The Collaborative Science, Technology, and Applied Research Program

Cooperative Research with the National Weather Service on the Occurrence and Predictability of High-Impact Precipitation Events in the Northeastern United States

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1. SUMMARY OF STUDENT RESEARCH ACTIVITIES

a) Severe convection in scenarios with low predictive skill
Graduate students: Matthew Vaughan and Pamela Eck
Co-PIs: Brian Tang and Lance Bosart
NWS focal points: Joe Villani (ALY), Mike Evans (BGM & ALY), and Matthew Kramar (PIT)

Research Summary:

Two subprojects were conducted under the umbrella project investigating severe convection in scenarios with low predictive skill. The first subproject was to isolate severe weather events with low predictive skill, i.e., those that were poorly predicted using objective metrics, and to determine if there were synoptic or mesoscale clues that could be used to better forecast such events. Matthew Vaughan worked on this subproject and finished his M.S. in December 2015. A publication, Vaughan et al. (2017), details the technical methodology and operationally-relevant findings. Here, we summarize the main findings of this work:

- An average of six low probability of detection (POD), high-impact events (see previous CSTAR V reports or Vaughan et al. (2017) for definitions) occur annually and peak during June, July, and August.
- Severe events under northwesterly and northerly 500-hPa flow have the lowest average threat scores. Low-POD, high-impact events are a greater percentage of total events under northwesterly and northerly flow regimes compared to other flow directions.
- The vertical wind shear magnitude between 1000–500 hPa is a discriminating factor in predictive skill. High-impact events with less than 31-kt shear have significantly lower threat scores than high-impact events with greater than 31-kt shear.
- Case study analyses of low-POD, high-impact events suggest the environment over which severe weather occurs is characterized by anomalously high downdraft convective available potential energy (DCAPE), steep low-level lapse rates, and high lifting condensation level (LCL) heights that contribute to an elevated risk of severe wind. Figure 1 shows a conceptual diagram of the setup for such events that forecasters should be cognizant of in order to increase situational awareness.

An example of a low-predictive-skill event occurred on 22 May 2014, when 10-cm diameter hail was reported in Amsterdam, NY and an EF-3 tornado hit Duanesburg, NY. An analysis of this severe weather event was led by co-PI Brian Tang in collaboration with Matthew Vaughan, PI Kristen Corbosiero, co-PI Lance Bosart, CSTAR VI R2O Focal Point Ross Lazear, and three NWS Albany forecasters. The work resulted in a *Weather and Forecasting* publication, Tang et al. (2016). The study examined the evolution of the supercell and the mesoscale environment ahead of the storm that may have led to the 10-cm hail and EF-3 tornado. The main conclusion from the study is that synergistic effects from terrain channeling and baroclinic boundaries were important for the evolution and severity of the supercell. Mesoscale inhomogeneities are important for forecasting severe convection in the Northeast and may be largely responsible for events with low predictive skill due to the absence of synoptic-scale favorability over a widespread region.
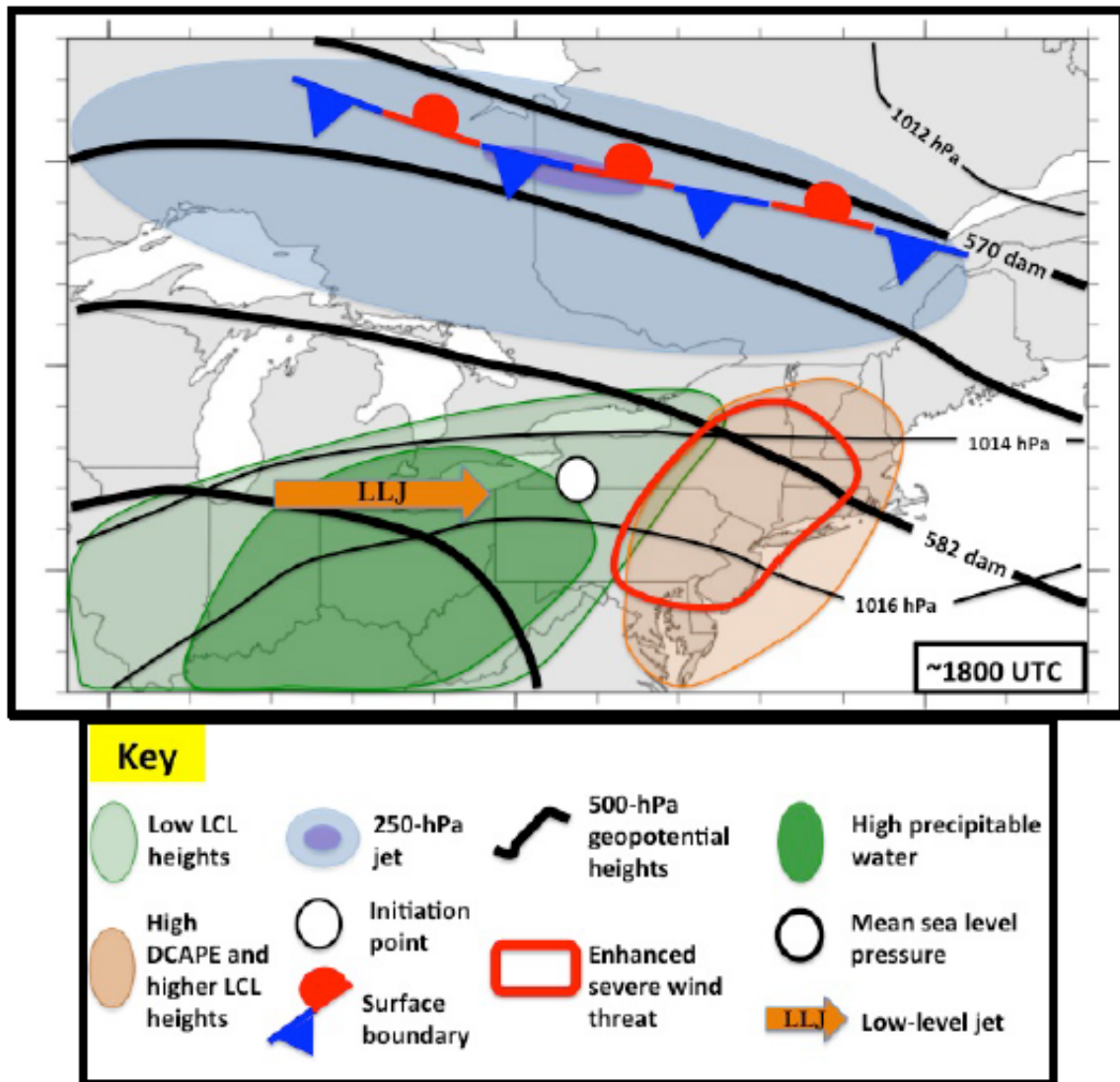
Figure 1. *Schematic for low-POD events under low-shear conditions. Background map is provided solely for scale. Upper-level forcing is weak and well removed from the point of convective initiation. Once convection initiates, it grows weakly upscale and moves toward the east and southeast into a region of high DCAPE and LCL heights, leading to an enhanced severe wind threat. From Vaughan (2015).*

Pamela Eck worked on the second subproject and finished her M.S. in July 2017. The second subproject, partially motived by the 22 May 2014 event, had two objectives. The first objective was to evaluate the scientific hypothesis that the intensity of convection is enhanced shortly after the intersection of local areas of upslope flow with convection, leading to an increase in lightning flash rate and an enhanced threat of severe weather. The second objective was to develop and evaluate the skill of products that integrate a combination of lightning, radar, and High Resolution Rapid Refresh (HRRR) data to provide guidance to forecasters where terrain interactions can increase the probability convection will become severe. To accomplish both objectives, we used a machine-learning algorithm called a random forest. A random forest is a collection of decision trees, each of which is structurally different and trained on a different subset of the data. The end result is a potentially powerful tool to predict whether a storm will be severe or non-severe, and to assess the overall importance of predictors in making the prediction.

