Friday map discussion for 10 Feb focused mostly on forecast challenges associated with the fast-moving snowstorm of 8–9 Feb 2017 over parts of the Northeast. Links used during the Friday map discussion can be found here: http://www.atmos.albany.edu/mapdisco/201702010/. Tomer Burg and Kyle Pallozzi assisted with the discussion. They also conducted a brief current weather discussion to close out map discussion.

The 8–9 Feb storm forecast challenges included: (1) GFS difficulty in predicting the synoptic-scale flow pattern correctly until 72–84 h in advance of the storm, (2) an unexpected precipitation minimum in parts of east-central Pennsylvania where much higher QPFs were anticipated, (3) widespread occurrences of thundersnow from the New York City-Long Island area northeastwards to central and eastern Massachusetts; a subsyoptic-scale snowband that formed in the northwestern periphery of the coastal cyclone between extreme northeastern Pennsylvania and southern Vermont and moved slowly eastward thereafter, and (4) a mesoscale Mohawk-Hudson Convergence (MHC) snowband that formed farther west than usual.

1. GFS Predictability Issues with the Synoptic-Scale Flow Pattern:

Assorted d(prog)/dt loops (Kyle Griffin):

(a) MSLP/850-hPa temperature/10 m winds/6 h precip (http://www.atmos.albany.edu/student/kgriffin/maps/dprog/A054/6hrprecip/namer/6hrprecip_namer_dprog.html)
(b) 500-hPa heights, temperatures, winds, vorticity, and ascent (http://www.atmos.albany.edu/student/kgriffin/maps/dprog/A054/500vort/namer/500vort_namer_dprog.html)
(c) Dynamic tropopause pressure/wind and 925–850 hPa relative vorticity (http://www.atmos.albany.edu/student/kgriffin/maps/dprog/A054/500vort/namer/500vort_namer_dprog.html)

These loops establish that the GFS was unable to forecast a coastal cyclone at 1800 UTC 9 Feb 2017 anywhere near the right location with the right strength with any degree of consistency until 60–72 h in advance of this time. The forecast difficulties appear to originate over the North Pacific. Earlier GFS runs (e.g., the 108 h, 138 h, and 168 h verifying 1800 UTC 9 Feb) insisted that cyclonic wave breaking (CWB) would occur west of Washington and Oregon in conjunction with a negatively tilted 500-hPa trough with only a flat trough downstream over the central and eastern U.S. Later GFS runs (e.g., 96 h) backed away from a CWB scenario and forecast a positively tiled 500-hPa trough over the eastern Pacific. Later GFS forecasts of a positively tilted forecast trough scenario in the eastern North Pacific resulted in a somewhat more amplified 500-hPa downstream ridge located 5–10 degrees farther east over the Rockies than in the earlier forecasts. Result: the downstream trough over the eastern CONUS was stronger and deeper and configured so as to permit the phasing of individual PV anomalies. Science opportunity: Determine the origin and impact of upstream forecast flow uncertainties over the North Pacific to establish why the predictability horizon was relatively short for this event.

2. East-central Pennsylvania Precipitation Minimum:

Richard Grumm posted to map about the failure of the operational models to forecast this observed precipitation minimum area. On 9 Feb 2017, I quote his text below (his text is followed by the relevant figures). Rich is the kind of experienced forecaster I would want with me on the Titanic II when the ship is sailing through an ice field even if uncertainties with the forecast are apt to give us a “sinking” feeling that something is going to go wrong. Given that Rich experienced short-term QPF-related challenges for this event as he enumerated below, the source of the QPF uncertainty should be investigated starting with why the aforementioned dry slots got farther north than expected.

"List

I would guess this case could be studied for a long time from many angles.

We thought we had a good handle on this event. **NOT.**

The GEFS and actually **EVERY MODEL** I examined, missed the QPE minimum in east-central PA. Right where we had the meat of our highest snowfall forecasts. Go figure.

Looking the GEFS and GFS QPFs below one could see why snow forecasts were a maximum in east-central PA. The NAM and HRRR did no better. All were too wet.

The highest QPE axis in the verification was north of all models. And the min ran right across the QPF maximum!

Not sure why. But, there were 2 dry slots on WV imagery. Both crossed over that QPE minimum.

Maybe other areas will be success stories. Who knows.

Our biggest worries were how much QPF would occur before the transition to snow. Turns out areas with 0.20 to 0.30 inches of QPF had 2 to 3 inches of snow. Not an issue. But the QPF as way too high. Lucky me it began as sleet/snow at 37F rates picked up and temps fell nicely into the 20s. I got 7 inches!

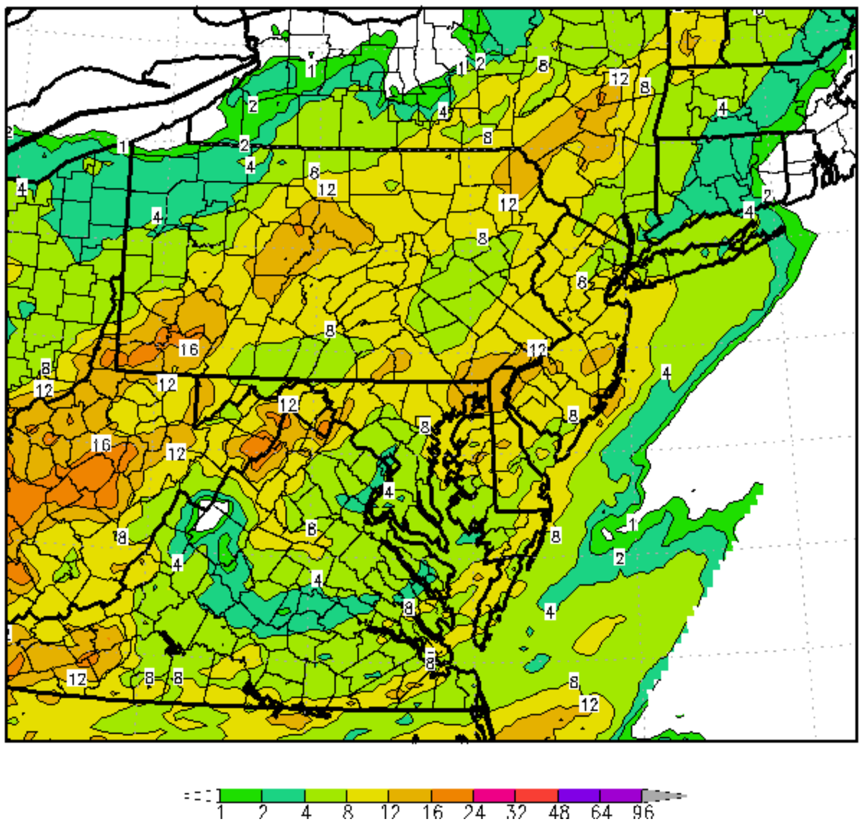
We have a long way to go. What the heck toss in a HRRR image too. See the dry slot?

