NOAA's National Weather Service

Improving Forecast Techniques and Procedures For Significant Lake Effect Snow Bands Across Northern New York and Vermont.

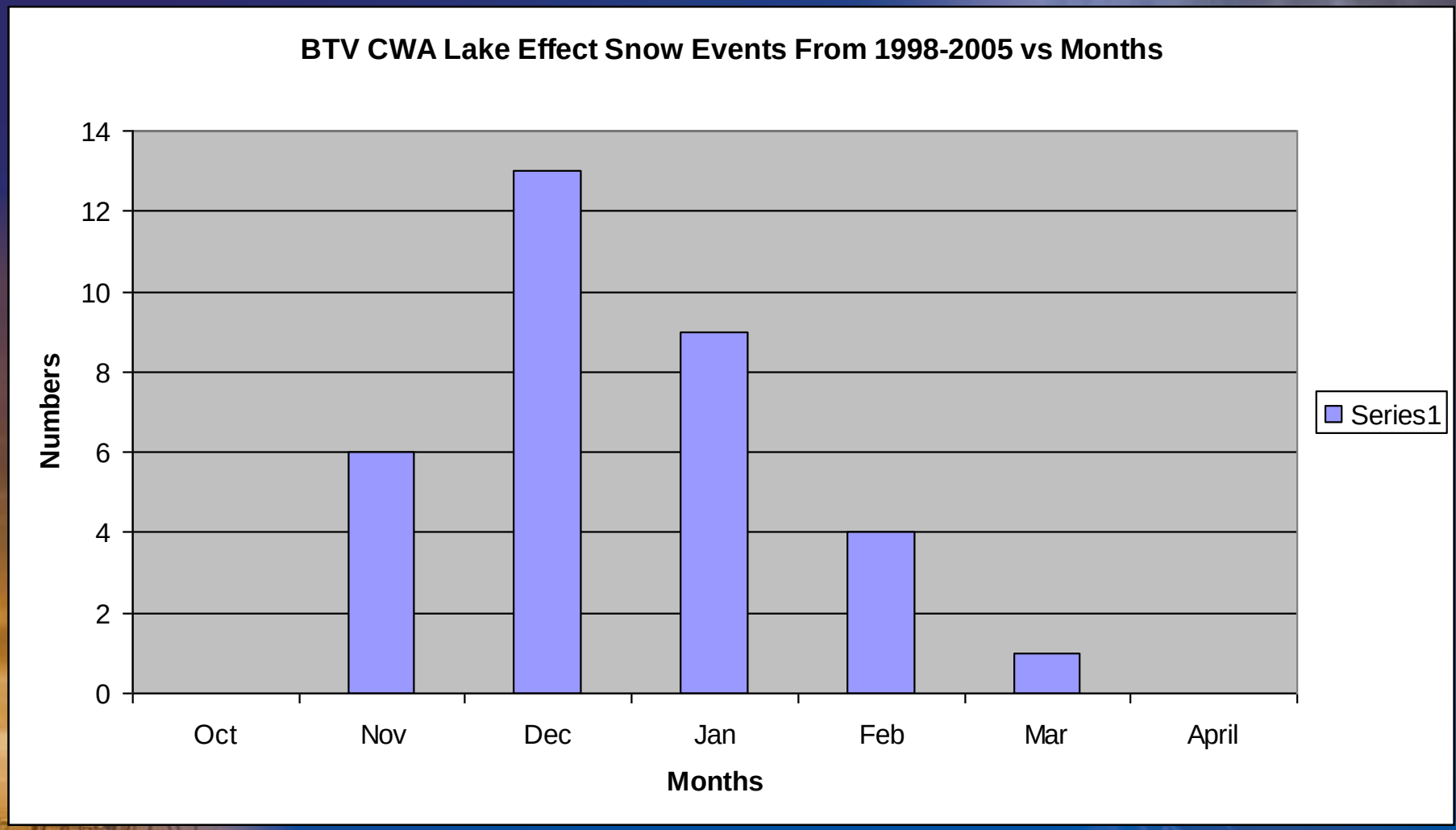
Brooke Taber

Discuss Items

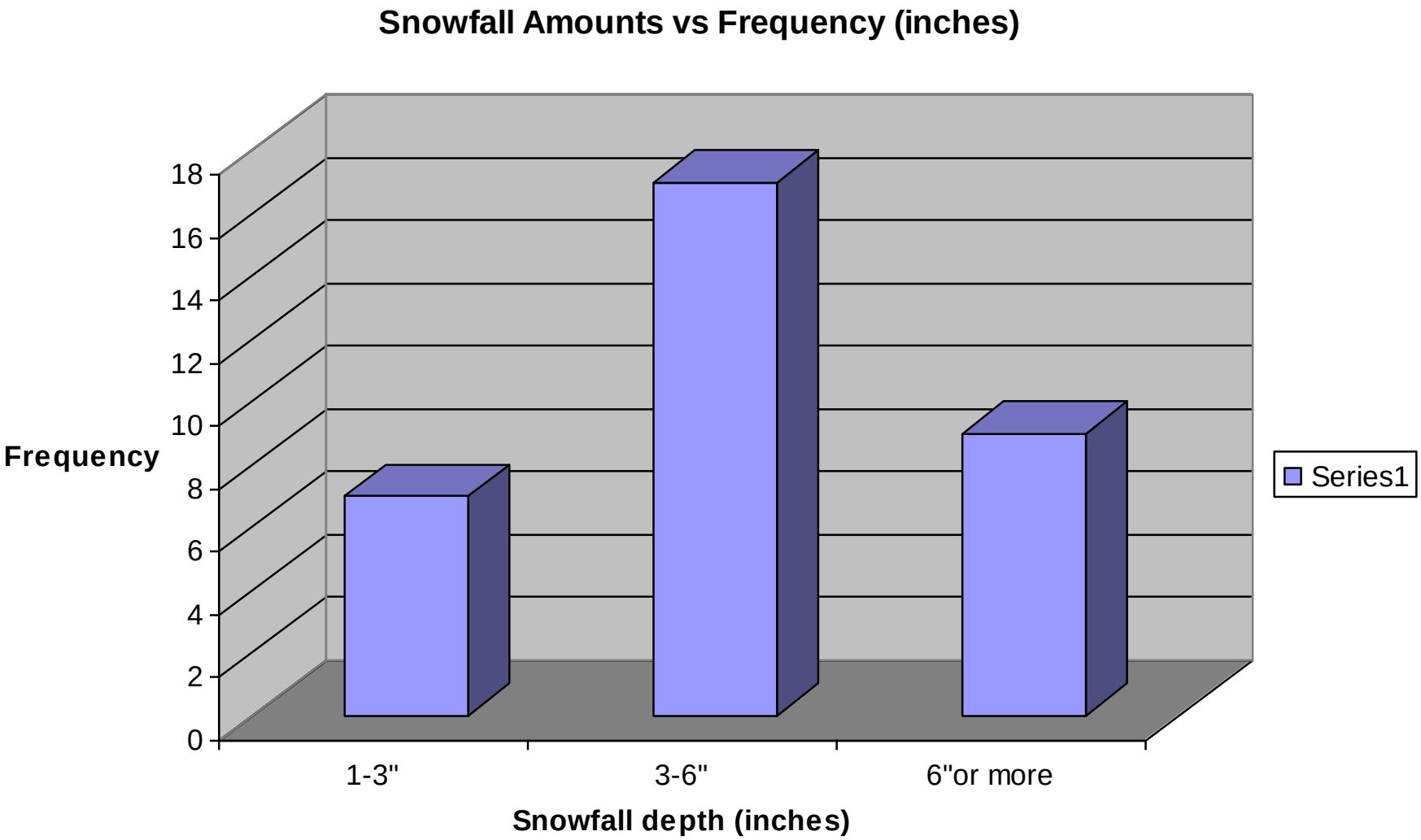
- Examined 8 Year Statistics (Storm Data, WES Cases, WFO Buf website)
- Lake Effect Impacts (Transportation, Economy)
- Discuss Two Events (Hybrid/Traditional)
  - *Hybrid Arctic/Warm Front Enhancing multi lake effect snow band from Lake Ontario*
  - *Traditional (well organized/quasi-stationary single band on sw flw/interacts with arctic boundary)*
- Roles of Low-Level Boundaries in moving band downwind of Lake Ontario
- Useful Forecasting Parameters (snowfall rates/amounts/duration)

  -Shear, Instability, Lift, Moisture

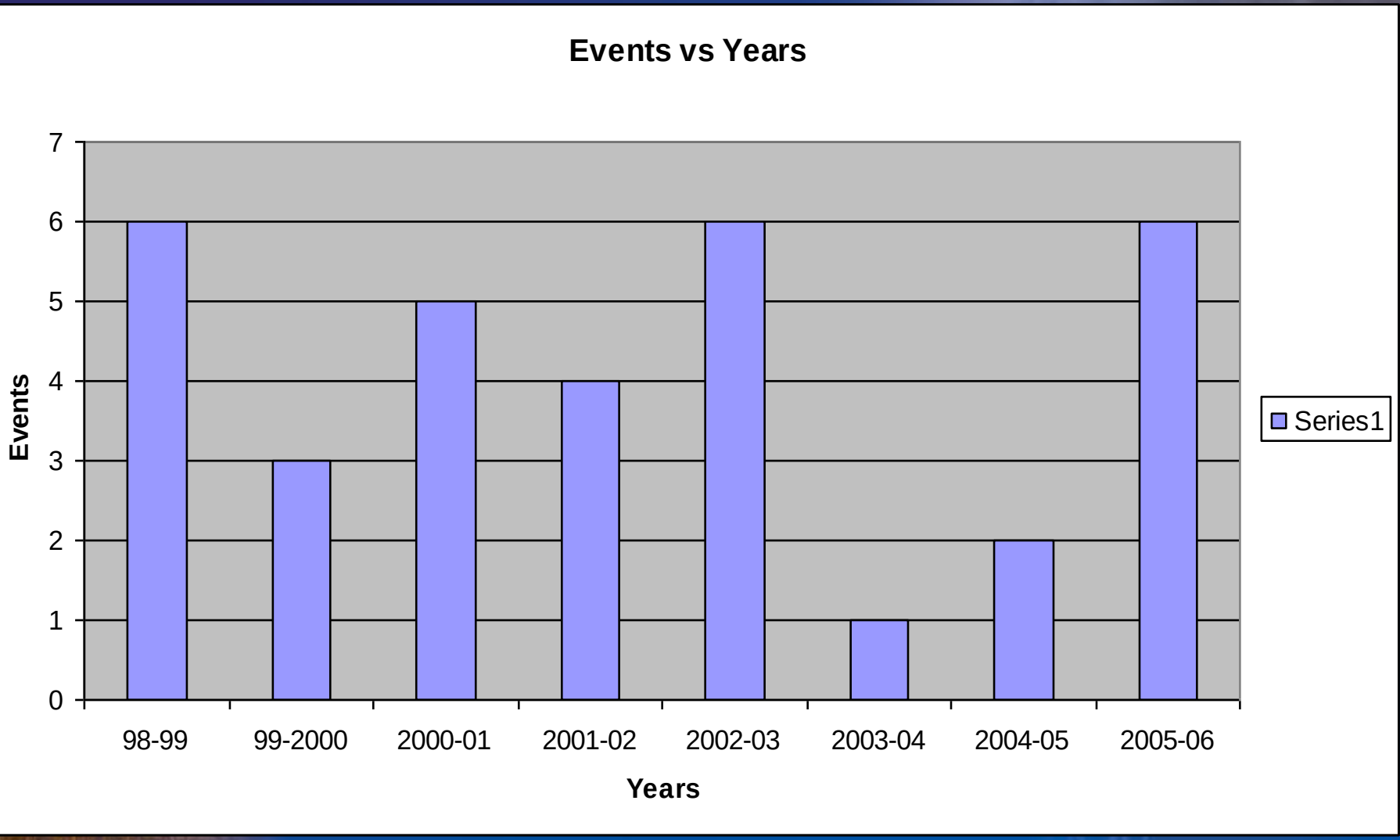
Events vs. Months



Snowfall vs. Frequency



Events vs. Years



Forecast Problems?

- Horizontal displacement of heavy lake effect snow squalls up to 350 km down wind of Lake Ontario
- Intensity of lake effect snow band (rate of snowfall)
- Impacts of strong low level winds on snowfall accumulations

I-89 PILE-UP

Icy roads covered with snow led to an 18-vehicle pile up a bit south of Exit 21 on Interstate 89 North on Monday, Feb. 6. The pile up, which included a number of cars and trucks, as well as one tractor trailer, happened at around 3:15 p.m. and involved both northbound lanes around and on the bridge that spans the Missisquoi River. While no serious injuries were reported, a number of motorists were taken to Northwestern Medical Center for treatment, according to the Vermont State Police. The Interstate was closed for roughly an hour in the area of the accident, backing traffic up "significantly," the state police said.

Photographs by Dave St. Pierre

Useful Forecasting Parameters

- Treat very much like convection (Moisture, Instability, Lift, Shear)
  - *Moisture (1000-700mb), PWS, Sfc Dwpts*
  - *Instability (Lake Induced Capes, 1000-700mb Lapse Rates)*

Useful Forecasting Parameters

- *Examine Low Level Shear/Wind Fields (Bufkit soundings, convective worksheets from AWIPS, and UA data analysis*

  Cloud Base (CCL) to Echo Top Shear (0.5-3.0km)

  Magnitude of low level wind field very important to horizontal displacement of significant snowfall downwind of Lake Ontario

- *Lift (enhanced by sfc boundary (warm or cold front), SW upslope flw)*

Topo Map of CWA

- Complex terrain (Mtn/Valleys)
- Band extends 300km downwind of Lake Ontario

Ausable and Saranac River Valley helps channel band

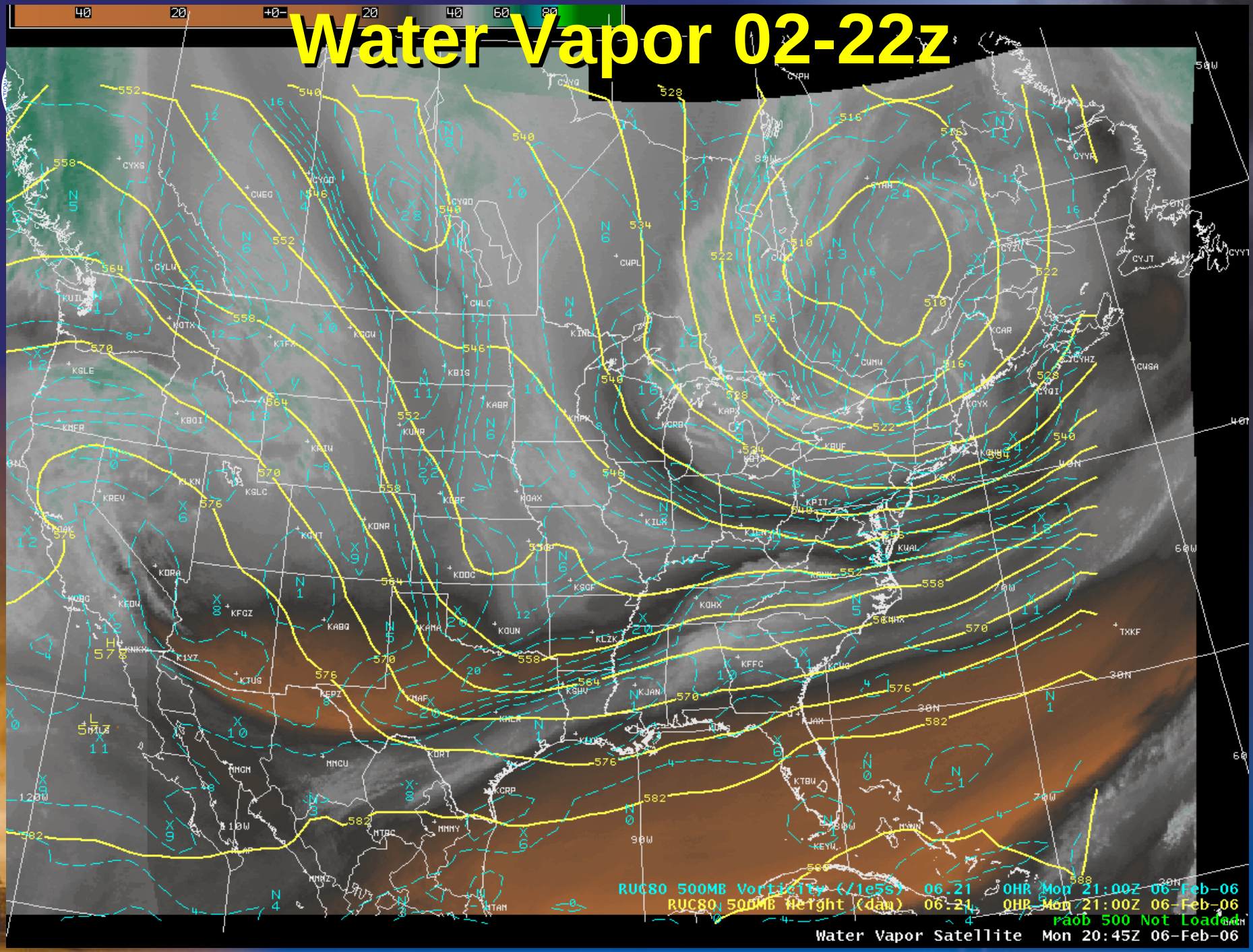
Jay Peak 300km downwind of Lake Ontario

Westerly flow cases that impact southern Green Mtns

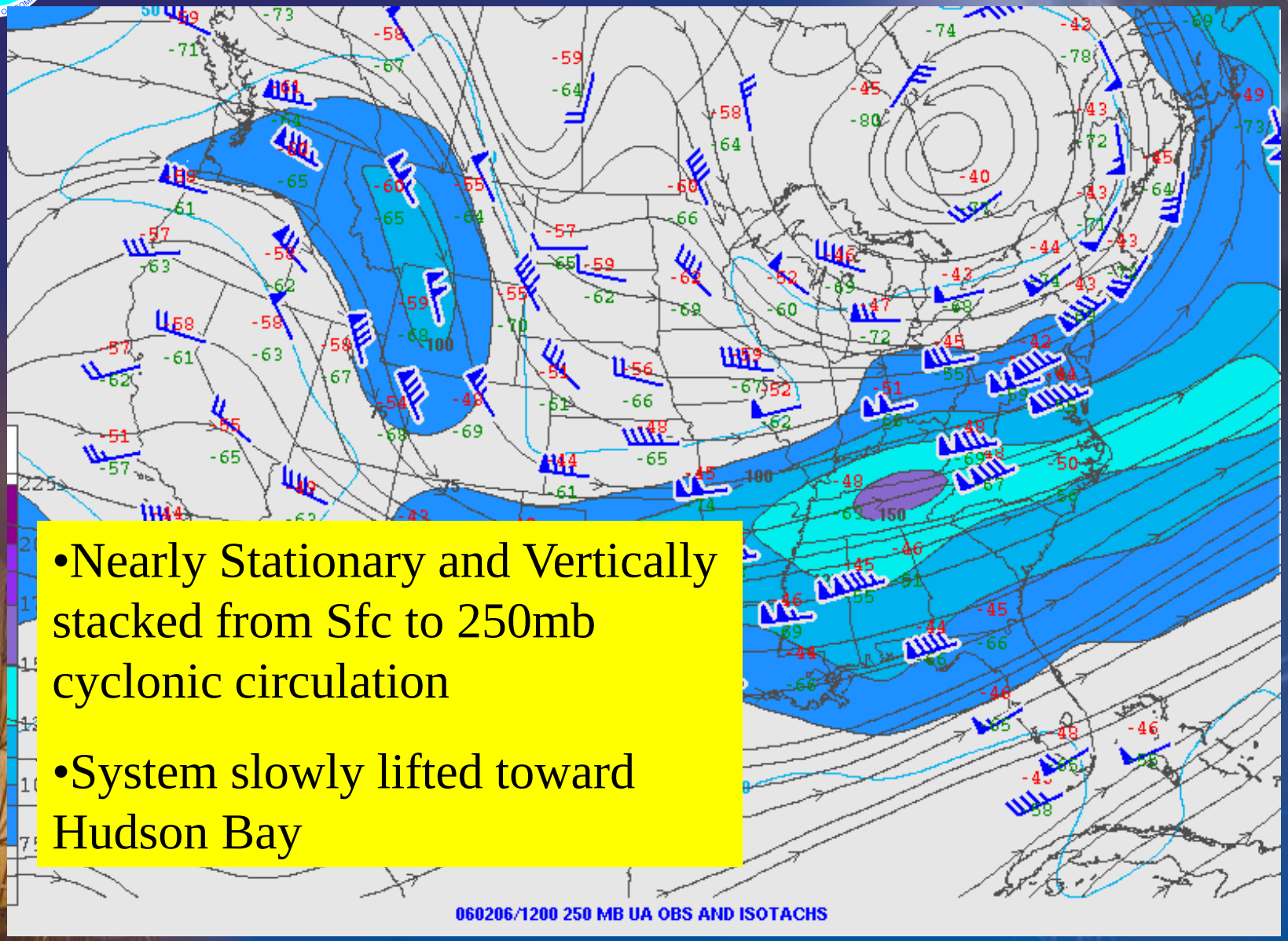
6 Feb 2006 Event

- Well established single lake effect snow band (eventually interacted with arctic boundary)
- Caused numerous problems across our CWA (I-89, I-87 closed due to multi car accidents)
- Snowfall rates of up to 4 inches per hour, along with near zero visibilities
- Produced warning criteria snowfall across our CWA 300km downwind of Lake Ontario