Technical information regarding the predictor data, and the training and testing of the random forest can be found in Pamela's M.S. thesis, Eck (2017). Here, we summarize the main findings of this work:

- Upslope flow is important for enhancing lightning flash rates and the threat of severe weather after convection intersects upslope flow.
- Lightning data, such as now provided by the Geostationary Lightning Mapper aboard the GOES-16, is valuable for warning on severe convection, but only when combined with other data, such as upslope flow and radar data.
- The random forest tool has potential to be operationally useful for warning on severe convection. When tested on severe weather days in July 2016, the random forest with upslope flow, lightning flash rate, the change of lightning flash rate with time, base reflectivity, and echo-top height as predictors yielded a probability of detection of 82% and a false alarm rate of 23%, indicating a skillful model (Fig. 2).
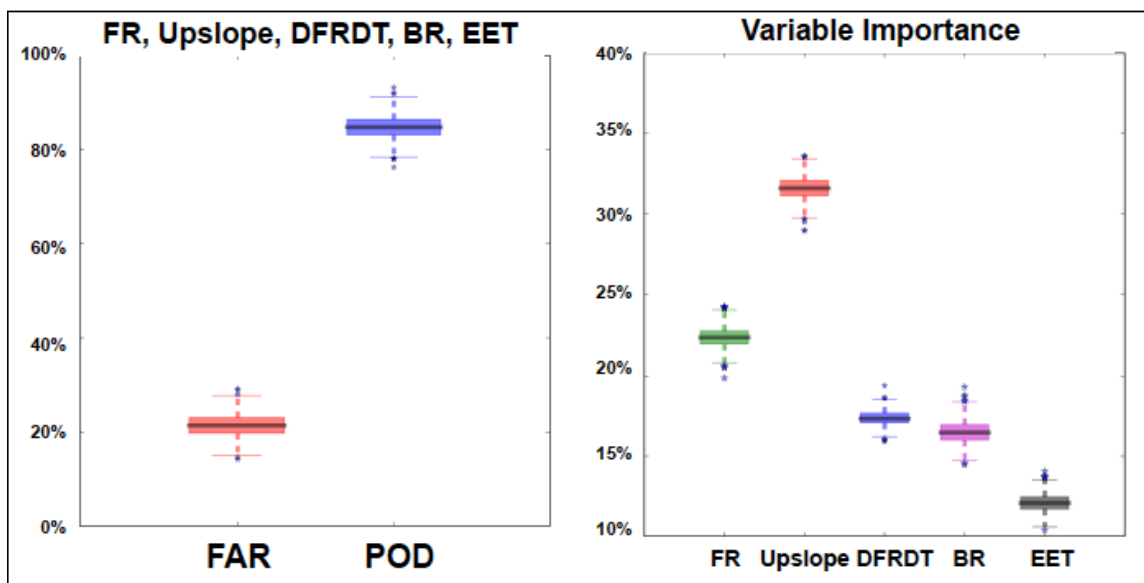

Figure 2. *(left) Box plots of the false alarm rate (FAR; red) and probability of detection (POD; blue) of severe weather, as determined by a random forest algorithm trained on severe weather days in the Northeast during July 2016. (right) Box plots of the variable importance of flash rate (FR; green), upslope flow (red), change in flash rate with time (DFRDT; blue), base reflectivity (BR; purple), and echo-top height (EET; black). From Eck (2017).*

NWS Interactions:

Numerous NOAA and NWS interactions occurred at both the local weather forecast office level to the national level. At the local level, research updates were given twice a year at CSTAR meetings at the NWS Albany office. Matthew Vaughan and Pamela Eck gave overview presentations and then discussion between the students, PI, co-PIs, and NWS Focal Points provided valuable feedback and future directions for the project. At the regional to national level, Matthew Vaughan, Pamela Eck, Brian Tang, and Lance Bosart gave presentations on this work at workshops and conferences, including the Northeast Regional Operational Workshop, the Northeastern Storms Conference, the Conference on Severe Local Storms, the Conference on Mesoscale Processes, and the American Meteorological Society Annual Meeting. Additionally,

Matthew Vaughan, Pamela Eck, and Lance Bosart attended the Hazardous Weather Testbed Spring Forecast Experiment in multiple years to discuss this work with National Severe Storms Laboratory and Storm Prediction Center scientists and forecasters. In order to enhance the R2O transfer of knowledge from these subprojects, CSTAR VI R2O Focal Point Ross Lazear worked with both Matthew Vaughan and Pamela Eck to develop summary points and conceptual diagrams of the operationally-relevant portions of their research to incorporate into the NOAA Virtual Laboratory (VLab).

b) Predictability of heavy precipitation associated with tropical moisture
Graduate student: Molly Smith
PI and co-PI: Kristen Corbosiero and Ryan Torn
*NWS focal points: Steve DiRienzo (ALY) and Mike Jurewicz (BGM)*

Research Summary:

Ensemble runs of weather models aid in the creation of probabilistic forecasts by illustrating several possible scenarios that can occur. Identifying the correct scenario is vital in the case of tropical cyclone (TC)-fueled rainfall, which can devastate entire communities. An in-depth case study was performed on Hurricane Irene (2011) to determine what particular modeling scenarios produce the heaviest precipitation over the northeastern United States, and to ascertain what ensemble metrics are the most useful in predicting such an event.

An 80-member ensemble of the 2014 version of the Global Forecast System (GFS) was initialized at 0000 UTC 27 August 2011, when Irene was situated off the coast of the Carolinas, and run through 0000 UTC 29 August 2011, when Irene became extratropical over New England. The 0.5° GFS output was then downscaled to 3 km using the Weather Research and Forecasting (WRF) model, in order to allow a better representation of mesoscale processes and the effects of terrain on the precipitation distribution. The physics used for this downscaling were comparable to those used in the HRRR model. The ensemble members were ranked by the amount of precipitation they brought to the Catskill region of New York, which received some of the worst flooding associated with Irene and are, thus, a good indicator of whether specific ensemble scenarios accurately captured the precipitation distribution.

The analysis revealed substantial variability in rainfall over the Catskills (Fig. 3). Three hypotheses are proposed to explain this variability: 1) wetter members feature the greatest upslope forcing over the Catskills, 2) wetter members have increased moisture flux convergence over the Catskills, and 3) wetter members position the region of maximum Q-vector convergence over the Catskills.

