P9.5 An Application of a Cutoff Low Forecaster Pattern Recognition Model to the 30 June - 2 July 2009 Significant Event for the Northeast

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1. INTRODUCTION

Predicting the sensible weather associated with cutoff lows remains a challenge to operational forecasters. The potential for severe weather, flooding, heavy precipitation, or non-impact sensible weather relies heavily on the track of a cutoff low, shear and instability profiles downstream, and various synoptic and mesoscale meteorological parameters. The Collaborative Science Technology and Applied Research (CSTAR) program has studied warm season cutoff lows impacting the Northeast for nearly a decade. Most recently, results have yielded an expanded precipitation climatology with cutoffs in the months of June to September across the Northeast, as well as five key patterns of cutoffs based on the tilt of the longwave 500 hPa trough (Figures 1 and 2). These five distinct conceptual or pattern recognition models examine lower-, middle-, and upper-level synoptic and mesoscale features such as temperature and moisture profiles, low-level jets and mid- and upper-level jet streaks associated with the cutoff and the sensible or extreme weather it produces.

A Great Lakes 500 hPa cutoff low impacted the Northeast from 30 June to 2 July 2009. On 30 June the cutoff resembled a neutral tilt "Type A" pattern (Fig. 1b) identified in CSTAR work. As the cutoff meandered eastward across Michigan (MI), severe convection became focused ahead of a surface trough and a potent mid-level short-wave trough, which were rotating around the cutoff. In addition, differential cyclonic vorticity advection and a potent upper-level jet streak helped to initiate the convection. The mesoscale environment featured steepening mid-level lapse rates, lowering wet bulb zero heights, modest low-level moisture and appreciable surface-based instability. On 30 June these synoptic and mesoscale features led to approximately 40 severe weather reports of damaging winds in excess of 50 knots (58 mph), and severe hail (greater than 1.9 cm) from Pennsylvania (PA) and New Jersey (NJ) northeast into New York (NY) and New England (U.S. Department of Commerce, Storm Data 2009).

A multi-scale analysis approach is utilized by applying the cutoff low conceptual model for the first day of the event. This application is done in order to understand the convective environment that produced the severe weather and isolated flash flooding on this day. Significant emphasis is placed on the use of observational data to find clues that led to the active weather with the Great Lakes warm season cutoff low.

2. DATA

Observational data used in the analysis include surface and upper air observations, satellite imagery, and KENX WSR-88D data. The WSR-88D data is high resolution 8-bit data from KENX. SPC upper air charts and soundings are also used (www.spc.noaa.gov). Short-Range Ensemble Forecast (SREF) data are examined (Tracton et al. 1998). The SREF consisted of 21 members (10 Eta, 5 Regional Spectral Model, and 6 WRF). Standardized anomalies (Grumm and Hart 2001) are calculated by using a 21-day (6-hour interval) centered mean of heights, U and V winds and precipitable water (PWAT) values over a 30-year period (1970-1999) using the North American Regional Reanalysis data (Mesinger et al. 2006). The 0.5° Global Forecast System (GFS) gridded analyses are also utilized (Scalora 2009).

3. BACKGROUND AND PAST WORK

A subjective cutoff low climatology impacting the Northeast from 1980-2000 in the months of May to September established seven categories and five key tracks of cutoffs (Novak et al. 2002, Najuch et al. 2004, Najuch 2004). There were

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170 cutoff lows in the climatology. These tracks consisted of the following: Northwest, Great Lakes, Southwest, Zonal, and Atlantic or Coastal (Fig. 3). There were also two minor categories that were miscellaneous and tropical cyclones. The Great Lakes and Northwest tracks accounted for about two thirds of the cases.

Furthermore, precipitation distributions were done for cutoff cyclones impacting the Northeast for the months of June to September from 1948-98 based on the National Centers for the Environmental Prediction(NCEP)/ Climate Prediction Center (CPC) Unified Precipitation Dataset (UPD) (Higgins et al. 1996). A comprehensive climatology was done for each month calculating the instantaneous daily average precipitation amount per day from cutoffs, and the percentage of climatological precipitation from the 500 hPa cutoffs (Najuch 2004). For example, the June daily average precipitation amount from cutoffs and the percentage from climatology of rainfall are shown in Figure 4 (Najuch 2004). Some locations in PA and southwestern NY can receive greater than 5 mm/day of precipitation when a cutoff cyclone is present. Also some strong orographic signals are present with greater than 5 mm/day possible near the White Mountains (Mt. Washington) in NH and the Catskill Mountains in southeastern NY (Fig. 4a). The greatest climatological percentage of precipitation (> 50%) from cutoffs in the month of June occurred across southeastern NY, eastern New England, and portions of PA (Fig 4b). It was determined that the heavy rainfall corridors generally occurred based on the track of the cutoff, its associated vorticity maxima's moving through the cutoff large scale trough based on its tilt, and the location of mid- and –upper level jet streaks (not shown).

Scalora (2009) identified five key synoptic-scale flow patterns of cutoffs based on the tilt of the longwave 500 hPa trough. These five conceptual or pattern recognition models were created to aid operational forecasters in the Northeast assess the sensible or significant weather threat (severe weather, flash flooding, etc.). The conceptual models examined lower-, mid-, and upper-level synoptic and mesoscale features based on the 500 hPa cutoff tilt. The pattern recognition or conceptual models included: two positive tilt (Type A and B), two neutral tilt (Type A and B) (Fig. 1), and one negative tilt (Fig. 2) from 20 cases in June to September 2000-08 examining 45 "Storm" days. A "Storm" day was an active weather day with severe weather or flash flooding that fit into a synoptic-scale flow pattern, and then was stratified based on the 500 hPa cutoff-trough tilt system. Precipitation, height, wind, and precipitable water (PWAT) anomaly data were also examined.

The most common pattern was the neutral tilt "Type A" (Fig. 1b), which occurred in seven of the 20 cases in the study. The composite cutoff was centered near the eastern Great Lakes region. A southerly low-level jet of 30 kts or greater was common near southern New England and NY. Differential cyclonic vorticity advection associated with a mid-level vorticity maximum rotating around the cutoff cyclone acts as a principle lifting mechanism. Sometimes, a sea-breeze front and a surface trough can provide low-level convergence to act as additional lifting mechanisms. The low-level south or southeast flow off the western Atlantic helped usher in low-level moisture (PWATs > 35 mm) over NY and New England. The study showed the various lifting mechanisms can generate stratiform and convective rainfall with this set-up. Severe weather was much more common with this conceptual model compared to either of the positive tilt ones. There was an average of 33 severe weather reports per day with this pattern (Scalora 2009). The big difference between the neutral tilt "Type B" and "Type A" patterns was that the cutoff is centered south of James Bay and followed a Northwest cutoff track (Novak et al 2002). The severe weather reports in the "Type B" pattern were also extremely high in the four out of 20 cases (57 per day.)

4. JUNE 30 2009 SYNOPTIC OVERVIEW

A cutoff low centered over eastern MI, Lake Huron and southern Ontario impacted the Northeast at 1200 UTC 30 June 2009 (Fig. 5). The synoptic environment fit very closely into the Neutral Tilt "Type A" conceptual model (Fig. 1b). The core of the coldest air at 500 hPa was -17ºC over Lake Superior and MI. A strong mid-level jet streak of 50-60 kts approached the Northeast from the Midwest and Mid Atlantic region. Several short-wave troughs rotated through the neutral-tilted mid-level trough over the Great Lakes region and into the Northeast. At 300 hPa, an area of upper level divergence over northern NY and New England occurred well in advance of a 75-80 kt jet streak over the Midwest and the Ohio (OH) Valley (Fig. 6). Portions of the Northeast were located in the vicinity of the left front quadrant of the mid- and upper-level jet streaks (Uccellini and Kocin 1987), which led to the area being conducive for severe weather during the afternoon.

Grumm and Hart (2001), and Stuart and Grumm (2009) showed standardized anomalies to be an effective approach for analyzing and forecasting significant weather events. The 1500 UTC SREF data had a 500 hPa height anomaly 3 to 4 standard deviations lower than normal over OH, southern MI, western PA and Lake Erie indicative of the strong cold pool aloft (not shown). The 3-hour forecast from the 1500 UTC SREF showed very strong positive V component wind anomalies of 1 to 3 standard deviations above normal over upstate NY, much of western New England, Long Island, NJ, and the Delmarva Region (Fig. 7). Despite this anomalous low level jet, PWAT values were only near normal to slightly above normal for the same time.

The 1500 UTC surface map depicted a surface trough (Fig. 1b) over west-central NY and PA ahead of an occluded boundary associated with the cutoff low (Fig. 8). Surface dewpoints were generally in the 15-17°C range across eastern NY and western New England. Clouds tops cooled ahead of the trough with developing showers and thunderstorms. The high resolution 0.5° GFS at 1800 UTC showed that cyclonic vorticity advection associated with the cutoff would impact eastern NY and New England in the afternoon (Fig. 9). The mid-level short-wave trough critical to the conceptual model as a key lifting mechanism for significant weather moved across north-central PA into NY during the early afternoon.

