DOMINANT HEAVY LAKE EFFECT SNOW BAND OVER NORTH CENTRAL UPPER MICHIGAN 22 FEB 2009

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Mike Dutter
NOAA/NWS Marquette, MI

Northern Plains Winter Storm Conference
November 10th, 2009

Outline

- Ingredients for heavy lake effect snow
- Quick overview
- 22 Feb 2009 Lake Effect Snow Band
- NWS MQT office performance
- How numerical models handled event
- Reproduced event using local office WRF-ARW Core
  - No Ice Run (control)
  - “Best Ice” Field
  - Total Ice
  - NARR Run
- Conclusions
- Questions?

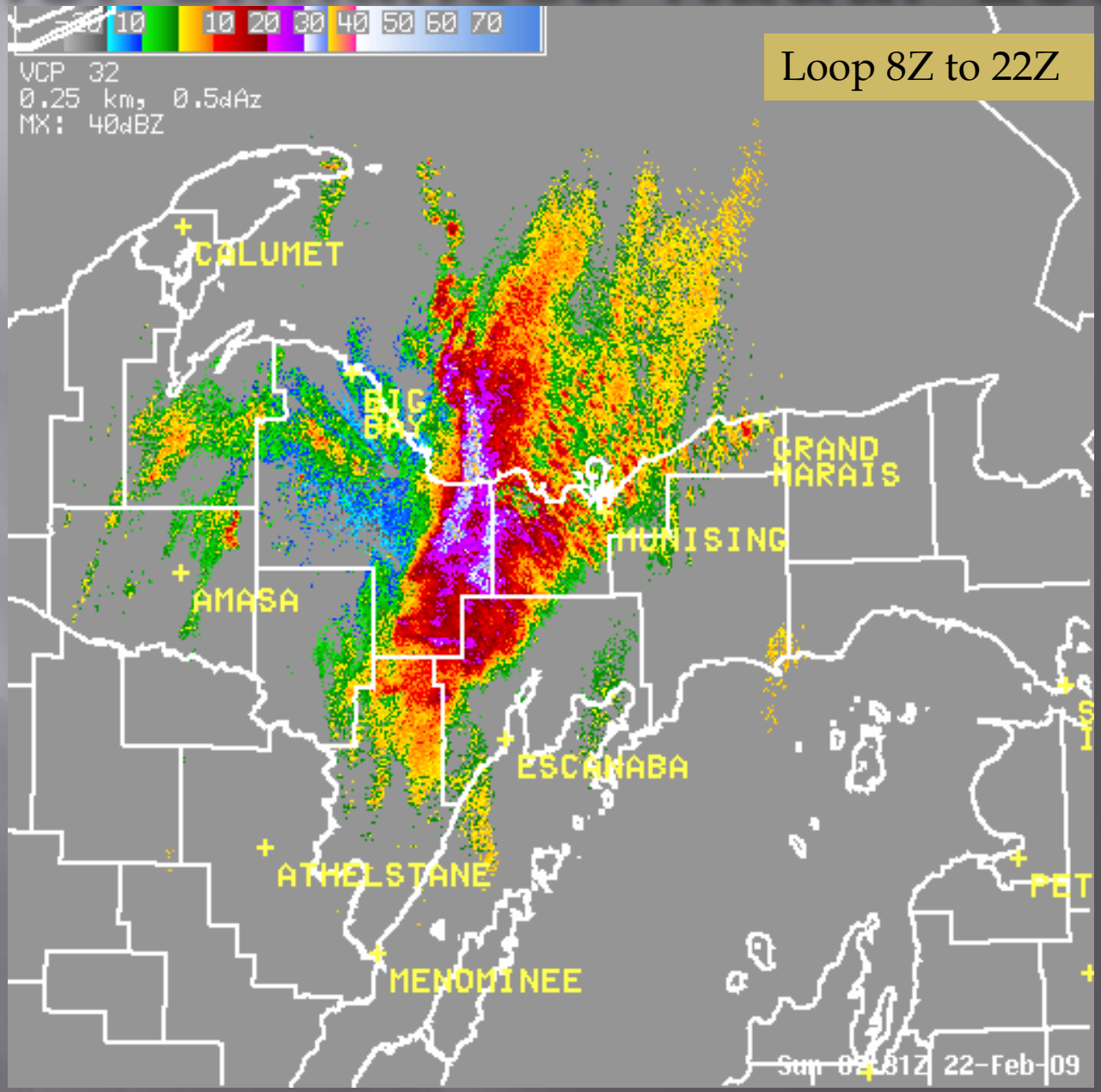
Ingredients for Heavy Lake Effect Snow

- Deep polar air mass to 700mb or higher with small directional shear
  - < 30 degrees surface to 850mb, < 60 degrees surface to 700mb
- 850mb temperature at least 13˚C colder than lake
  - Increase in temperature gradient increases conduction and turbulent mixing
- Almost any wind direction for Lake Superior
  - Wind needs to be relatively light (~10-30kt) for moisture convergence
- Ice free portion of lake with fetch at least 100km

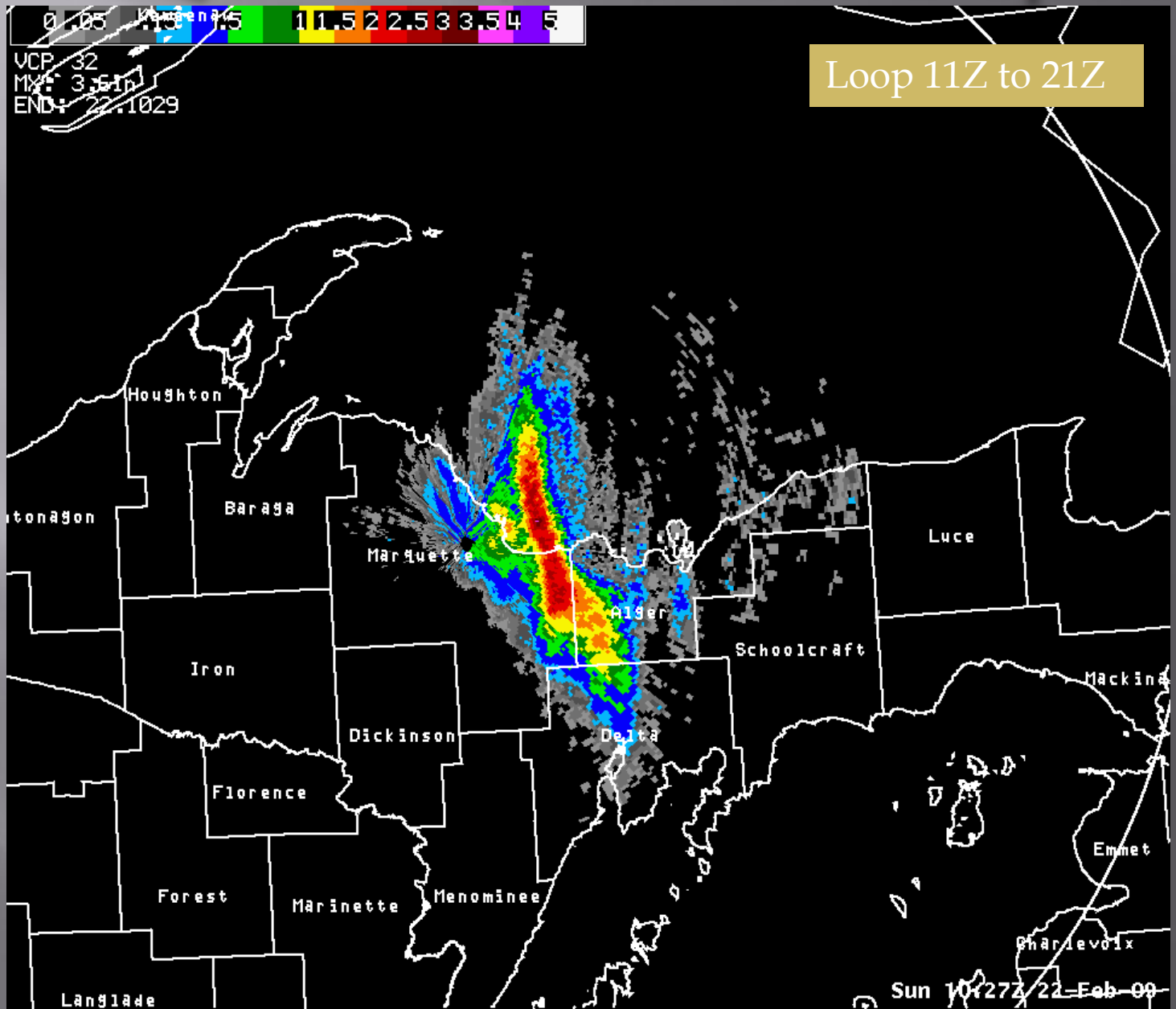
Overview

- Vertically stacked low pressure system moved across central/northern Lower MI Feb 21st
  - Dumped up to a foot of system snow on Upper MI
- Lake ice and northerly wind caused dominant snow band
- Over 2 feet of snow fell from near Marquette/Alger border to west of Au Train
- M-28 shut down and drivers stranded from over 5 inch per hour snowfall rates
  - Problems plowing out cars

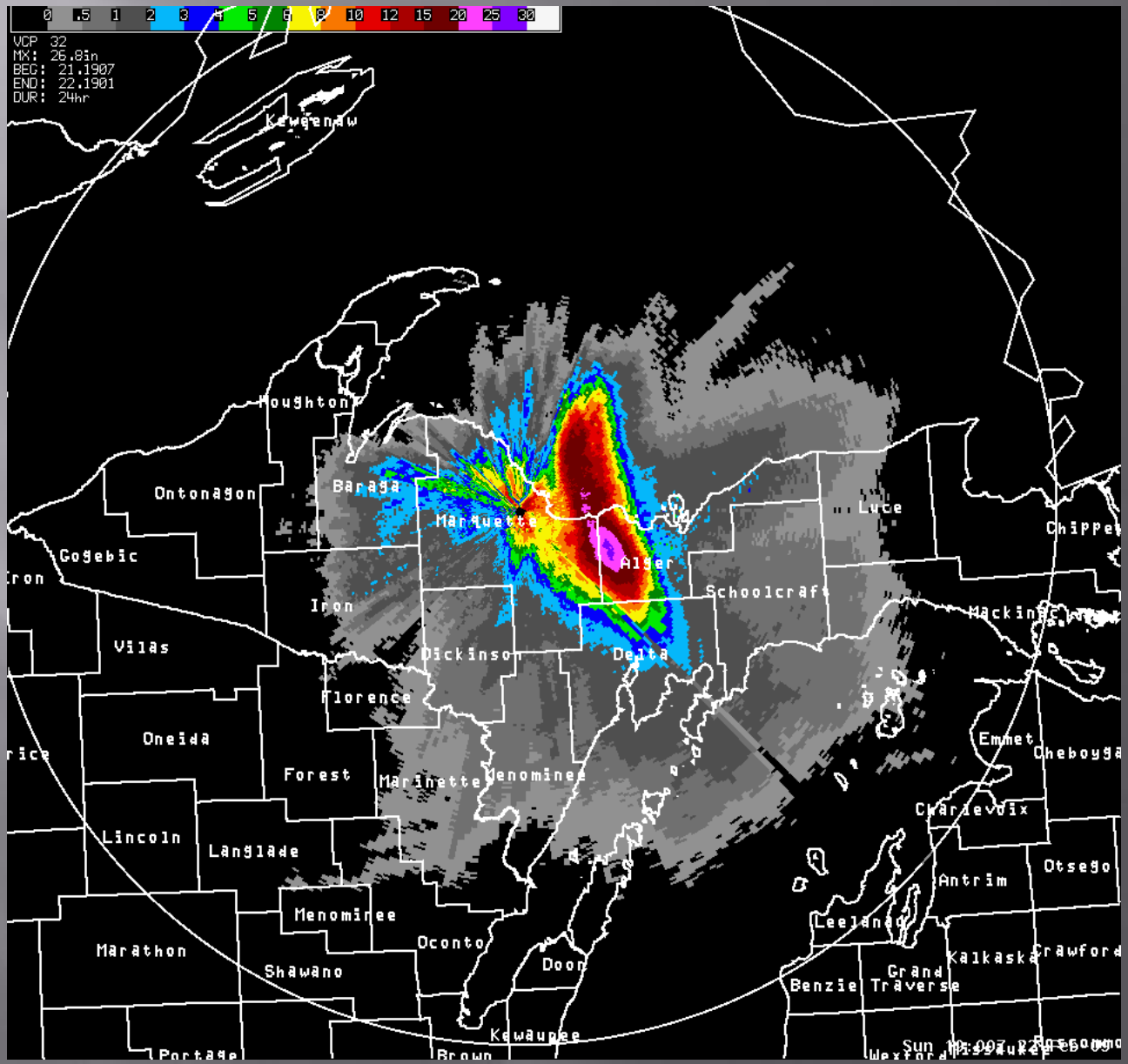
Color Enhanced Radar Loop

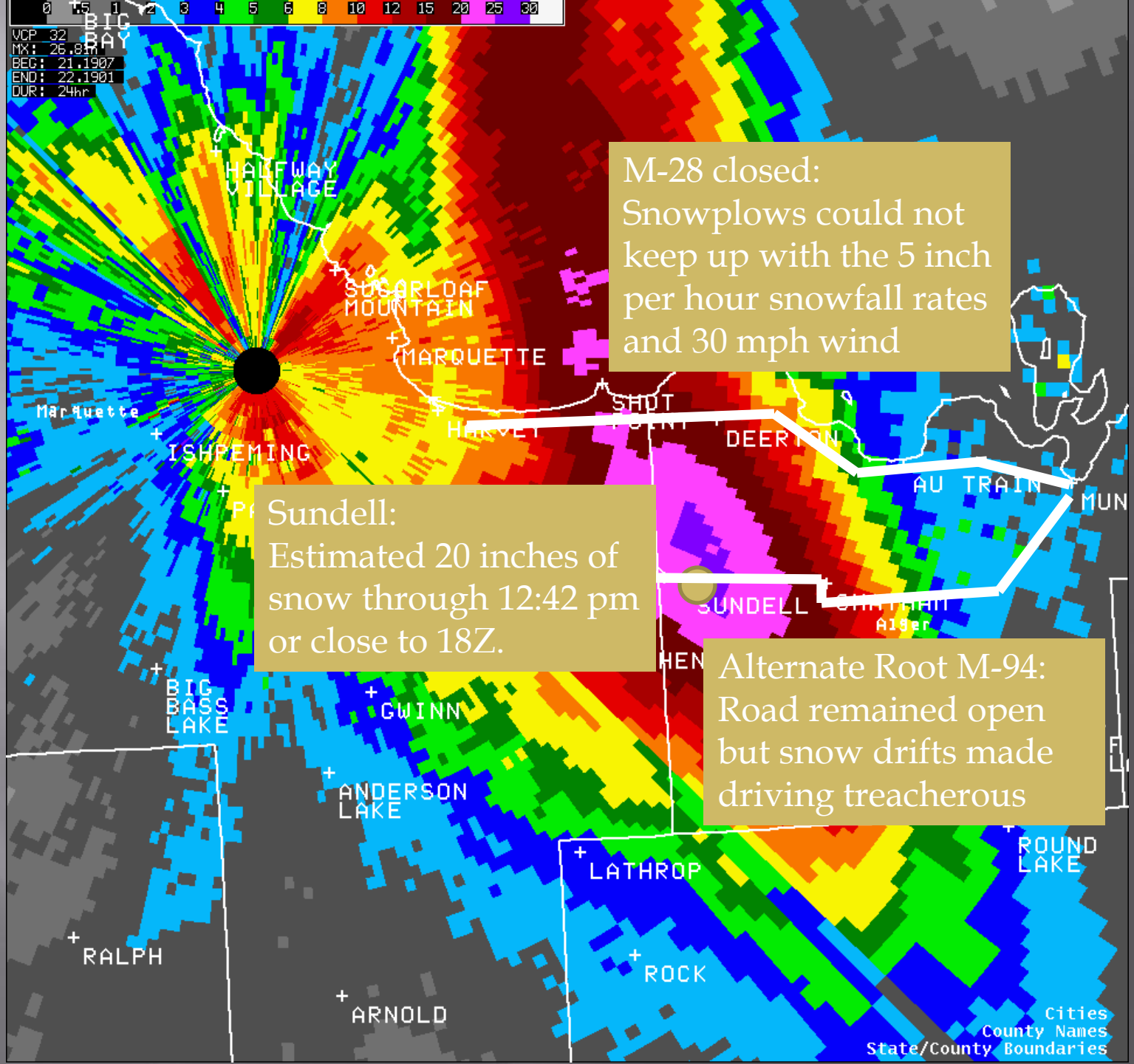


MQT 1-Hour Snow Depth



Total Snowfall Through 19Z

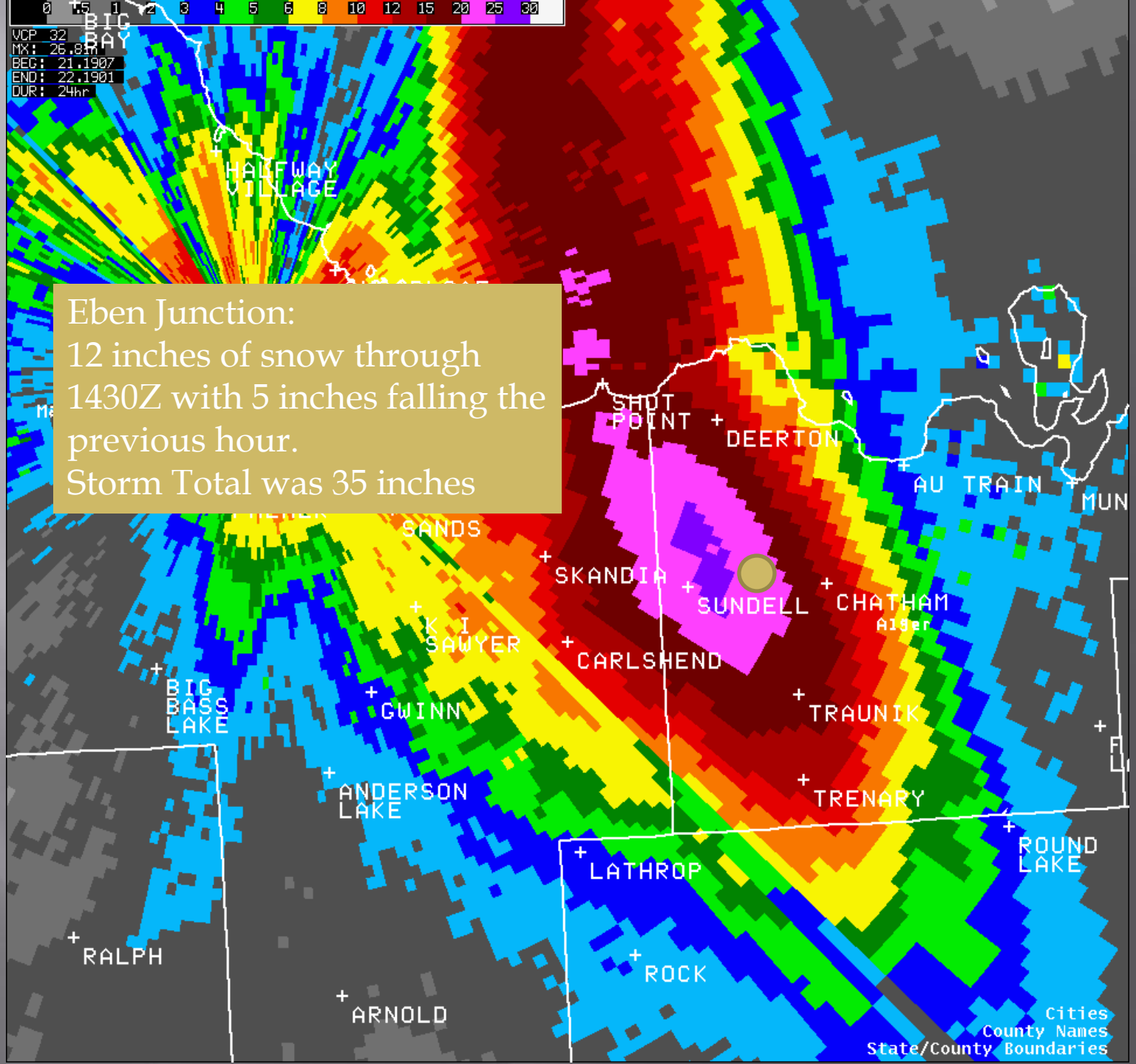




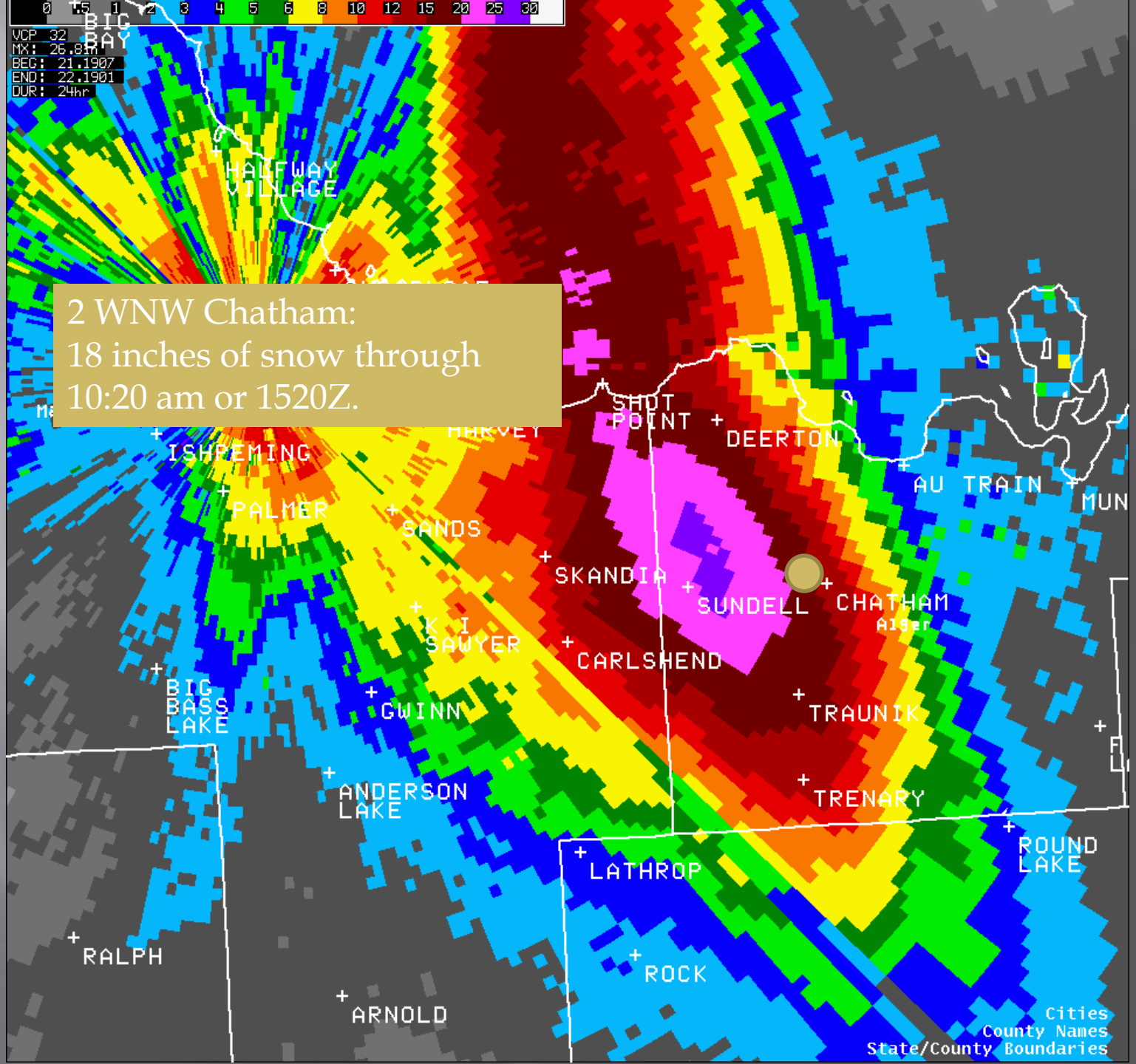
M-28 closed:
Snowplows could not keep up with the 5 inch per hour snowfall rates and 30 mph wind

Sundell:
Estimated 20 inches of snow through 12:42 pm or close to 18Z.