Figure 3. WRF 3-km ensemble rainfall distribution over the Catskill region of New York compared to the observed value (red dashed line).
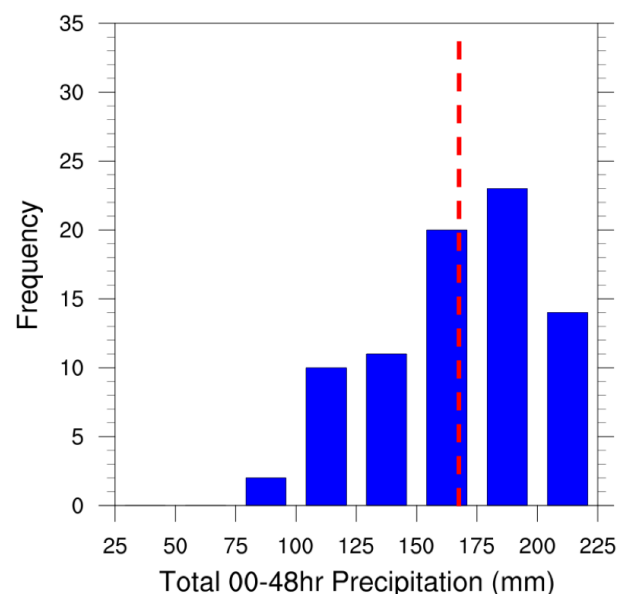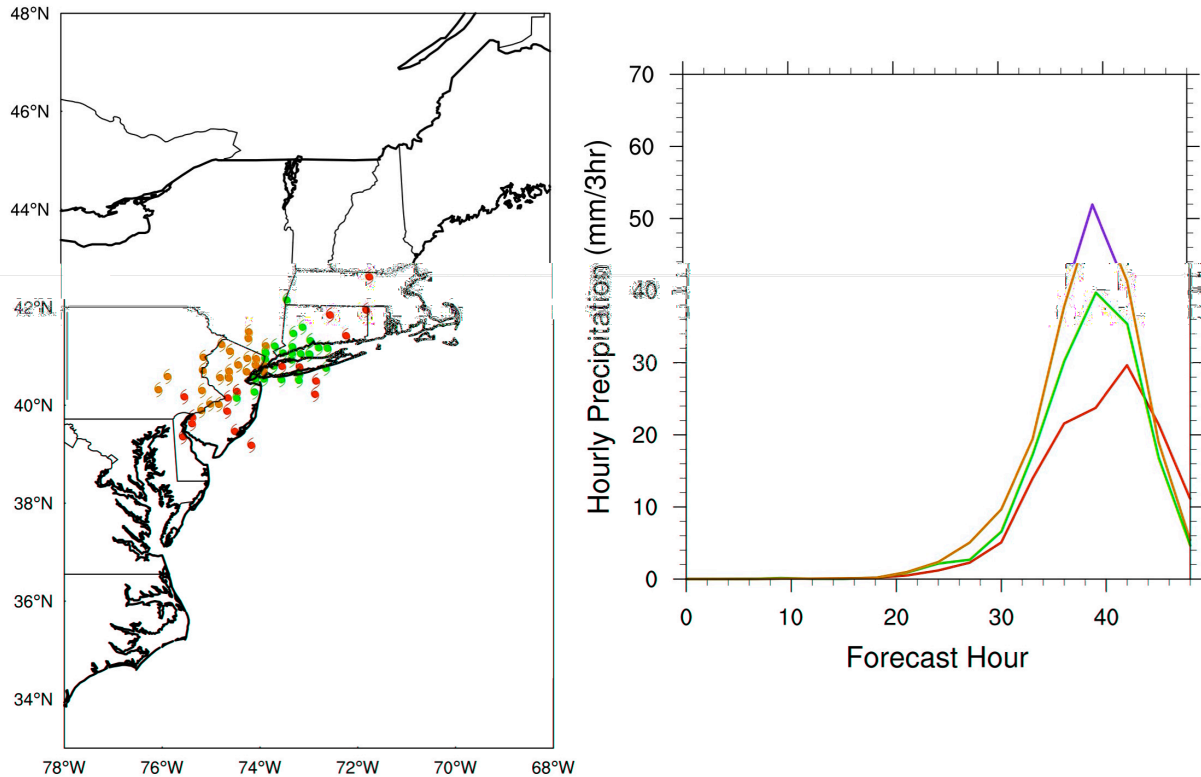
Figure 4. *Three objective clusters of ensemble members based on the horizontal precipitation distribution from 36–39-h. The blue markers and trace represent a "low-rain" cluster, the red an "eastward-tracking" cluster, and the purple a "westward-tracking" cluster. Panel a) shows the storm center position for each ensemble member and b) shows the composite precipitation rate for each cluster.*

These hypotheses were tested by objectively clustering the 80 ensemble members into three groups (Fig. 4) based on the horizontal precipitation distribution from 36–39-h (the period of maximum rainfall for the Catskills), representing three particular scenarios indicated by the ensemble. The first cluster, represented in blue in Figure 4, represents a "low rain" scenario, and consists of storms that were too far away at 39-h to bring much rain at all to the Catskills. The second cluster, represented in red in Figure 4, represents an "eastward-tracking" scenario, and consists of storms that were able to bring elevated precipitation to the region while moving to the eastern side of the track distribution. The third cluster, represented in purple in Figure 4, represents a "westward-tracking" scenario, and consists of storms that brought the largest precipitation totals to the Catskills, while moving to the western side of the track distribution. As the first, low-rain cluster represents residual storms, this study compares the other two clusters to determine why one brought elevated rainfall to the Catskills, and the other brought less.

Figure 5 shows that precipitation in the wetter cluster was driven primarily by mesoscale processes and terrain effects (strong upslope forcing and moisture convergence), while precipitation in the drier cluster was driven primarily by synoptic forcing for ascent. The wetter cluster featured easterly low-level flow directly into the sharp terrain gradient of the eastern Catskills, creating large upslope magnitudes, while the drier cluster had more northerly low-level flow, which failed to impact as large a terrain gradient. Likewise, the wetter cluster simulated stronger moisture transport into the region than the drier cluster, and greater convergence of that moisture (the larger upslope magnitudes likely contributed to this convergence). The drier

