Forecasting Snow Squalls

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NWS/WFO Burlington, Vermont

Lyndon State College, Atmospheric Science Seminar Series – 29 October 2015

Outline

Background information on squalls and societal impacts

Synoptic and mesoscale snow squall environments & dynamics

The Snow Squall Parameter (Research → Operations)

Conveying the message (Special Wx Statements, Social Media, Interactive Highway Signs, Action Plans w/ State Partners, etc.)

See our NWA journal article for more details: http://goo.gl/cCgFCs

What is a Snow Squall?

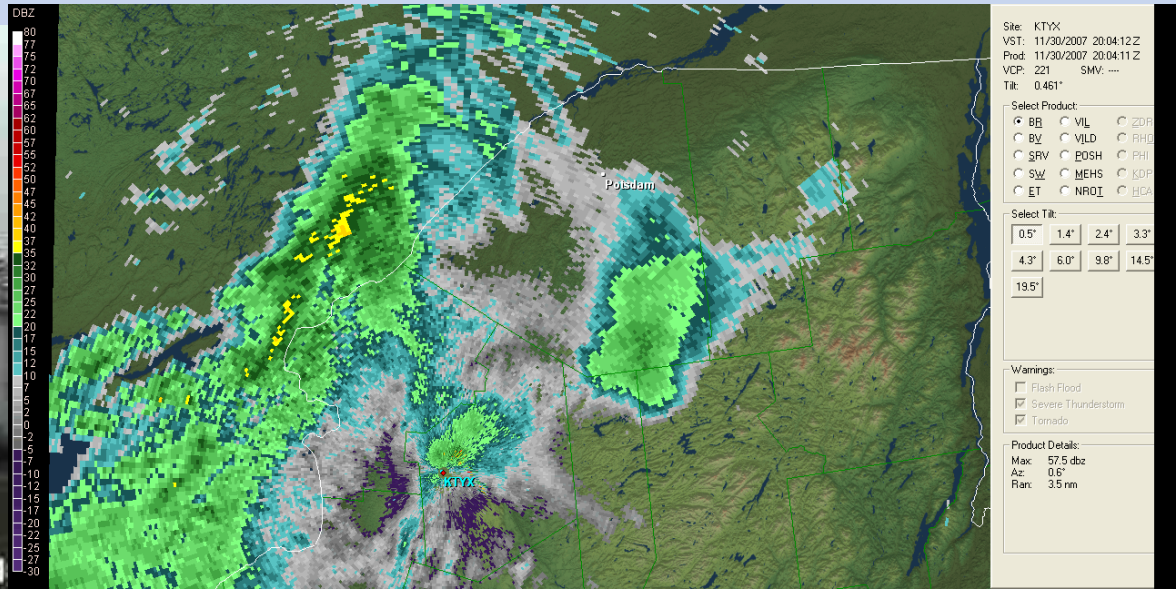
A mesoscale convective system producing gusty winds & heavy snow

- Tend to be short-lived (burst of S+ / wind increase / temp drop)
- Don’t reach NWS snow advisory criteria (e.g. “chance of snow showers”)
- Falling temperatures can produce a “flash freeze” situation
- Can have deadly road consequences (high-impact, sub-advisory, HISA)

Time-Matched Imagery 30 November 2007

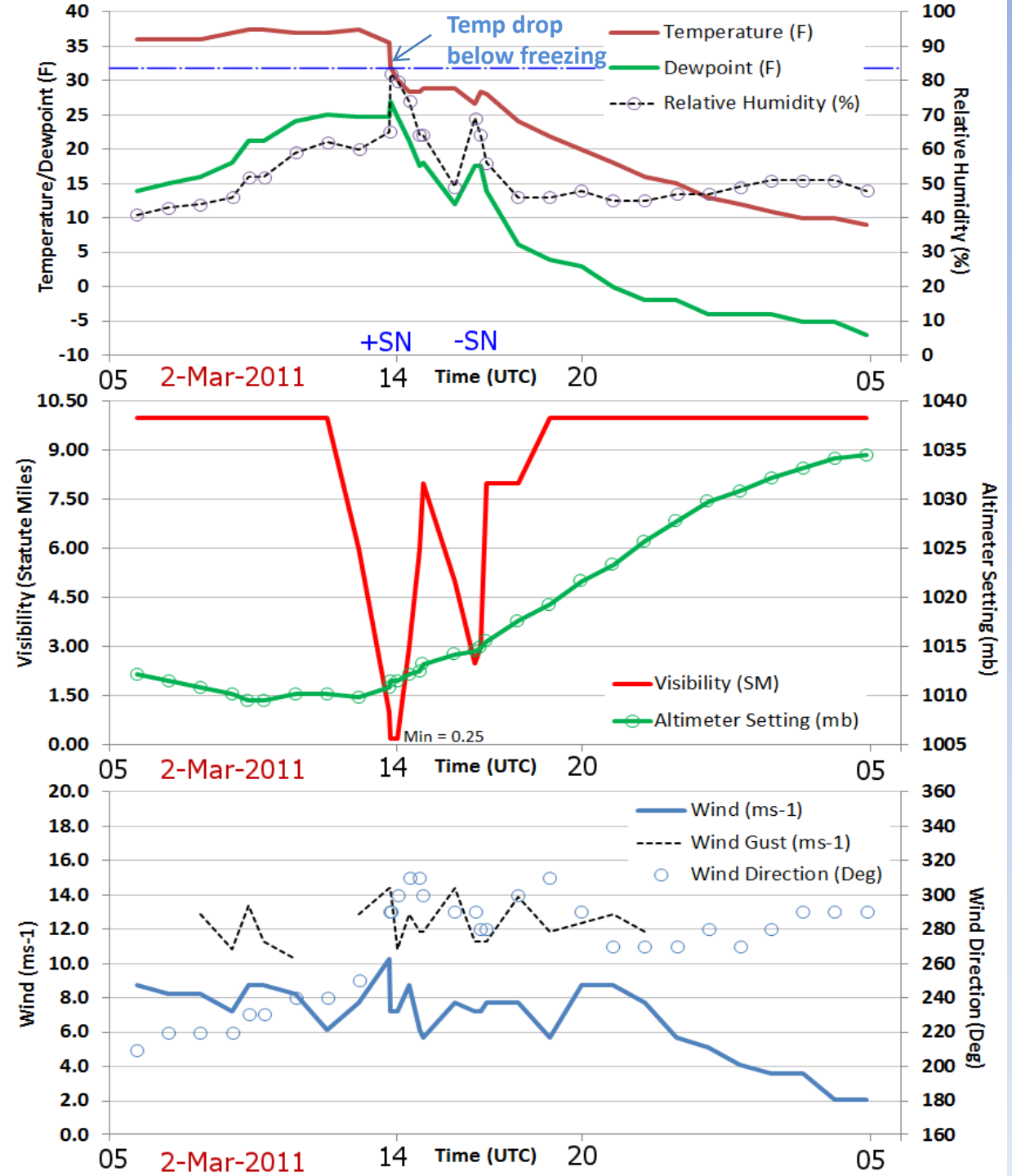
Elm St., Potsdam, NY

TYX 0.5° reflectivity loop



Snow Squall Meteogram

(Massena, NY - 2 Mar 2011)



Snow squall passes at 14 UTC

- Temp drop
- Pressure Rise
- Rapid fluctuations in Vsby
- Brief wind shift/increase

Long history of deadly accidents with snow squalls (~ 1”):

Huge Pile-Up on Indiana Interstate (with Photo & Video)

By Peter Neumann

January 31, 2013

Updated Jan 31, 2013 at 5:50 PM EST

HENDRICKS CO., In. (www.incnow.tv) --- A massive and perhaps unprecedented pile-up in Hendricks County has closed I-70 west of Indianapolis in both directions.

The initial accident happened at mile marker 59, near the Plainfield exit. Initial estimates are that forty vehicles are involved.

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NBC33 – Indianapolis

Burlington Free Press

The Detroit News

Metro and State Wayne County

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TRENDING TOPICS JHONNY PERALTA U-M WIN BLUE CHIPS L. BROOKS PATTERSON PACKARD PLANT MARK BRE

Home Metro Wayne County

FEBRUARY 1, 2013 AT 7:35 PM

Deadly snow squalls set off pileups; 3 die on I-75

30 vehicles tangle in multiple crashes on slick freeway

BY LAUREN ABDEL-RAZZAQ, TONY BRISCOE AND TOM GREENWOOD THE DETROIT NEWS 7 COMMENTS

A fatal, massive pileup during whiteout conditions Thursday morning, Jan. 31, 2013, involving multiple semi-trucks and vehicles has closed southbound Interstate 75 near Springwells, prompting an emergency request for 20 ambulances. (Tony Briscoe/The Detroit News)

…how do we mitigate this?

PREVIOUS STUDIES OF SNOW SQUALLS (non-lake effect)

- A few published case studies and one forecast technique: WINDEX, Lundstedt (1993).
- Cool-season MCS work also relevant (e.g., Low-Dewpoint MCS/derechos, Corfidi et al. '06).
- Some focus on external partnerships (Devoir 2004, NWS – PENNDOT)

WHAT WE WANTED TO DO:

Create a snow squall database and improve our meteorological understanding through composite analysis

Improve forecaster situational awareness by developing a new snow squall parameter (these are low QPF events)

Validate snow squall parameter against individual cases

Continue to improve operational messaging, education, and state/local partnerships

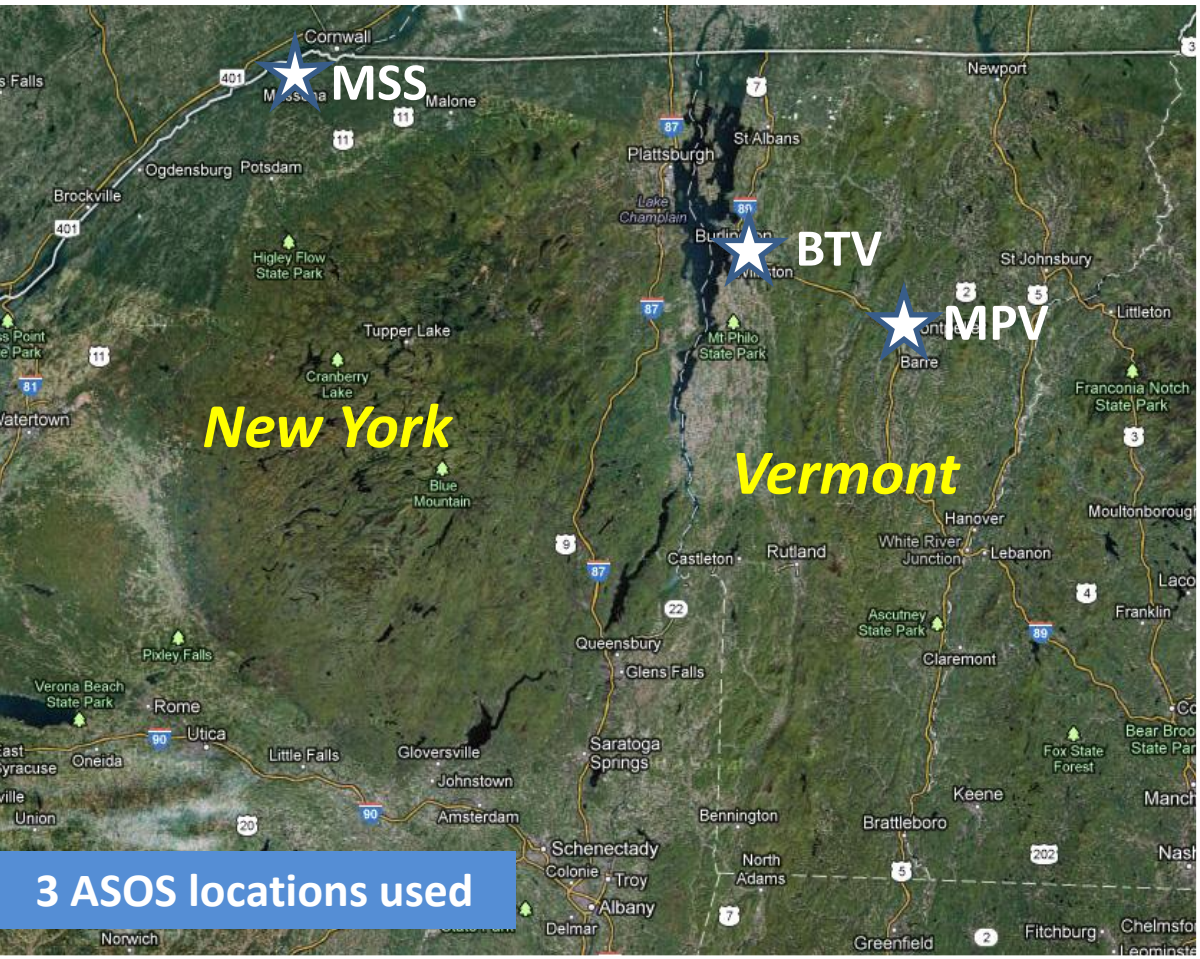
↓

END RESULT:

More certainty in forecast products, better lead times, Better communication.

Road crews pre-treat surfaces

Creating the Snow Squall Database



3 ASOS locations used

METHODS

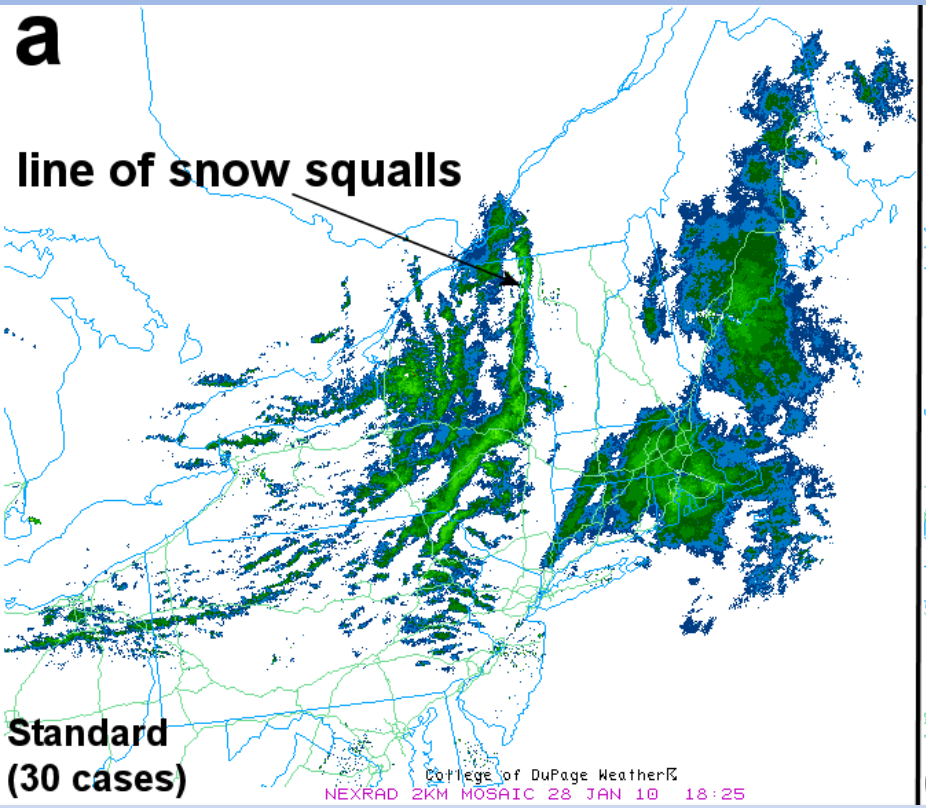
- Searched 10 years of ASOS data for moderate or heavy snow (VSBY ≤ ½ SM) with a west wind component.

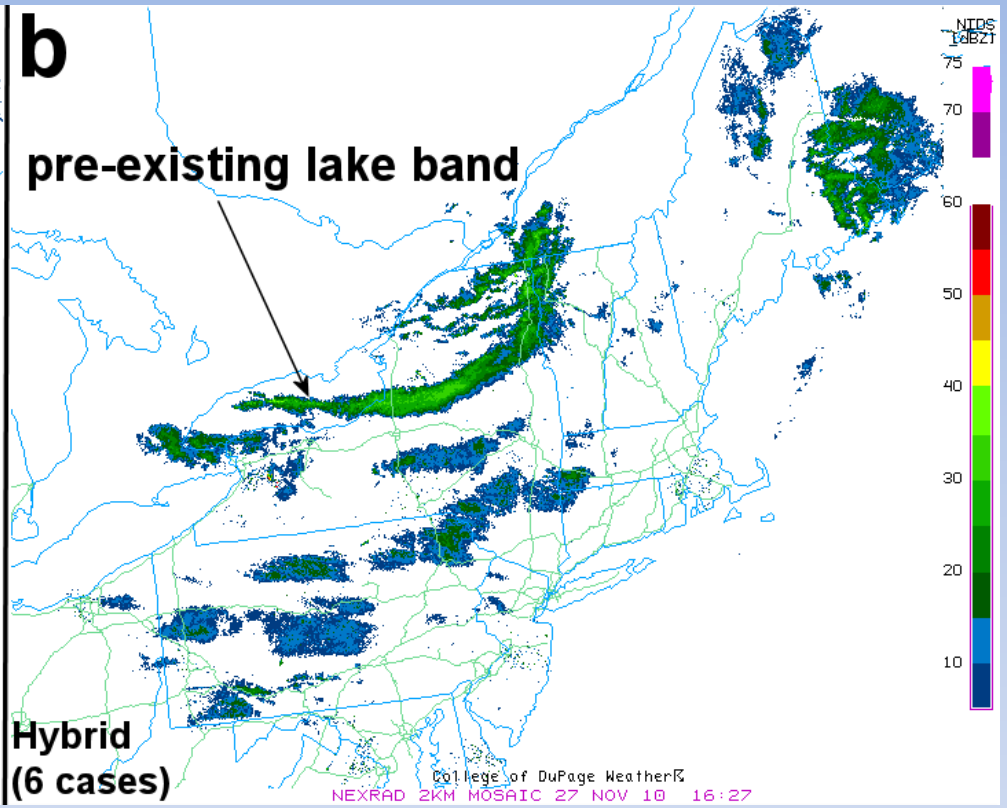
- Each S or S+ observation was compared with 2-km composite radar reflectivity to subjectively determine if the event was associated with a cold front or mobile upper trough (and not a stratiform/WAA case).