5. MESOSCALE AND SOUNDING ANALYSIS

The 1800 UTC 0.5° GFS initial analysis had an 850 hPa theta-e ridge over eastern NY and western New England. Theta-e values were in the 327-330 K range under this ridge (Fig. 10). A low-level jet of 25 kts (just below 30 kts from the conceptual model) transported Atlantic moisture over much of the region. The high resolution GFS also had surface-based convective available potential energy (SBCAPE) values predominantly of 500-1500 J kg^{-1} in place over much of eastern NY and western New England (Fig. 11). The model indicated a minimum in SBCAPE over southwestern New England. The 1000-500 hPa deep shear was generally between 25-35 kts from the GFS.

A special 1800 UTC sounding was taken at Albany. This sounding (Fig. 12) showed critical information pertaining to the mesoscale environment. The freezing level was 10.8 kft AGL, the -20°C height 22.1 kft AGL, and the wet-bulb zero height just under 10 kft AGL. The 850-500 hPa lapse rates were close to 6.5°C km^{-1}, the SBCAPE and Most Unstable CAPE values were 1,753 J kg^{-1}, the Mixed Layer CAPE was less than 1000 J kg^{-1}, and the Lifted Index was -4°C. There was 35 kts of shear in the 0-6 km layer indicative of mainly multicellular thunderstorm development. The atmosphere would have been more conducive for supercells and tornadoes, if there was lower Lifting Condensation Level heights, more Mixed Layer CAPE and deep shear (Thompson et al 2003). The flow was fairly unidirectional from the surface to 500 hPa. The strong southerly flow in the lower to mid troposphere indicated the potential for training thunderstorms and heavy rainfall despite the PWATS being only around 30 mm (1.24 inches). The multicellular clusters that did form had the potential to merge into lines with the persistent south to southwest flow aloft. A Severe Thunderstorm Watch box was issued for most of the ALY WFO forecast area that afternoon with large severe hail and damaging winds (wet microbursts) the main threats. There was an outside chance of flash flooding if any convection continuously moved over the same area.

6. BRIEF STORM-SCALE RADAR ANALYSIS

A multicellular cluster of convection formed ahead of the short-wave trough over central NY and moved north-northeast into the western Mohawk Valley. At 1723Z, this cluster was northwest of the KENX RDA in western Montgomery County (not shown). The 0.5° super resolution base reflectivity product had 66 dBZ near the town of Saint Johnsville. The Four Dimensional Stormcell Investigator (FSI) showed impressive vertical structure with this storm capable of producing large severe hail. The Constant Altitude Planned Position Indicator (CAPPI) depicted greater than 60 dBZ's at 21.5 kft AGL (Fig. 13). The cross-section of the storm in FSI displayed a vigorous hail core. There was a 65 dBZ reflectivity echo to 20.2 kft AGL. These reflectivity values were approximately 10 kft above the freezing level, and close to the -20°C height from the 1800 UTC sounding. A report of quarter-size hail (2.54 cm) came from the Department of Highways in St. Johnsville. The convection continued to train from south to north over the next hour with flash flooding reported, as a state route washed out downstream of St. Johnsville near the town of Palatine Bridge in Montgomery County.

Another multicellular cluster developed over the mid Hudson Valley east of the Catskill Mountains after 1900 UTC. The updraft to this thunderstorm was very intense. In FSI at 1914 UTC, the Planned Position Indicator reference line through the cell in extreme northeastern Ulster County yielded an impressive vertical cross-section with over 60 dBZ's to 24.8 kft MSL (Fig. 14). The city of Kingston received quarter size hail and damaging winds (downed tree limbs and power lines) from 1920-1930 UTC. The severe weather persisted into the late afternoon in the Albany forecast area. The multicellular clusters organized into a line of showers and thunderstorms late in the day (not shown). Overall, the amount of severe weather reports were very close to what was expected (around 40 large hail and damaging wind reports) based on the neutral tilt "Type A" conceptual model (33 severe reports per day).

7. SUMMARY

A Great Lakes cutoff low impacted eastern NY and PA, NJ and western New England with severe weather and isolated flash flooding on 30 June 2009. There were over 3 dozen reports of severe hail and damaging winds in the Northeast (Fig. 15). Some locations in eastern NY, and southwestern Vermont received 20-40 mm of rainfall from the convection (Fig. 16). The significant weather with the cutoff fit well into a neutral tilt – "Type A" conceptual model developed from CSTAR research.

Local forecast discussions in advance of the severe weather discussed several of the potential key synoptic and mesoscale features associated with this conceptual model. Portions of the Northeast were near the left front quadrant of an upper-level jet streak with divergence aloft. A mid-level short-wave and its associated surface trough were the focusing mechanisms tapping into an unstable environment. There was sufficient deep shear (25-35 kts) and instability in place ahead of the cutoff low for multicellular convection to form. The mid-level lapse rates were marginal, but low freezing levels and wet bulb zero heights were favorable for large severe hail. The PWAT values were not much above normal and were actually just below 35 mm from the conceptual model. However, the SREF indicated 850 hPa positive V anomalies 1 to 3 standard deviations above normal. The anomalous low-level jet advected in plenty of Atlantic moisture for heavy rainfall, and isolated flash flooding due to training convection.

Forecasters continued to use this conceptual model the next day. A timely flash flood watch was put up for the Albany forecast area. Several flash floods occurred, as well as scattered large severe hail producing thunderstorms. In the future, it is hoped that forecasters in the Northeast continue to use these cutoff low pattern recognition or conceptual models to forecast the potential significant weather associated with them.

8. ACKNOWLEDGEMENTS

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9. REFERENCES

Grumm R. H., and R. Hart, 2001: Standardized anomalies applied to significant cold season weather events: Preliminary Findings. *Wea. Forecasting*, **16**, 736–754.

Higgins, R. W., J. E. Janowiack, and Y. P. Yao, 1996: A gridded hourly precipitation data base for the United States (1963-1993). NCEP/CPC Atlas 1, National Centers for Environmental Prediction, 44 pp.

Mesinger, F., G. DiMego, E. Kalnay, K. Mitchell, P. C. Shafran, W. Ebisuzaki, D. Jović, J. Woolen, E. Rogers, E. H. Berberry, M. B. Ek, Y. Fan, R. Grumbine, W. Higgins, H. Li, Y. Lin, G. Manikin, D. Parrish, and W. Shi, 2006: North American Regional Reanalysis. *Bull. Amer. Meteor. Soc.*, **87, 3,** 343-360.

Najuch, J. S., L. F. Bosart, D. Keyser, T. A. Wasula, K. D. LaPenta, 2004: Case Studies of Warm Season Cutoff Cyclone Precipitation Distribution. *Preprints 20th Conference on Weather Analysis and Forecasting,* Seattle, WA, Amer. Meteor. Soc., 11-16 January 2004, CD-ROM, P 1.46.

Najuch, J.S., 2004: Forecasting heavy precipitation associated with warm-season cutoff cyclones. Masters of Science Thesis, Department of Earth and Atmospheric Sciences, University at Albany /SUNY, Albany, NY, 112 pp.

Novak, M. J., L.F. Bosart, D. Keyser, T. A. Wasula, and K. D. LaPenta, 2002: Climatology of warm season 500 hPa cutoff cyclones and a case study diagnosis of 14-17 July 2000. *Preprints, 19th Conference on Weather Analysis and Forecasting*. Amer. Meteor. Soc., 12-16 August 2002, San Antonio, TX, pp 68-71.

Scalora, M. A., 2009: Forecasting distributions of warm-season precipitation associated with 500 -hPa cutoff cyclones. Masters of Science Thesis, Department of Atmospheric and Environmental Sciences, University at Albany/SUNY, Albany, NY, 146 pp,

Stuart, N. A., R. H. Grumm, 2009: The use of ensemble and anomaly data to anticipate extreme flood events in the northeastern United States. Natl. *Wea. Dig.,* **33(2)**, 185–202.

Thompson, R.L., R. Edwards, J.A. Hart, K.L. Elmore, and P.M. Markowski, 2003: Close proximity soundings within supercell environments obtained from the Rapid Update Cycle. *Wea. Forecasting*, **18**, 1243-1261.

Tracton, M.S., J. Du, Z. Toth, and H Juang, 1998: Short-range ensemble forecasting (SREF) at NCEP/EMC. Preprints, *12th Conf. on Numerical Weather Prediction*, Phoenix, AZ, Amer. Meteor., Soc., 269-272.

Uccellini, L. W., P. J. Kocin, 1987: The interaction of jet streak circulations during heavy snow events along the East Coast of the United States. *Wea. Forecasting,* **2**, 289–309.

U. S. Department of Commerce, 2009: Storm Data, **51** (6). [Available from National Climatic Data Center, Federal Building, 151 Patton Ave., Asheville, NC 28801-5001].

