March 2, 2018

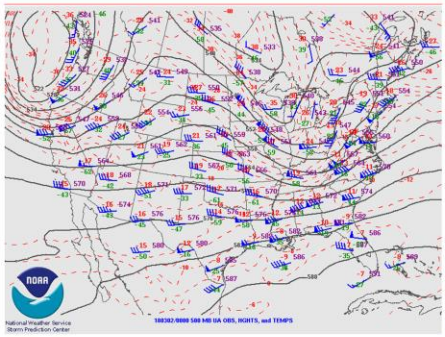
A major winter storm with p-type challenges at low elevations and extremely heavy snow at higher elevations.

Mike Evans

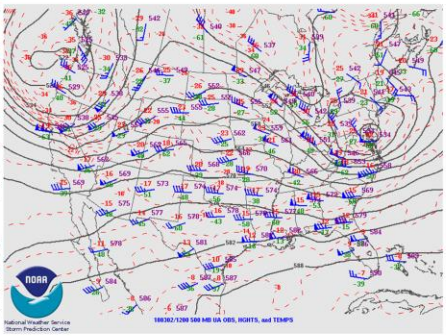
Outline

- Large-scale pattern
- Frontogenesis and banding
- Precipitation type forecasts
- Observations
- Summary

500 mb March 2, 2018



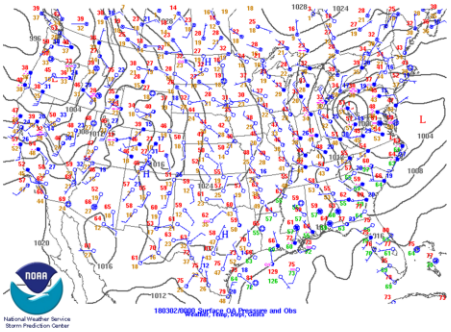
00z March 2, 2018



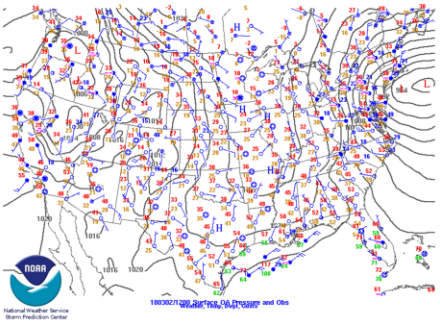
12z March 2, 2018

The 500 mb flow pattern with this storm featured a digging short wave moving east across the Ohio Valley. The wave deepened to become a closed-low along the mid-Atlantic coast.

Surface maps March 2, 2018



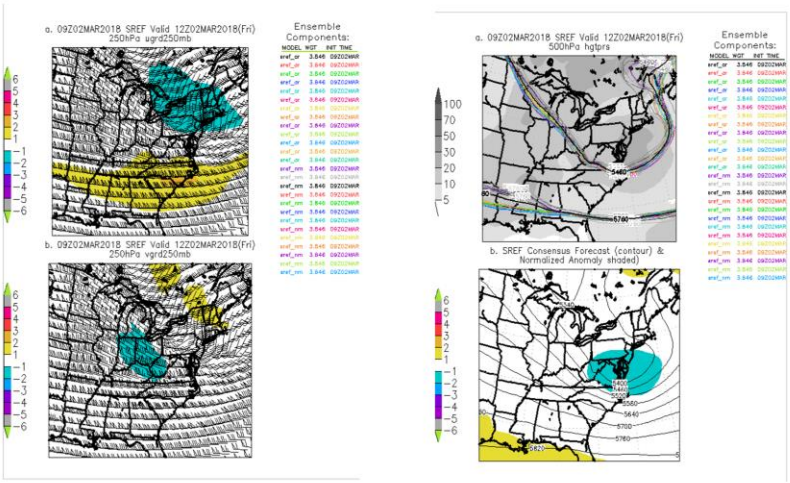
00z March 2, 2018



12z March 2, 2018

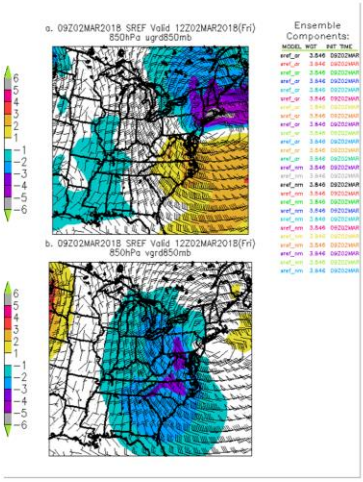
At the surface, the primary low pressure center was originally over the upper Ohio Valley, then shifted east off the east coast.

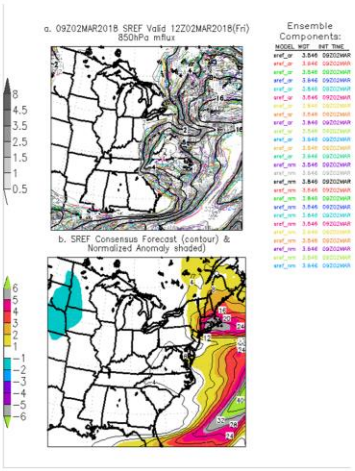
250 wind and 500 mb height anomalies



Mid-to-upper level winds and heights were not extremely anomalous with this event. The westerly component of the wind at 250 mb (upper left) indicated an upper-level jet moving off the mid-Atlantic coast, with the northern mid-Atlantic region within the left exit region. The 500 mb trough along the east coast was 1 to 2 standard deviations below normal (lower right).