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cluster, on the other hand, had stronger Q-vector convergence than the wetter cluster, which generally featured either weak or negative Q-vector convergence (and thus reduced synoptic forcing for ascent). All of this illustrates the importance of terrain and mesoscale processes in producing large rainfall totals, as the cluster with a favorable mesoscale setup was able to produce substantially more precipitation than the synoptically forced cluster.
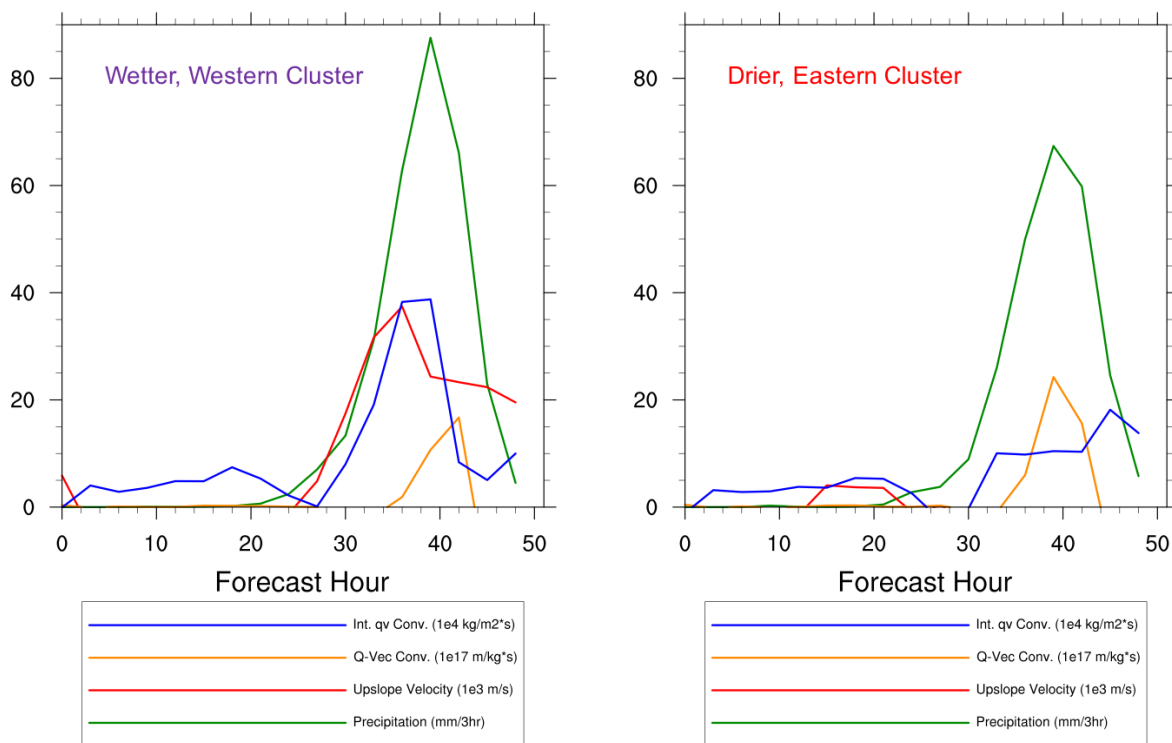

Figure 5. *WRF 3-km ensemble forecasted precipitation (green curve), upslope (red curve), moisture convergence (blue curve), and Q-vector convergence (orange curve) for the wetter, western cluster (a) and the drier, eastern cluster (b) over the Catskill region of New York between 0000 UTC 27 August 2011 and 0000 UTC 29 August 2011.*

NWS Interactions:

In regards to this project's R2O, we have continued to revise our GEFS ensemble forecast difference page (*http://www.atmos.albany.edu/facstaff/torn/CSTAR_ediff/index.php*), which is an outcrop of this research. Currently, the page displays the difference between members with higher or lower 48–72-h high temperature, low temperature, and precipitation for Albany, Buffalo, Binghamton, Upton, and Portland using forecast data every six hours. In addition, co-PI Torn has been engaged with our NWS focal points on developing training materials for how to interpret this output and disseminate to a broader set of forecasters. In the future, we will add capability to plot the difference between the ensemble-mean forecast and verifying analysis in anticipation of expanding to a real-time decision support product. Additionally, CSTAR VI R2O Focal Point Ross Lazear worked with Molly to develop summary points and diagrams of the operationally-relevant portions of her research for the UAlbany–NWS Albany VLab page, a screen shot of which appears below in Figure 6.
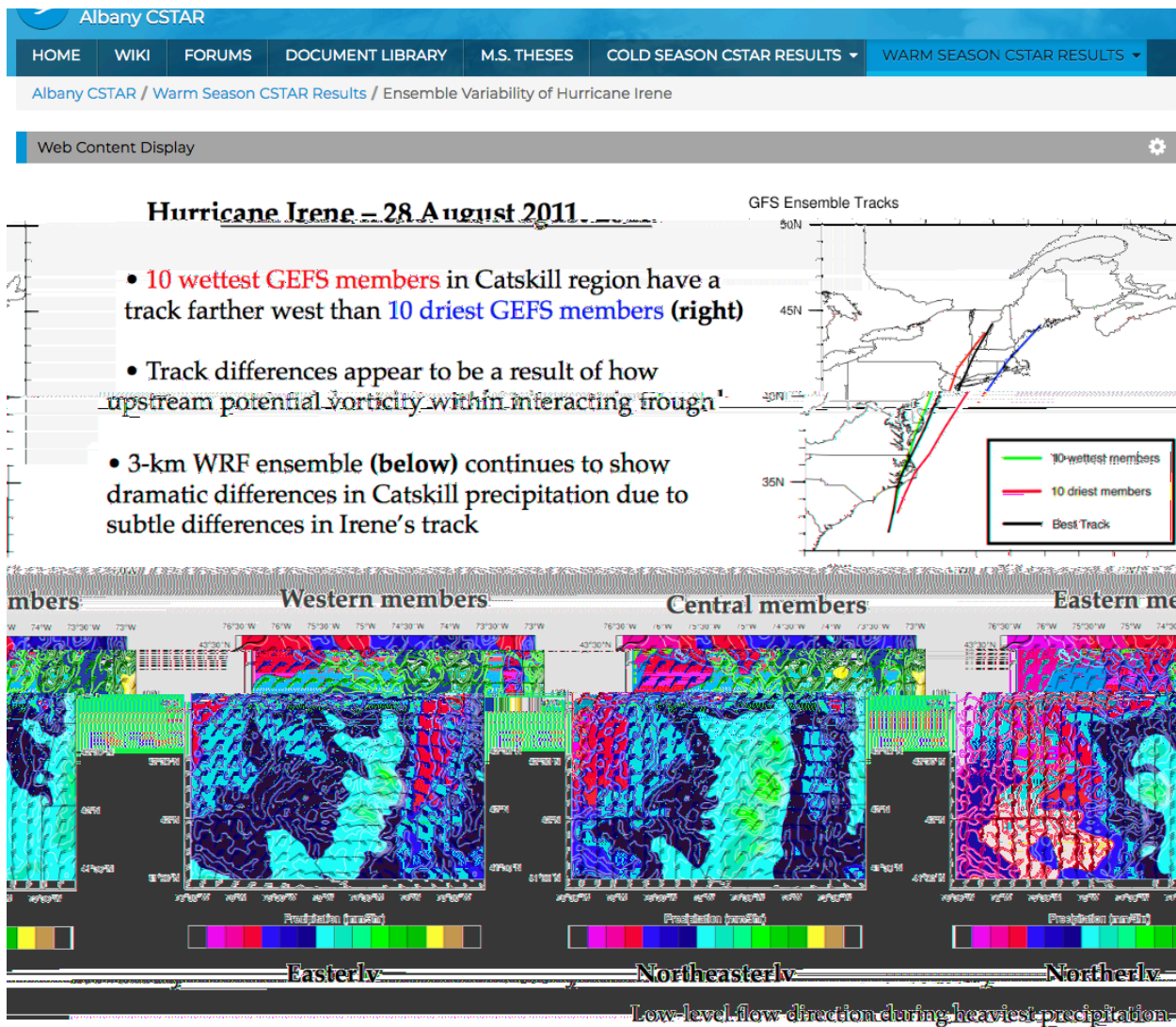
Figure 6. *Screen shot of the Albany CSTAR VLab page summarizing the main research results of CSTAR V research on Hurricane Irene.*

c) Transition season Northeast storms and East Coast atmospheric rivers
Graduate student: Rebecca Steeves
Co-PIs: Andrea Lang and Daniel Keyser
NWS focal points: Thomas Wasula (ALY) and Neil Stuart (ALY)

