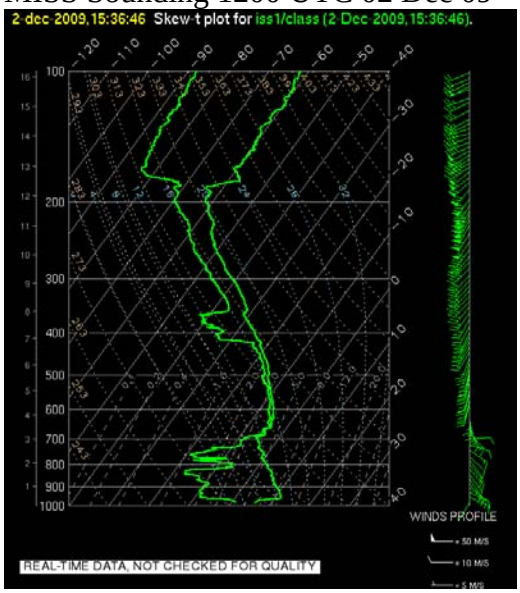
DATE	Launch	Nominal Date and time		Status
2009 12 02	**1409 UTC**	**2009 12 02**	**1400 UTC**	**Good**
2009 12 02	**1534 UTC**	**2009 12 02**	**1600 UTC**	**Good**
2009 12 02	**1735 UTC**	**2009 12 02**	**1800 UTC**	**Good**
2009 12 02	**1938 UTC**	**2009 12 02**	**2000 UTC**	**Good**
2009 12 02	**2129 UTC**	**2009 12 02**	**2200 UTC**	**Good**
2009 12 02	**2337 UTC**	**2009 12 03**	**0000 UTC**	**Good**
2009 12 03	**0142 UTC**	**2009 12 03**	**0200 UTC**	**Good**
2009 12 03	**0338 UTC**	**2009 12 03**	**0400 UTC**	**Incomplete & data issues**
2009 12 03	**0539 UTC**	**2009 12 03**	**0600 UTC**	**Good**