- Found **36** total snow squall events (2001-02 through 2010-11). **6** were "hybrid" events where pre-existing lake streamers interacted with cold fronts.

- Logged surface data characteristics for each case.

Snow Squall Examples



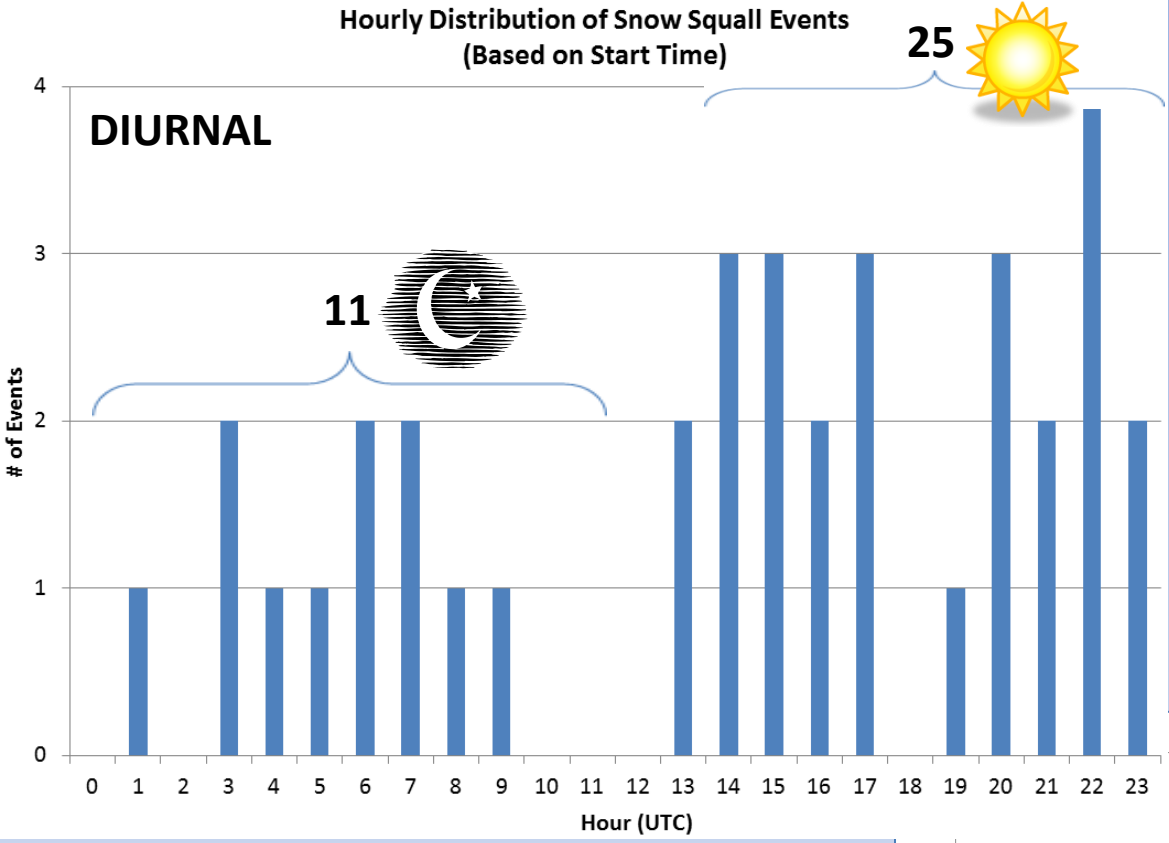


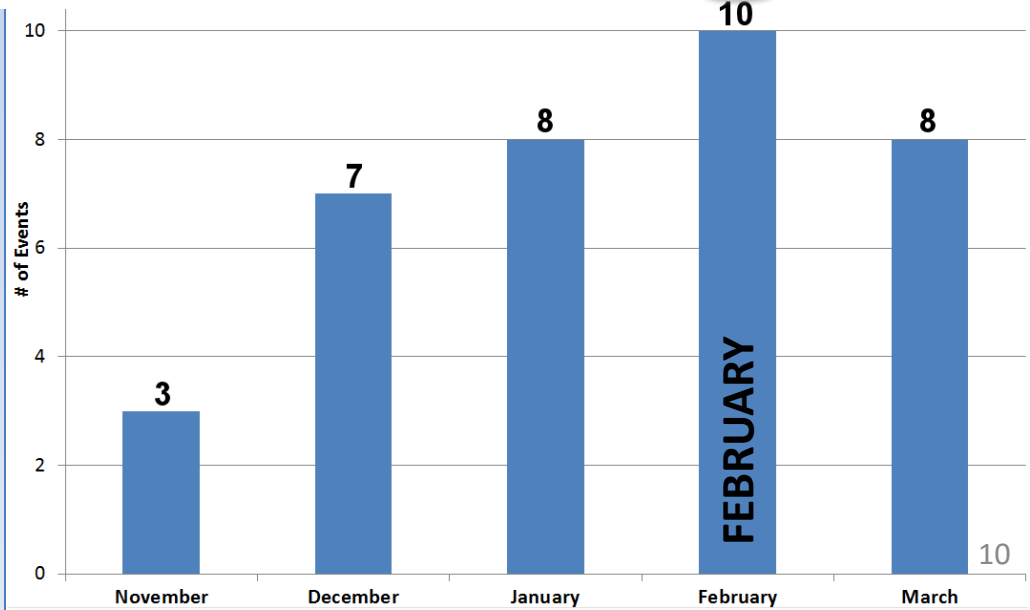
Usually along a front or with an upper-level trough

Pre-existing lake streamer entrained with airflow associated with cold front/trough

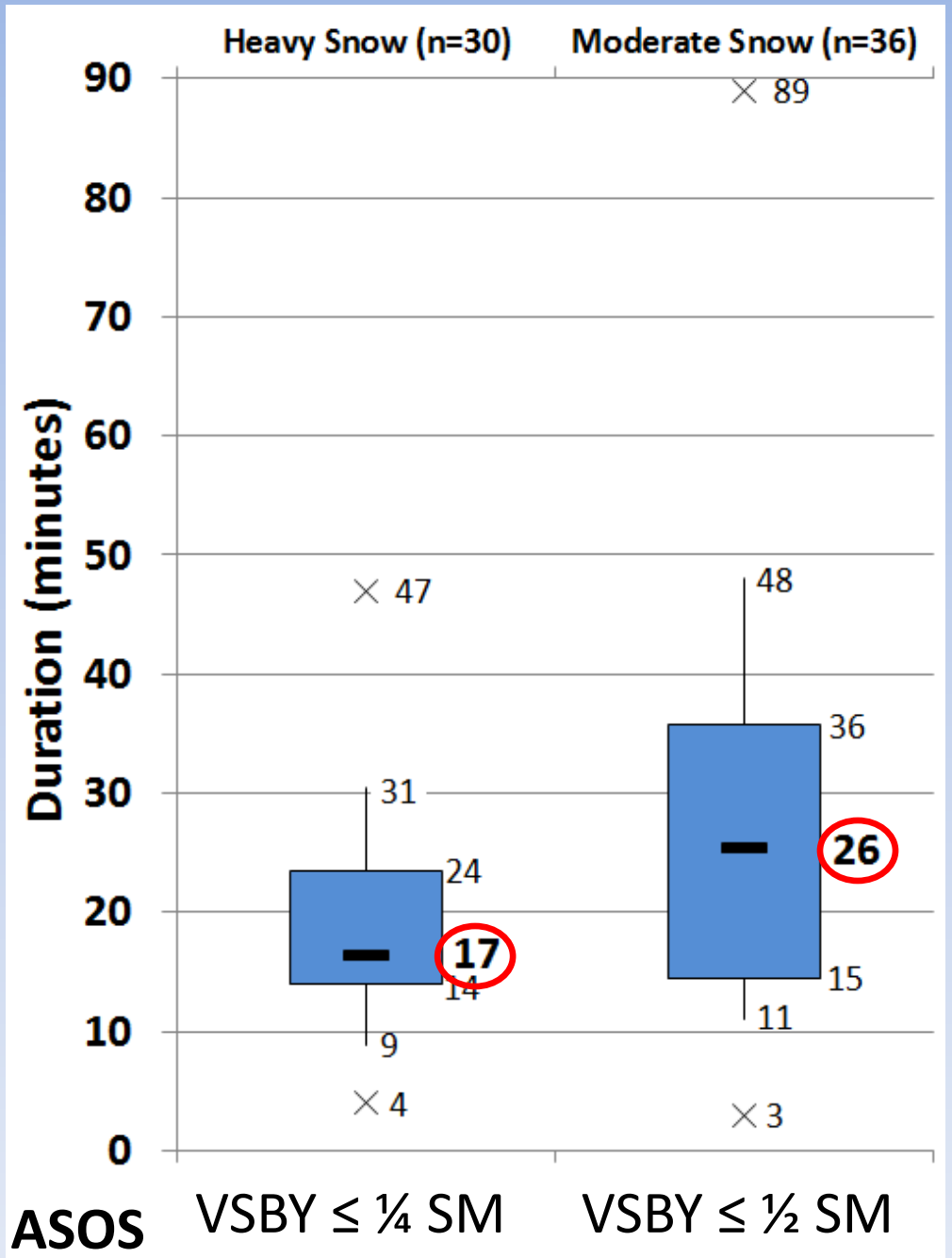
Surface and Synoptic Features

Analysis of our 36 cases based on ASOS data and NARR composites


Hourly Distribution of Snow Squall Events
(Based on Start Time)
DIURNAL
11
25
# of Events
Hour (UTC)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
0 1 2 3 4

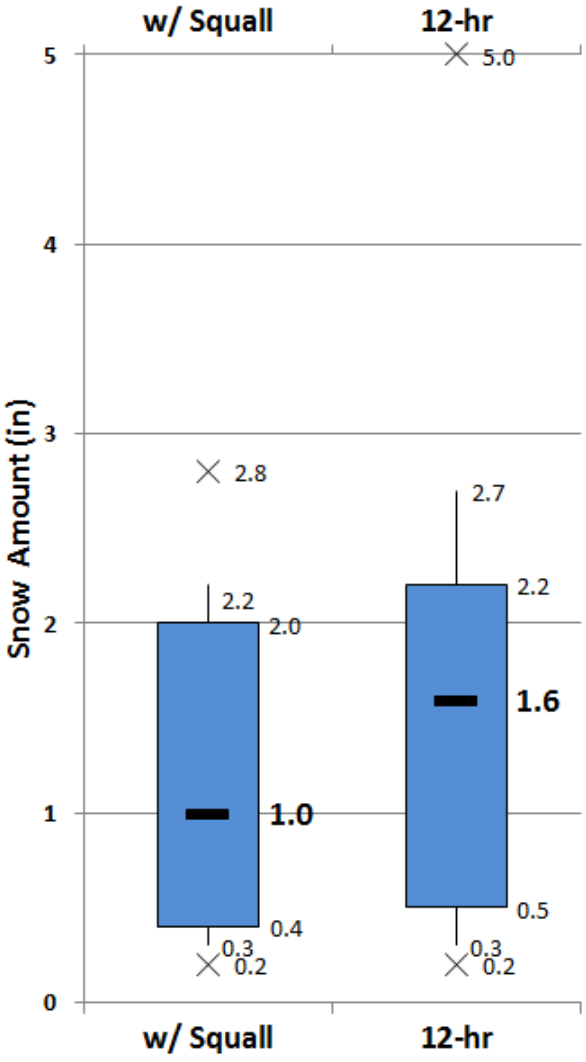

Monthly Distribution of Snow Squall Events
MONTHLY
# of Events
3
7
8
10
8
FEBRUARY
November
December
January
February
March
0 2 4 6 8 10

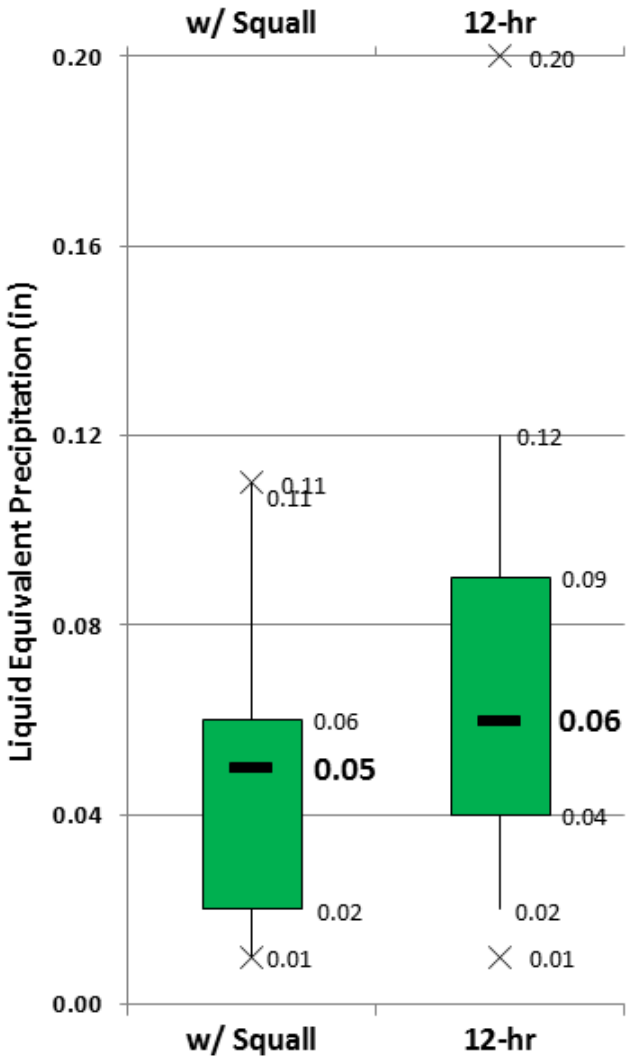
Snow squalls are short-lived events…

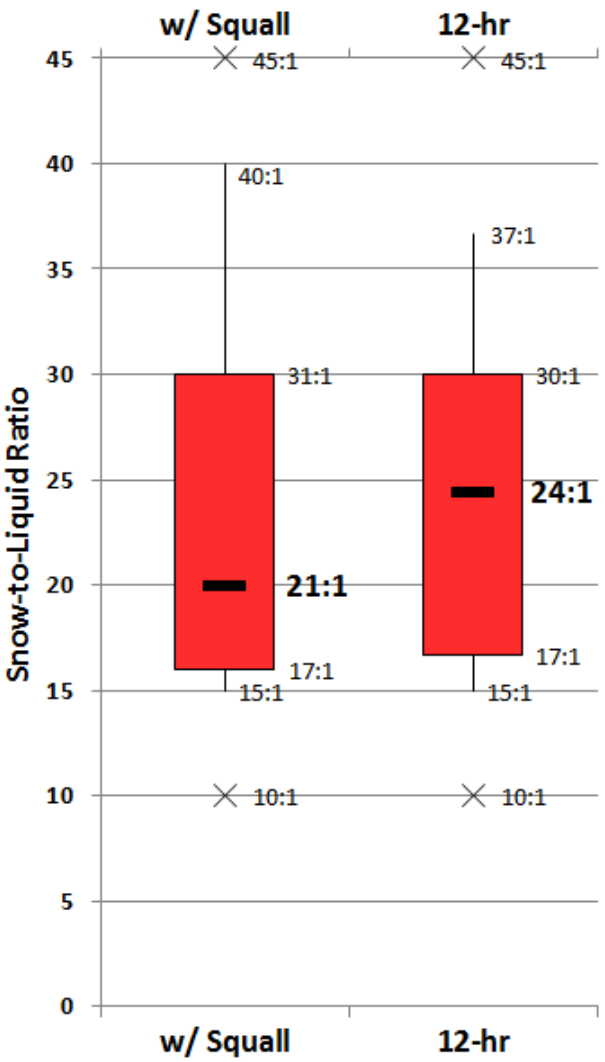


Snowfall, Liquid Equivalent Precipitation, and Snow-to-Liquid Ratio with Snow Squalls and highest inclusive 12-hr period (for 21 events at KBTV)

Solid Bar - Median Value; Boxes 25th-75th Percentile; Whiskers 10th/90th Percentile
(x - extreme values)