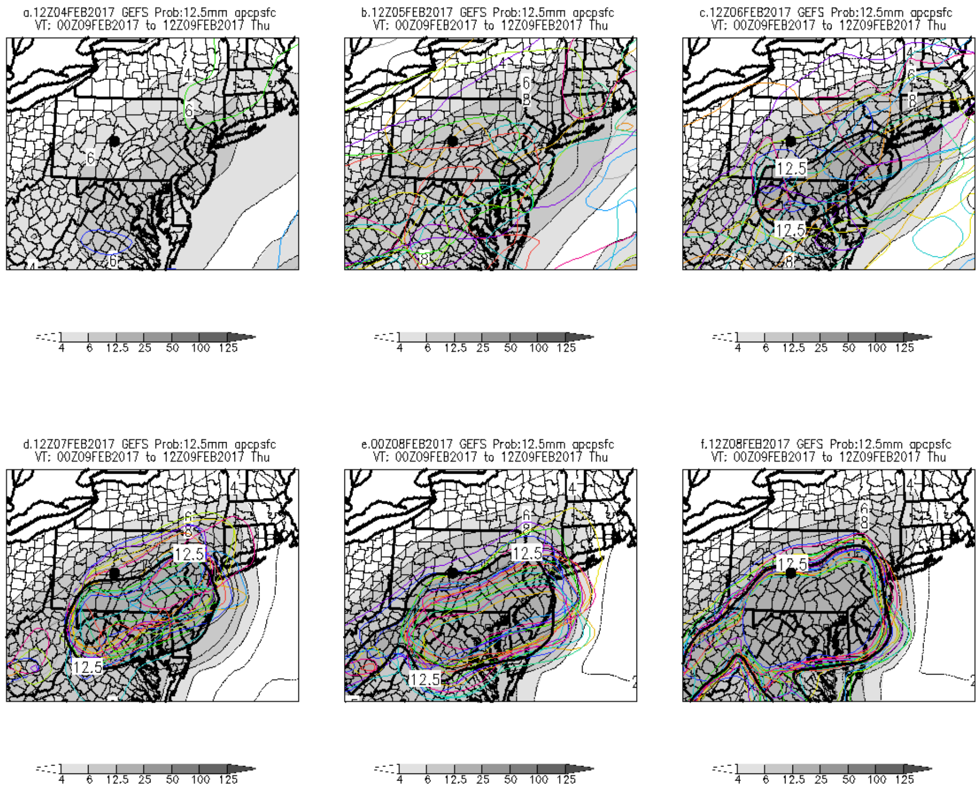
Most of the snow fell before 0800 UTC. The HRRR was too wet too far east just like all other guidance. Other data show it had too much QPF after 0600 UTC too.

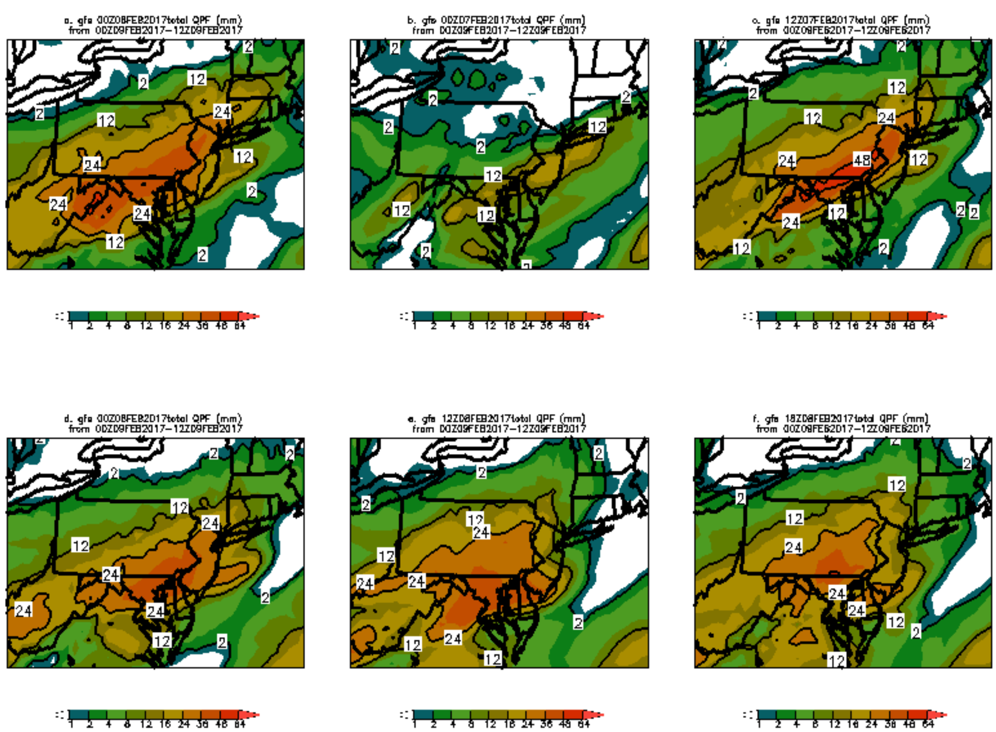
Hard to find a QPF minimum in these forecasts where we had a QPE min.

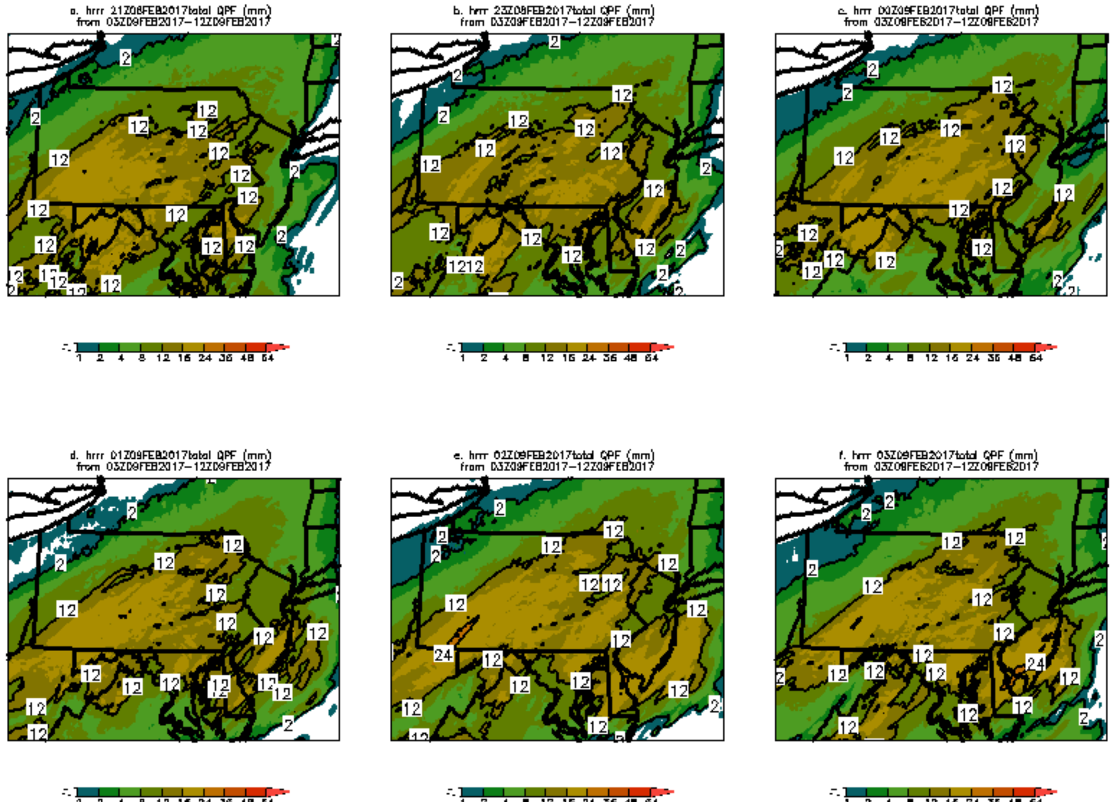
Rich"