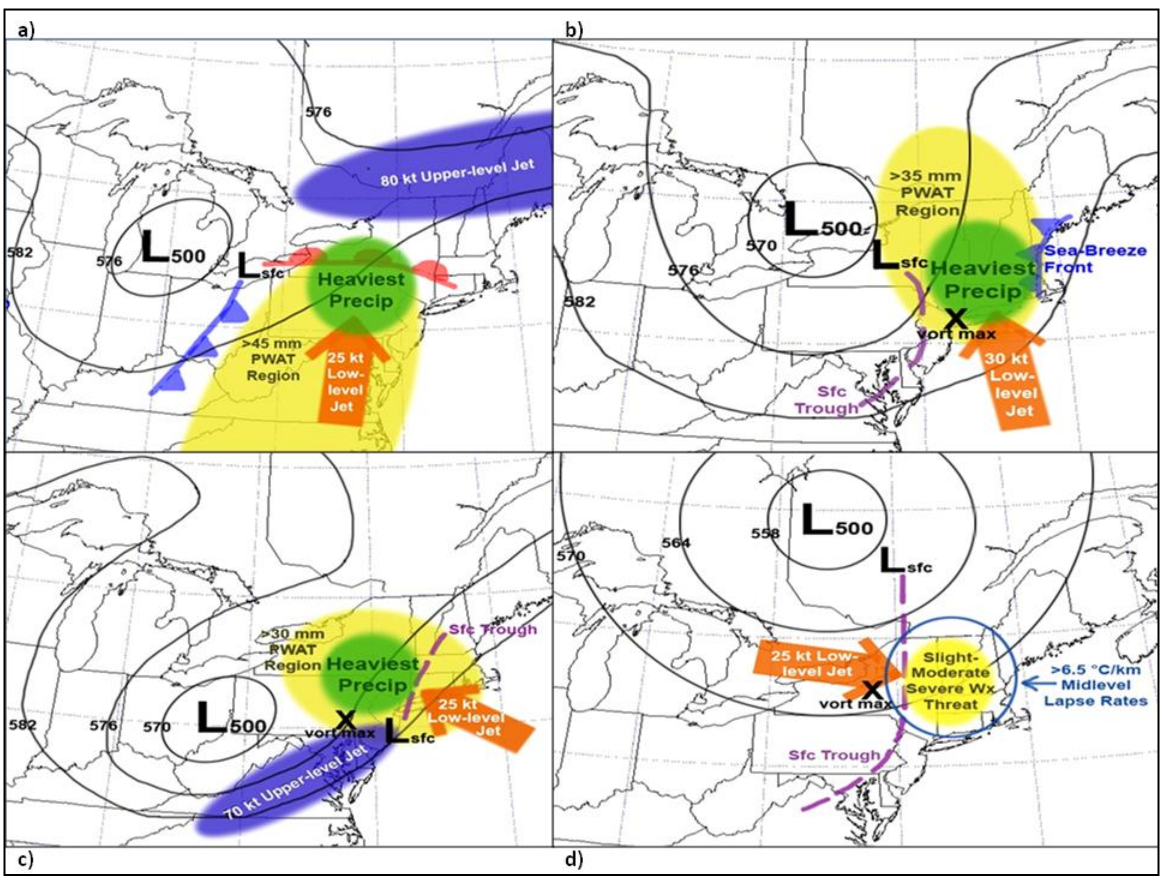

Figure 1: Conceptual Model Schematics for a) the positive tilt "Type A" pattern, b) the neutral tilt "Type A" pattern, c) positive tilt "Type B" pattern and d) neutral tilt "Type B" pattern. Source: Scalora (2009)

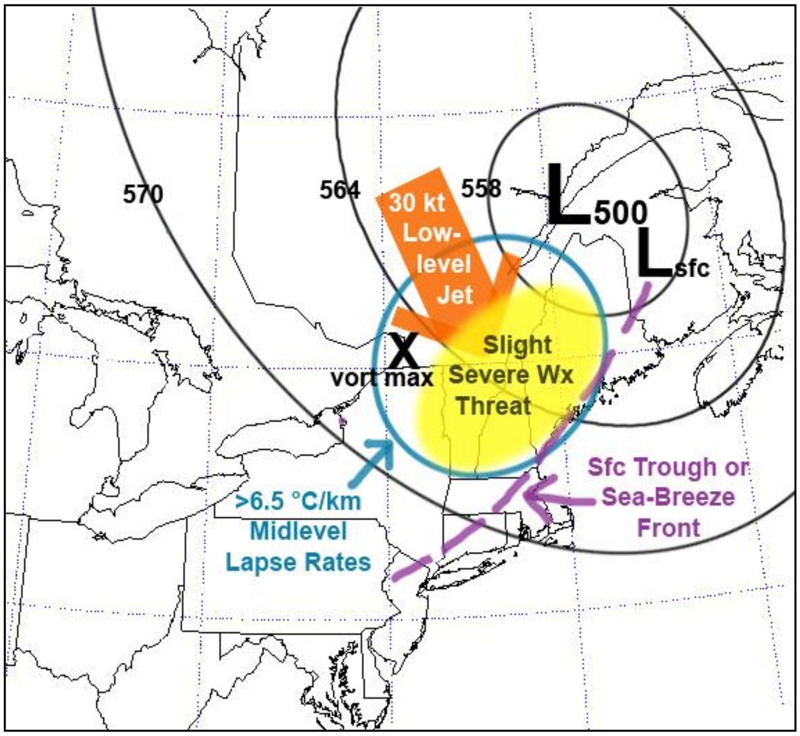

Figure 2: Conceptual Model Schematic for negative tilt pattern. Source: Scalora (2009)

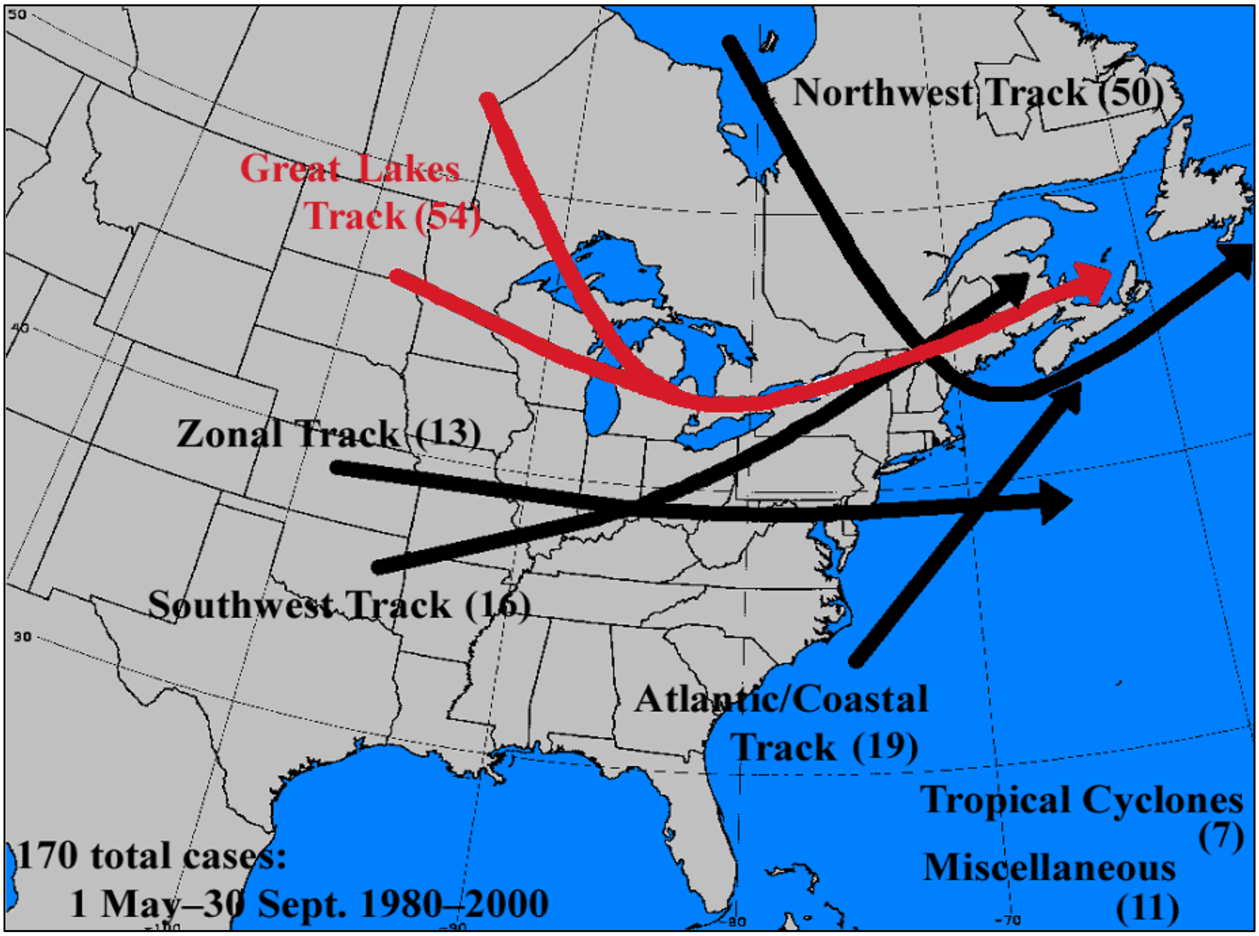

Figure 3: Five main tracks followed by 500 hPa cutoff cyclones during the warm season months of May to September (1980-200) from a subjective tracking scheme applying a closed isoheight for at least 24 hours. There are 170 cases in the dataset with the largest number in the Great Lakes and Northwest track category. Source: Novak et al. (2002).