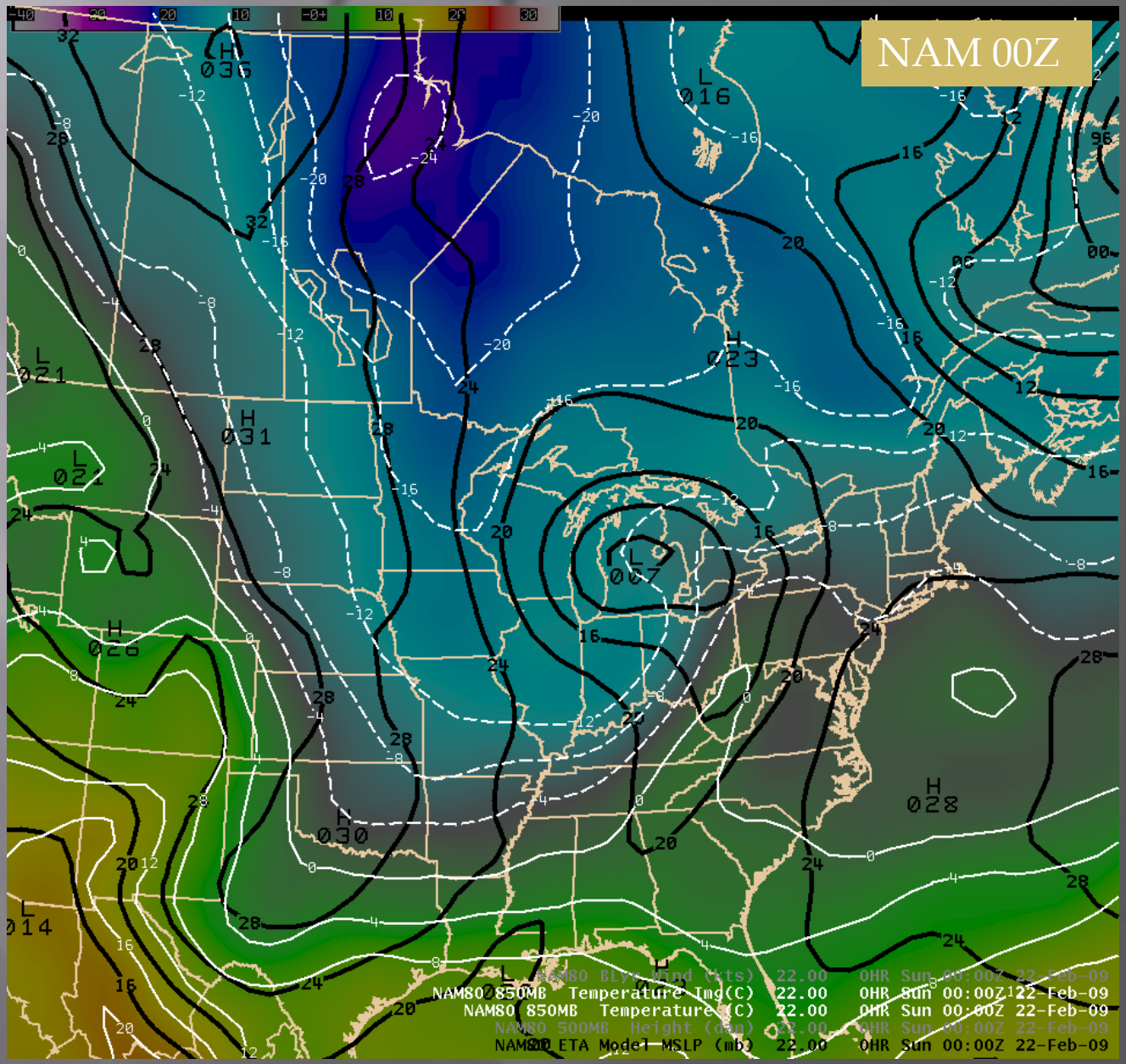
Alternate Root M-94:
Road remained open but snow drifts made driving treacherous

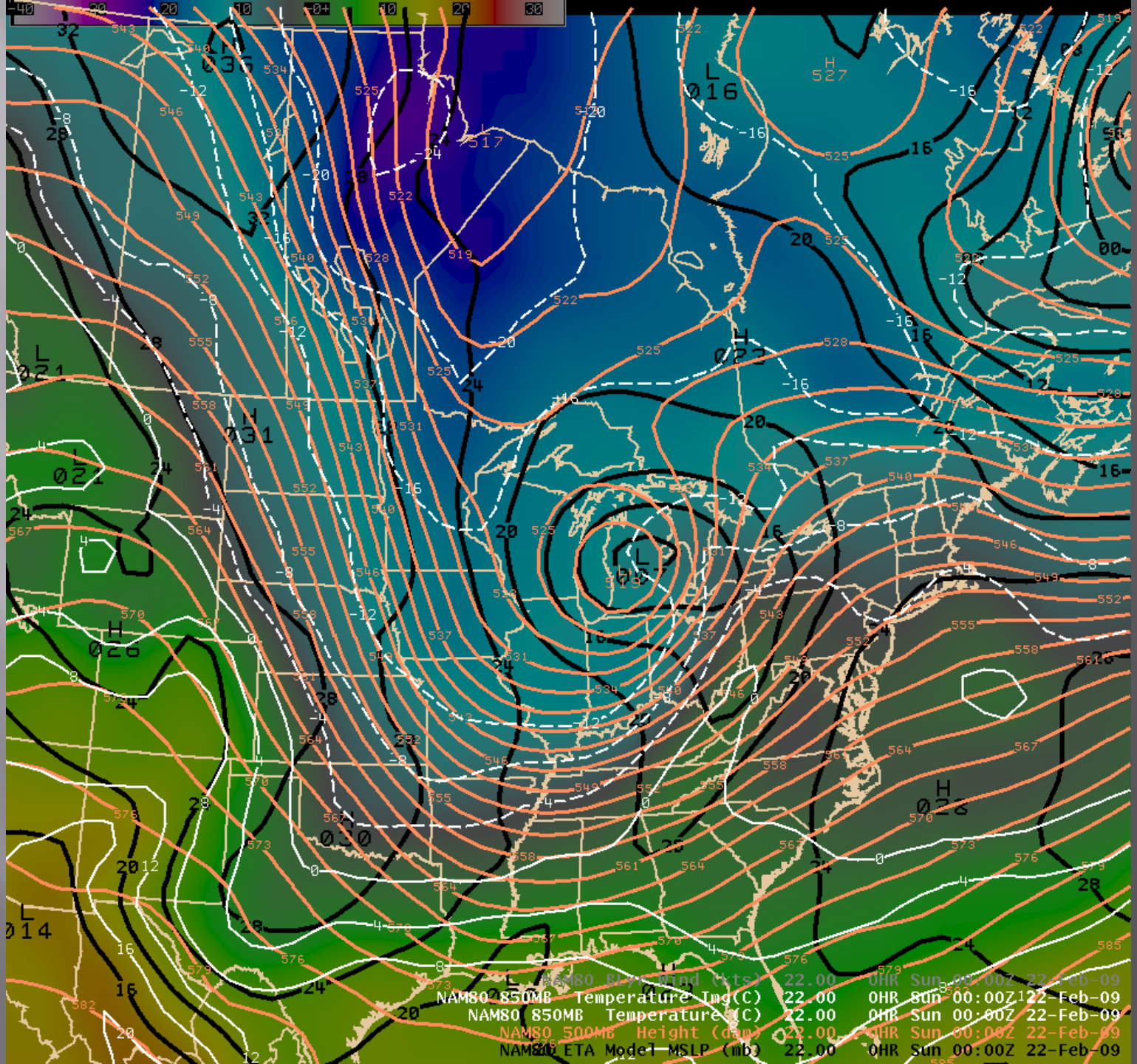


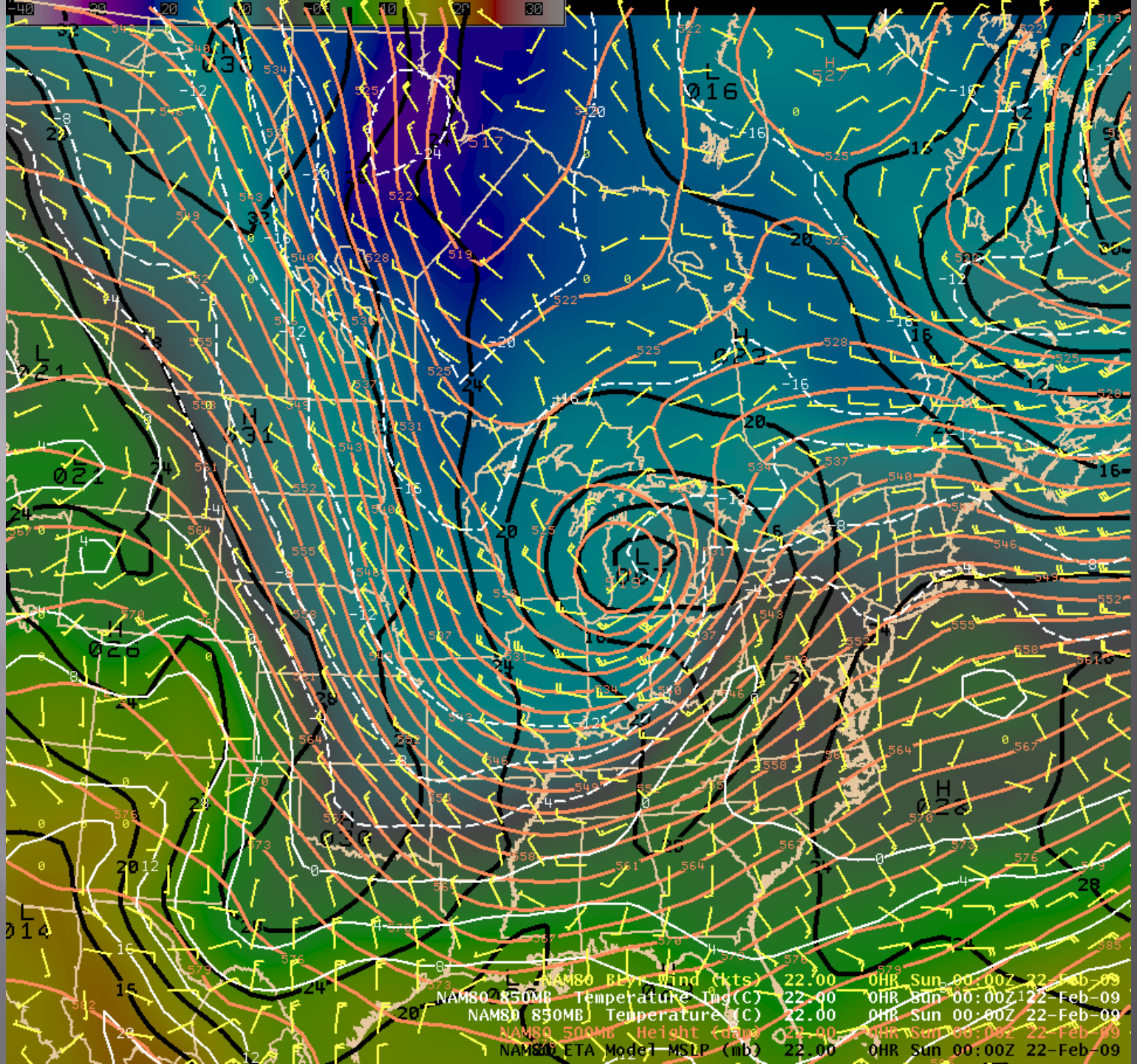
Eben Junction:
12 inches of snow through 1430Z with 5 inches falling the previous hour.
Storm Total was 35 inches


0 .5 1 2 3 4 5 6 8 10 12 15 20 25 30
VCP 32
MX: 26.84m
BEG: 21.1907
END: 22.1901
DUR: 24hr
BIG BAY
HALFWAY VILLAGE
2 WNW Chatham:
18 inches of snow through
10:20 am or 1520Z.
ISHPEMING
PALMER
SANDS
SKANDIA
SUNDELL
CHATHAM
Alger
K I SAWYER
CARLSHEND
SHOT POINT
DEERTON
AU TRAIN
MUN
BIG BASS LAKE
GWINN
TRAUNIK
ANDERSON LAKE
TRENARY
ROUND LAKE
LATHROP
RALPH
ROCK
ARNOLD
Cities
County Names
State/County Boundaries

Synoptic Look




NAM80 Bkgr Wind (kts) 22.00 0HR Sun 00:00Z 22-Feb-09
NAM80 850MB Temperature Img(C) 22.00 0HR Sun 00:00Z 22-Feb-09
NAM80 850MB Temperature (C) 22.00 0HR Sun 00:00Z 22-Feb-09
NAM80 500MB Height (dam) 22.00 0HR Sun 00:00Z 22-Feb-09
NAM80 ETA Model MSLP (mb) 22.00 0HR Sun 00:00Z 22-Feb-09


NAM80 BLyr Wind (kts) 22.00 0HR Sun 00:00Z 22-Feb-09
NAM80 850MB Temperature Img(C) 22.00 0HR Sun 00:00Z 22-Feb-09
NAM80 850MB Temperature (C) 22.00 0HR Sun 00:00Z 22-Feb-09
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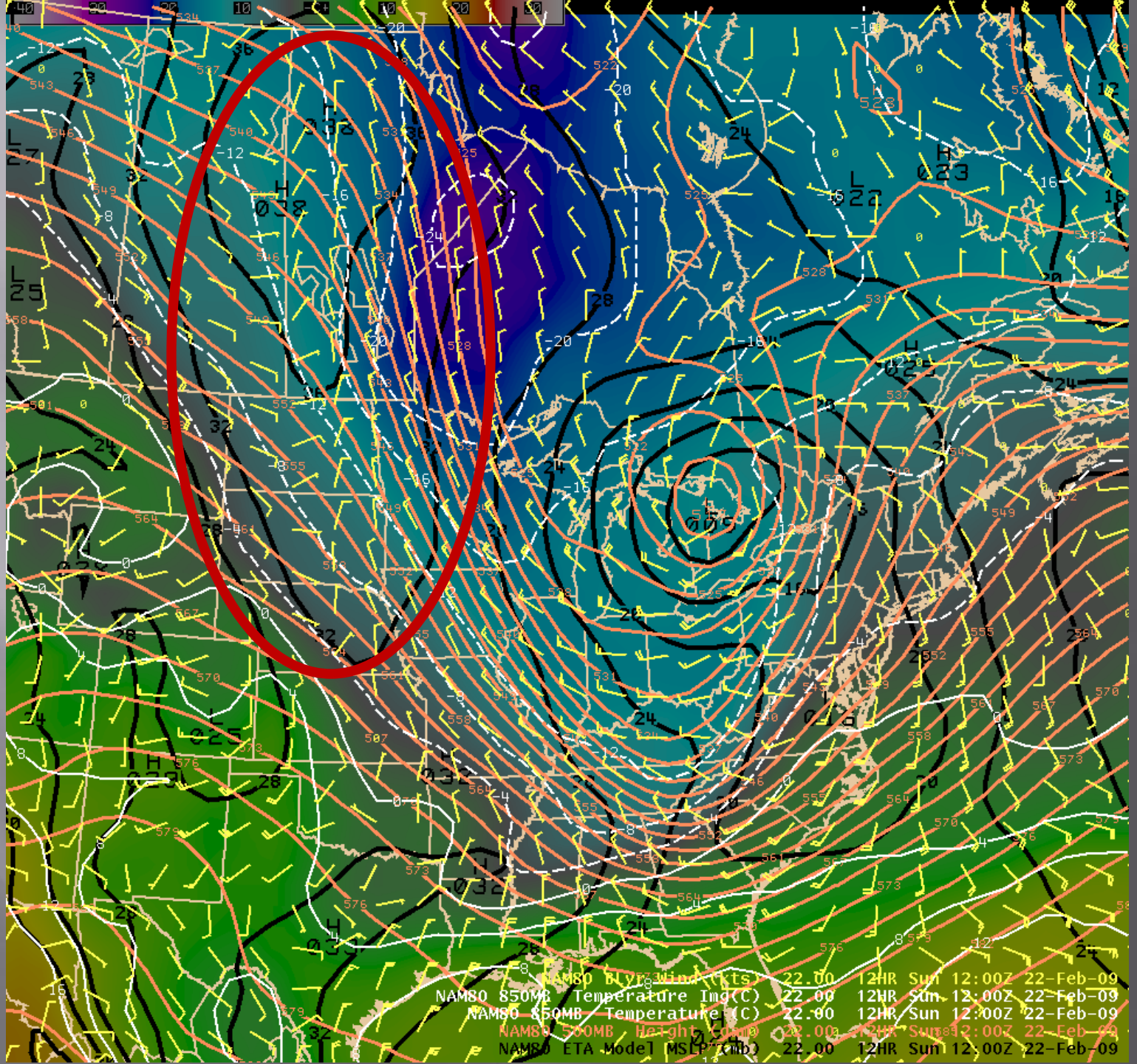
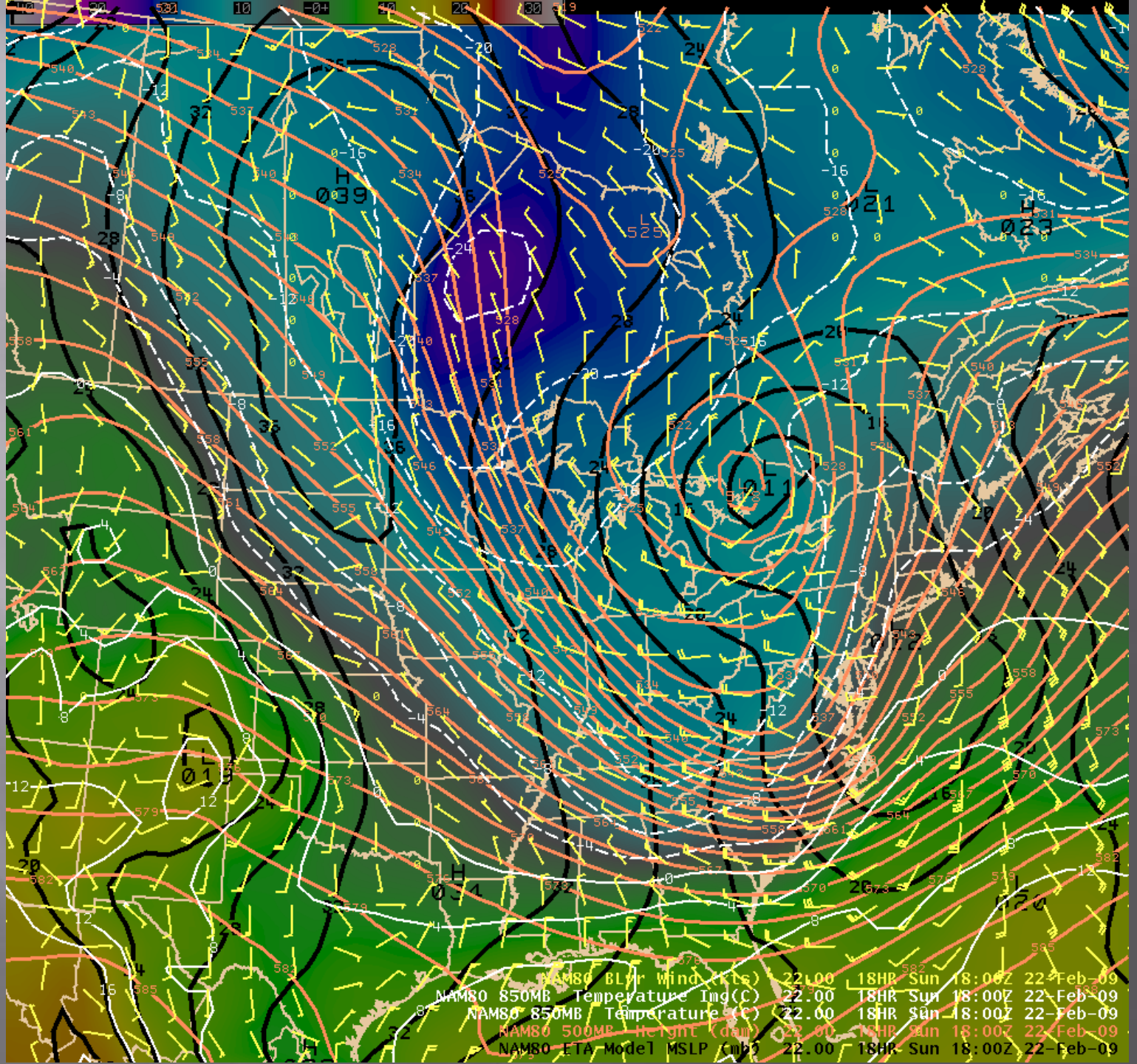
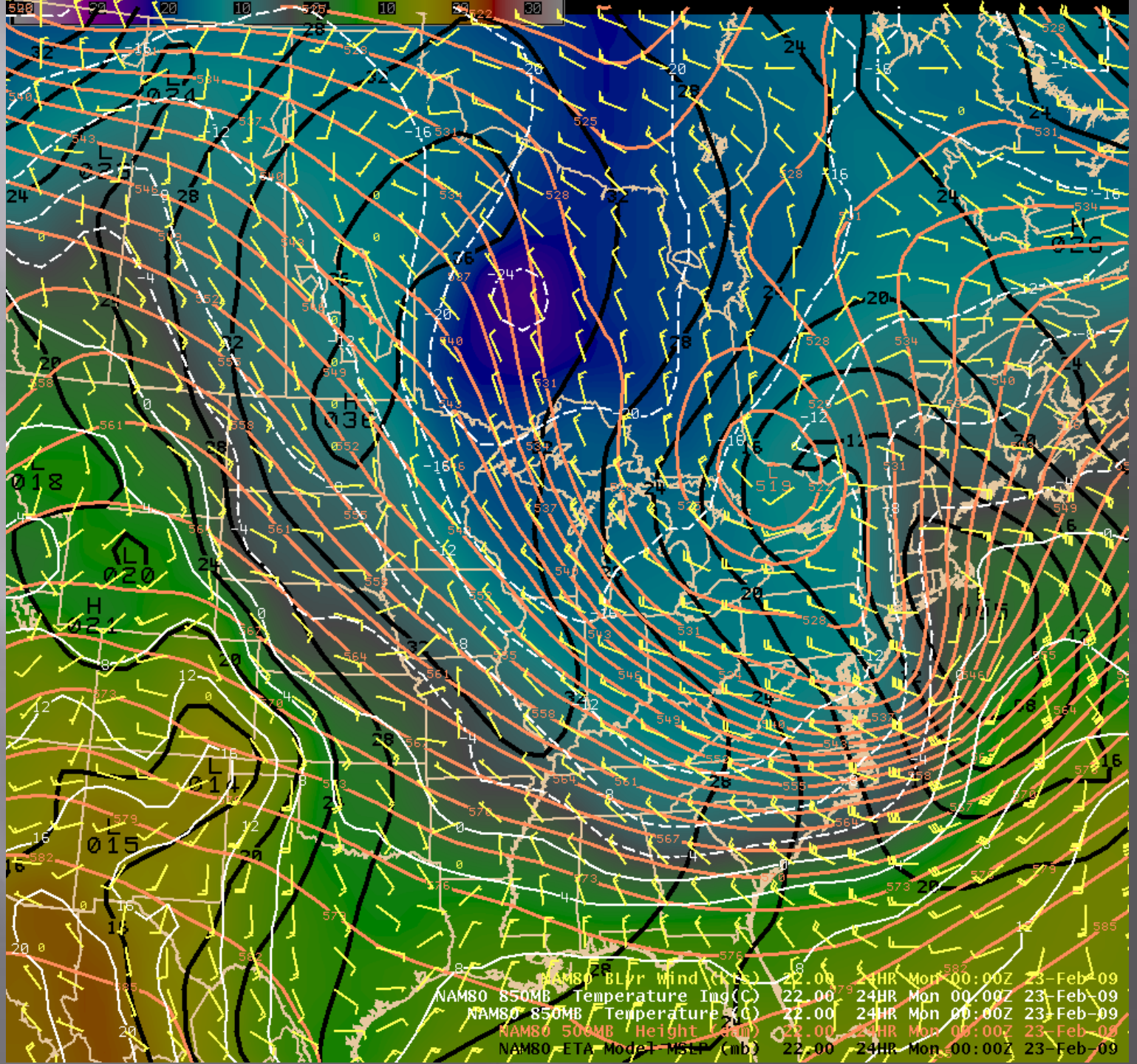
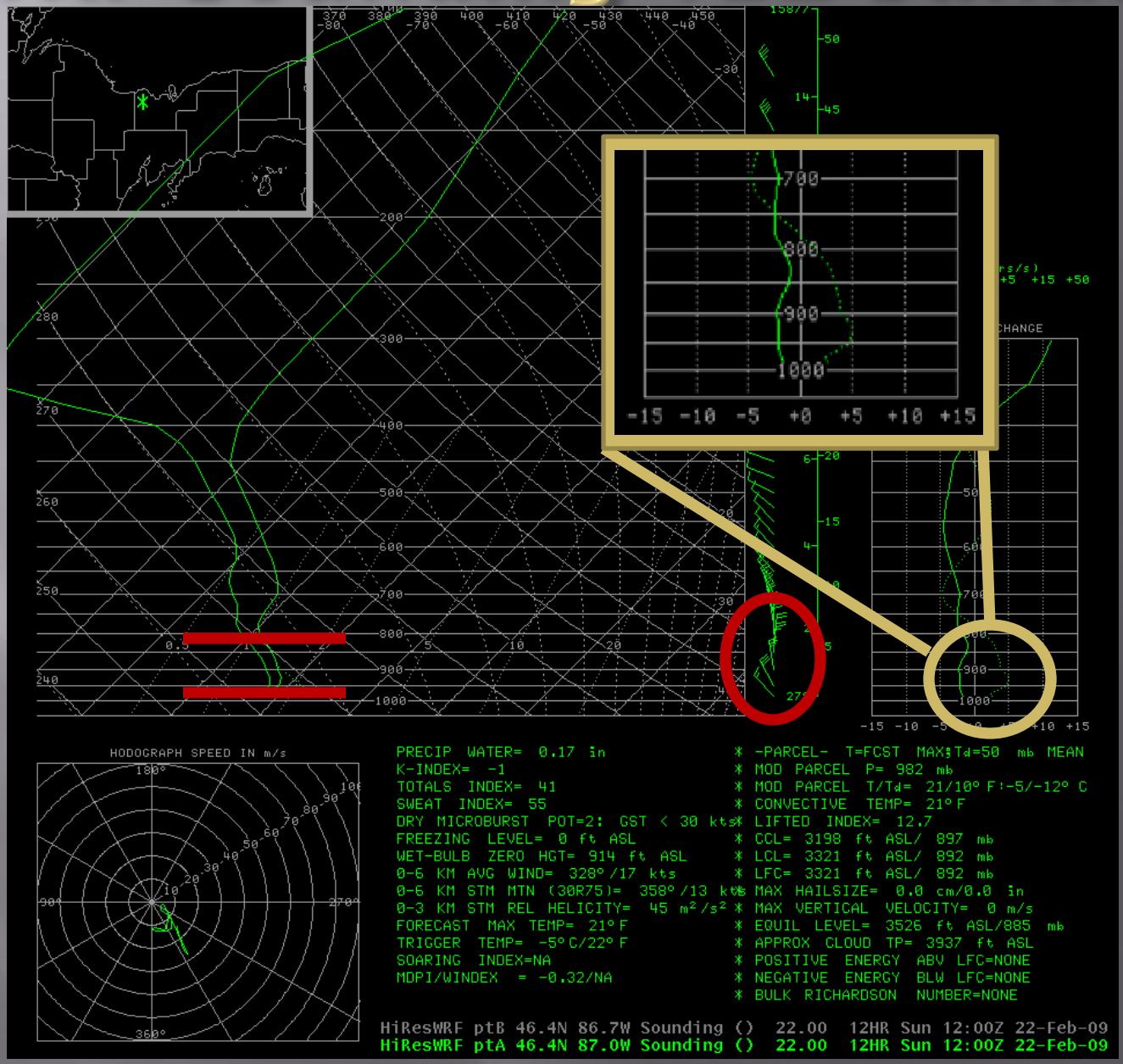