Water Vapor 02-22z

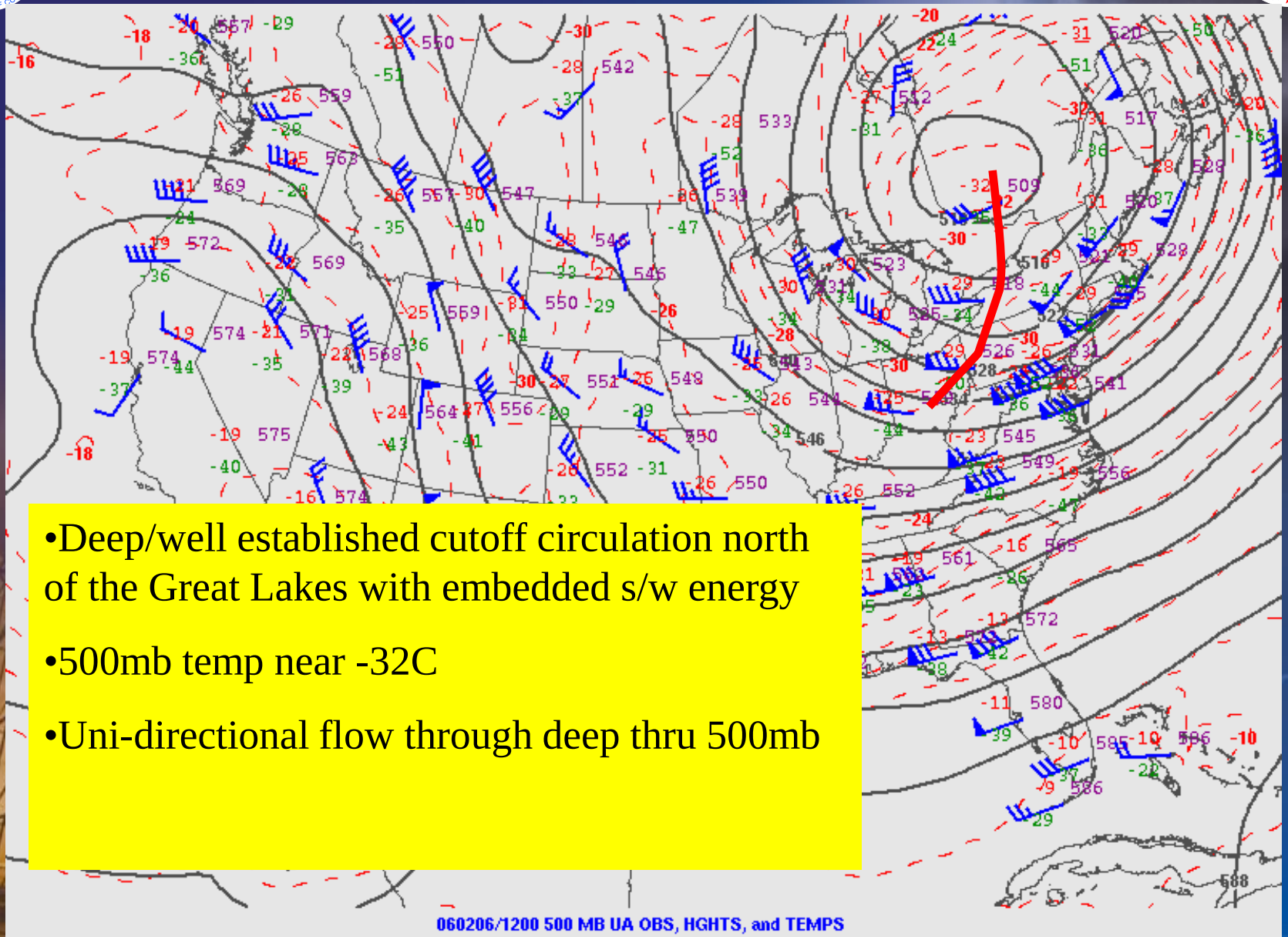


250mb 12z 02/06/06



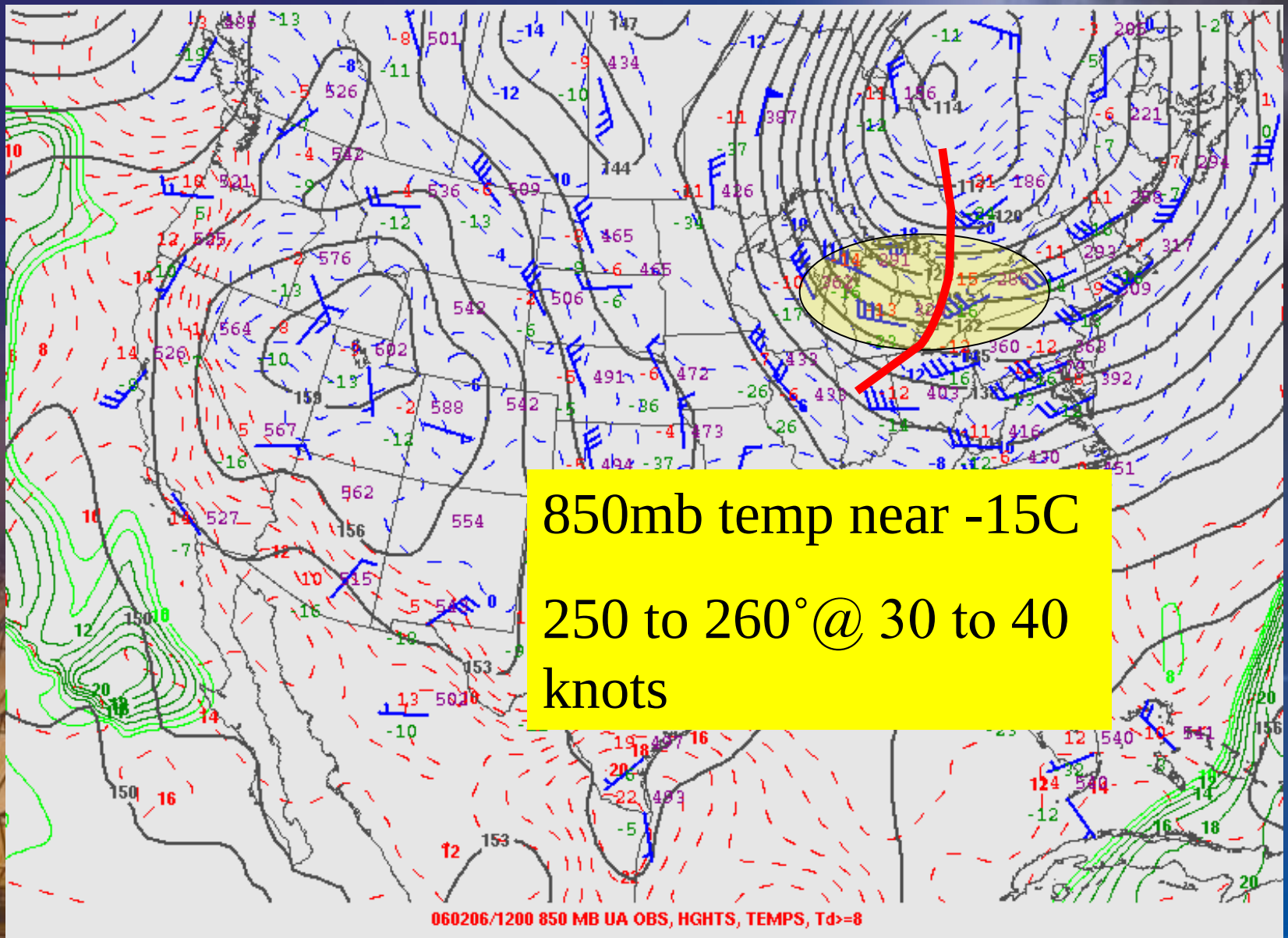
- Nearly Stationary and Vertically stacked from Sfc to 250mb cyclonic circulation
- System slowly lifted toward Hudson Bay

500mb 12z 02/06/06

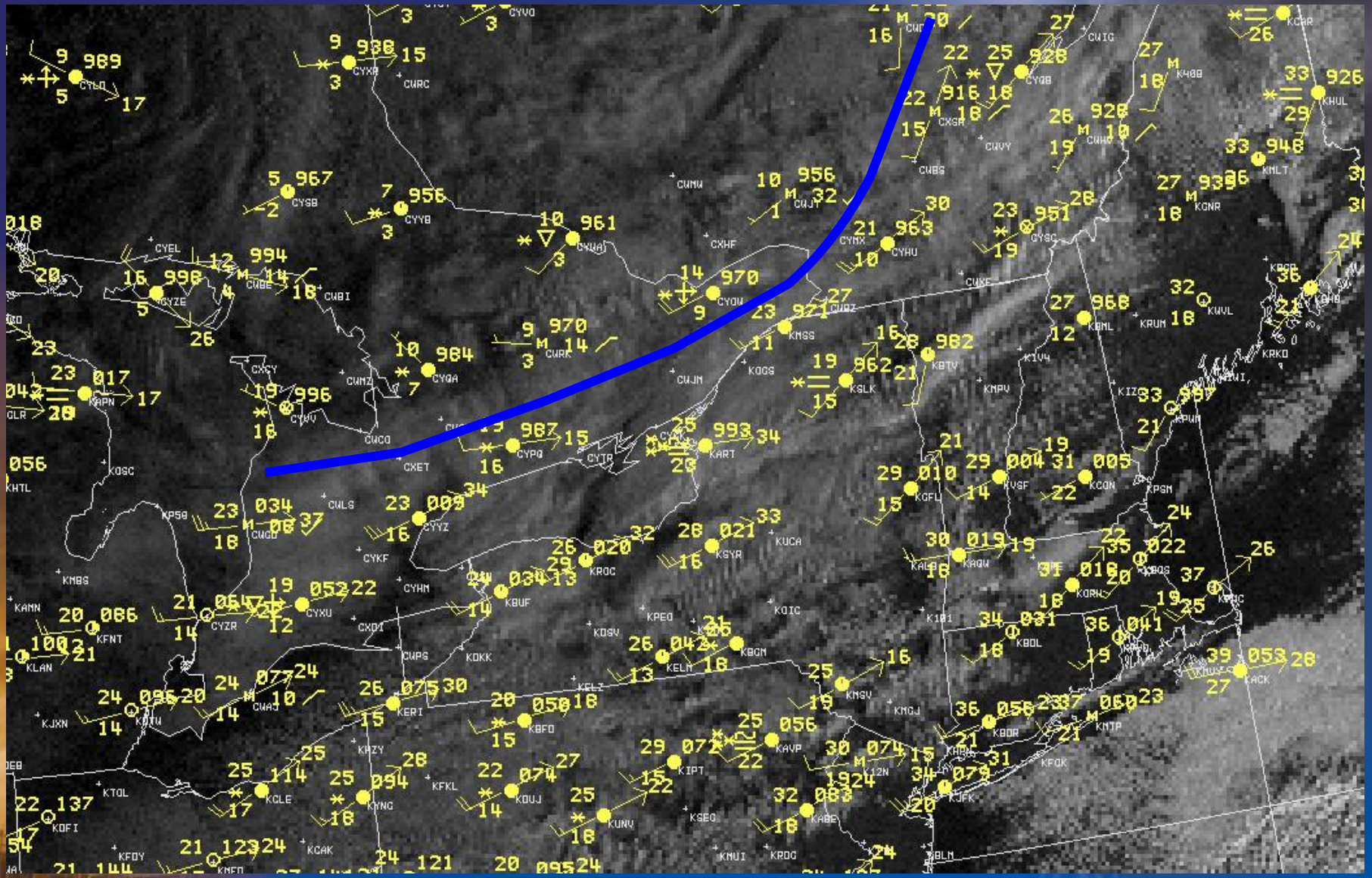


- Deep/well established cutoff circulation north of the Great Lakes with embedded s/w energy
- 500mb temp near -32C
- Uni-directional flow through deep thru 500mb

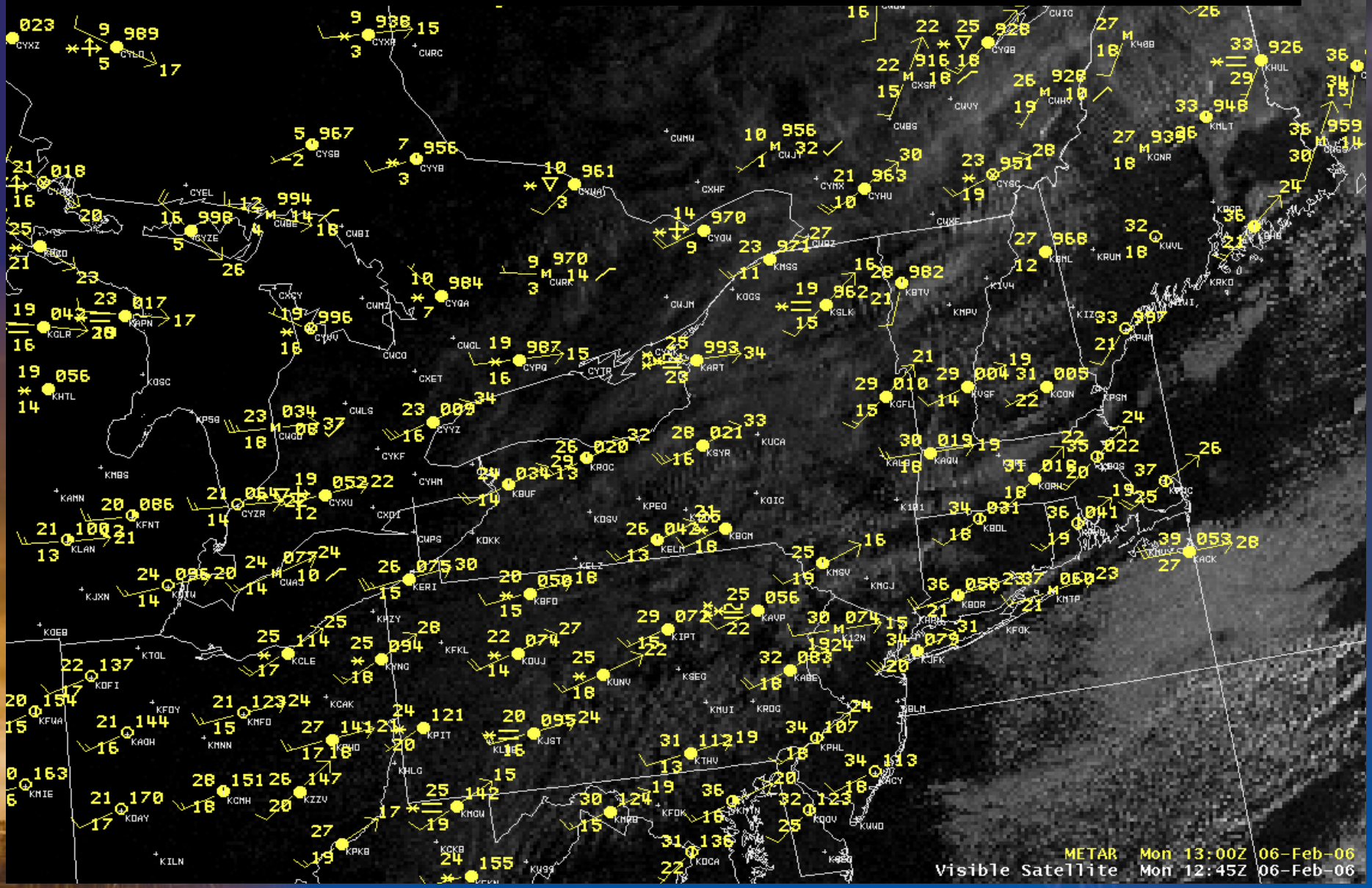
850mb 12z 02/06/06

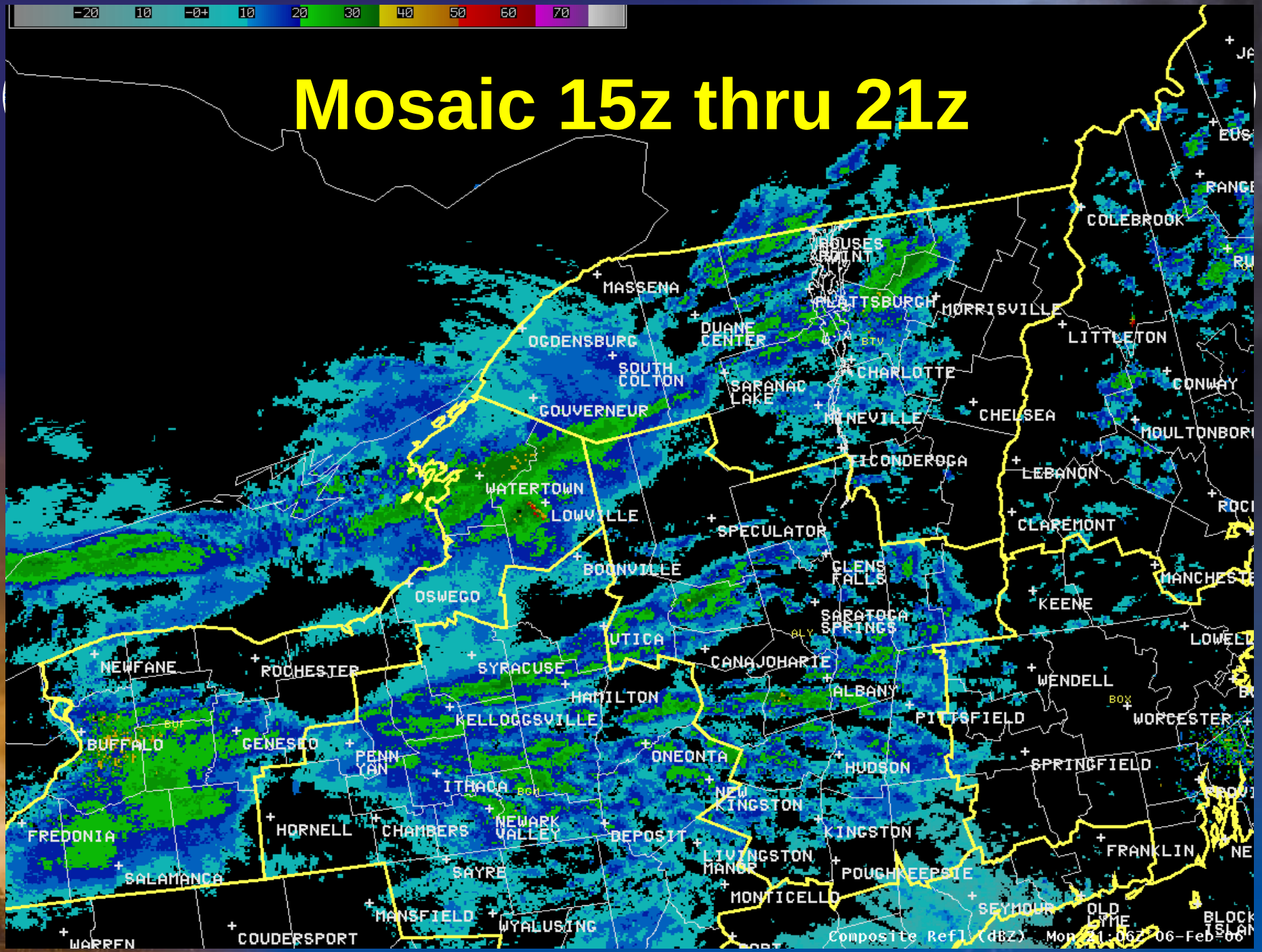


13z Surface

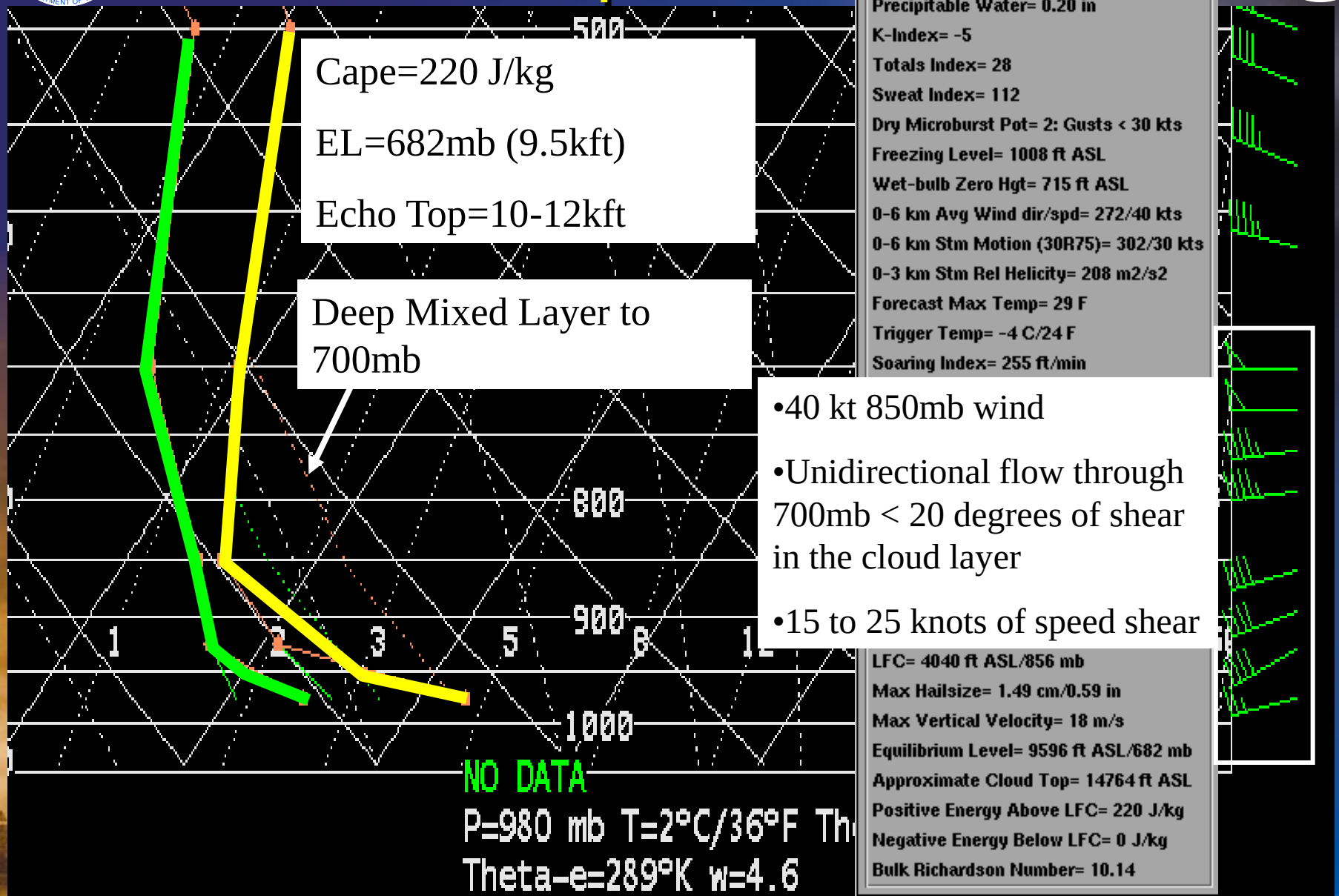


Vis Sat Loop 12z Thru 17z




-20 10 -0+ 10 20 30 40 50 60 70
Mosaic 15z thru 21z
MASSENA
OGDENSBURG
SOUTH COLTON
GOUVERNEUR
DUANE CENTER
SARANAC LAKE
PLATTSBURGH
MORRISVILLE
COLEBROOK
LITTLETON
CONWAY
CHARLOTTE
MINEVILLE
CHELSEA
TICONDEROGA
LEBANON
CLAREMONT
KEENE
WATERTOWN
LOWVILLE
SPECULATOR
BOONVILLE
GLENS FALLS
SARATOGA SPRINGS
OSWEGO
UTICA
CANAJOHARIE
ALBANY
WENDELL
PITTSFIELD
WORCESTER
SPRINGFIELD
NEWFANE
ROCHESTER
SYRACUSE
HAMILTON
KELLOGGSVILLE
BUFFALO
GENESEO
PENN YAN
ONEONTA
HUDSON
ITHACA
NEW KINGSTON
KINGSTON
FREDONIA
HORNELL
CHAMBERS
NEWARK VALLEY
DEPOSIT
LIVINGSTON MANOR
POUGHKEEPSIE
FRANKLIN
SALAMANCA
SAYRE
MONTICELLO
SEYMOUR
MANSFIELD
WYALUSING
WARREN
COUDERSPORT
Composite Refl (dBZ) Mon 21:06Z 06-Feb-06

