NOAA's National Weather Service Weather Forecast Office

Chicago, IL

December 8, 2005 Midway Airport Snow Event

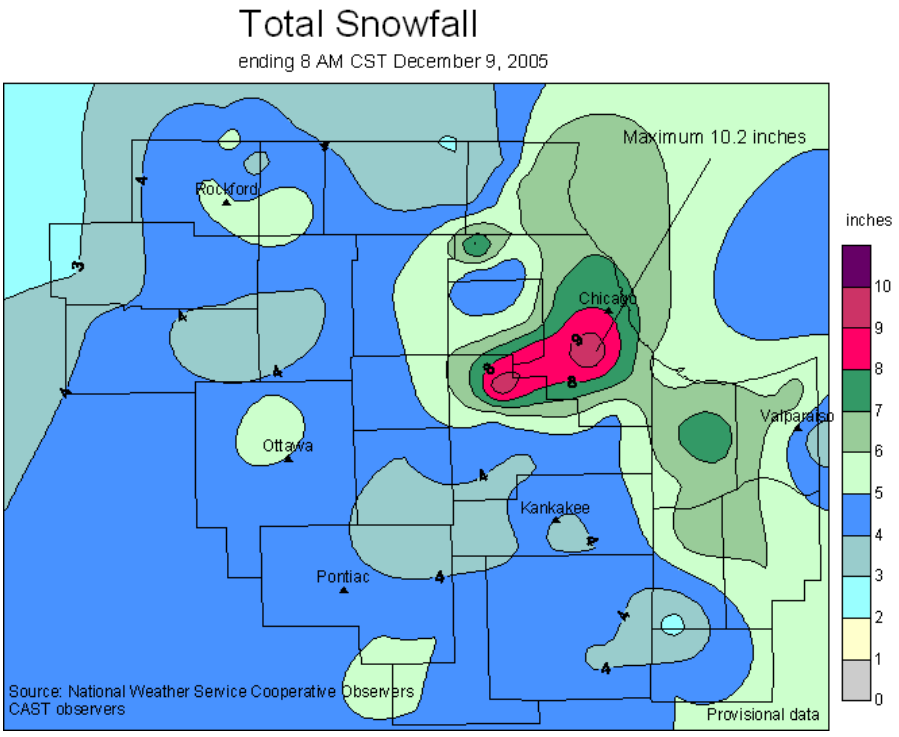
Probable Factors Contributing to the Snow Band

Affecting Midway Airport and the December 8, 2005 Southwest Airlines Incident

Introduction:

At 7:15 PM on December 8, 2005 a Southwest Airlines jet skidded of a runway at Midway Airport while attempting to land in a snow storm. The plane came to rest at an intersection at the northwest corner of the airport. One person in a car was killed.

The snow storm had begun during the early afternoon and affected all of northeast Illinois and northwest Indiana. Storm total snow of 3 to 6 inches was widespread except for a narrow zone extending from around Midway Airport westward into northern Will County (figure 1), where upwards of 11 inches of snow was recorded. The most intense snow occurred between 5 PM and 6 PM when the snowfall rate at Midway was nearly 3 inches per hour. A complete summary of Midway observations between 1:53 PM CST and 8:30 PM CST details the intensity of snowfall and accumulation on the ground is included as figure 2.



KMDW December 8, 2005 Weather Observations

Obs Type	Time (LST)	Wind Direc	Wnd Spd (KTS)	Visibility (SM)	Present Weather	Sky Condition	T F	Td F	Altimeter	Runway Visual Range R31C	Hourly Snowfall	Snow Depth	
H	1353	110	9	4	-SN	BKN029 OVC035	25	12	3027	P6000FT	T	2	
S	1403	100	9	3/4	-SN	FEW007 BKN012 OVC023	25	14	3026	4000FT			
S	1407	090	9	1/2	SN	BKN007 OVC019	24	15	3026	4000V5500FT			
S	1435	080	9	1/2	SN FZFG	VV004	23	19	3023	3000V4500FT			
H	1453	080	8	1/4	+SN FZFG	VV002	23	20	3021	3000FT	0.4	2	
S	1538	060	11	1/2	SN FZFG	VV003	24	21	3017	4000FT			
H	1553	080	11	1/2	SN FZFG	VV003	24	21	3016	5000FT	1.6	4	
S	1650	080	11	3/4	-SN BR	SCT004 OVC009	26	23	3012	5000FT			
H	1653	090	12	3/4	-SN BR	BKN004 OVC009	26	23	3012	5000FT	2.0	6	← 5 PM LST
S	1716	080	10	1/2	SN FZFG	BKN002 OVC009	26	23	3011	4000FT			
H	1753	100	9	1/4	SN FZFG	VV001	26	24	3009	3000FT	2.7	9	← 6 PM LST
S	1824	090	11	3/4	-SN BR	OVC003	26	24	3007	5500V6000FT			
5	1830	100	11	3/4	-SN BR	BKN003 BKN007 OVC012	26	24	3007	5500V6000FT			
5	1835	100	9	3/4	-SN BR	BKN003 OVC014	26	24	3007	5500V6000FT			
5	1840	100	8	3/4	-SN BR	BKN004 OVC014	26	24	3007	5500V6000FT			
5	1845	090	9	3/4	-SN BR	BKN004 OVC014	26	24	3007	5500V6000FT			
5	1850	100	9	1/2	SN FZFG	BKN004 OVC014	26	24	3006	4500FT			
H	1853	100	11	1/2	SN FZFG	BKN004 OVC014	26	23	3006	4500FT	1.1	10	
5	1855	090	10	1/2	SN FZFG	BKN004 OVC014	26	23	3006	4500V5000FT			
5	1900	110	7	1/2	SN FZFG	BKN004 OVC014	26	23	3006	4500V5000FT			
5	1905	120	9	1/2	SN FZFG	BKN004 OVC014	26	23	3006	4500V5000FT			
5	1910	110	8	1/2	SN FZFG	BKN004 OVC014	25	23	3006	4500V5000FT			←710 PM LST.....Time of Incident
5	1915	110	7	1/2	SN FZFG	VV003	25	23	3006	4500V5000FT			
5	1920	110	5	1/2	SN FZFG	VV003	25	23	3006	4500V5000FT			
5	1925	080	4	1/2	SN FZFG	VV003	25	23	3006	4500V5000FT			
5	1930	130	4	1/2	SN FZFG	VV003	25	24	3005	4500V5000FT			
5	1935	150	4	1/4	+SN FZFG	VV002	25	23	3005	3000FT			
S	1937	160	5	1/4	+SN FZFG	VV002	25	23	3005	3000FT			
5	1940	170	4	1/4	+SN FZFG	VV002	25	23	3005	3000FT			
5	1945	000	0	1/4	+SN FZFG	VV002	25	23	3005	3000FT			
5	1950	000	0	1/4	+SN FZFG	VV002	25	23	3004	4500FT			
H	1953	230	3	1/2	SN FZFG	VV002	25	23	3004	4000V4500FT	1.1	11	
5	1955	000	0	1/2	SN FZFG	VV002	25	23	3004	4500FT			
5	2000	000	0	1/2	SN FZFG	VV002	25	23	3004	4500FT			
5	2005	200	3	1/2	SN FZFG	VV002	25	23	3004	4500FT			
5	2010	200	3	1/2	SN FZFG	VV002	25	23	3004	4500FT			
5	2015	000	0	1/2	SN FZFG	VV002	25	23	3004	4500FT			
5	2020	000	0	1/2	SN FZFG	VV002	25	22	3004	4500FT			
5	2025	000	0	1/2	SN FZFG	VV002	25	22	3003	4500FT			
5	2030	000	0	1 1/4	-SN BR	BKN004 OVC033	25	22	3003	P6000FT			

Investigation of conditions contributing to the formation of this band and insights as to why the snow intensity peaked just prior to the airline incident reveal a combination of events which came together simultaneously for a short period over this area. It demonstrates how interaction between somewhat independent features can produce an enhanced event when coincident.