a. Acumm precipitation 12Z08Feb2017-12Z09Feb2017



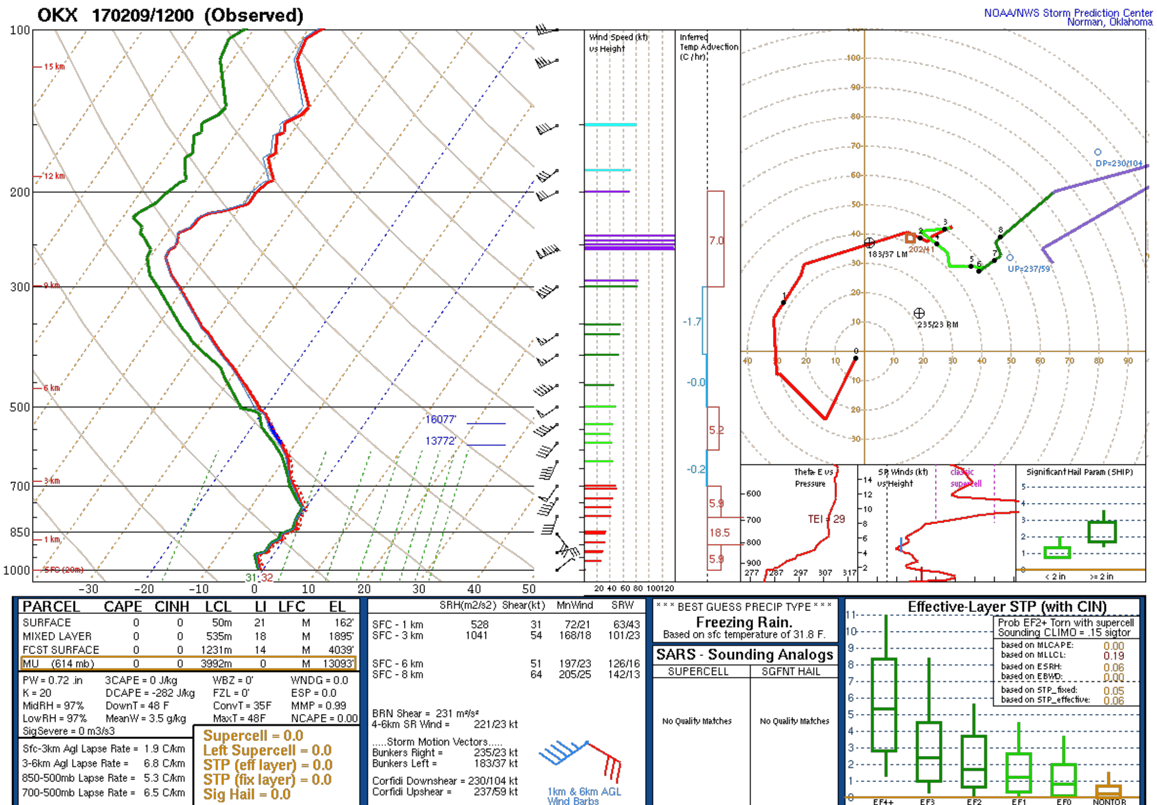

a.12Z04FEB2017 GEFS Prob:12.5mm apcpsfc
VT: 00Z09FEB2017 to 12Z09FEB2017 Thu
b.12Z05FEB2017 GEFS Prob:12.5mm apcpsfc
VT: 00Z09FEB2017 to 12Z09FEB2017 Thu
c.12Z06FEB2017 GEFS Prob:12.5mm apcpsfc
VT: 00Z09FEB2017 to 12Z09FEB2017 Thu
d.12Z07FEB2017 GEFS Prob:12.5mm apcpsfc
VT: 00Z09FEB2017 to 12Z09FEB2017 Thu
e.00Z08FEB2017 GEFS Prob:12.5mm apcpsfc
VT: 00Z09FEB2017 to 12Z09FEB2017 Thu
f.12Z08FEB2017 GEFS Prob:12.5mm apcpsfc
VT: 00Z09FEB2017 to 12Z09FEB2017 Thu
4 6 12.5 25 50 100 125