12Z Modified Buf Sounding Adjusted for Lake Temp of 36F



Cape=220 J/kg

EL=682mb (9.5kft)

Echo Top=10-12kft

Deep Mixed Layer to 700mb

KBUF 02/06/06 1200Z

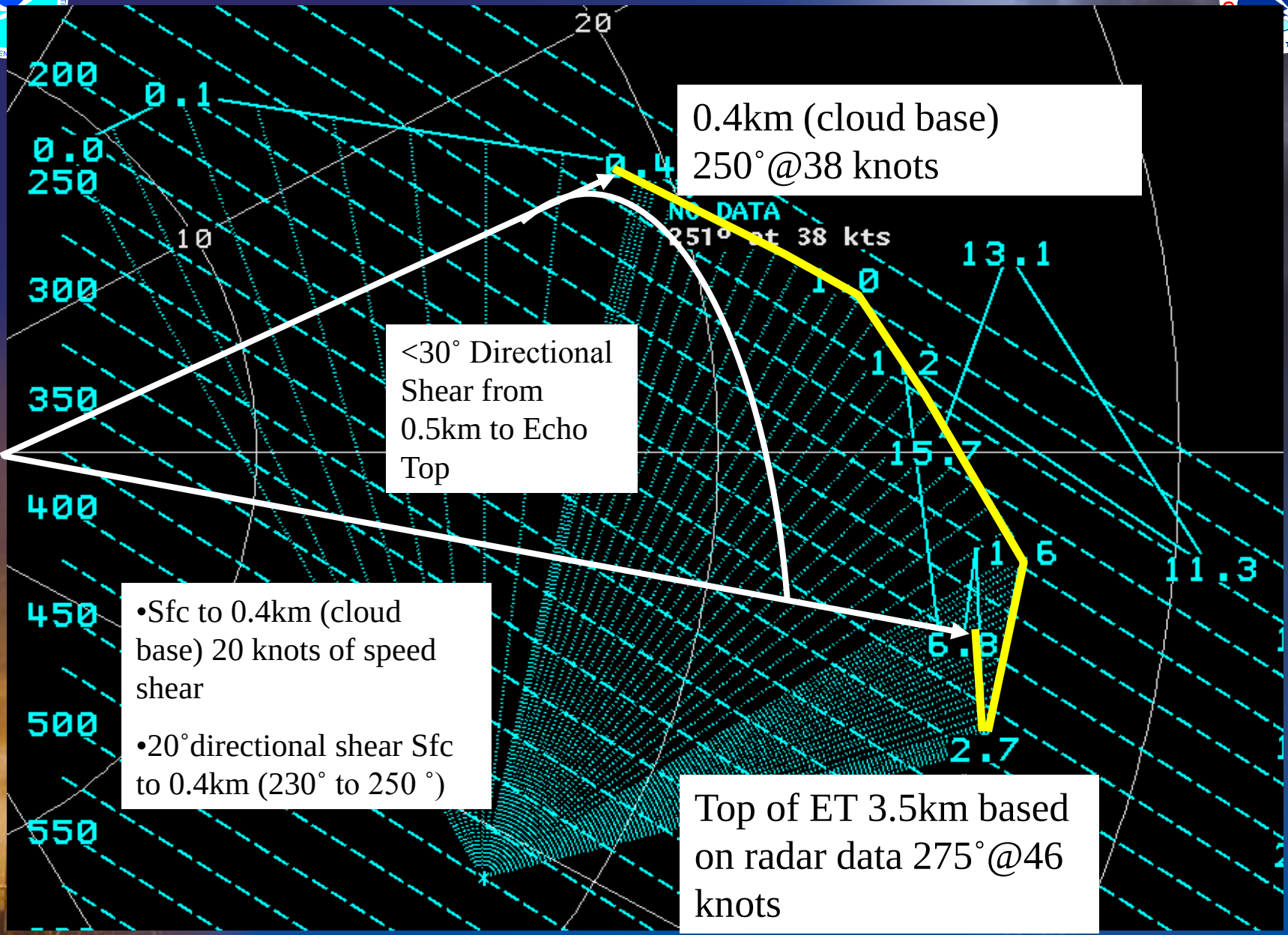
based on a PMAX Lift

Precipitable Water= 0.20 in
K-Index= -5
Totals Index= 28
Sweat Index= 112
Dry Microburst Pot= 2: Gusts < 30 kts
Freezing Level= 1008 ft ASL
Wet-bulb Zero Hgt= 715 ft ASL
0-6 km Avg Wind dir/spd= 272/40 kts
0-6 km Stm Motion (30R75)= 302/30 kts
0-3 km Stm Rel Helicity= 208 m2/s2
Forecast Max Temp= 29 F
Trigger Temp= -4 C/24 F
Soaring Index= 255 ft/min

- 40 kt 850mb wind
- Unidirectional flow through 700mb < 20 degrees of shear in the cloud layer
- 15 to 25 knots of speed shear

LFC= 4040 ft ASL/856 mb
Max Hailsize= 1.49 cm/0.59 in
Max Vertical Velocity= 18 m/s
Equilibrium Level= 9596 ft ASL/682 mb
Approximate Cloud Top= 14764 ft ASL
Positive Energy Above LFC= 220 J/kg
Negative Energy Below LFC= 0 J/kg
Bulk Richardson Number= 10.14

12z Buf Hodograph

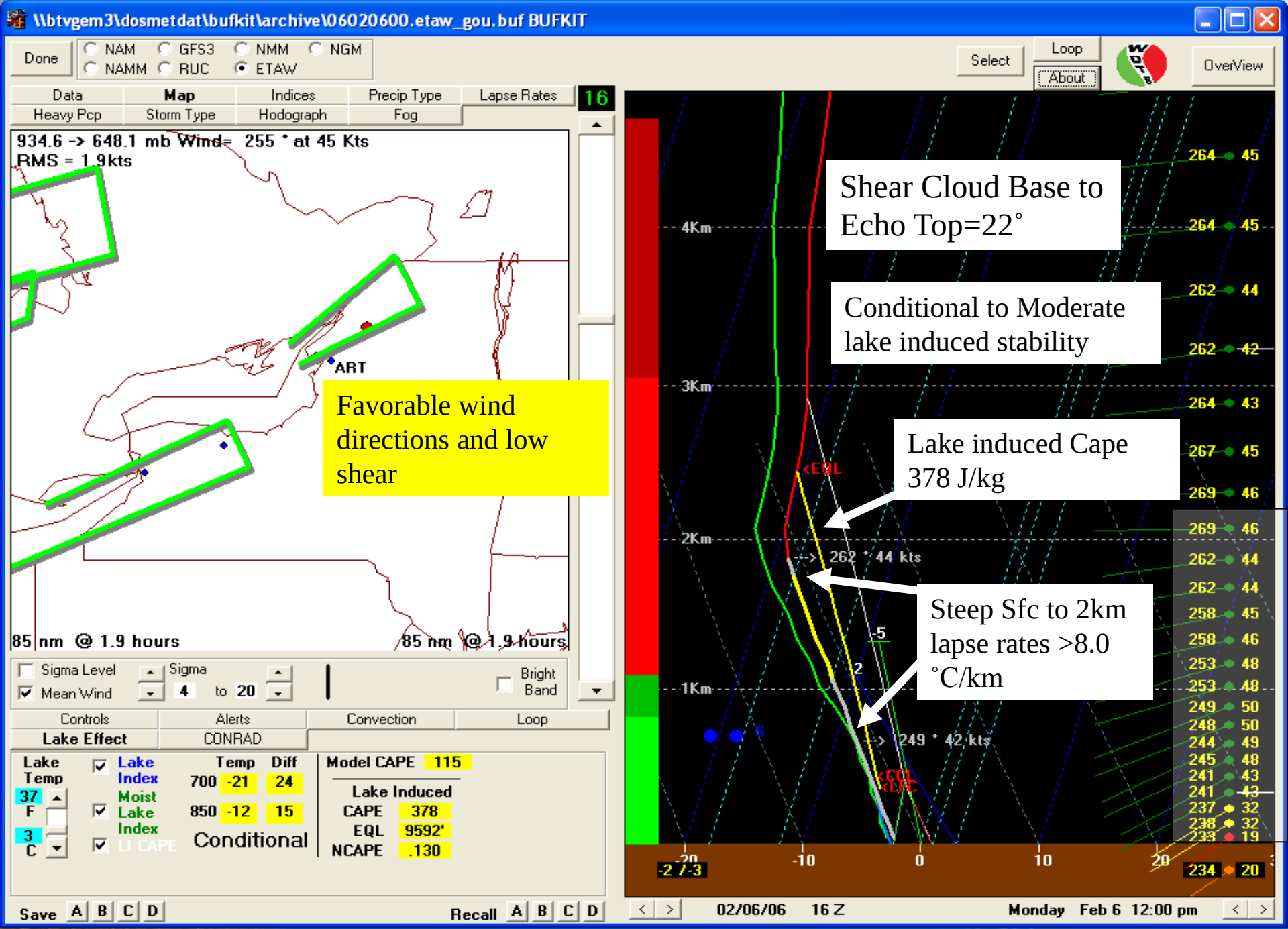


0.4km (cloud base)
250˚@38 knots

<30˚ Directional Shear from 0.5km to Echo Top

- Sfc to 0.4km (cloud base) 20 knots of speed shear
- 20˚directional shear Sfc to 0.4km (230˚ to 250 ˚)

Top of ET 3.5km based on radar data 275˚@46 knots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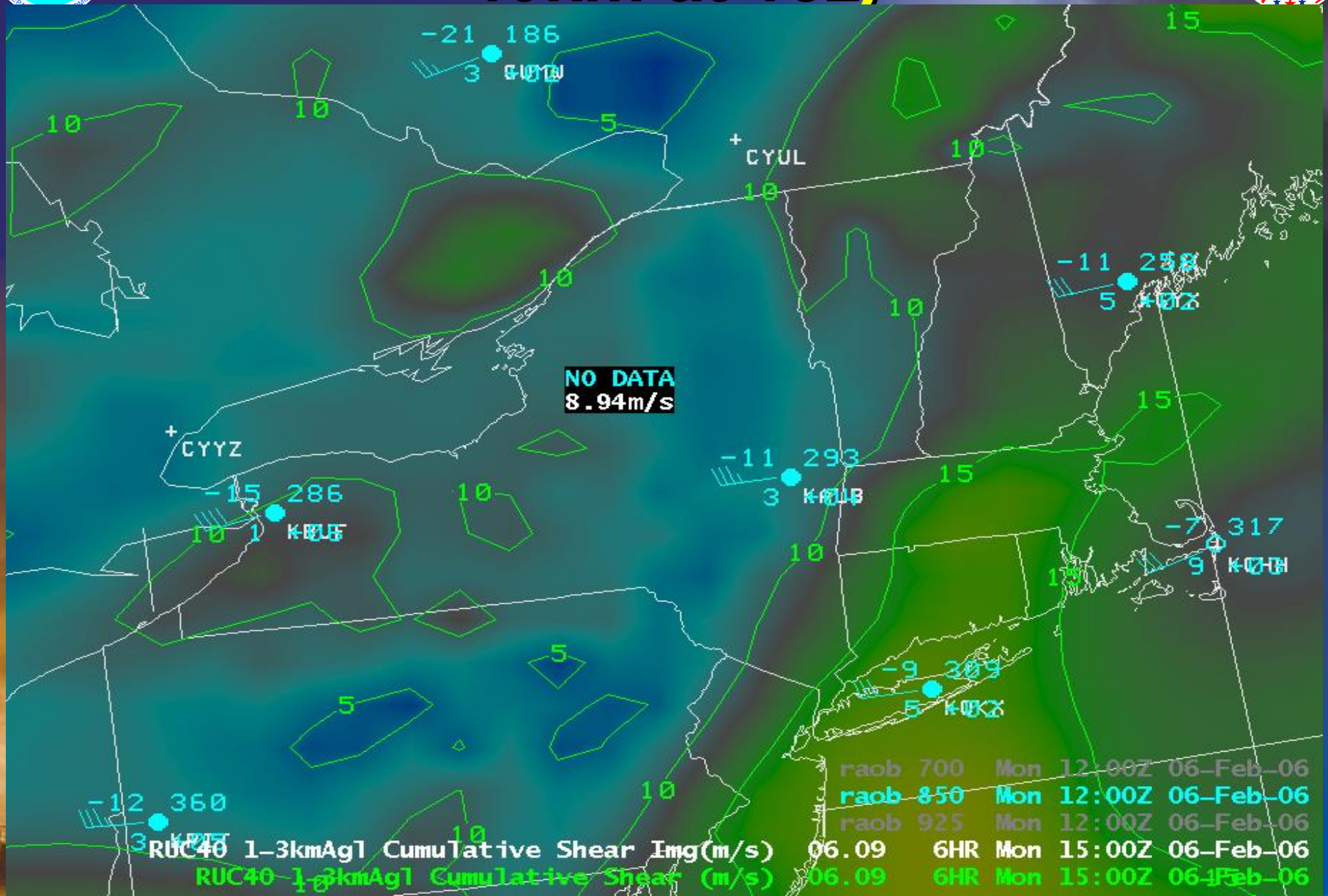
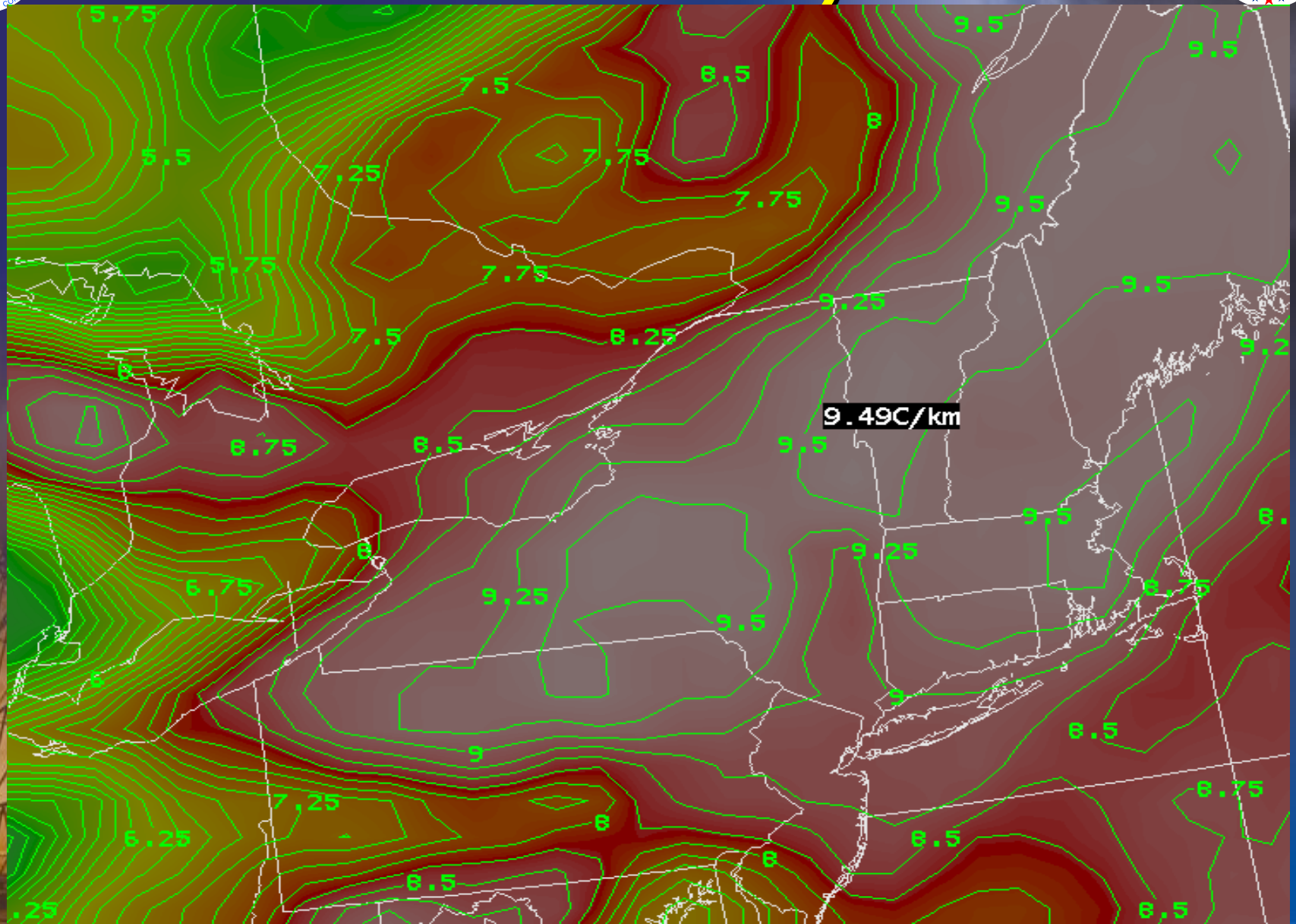
Done
NAM GFS3 NMM NGM
NAMM RUC ETAW
Select
Loop
About
OverView
Data Map Indices Precip Type Lapse Rates
Heavy Pcp Storm Type Hodograph Fog
16
934.6 -> 648.1 mb Wind= 255 ° at 45 Kts
RMS = 1.9kts
ART
Favorable wind directions and low shear
85 nm @ 1.9 hours
85 nm @ 1.9 hours
Sigma Level
Mean Wind
Sigma
4 to 20
Bright Band
Controls Alerts Convection Loop
Lake Effect CONRAD
Lake Temp
37 F
3 C
Lake Index
Moist Lake Index
LI CAPE
Temp Diff
700 -21 24
850 -12 15
Conditional
Model CAPE 115
Lake Induced
CAPE 378
EQL 9592'
NCAPE .130
Save A B C D
Recall A B C D
Shear Cloud Base to Echo Top=22˚
Conditional to Moderate lake induced stability
Lake induced Cape 378 J/kg
Steep Sfc to 2km lapse rates >8.0 ˚C/km
4Km
3Km
2Km
1Km
<EQL
262 ° 44 kts
249 ° 42 kts
-5
2
-2 /-3
-10
0
10
20
234 20
02/06/06 16 Z
Monday Feb 6 12:00 pm

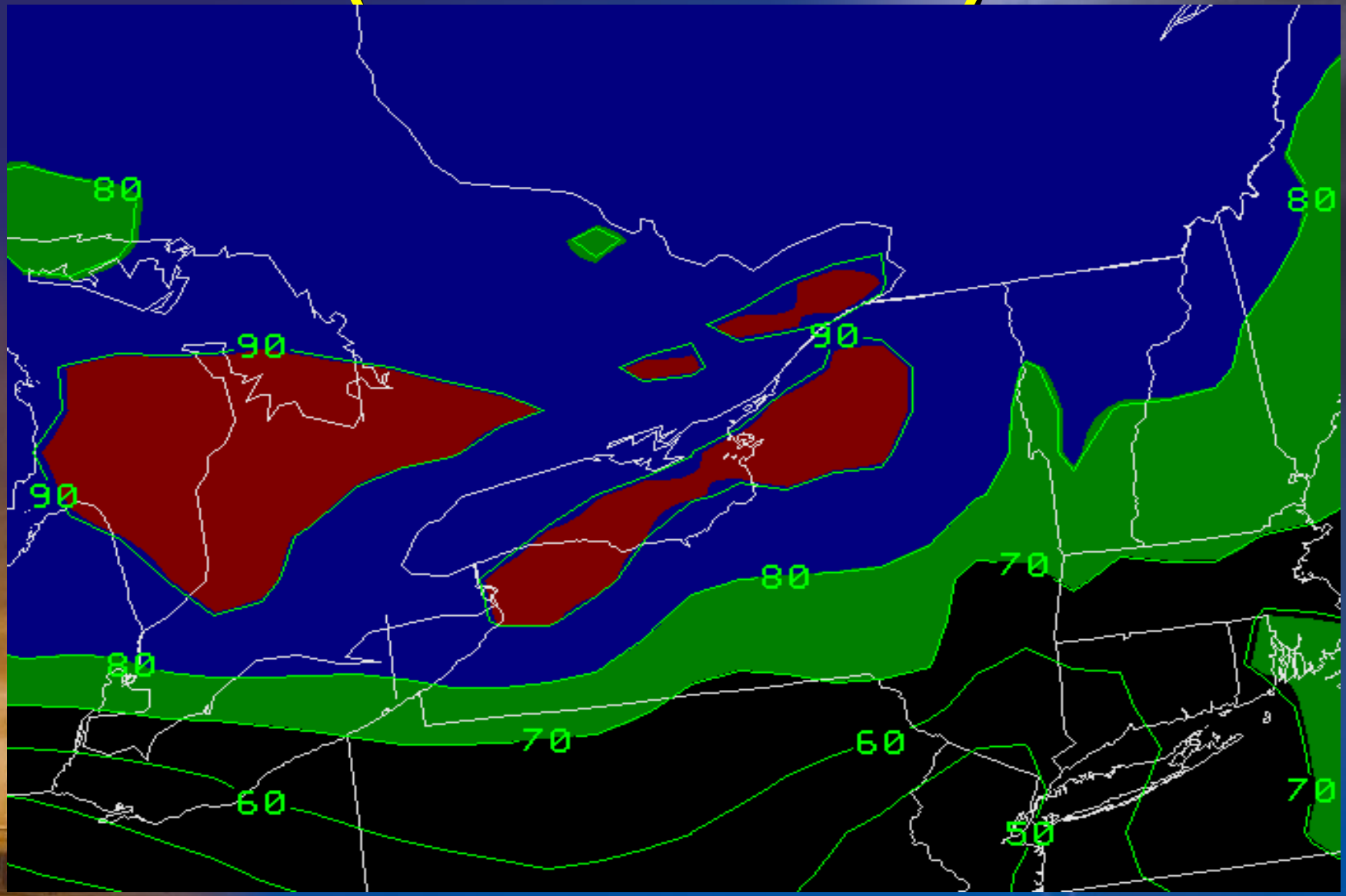
1-3km Cumulative Shear (RUC 40km at 18z)