NAM80 0Lyr Wind(kts) 22.00 12HR Sun 12:00Z 22-Feb-09
NAM80 850MB Temperature Img(C) 22.00 12HR Sun 12:00Z 22-Feb-09
NAM80 850MB Temperature(C) 22.00 12HR Sun 12:00Z 22-Feb-09
NAM80 500MB Height 22.00 12HR Sun 12:00Z 22-Feb-09
NAM80 ETA Model MSLP (Mb) 22.00 12HR Sun 12:00Z 22-Feb-09

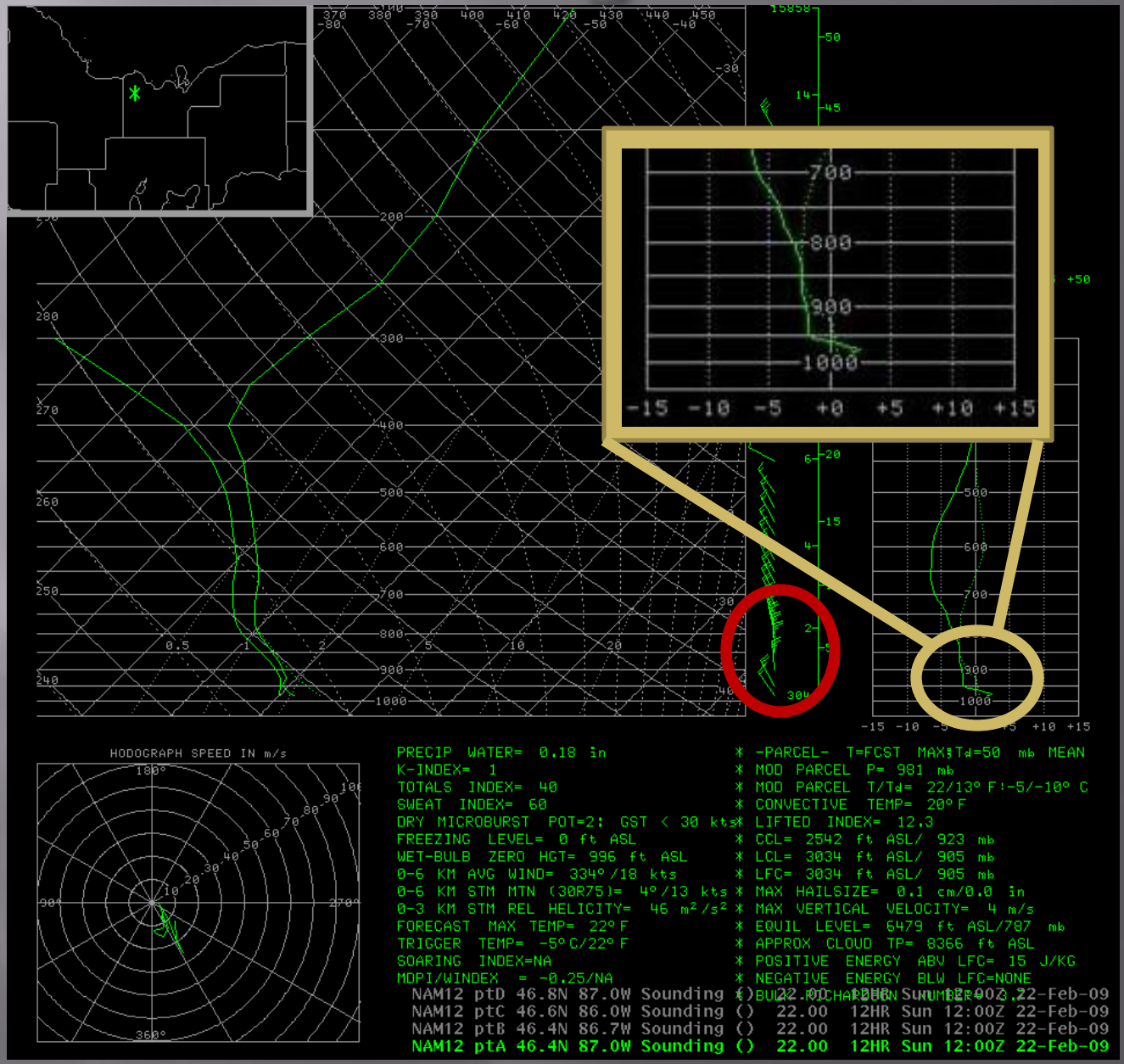

NAM80 BLyr Wind (Kts) 22.00 18HR Sun 18:00Z 22-Feb-09
NAM80 850MB Temperature Img(C) 22.00 18HR Sun 18:00Z 22-Feb-09
NAM80 850MB Temperature (C) 22.00 18HR Sun 18:00Z 22-Feb-09
NAM80 500MB Height (dam) 22.00 18HR Sun 18:00Z 22-Feb-09
NAM80 ETA Model MSLP (mb) 22.00 18HR Sun 18:00Z 22-Feb-09


NAM80 BLyr Wind (Kts) 22.00 24HR Mon 00:00Z 23-Feb-09
NAM80 850MB Temperature Img(C) 22.00 24HR Mon 00:00Z 23-Feb-09
NAM80 850MB Temperature (C) 22.00 24HR Mon 00:00Z 23-Feb-09
NAM80 500MB Height (DAM) 22.00 24HR Mon 00:00Z 23-Feb-09
NAM80 ETA Model MSLP (mb) 22.00 24HR Mon 00:00Z 23-Feb-09

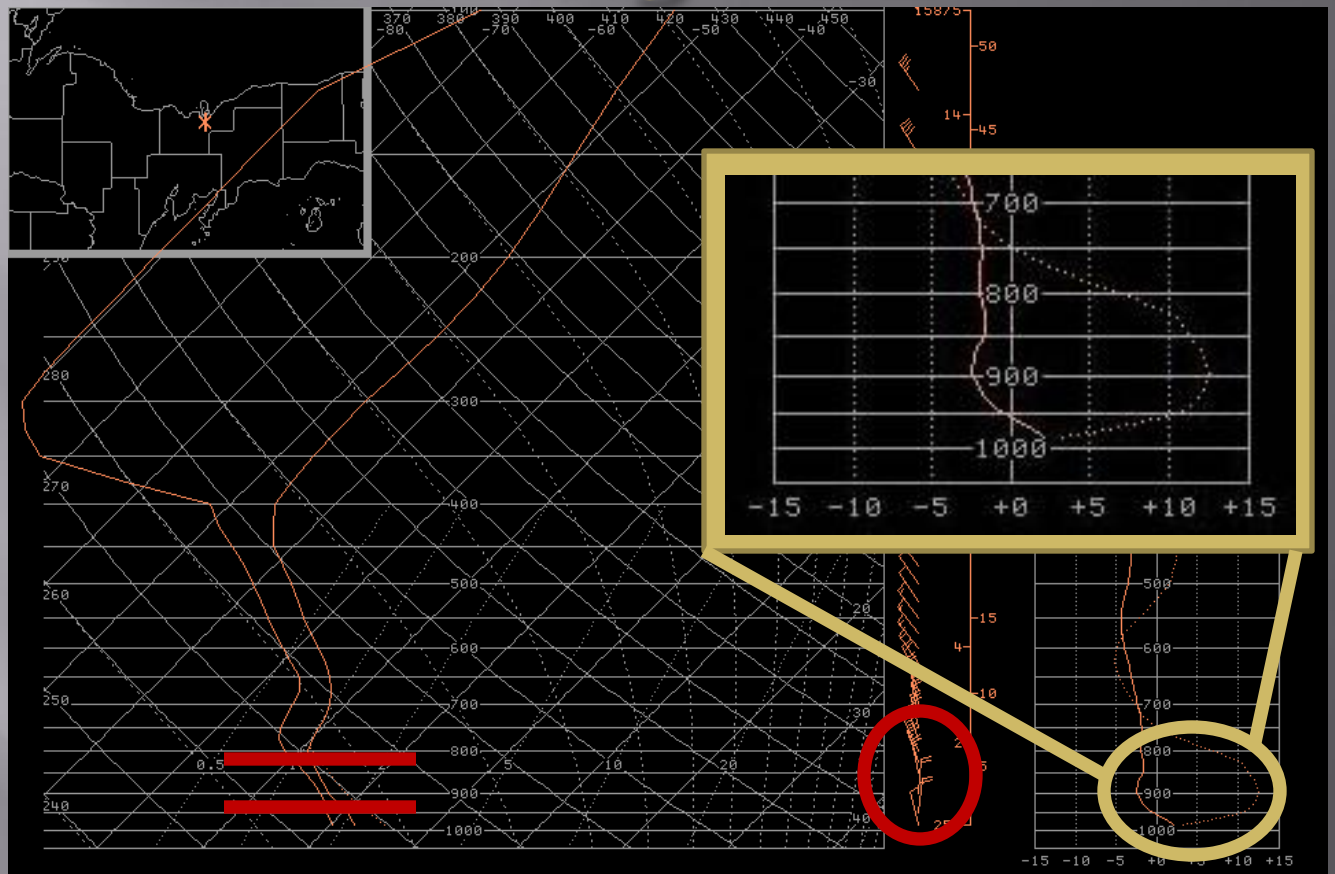
WRF Sounding 12Z Sundell

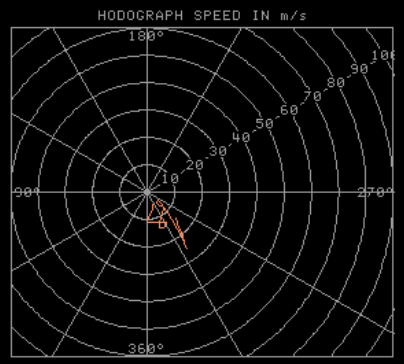


NAM Sounding 12Z Sundell



WRF Sounding 12Z Munising



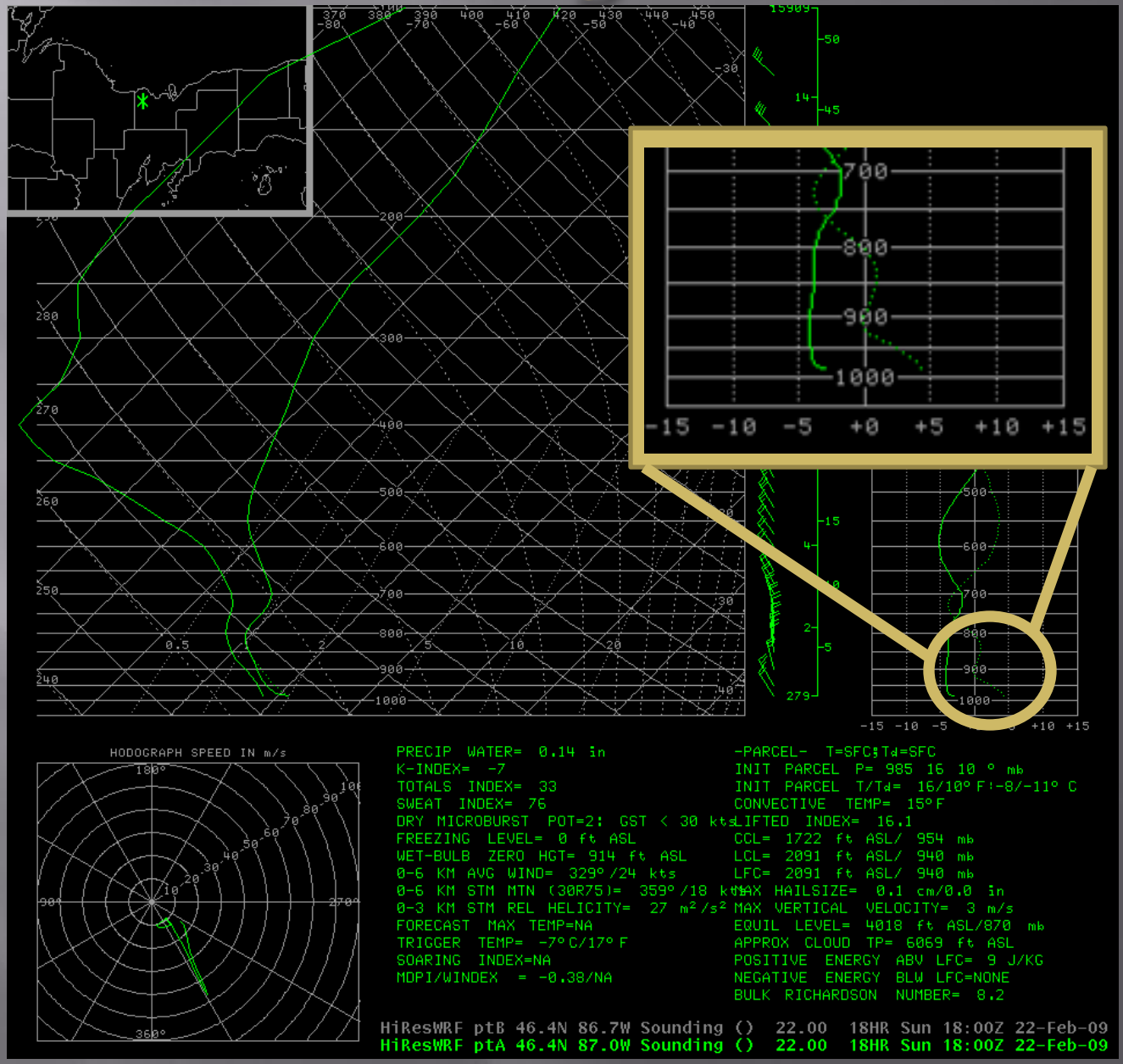


PRECIP WATER= 0.18 in
K-INDEX= -0
TOTALS INDEX= 40
SWEAT INDEX= 56
DRY MICROBURST POT=2: GST < 30 kts
FREEZING LEVEL= 0 ft ASL
WET-BULB ZERO HGT= 829 ft ASL
0-6 KM AVG WIND= 333°/18 kts
0-6 KM STM MTN (30R75)= 3°/13 kts
0-3 KM STM REL HELICITY= -17 m²/s²
FORECAST MAX TEMP= 24° F
TRIGGER TEMP= -5° C/21° F
SOARING INDEX= 215 ft/min
MDPI/WINDEX = -0.36/NA

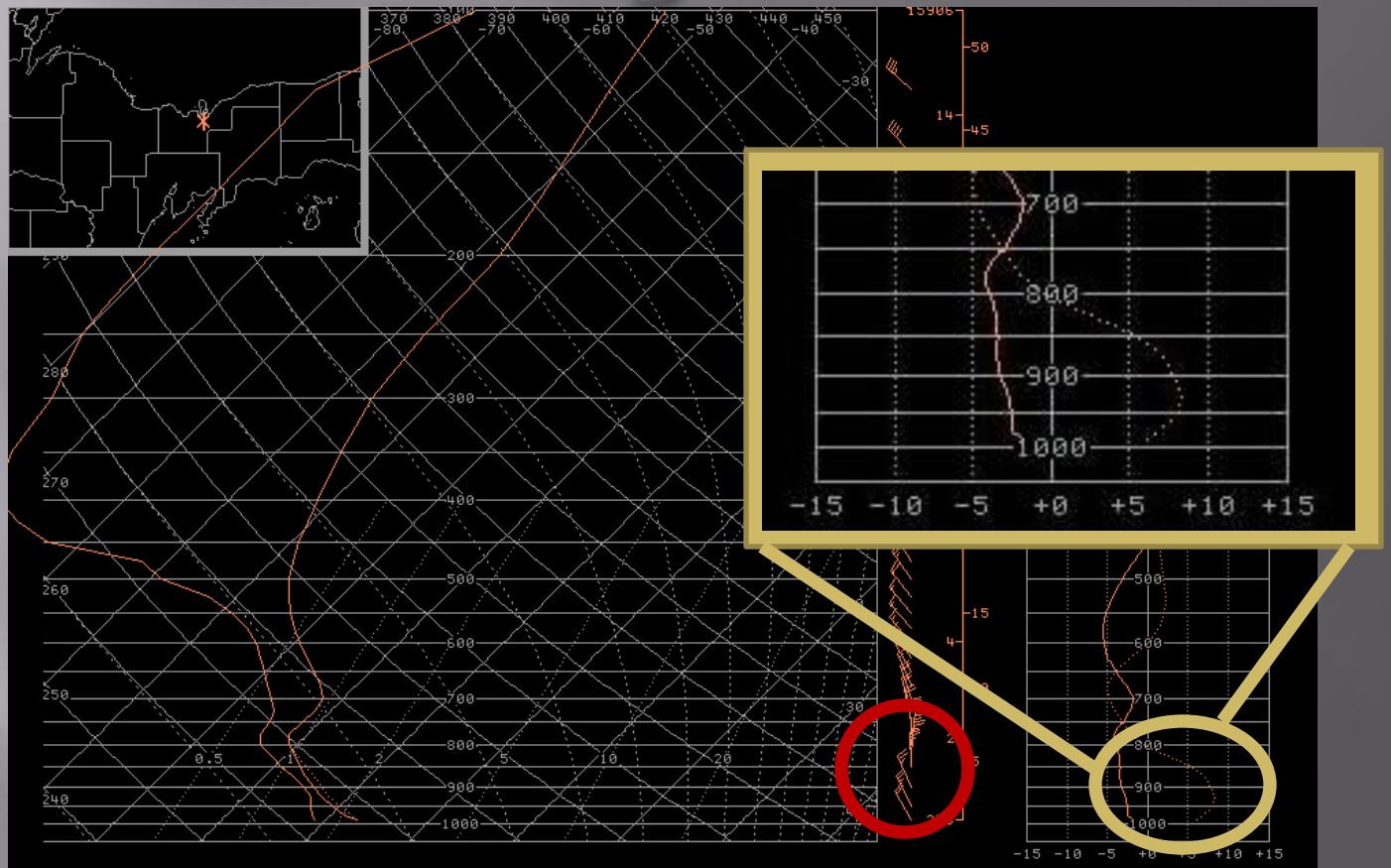
* -PARCEL- T=FCST MAX Td=50 mb MEAN
* MOD PARCEL P= 985 mb
* MOD PARCEL T/Td= 23/12° F:-4/-10° C
* CONVECTIVE TEMP= 20° F
* LIFTED INDEX= 11.8
* CCL= 2542 ft ASL/ 920 mb
* LCL= 3260 ft ASL/ 894 mb
* LFC= 3260 ft ASL/ 894 mb
* MAX HAILSIZE= 0.2 cm/0.1 in
* MAX VERTICAL VELOCITY= 7 m/s
* EQUIL LEVEL= 6315 ft ASL/790 mb
* APPROX CLOUD TP= 8202 ft ASL
* POSITIVE ENERGY ABV LFC= 34 J/KG
* NEGATIVE ENERGY BLW LFC=NONE
* BULK RICHARDSON NUMBER= 6.3