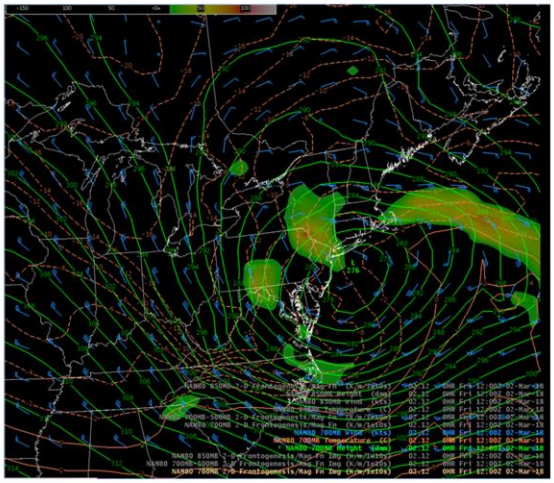
850 mb wind and moisture flux anomalies





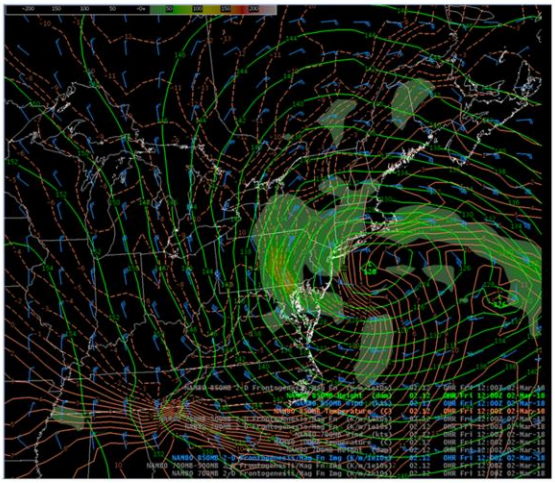
SREF forecasts of 850 mb easterly winds (upper left) were highly anomalous over southern New England, as was the moisture flux in that area (lower right).

00-hour 700 mb heights, wind, temperature and frontogenesis - 12z March 2nd



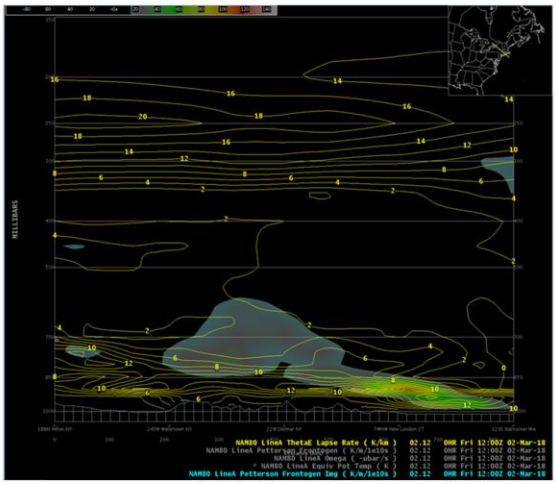
At 700 mb, a deep closed low was initialized along the east coast at 12z on the 2nd, which was near the peak of the storm for eastern New York and western New England. The shaded areas are regions of frontogenesis, the contours are temperature and wind barbs are blue; a band of frontogenesis was pivoting westward around the north side of the 700 mb low center.

00 hour 850 mb height , wind, temperature and frontogenesis - 12z March 2nd



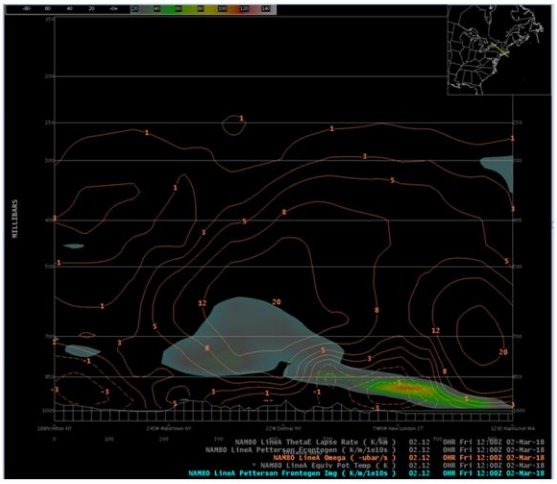
Features of note at 850 mb included 40-60 kt easterly winds across New England over-riding a frontal zone over central New York. Strong frontogenesis was indicated by the shaded area extending from central New York southward to central Pennsylvania.

Frontogenesis and lapse rate – 12z March 2



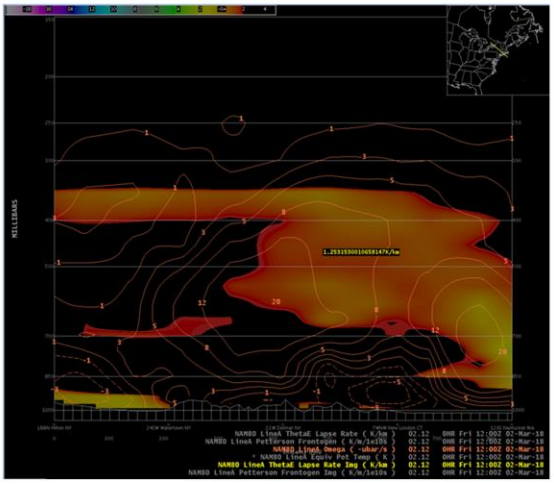
A cross-section taken across the front from southeast (right) to northwest (left) showed a sloping region of frontogenesis (shaded) based near the surface in the southeast near New York City, and sloping upward toward the eastern Great Lakes. A large area of small lapse rates (contoured), below 2 degrees C/km, can be seen above the frontal zone.