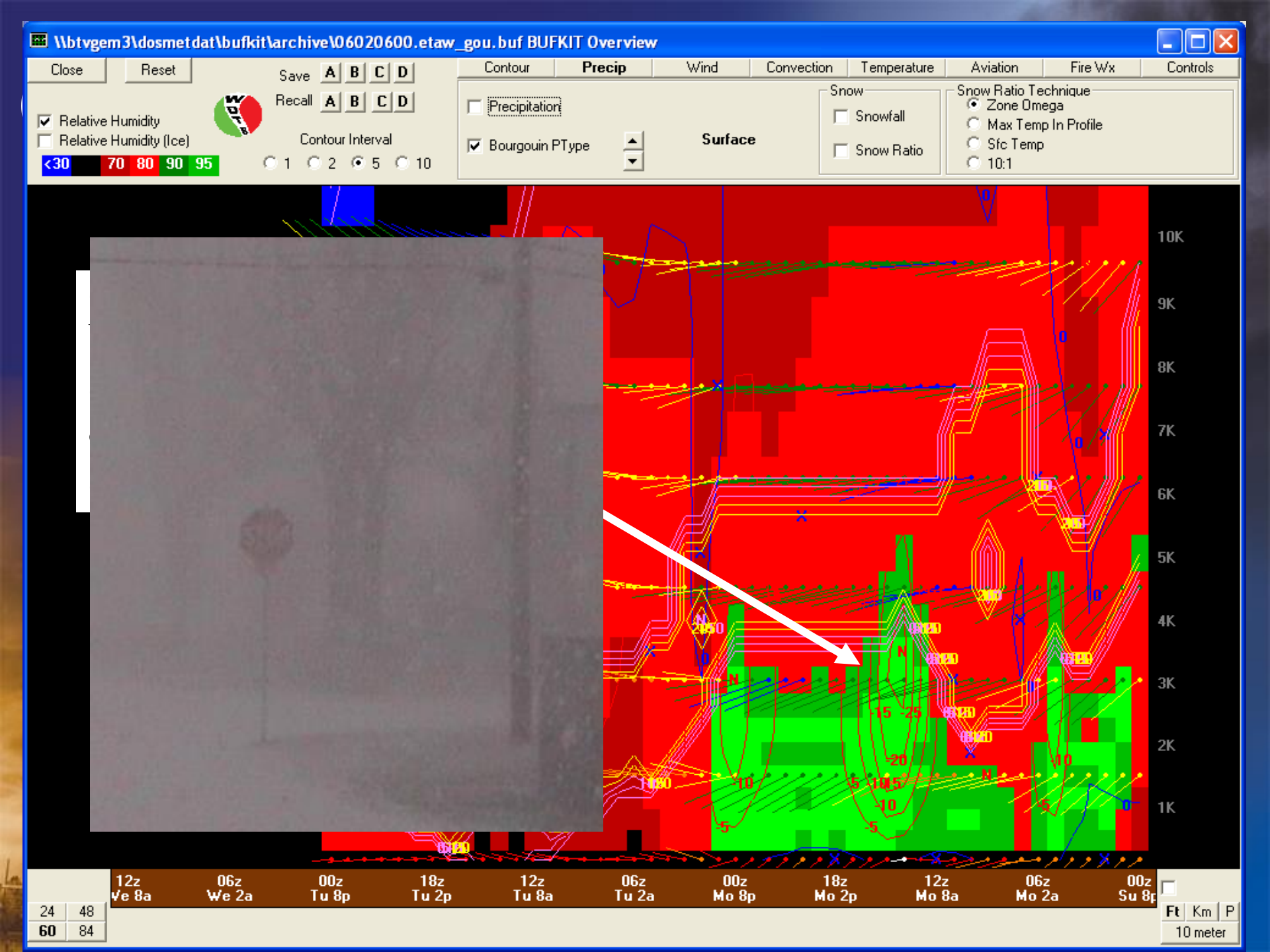


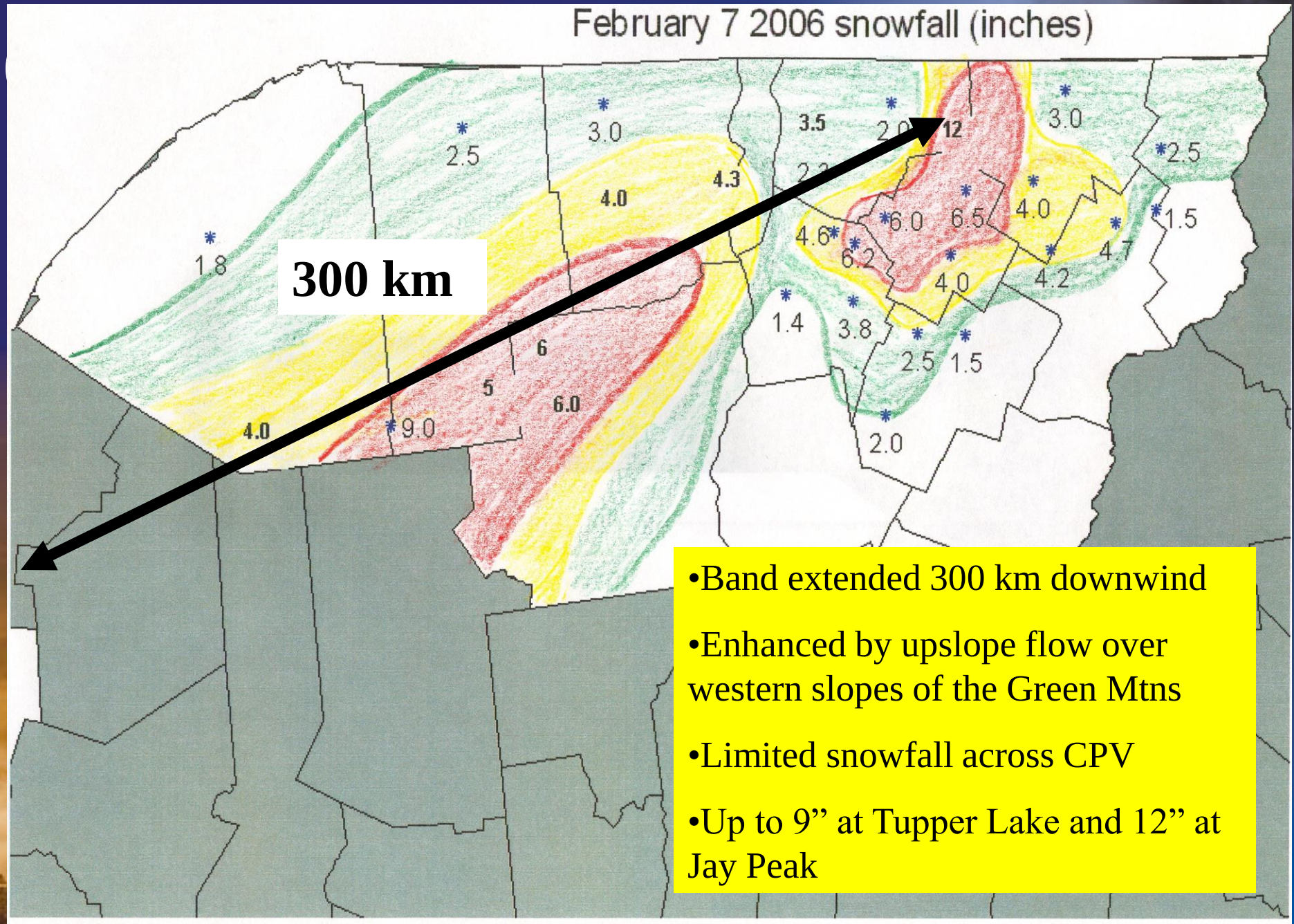
1000-700mb Lapse Rates (RUC 40km at 18z)



1000-700mb Relative Humidity (RUC 40km at 18z)




\\btvgem3\dosmetdat\bufkit\archive\06020600.etaw_gou.buf BUFKIT Overview
Close
Reset
Save A B C D
Recall A B C D
Relative Humidity
Relative Humidity (Ice)
<30 70 80 90 95
Contour Interval
1 2 5 10
Contour Precip Wind Convection Temperature Aviation Fire Wx Controls
Precipitation
Bourgouin PType
Surface
Snow
Snowfall
Snow Ratio
Snow Ratio Technique
Zone Omega
Max Temp In Profile
Sfc Temp
10:1
10K 9K 8K 7K 6K 5K 4K 3K 2K 1K
12z We 8a
06z We 2a
00z Tu 8p
18z Tu 2p
12z Tu 8a
06z Tu 2a
00z Mo 8p
18z Mo 2p
12z Mo 8a
06z Mo 2a
00z Su 8p
24 48
60 84
Ft Km P
10 meter


February 7 2006 snowfall (inches)
300 km
•Band extended 300 km downwind
•Enhanced by upslope flow over western slopes of the Green Mtns
•Limited snowfall across CPV
•Up to 9” at Tupper Lake and 12” at Jay Peak

Near Whiteout Conditions

- Light winds within heaviest lake effect band (UVV's/low level convergence)
- Large snowflake size (per max upward motions in saturated cloud layer in favorable dendritic snow growth region)
- Low snow density led to quick snowfall accumulations

Accident Near Swanton on I-89

- Several Multi Car Accidents
- Closed both I-87 and I-89

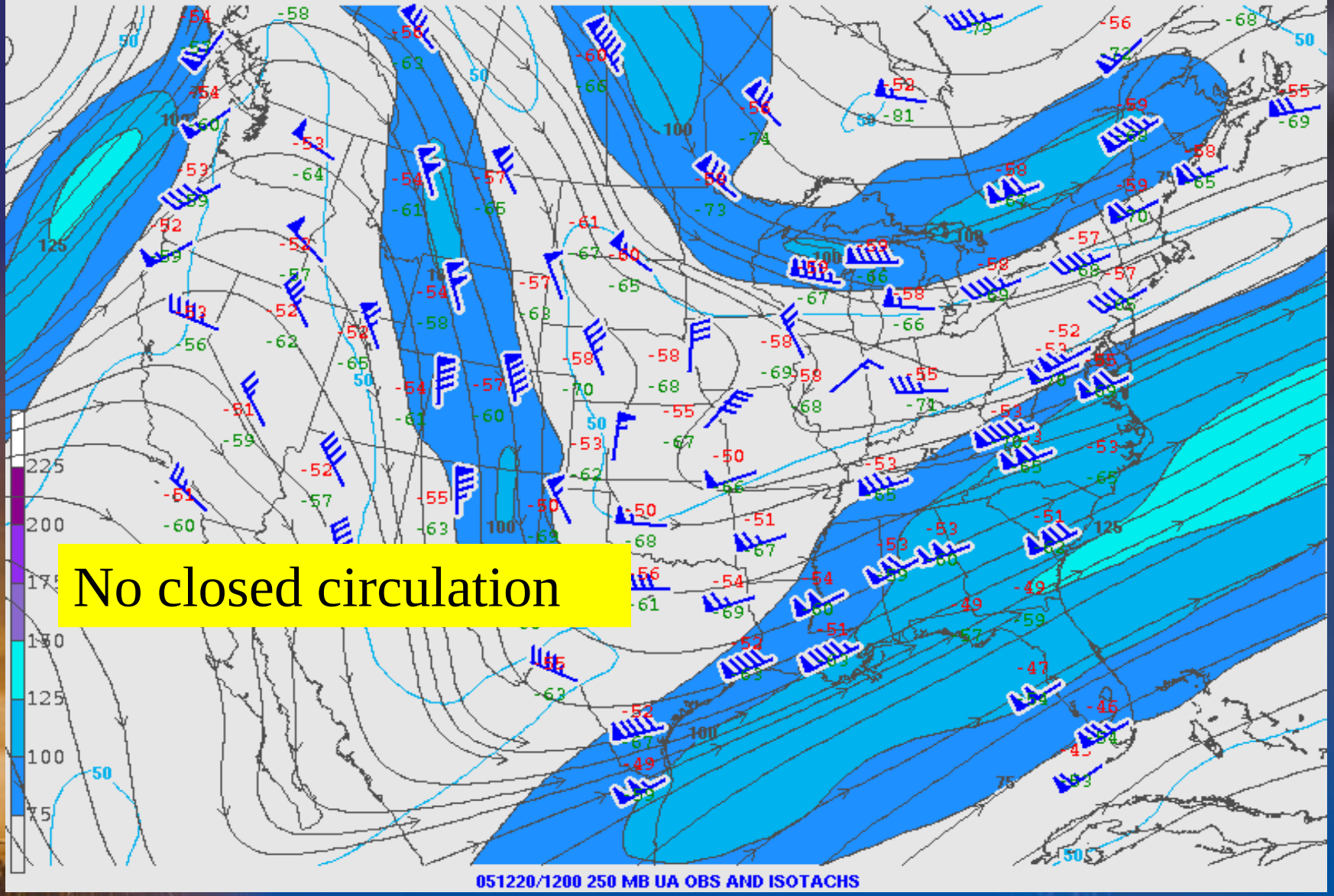
Conclusion

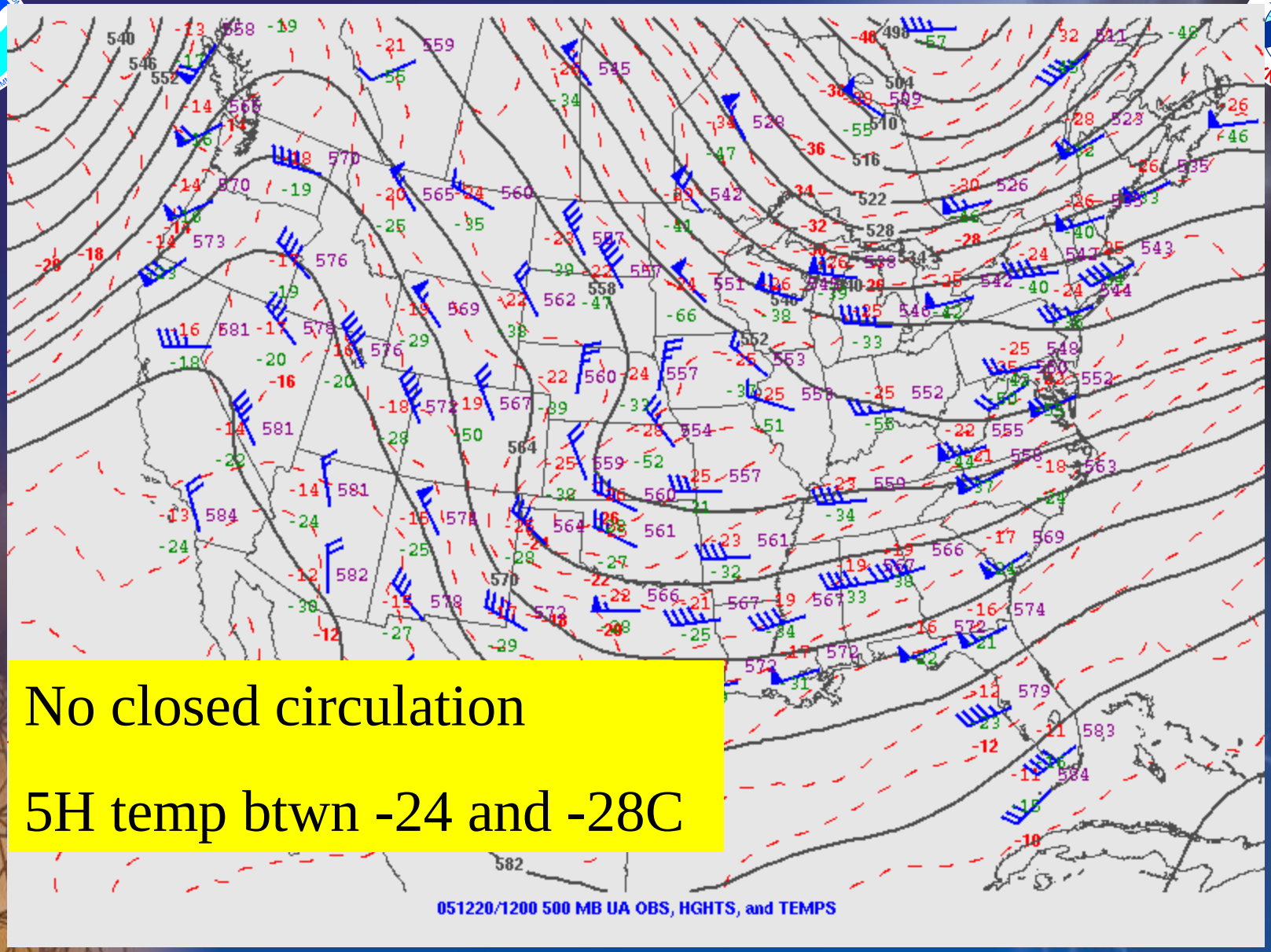
- Cloud layer wind around 40 knots aided to transfer moisture/band 200-300km downwind of Lake Ontario
- Well established cutoff circulation from Sfc to 250mb led to limited shear and helped to transfer significant lake effect snow 200-300 km downwind of Lake Ontario
- Uni-directional flow between 250-260˚
- Cloud layer (0.5-3km) shear (CCL to Echo Top)≤ 30˚ Favorable for single well organized band (Niziol 1987)
- >80% RH values between 1000-700mb and in favorable dendrite snow growth region with upward vertically velocities enhances snowfall accumulation rates

Dec 20, 2006 Event

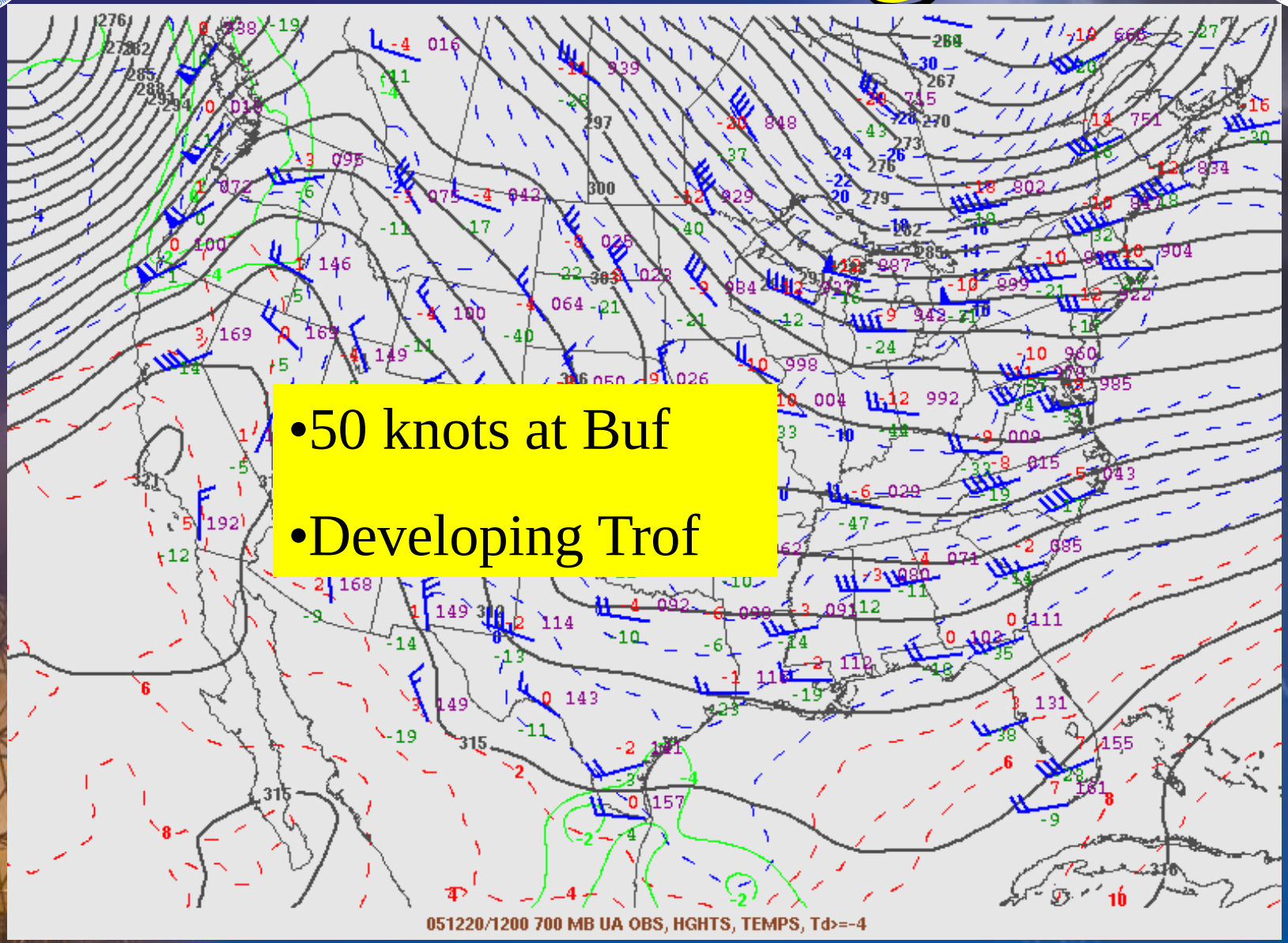
- Lake Ontario enhanced low level moisture along a strong sfc boundary to produce lake effect squall across our forecast area
- Produced a quick burst of snow with visibilities near zero
- Once again plenty of problems with 3 to 6 inches of snowfall <3hrs