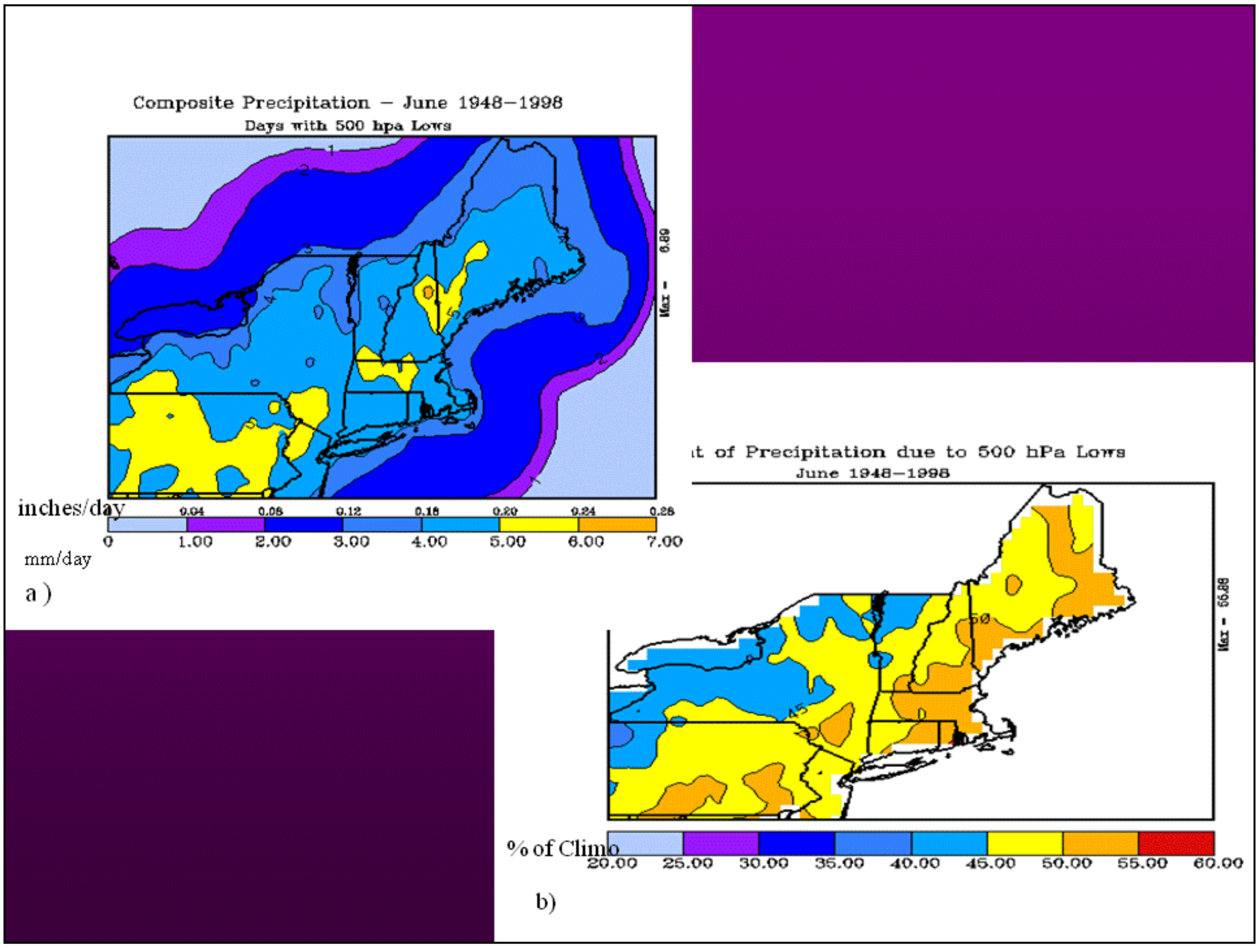

Figure 4a): Northeastern US composite precipitation for days with 500 hPa cutoff cyclones for the month of June (1948-98). Precipitation amounts are in inches/day (top of color bar) and mm/day (bottom of color bar), b): Percent of climatology precipitation associated with 500 hPa cutoff cyclones for the month of June (1948-98). Color bar values are in percent. Source: Najuch (2004)

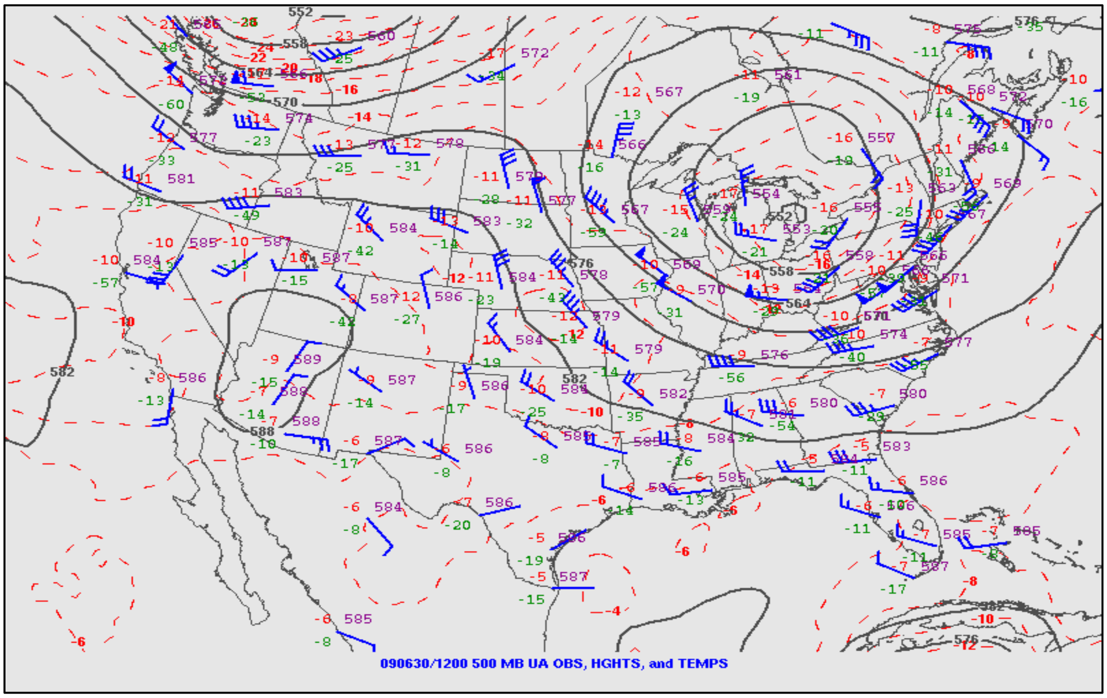

Figure 5: 500 hPa height (dam, solid), temperatures (°C, dashed red), winds (knots) and dewpoint depression from RAOB (green), valid 1200 UTC 30 June 2009 (www.spc.noaa.gov).

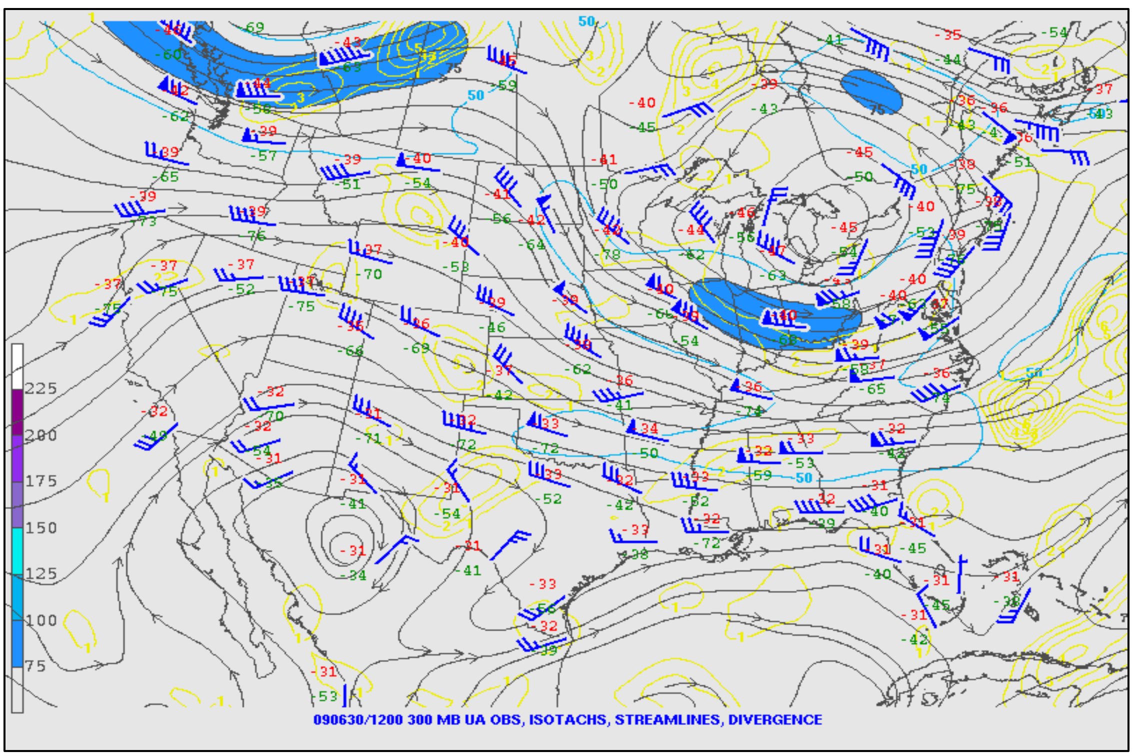

Figure 6: 300 hPa streamlines (black), temperatures and dewpoint depressions from RAOB (°C, red and green digits), isotachs (shaded, knots), winds (blue barbs, knots) and divergence (yellow), valid 1200 UTC 30 June 2009 (www.spc.noaa.gov).