Synoptic Environment:

During the day of December 8 a well defined upper level cyclone was moving across the Missouri River into southern Iowa. At 1800 UTC this low was near Omaha, Nebraska (KOMA) and featured a well defined jet streak (red) working into central Illinois from southern Missouri (figure 3). The surface low was well to the south over western Tennessee with an inverted trough extending north into eastern Iowa.

By December 9, 2005, at 0000 UTC the upper system was near Quincy, Illinois (KUIN) while the attendant complex surface low had developed northward into the mid Ohio River valley beneath the mid level jet streak. An inverted trough continued to be present across northeast Illinois in an area of marked diffluence aloft as noted in the 500-hPa height analysis (figure 4).

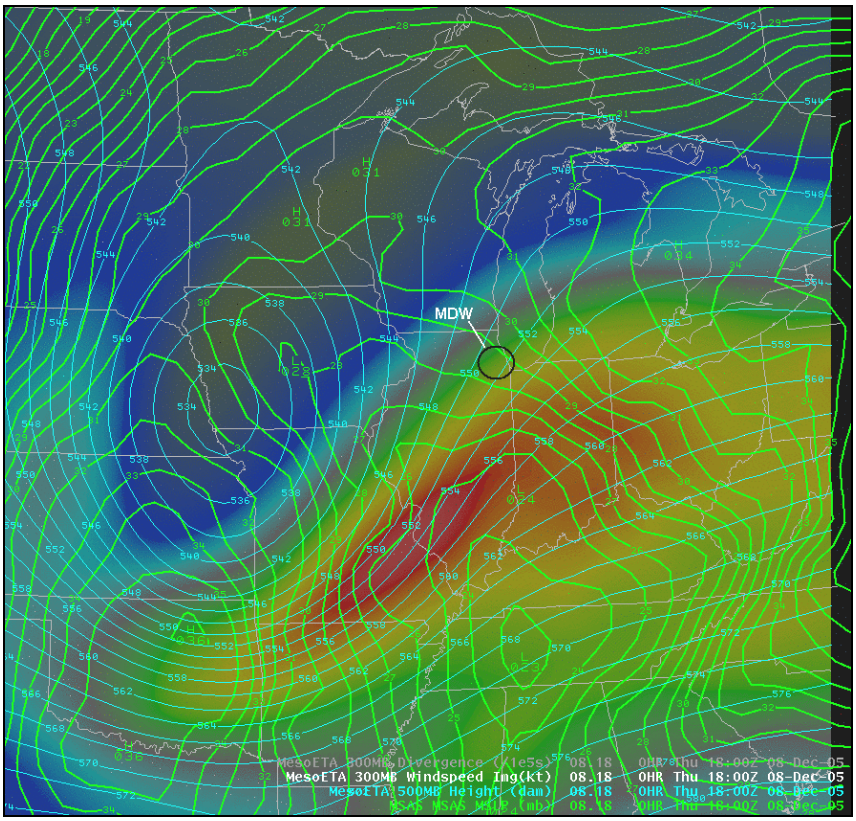


Figure 3 – 1800 UTC upper air features

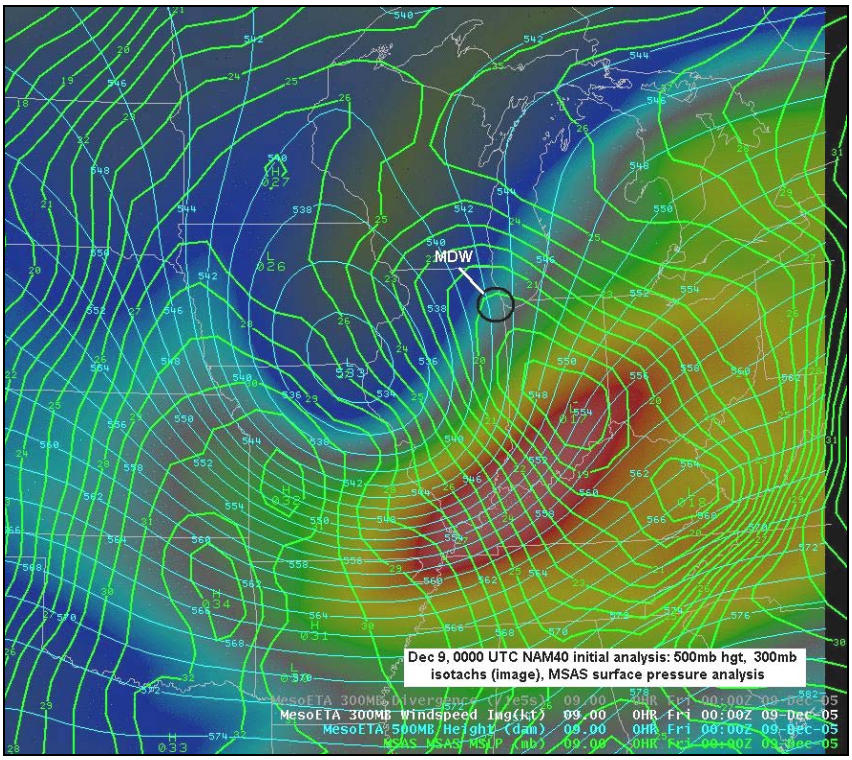


Figure 4 – 0000Z upper level diffluence pattern at 500-hPa

The thermodynamic environment was represented by RAOB soundings from Davenport (KDVN), Iowa, and Central Illinois (KILX) at 0000 UTC on December 9, 2005 (figure 5). The zone below 900-hPa was well capped by an inversion at around 850-hPa. This is particularly true at KDVN (yellow). The wind differential between the two site reflect the location of each relative to the system. Moist layer depth at KILX is also shallower than at KDVN. Later satellite images will clarify the observed variations.