250mb 12/20/05 @12z

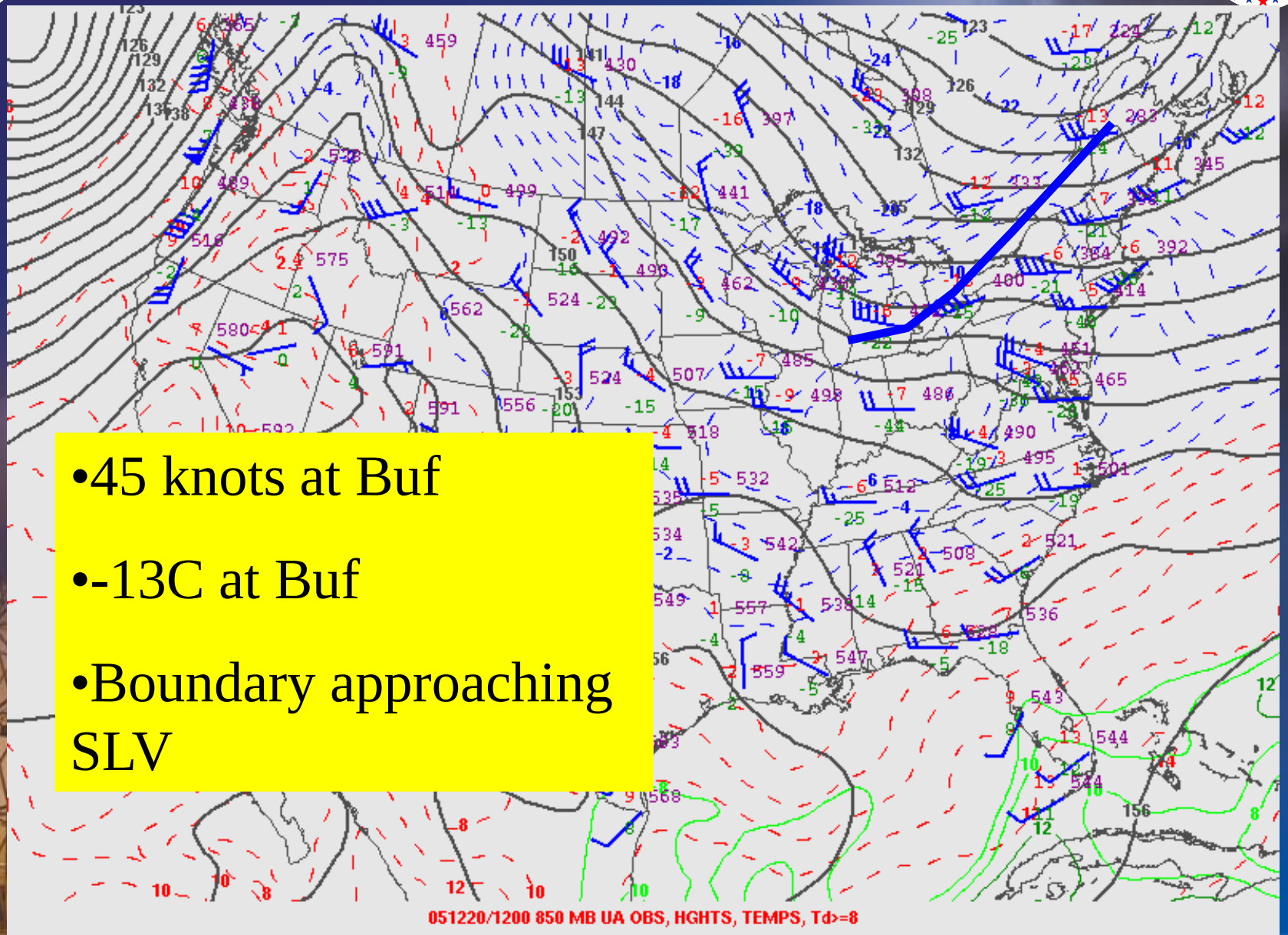



No closed circulation
5H temp btwn -24 and -28C
051220/1200 500 MB UA OBS, HGHTS, and TEMPS