HiResWRF ptB 46.4N 86.7W Sounding () 22.00 12HR Sun 12:00Z 22-Feb-09
HiResWRF ptA 46.4N 87.0W Sounding () 22.00 12HR Sun 12:00Z 22-Feb-09

WRF Sounding 18Z Sundell



WRF Sounding 18Z Munising

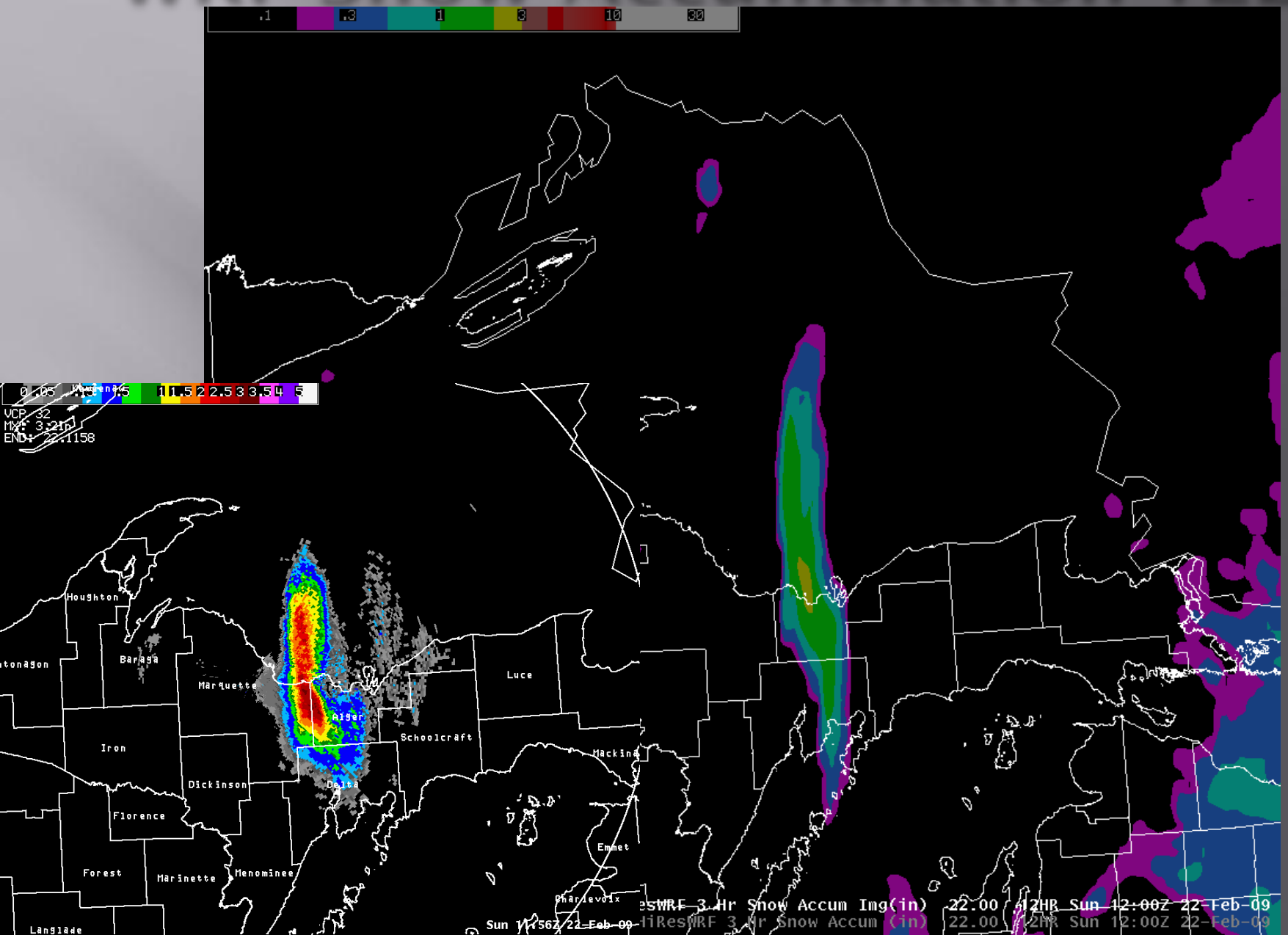


HODOGRAPH SPEED IN m/s

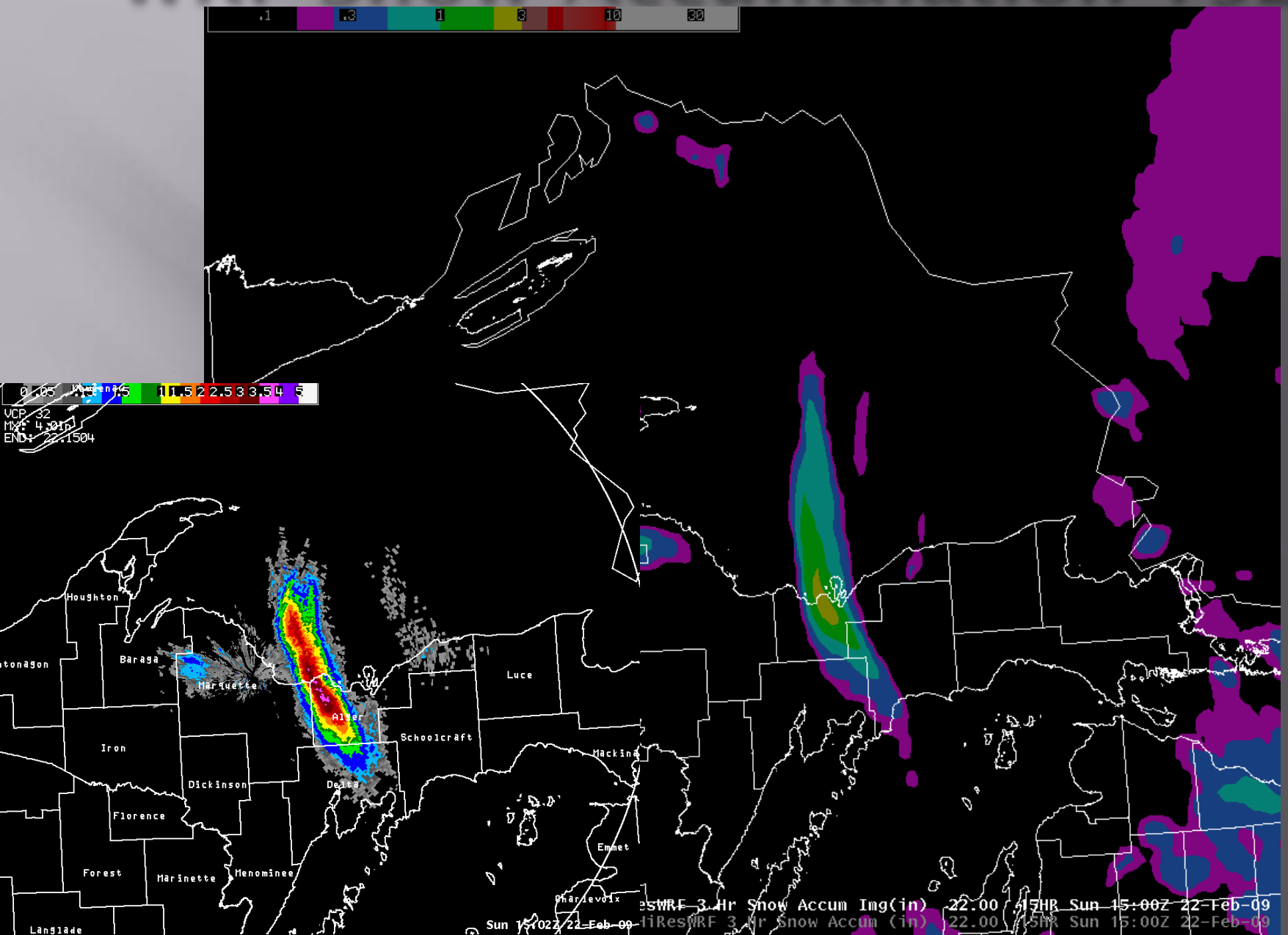
PRECIP WATER= 0.15 in	-PARCEL- T=SFC;Td=SFC
K-INDEX= -5	INIT PARCEL P= 988 19 11 ° mb
TOTALS INDEX= 36	INIT PARCEL T/Td= 19/11° F:-6/-11° C
SWEAT INDEX= 71	CONVECTIVE TEMP= 18° F
DRY MICROBURST POT=2: GST < 30 kts	LIFTED INDEX= 13.8
FREEZING LEVEL= 0 ft ASL	CCL= 2214 ft ASL/ 935 mb
WET-BULB ZERO HGT= 829 ft ASL	LCL= 2501 ft ASL/ 925 mb
0-6 KM AVG WIND= 329°/21 kts	LFC= 2501 ft ASL/ 925 mb
0-6 KM STM MTN (30R75)= 359°/16 kts	MAX HAILSIZE= 0.2 cm/0.1 in
0-3 KM STM REL HELICITY= 26 m²/s²	MAX VERTICAL VELOCITY= 5 m/s
FORECAST MAX TEMP=NA	EQUIL LEVEL= 6151 ft ASL/797 mb
TRIGGER TEMP= -7° C/19° F	APPROX CLOUD TP= 7874 ft ASL
SOARING INDEX=NA	POSITIVE ENERGY ABV LFC= 23 J/KG
MDPI/WINDEX = -0.33/NA	NEGATIVE ENERGY BLW LFC=NONE
	BULK RICHARDSON NUMBER= 8.4

HiResWRF ptB 46.4N 86.7W Sounding () 22.00 18HR Sun 18:00Z 22-Feb-09
HiResWRF ptA 46.4N 87.0W Sounding () 22.00 18HR Sun 18:00Z 22-Feb-09

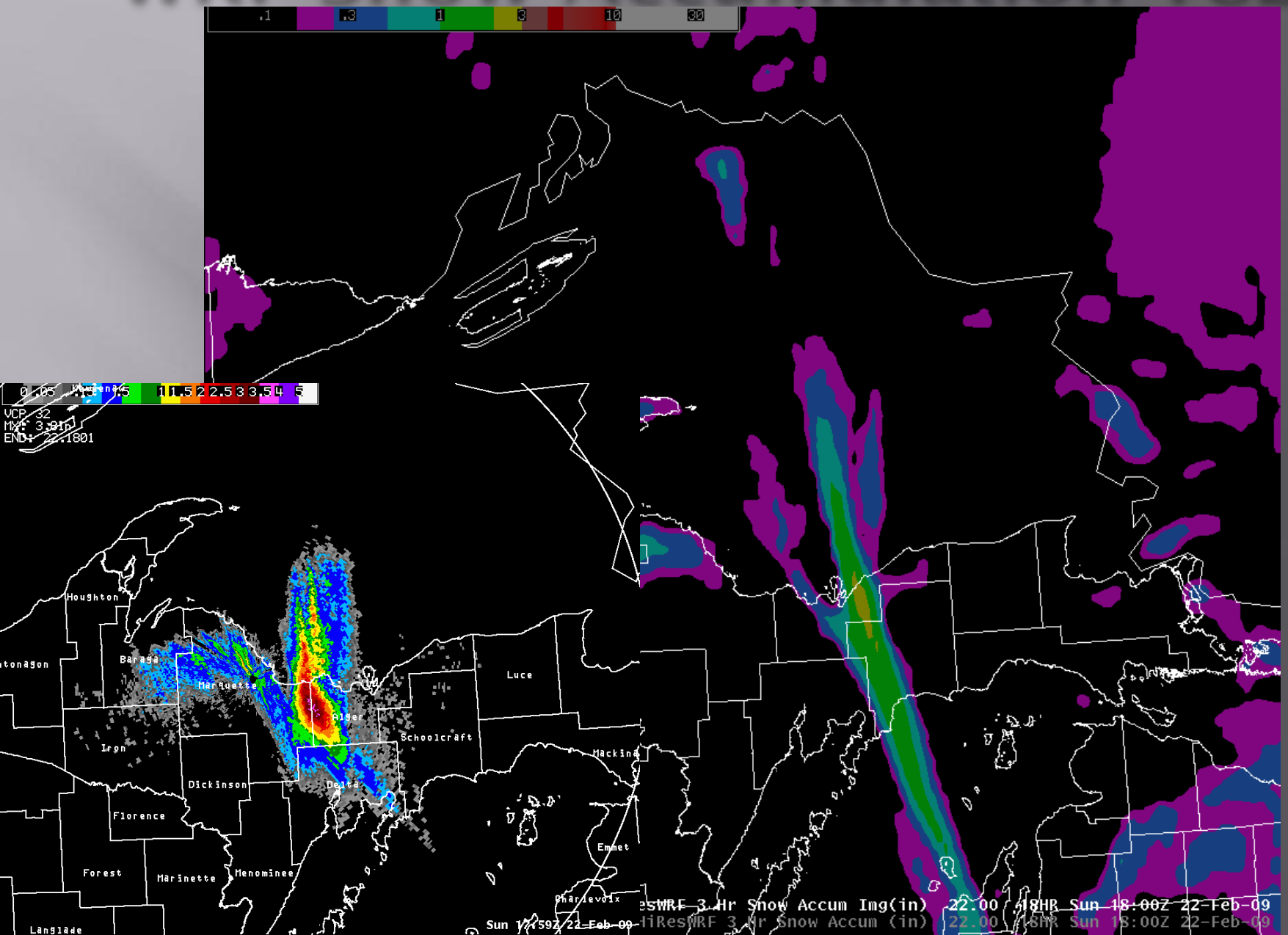
WRF Snow Accumulation 12Z



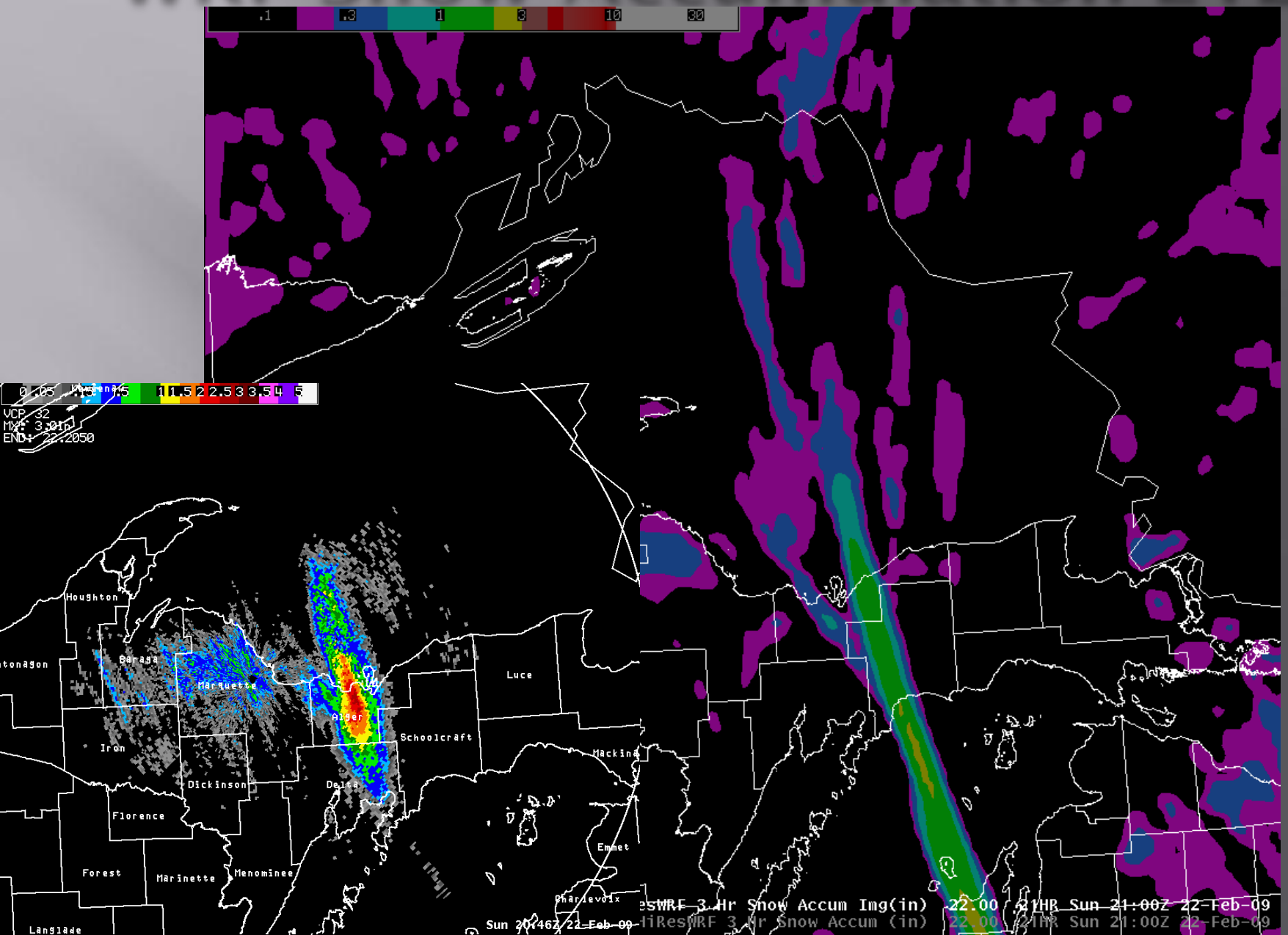
WRF Snow Accumulation 15Z



WRF Snow Accumulation 18Z



WRF Snow Accumulation 21Z



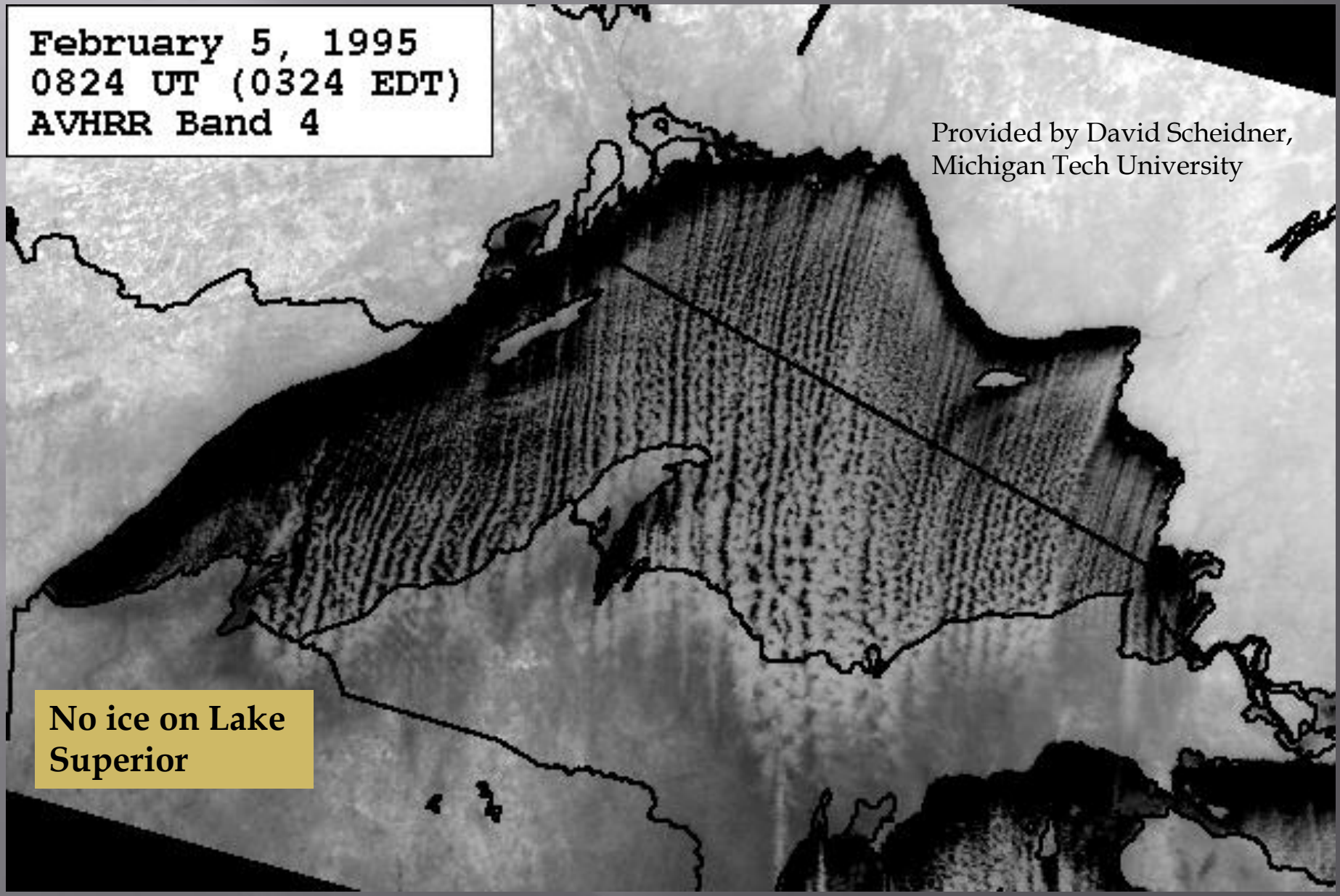
MIZ006-212330-
/O.NEW.KMQT.LE.W.0006.090222T0000Z-090223T1800Z/
ALGER-
INCLUDING THE CITY OF...MUNISING
1029 AM EST SAT FEB 21 2009

...LAKE EFFECT SNOW WARNING IN EFFECT FROM 7 PM THIS EVENING TO 1 PM EST MONDAY. .