Frontogenesis and omega – 12z March 2



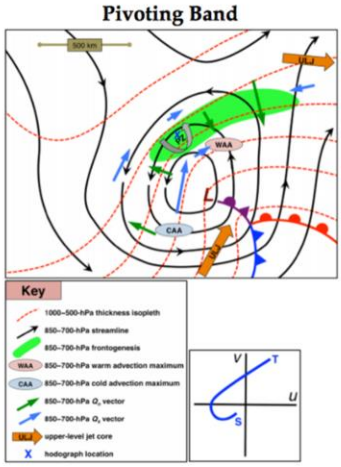
Vertical motion (contoured) was tied strongly to the frontogenesis, with maxima of lift (contoured) located above the sloping frontal zone (frontogenesis, shaded).

Omega and lapse rate – 12z March 2



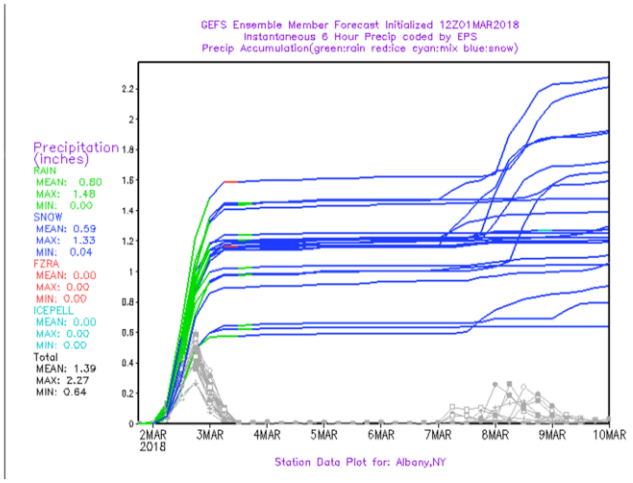
This slide shows areas of theta-e lapse rate below +2 C/km shaded. Vertical motion is contoured. Note that the lift associated with the frontogenesis extends upward into the shaded areas; vertical motion in areas of reduced stability is favorable for narrowing and intensification of frontogenetical circulations and intensified banding.

Pivoting band conceptual model (from Kenyon / CSTAR research)



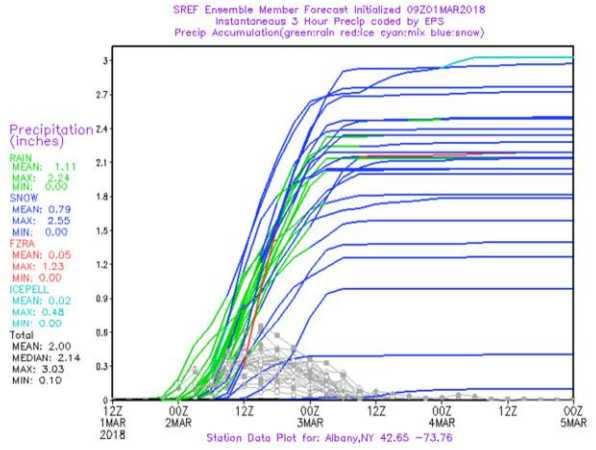
The schematic shown on this slide is a review of the pattern identified by James Kenyon for pivoting snow bands from his CSTAR research. Key features of note included the closed mid-level circulation, strong frontogenesis north-northwest of the circulation, coupled upper-level jets and a warm advection / cold advection dipole across the storm. The flow pattern associated with the March 2nd storm appeared to be quite similar to the pivoting snow band conceptual model.

12z March 1 GEFS QPF plumes at ALB



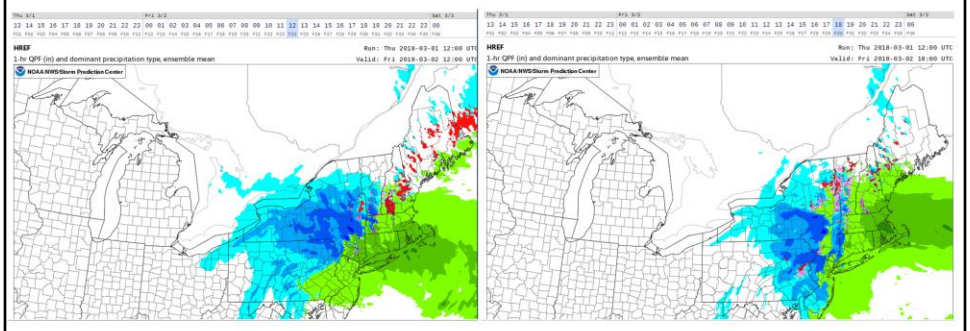
Precipitation type would turn out to be a very challenging issue for lower elevations in eastern New York including the Hudson River Valley. QPF plumes from the GEFS run at 12z on March 1st showed a period of precipitation on the 2nd that would be mostly rain at Albany (green plumes), however some members were indicating a period of snow (blue plumes).