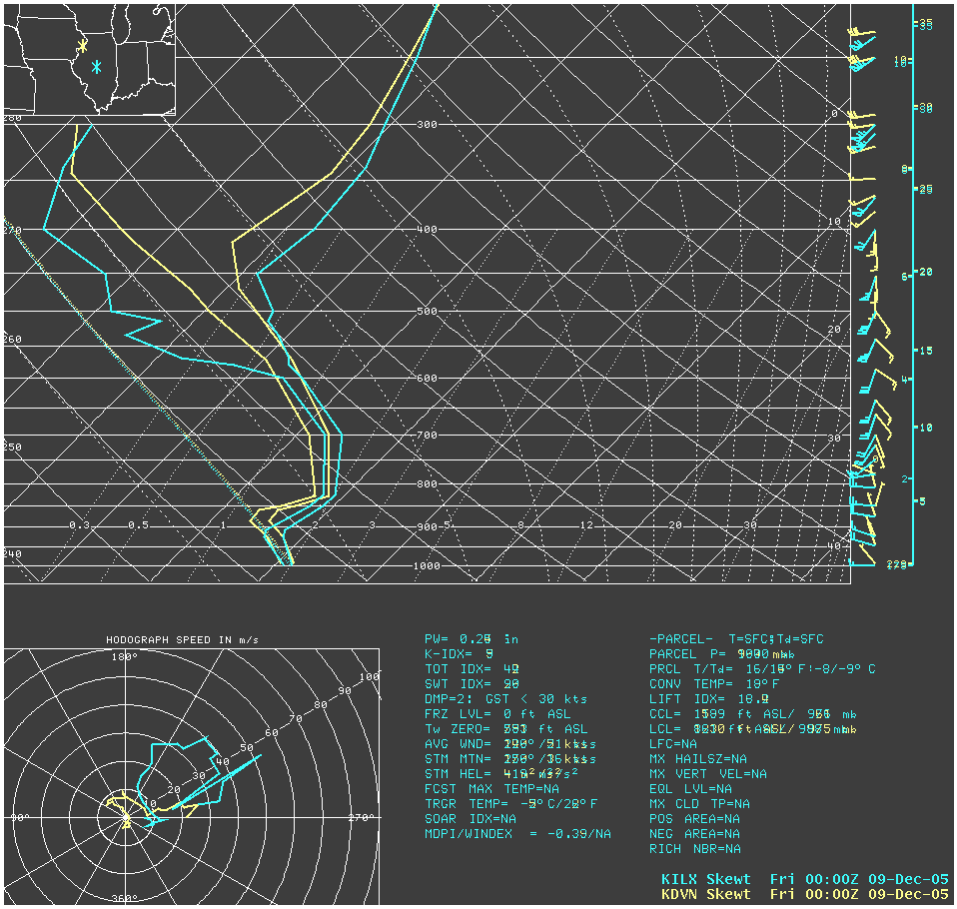


Figure 5 – 0000 ITC Soundings from KDVN and KILX

A review of the satellite animation between 1930 UTC through 0215 UTC, with profile data overlaid provided a sense of evolution of the upper air features, and identified several features.

1. A 135 knot (max) jet stream is detected at the Wolcott (IN) profiler.
2. The initial 25 knot southeasterly wind at 1,000 meters at Wolcott attests to the isentropic input or warm advection at lower levels.
3. Passage of the upper system at Slater Iowa is noted.
4. The initial north-to-south orientation of the cloud bands through Illinois changes during the period to a southeast-to-northwest orientation as the system appears to become negatively tilted.
5. Band striations across northeast Illinois darken as cloud tops cool.

The KLOT WSR-88D radar imagery between 2143 UTC and 0042 UTC provided an indication of the evolution of snow bands across the Midway Airport (KMDW) – Will County area.

The motion clearly reflects the satellite indication of a trend toward negative tilt of the system. The east-to-west enhanced reflectivity band from KMDW-northern Will county had developed over southern Will County about and hour prior to the start of the animation. This band has (at least) 3 characteristics: a) it and subsequent bands died out before making it north of central Cook County; b) it interacted with another enhanced band, with a north-to-south orientation, which approached from the southwest; and c) subsequent echo bands continued to move into or toward the southern Cook-northern Will county area during the latter part of this sequence.

Given the revelations of the reflectivity animation one can readily see why the maxima of snowfall occurred where it did. Let us now investigate some of the details.

Mesoscale Factors:

Against the backdrop of the synoptic scale forcing above, smaller scale conditions were instrumental in focusing snowfall. In is not uncommon in enhanced events of any type to find a number of coincident processes or alignments, which interact to produce the observed conditions.

Using the December 8, 2005, 2100 UTC RUC40 as the source of analysis and short term forecast, we first examine the 2100 UTC (figure 6) low-level atmosphere state defined as the 900- to 850-hPa average layer. In response to the upper level vortex moving into southwest Iowa a tongue of enhanced saturated theta-e air was being drawn into northeast Illinois and northwest Indiana. It can be seen as the yellow-red-green shaded image portion of the analysis. Overlaid on this thermodynamic field is the corresponding layer averaged ageostrophic wind, wind divergence and 3-hr pressure falls.

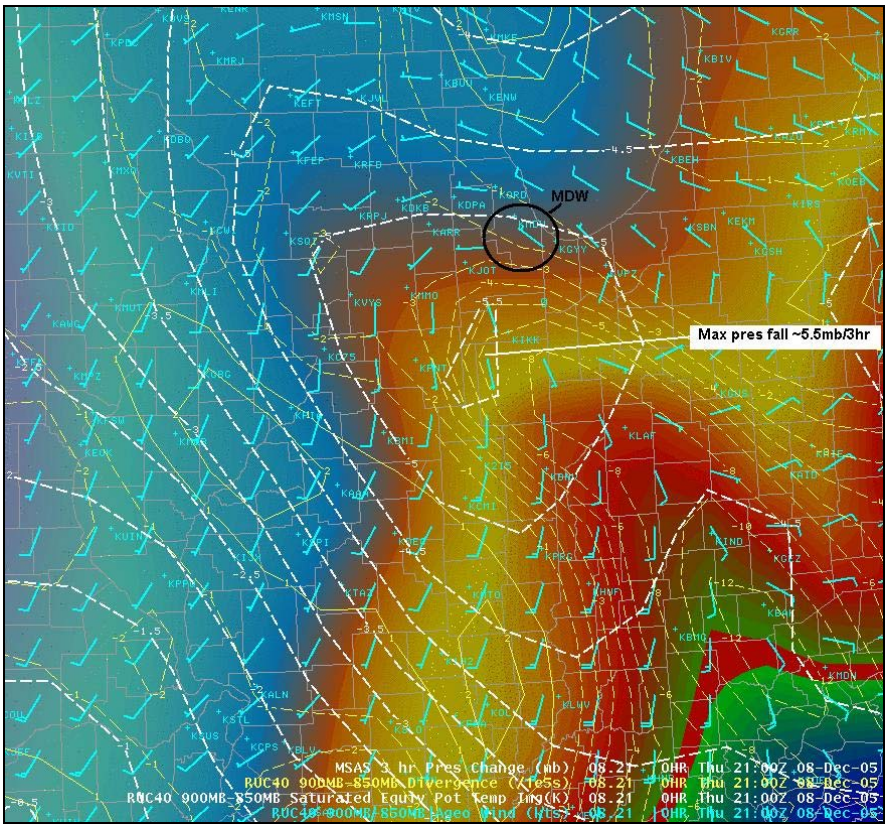


Figure 6 – 2100 UTC composite chart

An axis of convergence (negative divergence) from KLAF in western Indiana to just south of KMDW. The maxima of pressure falls is virtually coincident, just south of KMDW. The pressure fall pattern is potentially important for two reasons: a) it infers the area of strongest warm advection aloft (warmer air is less dense) and b) it induces a mass adjustment, which can be reflected in subsequent convergence.