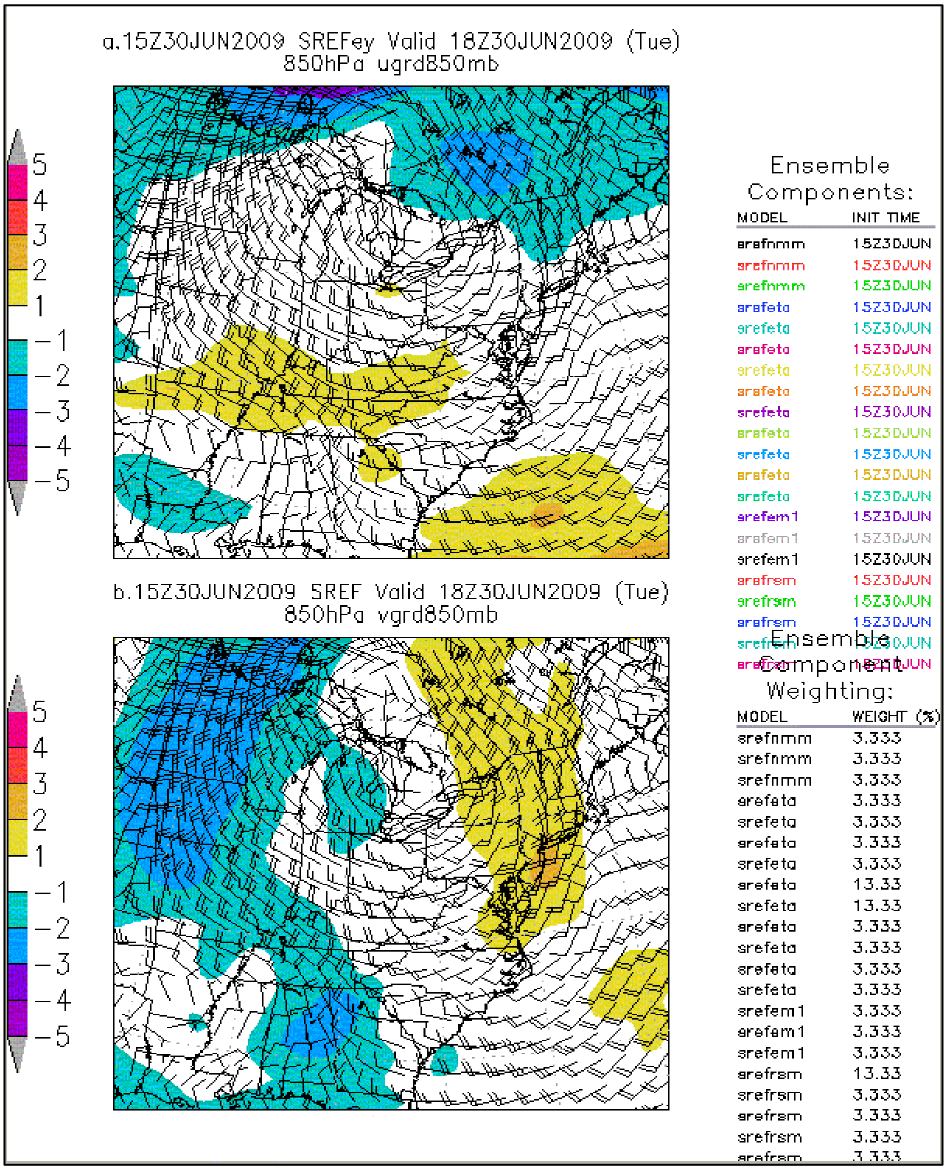

Figure 7: 1500 UTC SREF valid 1800 UTC 30 June 2009 a) 850 hPa wind barbs (kts) and U wind anomalies (color shaded), and b) wind barbs (kts) V wind anomalies (shaded).

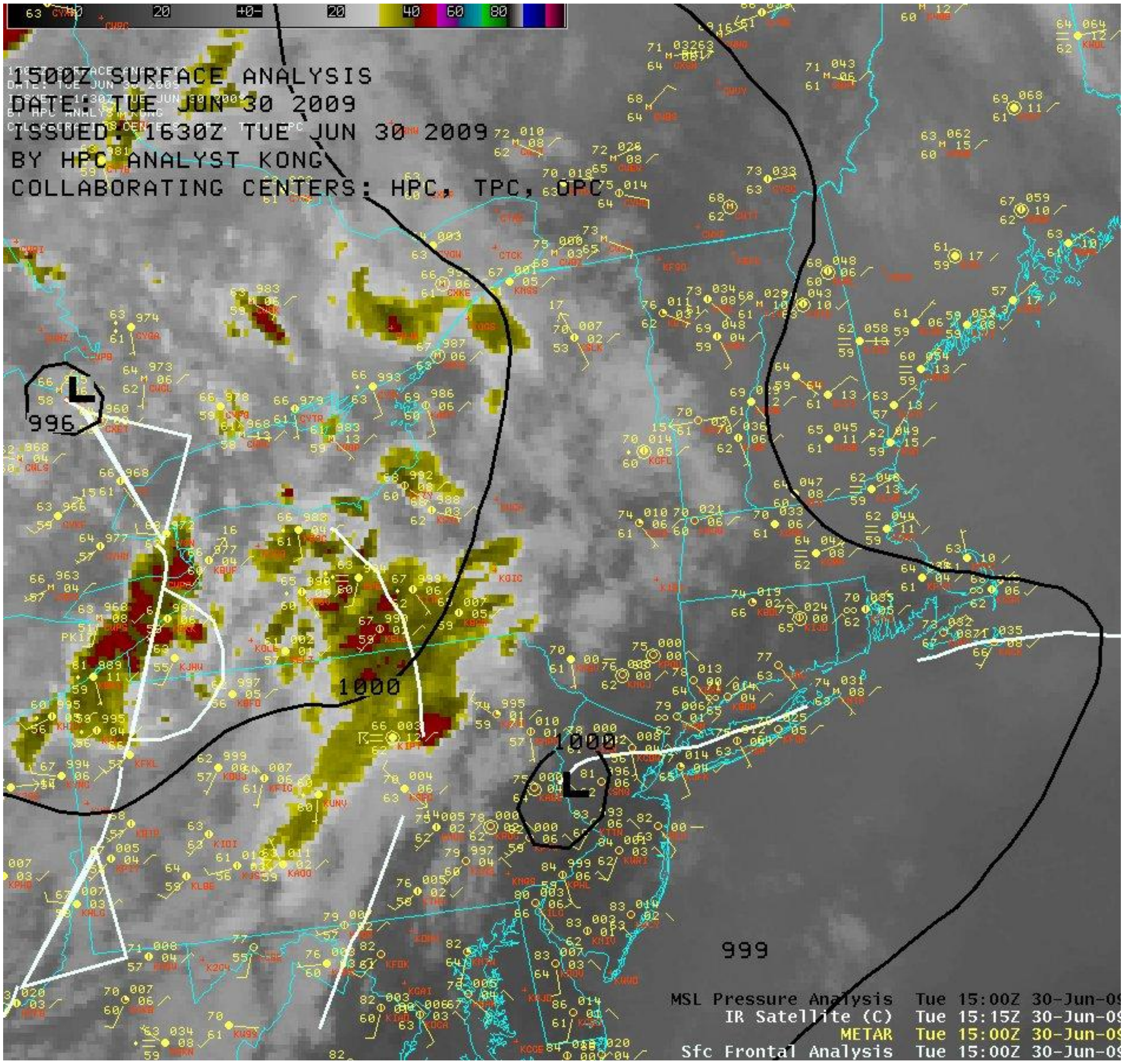

Figure 8: 1515 UTC Infrared Satellite Picture with 1500 UTC METARs (yellow) and the HPC MSLP and Fronts analysis.