09z March 1 SREF QPF plumes at ALB



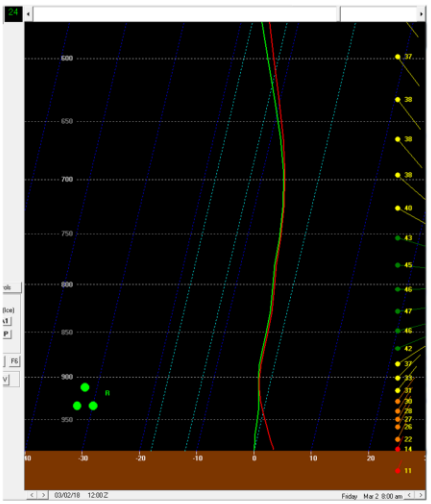
SREF plumes run at 09z on March 1st showed a period of heavy precipitation with a mix of rain and snow. In general, the QPF was somewhat higher than the GEFS forecasts, and more model runs indicated longer periods of snow.

12z Mar 1 HREF p-type valid 12z and 18z March 2nd

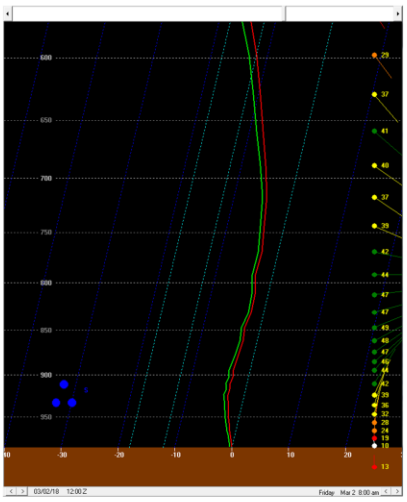


The HREF run at 12z on the 1st and concentrating on the Albany area showed a period of snow early on the 2nd, however the precipitation would change to rain in the Hudson valley by 18z. (Heavy snow was forecast to fall over higher terrain especially west of the Hudson valley through the period).

12z March 1st GFS and NAM valid at ALB at 12z March 2nd



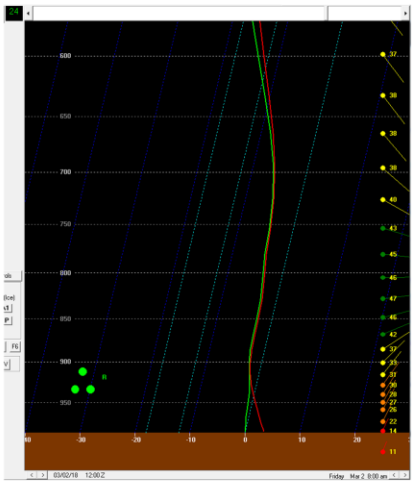
12z March 1st GFS valid 12z March 2nd

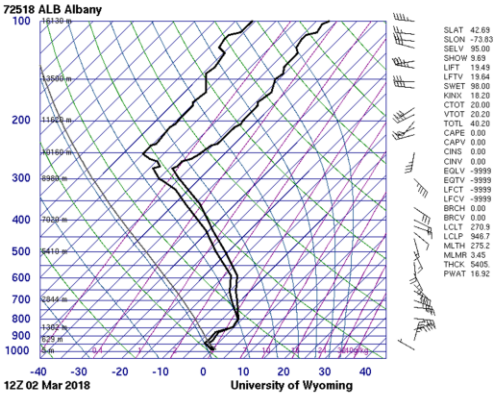


12z March 1st NAM valid 12z March 2nd

A forecast sounding from the 12z March 1 run of the GFS valid at ALB (left) at 12z on March 2nd is compared to a sounding from the 12z March 1 run of the NAM valid at ALB at 12z on March 2nd (right). The boundary layer is considering warmer in the GFS forecast, and a dry layer can be seen creating an apparent inverted V profile.

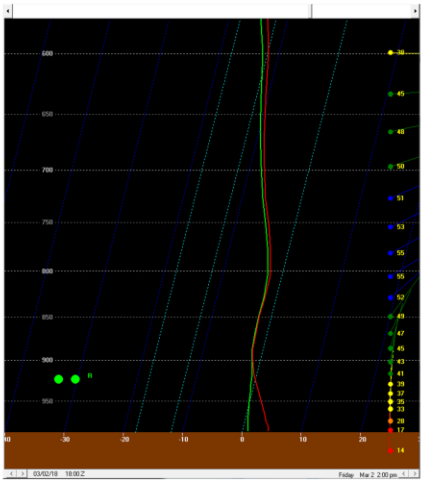
GFS 24 hour forecast vs. observed sounding valid at ALB at 12z March 2nd



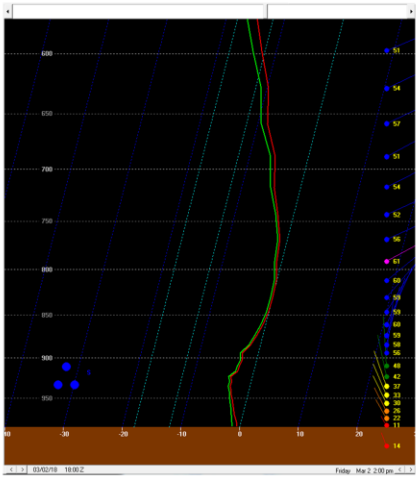


A comparison between the 24 GFS forecast valid at 12z on March 2nd at ALB and the observed ALB sounding at 12z on the 2nd shows some significant errors with the GFS forecast. The GFS was too warm, dry and unstable in the boundary layer. In addition, the GFS did not forecast the inversion which was observed between 900 and 800 mb.