By 2200 UTC (figure 7) the 'best' theta-e air extends from KMDW to the south and east. The 3-hour pressure fall maxima aligns very well with the convergence axis over Kankakee and Will Counties. Note the response in the ageostrophic winds. They now, at 2200 UTC, strongly reflect the location of the convergence axis. Comparing these developing fields to the 2200 UTC radar imagery (figure 8) and remembering the radar returns likely reflect a slope to these processes above the beam, offers a realistic relationship between the diagnosed processes and observed return.

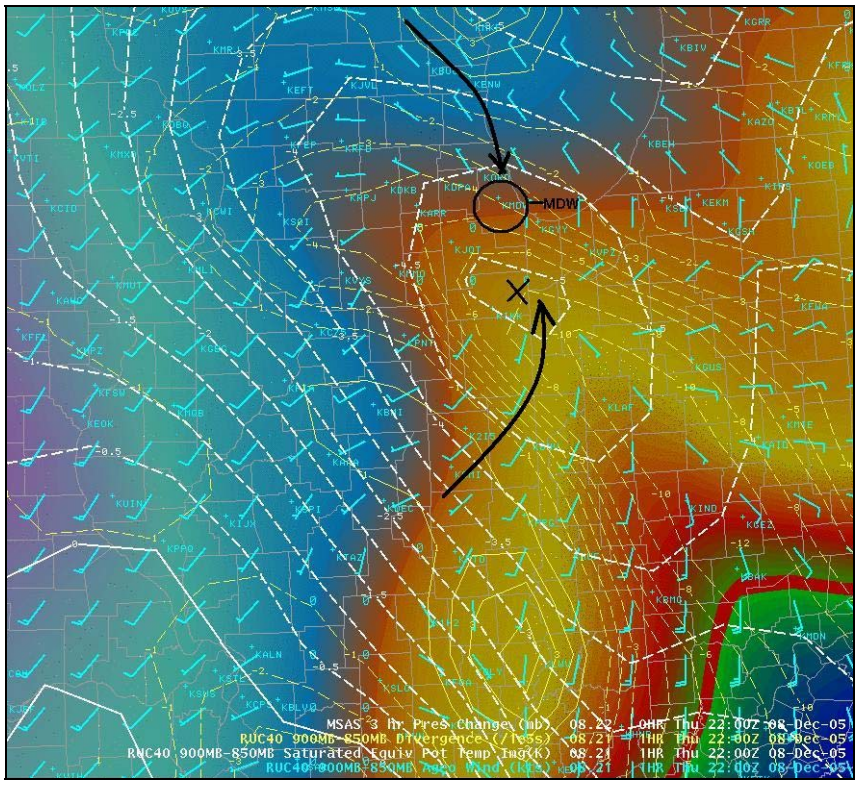


Figure 7 – 2200 UTC composite chart

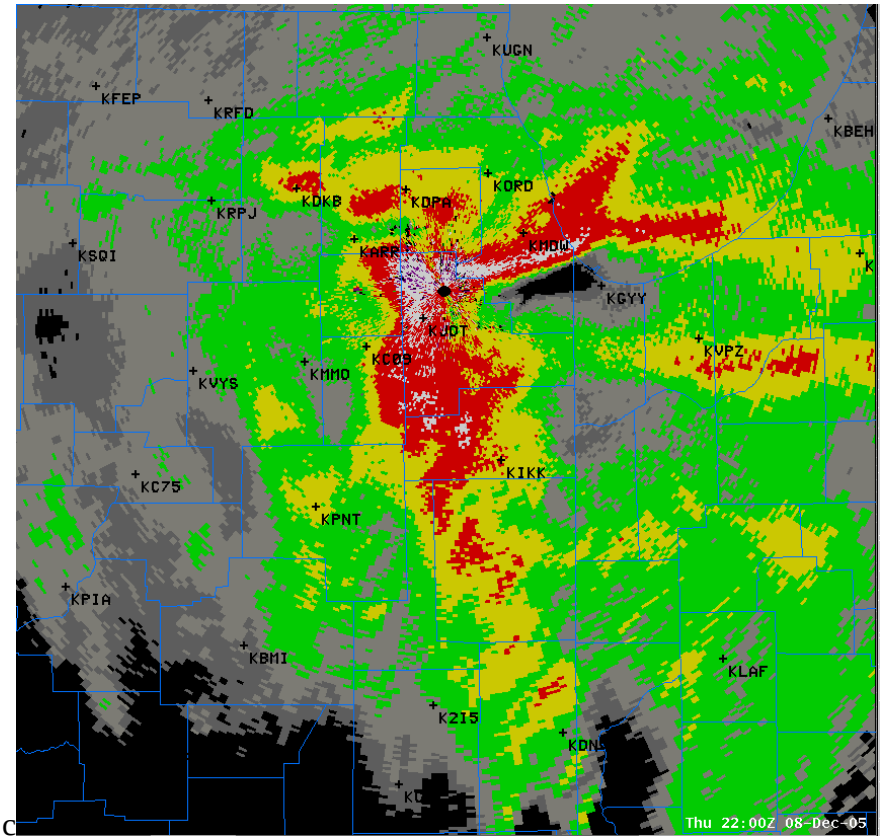


Figure 8 – Radar image at 2200 UTC

The next hour at 2300 UTC (figure 9), finds the same alignment of forcing just shifted a little further north. The ageostrophic component of the 900- to 850-hPa wind field is now solidly confluent and convergent across southern Cook County into northern Will County. Radar returns prior to this point and subsequent to 2300 UTC (for a couple hours) reflect the convergent nature of echoes approaching KMDW from the south and east.