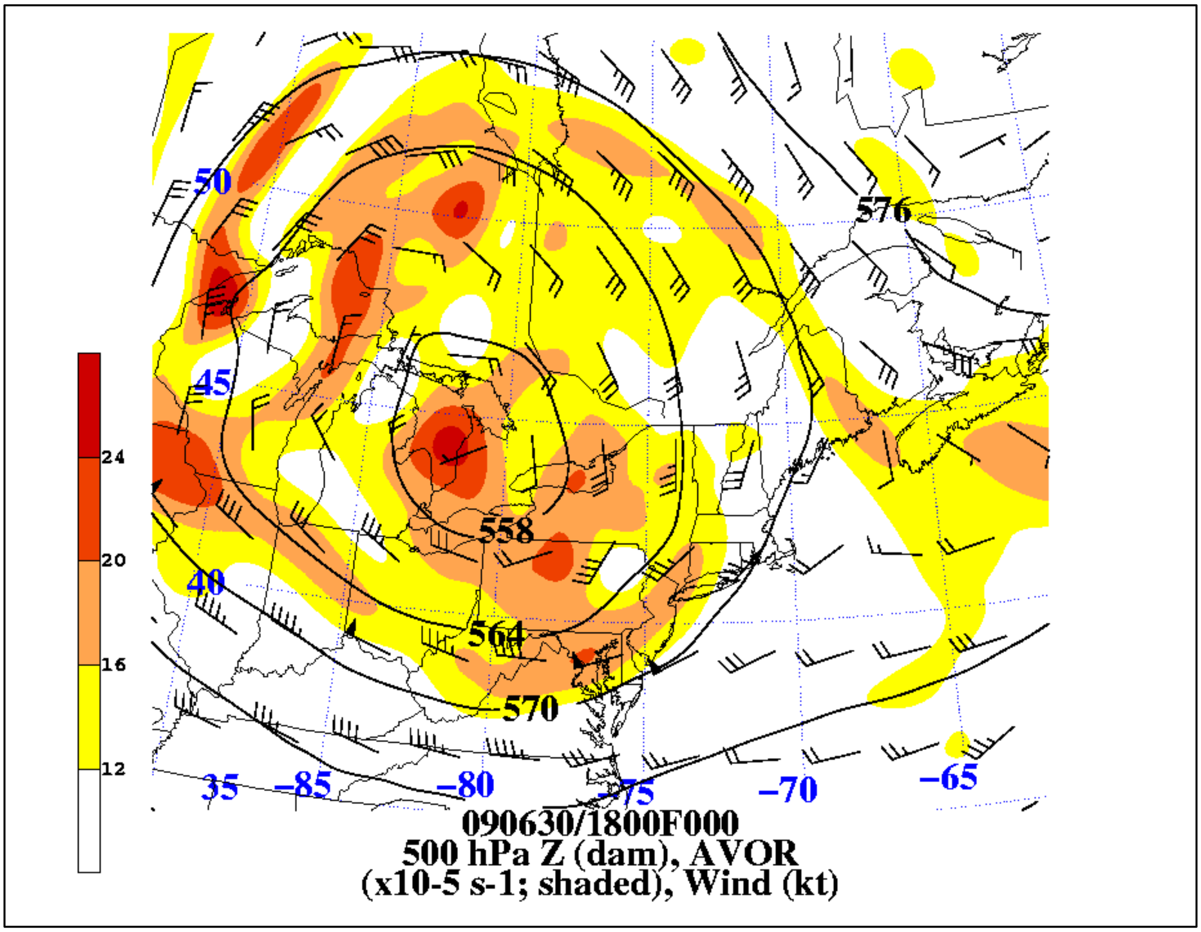

Figure 9: 1800 UTC 30 June 2009 0.5° GFS Initial Analysis 500 hPa Heights (dam), Absolute Vorticity ($x10^{-5}$ shaded) and Winds (kts).

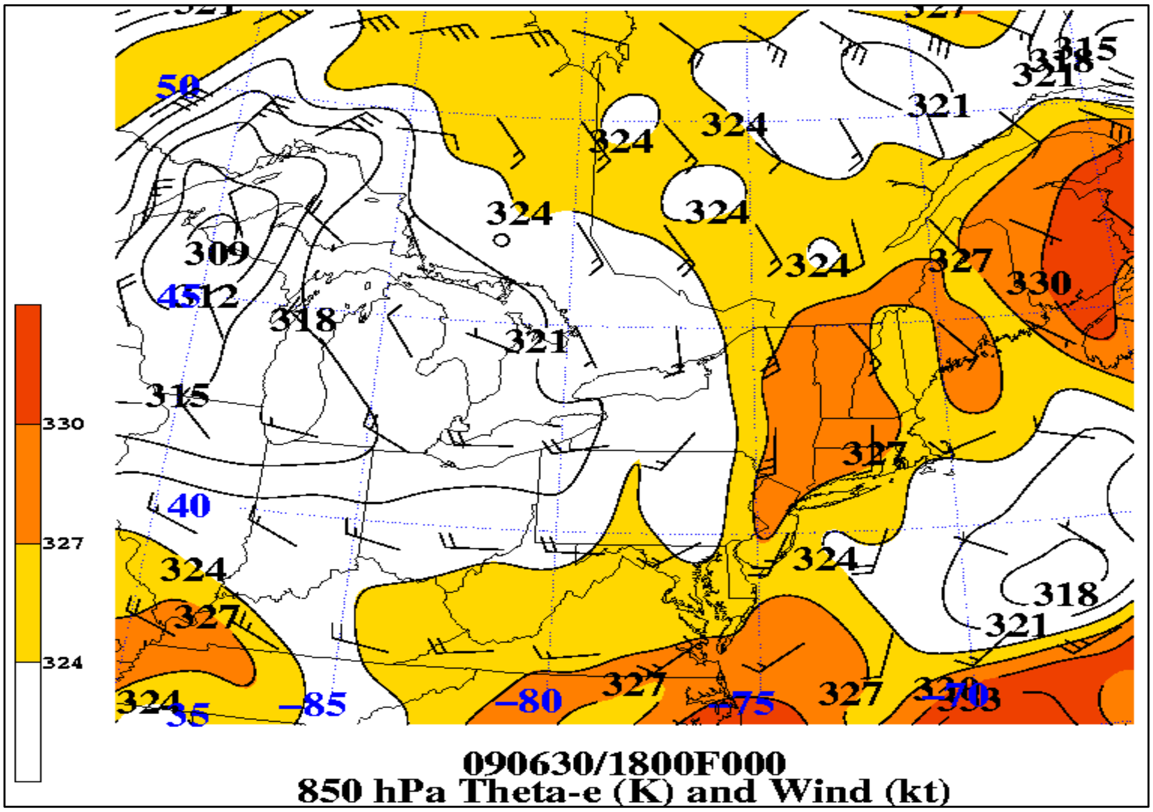

Figure 10: 1800 UTC 30 June 2009 0.5° GFS Initial Analysis 850 hPa Theta-e (K), and Winds (kts).

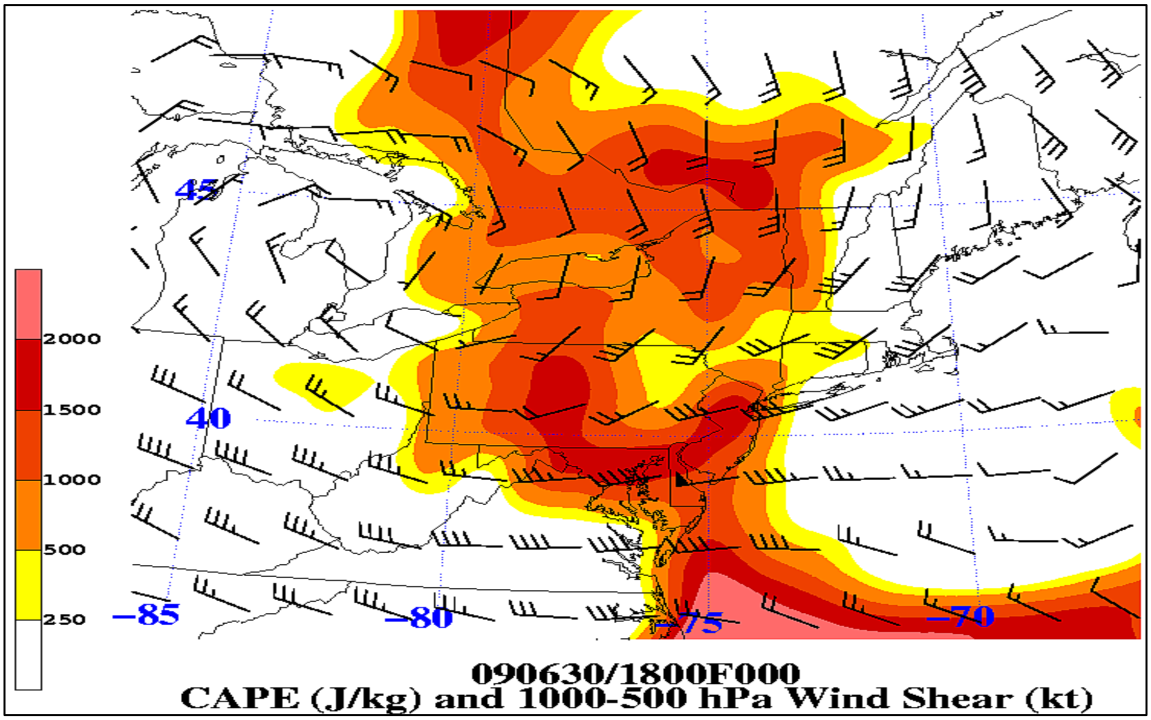

Figure 11: 1800 UTC 30 June 2009 0.5° GFS Initial Analysis SBCAPE (J kg^{-1}), and 1000-500 hPa Wind Shear (kts).