12z March 1st GFS and NAM valid 18z March 2nd at ALB



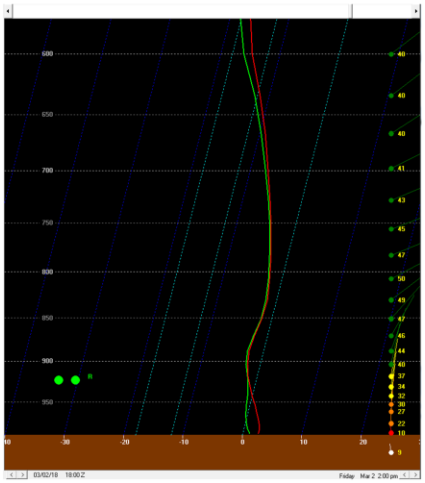
12z March 1 GFS valid 18z March 2



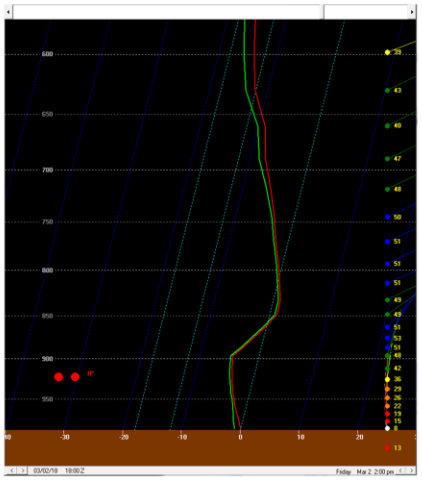
12z March 1 NAM valid 18z March 2

A comparison between the 12z run of the GFS (left) and NAM (right) models valid at ALB at 18z continued to show a warmer, dryer boundary layer on the GFS profile, compared to a colder low-level profile on the NAM. Note also that the NAM is forecasting a more pronounced inversion above 900 mb, while the GFS appears more isothermal from 900 to 850 mb. Forecast precipitation was also somewhat heavier on the NAM.

00z March 2nd GFS and NAM valid 18z March 2nd at ALB



00z March 2 GFS valid 18z March 2



00z March 2 NAM valid 18z March 2

The 00z March 2nd runs of the GFS and NAM continued to show the same discrepancies between the two models seen in earlier runs. The GFS had a warmer boundary layer, while the NAM was colder with a stronger inversion based around 900 mb.

Hourlies at ALB

6:51 PM	43.0 °F	36.4 °F	28.0 °F	56%	29.79 in	10.0 mi	NNE	12.7 mph	19.6 mph	N/A		Overcast
7:51 PM	41.0 °F	33.5 °F	28.0 °F	60%	29.76 in	10.0 mi	North	13.8 mph	-	N/A		Overcast
8:51 PM	37.9 °F	30.9 °F	28.0 °F	68%	29.74 in	10.0 mi	NNE	10.4 mph	24.2 mph	N/A		Overcast
9:51 PM	37.9 °F	30.0 °F	27.0 °F	65%	29.71 in	10.0 mi	North	12.7 mph	-	N/A		Overcast
10:51 PM	37.0 °F	28.1 °F	27.0 °F	67%	29.69 in	10.0 mi	NNE	15.0 mph	-	0.00 in	Snow	Light Snow
11:51 PM	35.1 °F	26.9 °F	28.9 °F	78%	29.66 in	8.0 mi	NNE	11.5 mph	-	0.00 in	Snow	Light Snow