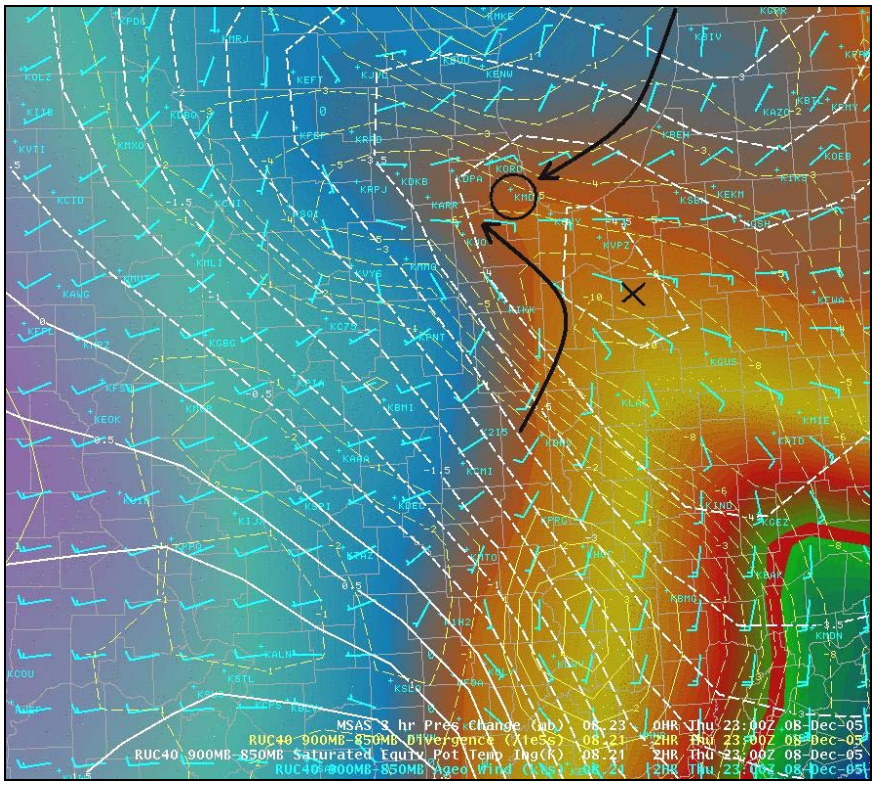


Figure 9 – 2300 UTC composite chart

By 0000 UTC on December 9, 2005 (figure 10), we see the moist theta-e air beginning to retreat to the east while the convergence zone sits right over KMDW. The pressure fall center is also slipping to the east. Just one hour later, at 0100 UTC (figure 11), the ageostrophic wind pattern has lost its convergent nature while the convergent axis edges off to the north.

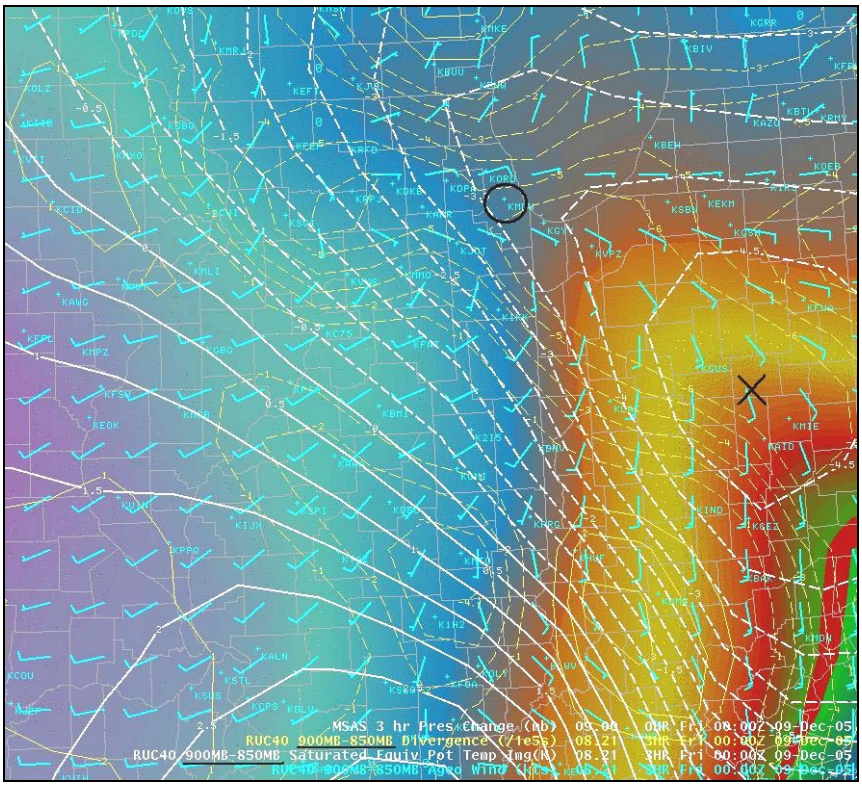


Figure 10 – 0000 UTC composite chart

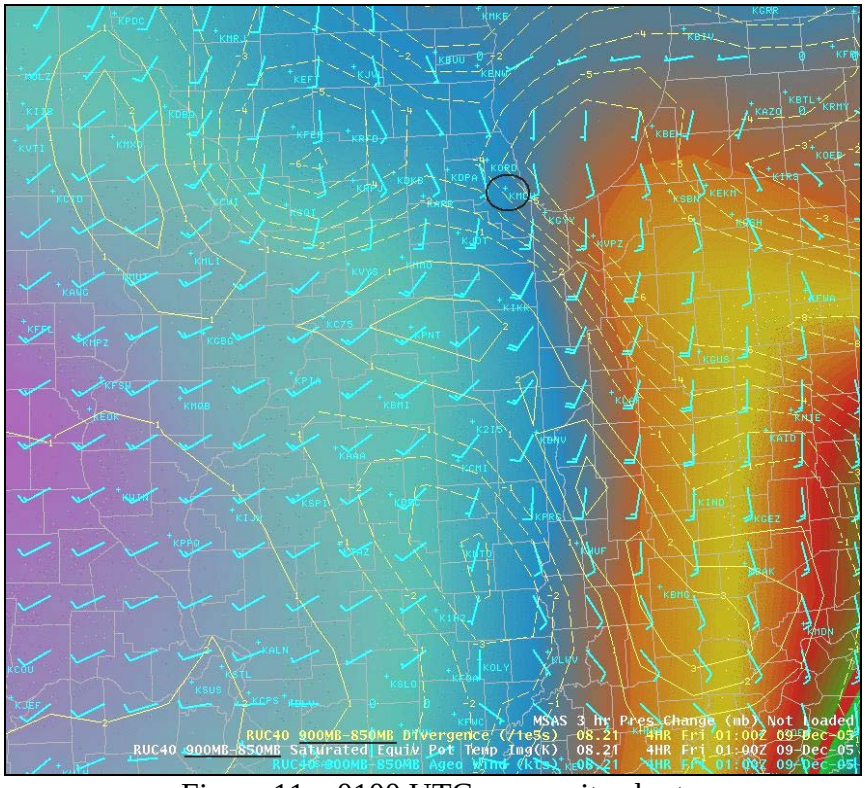


Figure 11 – 0100 UTC composite chart

The greatest snowfall rate at MDW occurred between 2300 UTC and 0000 UTC.

Observations during this late afternoon high intensity snowfall period also noted the 'large' size of the snowflakes. Often this can be an indication that lake effect snow processes are involved. Proximity ACARS temperature profiles at KMDW (figure 12) and Chicago O'Hare International Airport (KORD) (figure 13) show the traditional benchmark 850-hPa temperature at around -5 degrees C. Surface lake water temperatures were around +3 degrees C making the 8 degrees C difference shy of the traditional –13 degrees C standard. Easterly winds at KMDW were also no more than 15 knots in the boundary layer. The direction suggests a very restrictive fetch over water. While some enhancement from Lake Michigan cannot be totally dismissed there is evidence that another mechanism was more influential.