700mb 12/20/05 @12z

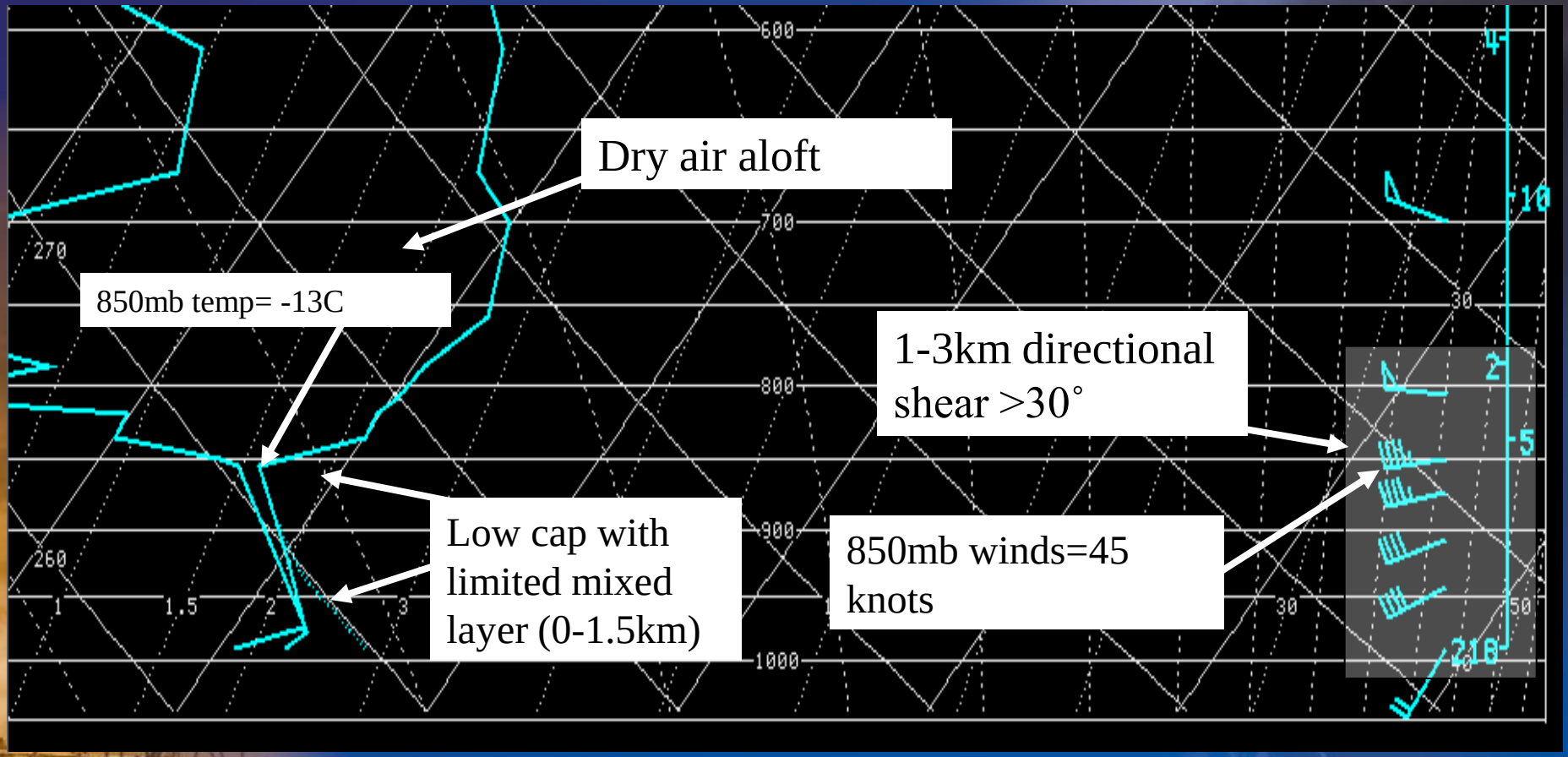


850mb 12/20/05 @12z

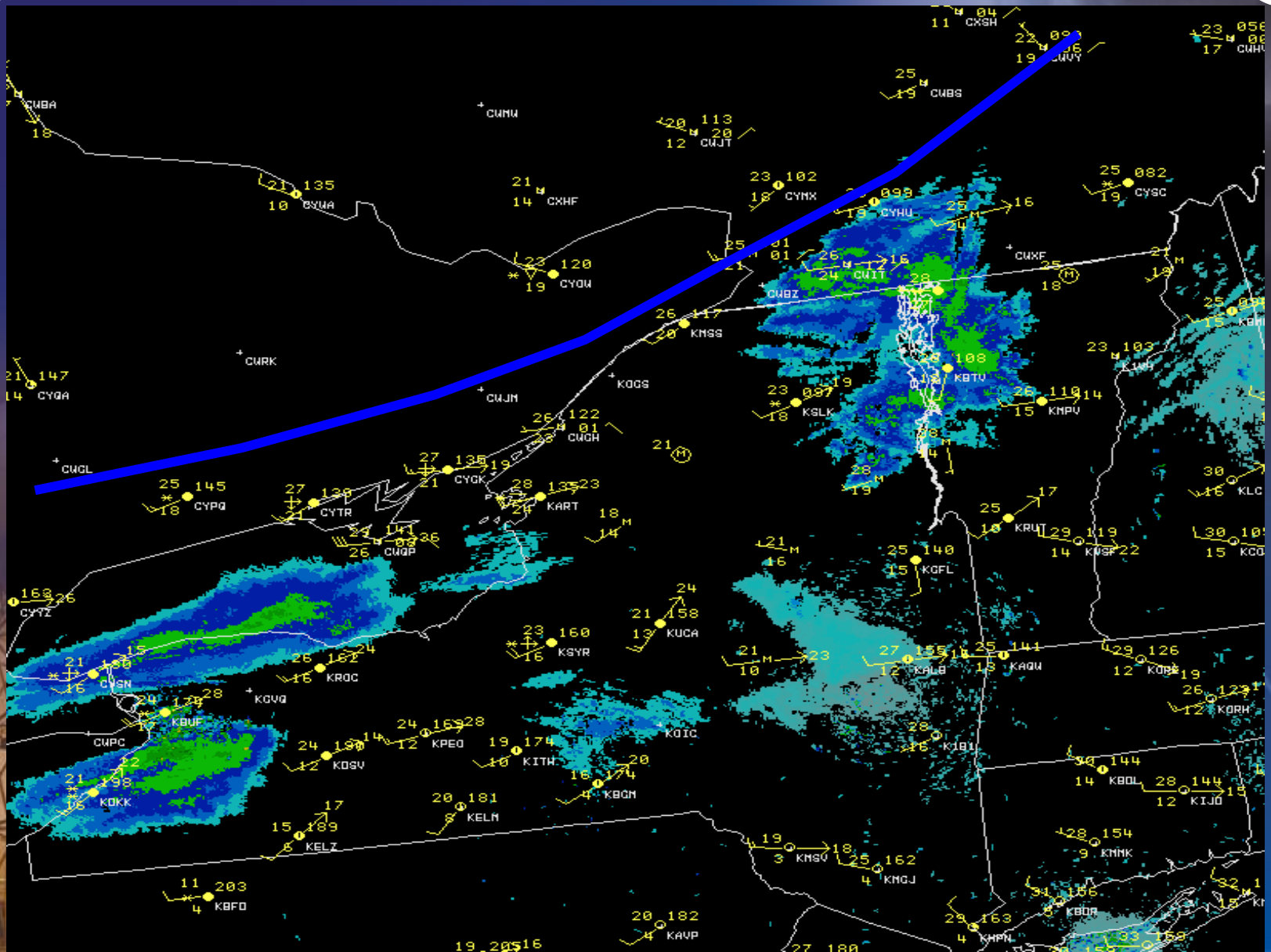


- 45 knots at Buf
- -13C at Buf
- Boundary approaching SLV

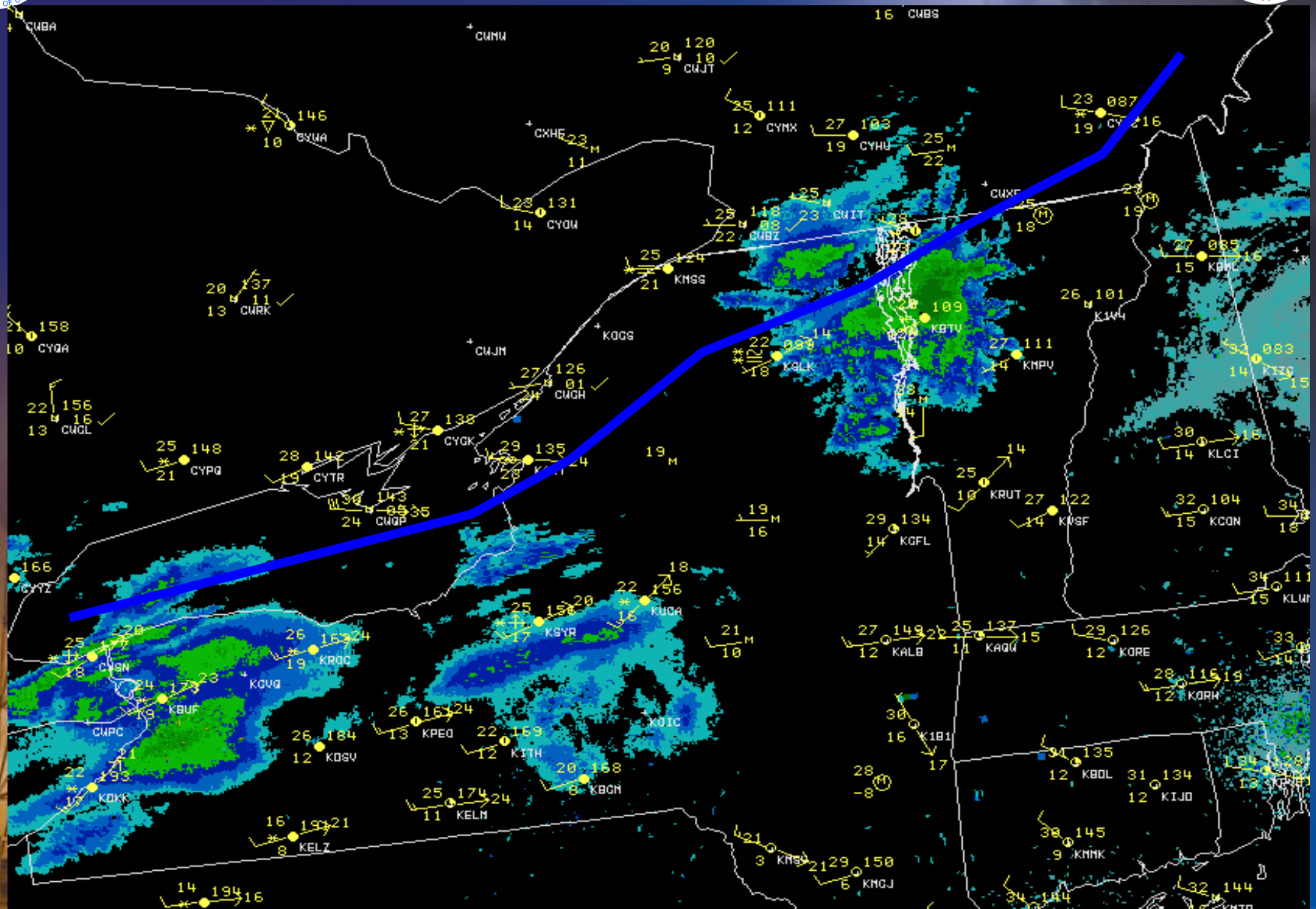
12Z Buf Sounding 12/20/05



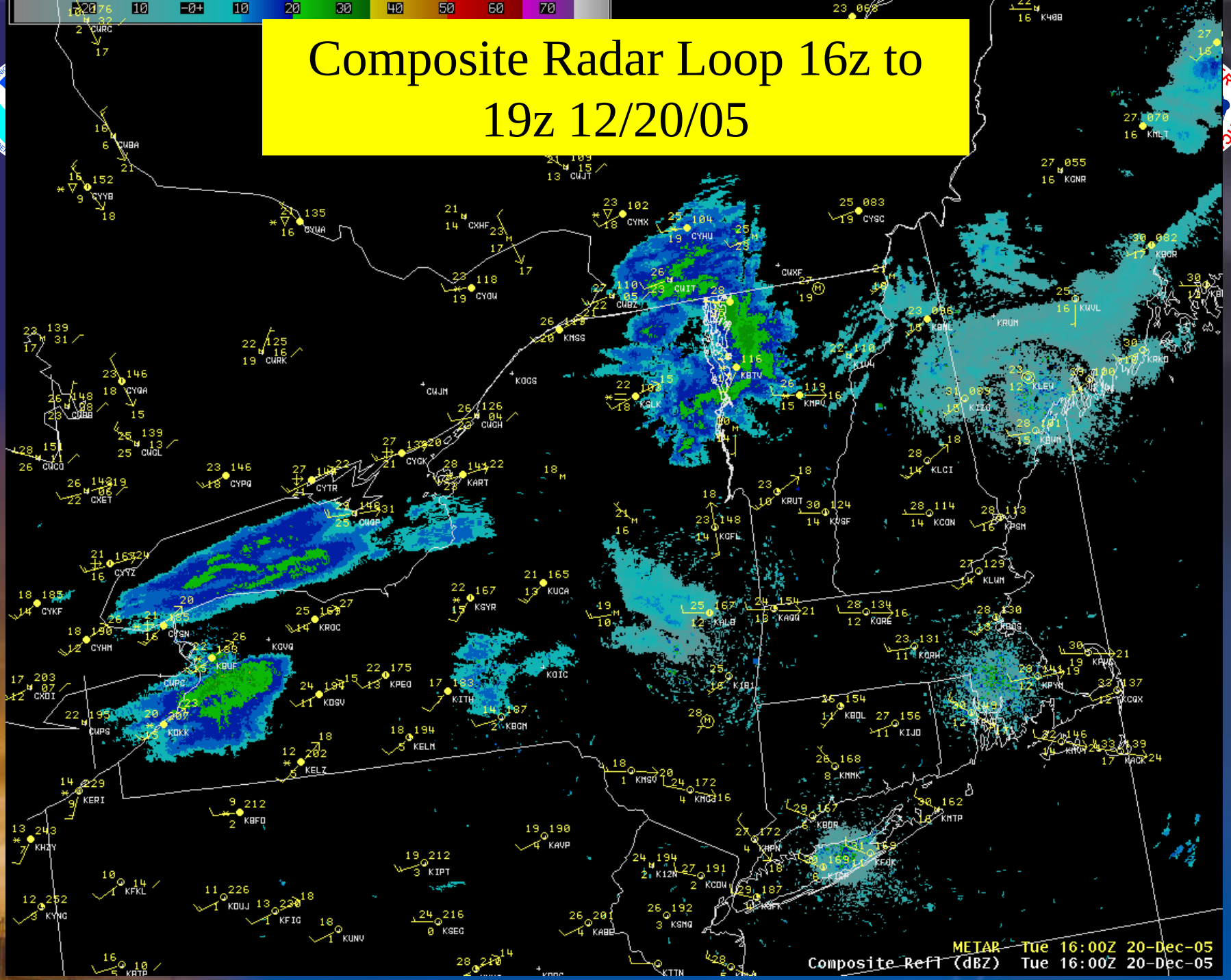
17z Surface 12/20/05



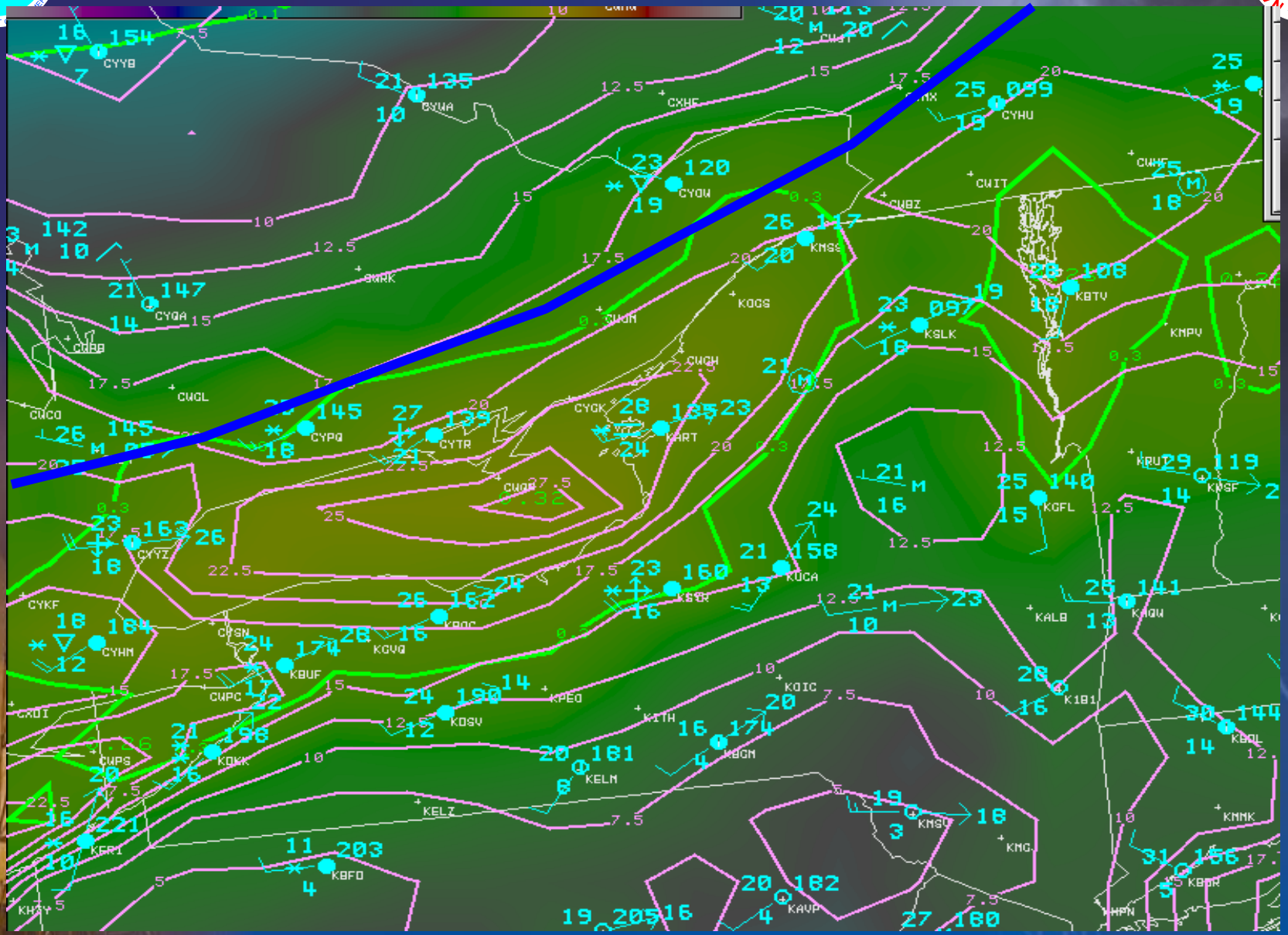
19z Surface 12/20/05



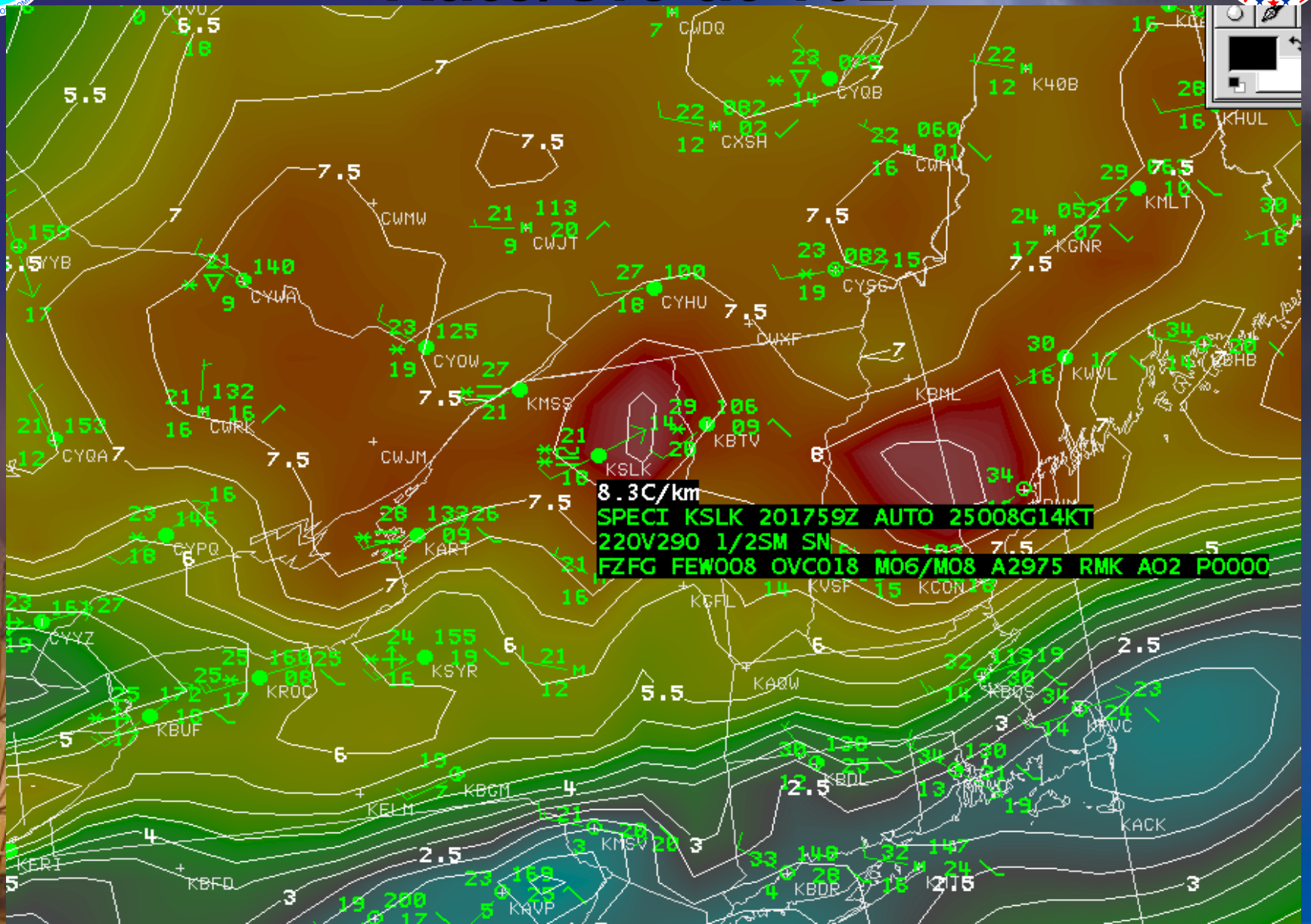
Composite Radar Loop 16z to 19z 12/20/05



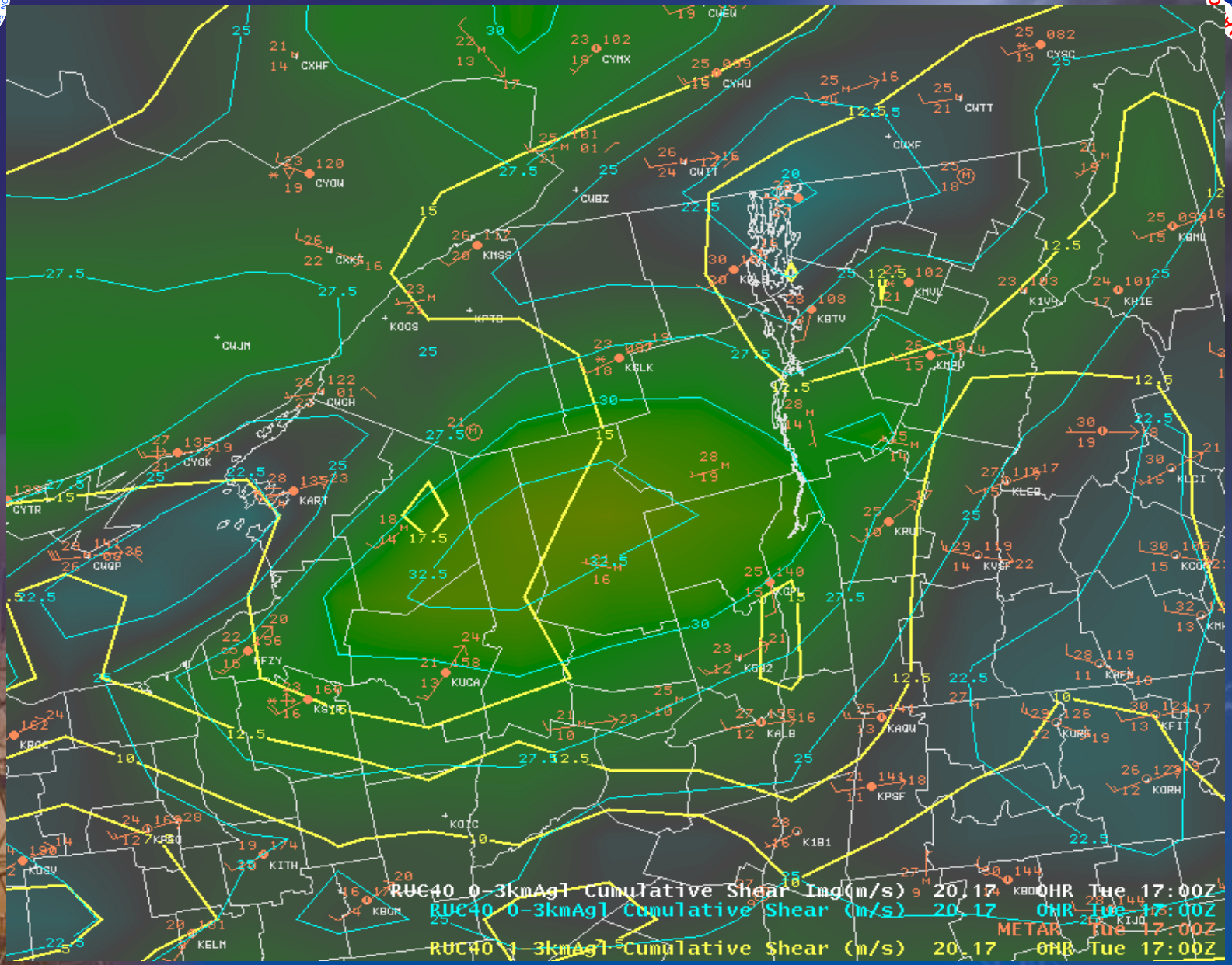
17z Sfc, Dwpt, PWs

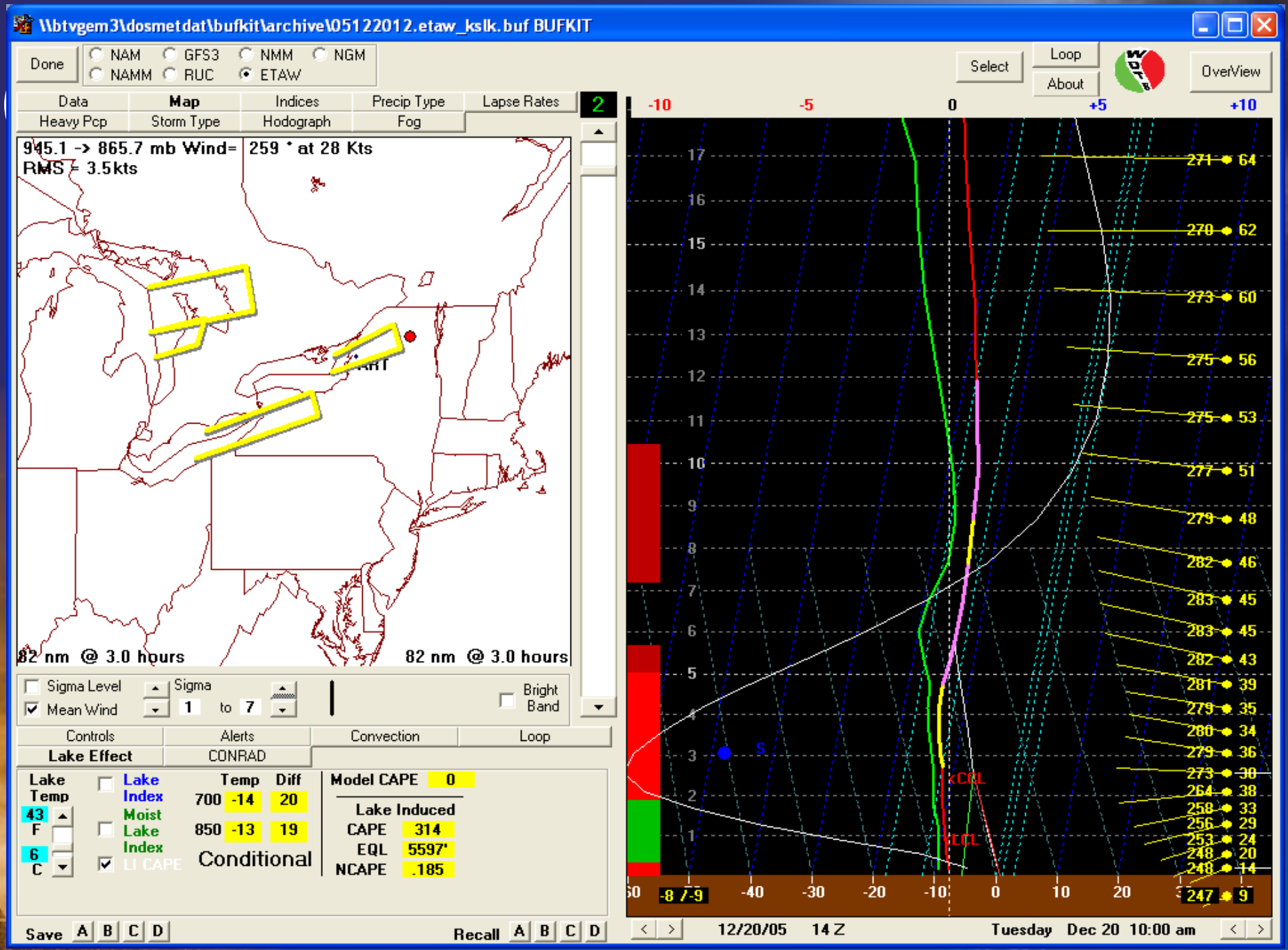


Laps 1000-850mb Lapse Rate/Sfc at 18z



RUC 0-3km Cumulative Shear at 17Z

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NAM
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OverView
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Indices
Precip Type
Lapse Rates
Heavy Pcp
Storm Type
Hodograph
Fog
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945.1 -> 865.7 mb Wind= 259 ° at 28 Kts
RMS = 3.5kts
82 nm @ 3.0 hours
82 nm @ 3.0 hours
Sigma Level
Mean Wind
Sigma
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to
7
Bright Band
Controls
Alerts
Convection
Loop
Lake Effect
CONRAD
Lake Temp
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6
C
Lake Index
Moist Lake Index
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850 -13 19
Conditional
Model CAPE 0
Lake Induced
CAPE 314
EQL 5597'
NCAPE .185
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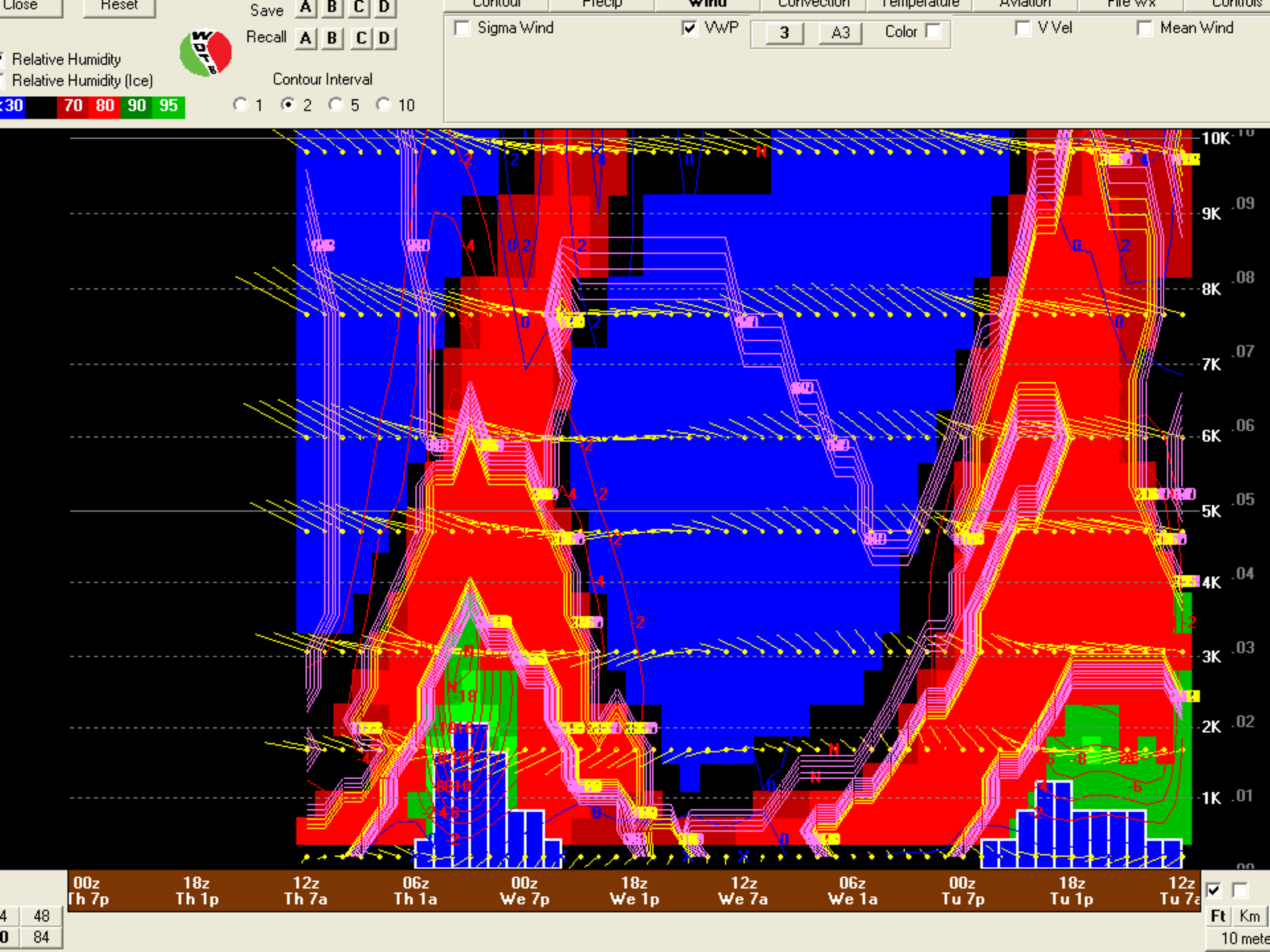
12/20/05 14 Z
Tuesday Dec 20 10:00 am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Reset
Save A B C D
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Relative Humidity
Relative Humidity (Ice)
30 70 80 90 95
Contour Interval
1 2 5 10
Contour Precip Wind Convection Temperature Aviation Fire Wx Controls
Sigma Wind
VWP
3
A3
Color
V Vel
Mean Wind
10K 9K 8K 7K 6K 5K 4K 3K 2K 1K
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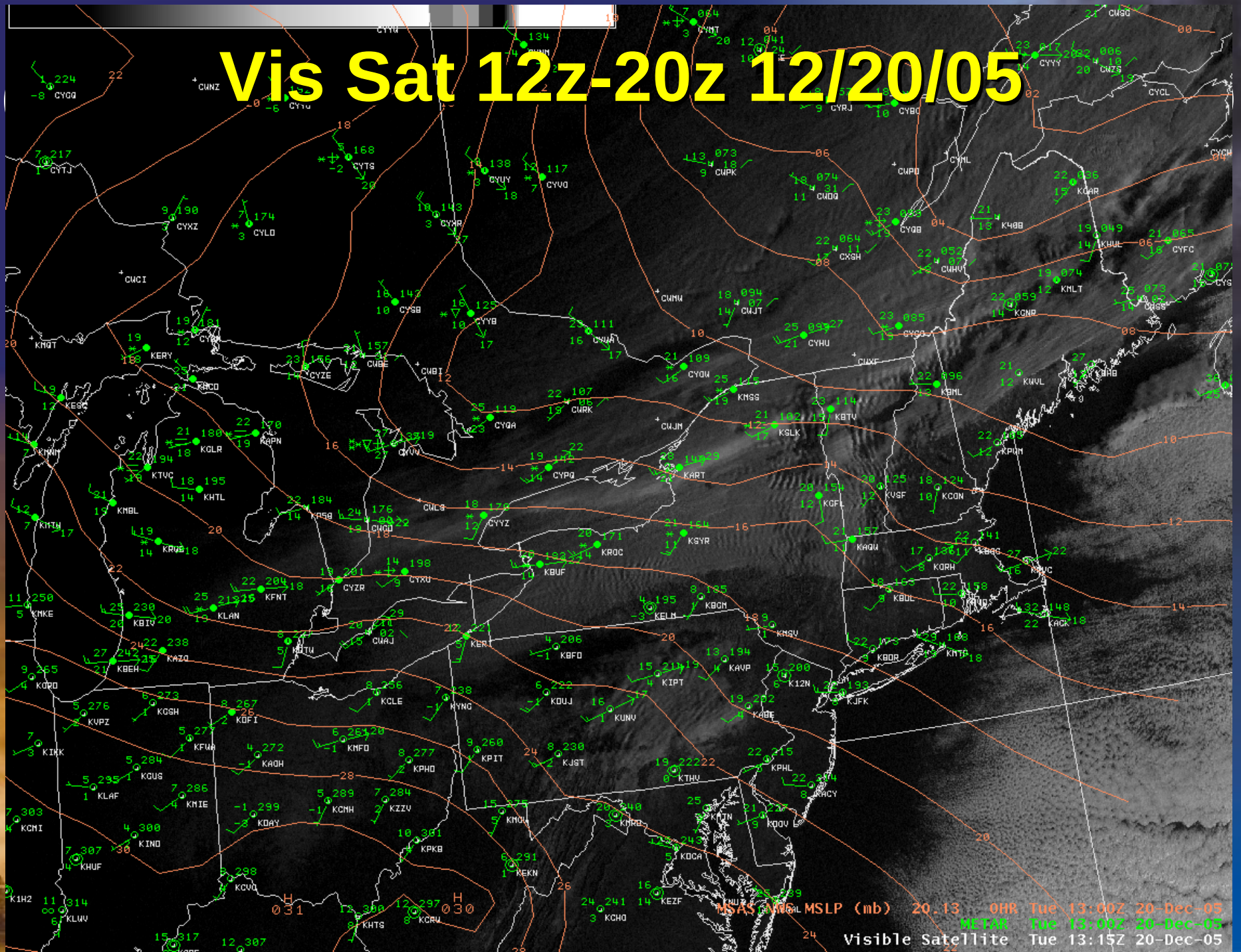
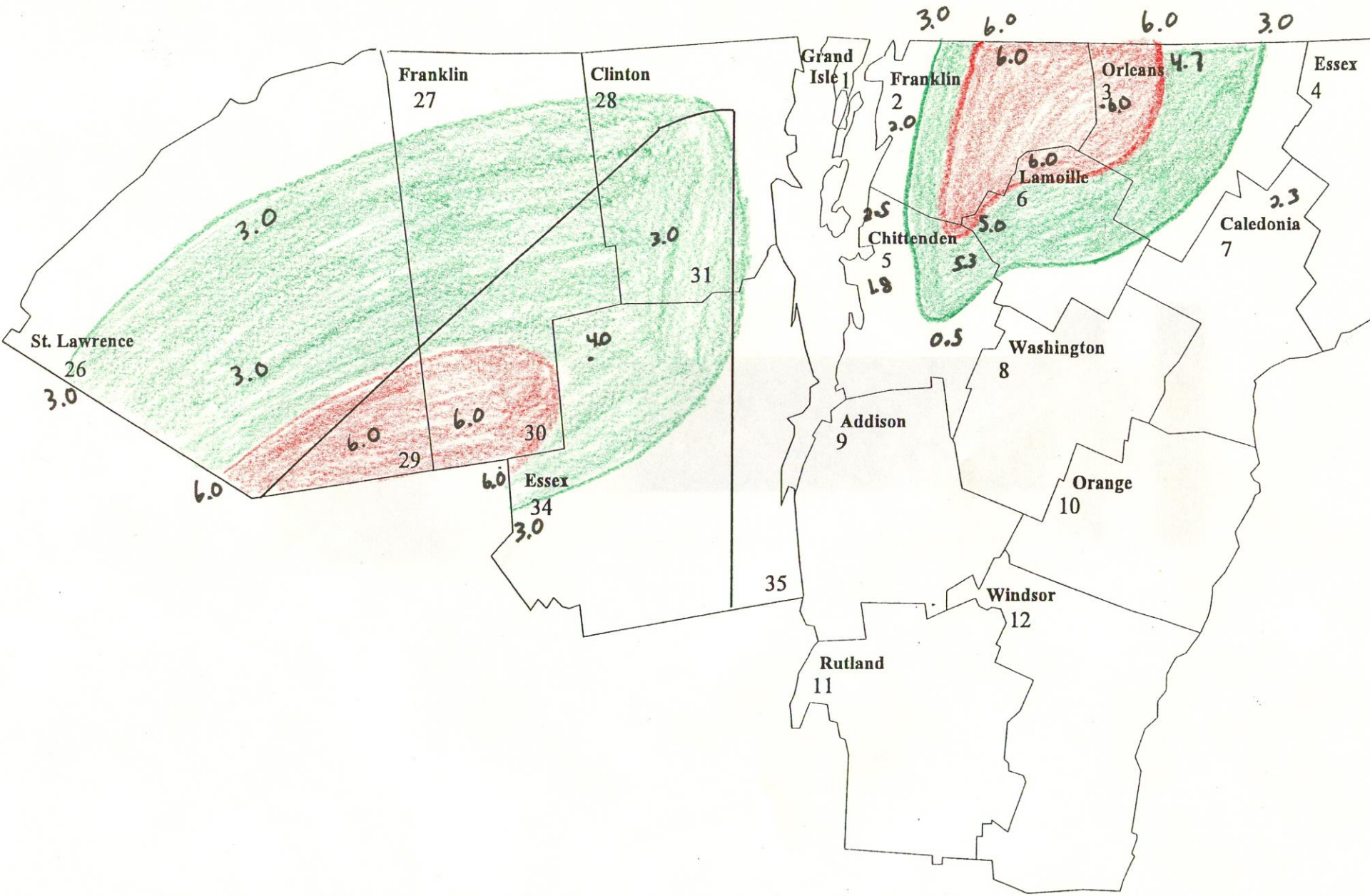
18z Th 1p
12z Th 7a
06z Th 1a
00z We 7p
18z We 1p
12z We 7a
06z We 1a
00z Tu 7p
18z Tu 1p
12z Tu 7a
Ft Km
10 mete