Research Summary:

Major transition season (fall and spring) Northeast snowstorms have the potential to cause widespread socioeconomic disruption in the form of transportation delays, infrastructure damage, and widespread power outages. Because heavy, wet snow tends to occur in transition season Northeast snowstorms, lesser accumulations can result in greater disruption than if the same accumulations occurred in winter season Northeast snowstorms. Motivated by the opportunity to improve scientific understanding and forecaster situational awareness of this class of snowstorms, this project supported M.S. thesis research and R2O activities on the multiscale

nature of these snowstorms. The project research included both a climatology and composite analysis, and emphasized atmospheric rivers (ARs) and lower-tropospheric cold air. Major transition season Northeast snowstorms used in the climatology and composite analysis were identified from National Centers of Environmental Information's monthly Storm Data publication during 1983–2013. From the identified snowstorms, this study found that major transition season Northeast snowstorms featured a variety of lower-tropospheric cold air patterns that provided a means to subset similar snowstorms.

The climatology focused on the snowstorms grouped by temporal characteristics and lower-tropospheric cold air patterns. The climatological analysis produced several key results. The first set of results considers snowstorms grouped by temporal characteristics and reveals the following: 1) spring snowstorms are the dominant type of major transition season Northeast snowstorms, with the majority occurring in March; 2) spatial distributions of cases with heavy snowfall for the months of March, April, and November tend to exhibit latitudinal gradients where more cases with heavy snowfall occur at high latitudes of the Northeast domain than at low latitudes of the Northeast domain; 3) March, April, October, and November feature maxima in the number of cases with heavy snowfall per month in regions of elevated terrain; and, 4) ARs are frequently observed during major transition season Northeast snowstorms in all months.

The second set of results considers snowstorms grouped by lower-tropospheric cold air pattern (i.e., Cold Pool, Baroclinic Zone: Westerly Thermal Wind, and Baroclinic Zone: Southwesterly Thermal Wind) and reveals the following key conclusions: 1) the Cold Pool category features the widespread occurrence of cold pools across the Northeast domain at the initial and midpoint times of the cold pools; 2) maxima in cold pool occurrence are typically located in regions of elevated terrain at the initial and midpoint times of the cold pools; 3) each lower-tropospheric cold air pattern exhibits a distinct spatial distribution of cases with heavy snowfall; and, 4) all of the lower-tropospheric cold air patterns feature maxima in number of cases with heavy snowfall in regions of elevated terrain.

In the composite analysis, the lower-tropospheric cold air pattern served as the basis for case-centered composites. Results from the climatology indicate that ARs are characteristic ingredients in the Cold Pool and the Baroclinic Zone: Southwesterly Thermal Wind categories. These two subsets have ARs on more than 50% of all case days and feature high AR axis density values over the Northeast domain for all case days. The majority of the cases in the Baroclinic Zone: Southwesterly Thermal Wind subset (20 of 29 cases) and the Cold Pool category (25 of 36 cases) are AR-influenced, meaning an AR axis was present within 250 km of the location of maximum snowfall. ARs were less of an important ingredient for the Baroclinic Zone: Westerly Thermal Wind subset than for the other two lower-tropospheric cold air patterns. The Baroclinic Zone: Westerly Thermal Wind subset has an AR fraction of 47.5%, which indicates that ARs are often present during snowstorms in this subset. However, the ARs present during these snowstorms do not appear to play a large role in transporting moisture into the Northeast domain, since the ARs observed during all case days are concentrated over the western North Atlantic Ocean and are infrequent in the vicinity the Northeast domain. Additionally, a low number of cases (5 of 20 cases) in the Baroclinic Zone: Westerly Thermal Wind subset are AR-influenced.

The composite analysis reveals various atmospheric flow patterns associated with the different lower-tropospheric cold air patterns of major transition season Northeast snowstorms. Conceptual diagrams (Figs. 6a–c) highlight the variations in the atmospheric flow patterns for each of the lower-tropospheric cold air patterns at t_0, which represents a time of heavy precipitation. The results for each subset are as follows:

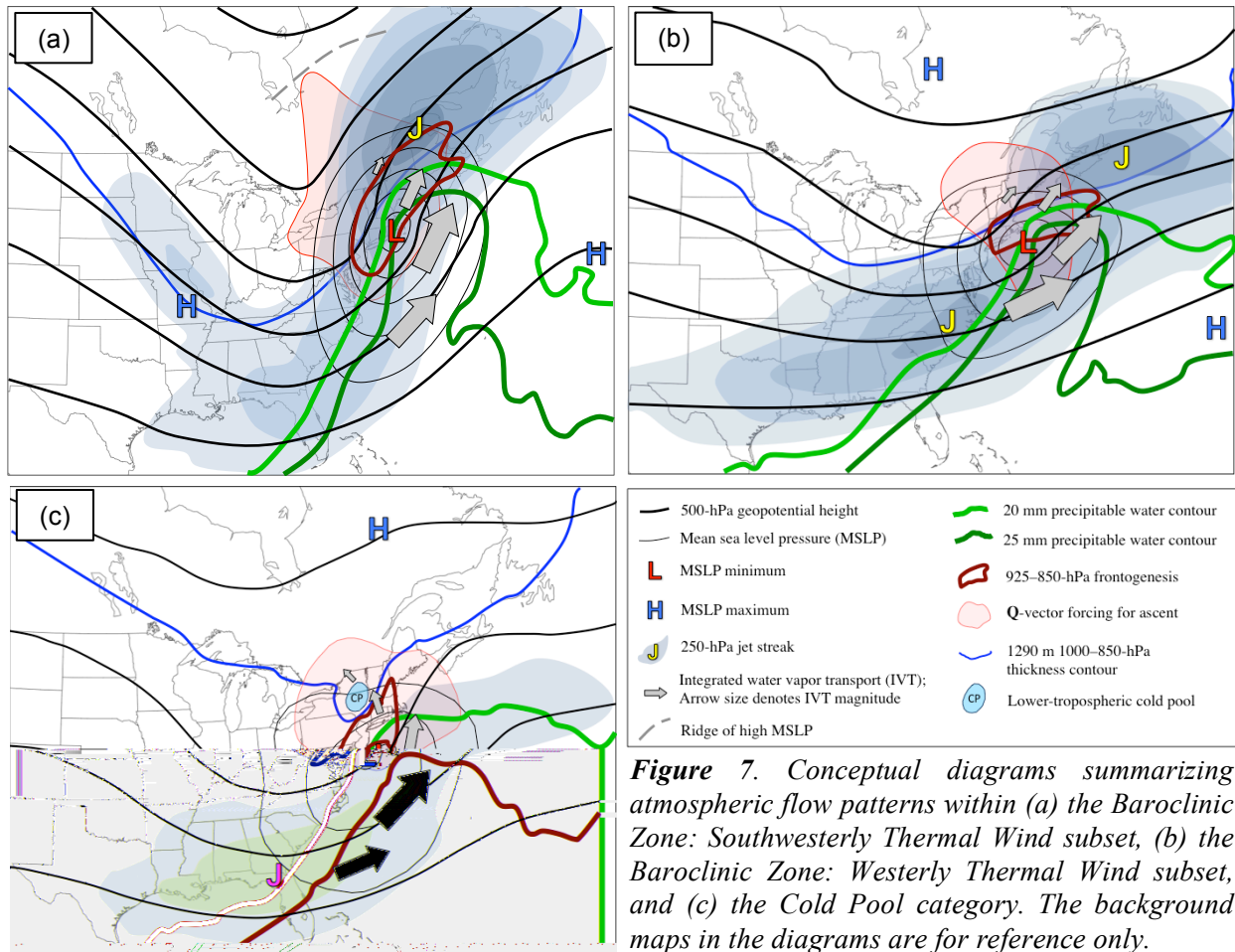|	
—— 500-hPa geopotential height	—— 20 mm precipitable water contour
—— Mean sea level pressure (MSLP)	—— 25 mm precipitable water contour
L MSLP minimum	925–850-hPa frontogenesis
H MSLP maximum	**Q**-vector forcing for ascent
J 250-hPa jet streak	—— 1290 m 1000–850-hPa thickness contour
Integrated water vapor transport (IVT); Arrow size denotes IVT magnitude	CP Lower-tropospheric cold pool
Ridge of high MSLP	