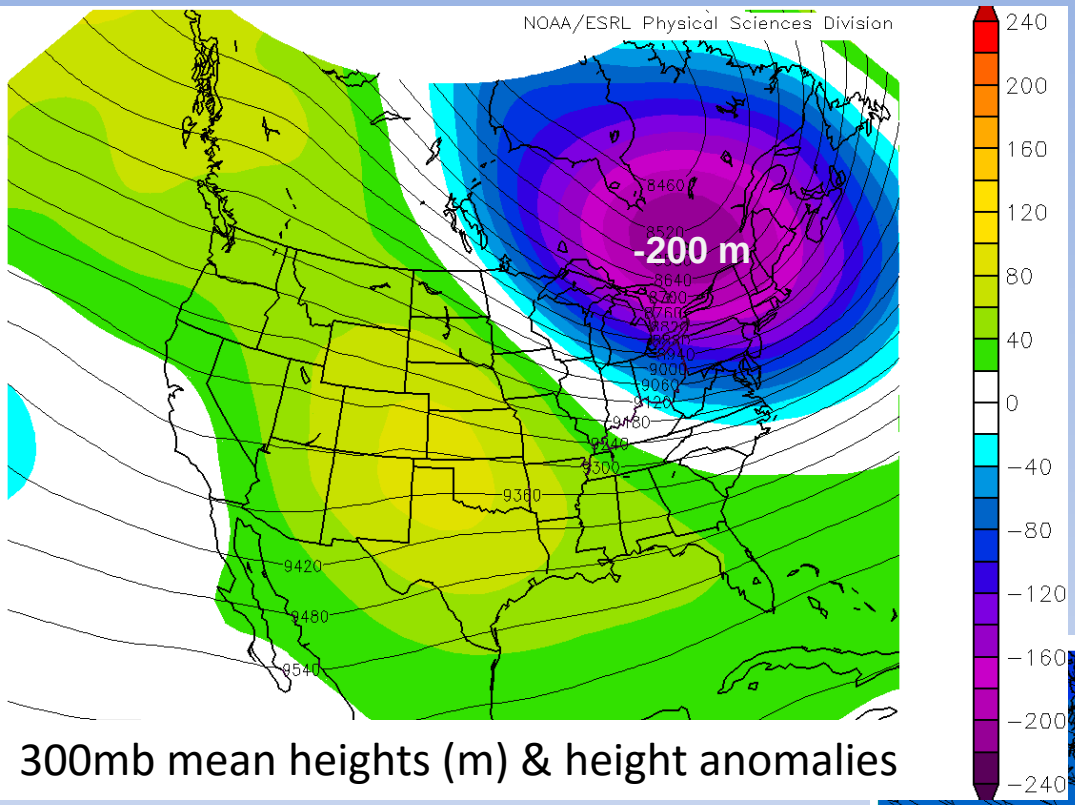




Small Snow Amounts

Small Liquid Equivalent

Continental SLRs

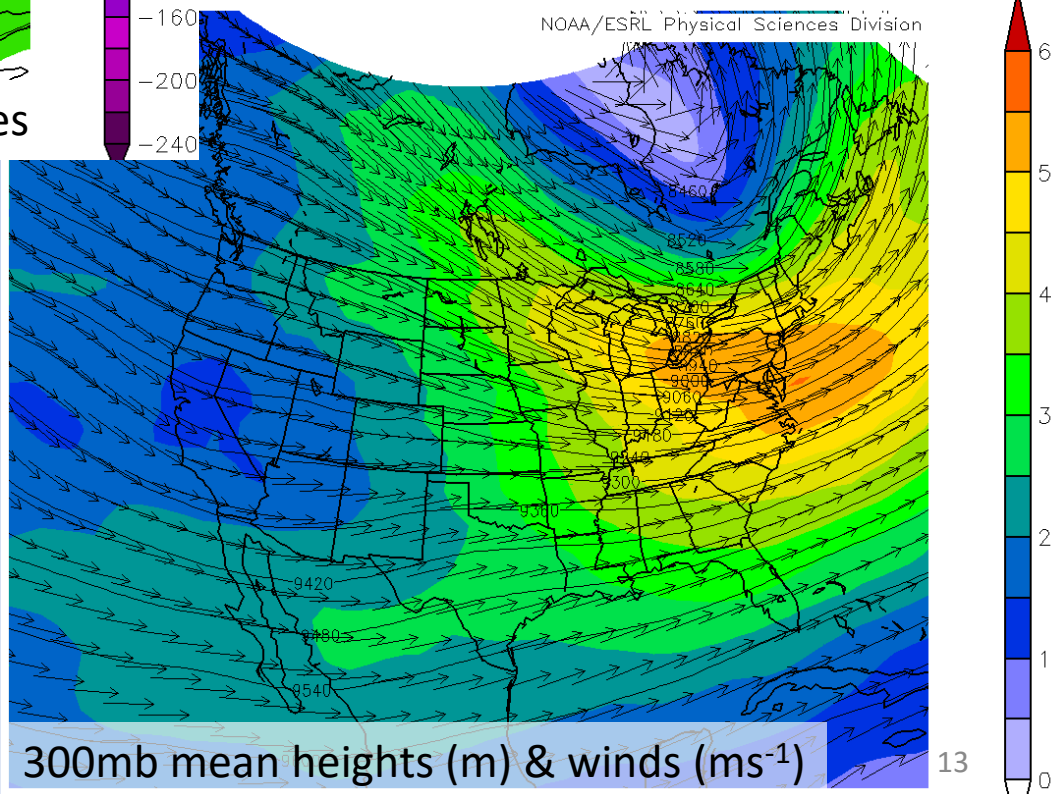


300mb mean heights (m) & height anomalies

NARR COMPOSITE RESULTS (all 36 cases)

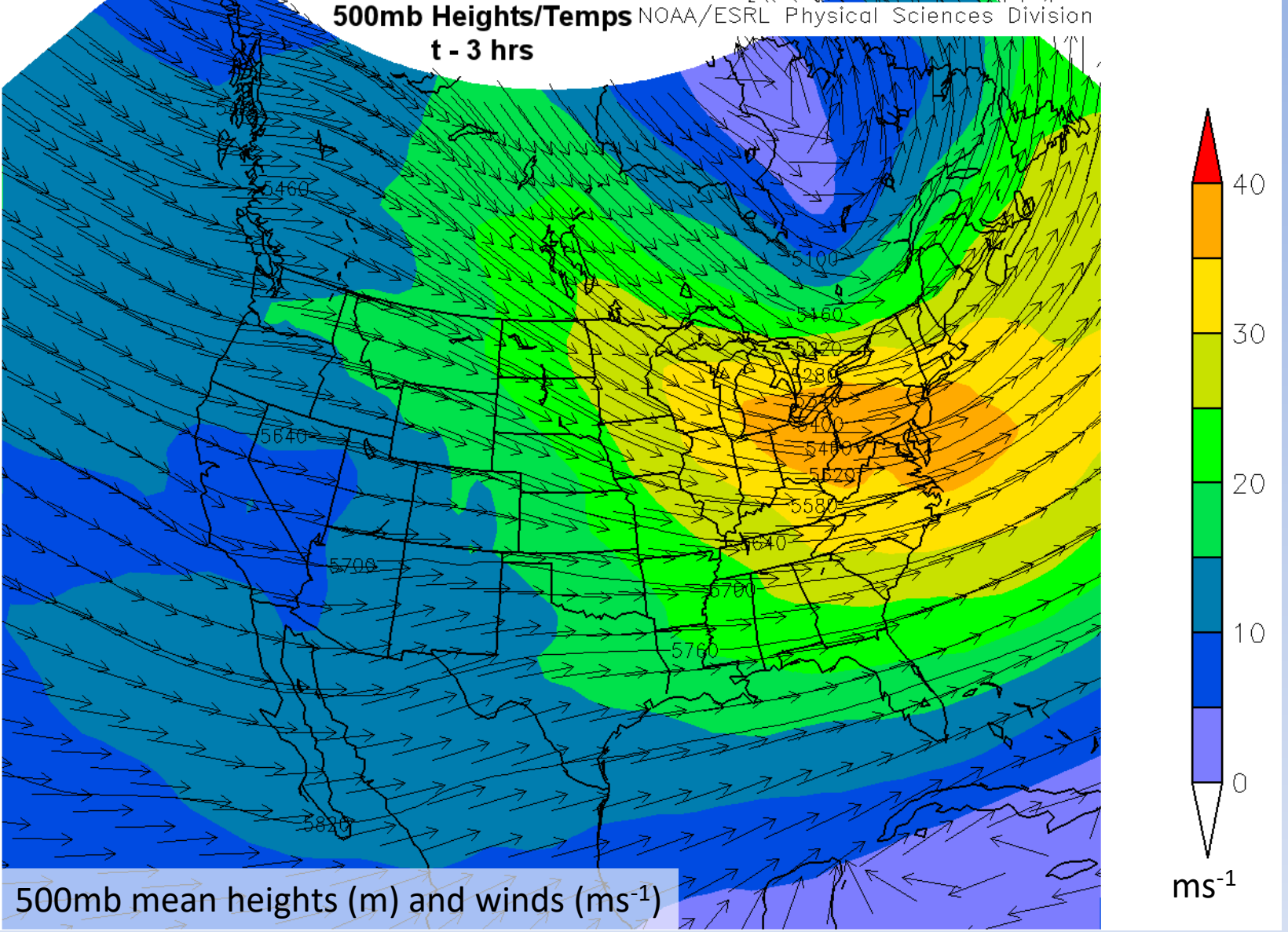
300mb Key Features:

- Cyclonic flow with negative height anomaly.
- Cyclonic shear side of upper jet (true for all 36 cases!).
- Split upper flow across the CONUS.
- Confluent flow/jet core east of the Delmarva peninsula.



300mb mean heights (m) & winds (ms^{-1})

Earth System Research Laboratory:
http://www.esrl.noaa.gov/psd/cgi-bin/data/narr/plothour.pl

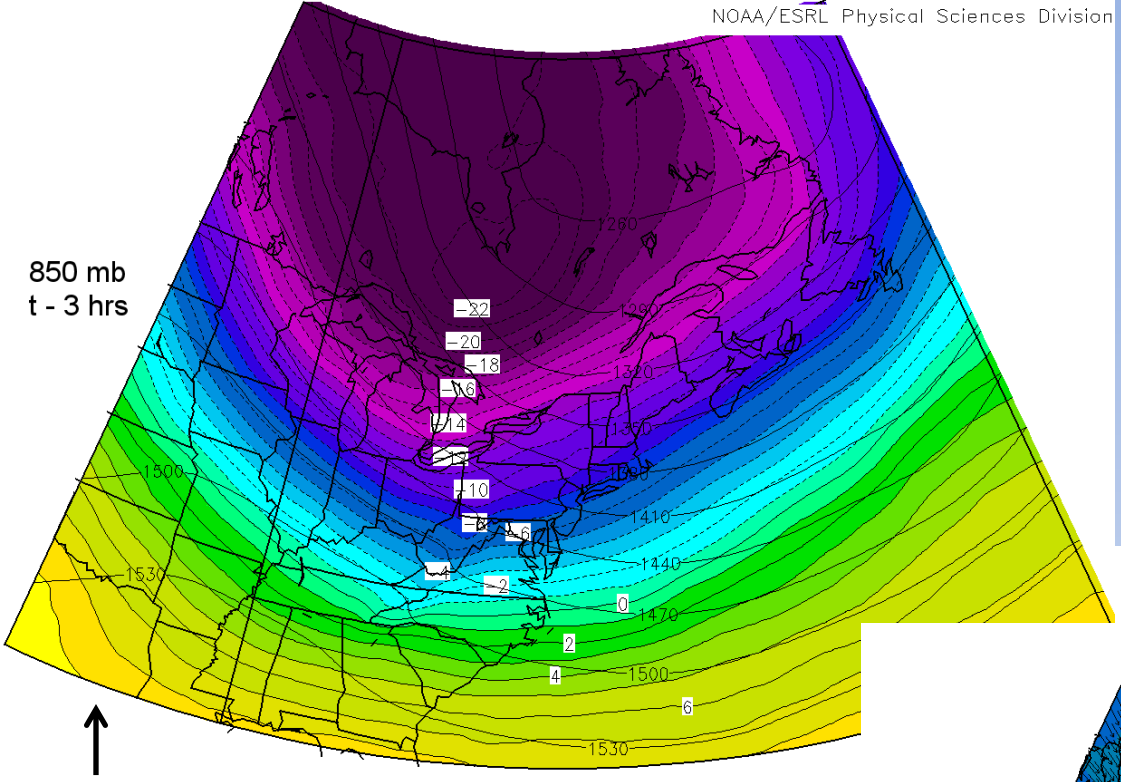


500mb mean heights (m) and winds (ms^{-1})

500mb Key Features:

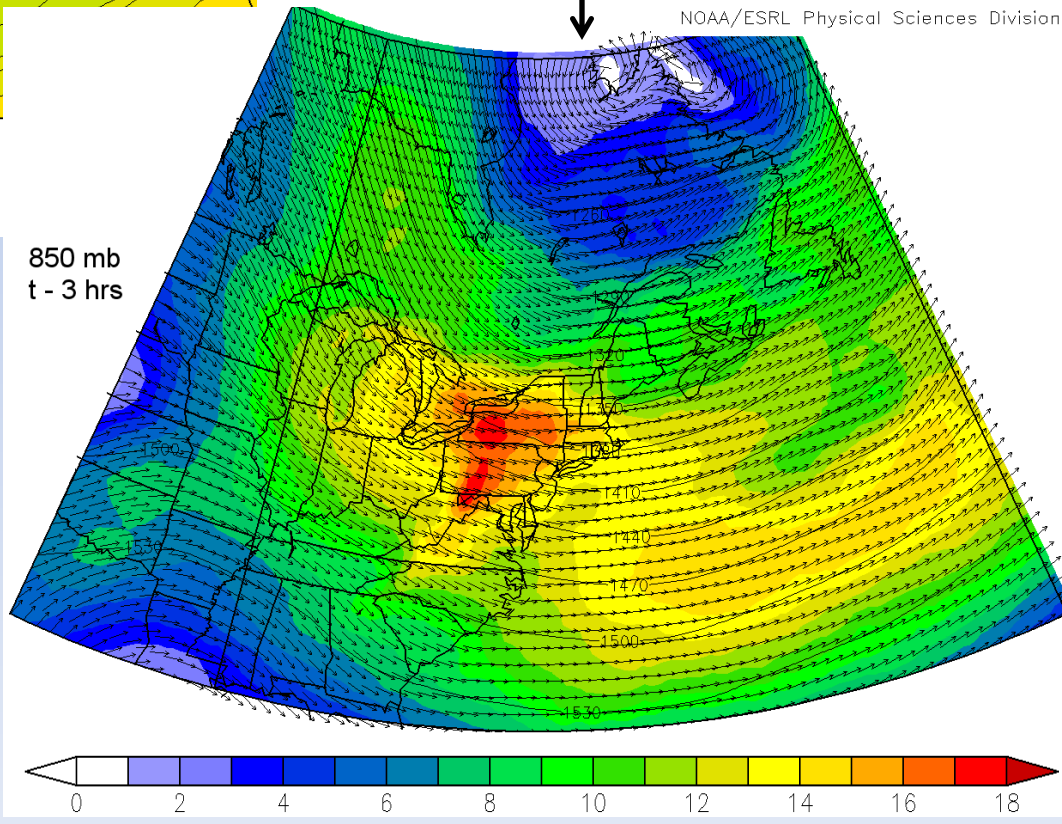
- Cyclonic flow
- Cyclonic shear side of 500mb jet (true for all 36 cases!)
- Near or just upstream of mean trough axis.

NARR COMPOSITE MEAN RESULTS (all 36 cases)



850 mb Heights (m) & Temperatures (C)

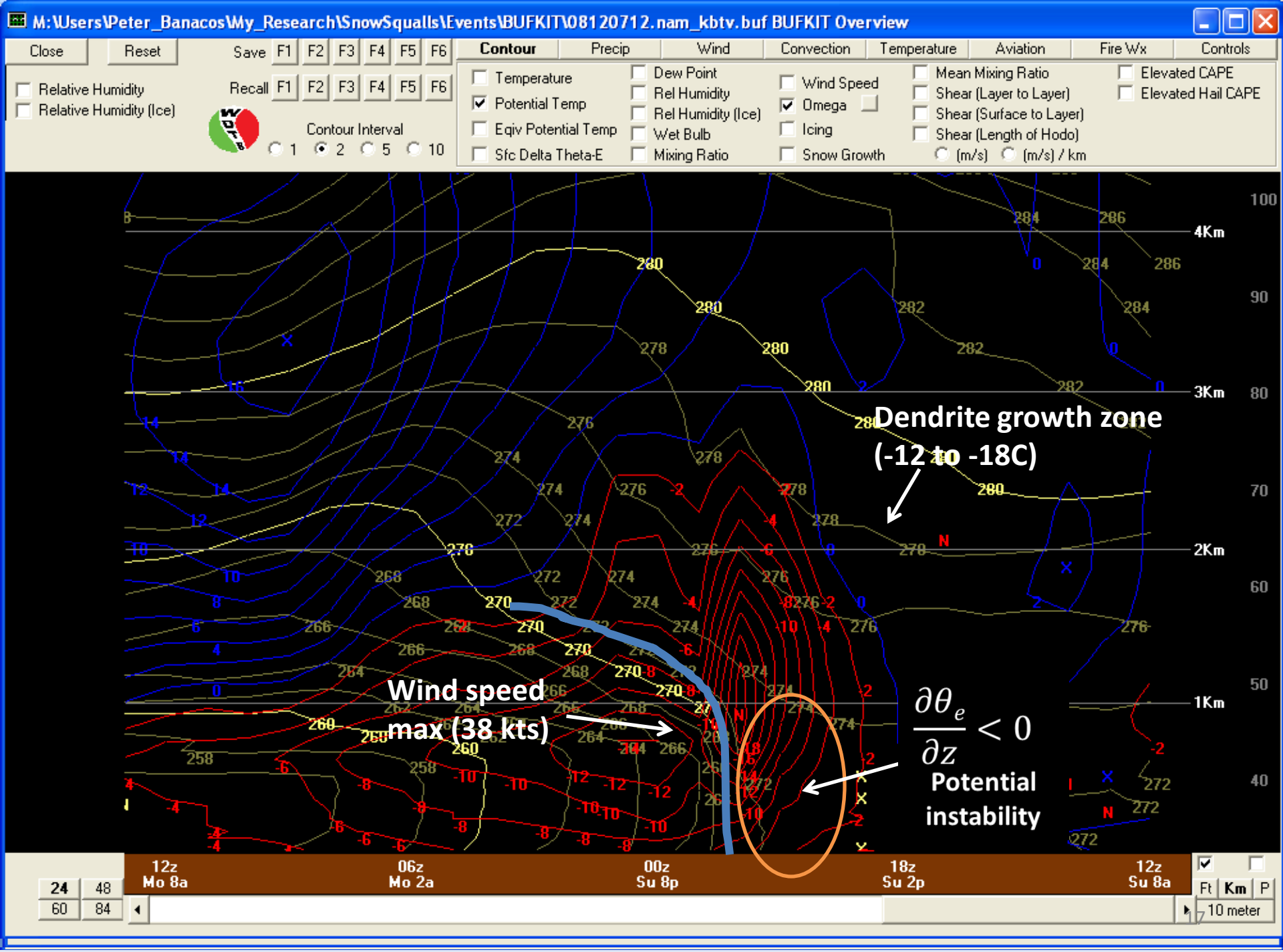
850 mb Heights (m) & Isotachs (ms^{-1})