Vis Sat 12z-20z 12/20/05
MSAS MSLP (mb) 20.13 OHR Tue 13:00Z 20-Dec-05
METAR Tue 13:00Z 20-Dec-05
Visible Satellite Tue 13:15Z 20-Dec-05

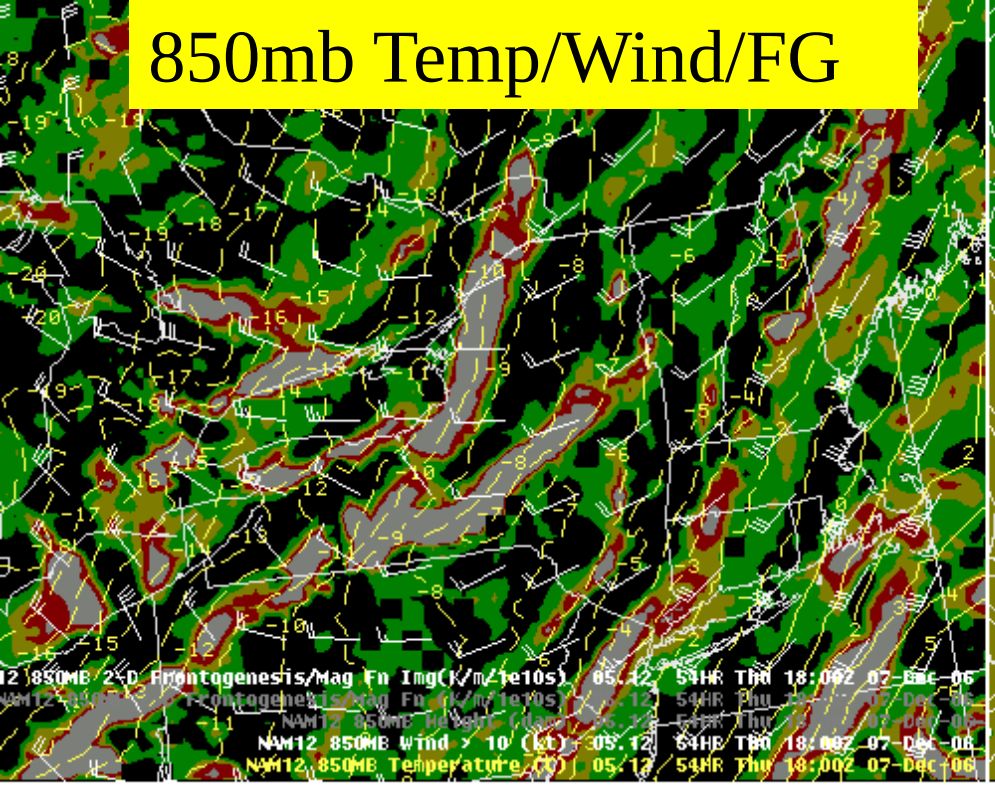

Grand Isle 1
Franklin 2
Orleans 3
Essex 4
Chittenden 5
Lamoille 6
Caledonia 7
Washington 8
Addison 9
Orange 10
Rutland 11
Windsor 12
Franklin 27
Clinton 28
St. Lawrence 26
Essex 34
31
30
29
35
3.0
6.0
6.0
3.0
6.0
6.0
4.7
.60
2.0
6.0
2.5
5.0
5.3
1.8
0.5
2.3
3.0
3.0
4.0
6.0
6.0
6.0
3.0

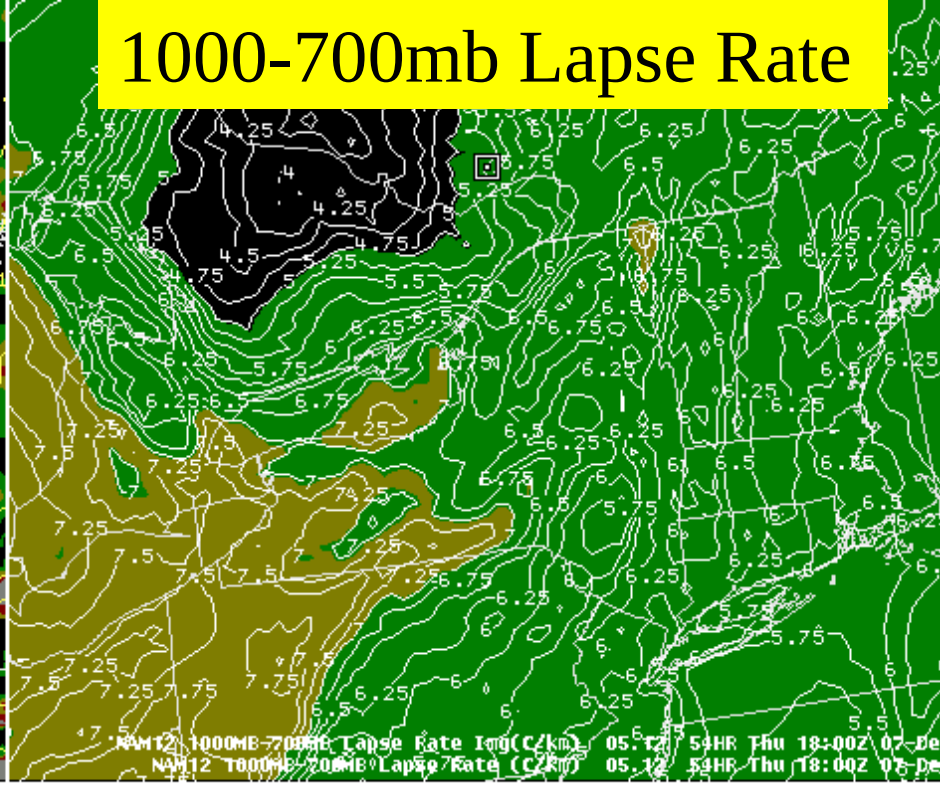
Other Conclusions

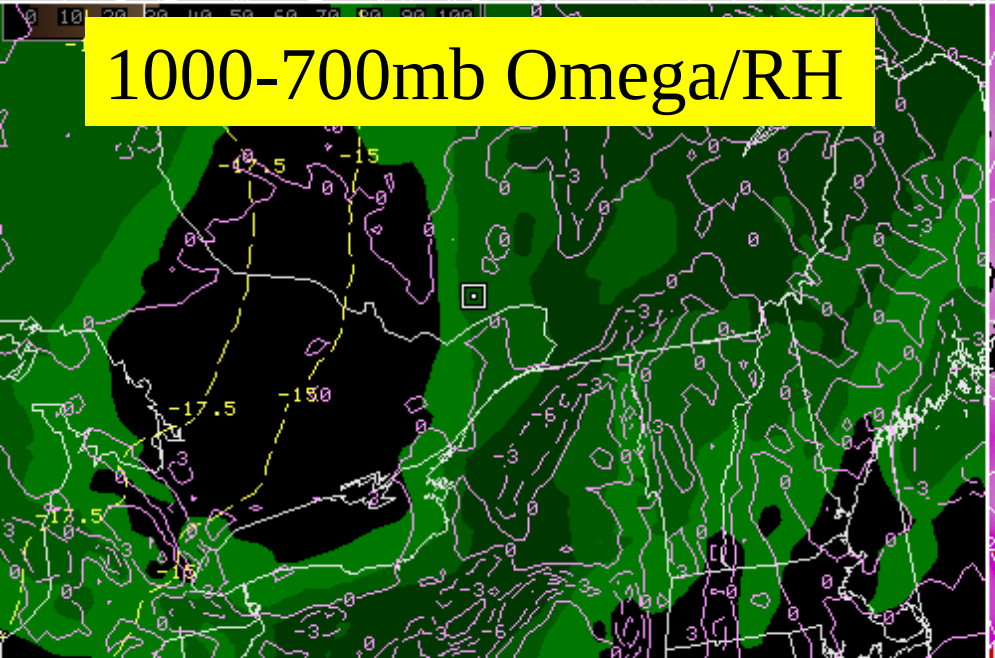
- Surface wind ≤ 20 knots enhances moisture and increases parcel time over the warmer waters
- Surface wind > 20 knots increases crystal fragmentation on the ground and causes higher snow density (less accumulation) (Roebber and Schultz 2002)
- Surface dewpoints near 20F and PW around 0.30”
- Southwest low level flow is enhanced by upslope lift from the Adirondacks and Western Slopes of The Green Mtns
- >8.0˚C/km 1000-700mb lapse rates and CAPE values between 200-400 J/kg create deep layer instability for convective bands producing very heavy snowfall rates
- Sfc front combined with strong 5h PVA helped to enhance lift and transfer significant snowfall 300 km downwind of Lake Ontario
- 30˚ to 60˚ of shear multi band event/un-organized/less propagation downwind (Produces less snowfall amounts and rates) (Niziol 1987)

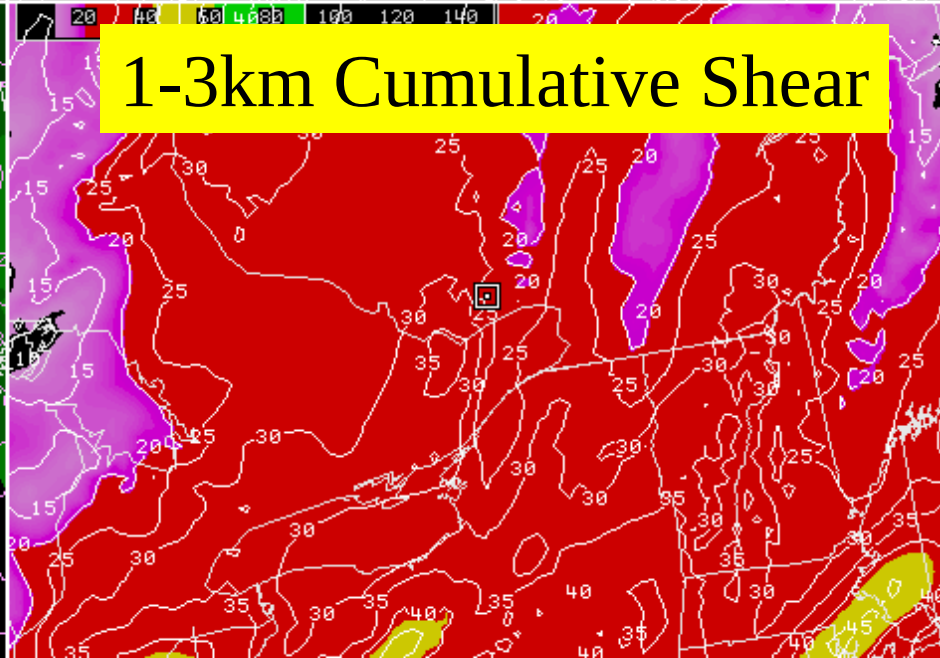
Improving Lake Effect Snow Forecasting

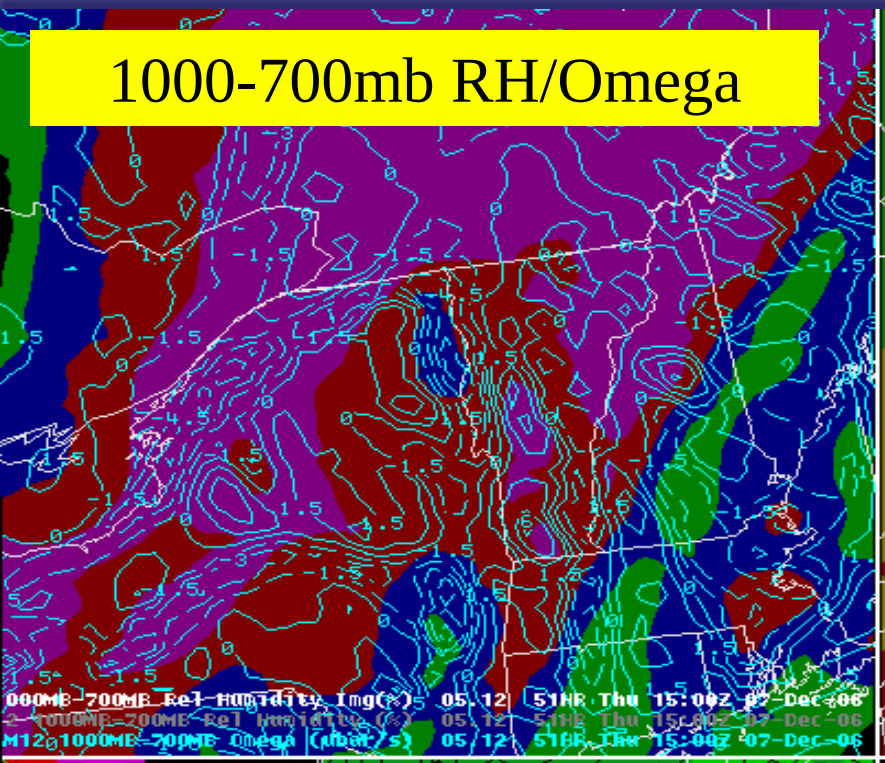
- Develop AWIPS procedures with colors/images displaying favorable lake effect parameters
- Increase forecaster situational awareness of lake effect events
- Develop checklist/decision tree very much like severe weather checklist
  - *Moisture, lift, shear, instability*