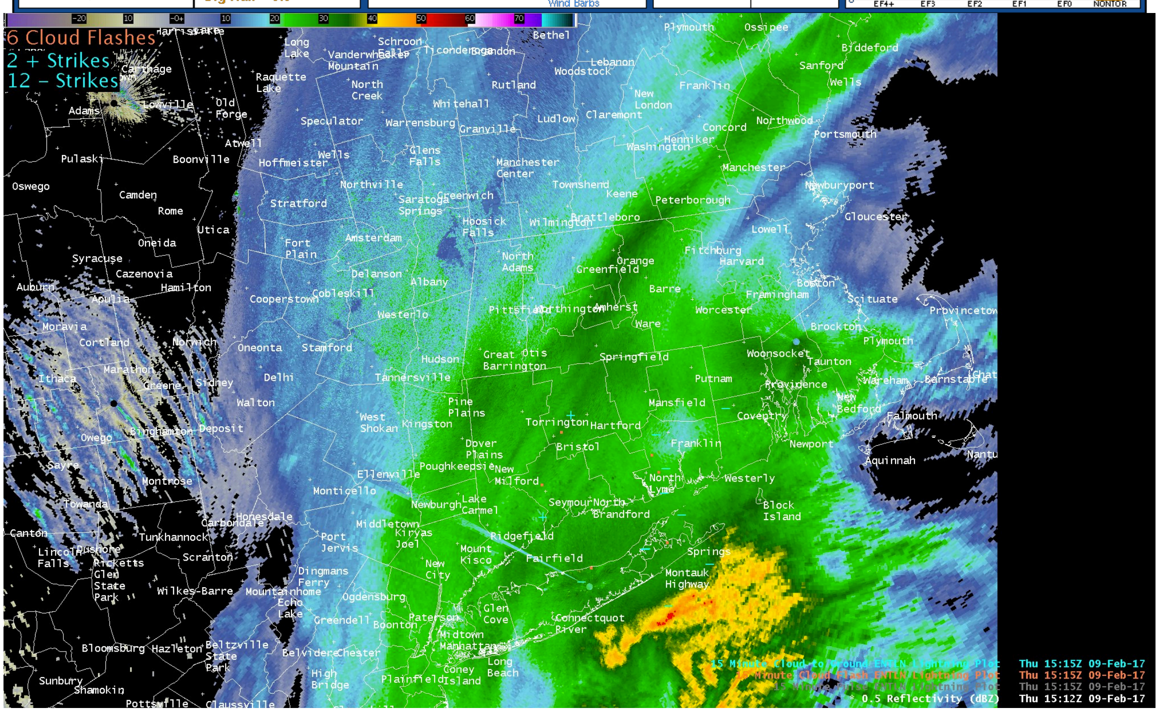

a. gfs 00Z06FEB2017total QPF (mm)
from 00Z09FEB2017-12Z09FEB2017
b. gfs 00Z07FEB2017total QPF (mm)
from 00Z09FEB2017-12Z09FEB2017
c. gfs 12Z07FEB2017total QPF (mm)
from 00Z09FEB2017-12Z09FEB2017
d. gfs 00Z08FEB2017total QPF (mm)
from 00Z09FEB2017-12Z09FEB2017
e. gfs 12Z08FEB2017total QPF (mm)
from 00Z09FEB2017-12Z09FEB2017
f. gfs 18Z08FEB2017total QPF (mm)
from 00Z09FEB2017-12Z09FEB2017
1 2 4 8 12 16 24 36 48 64

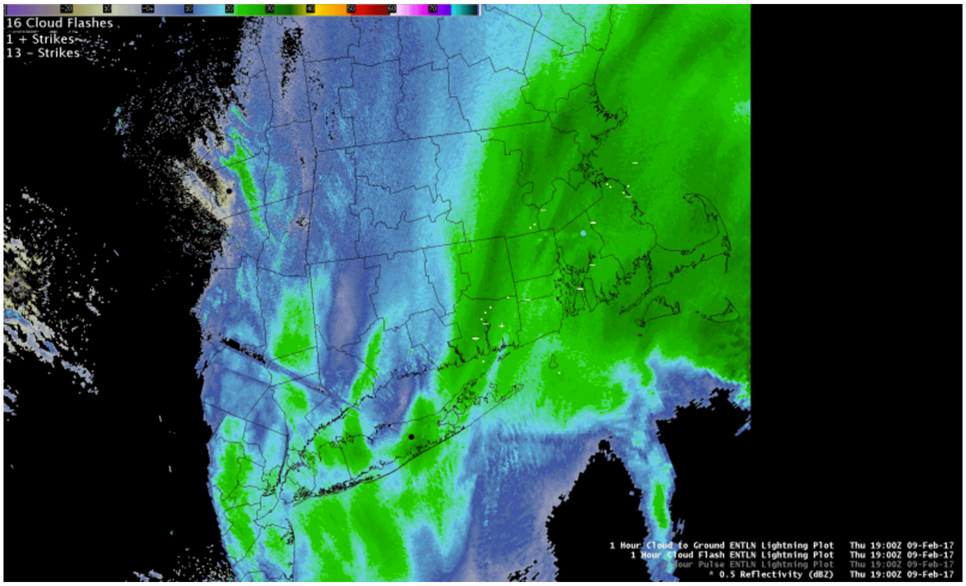


3. Widespread Thundersnow and an Intense Subsynoptic Scale Snowband:

The NYC and Long Island area as well as much of southern and eastern New England experienced widespread thundersnow in this event. While no "electrifying" 1800 UTC 9 Feb soundings were taken, alas, the appended 1200 UTC 9 Feb sounding from OKX shows a borderline area of instability centered near 700 hPa.above a layer of deep warm-air advection in a moderately sheared (54 kt) 0–3 km environment and below the 600–500 hPa layer (-10 to -20 C) where dendritic snow growth and charge separation should be maximized. Strong frontogenesis and the associated strong ascent with the pronounced sub-synoptic scale snowband over central New England were likely very conducive to this unusually electrically active storm.


OKX 170209/1200 (Observed)
NOAA/NWS Storm Prediction Center
Norman, Oklahoma
PARCEL CAPE CINH LCL LI LFC EL
SURFACE 0 0 50m 21 M 162'
MIXED LAYER 0 0 535m 18 M 1895'
FCST SURFACE 0 0 1231m 14 M 4039'
MU (614 mb) 0 0 3992m 0 M 13093'
PW = 0.72 in 3CAPE = 0 J/kg WBZ = 0' WNDG = 0.0
K = 20 DCAPE = -282 J/kg FZL = 0' ESP = 0.0
MidRH = 97% DownT = 48 F ConvT = 35F MMP = 0.99
LowRH = 97% MeanW = 3.5 g/kg MaxT = 48F NCAPE = 0.00
SigSevere = 0 m3/s3
Sfc-3km Agl Lapse Rate = 1.9 C/km
3-6km Agl Lapse Rate = 6.8 C/km
850-500mb Lapse Rate = 5.3 C/km
700-500mb Lapse Rate = 6.5 C/km
Supercell = 0.0
Left Supercell = 0.0
STP (eff layer) = 0.0
STP (fix layer) = 0.0
Sig Hail = 0.0
SRH(m2/s2) Shear(kt) MnWind SRW
SFC - 1 km 528 31 72/21 63/43
SFC - 3 km 1041 54 168/18 101/23
SFC - 6 km 51 197/23 126/16
SFC - 8 km 64 205/25 142/13
BRN Shear = 231 m²/s²
4-6km SR Wind = 221/23 kt
.....Storm Motion Vectors.....
Bunkers Right = 235/23 kt
Bunkers Left = 183/37 kt
Corfidi Downshear = 230/104 kt
Corfidi Upshear = 237/59 kt
1km & 6km AGL Wind Barbs
*** BEST GUESS PRECIP TYPE ***
Freezing Rain.
Based on sfc temperature of 31.8 F.
SARS - Sounding Analogs
SUPERCELL SGFNT HAIL
No Quality Matches No Quality Matches
Effective-Layer STP (with CIN)
Prob EF2+ Torn with supercell
Sounding CLIMO = .15 sigtor
based on MLCAPE: 0.00
based on MLLCL: 0.19
based on ESRH: 0.06
based on EBWD: 0.00
based on STP_fixed: 0.05
based on STP_effective: 0.06
EF4+ EF3 EF2 EF1 EF0 NONTOR
Wind Speed (kt) vs Height
Inferred Temp Advection (C/hr)
Theta-E vs Pressure
SR Winds (kt) vs Height
Significant Hail Param (SHIP)
TEI = 29
183/37 LM
235/23 RM
202/11
DP=230/104
UP=237/59


6 Cloud Flashes
2 + Strikes
12 - Strikes
15 Minute Cloud-to-Ground EN Lightning Plot Thu 15:15Z 09-Feb-17
15 Minute Cloud Flash ENTLN Lightning Plot Thu 15:15Z 09-Feb-17
0.5 Reflectivity (dBZ) Thu 15:12Z 09-Feb-17