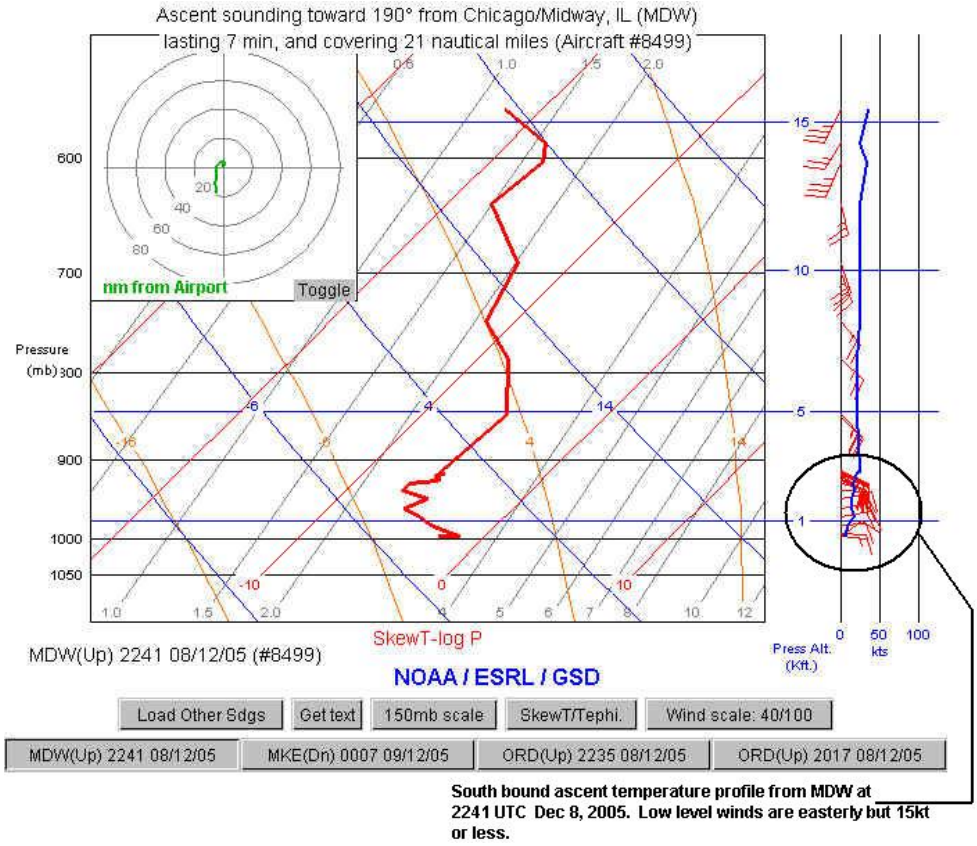


Figure 12 – KMDW ascent sounding at 2241 UTC

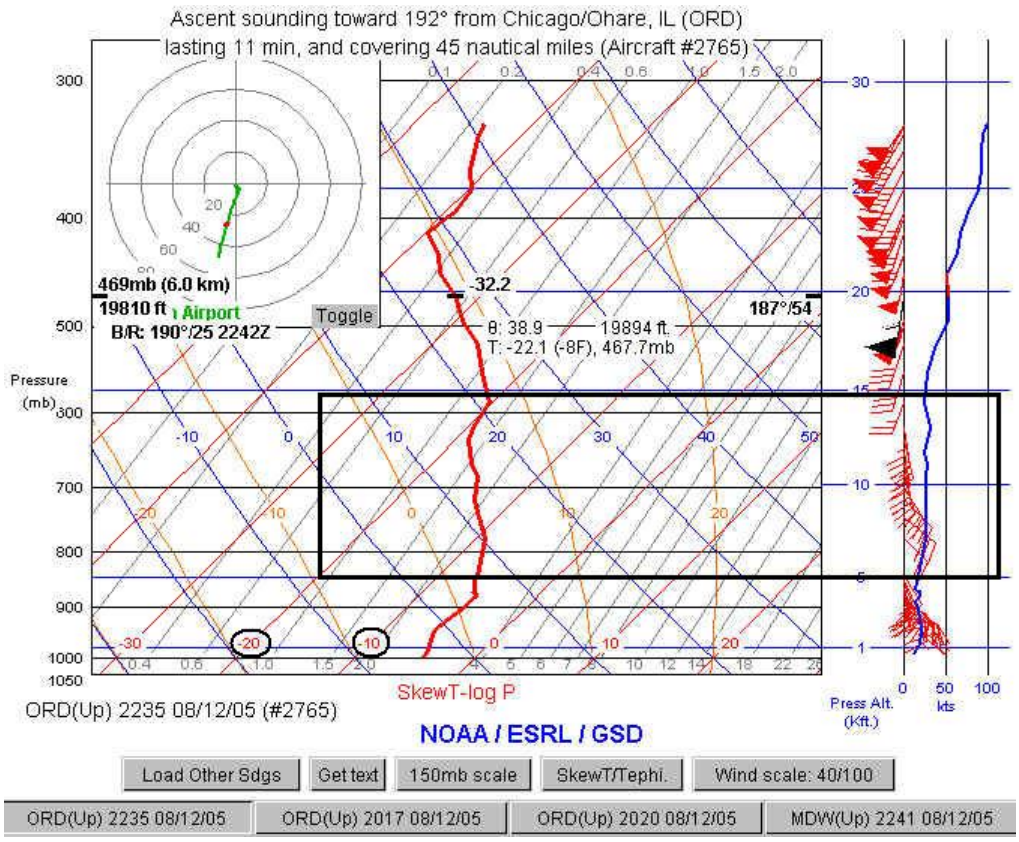


Figure 13 – KORD ascent sounding at 2235 UTC

In addition, the KORD profile reveals a very marked veering signature between about 800-hPa and 600-hPa (outlined) suggesting a zone of strong warm advection. This is occurring exactly within the temperature zone of –12 to –18 degrees C, where snowflake growth can be maximized. In fact the plane was ascending from Chicago O'Hare toward the south adding further credence to the sampling near the heaviest snow.

Part of the synoptic environment was characterized by the trend, at this time, for the upper trough to realign itself in a negative tilt. This was driven by the strong 130 to 150 knot upper jet working through the Ohio Valley. The infrared satellite image at 2345 UTC (figure 14) also clearly shows a series of south-southeast to north-northwest striations moving northeastward across northeast Illinois.