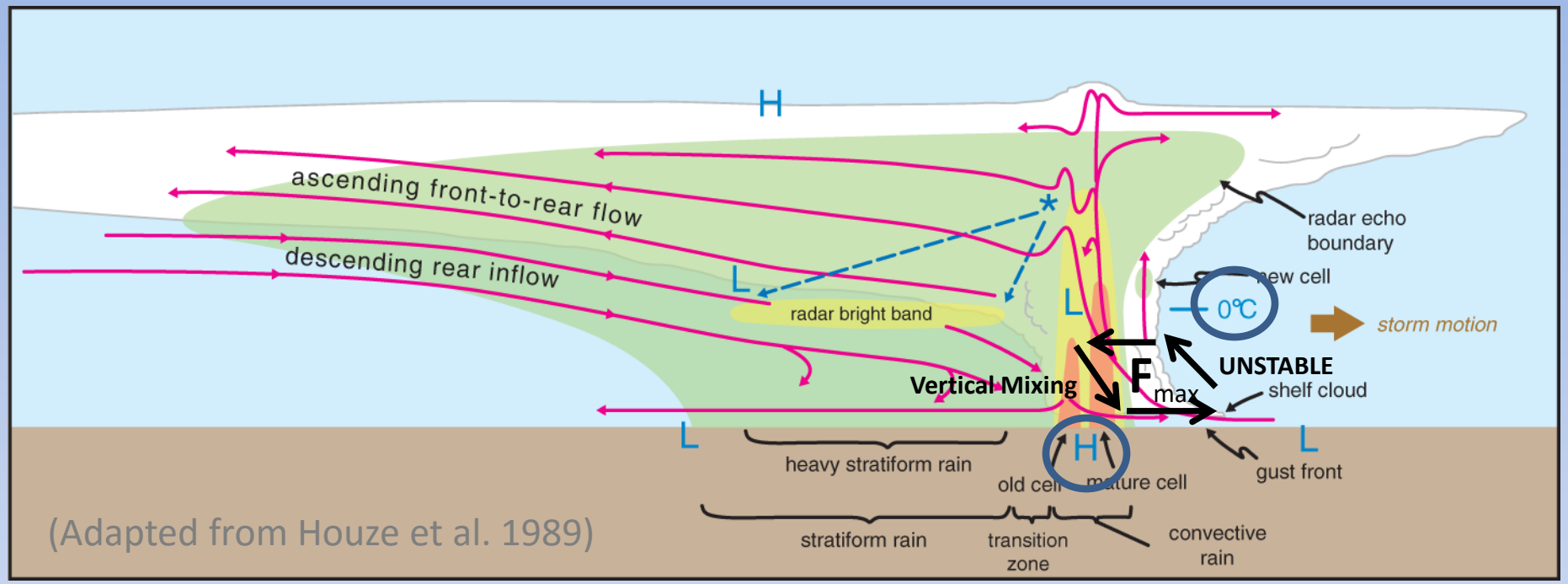
850mb Key Features:

- Strong NW flow with cyclonic curvature
- Approaching baroclinic zone/cold front in the mean (CAA)

What about BUFKIT?


M:\Users\Peter_Banacos\My_Research\SnowSqualls\Events\BUFKIT\08120712.nam_kbtv.buf BUFKIT Overview
Close
Reset
Save F1 F2 F3 F4 F5 F6
Recall F1 F2 F3 F4 F5 F6
Relative Humidity
Relative Humidity (Ice)
Contour Interval
1 2 5 10
Contour
Precip
Wind
Convection
Temperature
Aviation
Fire Wx
Controls
Temperature
Potential Temp
Eqiv Potential Temp
Sfc Delta Theta-E
Dew Point
Rel Humidity
Rel Humidity (Ice)
Wet Bulb
Mixing Ratio
Wind Speed
Omega
Icing
Snow Growth
Mean Mixing Ratio
Shear (Layer to Layer)
Shear (Surface to Layer)
Shear (Length of Hodo)
(m/s) (m/s) / km
Elevated CAPE
Elevated Hail CAPE
4Km
3Km
2Km
1Km
Dendrite growth zone
(-12 to -18C)
Wind speed
max (38 kts)
$\frac{\partial \theta_e}{\partial z} < 0$
Potential
instability
12z
Mo 8a
06z
Mo 2a
00z
Su 8p
18z
Su 2p
12z
Su 8a
24
48
60
84
Ft
Km
P
10 meter

Warm Season Squall Line Conceptual Model



- **Evaporative cooling** with convective downdrafts results in a mesoscale cold pool.
  - ➢ Development of a "meso-high" in rain-cooled air.
- Can't rely on dynamic pressure perturbations / water loading / evaporative cooling in downdrafts to develop meso-highs in snow squall environment:
  - ❖ Frozen Condensate
  - ❖ Low moisture (PW < 0.25") / Low CAPE
  - ❖ Relatively shallow convective layer (2-4 km vs. 10-15 km).
- We'll see this strong p-gradient develop almost entirely through *baroclinic* processes and a frontogenetic circulations with small amounts of CAPE; < 100 J kg^{-1}).
  - The instability helps shrink the scale of the frontogenetic circulation.

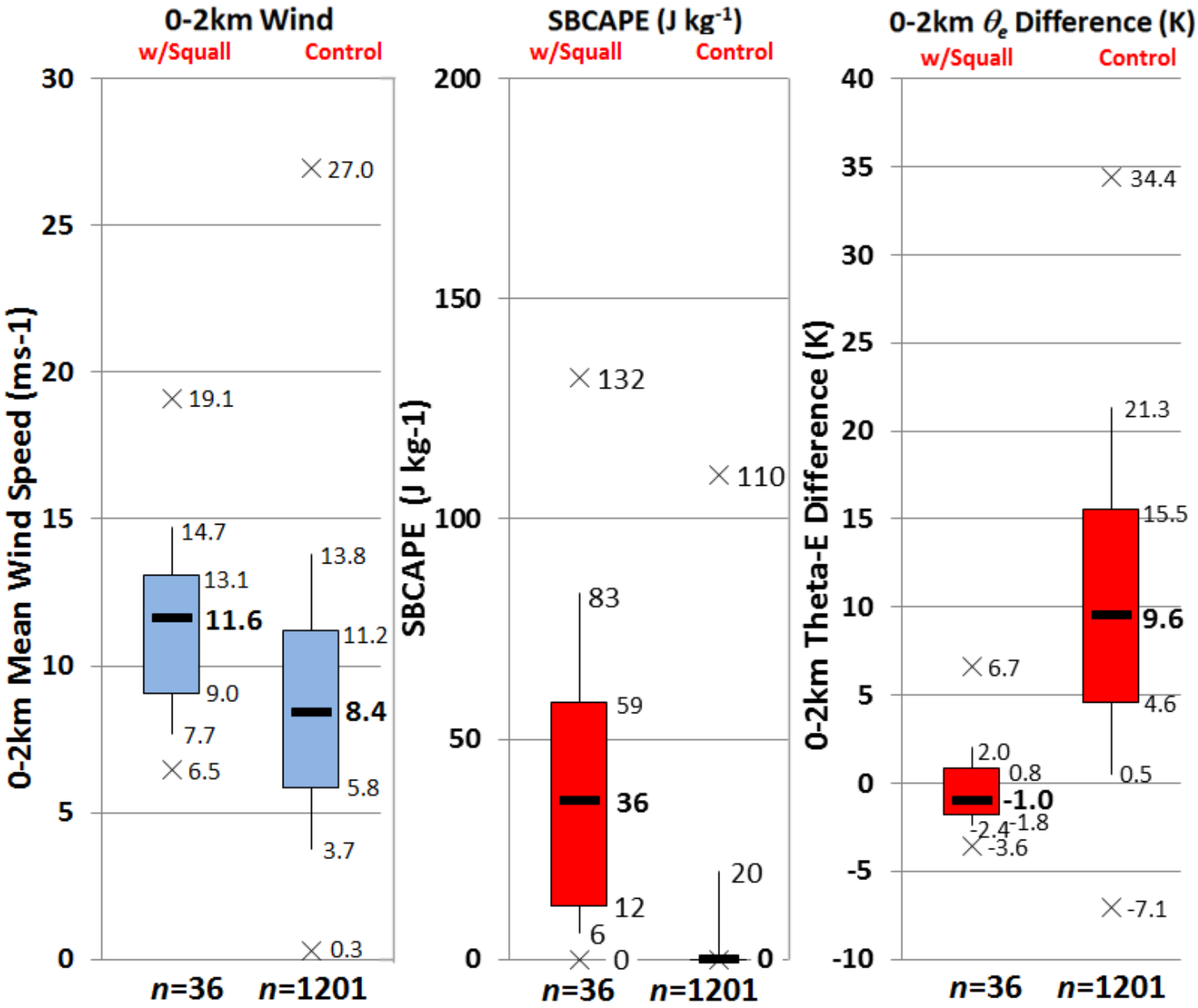
3-hrly NARR Variables Examined in GEMPAK
(analysis times immediately before and after squall time)

- **36 Snow Squall cases and a Control Sample (entire 2005-06 Winter season)**

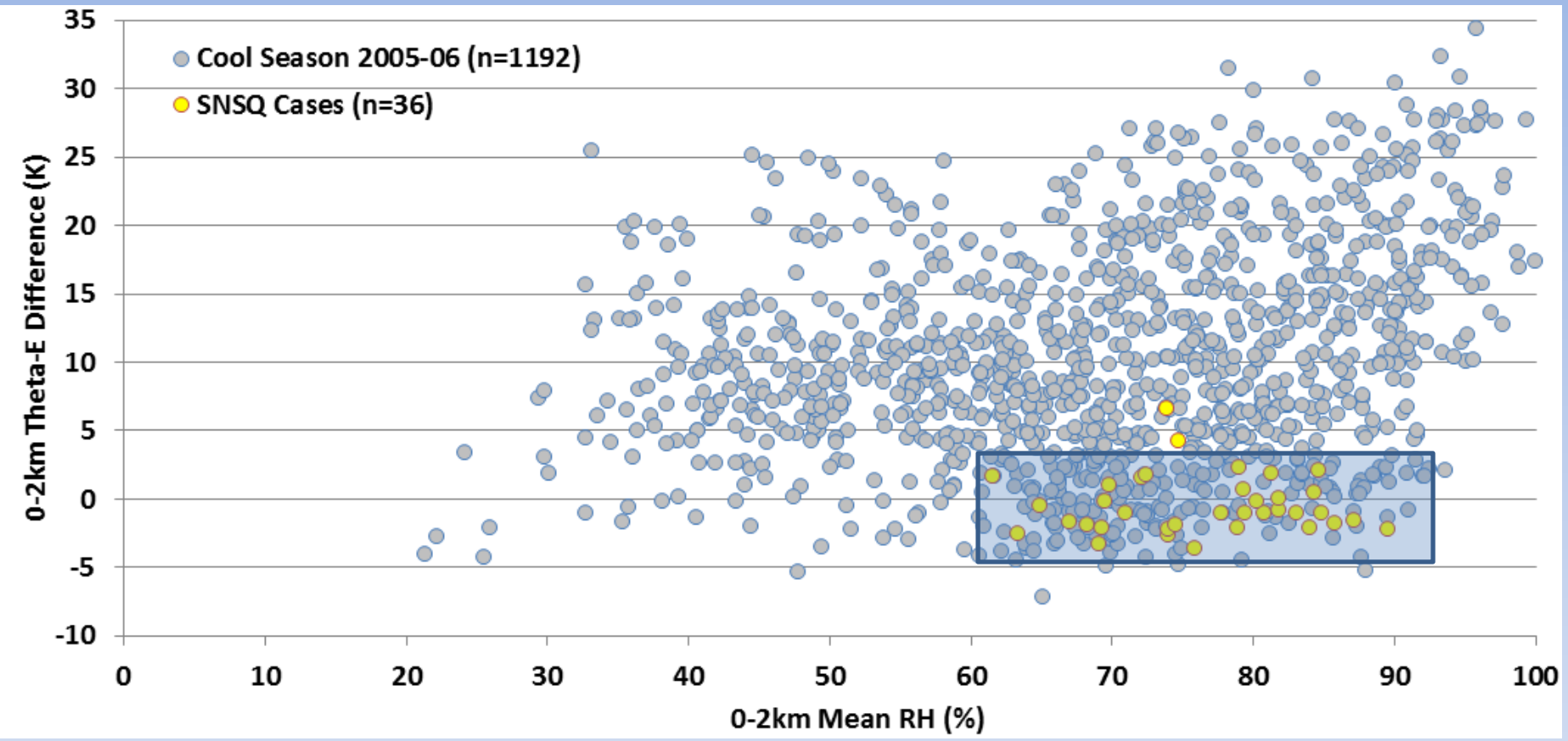
SBCAPE	**MUCAPE (0-180mb)**
Sfc-2km Theta-e difference	**Sfc-2km RH**
Sfc-2km mean wind	**Sfc-2km wind shear**
925mb frontogenesis	**Surface isallobars (3hrly)**
850mb frontogenesis	**WBZ height**
Precipitable Water	**300mb Divergence**
925mb θe Adv.	**850mb θe Adv.**
850mb temperature advection	**0-2km AGL lapse rate**

Select Variable Distribution for 36 Snow Squall Events

Normalized between 25th and 50th percentile values… 9ms^{-1}, 75%, 0K/2km



NARR SCATTERPLOT of 0-2km mean RH vs. THETA-E Difference (36 SNSQ CASES)



Favored parameter space

Necessary Ingredients for Squalls

Shallow Moist Convective structures, but cold enough for snow.

(1) moisture, (2) lift, (3) instability, (4) wind, and (5) vertical temperature structure

Snow Squall Parameter (SNSQ, non-dimensional)

plot only for values > 0 and where $T_w \leq 1$ C @ 2m ← **Cold enough for snow**

$$SNSQ = \left(\frac{\overline{RH}_{0-2km} - 60\%}{15\%}\right)\left(\frac{4\ K/2km - \left.\frac{\partial \theta_e}{\partial z}\right|_{0-2km}}{4\ K/2km}\right)\left(\frac{\left\|\vec{\bar{V}}\right\|_{0-2km}}{9\ ms^{-1}}\right)$$

Moisture **low-level Instability** **Wind**

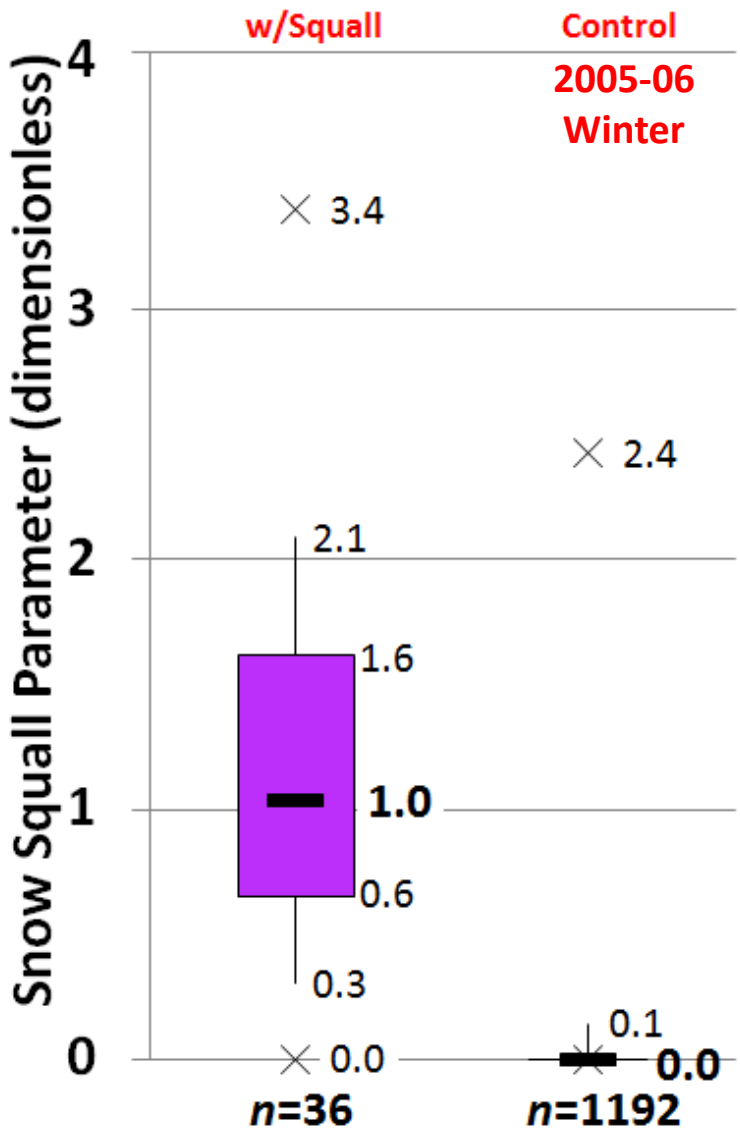
- SNSQ approaches **zero** as any of these factors approach zero.
- Lift (forcing) assessed independently (look for surface pressure rise/fall couplet).
- Calibration was done using the **NARR**. Operational models tend to give higher values of SNSQ (especially very high resolution models).