Hourly Weather History & Observations

Time (EST)	Temp.	Windchill	Dew Point	Humidity	Pressure	Visibility	Wind Dir	Wind Speed	Gust Speed	Precip	Events	Conditions
12:22 AM	34.0 °F	26.6 °F	28.0 °F	79%	29.66 in	2.5 mi	North	9.2 mph	-	0.00 in	Snow	Light Snow
12:28 AM	34.0 °F	26.0 °F	28.0 °F	79%	29.66 in	1.5 mi	NNE	10.4 mph	-	0.00 in	Snow	Light Snow
12:51 AM	33.1 °F	24.9 °F	28.9 °F	85%	29.65 in	1.2 mi	NNE	10.4 mph	-	0.03 in	Snow	Light Snow
1:02 AM	33.1 °F	23.9 °F	30.0 °F	89%	29.65 in	1.5 mi	North	12.7 mph	-	0.01 in	Snow	Light Snow
1:09 AM	33.1 °F	24.4 °F	28.9 °F	85%	29.64 in	0.8 mi	North	11.5 mph	-	0.02 in	Snow	Light Snow
1:19 AM	33.1 °F	25.5 °F	30.0 °F	89%	29.65 in	1.0 mi	NNE	9.2 mph	-	0.05 in	Snow	Light Snow
1:27 AM	33.1 °F	25.5 °F	30.0 °F	89%	29.65 in	1.0 mi	North	9.2 mph	-	0.06 in	Snow	Light Snow
1:51 AM	33.1 °F	25.5 °F	28.9 °F	85%	29.65 in	1.0 mi	North	9.2 mph	-	0.11 in	Snow	Light Snow
2:06 AM	32.0 °F	23.6 °F	28.9 °F	88%	29.63 in	0.8 mi	North	10.4 mph	-	0.02 in	Snow	Light Snow
2:20 AM	32.0 °F	23.0 °F	28.9 °F	88%	29.62 in	0.5 mi	North	11.5 mph	-	0.05 in	Fog , Snow	Snow
2:51 AM	32.0 °F	23.6 °F	30.0 °F	92%	29.62 in	0.5 mi	North	10.4 mph	-	0.13 in	Fog , Snow	Snow
3:27 AM	32.0 °F	21.6 °F	30.0 °F	92%	29.58 in	0.5 mi	North	15.0 mph	-	0.11 in	Fog , Snow	Snow
3:51 AM	33.1 °F	22.2 °F	30.0 °F	89%	29.58 in	0.5 mi	North	17.3 mph	27.6 mph	0.14 in	Fog , Snow	Snow
4:17 AM	33.1 °F	22.6 °F	30.0 °F	89%	29.57 in	0.8 mi	North	16.1 mph	21.9 mph	0.05 in	Snow	Light Snow
4:41 AM	33.1 °F	23.0 °F	30.0 °F	89%	29.56 in	0.5 mi	North	15.0 mph	25.3 mph	0.08 in	Fog , Snow	Snow
4:51 AM	32.0 °F	20.5 °F	30.0 °F	92%	29.57 in	0.5 mi	North	18.4 mph	25.3 mph	0.10 in	Fog , Snow	Snow
5:07 AM	33.1 °F	21.5 °F	30.0 °F	89%	29.55 in	0.8 mi	NNE	19.6 mph	26.5 mph	0.02 in	Snow	Light Snow
5:26 AM	33.1 °F	22.2 °F	30.0 °F	89%	29.54 in	1.0 mi	NNE	17.3 mph	25.3 mph	0.04 in	Snow	Light Snow
5:51 AM	33.1 °F	21.9 °F	30.0 °F	89%	29.55 in	1.0 mi	North	18.4 mph	28.8 mph	0.05 in	Snow	Light Snow
6:14 AM	33.1 °F	22.2 °F	30.0 °F	89%	29.53 in	0.8 mi	North	17.3 mph	28.8 mph	0.01 in	Snow	Light Snow
6:30 AM	33.1 °F	22.6 °F	30.0 °F	89%	29.53 in	0.5 mi	North	16.1 mph	29.9 mph	0.04 in	Fog , Snow	Snow
6:51 AM	33.1 °F	21.9 °F	30.0 °F	89%	29.54 in	0.5 mi	NNE	18.4 mph	25.3 mph	0.06 in	Snow	Light Snow

The hourly observations at Albany during the onset of the storm showed that the precipitation began as snow late in the evening on the 1st, and continued as snow all night. Dew points fell into the mid to upper 20s ahead of the storm during the evening, then temperatures cooled to between 32 and 33 as heavier precipitation developed.

Hourlies at ALB

7:24 AM	33.1 °F	21.9 °F	30.0 °F	89%	29.53 in	0.8 mi	North	18.4 mph	27.6 mph	0.04 in	Snow	Light Snow
7:45 AM	33.8 °F	21.9 °F	30.2 °F	87%	29.54 in	0.5 mi	North	21.9 mph	31.1 mph	0.05 in	Fog , Snow	Snow
7:51 AM	33.1 °F	20.6 °F	30.0 °F	89%	29.55 in	0.5 mi	North	23.0 mph	31.1 mph	0.05 in	Fog , Snow	Snow
8:08 AM	33.1 °F	21.5 °F	30.0 °F	89%	29.53 in	0.2 mi	North	19.6 mph	27.6 mph	0.02 in	Fog , Snow	Heavy Snow
8:47 AM	33.8 °F	23.2 °F	30.2 °F	87%	29.54 in	0.2 mi	North	17.3 mph	26.5 mph	0.09 in	Fog , Snow	Heavy Snow
8:51 AM	33.1 °F	21.2 °F	30.0 °F	89%	29.55 in	0.2 mi	North	20.7 mph	26.5 mph	0.09 in	Fog , Snow	Heavy Snow
9:04 AM	33.1 °F	22.2 °F	30.0 °F	89%	29.55 in	0.2 mi	North	17.3 mph	27.6 mph	0.02 in	Fog , Snow	Snow
9:51 AM	33.1 °F	22.2 °F	30.0 °F	89%	29.57 in	0.2 mi	North	17.3 mph	-	0.08 in	Fog , Snow	Snow
9:58 AM	33.1 °F	22.6 °F	30.0 °F	89%	29.56 in	0.5 mi	North	16.1 mph	23.0 mph	0.01 in	Fog , Snow	Snow
10:27 AM	34.0 °F	24.6 °F	30.0 °F	85%	29.58 in	1.0 mi	North	13.8 mph	26.5 mph	0.04 in	Snow	Light Snow
10:51 AM	34.0 °F	23.4 °F	30.0 °F	85%	29.60 in	1.0 mi	North	17.3 mph	25.3 mph	0.06 in	Snow	Light Snow
11:03 AM	34.0 °F	24.6 °F	30.9 °F	89%	29.59 in	0.8 mi	North	13.8 mph	23.0 mph	0.01 in	Snow	Light Snow
11:51 AM	34.0 °F	24.6 °F	30.9 °F	89%	29.62 in	0.8 mi	North	13.8 mph	21.9 mph	0.05 in	Snow	Light Snow
12:51 PM	34.0 °F	23.8 °F	30.9 °F	89%	29.64 in	0.8 mi	North	16.1 mph	24.2 mph	0.06 in	Snow	Light Snow
1:51 PM	34.0 °F	24.6 °F	30.0 °F	85%	29.67 in	0.8 mi	North	13.8 mph	21.9 mph	0.04 in	Snow	Light Snow
2:37 PM	34.0 °F	24.6 °F	30.0 °F	85%	29.69 in	1.0 mi	North	13.8 mph	23.0 mph	0.01 in	Snow	Light Snow
2:51 PM	34.0 °F	25.0 °F	30.0 °F	85%	29.71 in	1.0 mi	North	12.7 mph	-	0.02 in	Snow	Light Snow
3:15 PM	34.0 °F	24.2 °F	30.0 °F	85%	29.72 in	10.0 mi	North	15.0 mph	21.9 mph	0.00 in	Snow	Light Snow