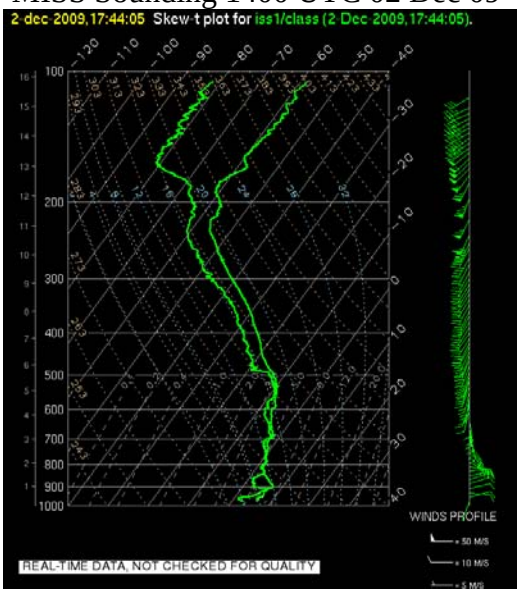
MISS Sounding 1200 UTC 02 Dec 09



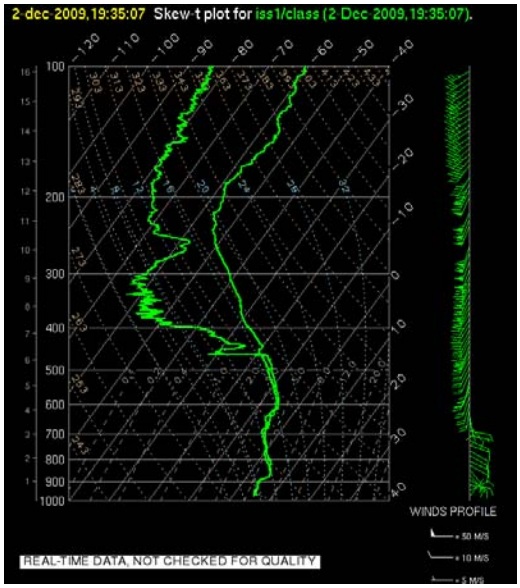
MISS Sounding 1400 UTC 02 Dec 09



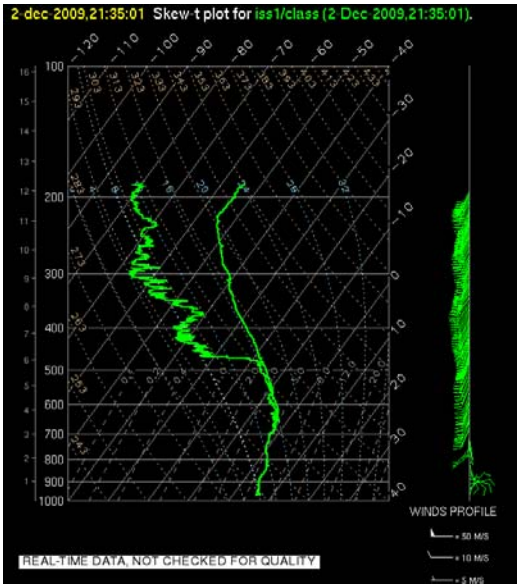
MISS Sounding 1600 UTC 02 Dec 09



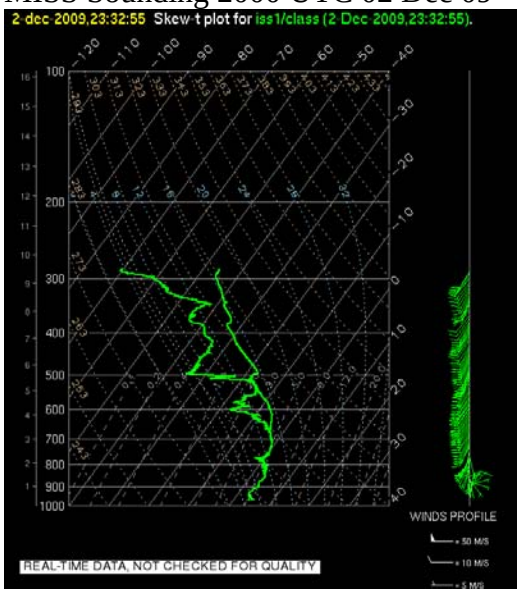
MISS Sounding 1800 UTC 02 Dec 09



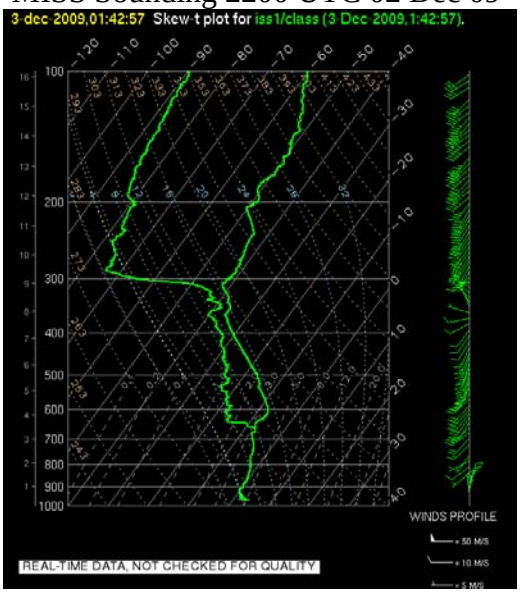
MISS Sounding 2000 UTC 02 Dec 09



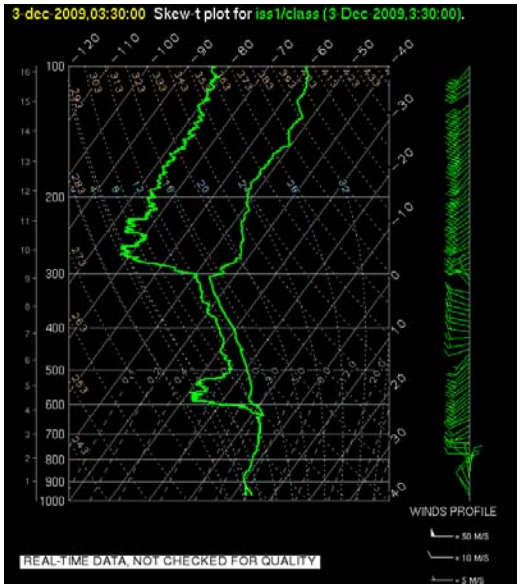