THE NATIONAL WEATHER SERVICE IN MARQUETTE HAS ISSUED A LAKE EFFECT SNOW WARNING FOR HEAVY LAKE EFFECT SNOW...WHICH IS IN EFFECT FROM 7 PM THIS EVENING TO 1 PM EST MONDAY.

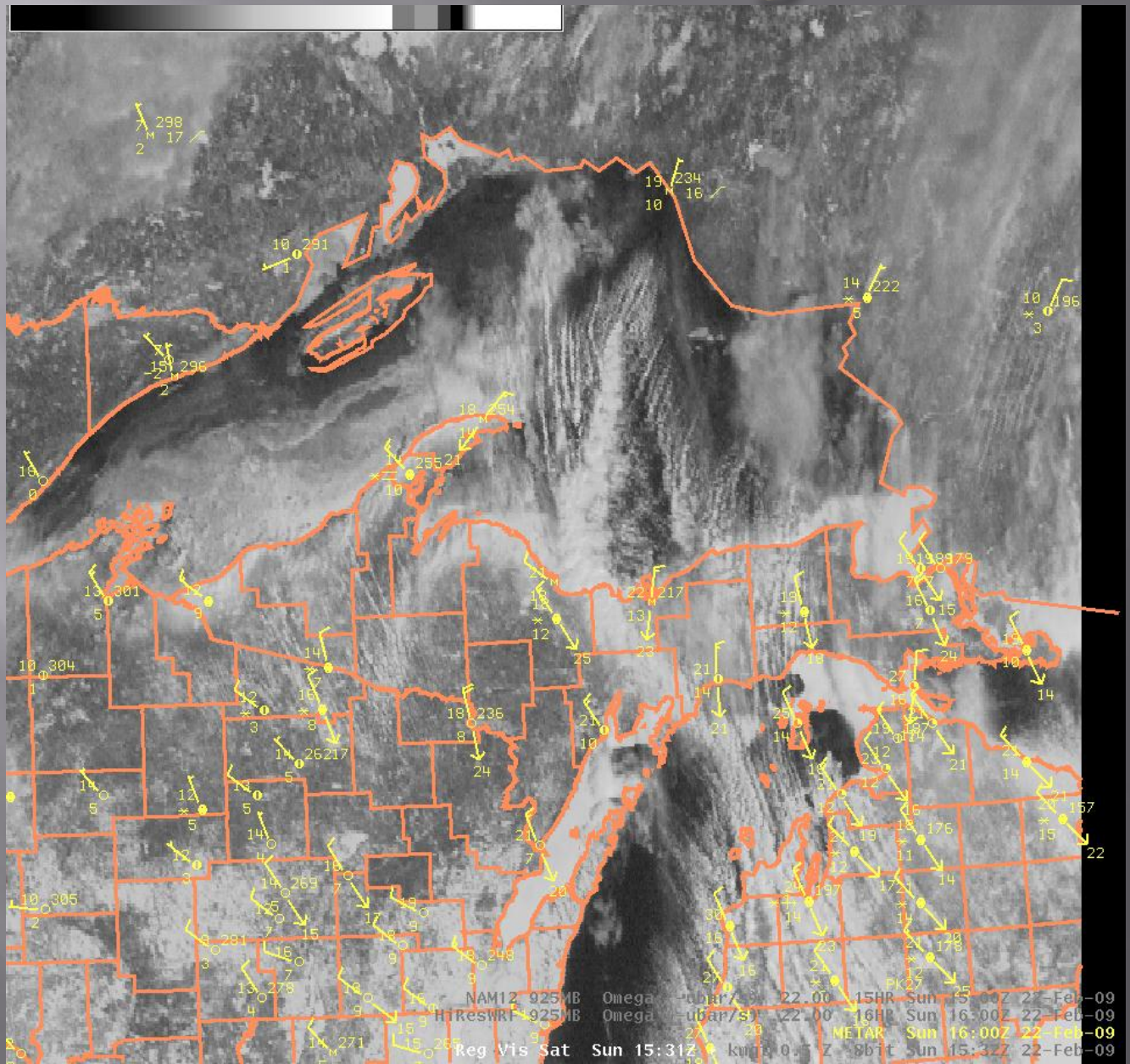
LAKE EFFECT SNOW SHOWERS WILL BEGIN THIS EVENING AS WINDS TURN NORTHERLY OFF OF LAKE SUPERIOR. FROM THIS EVENING INTO MONDAY MORNING AS MUCH AS A FOOT OF FLUFFY LAKE EFFECT SNOW MAY FALL ACROSS PORTIONS OF WESTERN AND CENTRAL ALGER COUNTY. THESE SNOW SHOWERS ARE EXPECTED TO CONTINUE INTO MONDAY AFTERNOON AS WINDS REMAIN NORTHWESTERLY OFF LAKE SUPERIOR BEFORE DIMINISHING MONDAY EVENING.

Typical North Flow Multiband

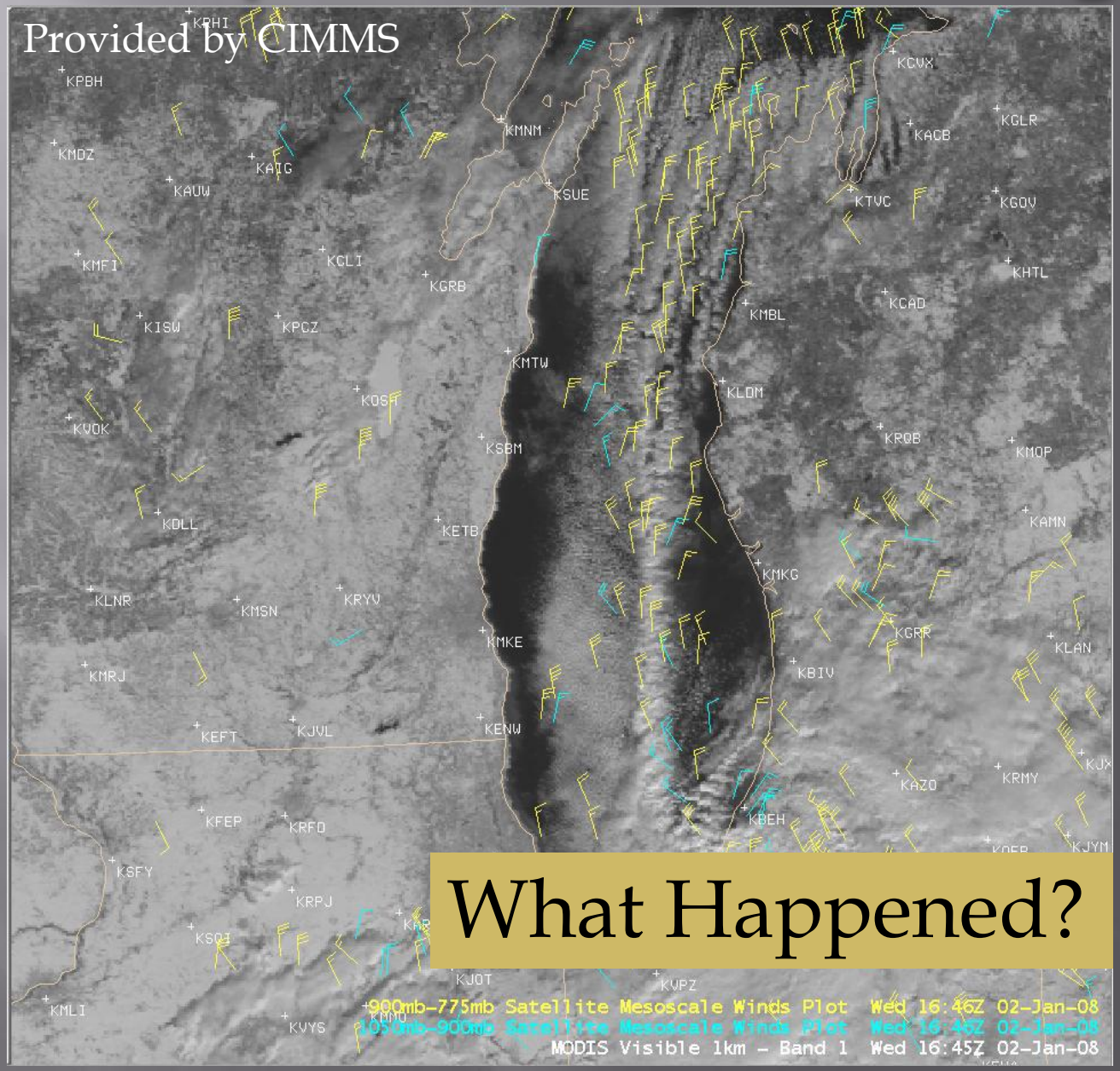


Typical Dominant Bands

Mid-Lake Convergent Band

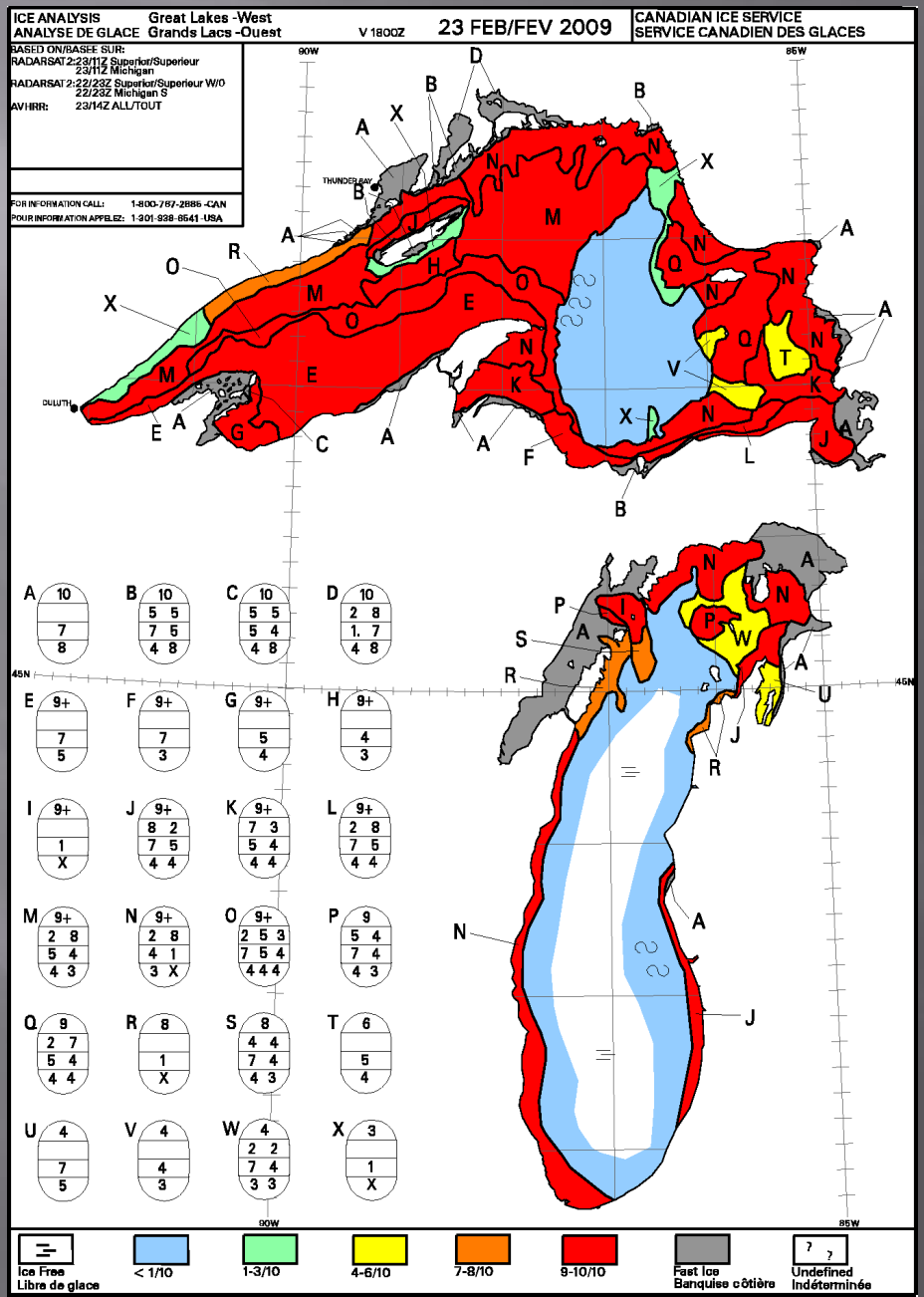


Lake Superior = Lake Michigan?

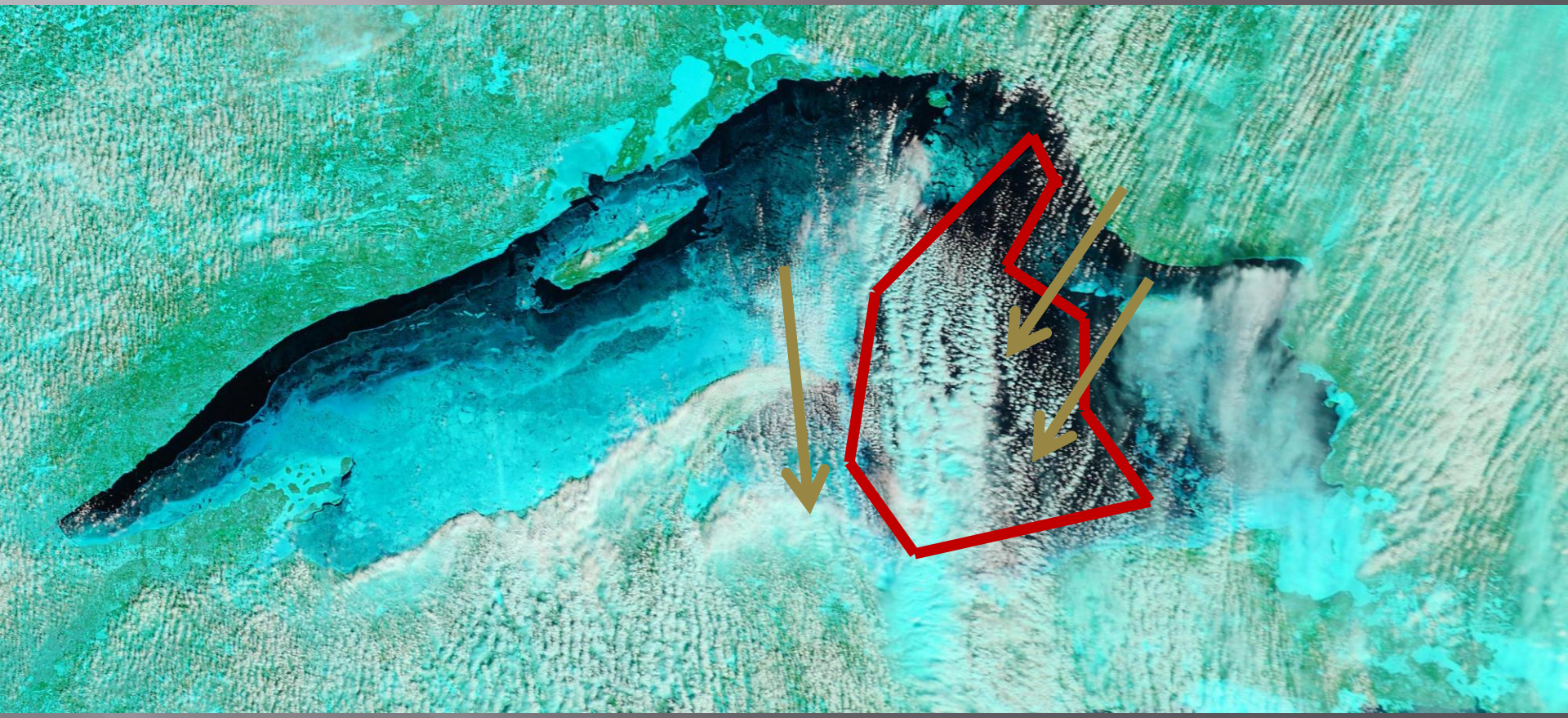


What Happened?