NARR Results

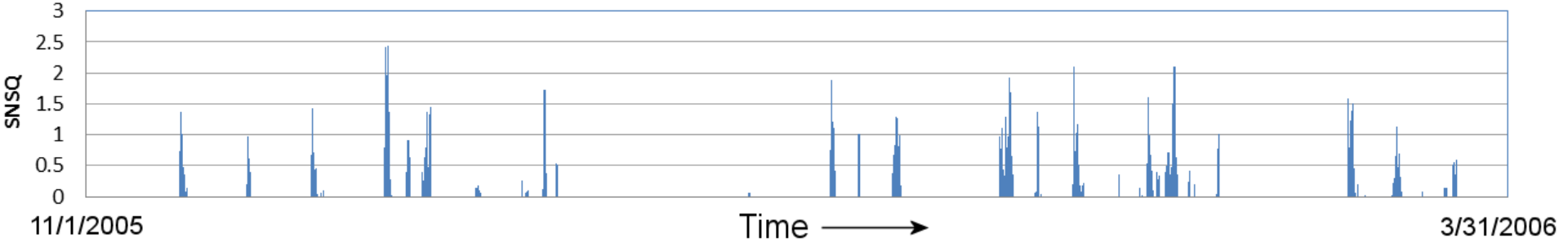
SNSQ Parameter

One # to highlight where it is moist, unstable, windy, and cold enough for snow

POD & FAR Statistics are available in the paper.

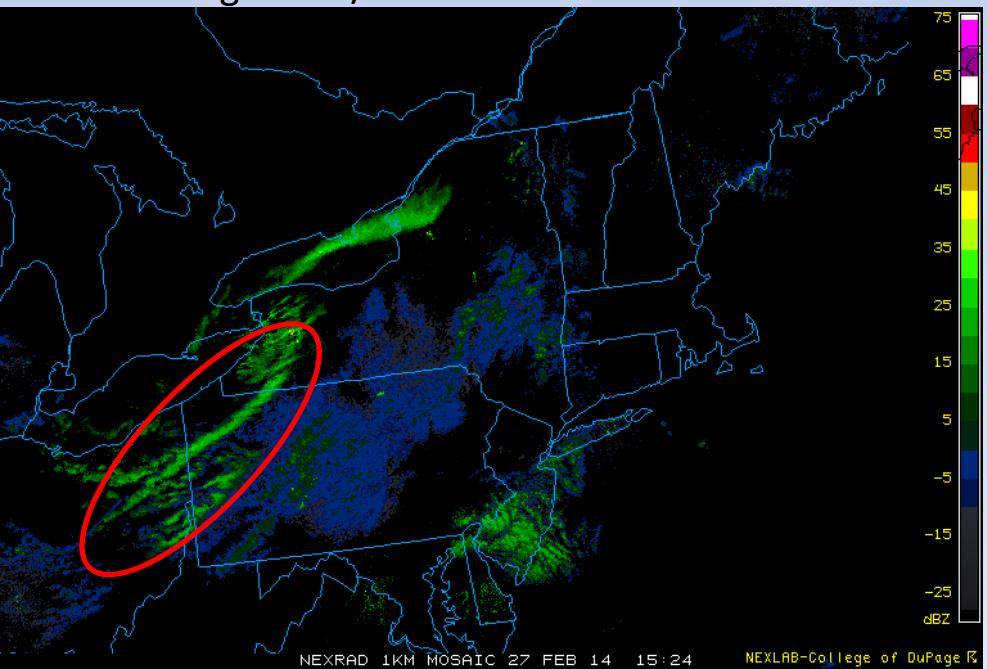


3-hrly NARR SNSQ time series at BTV (5 months)

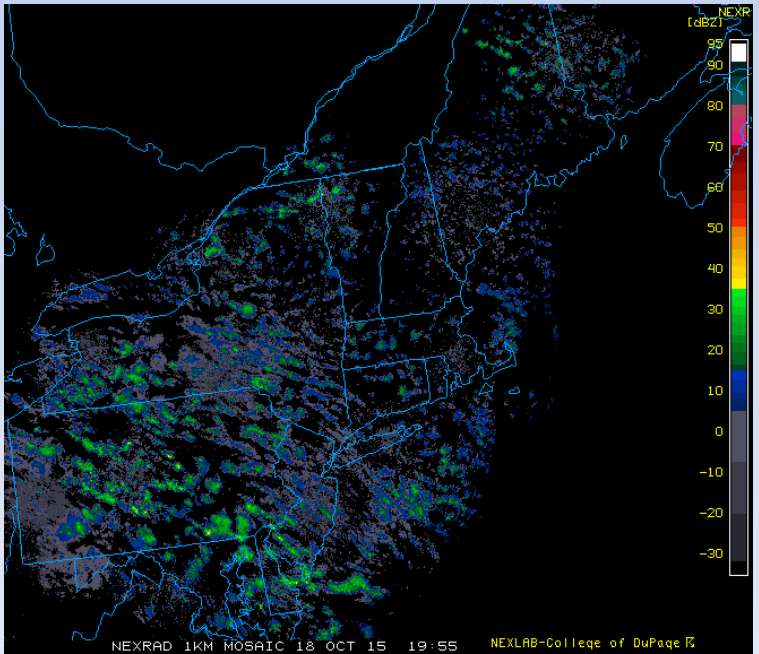


SNSQ Parameter Interpretation w.r.t. Convective Mode

- Well defined pressure rise/fall couplet
- Low-level frontogenesis maximum
- More organized/intense



- Absence of pressure rise/fall couplet
- Absence of frontogenesis maximum
- Less organized/less intense



Case Examples

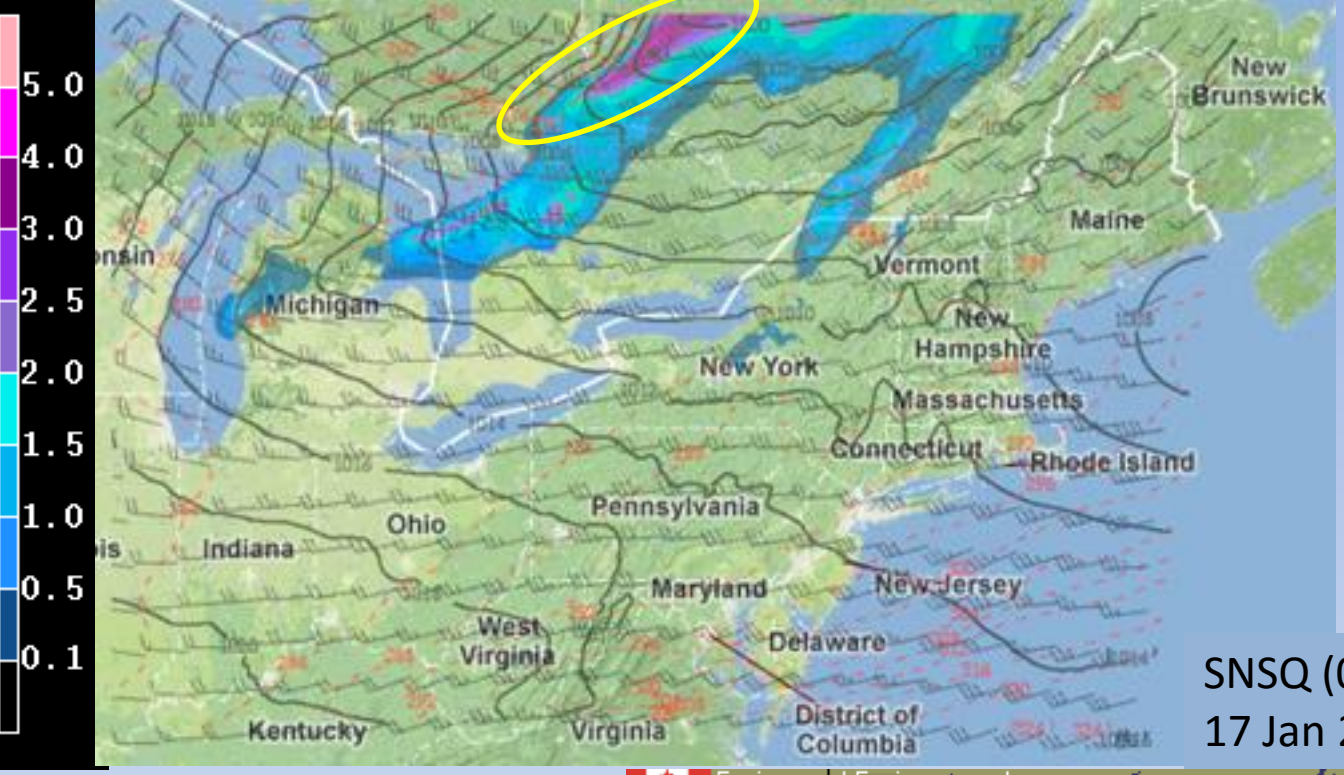
- **17 January 2013 (using the BTV-12km WRF)**
- **14 February 2015 (using NAM and SPC Mesoanalysis)**

BTV-12km WRF:
Initialized with the GFS and no convective parameterization.

SPC Mesoanalysis:
RAP-based and modified with surface observations.

16-17 January 2013

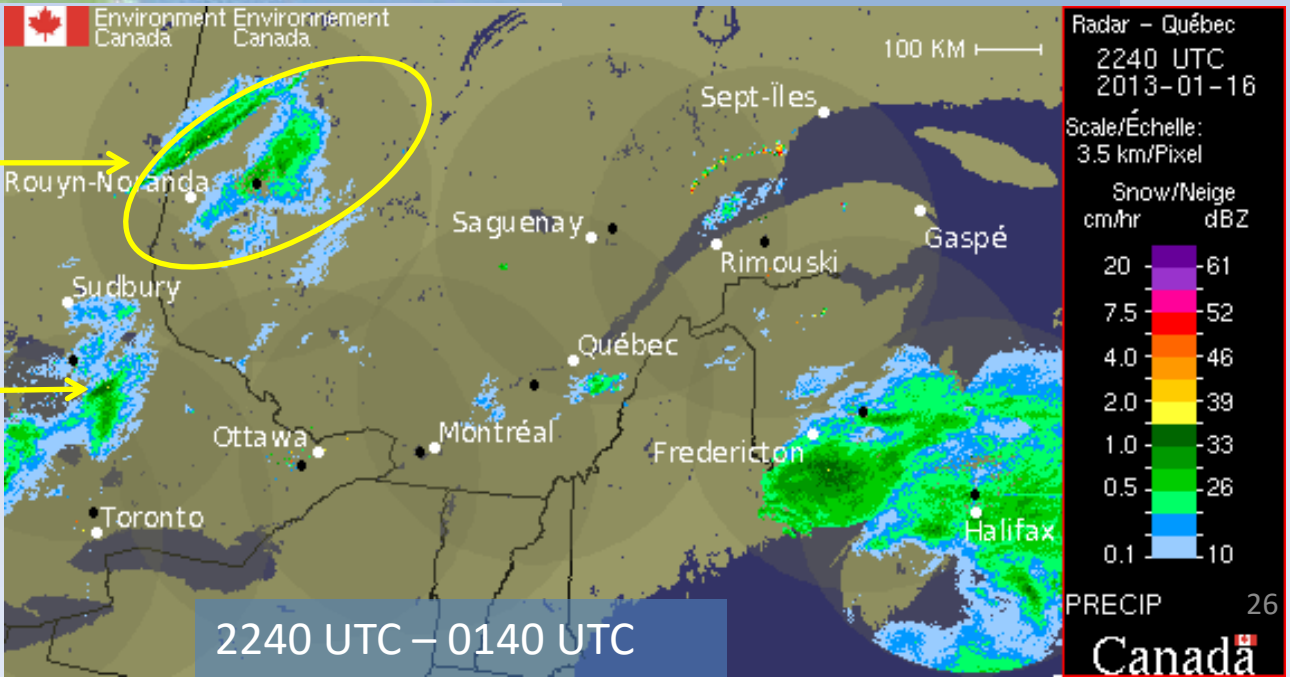
Well-organized frontal band case



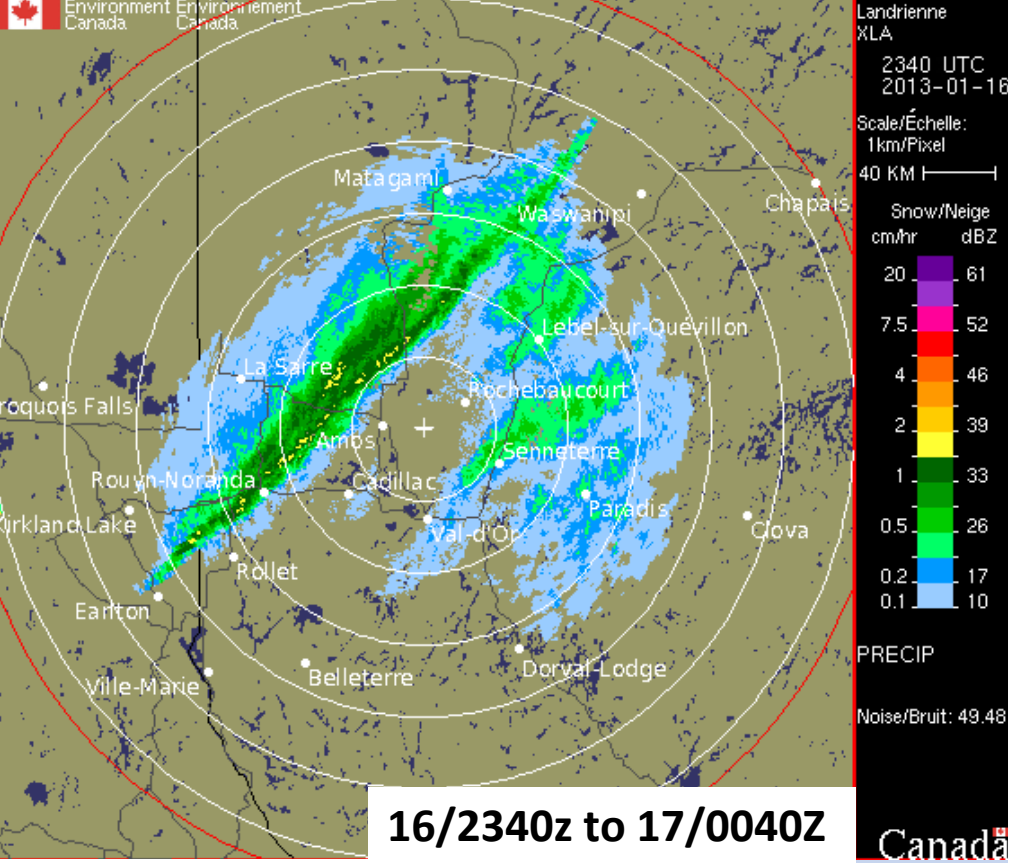
SNSQ (03z, 9 h forecast)
17 Jan 2013

Intense snow squalls along sharp cold front

Lake effect snow showers (less organized, not linearly forced)



2240 UTC – 0140 UTC



16/2340z to 17/0040Z

Reflectivity – Landrienne, Quebec

16-17 January 2013 Case

SNOW SQUALL OBSERVATIONS:

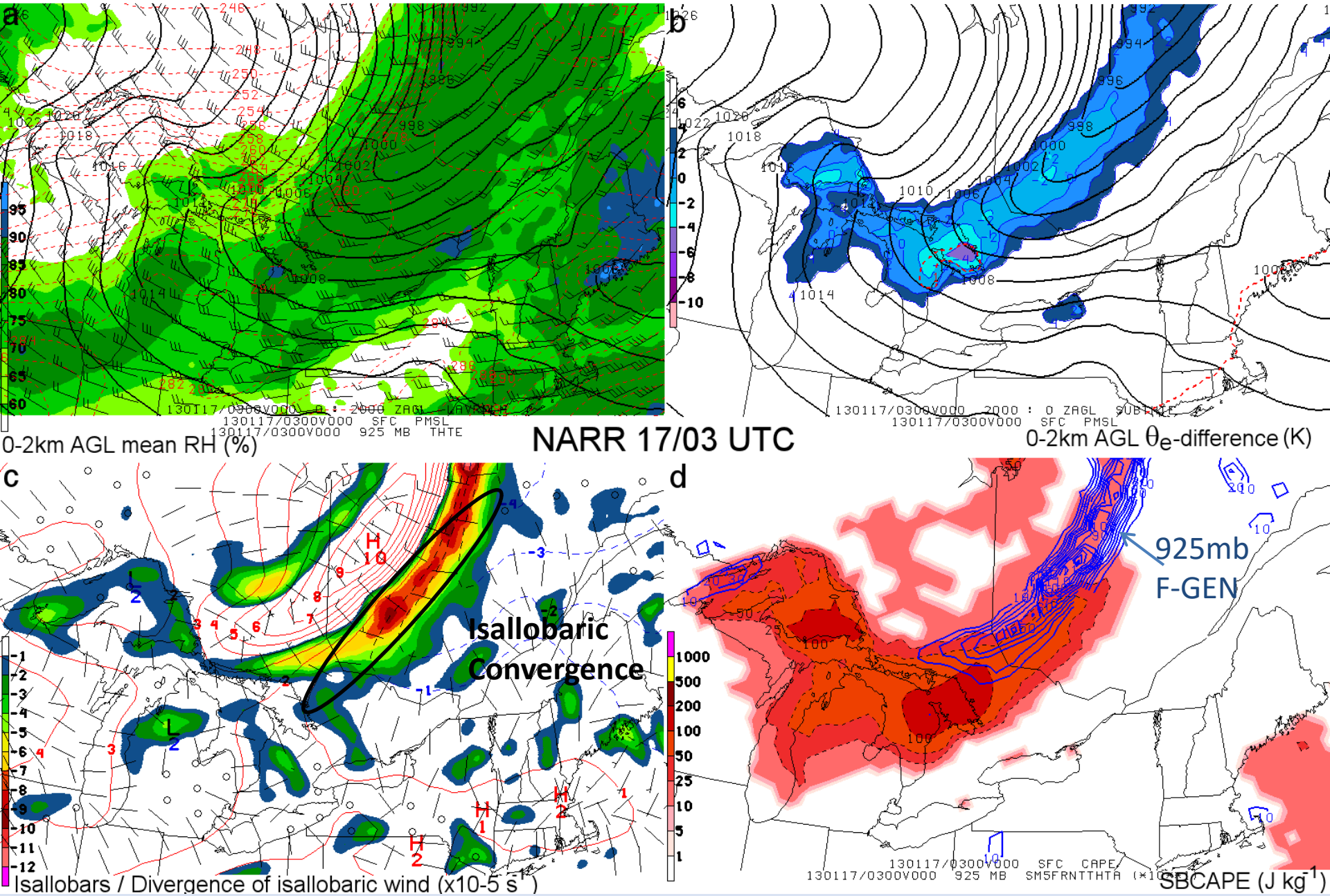
CYYU 161900Z 33020KT **1/8SM +SN +BLSN** VV001 M14/M35 A2944 RMK SN8 PRESRR SLP962

CYNM 162300Z AUTO 33028G37KT **1/4SM +SN** BLSN VV005 M17/M19 A2936 RMK MAX WND 33037KT AT 2300Z PRESRR SLP968

CYXR 162354Z AUTO 32028G38KT 230V330 **1/8SM +SN** SCT014 BKN019 BKN027 OVC070 M08/M10 A2948 RMK MAX WND 27038KT AT 2345Z PRESRR SLP998

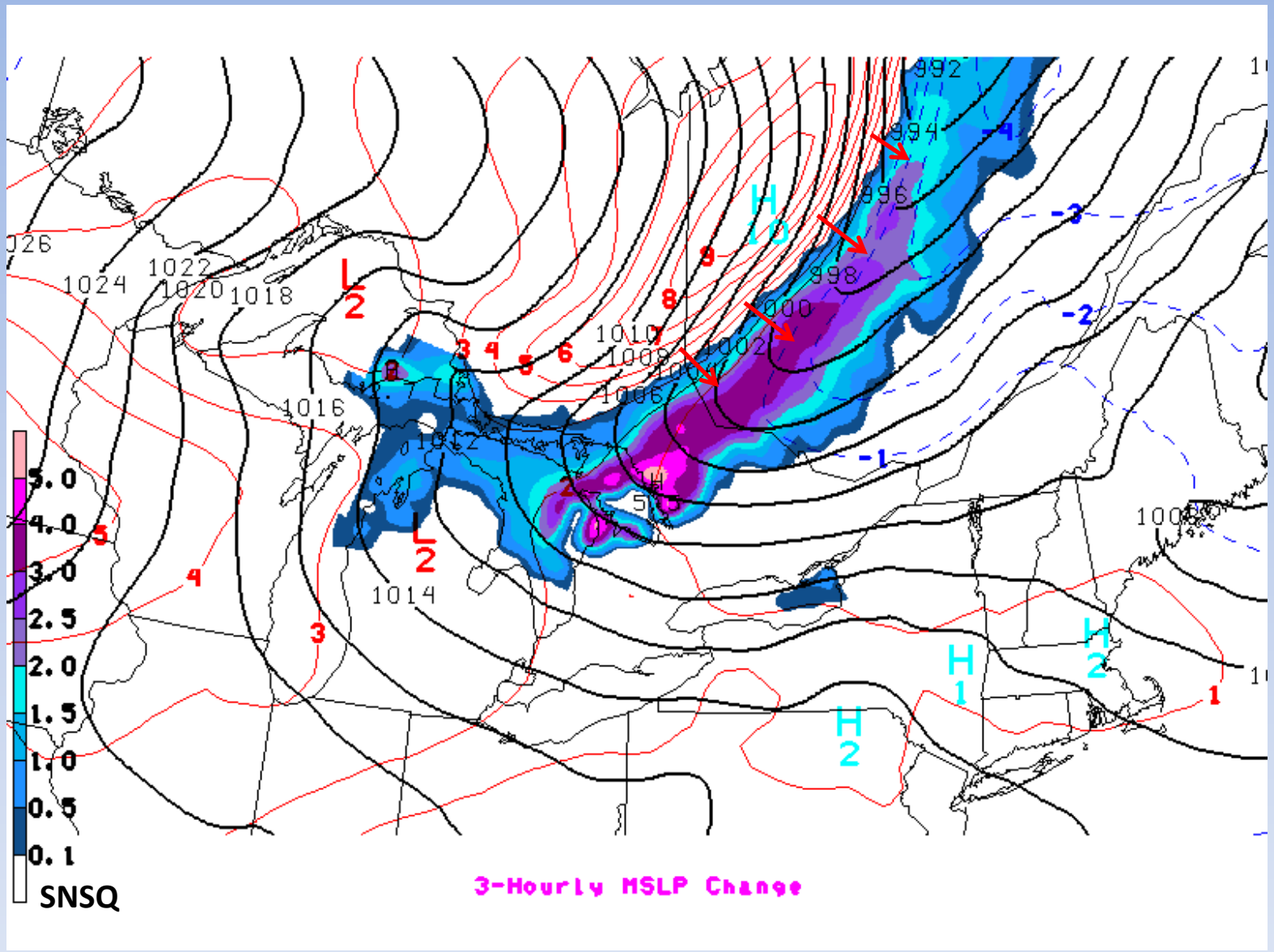
CYSB 170146Z 35021G28KT **1/2SM** R22/2800VP6000FT/D **SHSN** DRSN VV003 RMK SN8

CYVO 170148Z 32020G28KT **1/2SM -SN** BLSN VV007 M14/M15 A2951 RESN RMK BLSN8 PRESRR SLP022



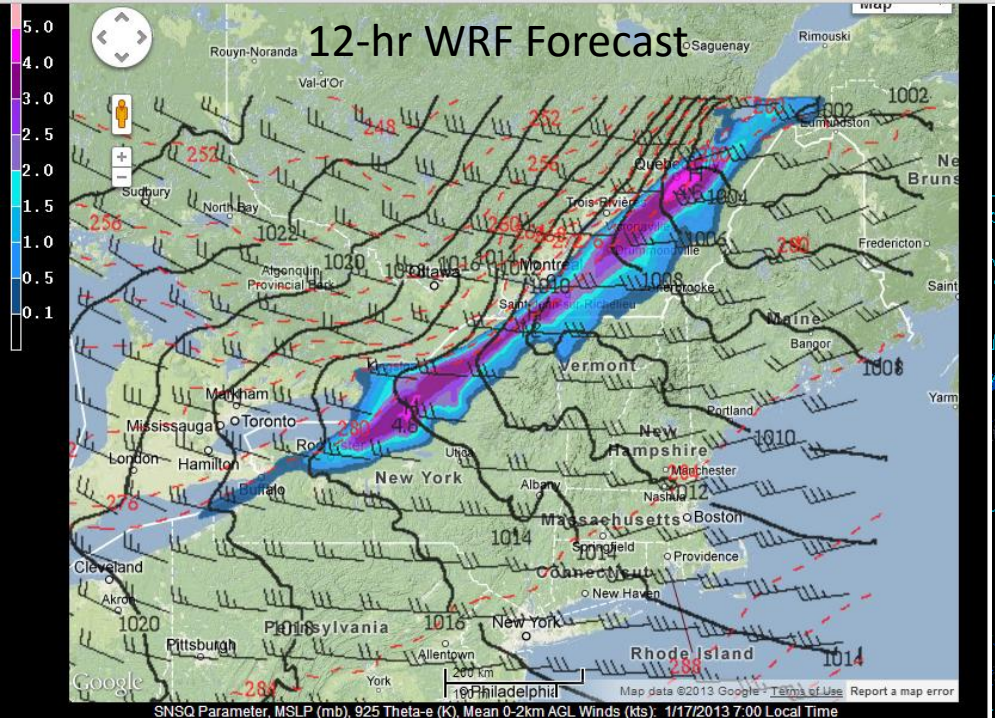
Convergence / frontogenesis forcing add in linear organization, in favorable moist and unstable environment.

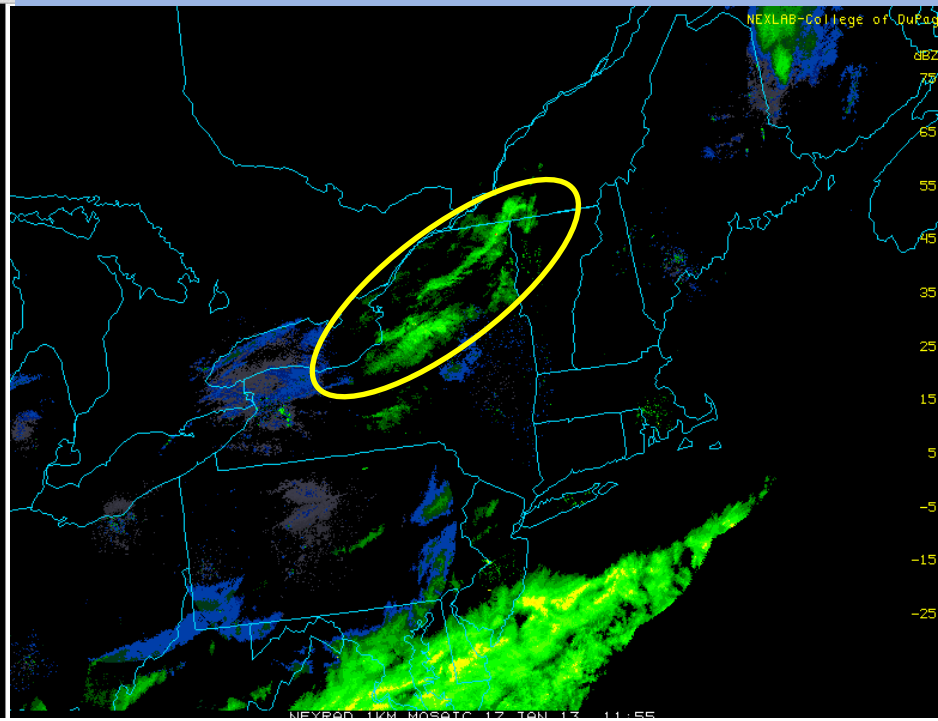
NARR SNSQ parameter with PMSL and isallobars (03z 17 Jan 2013)



→ isallobaric wind

Convergence maximized on leading edge of isallobaric gradient (usually near zero change line).

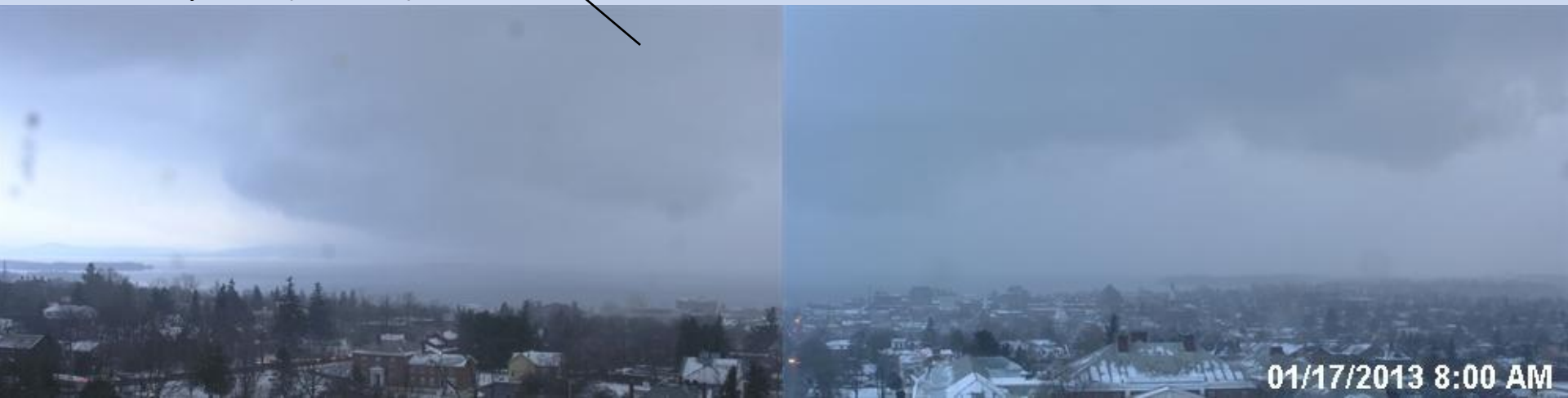




SNSQ Parameter (17/12z) (BTV-12km WRF 12-hr FCST)

Mosaic Composite Reflectivity (17/1155z)

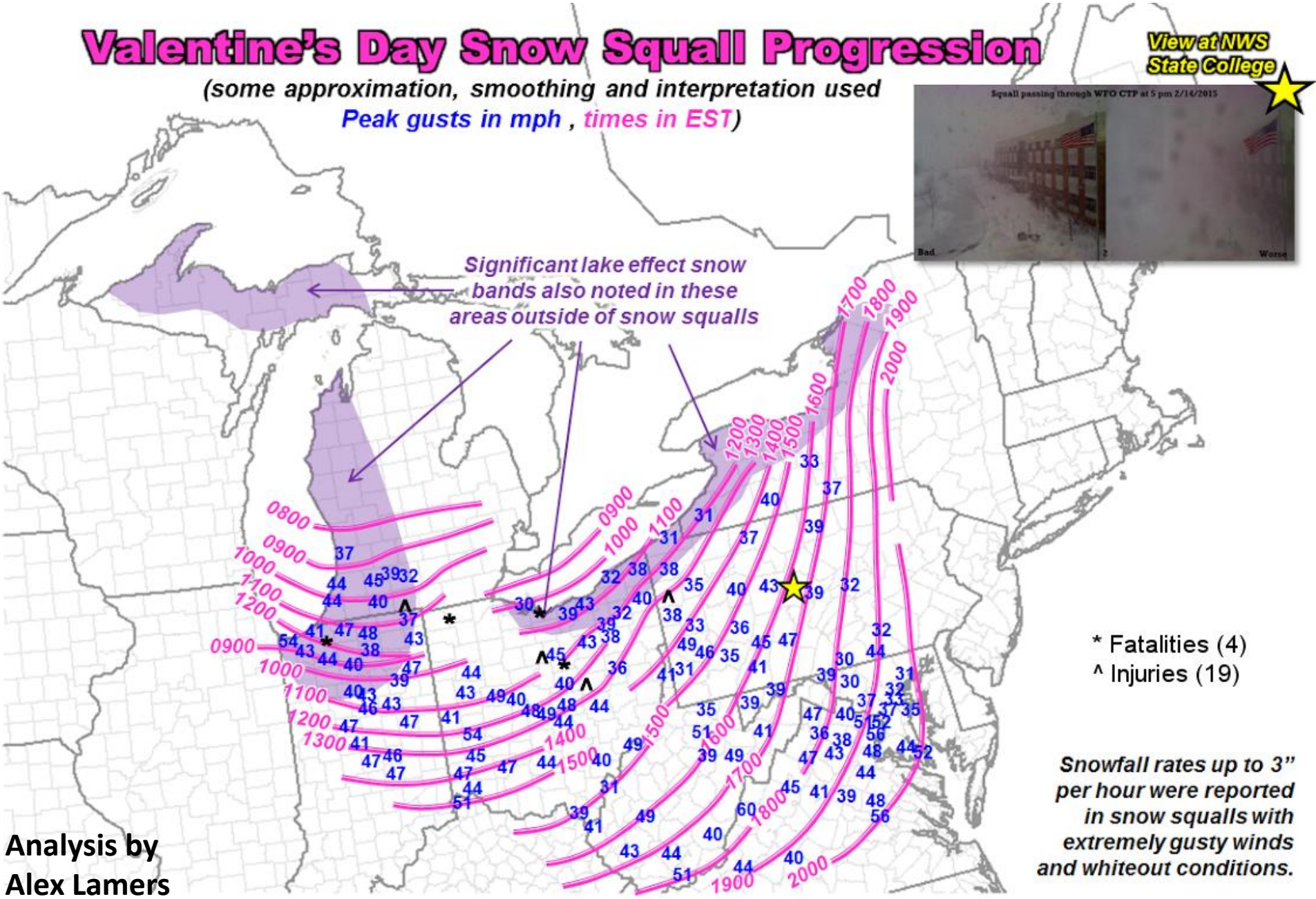
View from Burlington, VT of snow squall crossing Lake Champlain (17/13z)



14 Feb 2015 Snow Squall Event

- Southern Great Lakes to the Mid-Atlantic Coast
- For Winter 2014-2015, full Research-to-operations had taken place.

14 Feb 2015 Snow Squall Event



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Wind, white-out conditions cause fatal crashes

Icy roads, blinding snow cause pileups across state, killing at least 4

PREVIOUS | NEXT

REQUEST TO BUY THI

MICHI RELVAS I FOR THE D

The pileup involving more than 30 vehicles closed the interstate.