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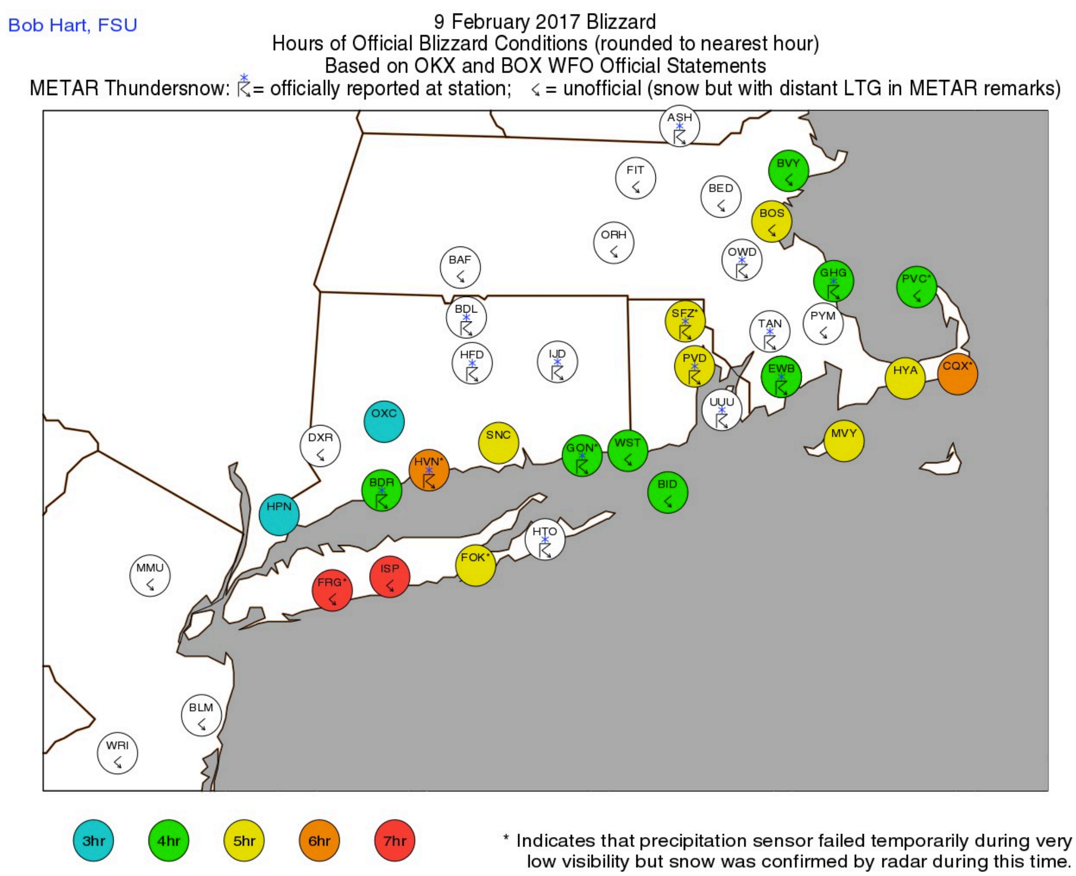
Bob Hart posted separately to map about the widespread thunder snow in this event. With Bob's permission, I am including his color-coded map of station blizzard hours and station thundersnow reports in southern New England and Long Island. Bob's map "illuminates" the widespread thundersnow activity. across the region.



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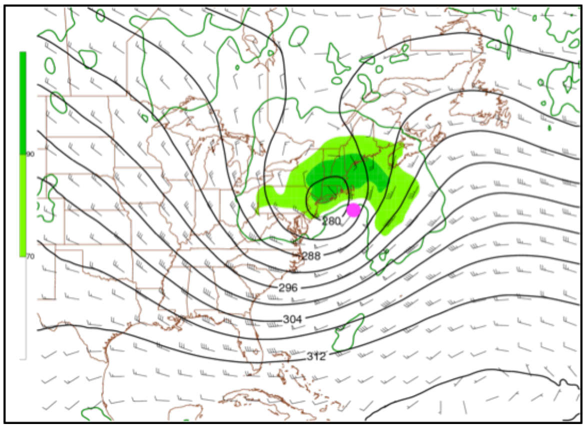
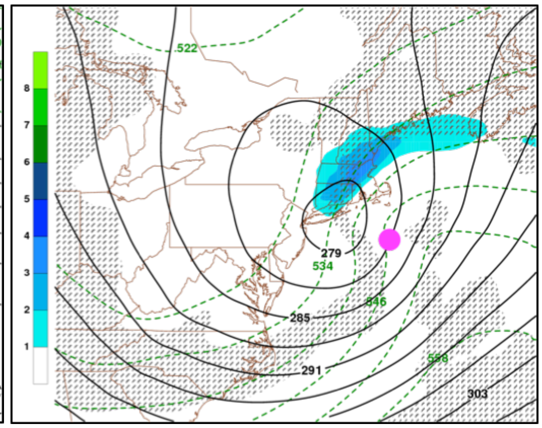
Kyle Meier completed an as yet unpublished UAlbany CSTAR thesis on thundersnow in 2014 (http://cstar.cestm.albany.edu/CAP_Projects/Meier/NPDF.pdf). His 700-hPa composite analyses based on 31 thundersnow events in the Northeast (see the two below figures from his M.S. thesis) look similar to the corresponding 700 hPa analyses for 1200 and 1800 UTC 9 February 2017 (source: Alicia Bentley: http://www.atmos.albany.edu/student/abentley/realtime/northamer_pw.php).





Left: Nor'easter thundersnow event category composite (N = 31) 700-hPa geopotential height (black contours, dam), relative humidity (fills, percent), and wind barbs (kt). The heavy magenta dot marks the surface cyclone center and the star marks the composite thundersnow location, a position ~295 km to the northwest of the surface cyclone center. Source: Kyle Meier (2014).

Right: Nor'easter thundersnow event category composite (N = 31) 700-hPa geopotential height (black contours, dam), frontogenesis [fills, K (100 km)$^{-1}$ (3 h)$^{-1}$], and 700−500-hPa saturation equivalent potential vorticity (hatched, ≤ 0.25 PVU). The heavy magenta dot marks the surface cyclone center and the star marks the composite thundersnow location, a position ~295 km to the northwest of the surface cyclone center. Source: Kyle Meier (2014).