MISS Sounding 2200 UTC 02 Dec 09



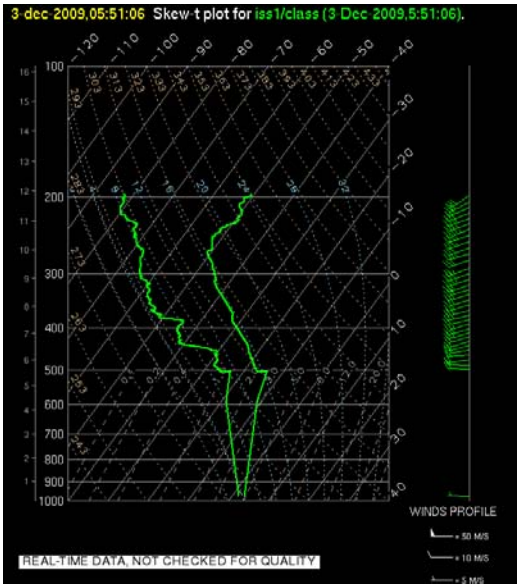
MISS Sounding 0000 UTC 02 Dec 09



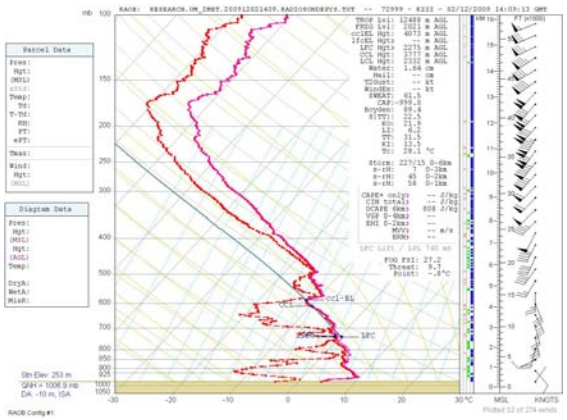
MISS Sounding 0200 UTC 02 Dec 09



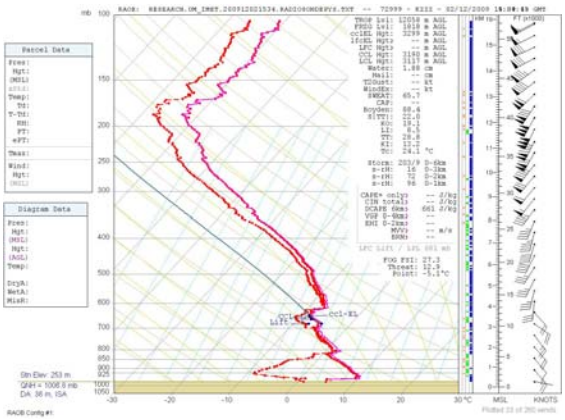
MISS Sounding 0400 UTC 02 Dec 09



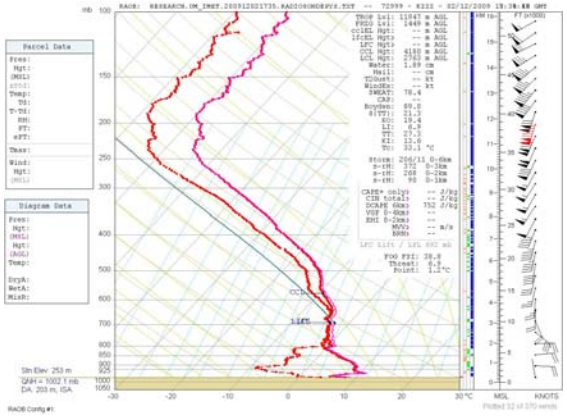
MISS Sounding 0600 UTC 02 Dec 09



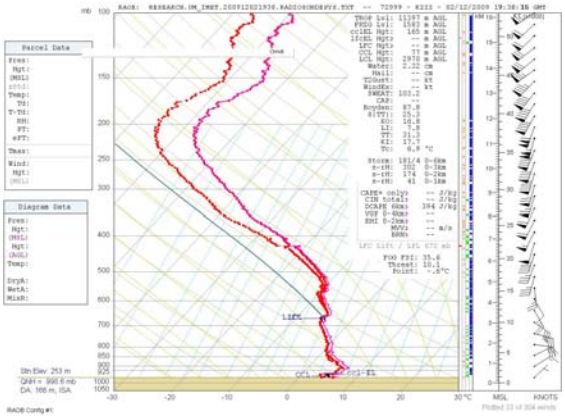
UM Sounding 1400 UTC 02 Dec 09



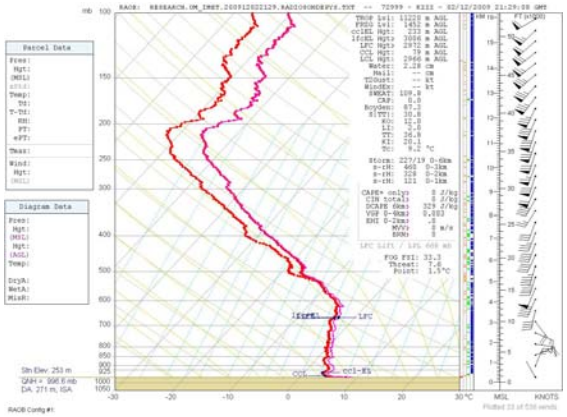