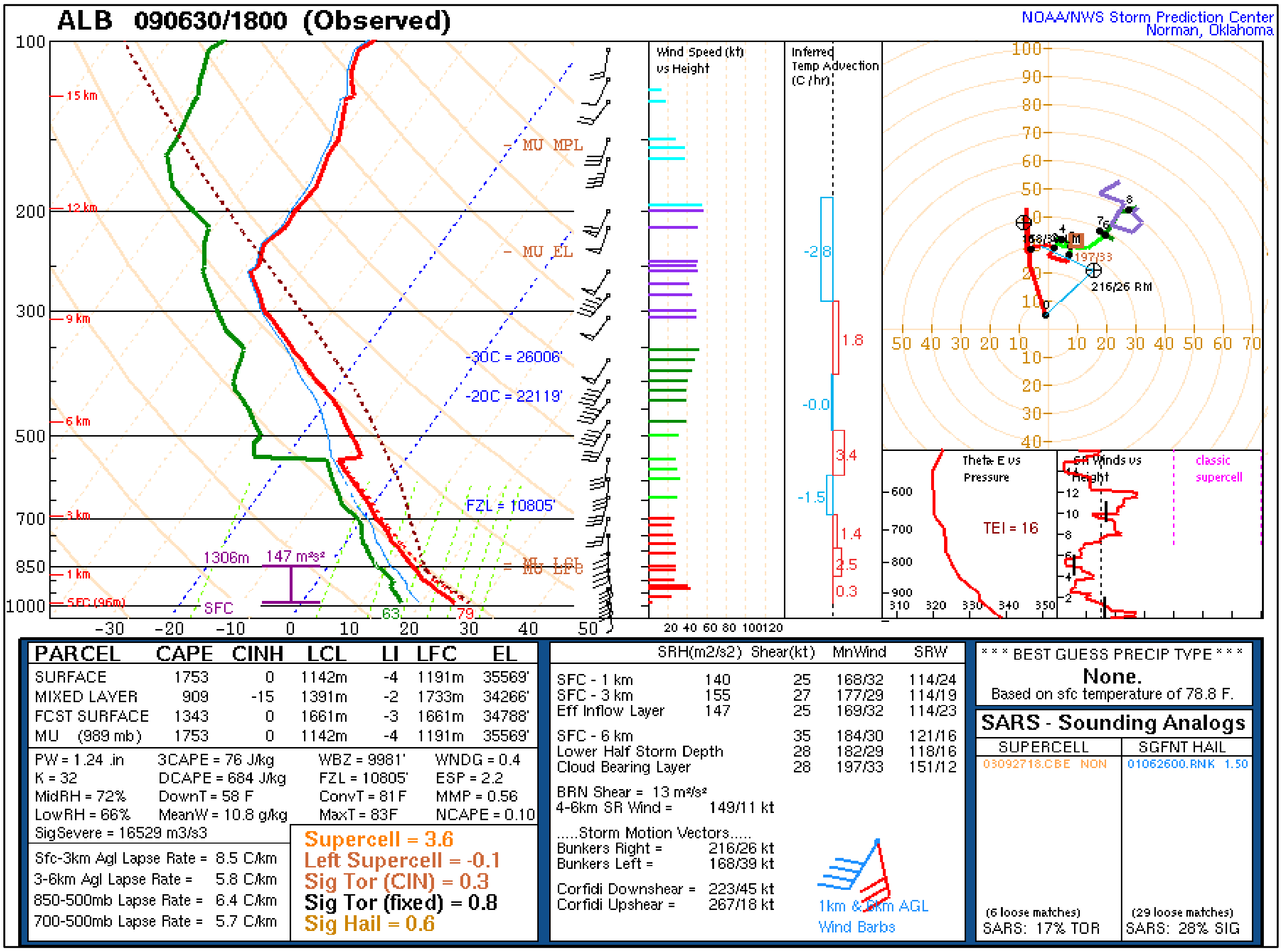

Figure 12: 1800 UTC 30 June 2009 Albany, NY (ALB) Sounding (www.spc.noaa.gov).

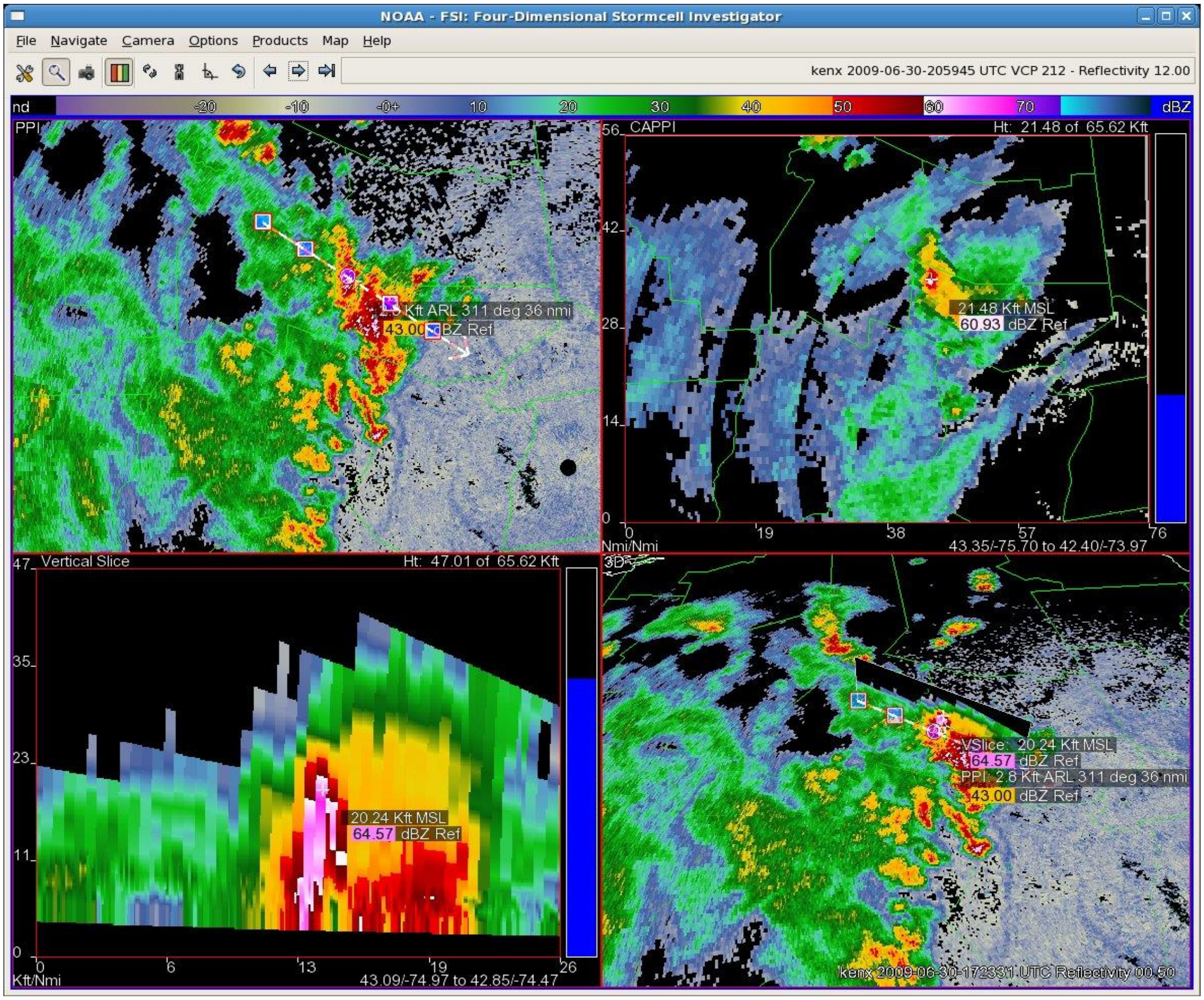

Figure 13: 1723 UTC 30 June 2009 KENX 4-Panel Display of Reflectivity (dBZ). The upper left panel is the Plan Position Indicator (PPI) panel showing radar data at a constant elevation angle of 0.5°. The vertical cross-section reference line is overlayed sampling a storm in northwestern Montgomery County northwest of the KENX radar. The upper right panel is the Constant Altitude PPI (CAPPI) panel showing radar data from several elevation angles at an altitude of 21.5 kft AGL above radar altitude. The lower left panel is the Vertical Dynamic XSection (VDX) depicting the radar data from the current volume scan and the corresponding position of the reference line from the upper left panel. The lower right panel is the 3D Flier panel where reflectivity textures represent elevation scan data, vertical cross-section data, and CAPPI data are shown. The VDX shows the 65 dBZ reflectivity echo to 20.2 kft AGL which produced quarter-size hail.