Figure 7. Conceptual diagrams summarizing atmospheric flow patterns within (a) the Baroclinic Zone: Southwesterly Thermal Wind subset, (b) the Baroclinic Zone: Westerly Thermal Wind subset, and (c) the Cold Pool category. The background maps in the diagrams are for reference only.

- The Baroclinic Zone: Southwesterly Thermal Wind subset features a northeastward-moving surface cyclone and a southeastward-moving surface anticyclone located to the west of the surface cyclone at t_0 (Fig. 7a). The surface cyclone features a northeastward advancing plume of high precipitable water collocated with integrated vapor transport (IVT) directed toward the northeast. Low-level flow, established by the juxtaposition of the surface cyclone and a surface anticyclone centered over the Atlantic Ocean, aids in advecting the plume of high precipitable water northeastward. While the surface cyclone moves northeastward, it is located within the equatorward entrance region of a 250-hPa jet streak. At t_0, the surface cyclone is associated with a high-amplitude 500-hPa trough. In the northwest sector of the surface cyclone at t_0, Q-vector forcing for ascent is collocated with a band of frontogenesis, which stretches from the southwest to the northeast. Also in the northwest sector of the surface cyclone at t_0, lower-tropospheric cold air is established. Cooling due to ascent and horizontal cold air advection by the total wind, reinforces this cold air.

- The Baroclinic Zone: Westerly Thermal Wind subset features an eastward-moving surface cyclone and surface anticyclone (Fig. 7b). The surface anticyclone is located to the northeast of the surface cyclone before t_0. At t_0, high surface pressure is evident toward the north of the surface cyclone. As the surface cyclone moves eastward, low-level flow associated with the surface cyclone and enhanced by a surface anticyclone over the western North Atlantic Ocean advects a plume of high precipitable water poleward, which is collocated with IVT

directed toward the east-northeast. At upper levels, the cyclone is associated with a low-amplitude 500-hPa trough. Also at t_0, a signature of jet coupling at 250 hPa is evident over the cyclone. Toward the north and northwest of the surface cyclone at t_0, Q-vector forcing for ascent occurs and overlaps with a band of frontogenesis, which stretches from west to east. Cold air in the lower troposphere is established in the northern portion of the snowstorm as indicated by the southward extent of the 1290 m 1000–850-hPa thickness contour. Cooling due to ascent and horizontal cold air advection by the total wind reinforces the cold air.

- The Cold Pool category features a northeastward-moving surface cyclone and an eastward-moving surface anticyclone, which is located to the north of the surface cyclone (Fig. 7c). At upper levels, this surface cyclone is associated with a moderate-amplitude 500-hPa trough at t_0. Also at upper levels, this surface cyclone is located toward the poleward exit region of a jet streak at 250 hPa. As the surface cyclone moves northeast, it features a broad area of northeastward advancing precipitable water that overlaps with IVT that transitions from indicating northeastward moisture transport in the southern portion of the surface cyclone to northwestward moisture transport in the northern portion of the surface cyclone. Also in the northern portion of the surface cyclone, Q-vector forcing for ascent is apparent over a lower-tropospheric cold pool, and an area of frontogenesis located to the southeast of the lower-tropospheric cold pool coincides with the Q-vector forcing for ascent. Lower-tropospheric cold air is evident in the form of a narrow thermal trough with 1000–850-hPa thickness values ≤ 1290 m toward the north of the surface cyclone (Figs. 7c and 7a). Within this narrow thermal trough, a lower-tropospheric cold pool is apparent in regions that display cooling due to ascent, horizontal cold air advection by the total wind (Fig. 8a), and horizontal cold air advection by the ageostrophic wind (Fig. 8b). Signatures characteristic of diabatic cooling (i.e., moistening and cooling) are apparent within the lower-tropospheric cold pool, in both composite maps and composite soundings (not shown). These signatures indicate that diabatic cooling is likely important to the development of the lower-tropospheric cold pool. The lower-tropospheric cold pool occurs beneath the cross-hair signature, a signature of heavy snowfall, and frontogenesis overspreads the lower-tropospheric cold pool (Fig. 8b).

NWS Interactions:

Rebecca met with Ross Lazear, the liaison between the University at Albany CSTAR project and NWS operations, in order to discuss plans for transitioning her M.S. thesis research to operations. The conceptual models (Figs. 7a–c) and the case studies conducted during the course of the research are being formatted for integration into the NWS Virtual Laboratory tool.