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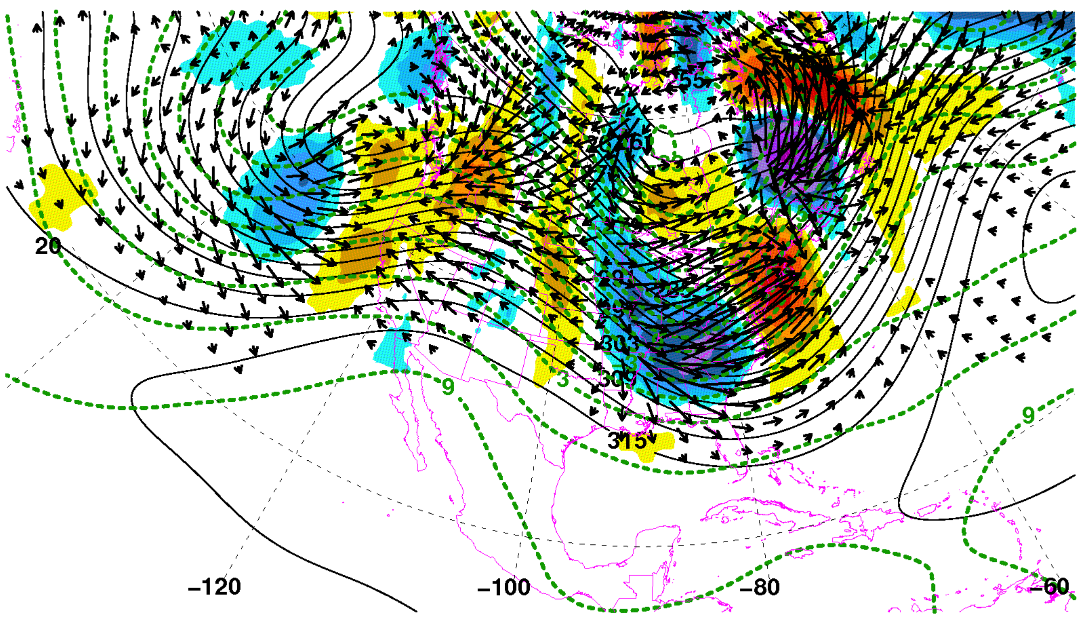
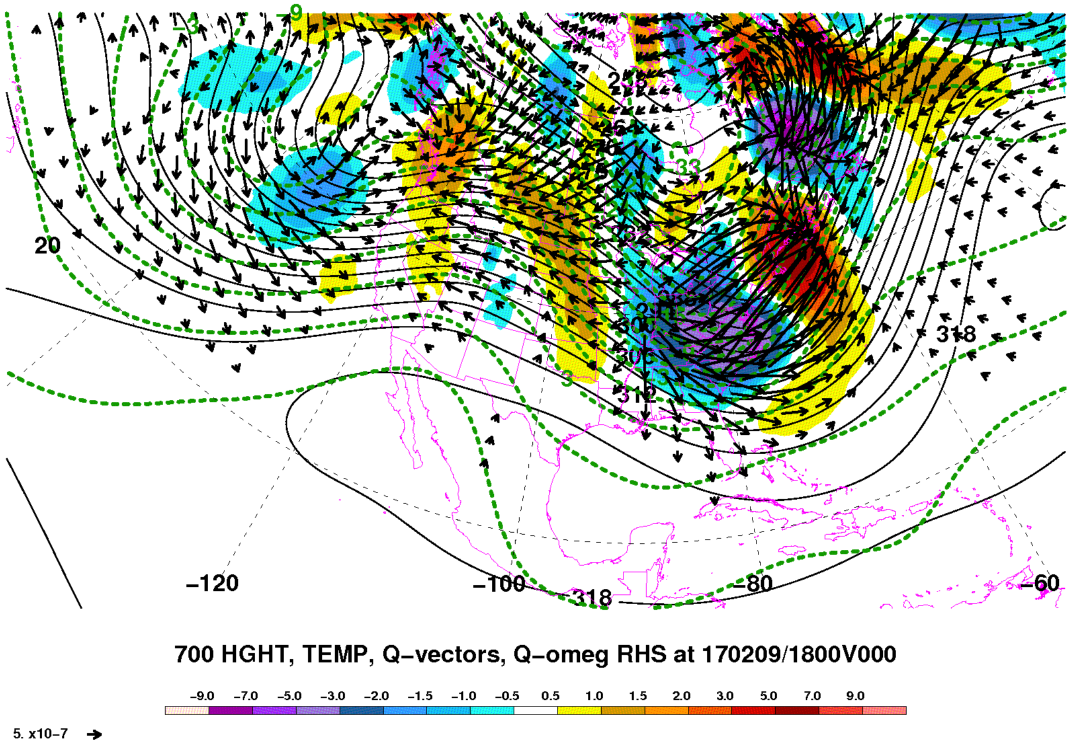
Evidence for the earlier statement that frontogenetical forcing was likely important in subsynoptic scale snowband formation and organization can be found in Tom Galarneau's attached 700-hPa Q-vector and Q-vector convergence analyses for 1200 and 1800 UTC 9 feb 2017 (see: http://www.atmo.arizona.edu/~tgalarneau/realtime/qg_diag/Qvect700-NorAmer/res.html). The 700-hPa Q-vectors are pointing strongly across the isotherms toward warmer air at the leading edge of the region of Q-vector convergence, indicative of strong frontogenetical forcing at the leading edge of the region of strong and deep ascent. Meteograms from four New York State mesonet stations in the vicinity of Albany suggest that just prior to subsynoptic-scale mesoscale snowband formation and intensification between 0800-1000 UTC 9 Feb a mesoscale inertia-gravity wave (IGW) with a MSLP amplitude of 2–4 hPa traversed the area from south-southwest to north-northeast (http://www.atmos.albany.edu/mapdisco/20170210/images/MHCimages.pdf). Whether the passage of this apparent IGW can be linked to subsequent sub synoptic-scale mesoscale band formation is unknown, but should be investigated.



700 HGHT, TEMP, Q−vectors, Q−omeg RHS at 170209/1200V000

−9.0 −7.0 −5.0 −3.0 −2.0 −1.5 −1.0 −0.5 0.5 1.0 1.5 2.0 3.0 5.0 7.0 9.0

5. x10−7



An hourly loop of KENX base reflectivity with superimposed positive and negative charge lightning flash locations (courtesy of Neil Stuart) that illustrates the evolution of the aforementioned sub-synoptic-scale snowband, which initially moved eastward slowly, and then semi-stalled over central New England before rotating cyclonically and accelerating eastward over eastern New England, can be found here (http://www.atmos.albany.edu/mapdisco/20170210/images/feb9tsnowloop.gif). The cumulative signature of this sub-synoptic scale snowband can be seen in Tomer Burg's storm-total snowfall map (http://www.atmos.albany.edu/mapdisco/20170210/images/20170209.png). The corridor of maximum snowfall from north-central Connecticut to southeastern New Hampshire marks the region where the aforementioned snowband was moving eastward the slowest.