National

2 deadly pileups close Ohio Turnpike; snow grounds flights

Savings Account NO MINIMUMS START SAVING EARN INTEREST Member FDIC

First responders check on occupants of a multi-vehicle accident in near white out conditions, blocking west bound I-70, Saturday, Feb. 14, 2015 west of Columbus, Ohio. Heavy blowing snow is making travel difficult across Ohio and has caused quite a few accidents on the interstates. (Alex Brandon/Associated Press)

Whiteout conditions cause deadly pileups in Indiana, Ohio, traffic snarls in Michigan

Share 189 | 8+1 4 | Tweet 0 | Recommend 9 | Pin it

CAPTIONS

1/13

Tribune wire reports

1:26 a.m. EST, February 15, 2015

Blowing snow fueled by wind gusts of more than 40 mph caused whiteout conditions across Indiana on Saturday, causing pileups including one that killed a child and forcing the closure of highways in the north and east.

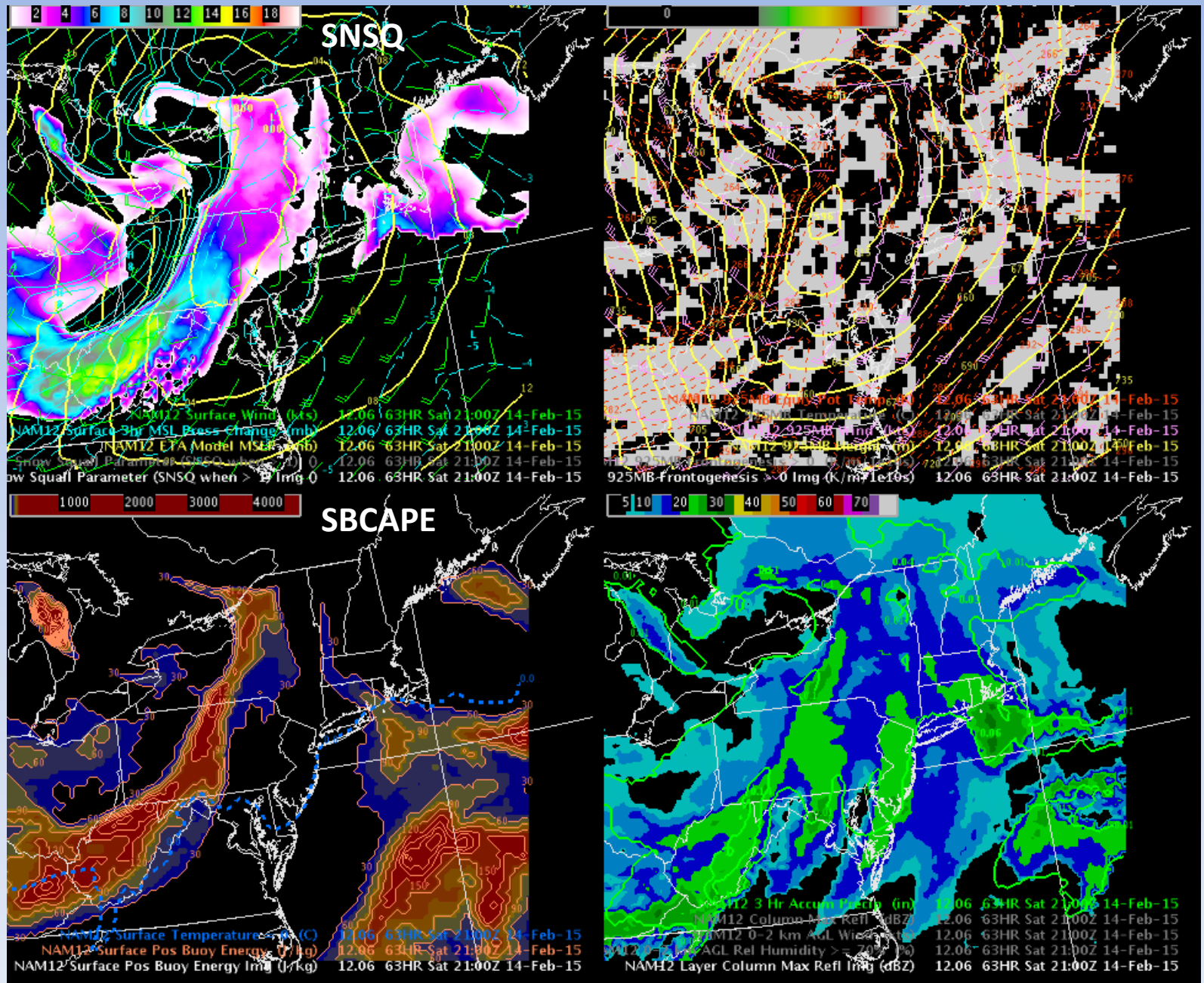
Snow squalls cause whiteout conditions, accidents throughout Pittsburgh area

REQUEST TO BUY THIS PHOTO

Newspaper Photos
14 February 2015

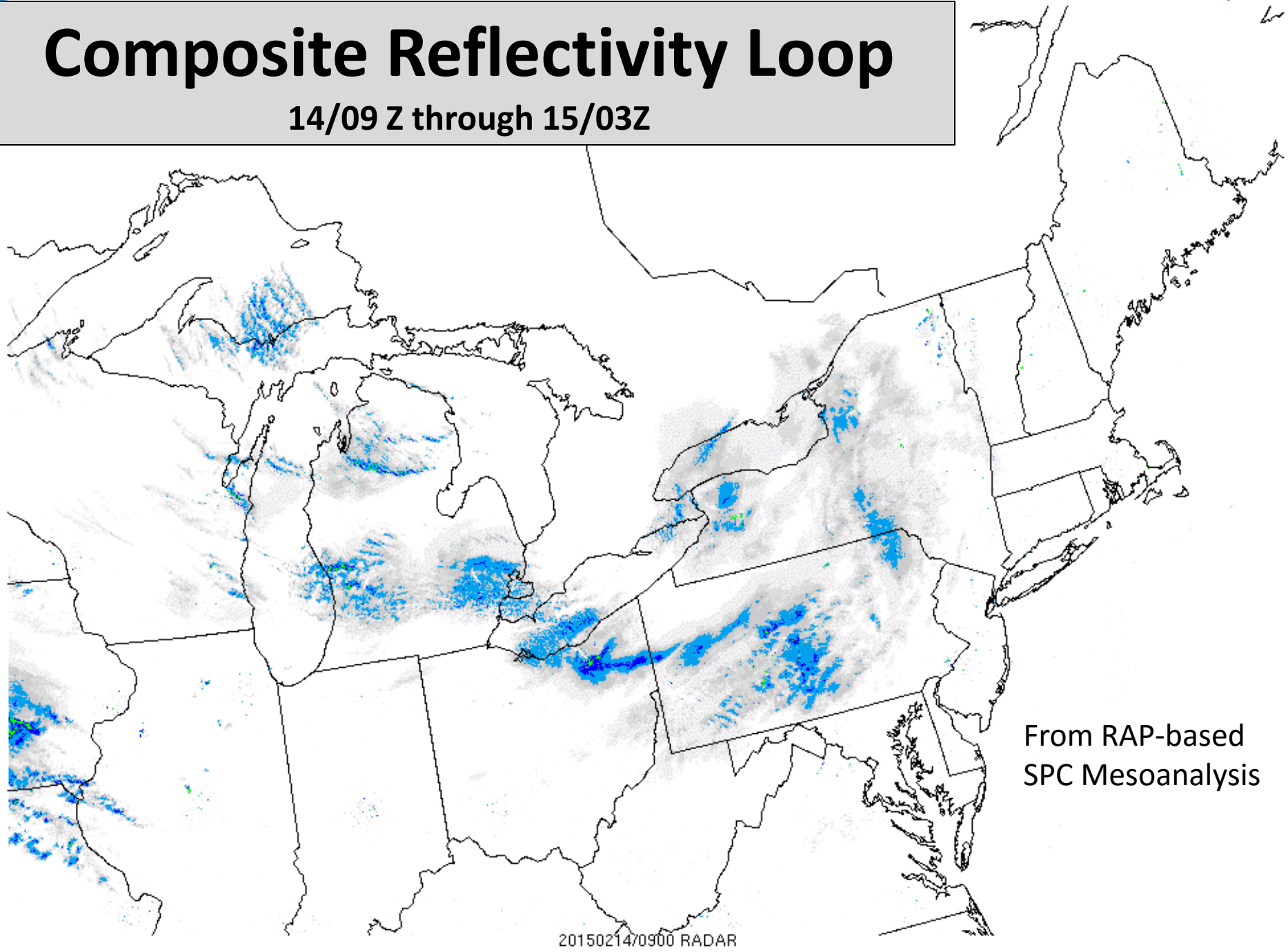
12km NAM 63-h Forecast (Valid 21Z 14 Feb)