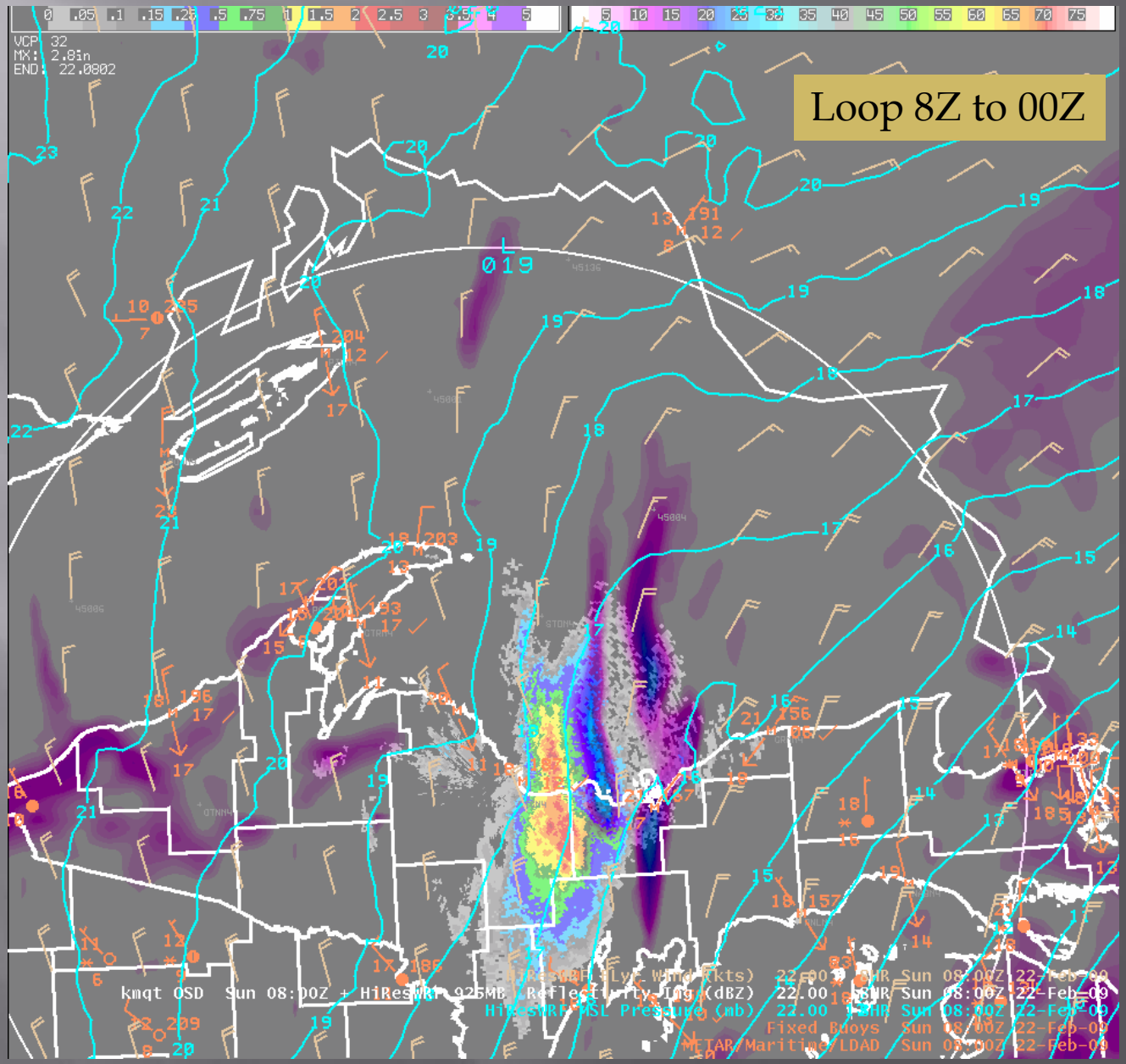
National Ice Center Ice Analysis

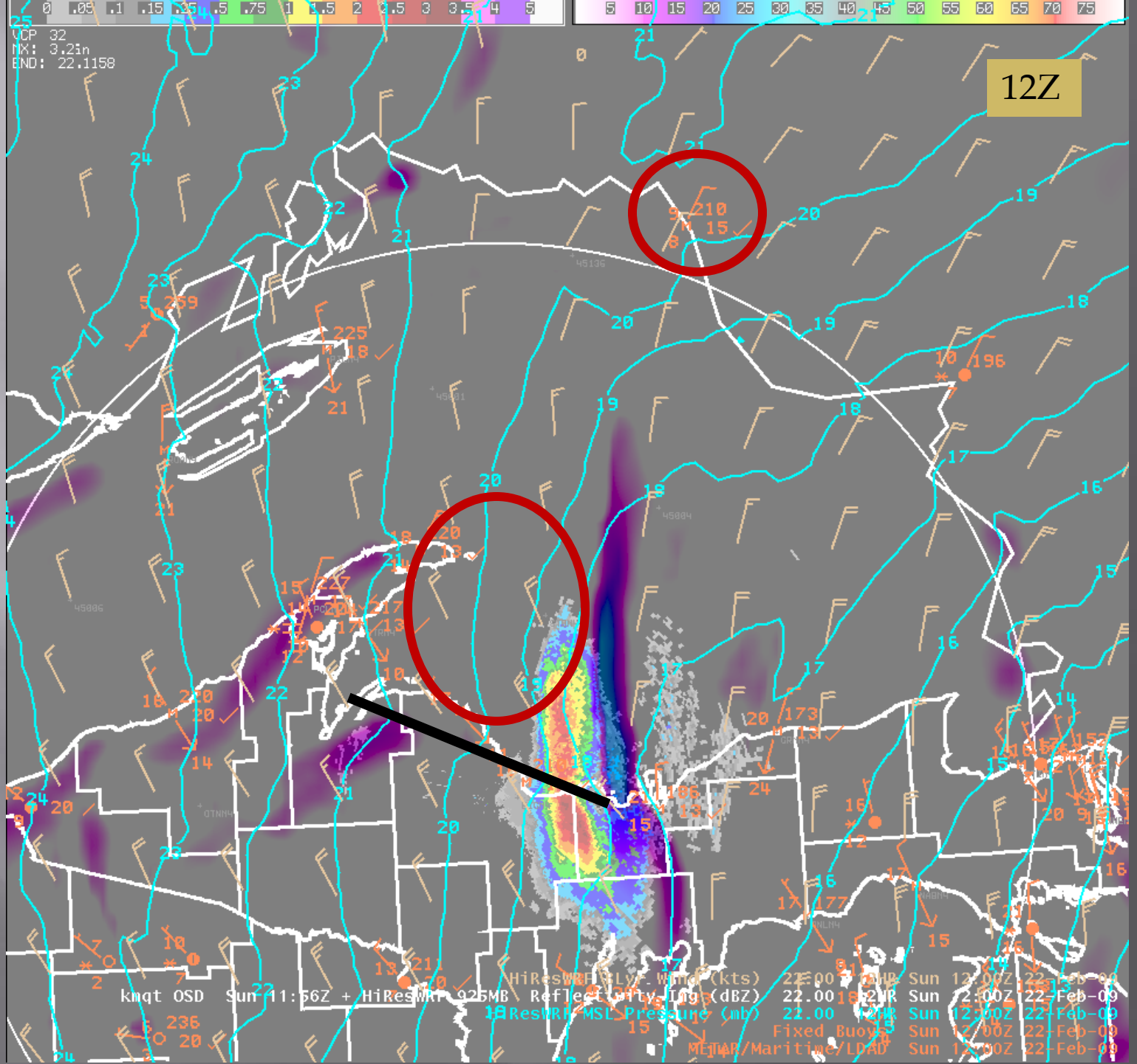


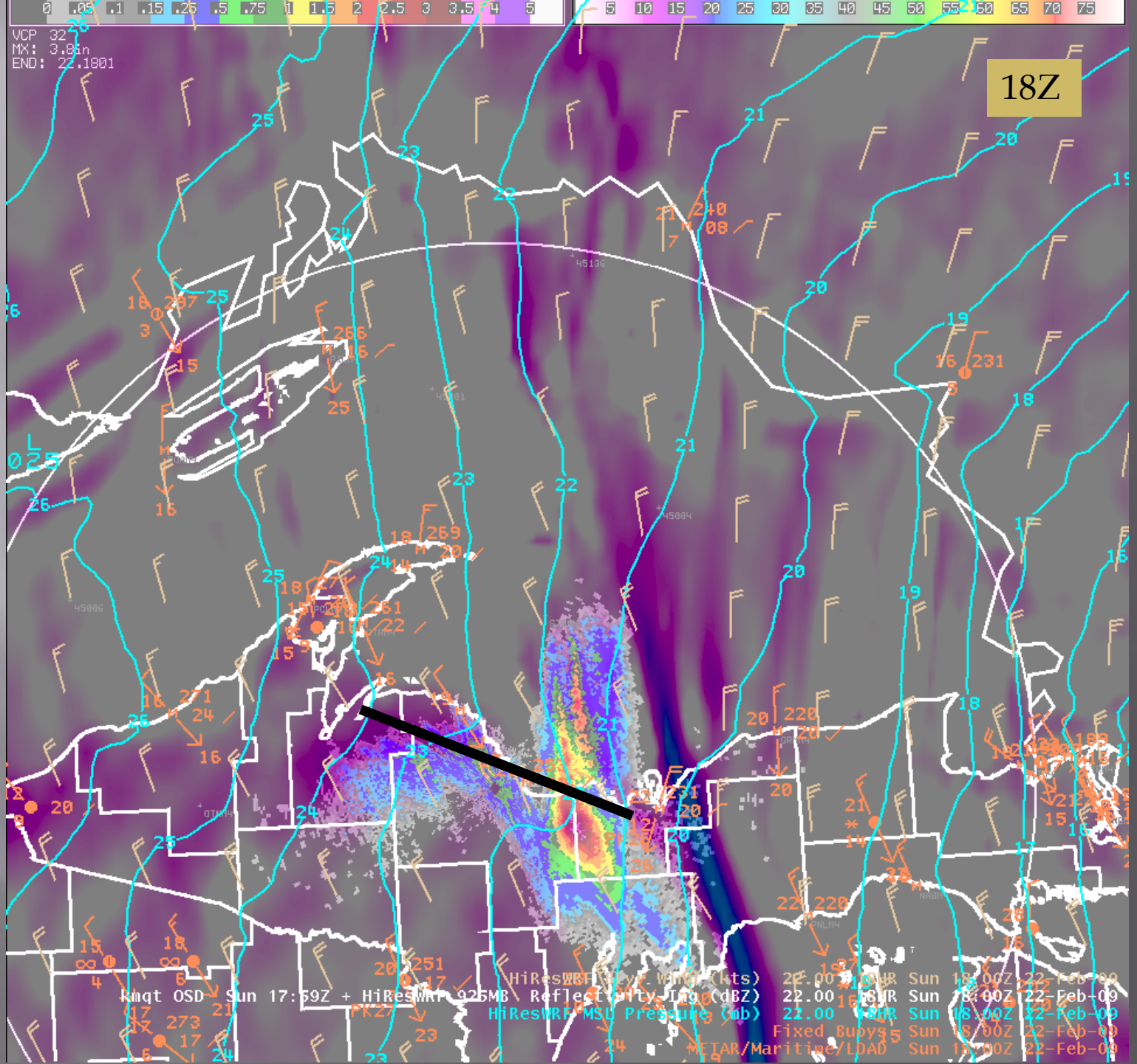
MODIS False Color Image

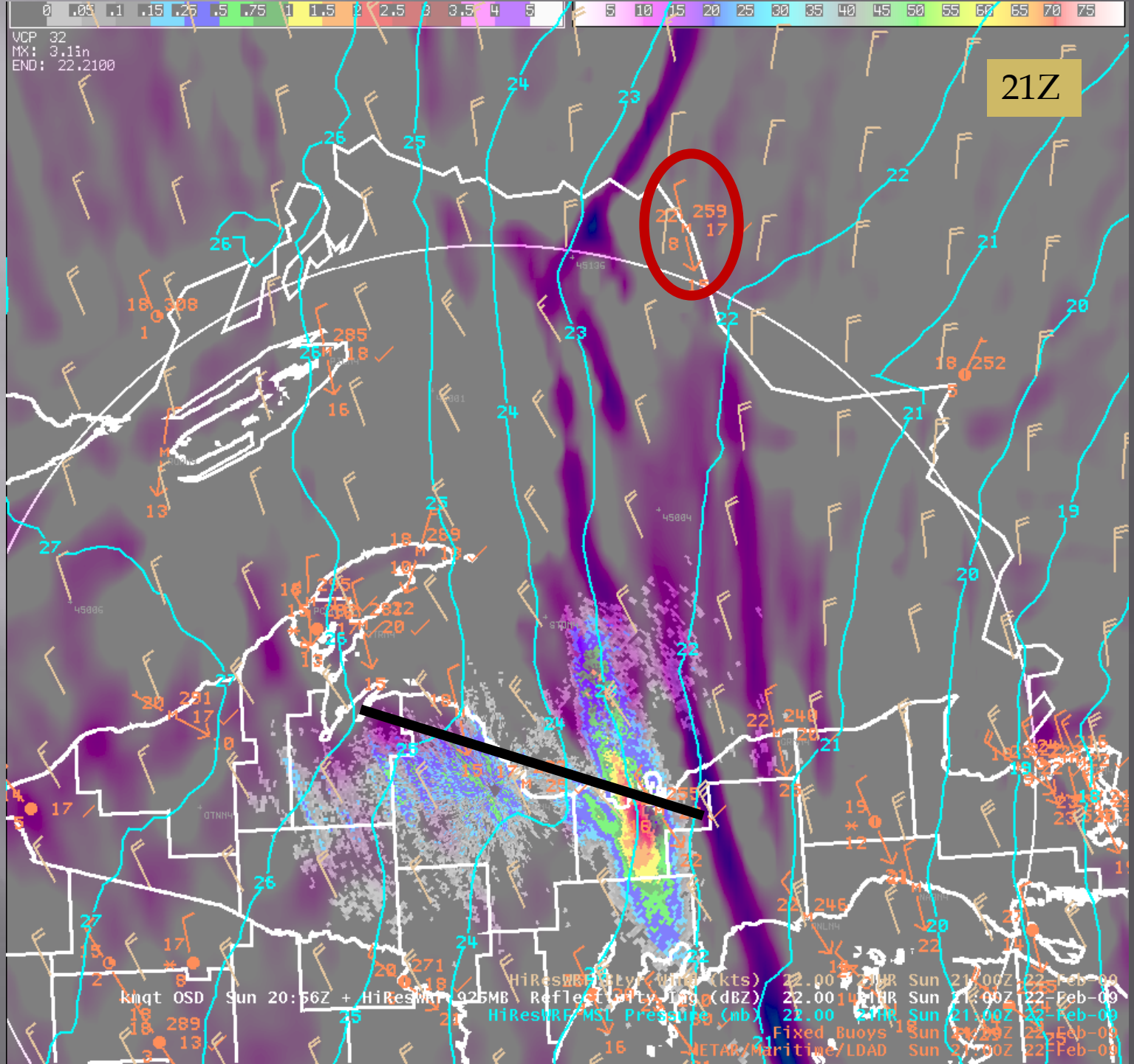


Local WRF-ARW Core and Radar

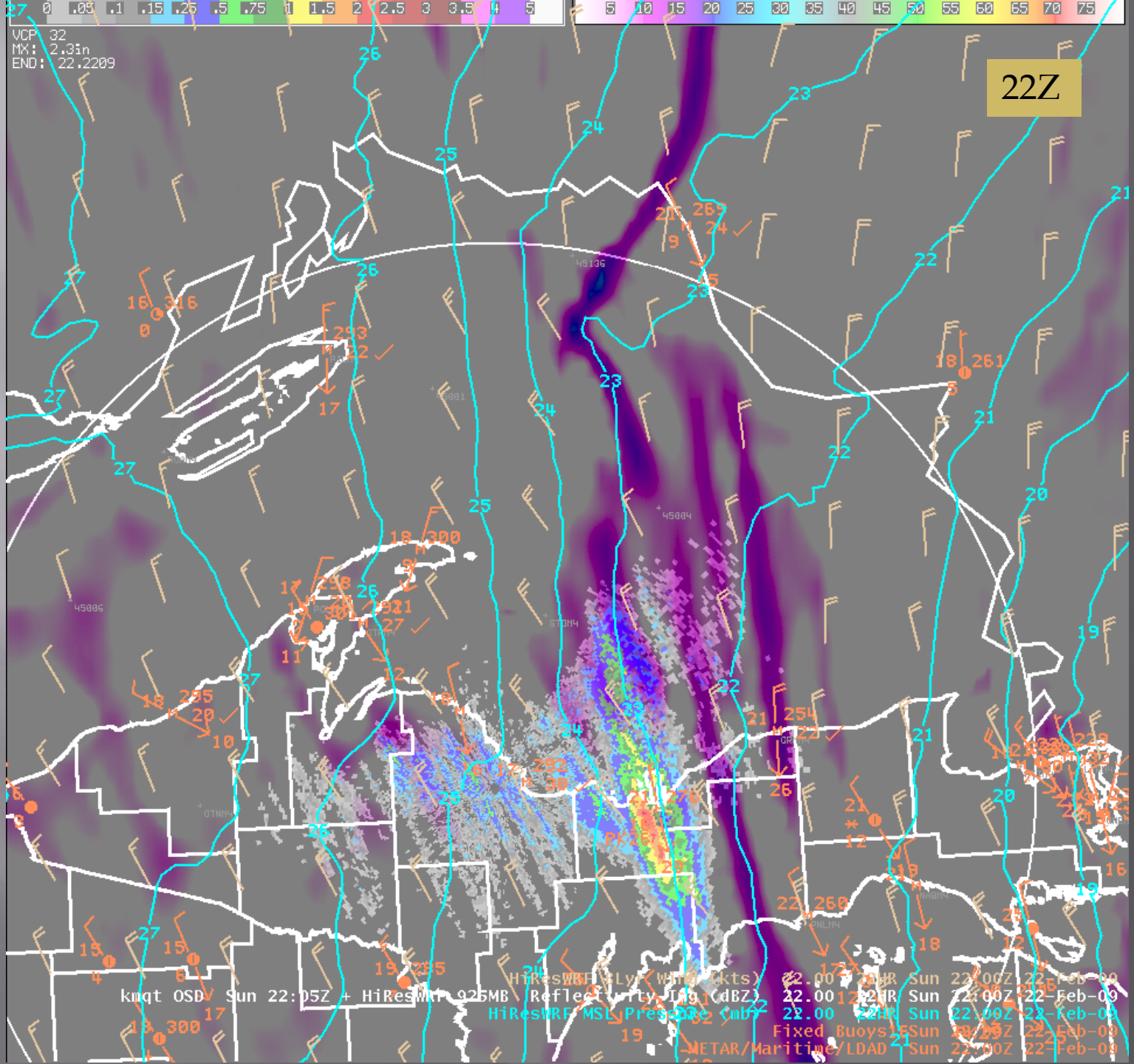


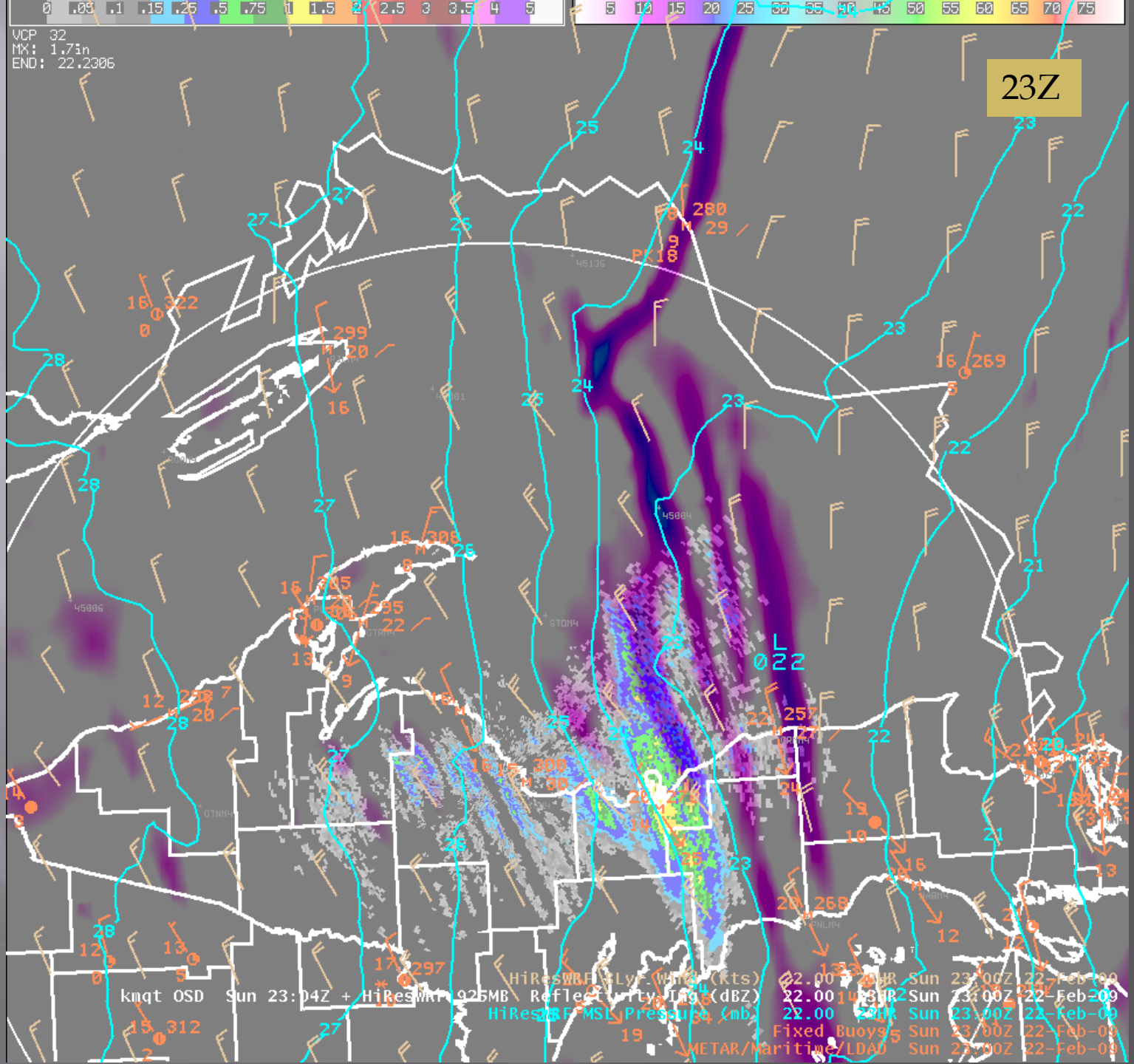

12Z
VCP 32
MX: 3.2in
END: 22.1158
kmqt OSD Sun 11:56Z + HiResWRF 925MB
HiResWRF Lyr Wind (kts) 22.00 12HR Sun 12:00Z 22-Feb-09
HiResWRF Reflectivity Img (dBZ) 22.00 12HR Sun 12:00Z 22-Feb-09
HiResWRF MSL Pressure (mb) 22.00 12HR Sun 12:00Z 22-Feb-09
Fixed Buoys Sun 12:00Z 22-Feb-09
METAR/Maritime/LDAD Sun 12:00Z 22-Feb-09


18Z
VCP 32
MX: 3.86in
END: 22.1801
0 .05 .1 .15 .25 .5 .75 1 1.5 2 2.5 3 3.5 4 5
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
Kmqt OSD Sun 17:59Z + HiResWRF 925MB \ Reflectivity Img (dBZ)
HiResWRF MSU Pressure (mb) 22.00 6HR Sun 18:00Z 22-Feb-09
Fixed Buoys Sun 18:00Z 22-Feb-09
MEIAR/Maritime/LDAD Sun 18:00Z 22-Feb-09

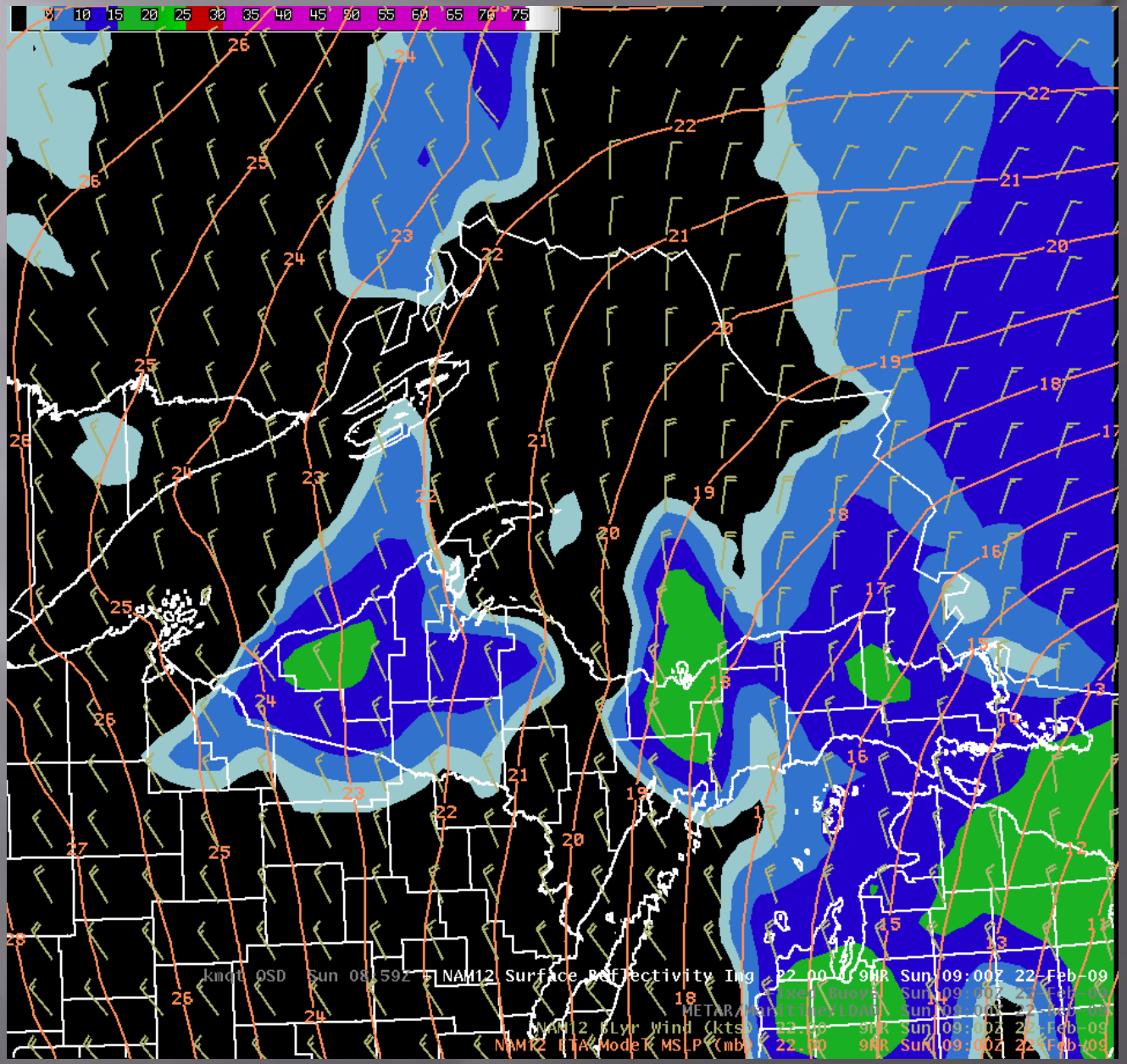


VCP 32
MX: 3.1in
END: 22.2100
21Z
kmqt OSD Sun 20:56Z + HiResWRF 925MB Reflectivity Img (dBZ) 22.00 21HR Sun 21:00Z 22-Feb-09
HiResWRF MSL Pressure (mb) 22.00 21HR Sun 21:00Z 22-Feb-09
Fixed Buoys Sun 21:00Z 22-Feb-09
ETAR/Maritime/LDAD Sun 21:00Z 22-Feb-09

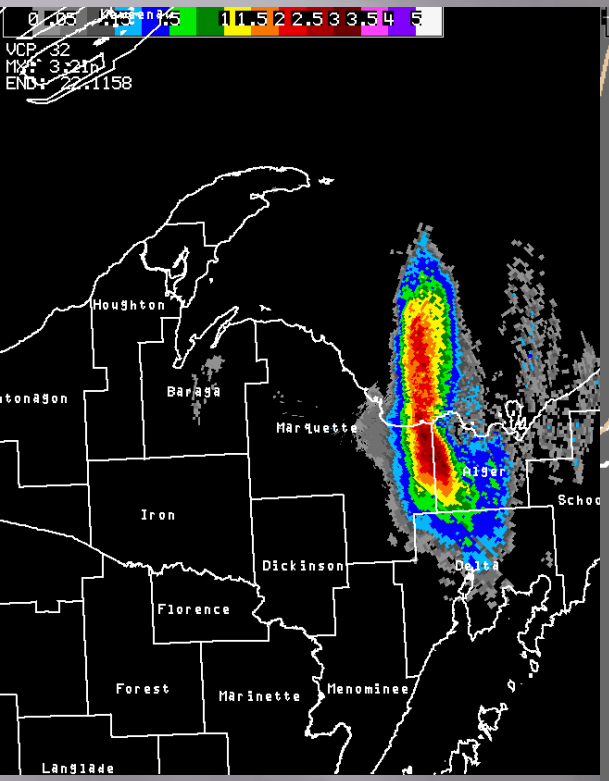

VCP 32
MX: 2.3in
END: 22.2209
22Z
kmqt OSD Sun 22:05Z + HiResWRF 925MB
HiResWRF SLyr Wind (kts) 22.00 + 00HR Sun 22:00Z 22-Feb-09
HiResWRF Reflectivity Mag (dBZ) 22.00 + 00HR Sun 22:00Z 22-Feb-09
HiResWRF MSL Press (mb) 22.00 + 00HR Sun 22:00Z 22-Feb-09
Fixed Buoys Sun 22:00Z 22-Feb-09
METAR/Maritime/LDAD Sun 22:00Z 22-Feb-09