Hourly conditions during the day on the 2nd showed that temperatures remained nearly steady between 33 and 34 degrees as moderate to heavy snow fell. Some sleet was reported across portions of the Capital District as well, indicating that there likely was an inversion between 900 and 800 mb, similar to what was shown in the NAM forecasts.

GFS MAV temperatures at ALB

[KALB] GFS MOS tmp Table Centered On: 2018 Mar 05, 00Z

	Model Run Initialized at:							
Valid:	**01/12Z**	**01/18Z**	**02/00Z**	**02/06Z**	**02/12Z**	**02/18Z**	**03/00Z**	**03/06Z**
02/00Z	48	45						
02/03Z	45	43						
02/06Z	43	43	37					
02/09Z	42	42	37					
02/12Z	40	40	36	40				
02/15Z	42	41	39	40				
02/18Z	44	42	41	42	39			
02/21Z	43	41	40	41	38			
03/00Z	42	40	40	40	38			

The MAV temperature forecasts at ALB for several runs of the GFS are shown on this table. Note that forecast high temperatures from 06z on the 2nd to 00z on the 3rd were in the lower to mid 40s in earlier runs, and trended slightly cooler with time. However, even the 12z run on the 2nd predicted temperatures well above freezing (upper 30s) during the storm.

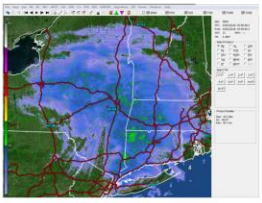
NAM MET temperatures at ALB

[KALB] NAM MOS tmp Table Centered On: 2018 Mar 05, 00Z

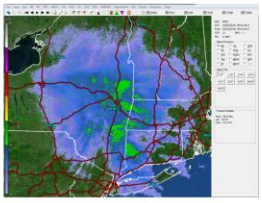
	Model Run Initialized at:			
Valid:	**01/12Z**	**02/00Z**	**02/12Z**	**03/00Z**
02/00Z	44			
02/03Z	41			
02/06Z	41	37		
02/09Z	40	37		
02/12Z	38	35		
02/15Z	33	35		
02/18Z	34	35	34	
02/21Z	33	34	33	
03/00Z	34	33	33	

The NAM-based MET forecasts were much colder than the GFS-based MAV guidance. The verifying high temperature on the 2nd was 34, so these forecasts were quite good, although note that this guidance was still too warm during the onset of the storm from 00z through 12z on the 2nd. However all runs forecast temperatures in the mid 30s during the day on the 2nd, which was quite accurate.