4. Mohawk-Hudson Valley Convergence (MHC) mesoscale snowband:

A radar reflectivity loop of the evolution of the MHC can be found here (http://www.atmos.albany.edu/mapdisco/20170210/images/ENX.gif). Assorted imagery pertaining to this MHC feature can be found here (http://www.atmos.albany.edu/mapdisco/20170210/images/MHCimages.pdf). A good part of Friday map discussion was spent arguing about why the MHC mesoscale snowband formed to the west instead of to the east of the Hudson Valley as it usually does. The "traditional" cool-season MHC forms as a result of the confluence of west-northwesterly flow down the Mohawk Valley with northerly flow down the Hudson Valley. Details about the MHC, documented in Mike Augustyniak's 2008 M.S. thesis, can be found here (http://cstar.cestm.albany.edu/CAP_Projects/Project13/index.htm). Justin Minder and Brian Tang wondered whether the MHC in this case could have been driven by a horizontal convective roll-like instability in the presence of a steep lapse rate in a sheared environment. They suggested that one reason that the MHC formed farther west than it usually does was because it was a result of the aforementioned instability. A counter argument was that since the large-scale flow pattern at 1700 UTC 9 Feb, just prior to MHC snowband formation, featured a broadly confluent flow pattern with a north-south asymptote of confluence centered on the western side of the Hudson Valley it favored a more westward MHC formation region (http://www.atmos.albany.edu/mapdisco/20170210/images/MHCimages.pdf).

To address some of these questions, I used the NOAA HYSPLT trajectory model to compute 18 h back trajectories from the 3 km HRRR model ending at 1700 UTC 9 Feb 2017 at 100, 300, and 500 m above a station in the eastern Mohawk Valley (Amsterdam), a station at the mouth of the Mohawk Valley (Schenectady), and a station in the Hudson Valle). Maps of these three sets of back trajectories are appended below. Air parcels arrive at Amsterdam from the northwest, at Schenectady from the north and north-northeast, and at Albany from the north-northeast. The bulk of the horizontal confluence implied by these trajectories is between Amsterdam and Schenectady, and is consistent with the observed radar imagery and the large-scale surface flow pattern at 1700 UTC 9 Feb (http://weather.rap.ucar.edu/surface/displaySfc.php?region=alb&endDate=20170209&endTime=17&duration=0). Nick Bassill computed a loop of surface divergence, vector winds, and 3 h MSLP change from the New York Mesonet data for the period 1655–1835 UTC 9 Feb 2017 (http://www.atmos.albany.edu/facstaff/nbassill/live/CON.gif). Nick's analysis shows that the MHC is marked by a quasi-stationary, north-south oriented band of convergence centered where the Mohawk Valley joins the Hudson Valley. The MHC is fed on its eastern side by a N/NNE flow that looks to be entering New York State via western Vermont near the southern end of Lake Champlain and on its western side by a WNW flow down the Mohawk Valley. These trajectory maps indicate that there is likely at least some measure of larger scale control over the more westward location of the MHC in this event. Further investigation, including perhaps a WRF simulation, is required to sort out the details.

Philippe Papin used the HRRR 1 h forecast from the 1700 UTC 9 Feb 2017 to calculate an west–east oriented vertical cross section across the MHC along 42.8 N across the Hudson Valley valid at 1800 UTC 9 Feb. He also constructed a 10-m wind analysis from the HRRR centered on eastern New York at the same time. Both of Philippe's images can be found here (scroll to the last two images; http://www.atmos.albany.edu/mapdisco/20170210/images/MHCimages.pdf). Philippe's images show that frontogenesis along the MHC is shallow and is confined mostly below 950 hPa. Upward motion is strongest just above this frontogenesis region where west-northwesterly flow down the Mohawk Valley converges with northerly flow down the Hudson Valley. Note that the ascent maximum centered near 900 hPa is centered between the -12 C and -18 C isotherms, indicative that ascent in the dendritic growth zone is especially conducive to snow crystal growth and the production of relatively high snowfall rates. More generally, as Philippe noted, MHC events associated with relatively low-level cold air masses in which ascent coincides with the dendritic growth zone should be especially effective for growing ice crystals. Finally, the HRRR 10-m wind analysis valid 1800 UTC 9 Feb indicates that low-level NNE flow is present on the western side of the Hudson Valley north of where the Mohawk Valley joins the Hudson Valley. This result is consistent with the results of the aforementioned HRRR-derived trajectory analyses. At issue is whether this westward-displaced very low-level moist north-northeasterly flow could have contributed to orographic precipitation enhancement along the eastern edges of the higher terrain on the western side of the Hudson Valley.

Finally, I raised the issue as to whether isallobaric effects could also have contributed to the formation of a westward-displaced MHC in this case. Appealing to some "ancient" class handwritten notes of mine on….gasp…..yellow paper…..on the geostrophic departure vector and the isallobaric wind equation circa 1990 that were originally derived from even older notes by Fred Sanders (http://www.atmos.albany.edu/daes/atmclasses/atm509/protected/Lance_notes_isallobaric_wind.pdf), I raised the issue as to whether the dominant A term in the geostrophic wind equation at the bottom of p. 3 might have had some help in this case from term C which is normally an order of magnitude smaller than term A (1 m/s vs. 10 m/s). In this case, however, there was ~10 m/s of NNE shear below 1 km and the vertical motion was unusually vigorous in the MHC as evidenced by Philippe Papin's HRRR-based calculation above. Given a NNE shear vector and the fact that the local acceleration of the geostrophic wind would be in the direction of this shear vector, there would be a small component of the local acceleration of the geostrophic wind that would be directed westward. Far fetched? Probably, but worth checking out if only for an academic exercise.

In closing, I will remember this snow event fondly for awhile because I got to experience two snowbands. The first snowband was the most intense and produced ~6" in two hours with 4" falling between 1000–1100 UTC at which time I was unable to see a dense grove of trees from our bedroom window, Yes! The second snowband sat over my house between 1700–1930 UTC and produced ~5" of snow. I measured a storm-total of 16.2" with almost almost 11" of that total occurring in two bands. Definitely a keeper. I have no explanation as to why the atmosphere gift-wrapped me two intense snowbands in one storm. My working assumption is that the atmosphere must have thought I was still in Seattle.