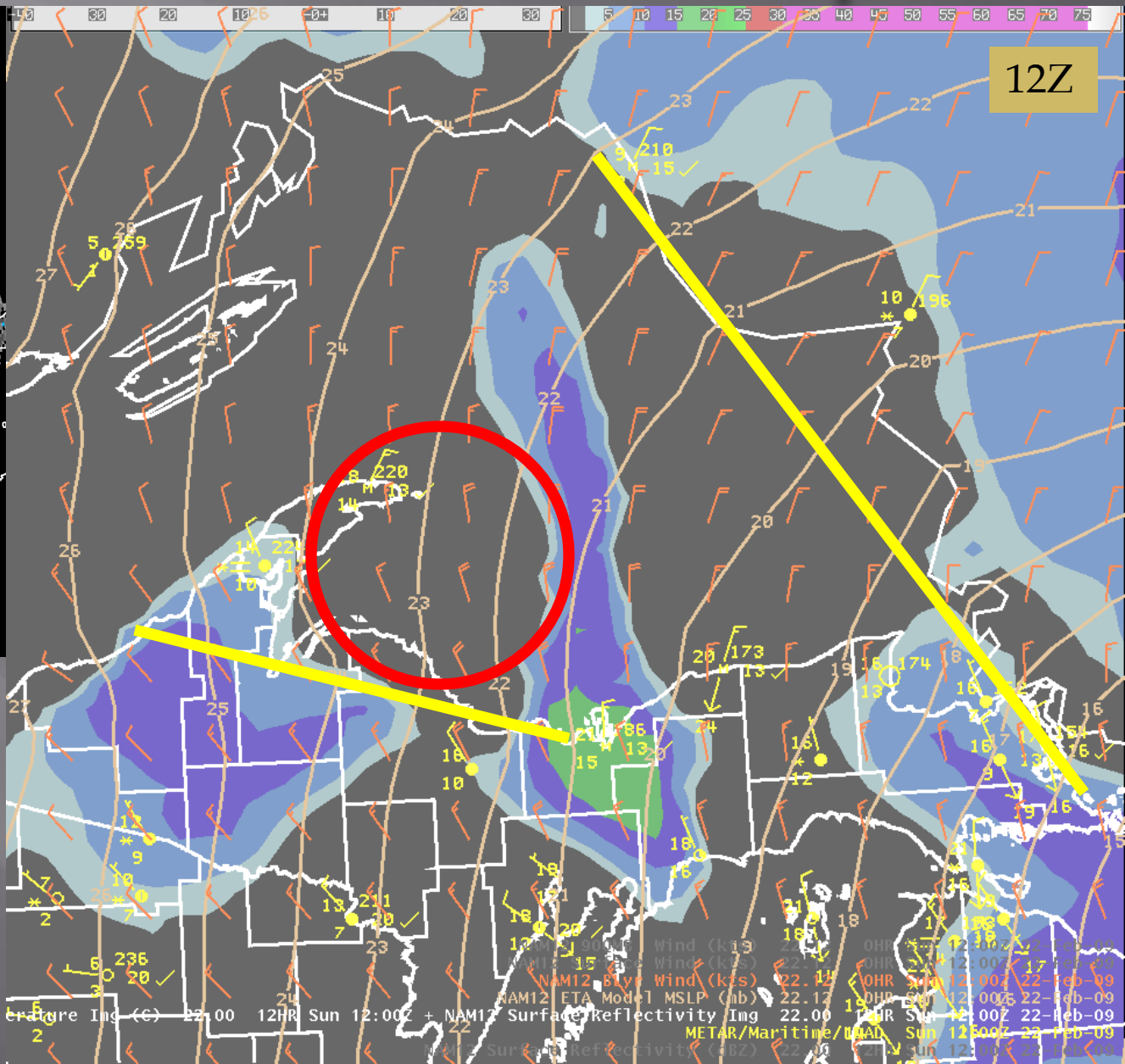

VCP 32
MX: 1.7in
END: 22.2306
23Z
kmqt OSD Sun 23:04Z + HiResWRF 925MB Reflectivity Img (dBZ) 22.00 +00HR Sun 23:00Z 22-Feb-09
HiResWRF MSL Pressure (mb) 22.00 +00HR Sun 23:00Z 22-Feb-09
Fixed Buoys Sun 23:00Z 22-Feb-09
METAR/Maritime/LDAD Sun 23:00Z 22-Feb-09

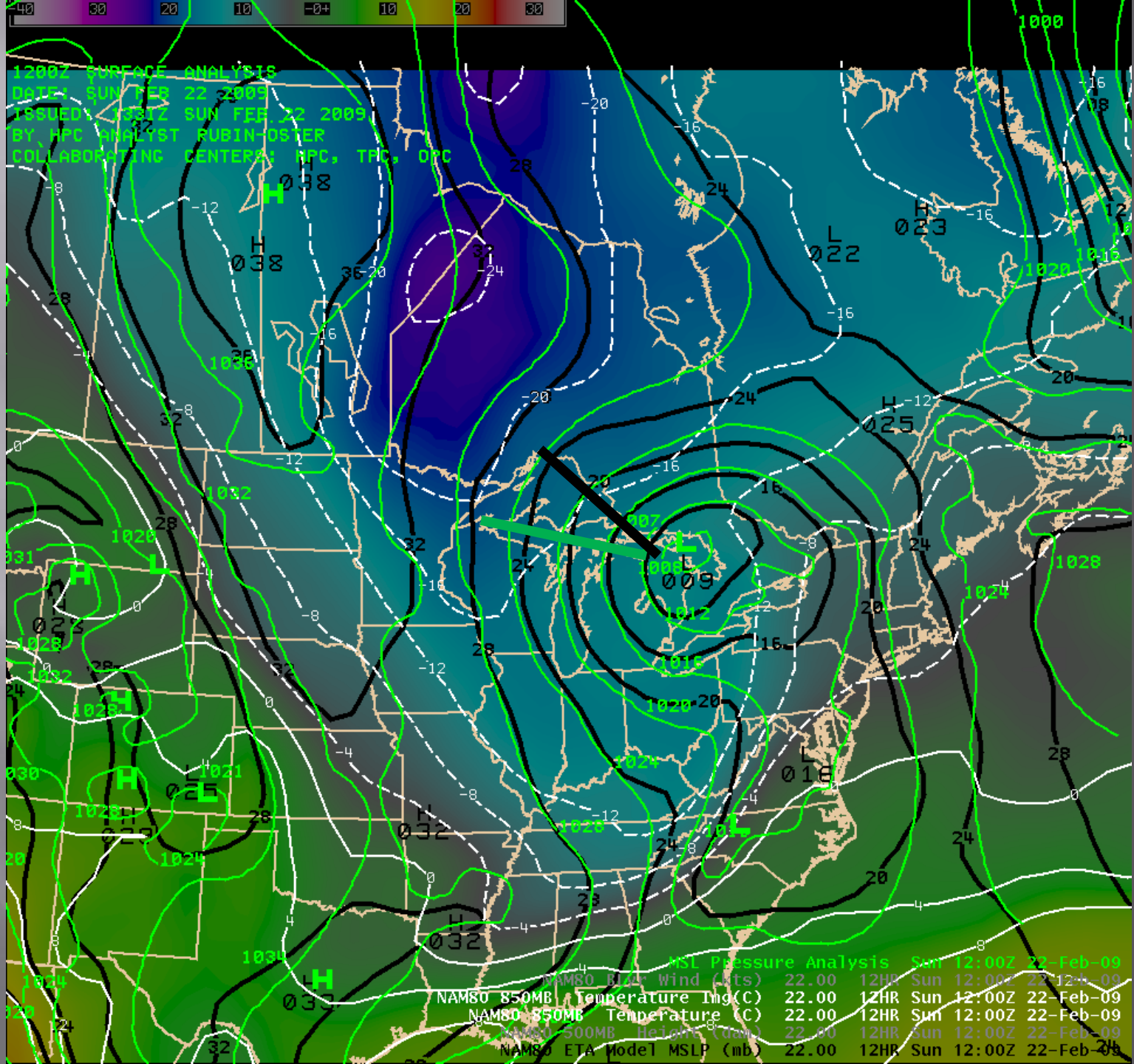
NAM Surface Reflectivity



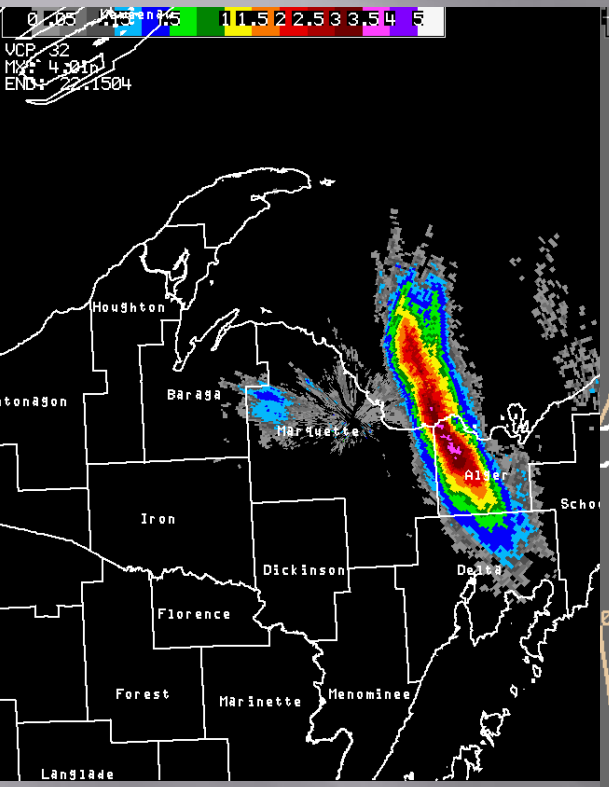
NAM and Radar Snow Depth

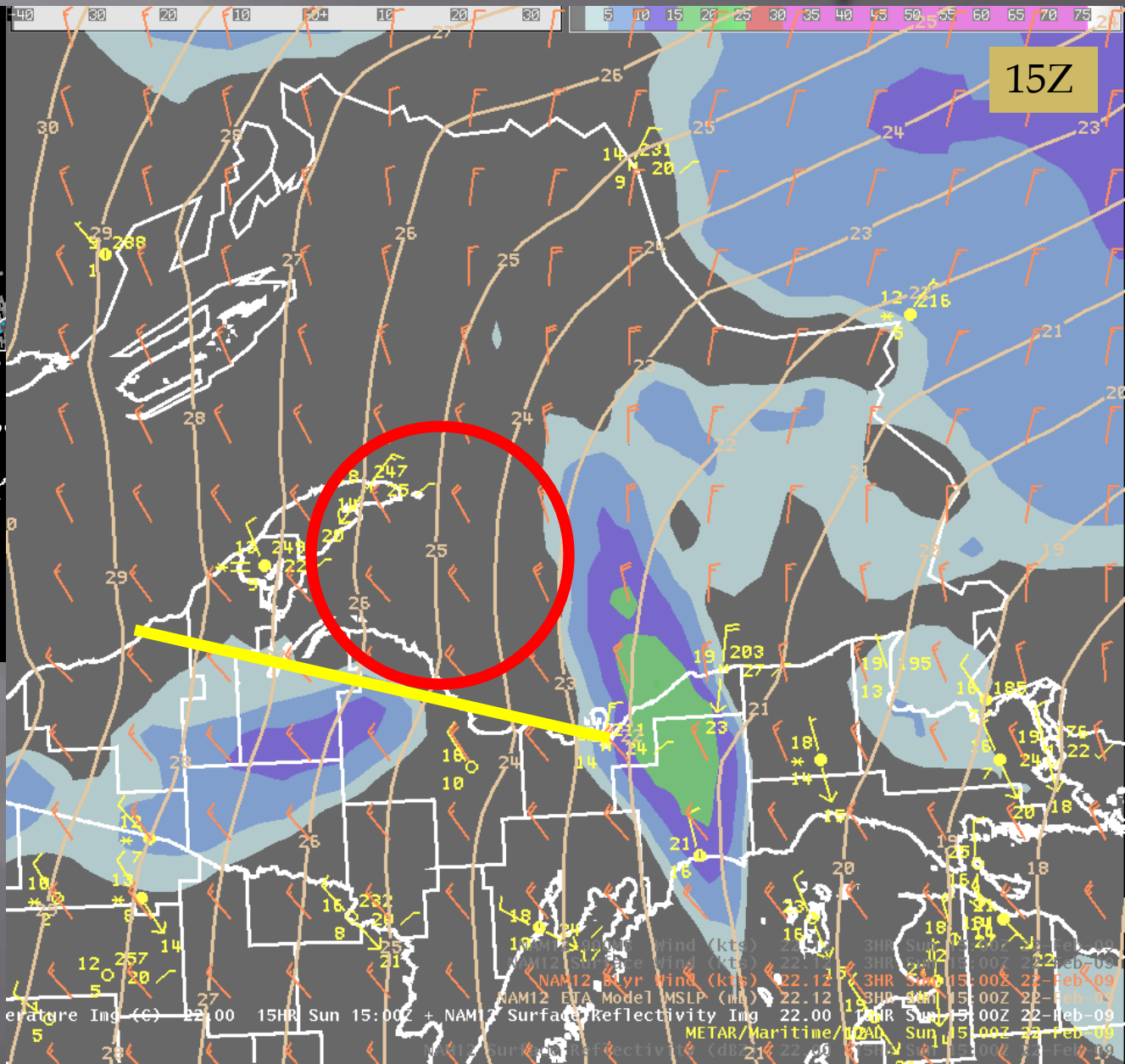




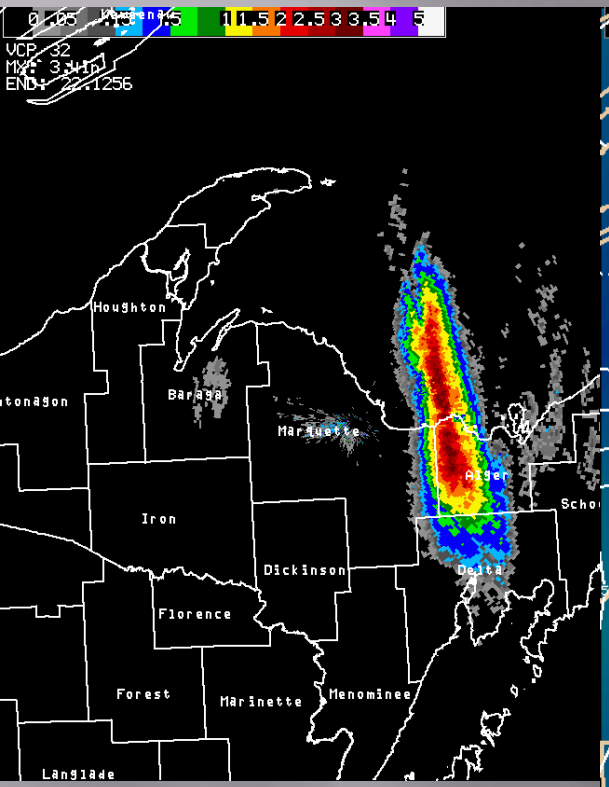

1200Z SURFACE ANALYSIS
DATE: SUN FEB 22 2009
ISSUED: 1331Z SUN FEB 22 2009
BY HPC ANALYST RUBIN-OSTER
COLLABORATING CENTERS: HPC, TPC, OPC
MSL Pressure Analysis Sun 12:00Z 22-Feb-09
NAM80 Bias Wind (kts) 22.00 12HR Sun 12:00Z 22-Feb-09
NAM80 850MB Temperature Img(C) 22.00 12HR Sun 12:00Z 22-Feb-09
NAM80 850MB Temperature (C) 22.00 12HR Sun 12:00Z 22-Feb-09
NAM80 500MB Heights (dam) 22.00 12HR Sun 12:00Z 22-Feb-09
NAM80 ETA Model MSLP (mb) 22.00 12HR Sun 12:00Z 22-Feb-09