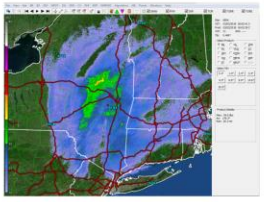
KENX Reflectivity



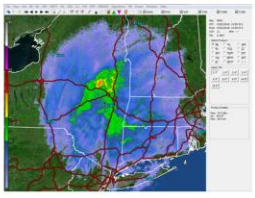
06z March 2nd



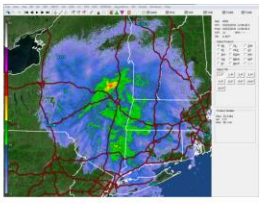
09z March 2nd



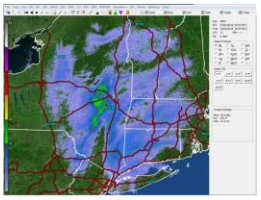
12z March 2nd



15z March 2nd



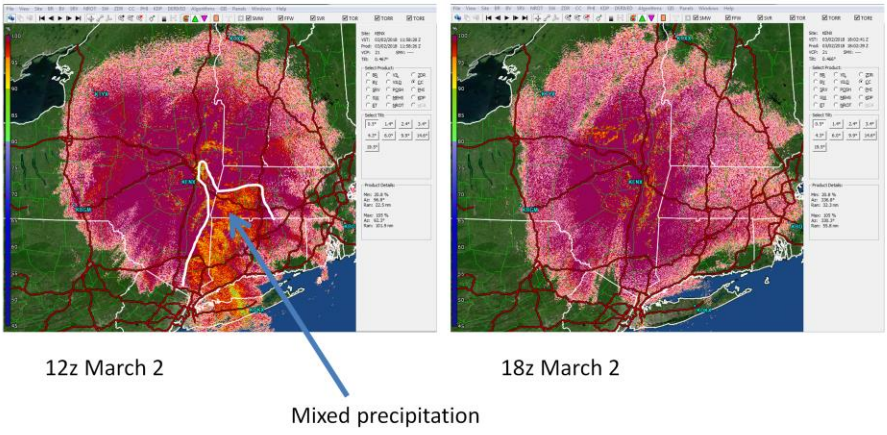
18z March 2nd



21z March 2nd

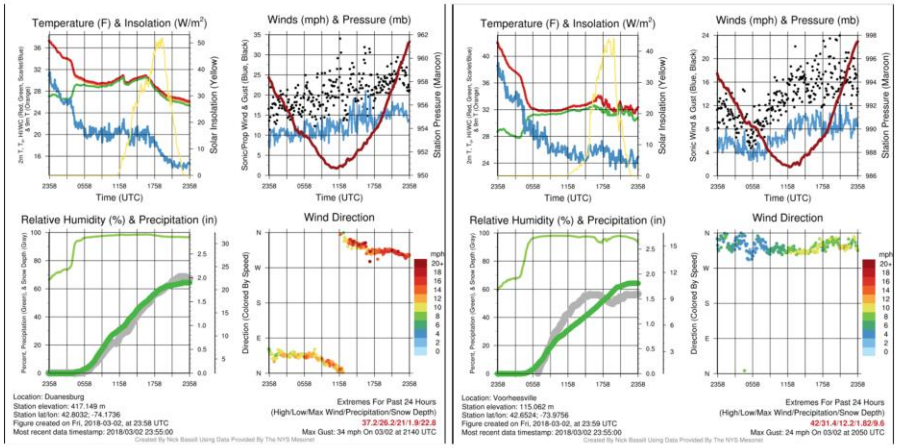
Reflectivity from the KENX radar shows a large area of snow overspreading the area during the predawn hours on the 2nd. Heavy banding developed by 12z on the 2nd and appeared to pivot near to just west of the Capital District. Some of the highest reflectivities were associated with mixed precipitation near to just north-northwest of Albany.

KENX correlation coeficient



The mixed precipitation could be identified from the correlation coefficient product (CC) at 12z on the 2nd. At that time, mixed precipitation was occurring from southwest New England northwest to near Albany. By 12z most of the mixed precipitation had changed to snow, at least at the level of the radar beam (which was several thousand feet above the ground over southwest New England).

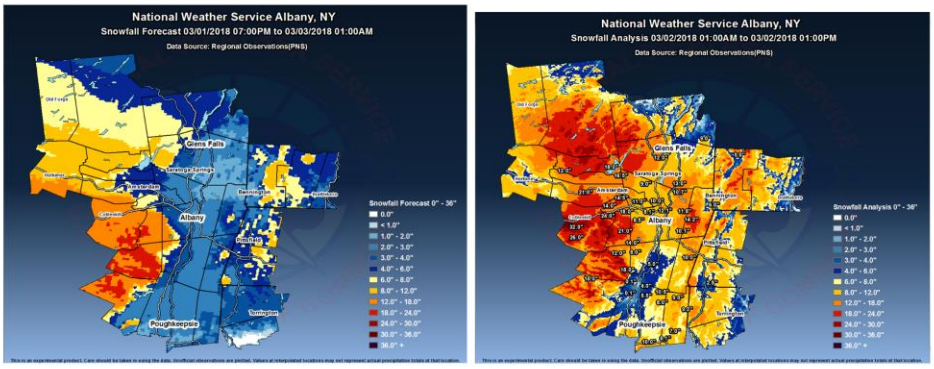
Meso-net data – Duanesburg vs. Voorheesville



Duanesburg Voorheesville

A review of meso-net data at Duanesburg, located over higher terrain west of Albany (left) and Voorheesville, located about 300 feet above sea-level south of Albany showed that temperatures remained near 30 at Duanesburg through the storm (upper left), while temperatures were near to just above 32 at Voorheesville (right).

Forecast vs observed snowfall



Forecast snowfall for eastern NY and western New England is compared to observed snowfall on this slide. Snowfall at Albany was around a foot. The lowest elevations along the Hudson River Valley south of Albany had variable snowfall amounts generally less than or equal to 6 inches, while many locations at higher elevations west of the Hudson Valley had over 2 feet. While this presentation focused largely on the forecast snowfall challenges in the immediate Albany area, other interesting features were noted. For example, large snowfall gradients were observed within the Hudson Valley south of Albany, with less than 2 inches reported at the base of the Catskill mountains while areas just a few miles away and at similar elevation reported around 6 inches.

Summary

- A major storm on March 2nd, 2018 was associated with major precipitation type forecast challenges in the Hudson Valley of eastern New York.
- The synoptic pattern was favorable for a significant, pivoting snowband.
- Models indicated a mix of precipitation.
- The NAM was colder than the GFS in the boundary layer which turned out to be correct.
- GFS MAV guidance in particular was much too warm for this case.
- Forecasts then blended NAM and GFS inputs under-forecast the snow that fell in the Hudson valley around Albany, as the precipitation remained in the form of snow during the event.
- Questions resulting from this event include why the GFS was so warm in the boundary layer, and does the GFS have a boundary layer warm bias in these types of events that should be considered the next time we are faced with a similar case.