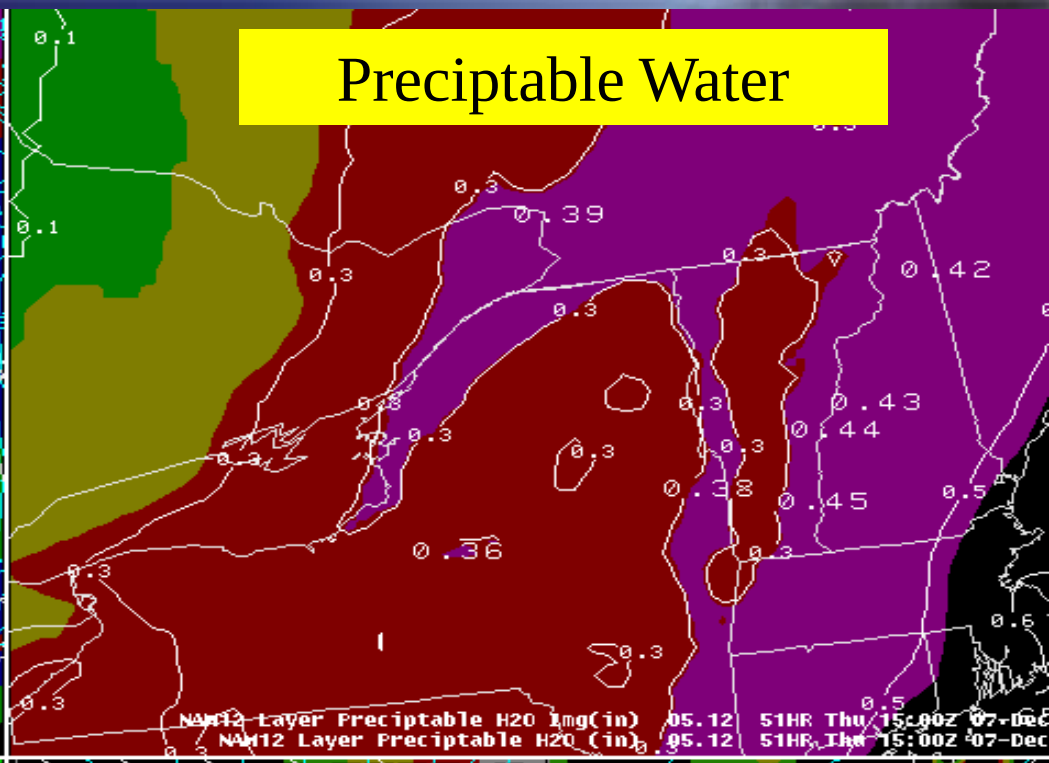

850mb Temp/Wind/FG

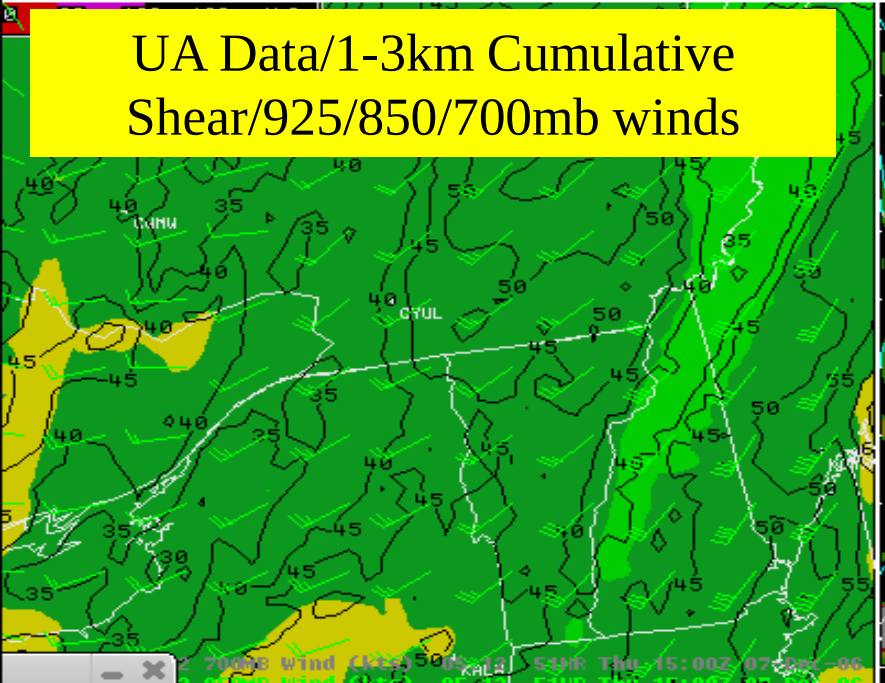

1000-700mb Lapse Rate

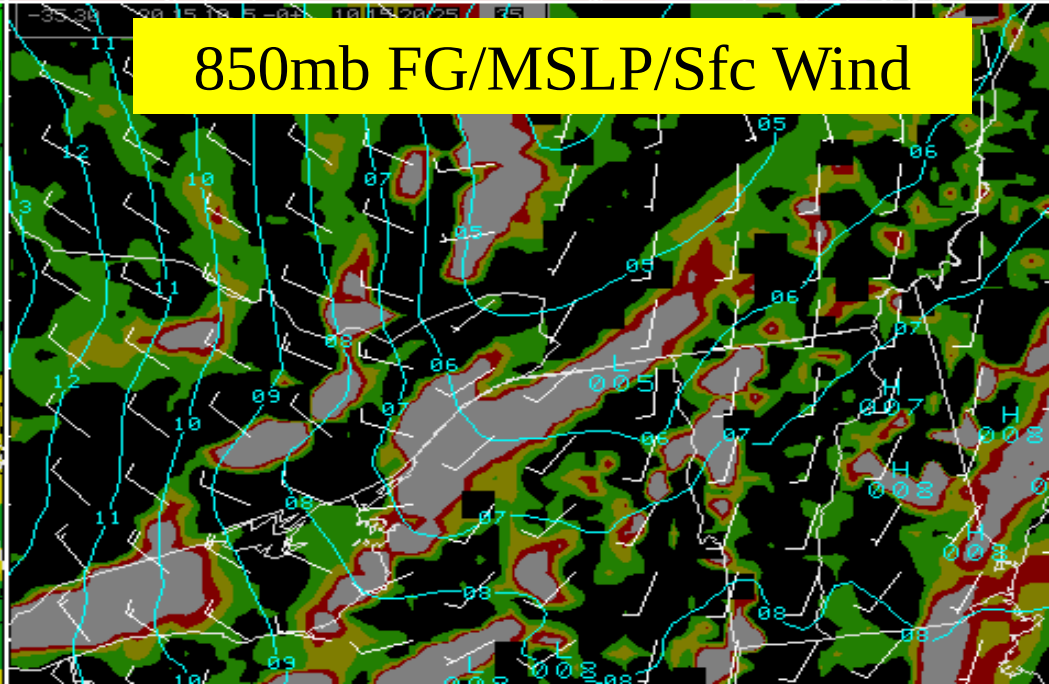

1000-700mb Omega/RH


1-3km Cumulative Shear

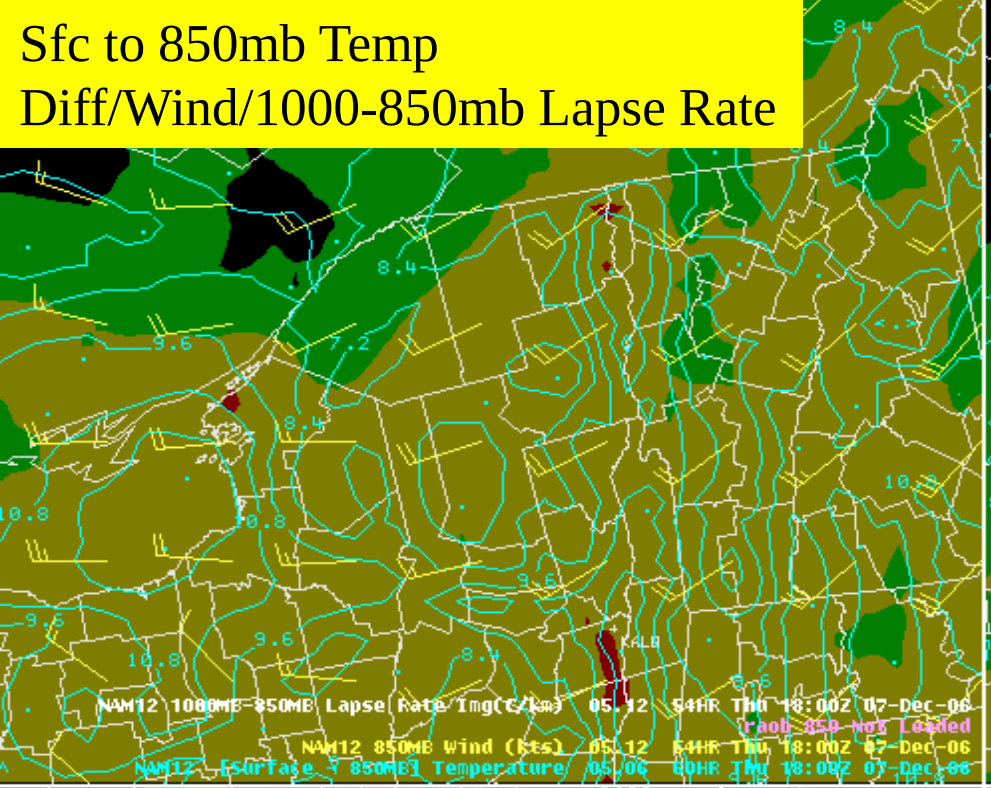

1000-700mb RH/Omega


Preciptable Water

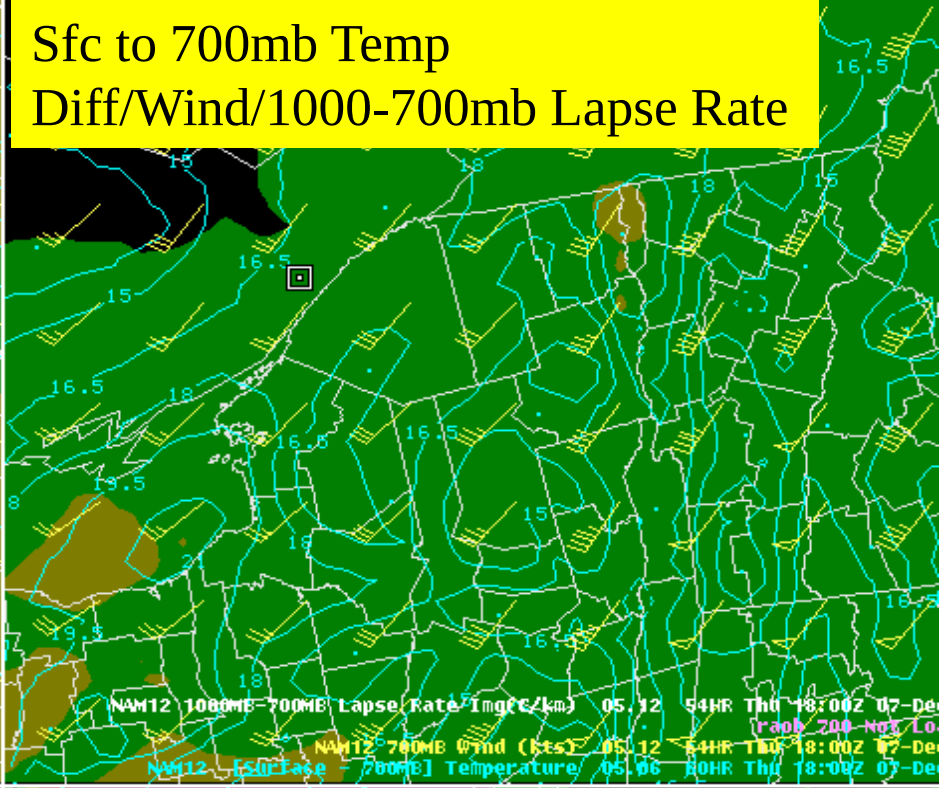

UA Data/1-3km Cumulative
Shear/925/850/700mb winds


850mb FG/MSLP/Sfc Wind

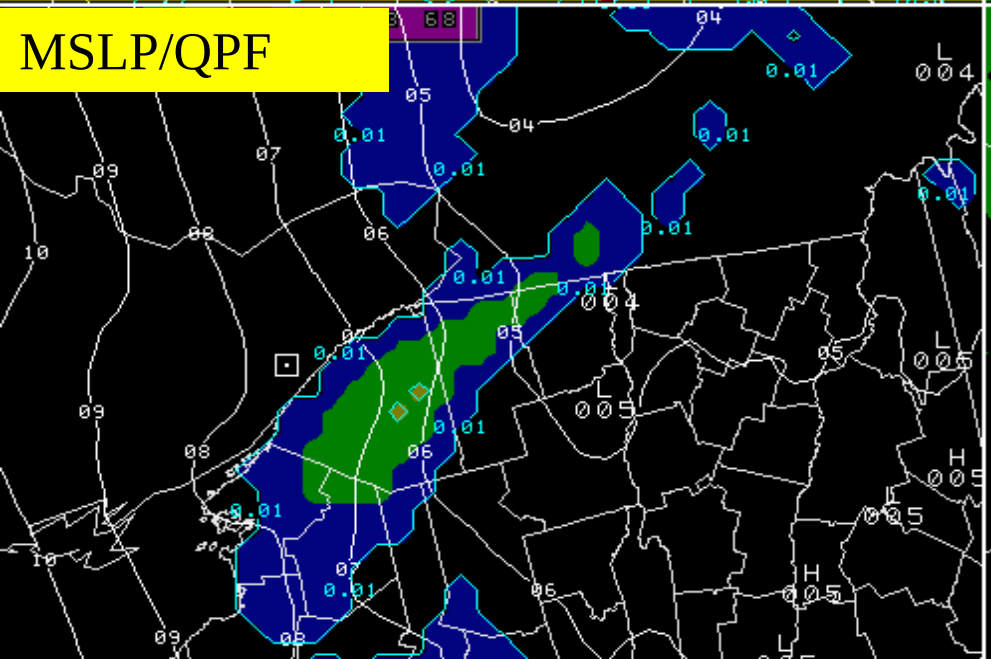
Sfc to 850mb Temp
Diff/Wind/1000-850mb Lapse Rate



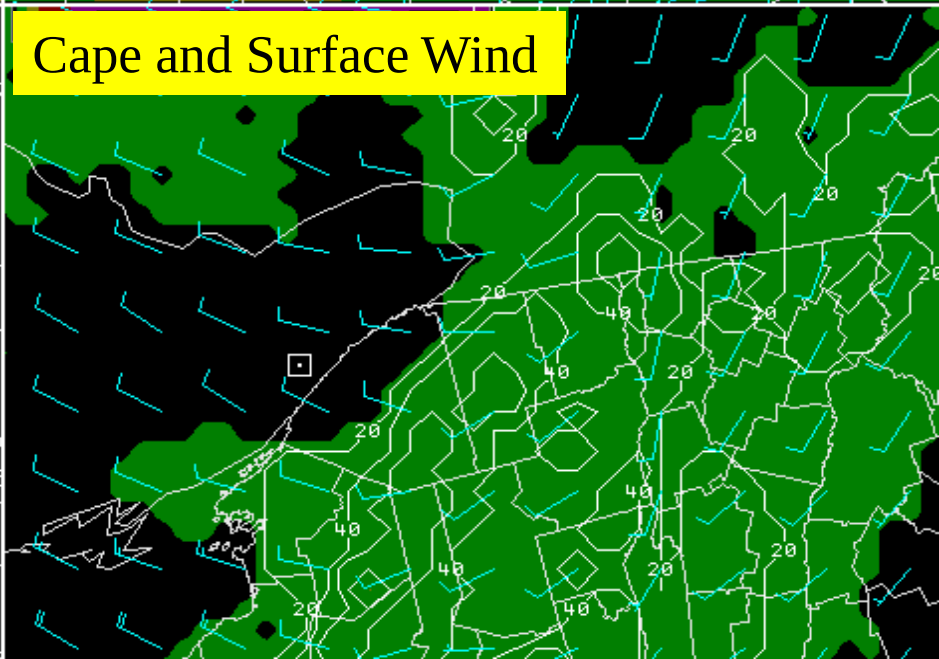
Sfc to 700mb Temp
Diff/Wind/1000-700mb Lapse Rate



MSLP/QPF

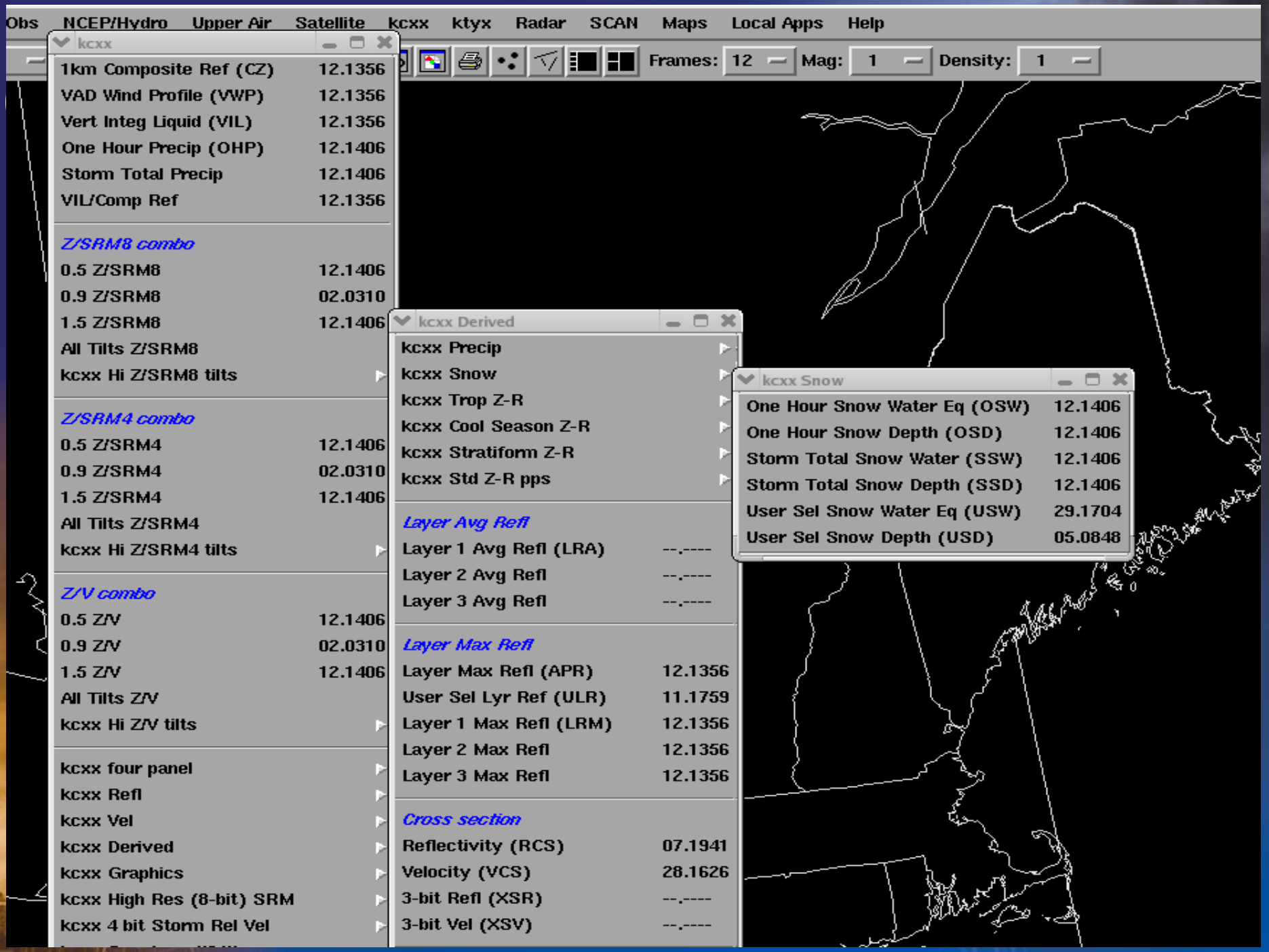


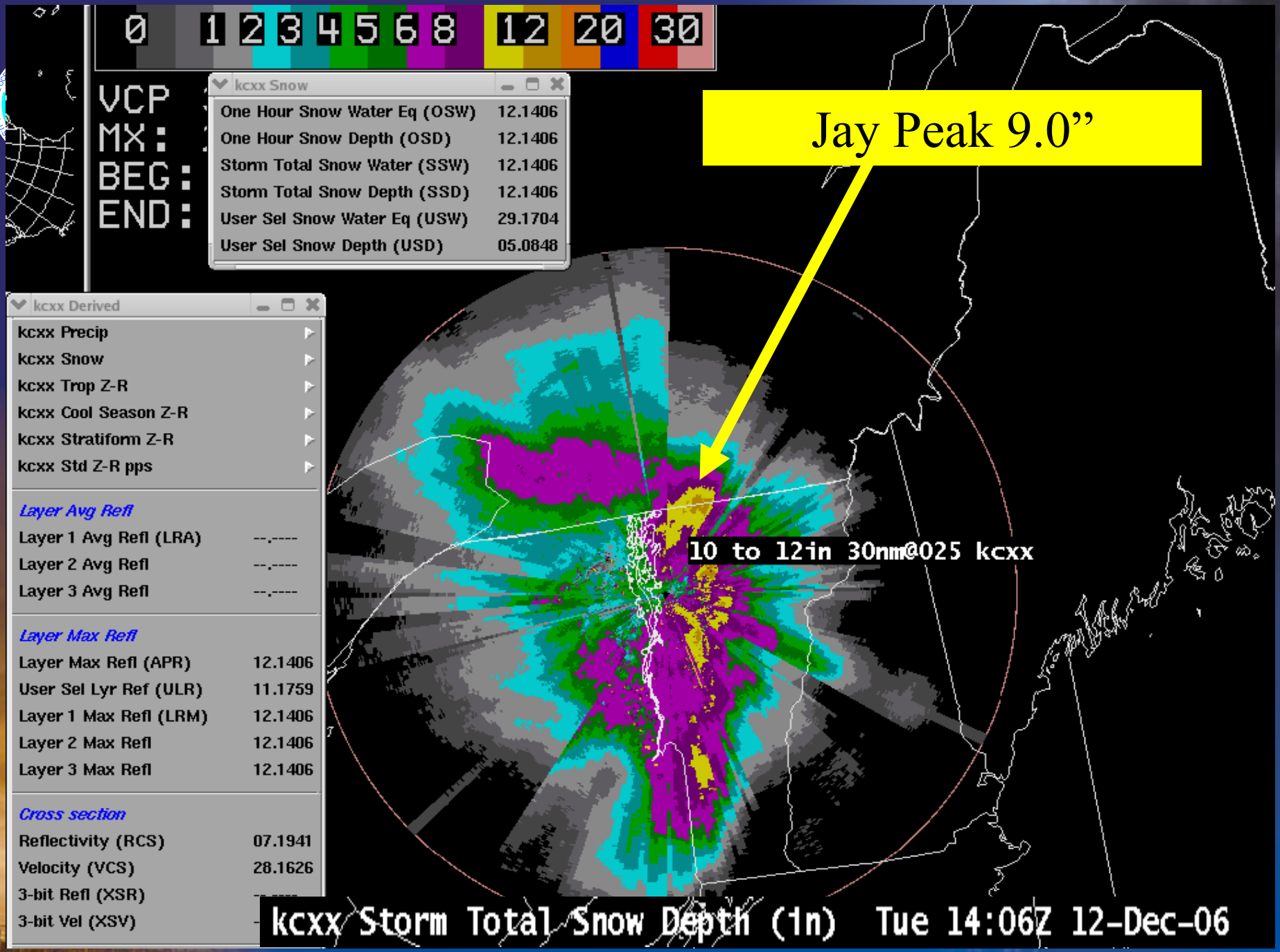
Cape and Surface Wind

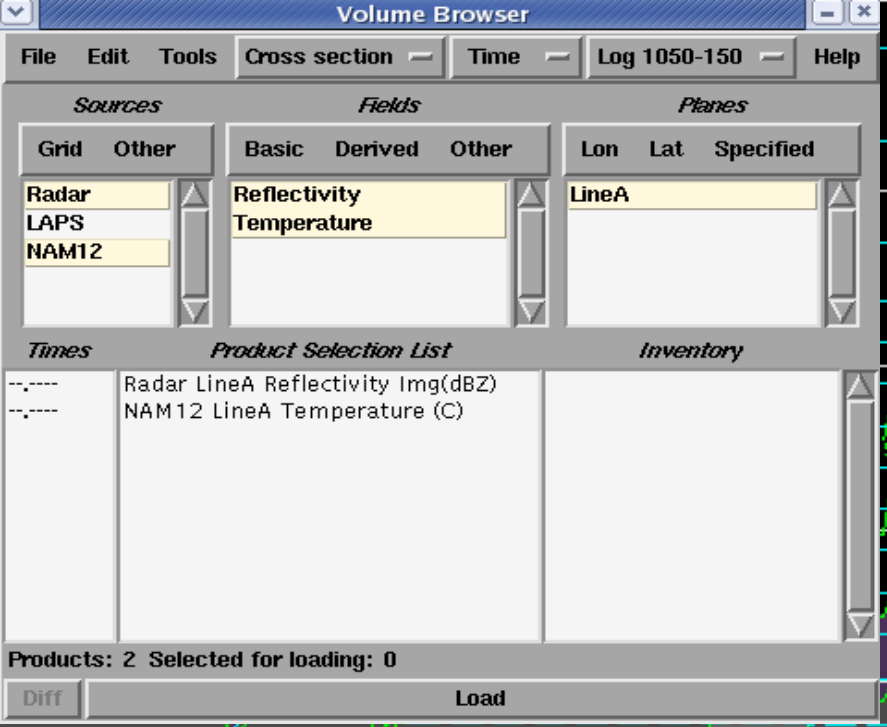


Future Work

- Develop composite study of events from past 10 years
- Other events (Rutland County/Oct 29, 2006)
- Examine more sounding/real-time data
- Develop rules of thumb for lake effect snow events, along with checklist
- Continue with spread sheet of significant lake effect parameters


Obs
NCEP/Hydro
Upper Air
Satellite
kcxx
ktyx
Radar
SCAN
Maps
Local Apps
Help
Frames: 12
Mag: 1
Density: 1
kcxx
1km Composite Ref (CZ) 12.1356
VAD Wind Profile (VWP) 12.1356
Vert Integ Liquid (VIL) 12.1356
One Hour Precip (OHP) 12.1406
Storm Total Precip 12.1406
VIL/Comp Ref 12.1356
Z/SRM8 combo
0.5 Z/SRM8 12.1406
0.9 Z/SRM8 02.0310
1.5 Z/SRM8 12.1406
All Tilts Z/SRM8
kcxx Hi Z/SRM8 tilts
Z/SRM4 combo
0.5 Z/SRM4 12.1406
0.9 Z/SRM4 02.0310
1.5 Z/SRM4 12.1406
All Tilts Z/SRM4
kcxx Hi Z/SRM4 tilts
Z/V combo
0.5 Z/V 12.1406
0.9 Z/V 02.0310
1.5 Z/V 12.1406
All Tilts Z/V
kcxx Hi Z/V tilts
kcxx four panel
kcxx Refl
kcxx Vel
kcxx Derived
kcxx Graphics
kcxx High Res (8-bit) SRM
kcxx 4 bit Storm Rel Vel
kcxx Derived
kcxx Precip
kcxx Snow
kcxx Trop Z-R
kcxx Cool Season Z-R
kcxx Stratiform Z-R
kcxx Std Z-R pps
Layer Avg Refl
Layer 1 Avg Refl (LRA) --.----
Layer 2 Avg Refl --.----
Layer 3 Avg Refl --.----
Layer Max Refl
Layer Max Refl (APR) 12.1356
User Sel Lyr Ref (ULR) 11.1759
Layer 1 Max Refl (LRM) 12.1356
Layer 2 Max Refl 12.1356
Layer 3 Max Refl 12.1356
Cross section
Reflectivity (RCS) 07.1941
Velocity (VCS) 28.1626
3-bit Refl (XSR) --.----
3-bit Vel (XSV) --.----
kcxx Snow
One Hour Snow Water Eq (OSW) 12.1406
One Hour Snow Depth (OSD) 12.1406
Storm Total Snow Water (SSW) 12.1406
Storm Total Snow Depth (SSD) 12.1406
User Sel Snow Water Eq (USW) 29.1704
User Sel Snow Depth (USD) 05.0848


0 1 2 3 4 5 6 8 12 20 30
VCP
MX:
BEG:
END:
kcxx Snow
One Hour Snow Water Eq (OSW) 12.1406
One Hour Snow Depth (OSD) 12.1406
Storm Total Snow Water (SSW) 12.1406
Storm Total Snow Depth (SSD) 12.1406
User Sel Snow Water Eq (USW) 29.1704
User Sel Snow Depth (USD) 05.0848
Jay Peak 9.0”
kcxx Derived
kcxx Precip
kcxx Snow
kcxx Trop Z-R
kcxx Cool Season Z-R
kcxx Stratiform Z-R
kcxx Std Z-R pps
Layer Avg Refl
Layer 1 Avg Refl (LRA) --.----
Layer 2 Avg Refl --.----
Layer 3 Avg Refl --.----
Layer Max Refl
Layer Max Refl (APR) 12.1406
User Sel Lyr Ref (ULR) 11.1759
Layer 1 Max Refl (LRM) 12.1406
Layer 2 Max Refl 12.1406
Layer 3 Max Refl 12.1406
Cross section
Reflectivity (RCS) 07.1941
Velocity (VCS) 28.1626
3-bit Refl (XSR)
3-bit Vel (XSV)
10 to 12in 30nm@025 kcxx
kcxx Storm Total Snow Depth (in) Tue 14:06Z 12-Dec-06



- Shows temp profile vs UVV's and regions of favorable snow growth
- Temps vs. Elevation
- Precip Enhancements across the mtns/downsloping effects
- Correlate dBZ returns with 0C and -20C isotherms for svr potential