SNSQ Upper Left Panel…good advance situational awareness of potential



Composite Reflectivity Loop

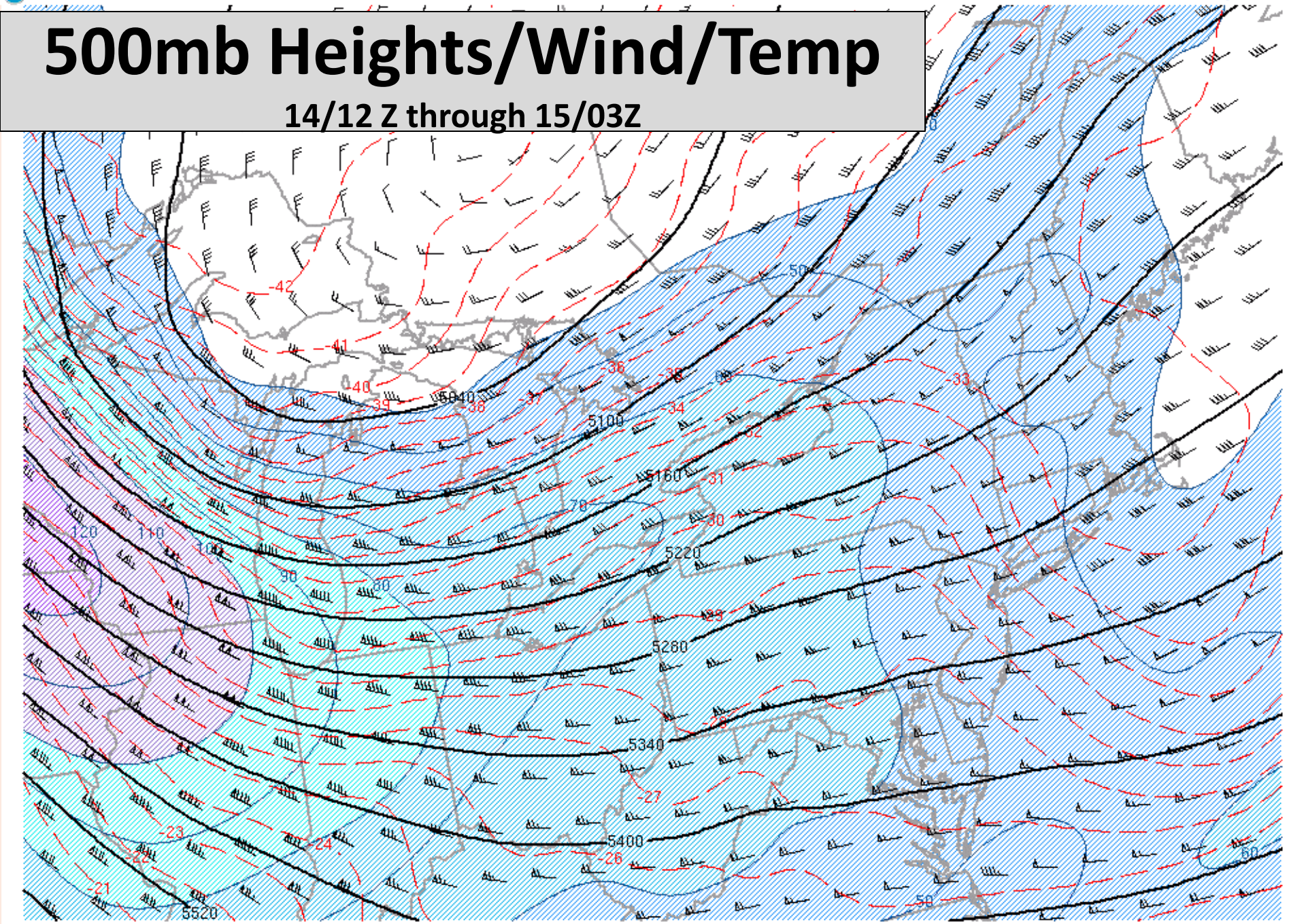
14/09 Z through 15/03Z



From RAP-based
SPC Mesoanalysis

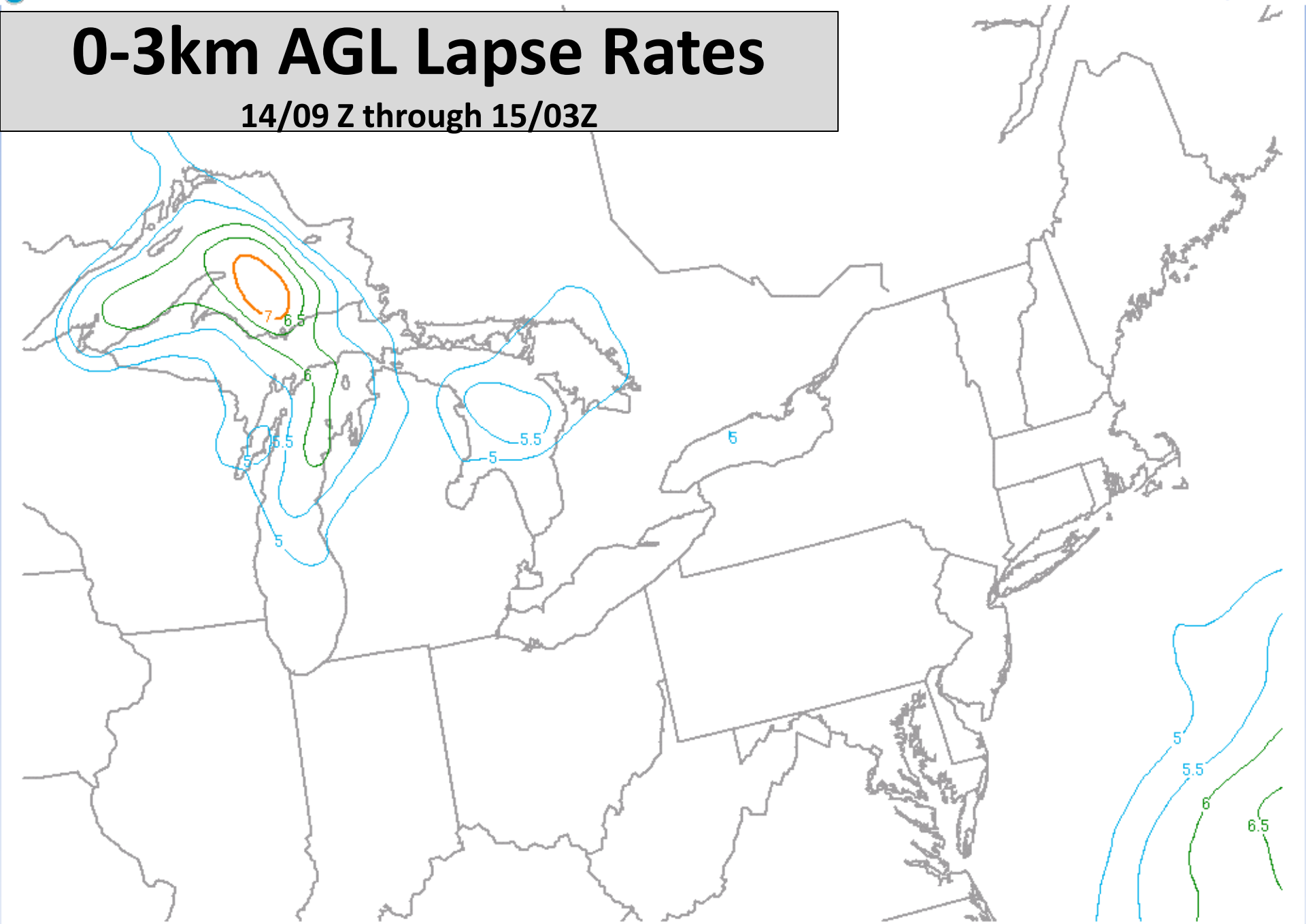
500mb Heights/Wind/Temp

14/12 Z through 15/03Z



0-3km AGL Lapse Rates

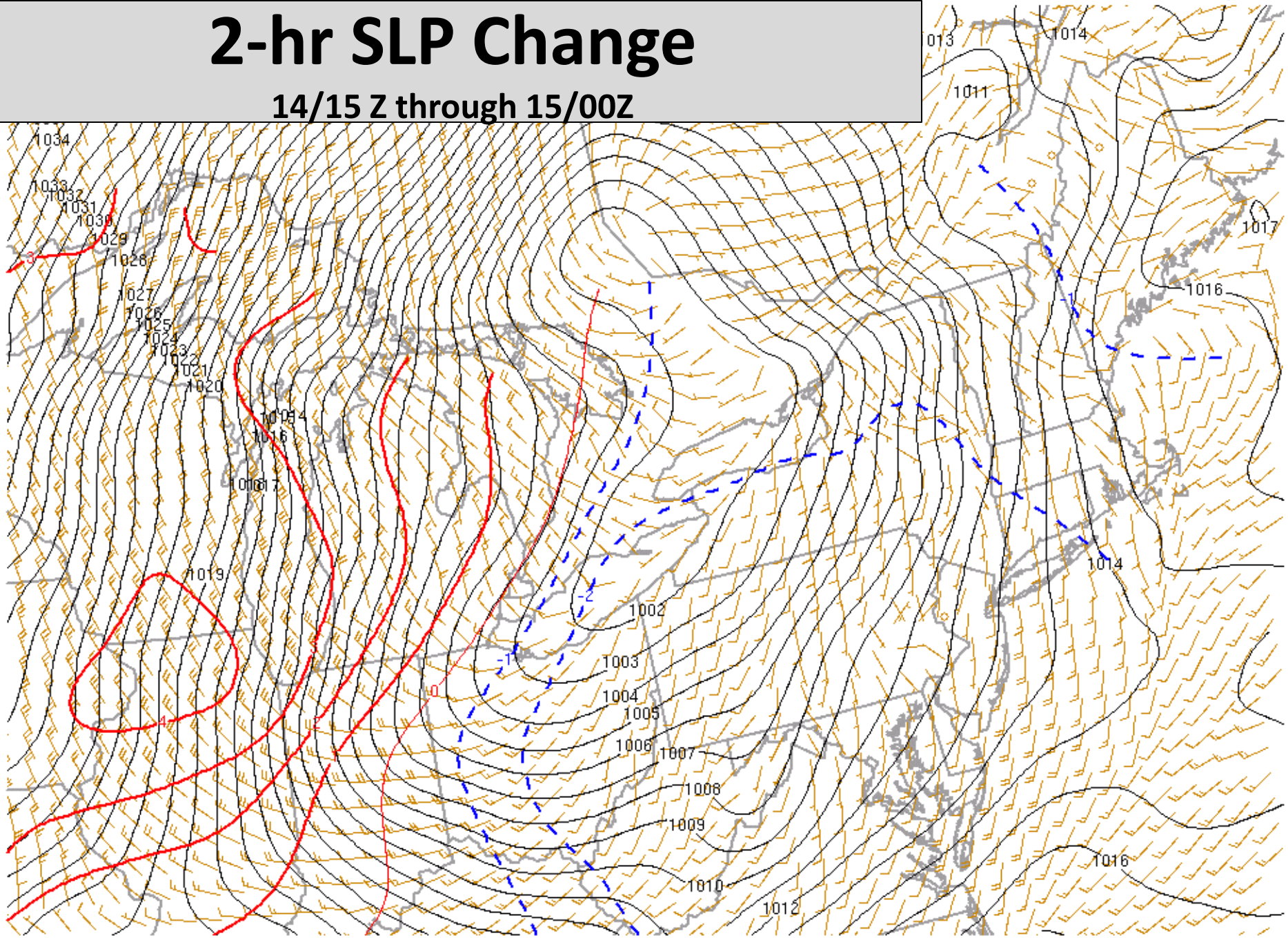
14/09 Z through 15/03Z



150214/0900 0-3 km lapse rate (C/km)

2-hr SLP Change

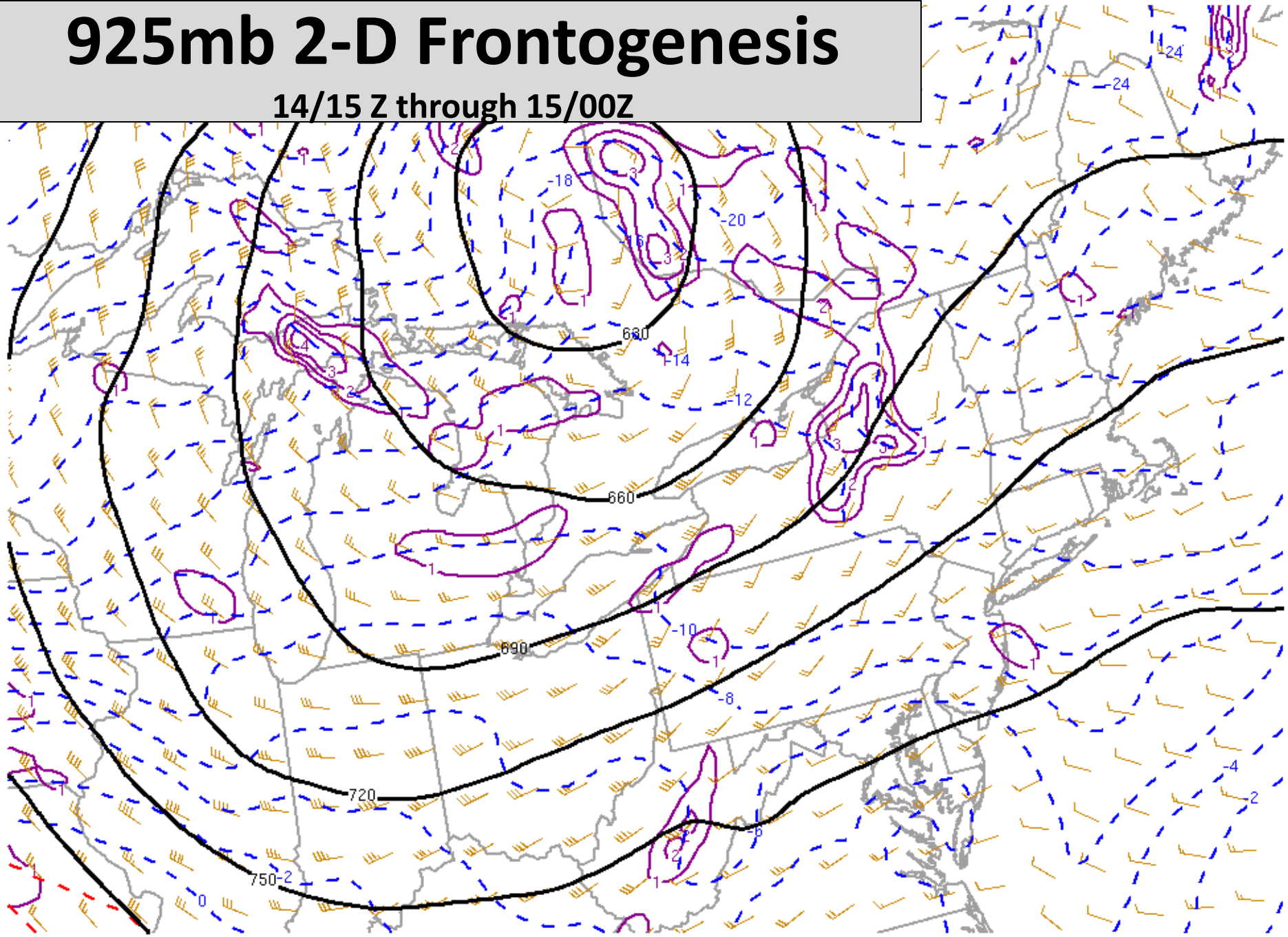
14/15 Z through 15/00Z



150214/1500 2hr sfc pres chg (mb)

925mb 2-D Frontogenesis

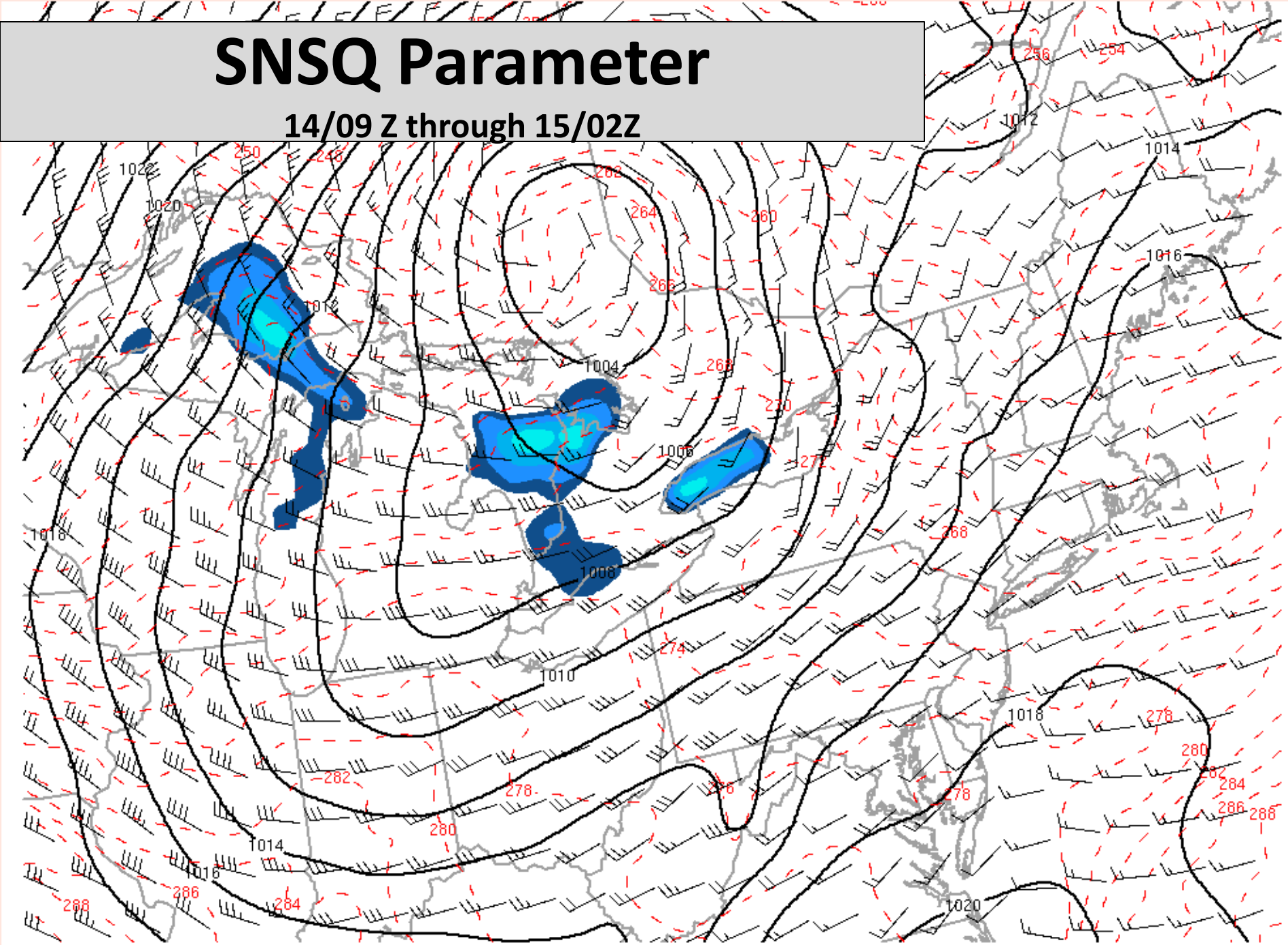
14/15 Z through 15/00Z



150214/0900V001 925 mb Petterssen frontogenesis (K/100 km/3 hr, purple)

SNSQ Parameter

14/09 Z through 15/02Z

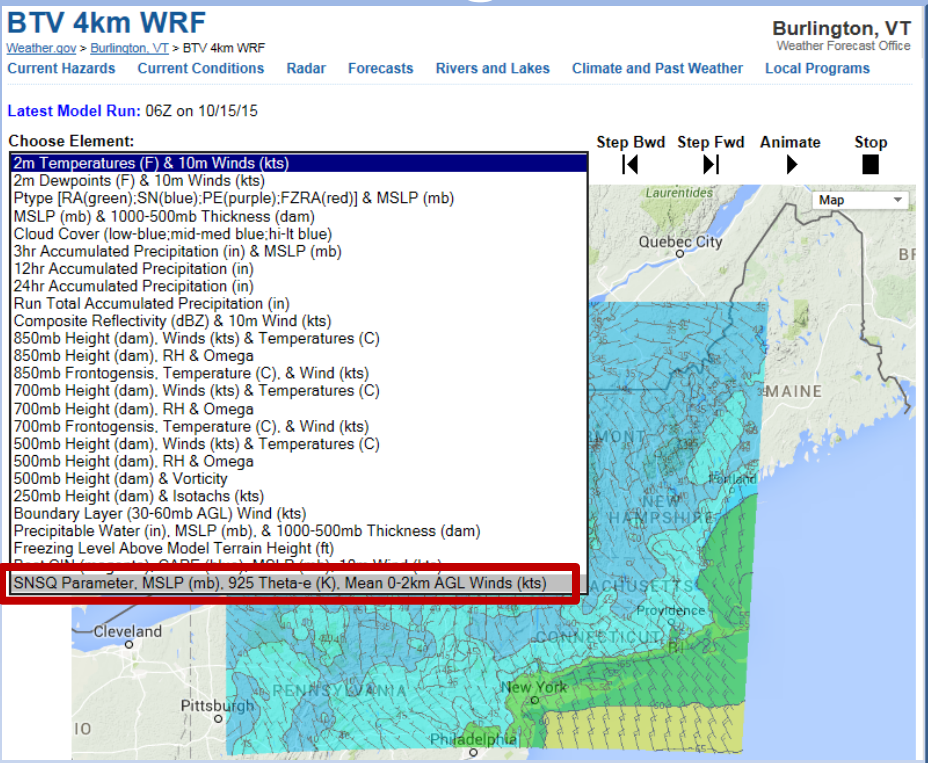


Silver Spring, MD Snow Squall Video:

https://www.youtube.com/watch?v=bRHV74J-Lzo

KDCA 150014Z **30026G45KT 1/4SM** R01/1600VP6000FT SN BR BKN009 BKN021 OVC047 01/M03 A2955 AO2 PK WND 27045/0007 SNB08 **PRESRR** P0000

Viewing the SNSQ Parameter in Real-Time

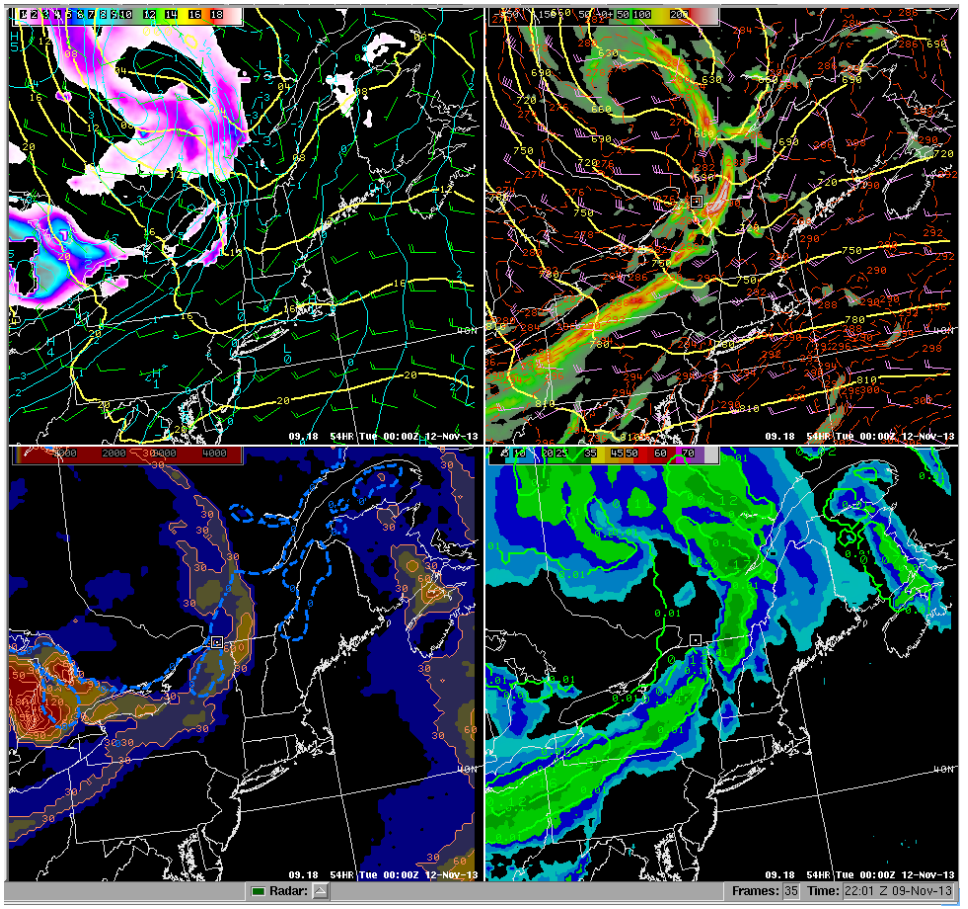


On the Web (BTV 4 and 12km WRF runs)

URLs:

http://www.weather.gov/btv/4kmwrf

http://www.weather.gov/btv/12kmwrf



AWIPS 4-panel procedures

(For NWS Offices)

- SPC Mesoanalysis (full CONUS availability): http://www.spc.noaa.gov/exper/mesoanalysis/
- St. Louis University CIPS Model Page: http://www.eas.slu.edu/CIPS/MODEL/WXmodelx.php

How do we get the message out?

- Snow Squalls can range from being a nuisance to a deadly transportation hazard. "High Impact, Sub-advisory".

- Minimal QPF, No formal warning product…can be tough to get the message out.

- Maintain good situational awareness:
  - Be aware of higher traffic volumes (weekday rush hours, weekend routes to and from ski areas)
  - Watch for temperatures falling below freezing creating icy road conditions.

- Proactive SPS issuances.

- Use Facebook and Twitter to provide "heads up" message.

- Call DOT/State Police/airport control towers. (Pre-treatment of surfaces)

- Establish State Police/DOT partnerships (e.g., use of electric highway ITS signs)

QUESTIONS?

E-MAIL

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greg.devoir@noaa.gov