Lance

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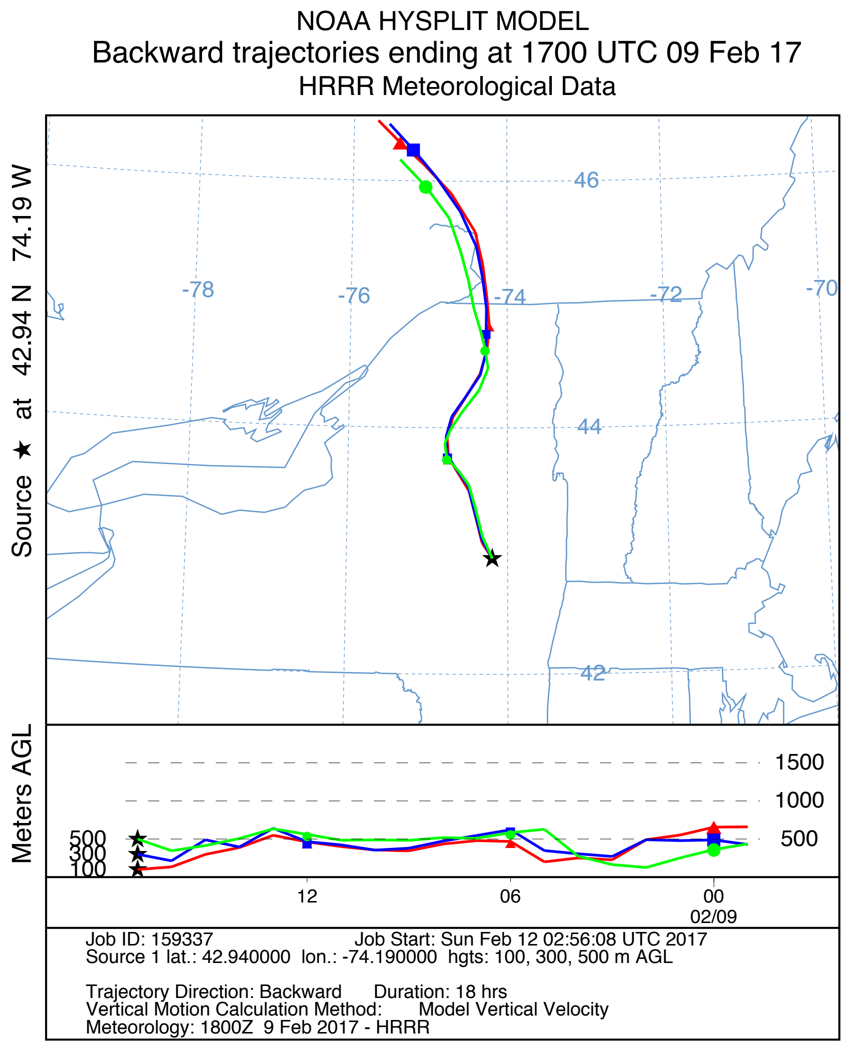
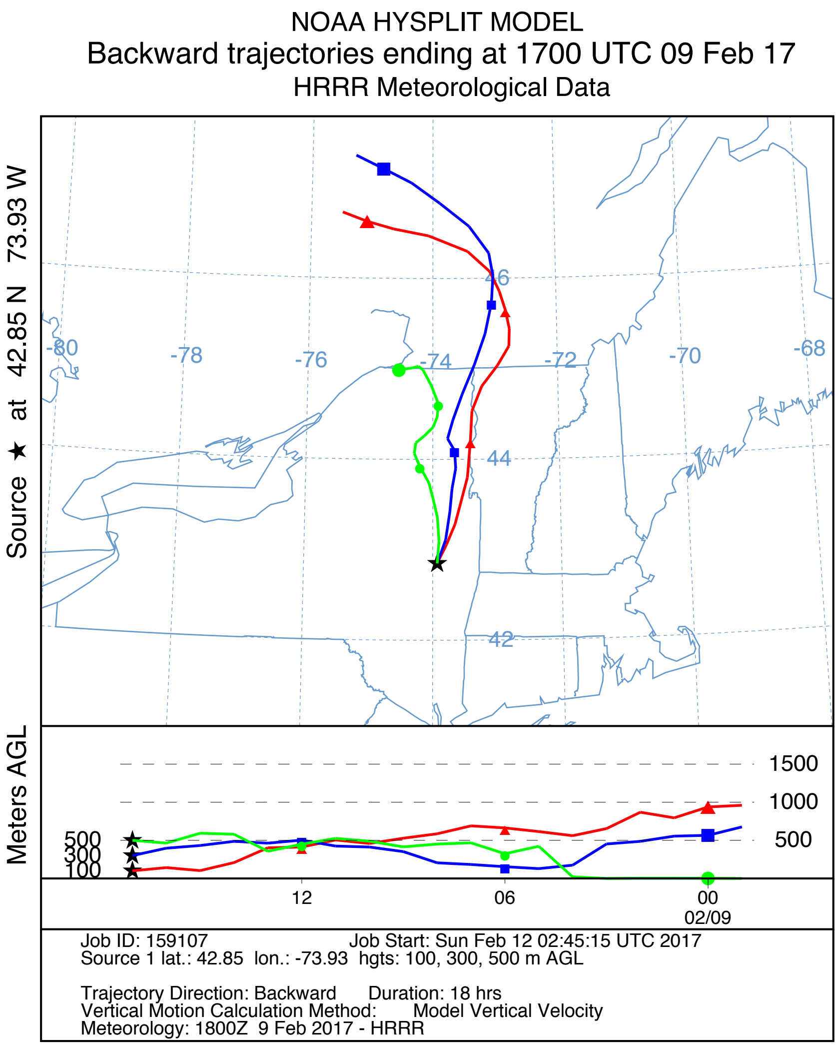
Amsterdam, NY:

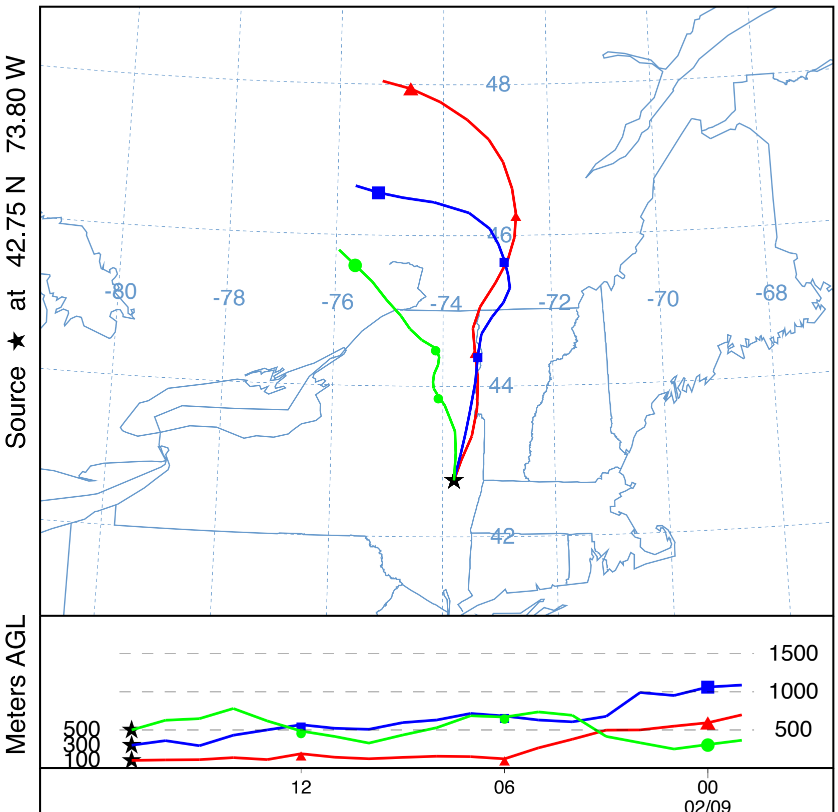


Schenectady, NY:



Albany, NY

NOAA HYSPLIT MODEL
Backward trajectories ending at 1700 UTC 09 Feb 17
HRRR Meteorological Data



Job ID: 159178 Job Start: Sun Feb 12 02:48:17 UTC 2017
Source 1 lat.: 42.75 lon.: -73.8 hgts: 100, 300, 500 m AGL

Trajectory Direction: Backward Duration: 18 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Meteorology: 1800Z 9 Feb 2017 - HRRR

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