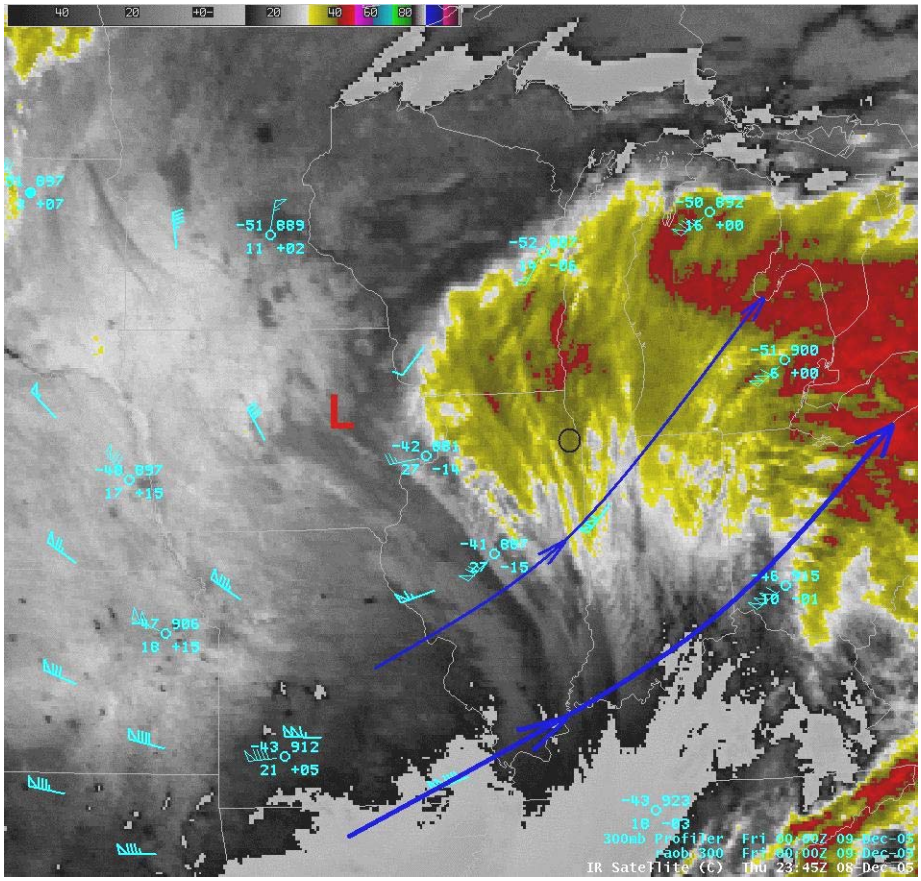


Figure 14 – satellite image at 2345 UTC with jet stream features

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Closer examination of these bands adds another dimension to the story. An IR satellite image at the 2145 UTC combined with 300-hPa profiler and raob (0000 UTC) data offers an insight to the magnitude of the lateral wind shear within this system. Wind speeds of 80 to 115 knots from central Illinois into west central Indiana drop off to 25 knots at KDVN. At this time a series of cloud bands is approaching KMDW (figure 15).

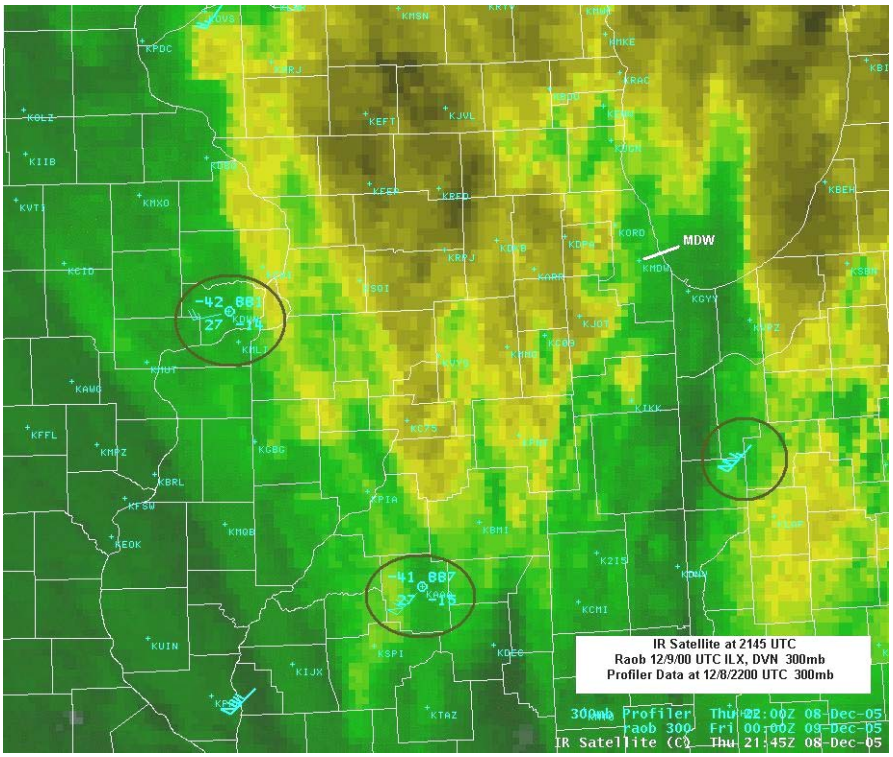

Figure 15 – satellite image at 2145 UTC with sounding data

By 2301 UTC (figure 16) one of the enhanced bands (A-A') was over western Will County. Correspondingly the WSR-88D reflectivity image at 2241 UTC (figure 17) showed an enhanced south-southeast to north-northwest area moving east toward the prepositioned zone over KMDW. The radar return appears to be a reflection of the feature seen in the satellite imagery.