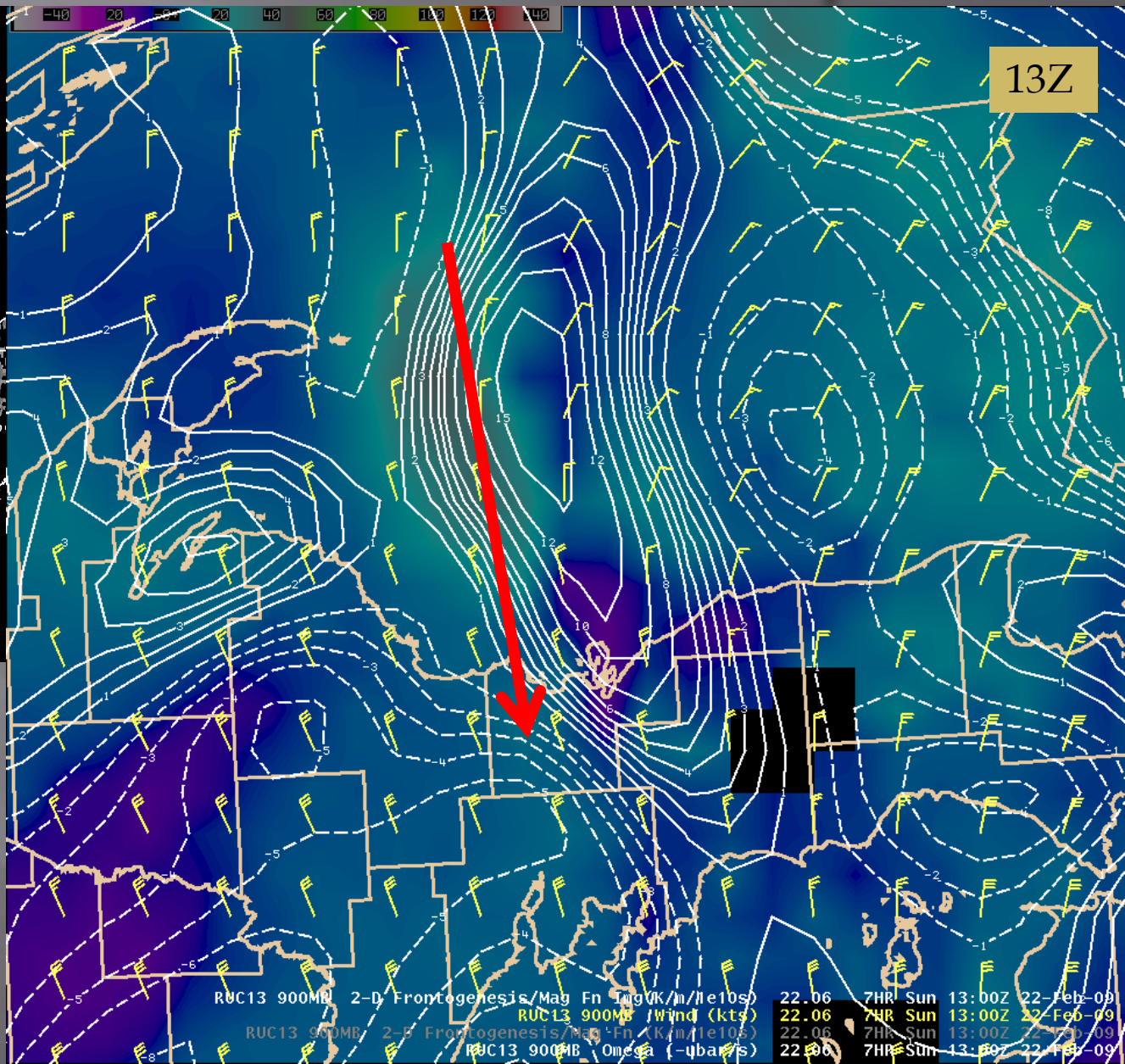
NAM and Radar Snow Depth



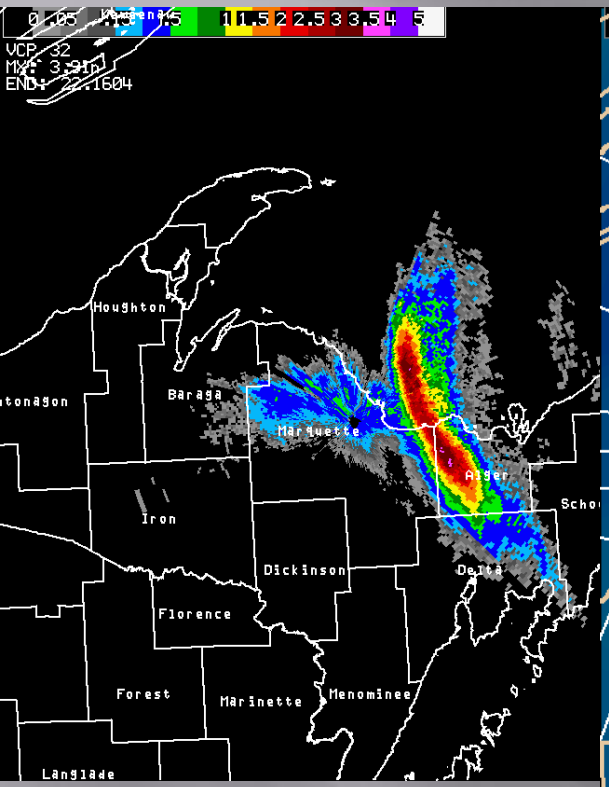


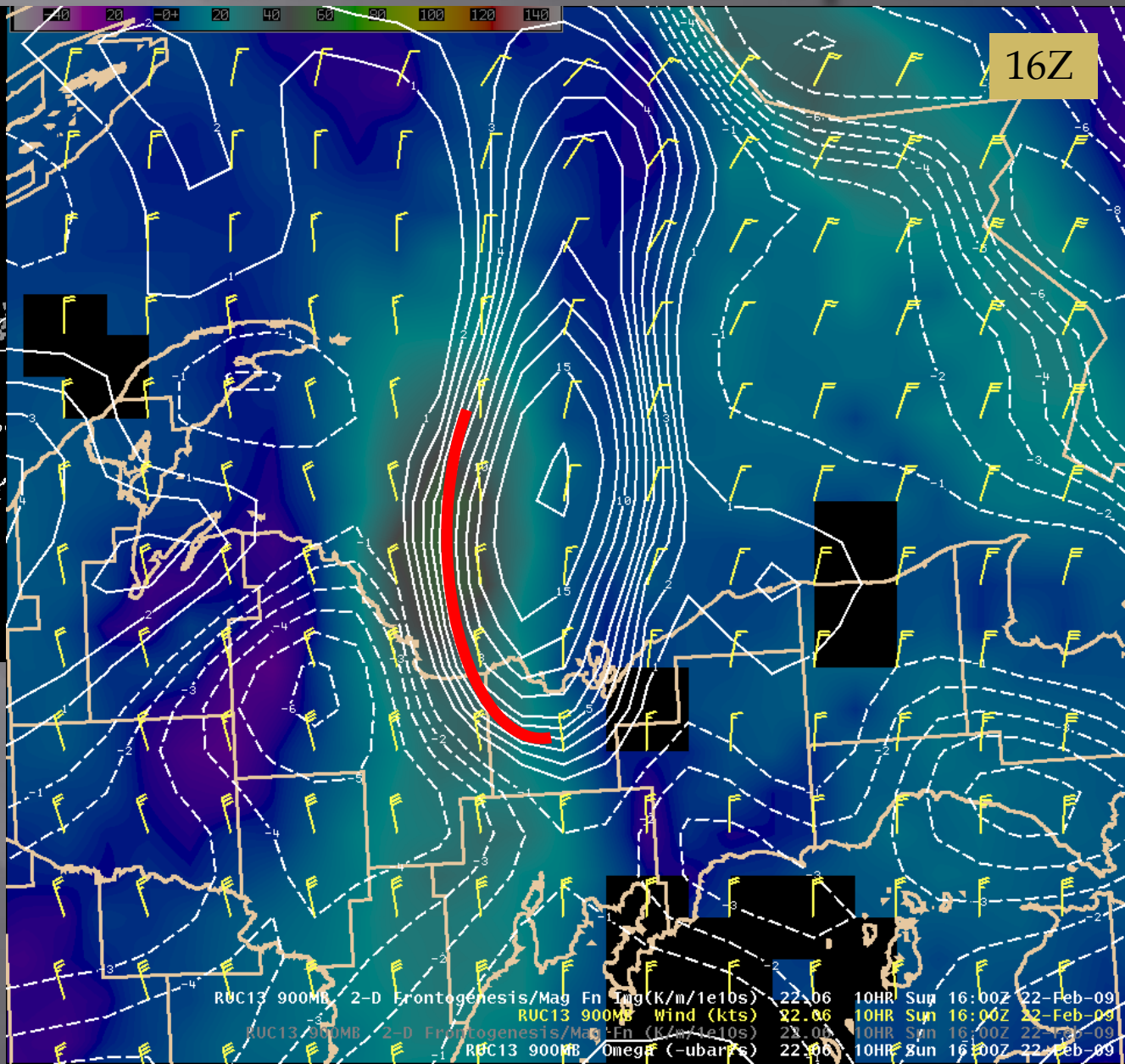
RUC and Radar Snow Depth





RUC and Radar Snow Depth

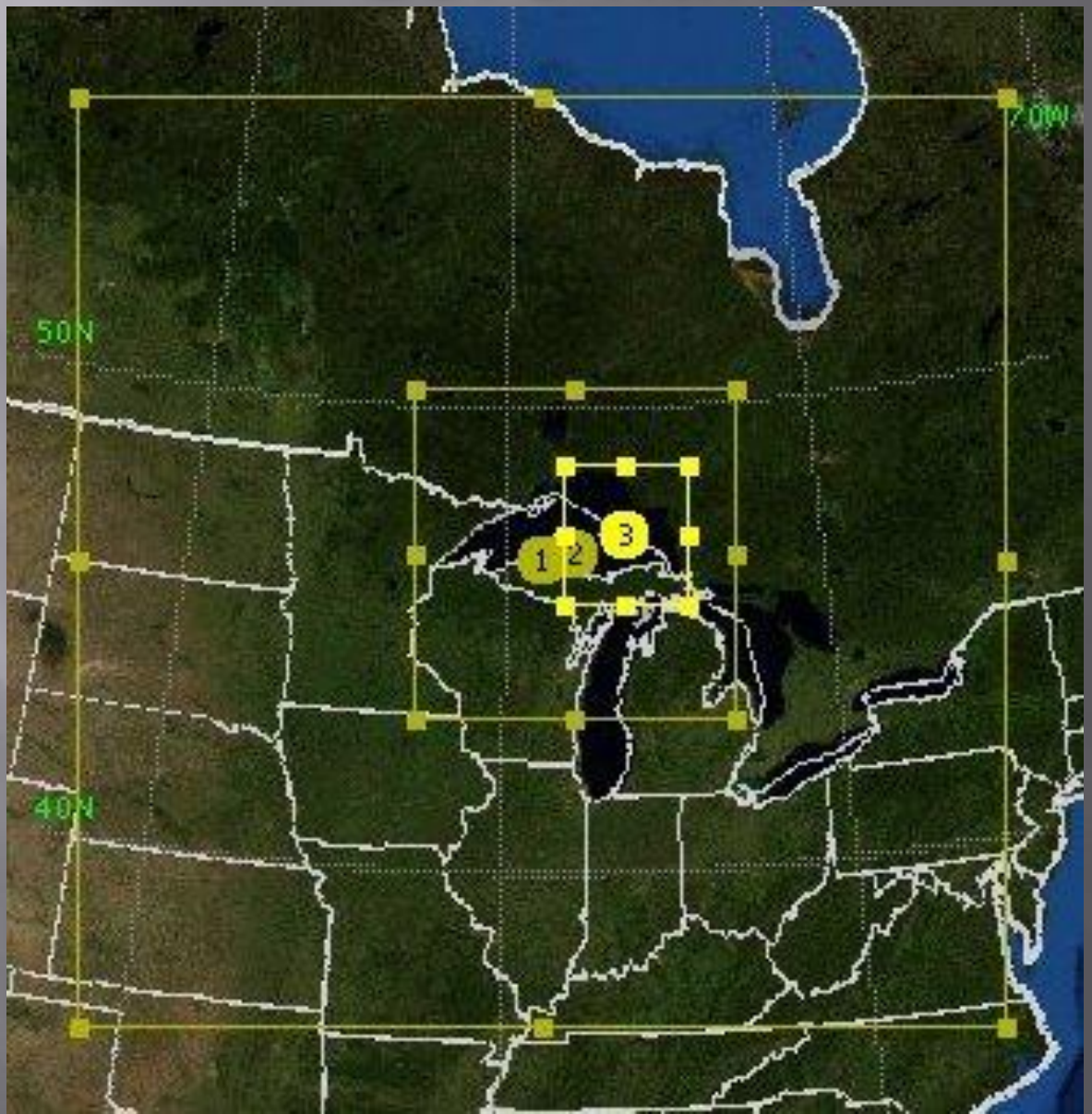




Weather and Research Forecast Model V3 (WRF) ARW Core

- Used 3 domains, nested, boundary conditions from NAM, and feedback turned on
  - Domain 1 – 18 km (KF Cumulus Scheme, Lin et al. Microphysics, Yonsei PBL scheme, Noah LSM)
  - Domain 2 – 6 km (Explicit Cumulus Parametrization, Lin et al. Microphysics, Yonsei PBL scheme, Noah LSM)
  - Domain 3 – 2 km (Explicit Cumulus Parametrization, Lin et al. Microphysics, Yonsei PBL scheme, Noah LSM)
- 4 runs
  - Control with no ice
  - "Best ice" – changed the sea-ice threshold to 273K to make ice analysis more representative
  - Total ice
  - North American Reanalysis (NARR)

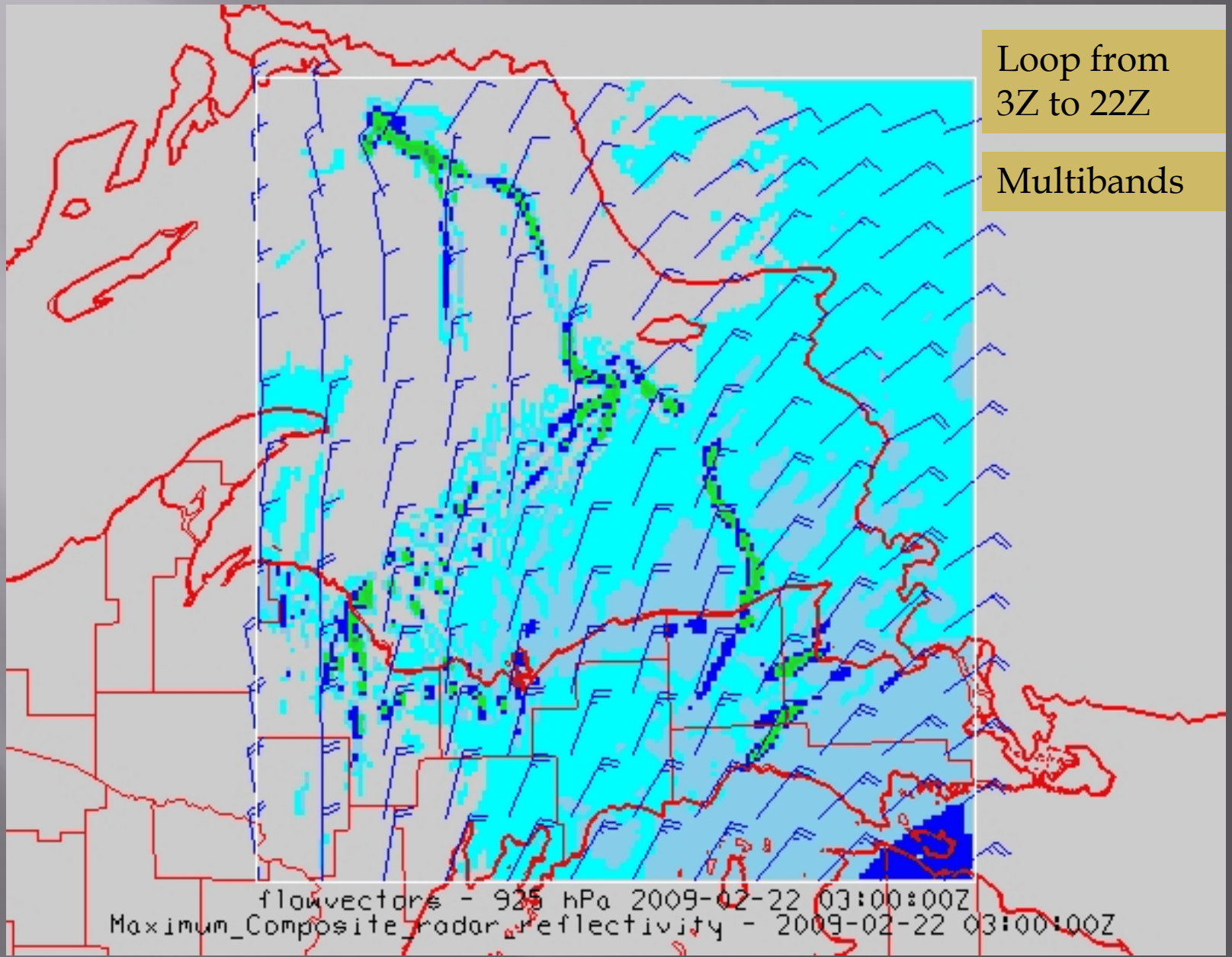
Domains for Local WRF-ARW Core Runs



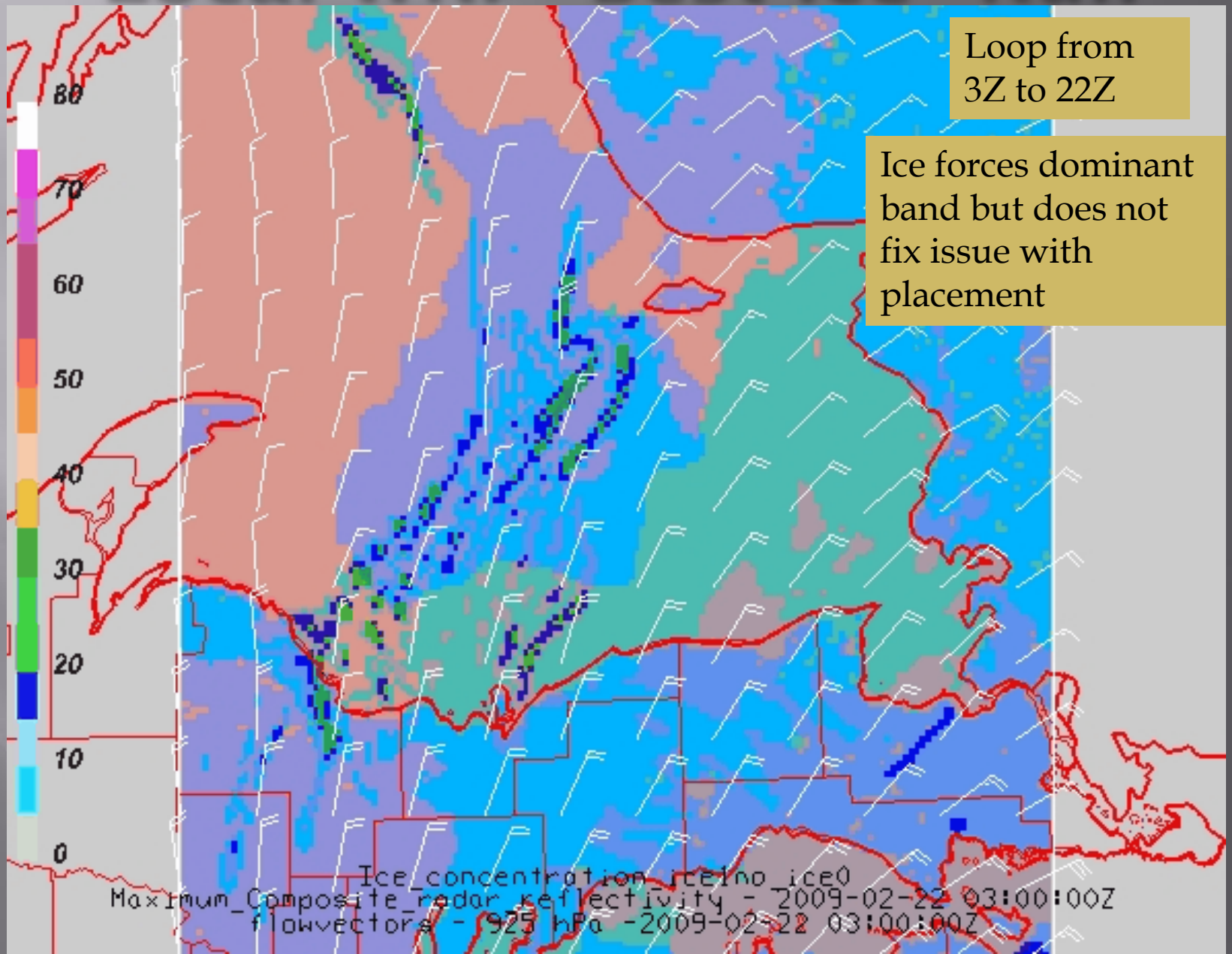
Hypotheses

- Ice cover forces dominant band
- Ice is cause of placement of band to the east in local office WRF with ARW core

Local WRF Control (No Ice) Run



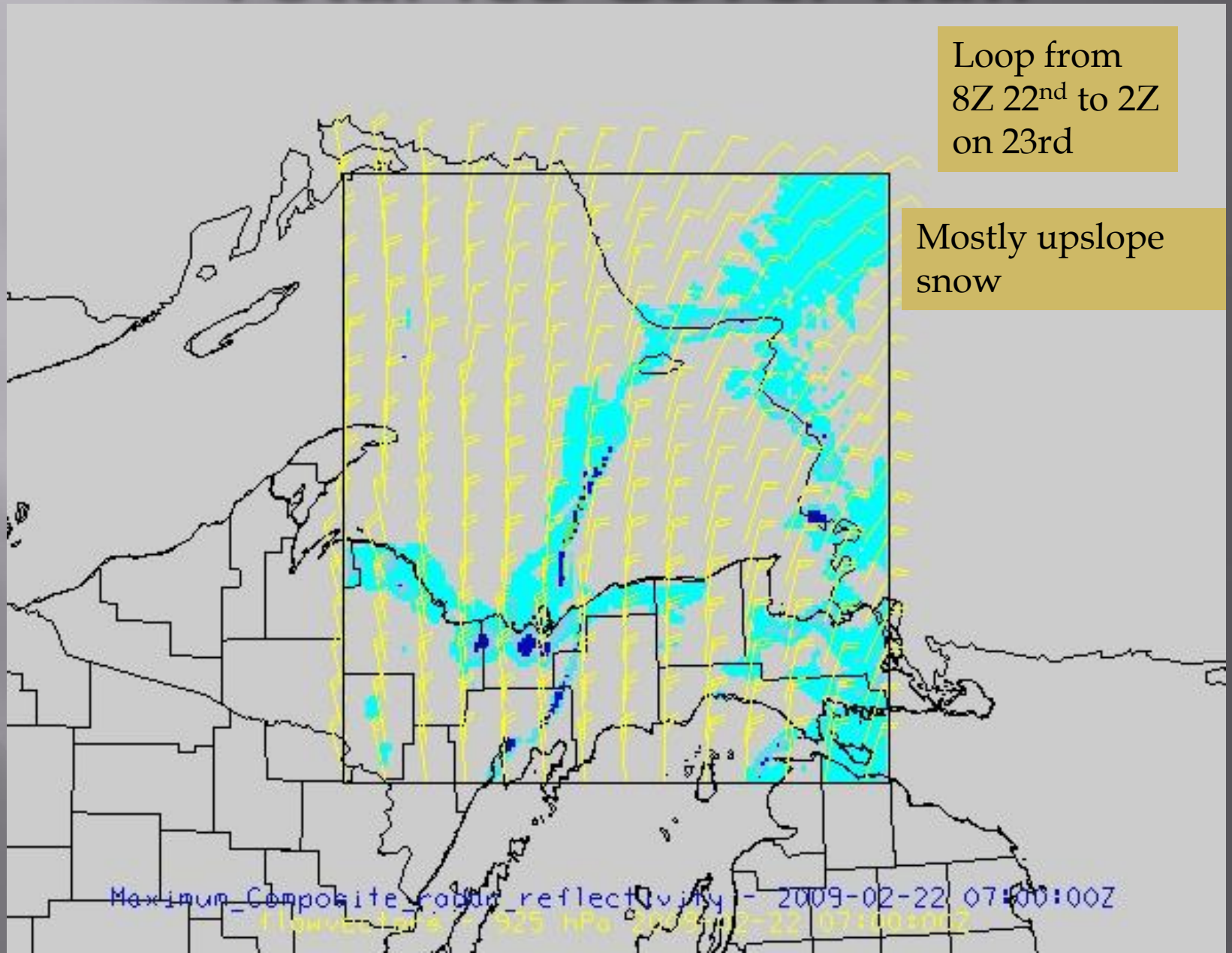
Local WRF "Best Ice" Run



Loop from 3Z to 22Z

Ice forces dominant band but does not fix issue with placement

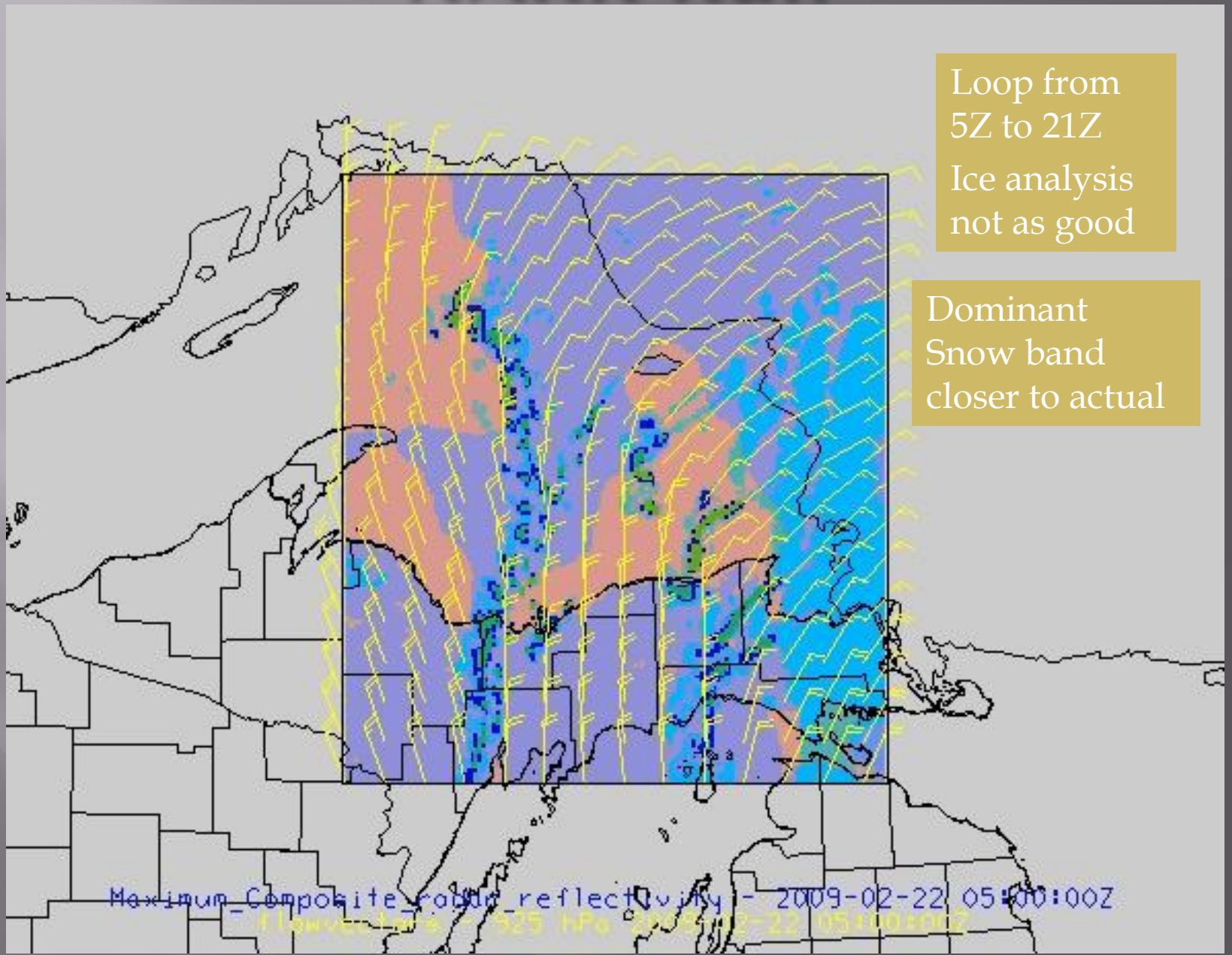
Total Ice Cover Run



Loop from 8Z 22nd to 2Z on 23rd

Mostly upslope snow

NARR Run


Loop from 5Z to 21Z
Ice analysis not as good
Dominant Snow band closer to actual
Maximum_Composite_radar_reflectivity - 2009-02-22 05:00:00Z

Conclusions

- Heavy lake effect snow band forced by ice cover
- Models performed adequately with the dominant band
  - Brought ridge axis in too quickly shifting band east
- MQT office had excellent lead time for warning for Alger County
  - Amounts too low (expecting band to move east)
- "Best Ice" Run from WFR-ARW Core does not solve the problem
- NARR solution is better but not perfect

Questions?