2. RESEARCH TO OPERATIONS

In January 2017, the *Albany CSTAR* Virtual Lab (VLab) community page was created, with Ross Lazear (UAlbany) and Vasil Koleci (NWS-ALY) as community owners. The page was organized into *Warm Season* (Fig. 6) and *Cold Season* studies. To test the page's functionality, a web page with mesoscale snowband research from CSTAR IV was added with several keywords that will allow all CSTAR work to be linked directly to AWIPS through the AWIPS Interactive Reference (AIR) tool. The ultimate goal is to move all CSTAR-related research, conceptual diagrams, and other operationally relevant research results from the current webpage (*http://cstar.cestm.albany.edu/*) onto the Albany CSTAR VLab pages. Updates on our R2O efforts will be provided regularly in CSTAR VI six-month reports.
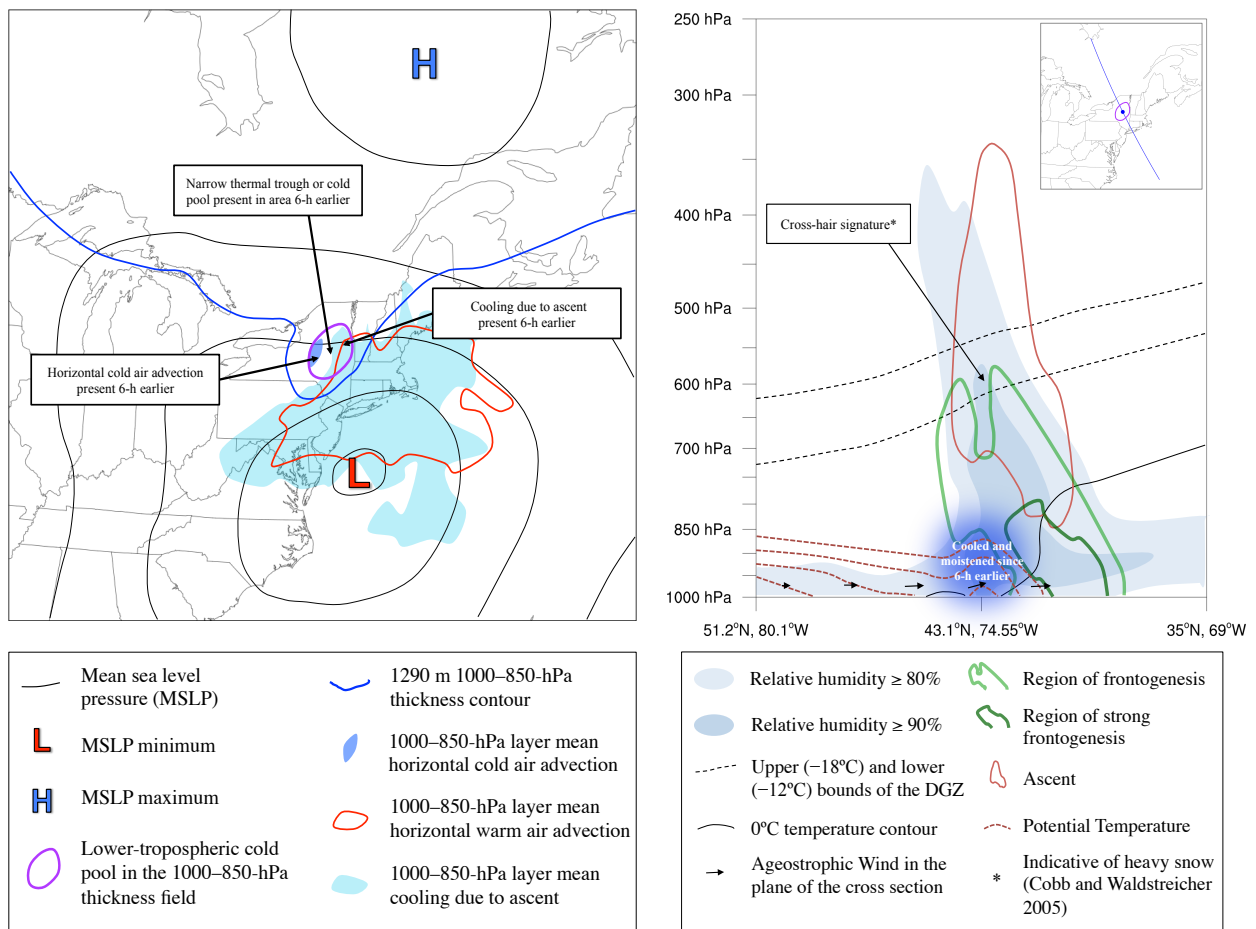
Figure 8. *Conceptual diagram for the Cold Pool category summarizing synoptic-to-mesoscale atmospheric flow patterns surrounding a lower-tropospheric tropospheric cold pool at t_0 for (a) the 1000–850-hPa layer and (b) a cross section through the cold pool. The cross section corresponds to the blue line in the inset map, and the center tick mark of the cross section corresponds to the solid blue circle in the inset map. The inset map includes the lower-tropospheric cold pool (purple line) from Fig. 7a. The background maps in the conceptual diagram is for reference only.*

3. NWS PERSPECTIVE ON CSTAR V PROGRESS *(Raymond O'Keefe, MIC WFO ALY)*

The three major projects of CSTAR V are complete. CSTAR students Matthew Vaughan, Pamela Eck, and Molly Smith received their M.S. Degrees, with Rebecca Steeves to receive her degree in December 2017. Matt (Pamela) received his (her) M.S. Degree in December 2015 (August 2017) for his (her) work on "Severe convection in scenarios with low-predictive skill". Molly received her M.S. degree in August 2017 for her research on "Predictability of heavy precipitation associated with tropical moisture". I had the honor to attend both Rebecca's and Molly's thesis presentations this summer. The quality of their research and presentations were outstanding. I am very proud that NWS research funding supports these students.

The next step is to get the findings of CSTAR V research into operations. The primary method for this will be through the interactive reference tool in AWIPS, which will link our AWIPS workstations to graphics and text summaries of the research in VLab. Recorded training was completed on Matt Vaughn's project that has been made available to NWS forecasters via the NWS Eastern Region Scientific Services Recorded Training resource. I will be working with

NWS and DAES staff to create NOAA Virtual Lab references for this work. I will also explore a NWS ER webinar this winter on Rebecca's study.

CSTAR continues to provide a large payback to the NWS for the modest amounts expended. This grant's projects continue to build on CSTAR's legacy of completing operationally focused research, engaging the academic community at a high level with operational forecasters, providing the NWS with top quality applicants, and enabling the involvement of dozens of operational meteorologists in applied research and conferences from numerous NWS offices across the Northeast United States. CSTAR resources in the NWS Collaborative and Associate Projects of this grant also raise the level and sophistication of involvement by NWS Albany staff and UAlbany undergraduates in support of CSTAR.