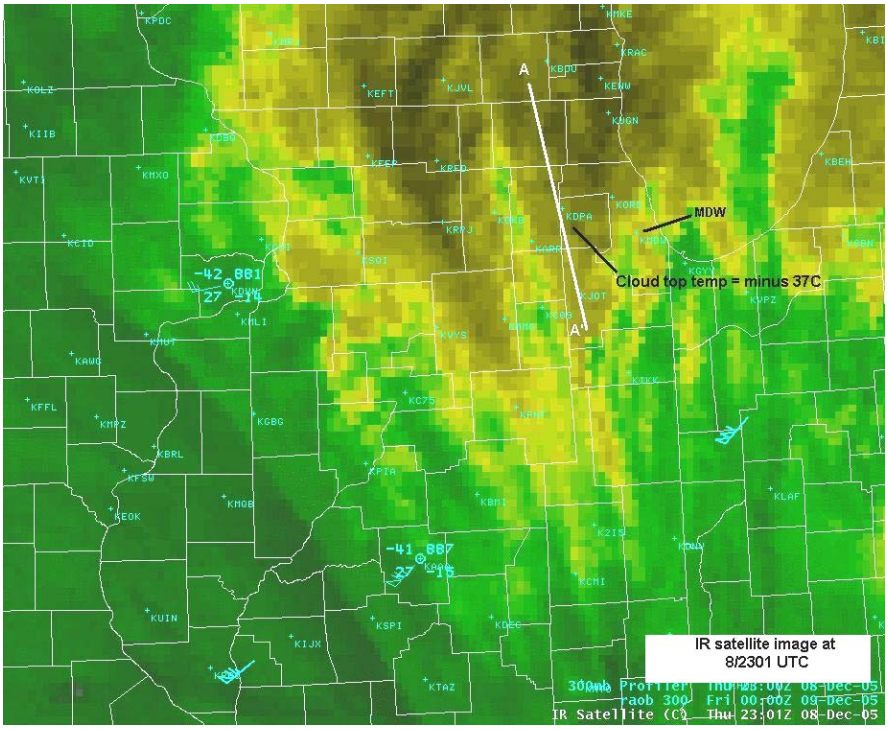

Figure 16 – satellite image at 2301 UTC

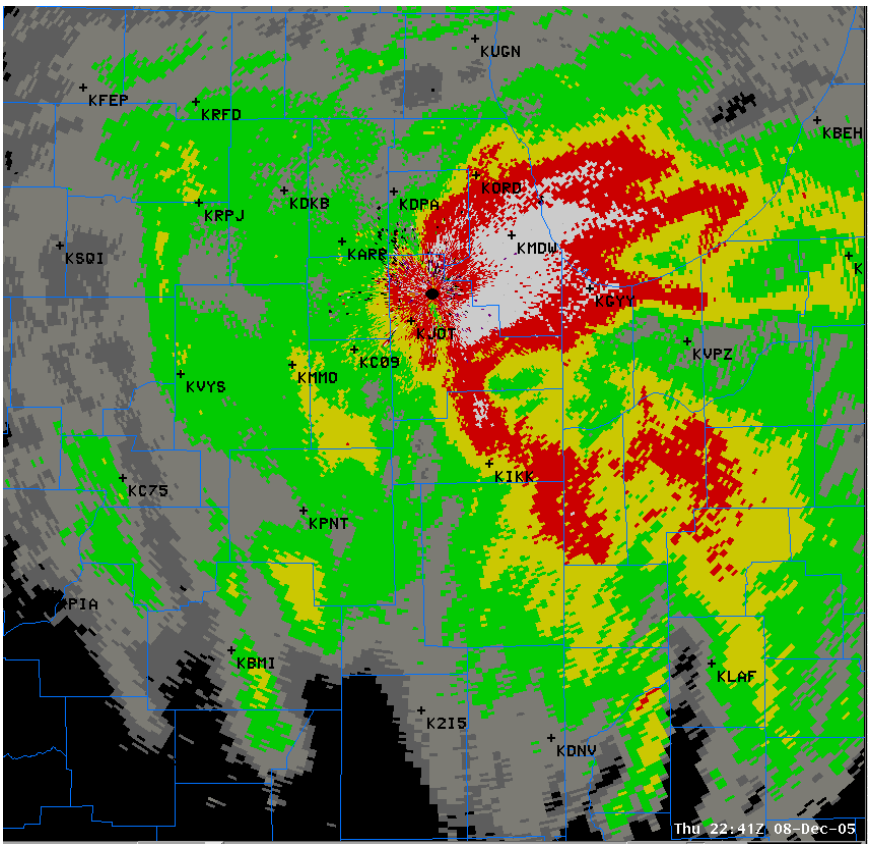

Figure 17 – radar image at 2241 UTC

During the next 45 minutes the band noted as A-A' in the 2301 UTC image expands and cloud tops cool. By 2345 UTC (figure 18) cloud tops have cooled 2 to 3 degrees C from 2301 UTC and have become better defined. During this interval snowfall intensity maximized at KMDW. The 2321 UTC radar image distinctly shows the axis of enhanced reflectivity over KMDW extending westward toward the radar site.

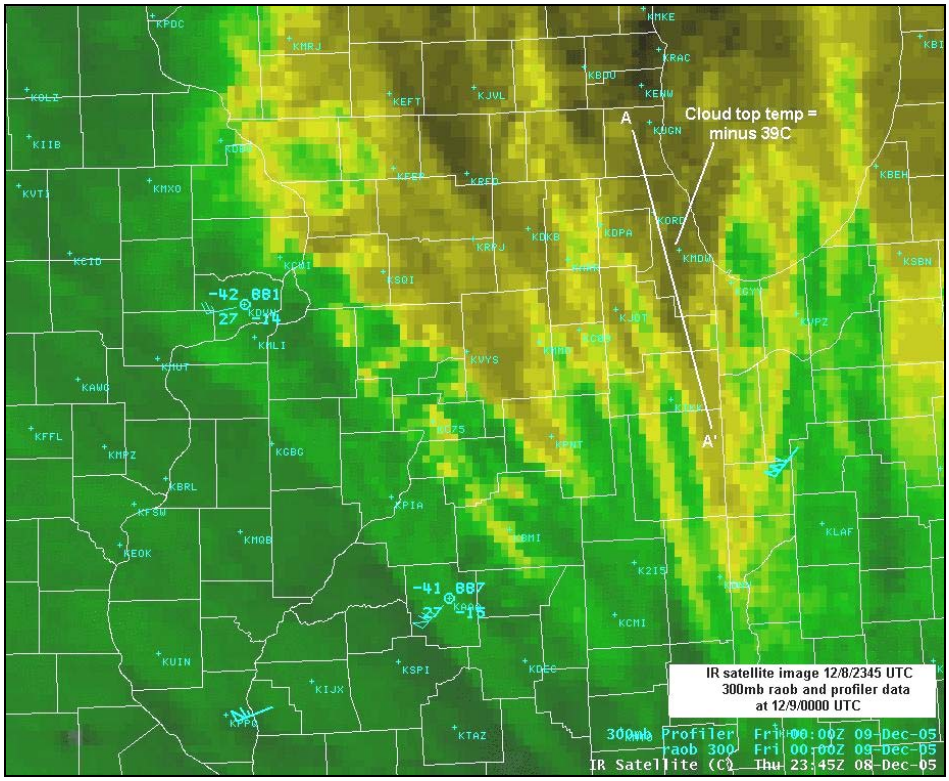

Figure 18 – satellite image at 2345 UTC

Proximity in time and space of satellite cloud top cooling and expansion, corresponding movement of radar returns and resultant increase in snow intensity over the target area strongly suggests that increased cloud depth and seeding from higher synoptically related cloud bands was instrumental in creating enhanced snowfall.

Concluding Thoughts:

Enhanced banded snowfall is not an uncommon feature of winter storms. Often it is attributed to slantwise convective processes (CSI). There was no clear evidence of that here. Other processes can result in similar focusing of snowfall. These can include, among others, lake enhancement, terrain, barrier jets and ageostrophic circulations related to low level jets. Proximity aircraft derived thermal profiles via ACARS from KORD and KMDW suggest lake effect processes were negligible due to the lack of temperature contrast between air and water, and implied short fetch over water due to wind direction.

The case of December 8, 2005 was notable in that the enhanced banding occurred over a major airport and was a contributing factor in a fatal aircraft incident by Southwest Airlines. Intense snowfall of up to 3 inches per hour in a period of about 1 hour prior to the incident may have impacted the ability of the airport to maintain runway composure.

In a purely meteorological sense this event highlighted the ability of the atmosphere to combine multiple processes and circumstances into a scenario, which produced marked albeit small zone of magnified snowfall from MDW into northern Will County.

The evidence suggests the following contributing factors:

1. Maxima tongue of 925 to 850-hPa layer saturated theta-e air wrapping northwestward into extreme northeast Illinois during the mid and late afternoon.

2. Development of a convergent axis in this same layer due at least in part to mass adjustments related to pressure falls and the corresponding reflection the ageostrophic component of the wind field.

3. Spatial proximity and interaction between number 1 and number 2.

4. Migration of synoptically related cloud bands which were becoming enhanced by the increasingly negative tilt to the overall trough aloft.

5. Added cloud depth, increased vertical motion and seeding/feeding of the lower snowfall producing mechanism.

It appears then that the juxtaposition in time and space of processes noted in number 3 and number 5 were highly instrumental in creating the observed band of snow which fell across southern Cook and northern Will counties during the late afternoon and evening of December 8, 2005.