UM Sounding 1600 UTC 02 Dec 09



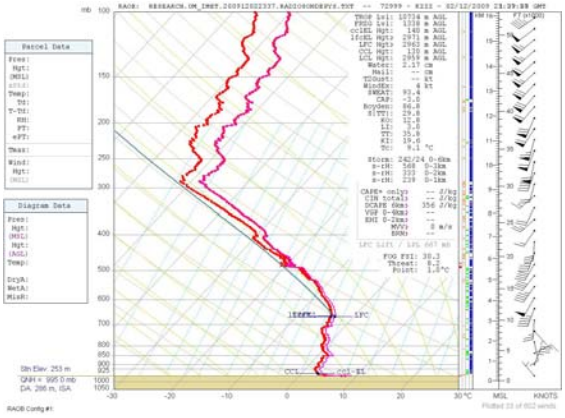
UM Sounding 1800 UTC 02 Dec 09



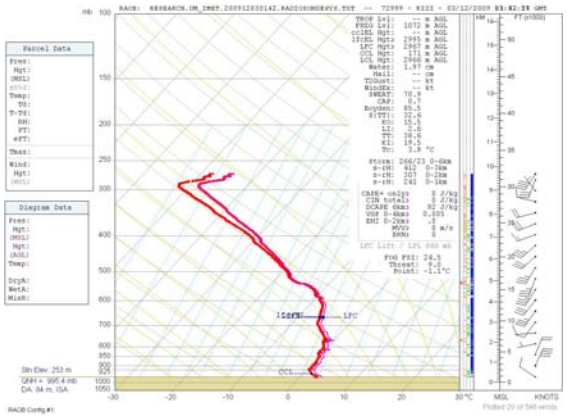
UM Sounding 2000 UTC 02 Dec 09



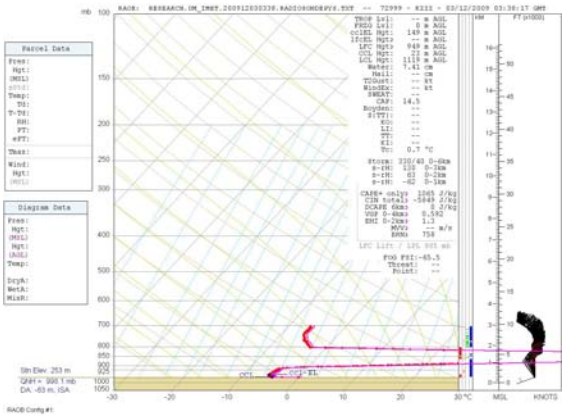
UM Sounding 2200 UTC 02 Dec 09



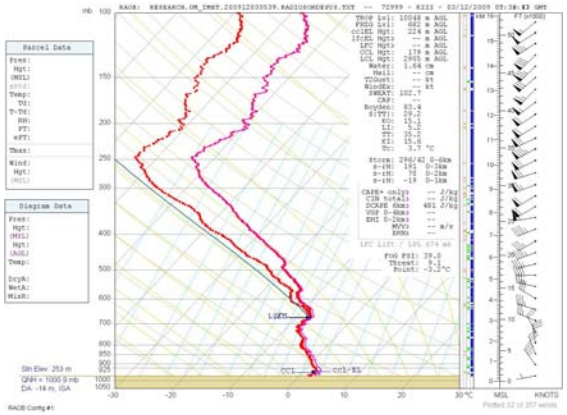
UM Sounding 0000 UTC 03 Dec 09



UM Sounding 0200 UTC 03 Dec 09



UM Sounding 0400 UTC 03 Dec 09



UM Sounding 0600 UTC 03 Dec 09