4. STATUS OF "SNYDER PLAN IV" PROJECTS *(Raymond O'Keefe and focal points)*

This status report addresses work on CSTAR V projects, which began on 1 October 2013. The project descriptions are available in the grant, and have been omitted to conserve space. (* Denotes the Team Lead of each project)

CSTAR V Collaborating Projects

1. Development of Improved WSR88D Warning Criteria

Team: Thomas Wasula*, Brian Frugis, Ian Lee (now MFL), Luigi Mecarriello (now AMA), and Steve Moore (ALY); Sarah Jameson and Robert LaPlante (CLE); Mark McKinley (ZOB)

Part 1: Identifying new capabilities of dual-pol data

a. WFO ALY participated in the Eastern Region (ER) Quantitative Precipitation Estimation (QPE) Field Test for the 2014–2015 winter season. Nearly 10 cases were saved from the winter to assess a new dry snow multiplier (1.9) and most of these cases have been analyzed. The 2014–2015 cases tested the 1.9 coefficient and have yielded a mean coefficient of 2.04, showing that our coefficient is really close. Additionally, a comparison was done on how much overestimation was occurring between the QPE and gauge data with the pre-1.9 coefficient. With the 1.9 coefficient, overestimation has fallen from 0.23" to 0.06". We hope to have a report for the Radar Operations Center in the fall.

b. A database of 69 tornadic events since 2012 over the Northeast U.S. was developed and used in the following projects:

    i. Tornadic debris signature (TDS) height project: Twenty-four events showed evidence of a TDS, including all tornados rated EF2+, similar to Entremont and Lamb (2015). The stronger the tornado, the higher the debris was lofted as seen in Dual-pol radar data. Results will be shown at NROW XVI and the 2015 National Weather Association (NWA) Annual Meeting. Tools for operational use, including box and whisker plots, will be ready for the 2016 convective season.

    ii. Normalized rotation (NROT) study: Using GR2Analyst software, all 69 tornado events were examined for the value of NROT. Sixty of these events were useable after quality control; twenty-one null events were also examined. There was a correlation seen between the value of NROT and the strength of the tornado. The stronger the tornado, the higher the value of NROT. The tornadic events had higher values, on average, as compared to the null events. Data from this study will also be shown at the NWA Annual Meeting and NROW XVI.

c. Eastern Region (ER) Technical Attachment 2015-03 titled, "A proposed radar strategy for prediction and warning of severe hail using polarimetric radar data", was published in March 2015.

Part 2: Establish modern Vr-shear tornado warning thresholds for the Northeast
Tom Wasula gave an oral presentation at the 42nd Northeastern Storm Conference on 12 March 2017 in Saratoga Springs, NY entitled, "A multiscale analysis of the 1 July 2016 null tornado watch across eastern New York and western New England". Brian Frugis was a co-author. Results in the Vr-shear and nrot study led by Brian, and assisted by Tom, were shown for a couple of warned severe thunderstorms that did not produce tornadoes. The convective environment did yield 25 damaging wind and large hail reports (this event accounted for six out of the 12 large hail severe reports for the entire season in the Albany forecast area). Dual-pol applications were also briefly shown for the large hail. The lack of tornadoes was likely due to low/moderate instability (dew points in the 50s to lower 60s), the LCL heights being slightly too (high based on past research studies), lack of very steep mid-level lapse rates, and lack of an elevated mixed layer (EML). This case was a high societal impact weather event due to the kick-off to the long Independence Day holiday weekend.

2. Applications of mesoscale modeling
Team: Warren Snyder* (retired), Vasil Koleci, and Ian Lee (now at DTX) (ALY); Mike Evans (BGM now ALB); Mark McKinley (ZOB); David Knight (University at Albany)

This project has ended with the NWS focus toward using local modeling only in support of research. Two versions of the WRF continue to run, one on the UAlbany RIT System, and the other on a local cluster.

3. Probabilistic QPF
Team: Neil Stuart* and Vasil Koleci (ALY)

This project has been superseded by national initiatives and has been cancelled.

4. Improvement of forecasts of IFR ceilings and visibility in TAFs: Develop methods to improve IFR forecasts of TAFs and improve accuracy in forecasting flight categories
Team: Kevin Lipton*, Hugh Johnson, and Ian Lee (now at DTX) (ALY); Mike Evans (BGM, now ALB); David Fitzjarrald (University at Albany's Atmospheric Sciences Research Center [ASRC])

Ian Lee developed a decision aide to assist forecasters in application of the methods he developed. A Java-based algorithm was developed and used to create an AWIPS application to use this method operationally. In addition, a Google form was created to allow performance of the research to be verified. Operational staff entered feedback on its successes and failures during the fall 2015 fog season.

5. Graphical TAF verification of ceiling and visibility forecasts at Taunton, Massachusetts
Team: Joseph Dellacapini*, Kevin Cadima, and Frank Nocera (BOX)

WFO Taunton has produced digital ceiling and visibility forecasts in support of its aviation forecast program since February 2010. Since there is currently no method to verify these fields in a gridded format, the office creates Virtual TAFs (VTAFs) for nearly two-dozen METAR locations that do not have an official TAF. These VTAFs are created in the AWIPS background and are transmitted internally to the NWS Verification Branch for processing, to provide a measure of the quality of digital aviation forecasts.

6. Using and assessing new technology to provide decision support service (DSS) to a variety of customers as part of Weather Ready Nation initiative
Team: Brian Montgomery and Steve DiRienzo (ALY)

DSS continues to be at the forefront of our Weather Ready Nation (WRN) initiative. Most of our staff has completed the required training for active deployments with recent enhancements to local checklists, which are available on our Google site's intranet to ensure all items for deployment are available. Skype has been approved for use at WFO Albany. We first utilized Skype during a television interview with the Weather Channel on 16 February 2016. WFO Albany is creating a "studio" to enhance our dissemination services. Finally, WFO Albany has successfully tested New York State's Mutualink system with the New York State Office of Emergency Management. Mutualink facilitates sharing of voice, video, and data for cross-agency collaboration in real-time.

7. An evaluation of winter weather warning and advisory criteria in the NWS Eastern Region from a scientific and societal impact perspective
Lead: John Quinlan (ALY)

This project has been cancelled.

CSTAR V Associate Projects
1. Improving forecasts of snow along the west facing slopes of the Appalachians
Lead: Matt Kramar (PIT)

This project has been moved to CSTAR VI.

2. Heat waves/extreme heat events in the Northeast United States
Team: Kevin Lipton*, Neil Stuart, and Steve DiRienzo (ALY)

a. Neil attended a meeting on the NASA ROSES research grant at the NY State Department of Health. The partners include the EPA, CDC, Florida Department of Health (DOH), Universities Space Research Association, University of Alabama Huntsville, and New York City DOH. Neil also presented a brief summary of how the NYS DOH studies associated with the NASA grant are benefitting the NWS.
b. The NYS DOH completed work on their website creating links to vulnerability index maps accessible to the public. These links display county-by-county differences for various vulnerabilities such as language, heat, socio-economic, environmental and elderly.
c. Dr. Shao Lin and her colleagues at the UAlbany School of Public Health submitted a

paper to the publication *Environmental Health Perspectives* with Neil, Steve, and Kevin as coauthors. The title is, "Does wind chill temperature better predict the risk of cardiovascular disease than temperature only in cold seasons?", and is in the review process. Dr. Shao Lin also has sent a draft proposal for a new National Institute of Health research grant to assess how multi-weather factors or large temperature variation and air pollution jointly affect human health. Neil, Steve, and Kevin would act as consultants providing weather data and analysis if this proposed research grant becomes funded. The Atmospheric Science Research Center and the NYS DOH are also included in this proposed research grant.

d. Kevin Lipton has proposed a workshop or seminar on extreme heat in 2018. This workshop would be a collaboration with the UAlbany Department of Atmospheric and Environmental Sciences, and School of Public Health and Public Policy. Local media and other NWS offices in the region would also participate.