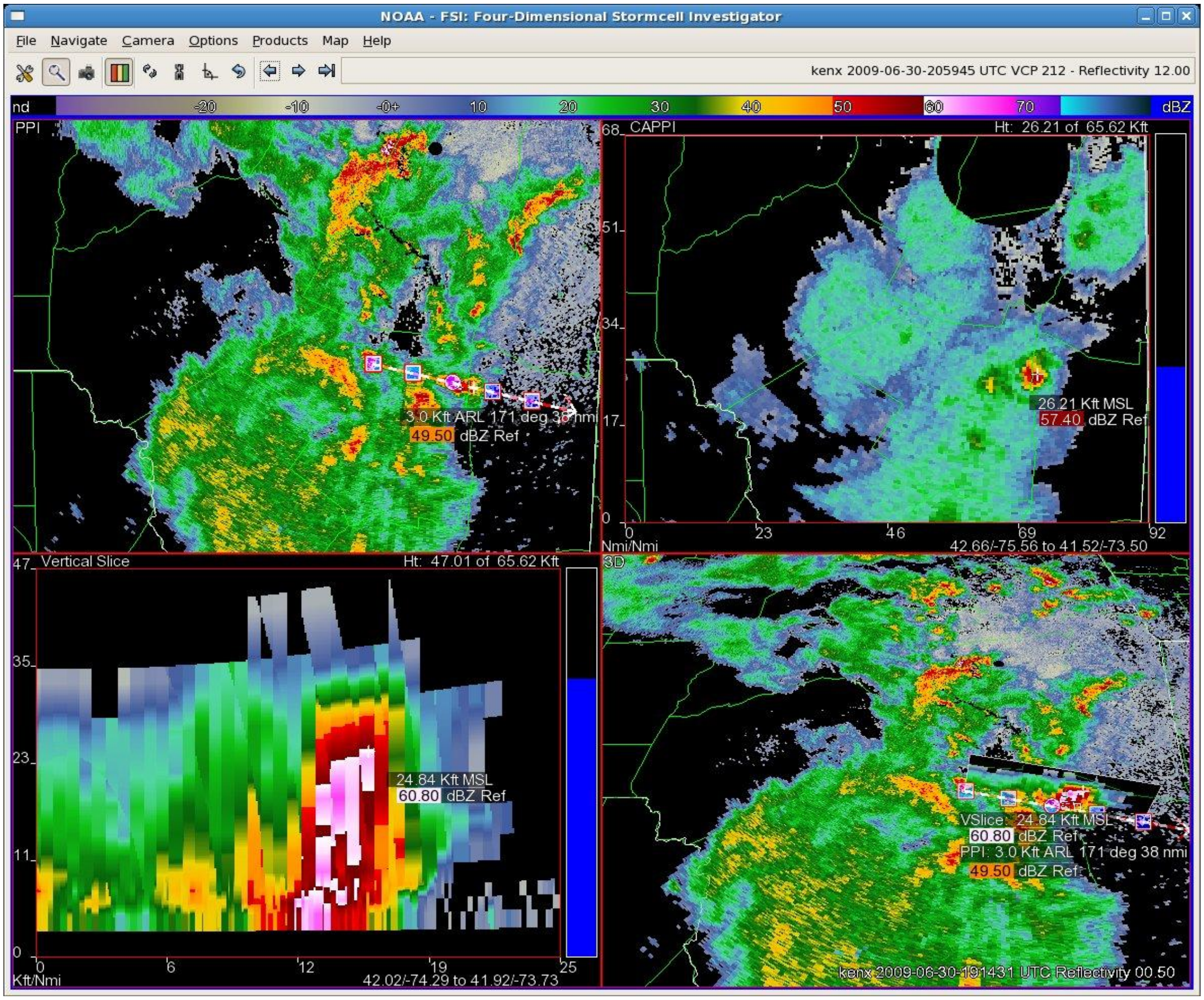

Figure 14: 1914 UTC 30 June 2009 KENX 4-Panel Display of Reflectivity (dBZ). The upper left panel is the Plan Position Indicator (PPI) panel showing radar data at a constant elevation angle of 0.5°. The vertical cross-section reference line is overlayed sampling a storm in northeastern Ulster County over the city of Kingston south of the KENX radar. The upper right panel is the Constant Altitude PPI (CAPPI) panel showing radar data from several elevation angles at an altitude of 26.2 kft AGL above radar altitude. The lower left panel is the Vertical Dynamic XSection (VDX) depicting the radar data from the current volume scan and the corresponding position of the reference line from the upper left panel. The lower right panel is the 3D Flier panel where reflectivity textures represent elevation scan data, vertical cross-section data, and CAPPI data are shown. The VDX shows the 60+ dBZ reflectivity echo to nearly 25 kft AGL which produced quarter-size hail.

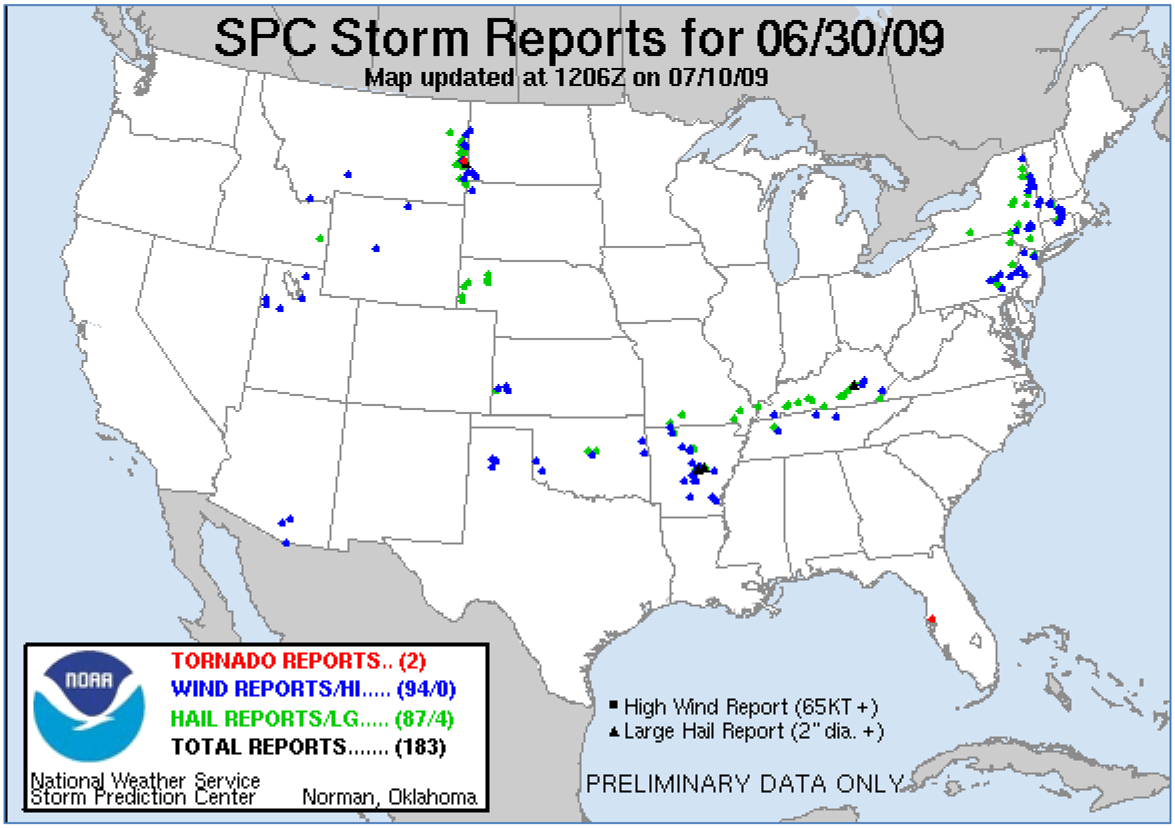

Figure 15: SPC Storm Reports (www.spc,noaa.gov)

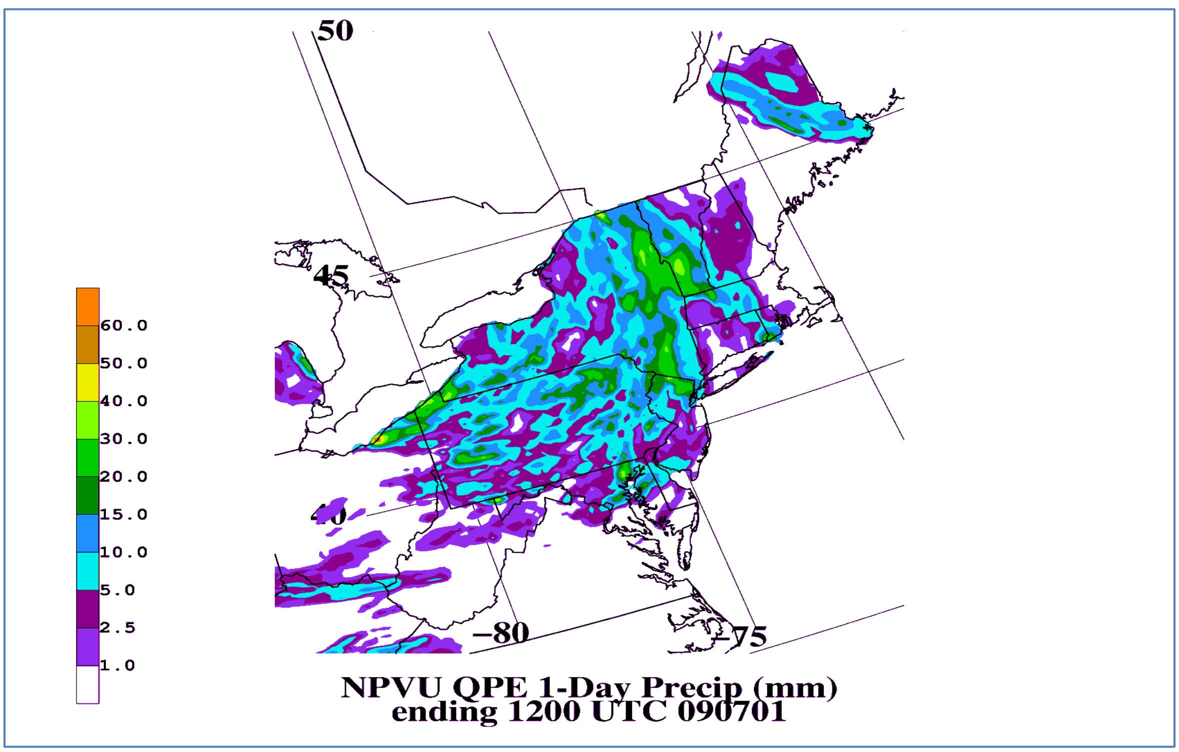

Figure 16: NWS National Precipitation Verification Unit 24-hour QPE. The color bar is in mm.