The Collaborative Science, Technology, and Applied Research (CSTAR) Program

Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain

University: University at Albany

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NWS/AFWA/Navy Office: National Weather Service, Albany, New York

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1. SUMMARY OF STUDENT RESEARCH ACTIVITIES

a) Near-freezing winter precipitation type in complex terrain

Graduate student: Matthew Seymour
PI and co-PIs: Justin Minder, Nick Bassill, Robert Fovell, Andrea Lang
NWS focal points: Michael Evans (ALY) and Frank Nocera (BOX)

Research summary:

During the reporting period, a new graduate student, Matthew Seymour, was recruited to work on this project. Under the guidance of Dr. Minder, Matthew has been conducting an in-depth literature review to build his background knowledge on physical processes and forecasting procedures related to near-freezing winter precipitation events. He has also taken a full load of three graduate courses covering: atmospheric dynamics, mesoscale processes, and atmospheric physics. Additionally, Matt has begun to learn how to run and analyze output from the Weather Research and Forecasting (WRF) model. He drafted an initial outline of his research plan, which he presented at our semiannual, Fall CSTAR meeting, receiving feedback from other University and NWS participants.

Over the next six months, Matthew will continue working on both his education and research efforts. During January 2020, he will be visiting the NWS ALY Office to learn more about the operational forecasting of winter precipitation and to get input into his research plan. During Spring 2020, Matt will be taking coursework on atmospheric physics and numerical weather prediction. During the spring semester, his research will focus on using observations, forecasts, and expert input to identify near-freezing precipitation events for further study. He will also begin to simulate a subset of these events with WRF and evaluate the simulations against mesoscale observations.

b) Severe convection in complex terrain and across severe-weather environments

Graduate student: Brennan Stutsrim
PIs and co-PIs: Brian Tang and Robert Fovell
NWS focal points: Thomas Wasula (ALY) and Joe Dellicarpini (BOX)

Research summary:

Graduate student Brennan Stutsrim began his work on this CSTAR project in August 2019. Brennan, Co-PI Brian Tang, and Co-PI Robert Fovell had a number of discussions to develop research ideas and plans. Several possible research ideas were discussed, including: 1) investigating the role of topography and antecedent convection on the initiation of new convection; 2) analyzing/validating the boundary-layer structure in the HRRR model; and, 3) studying convective mode changes and variations due to mesoscale inhomogeneities and flow interactions caused by complex terrain.

Fortuitously, August 2019 was an unusually active severe weather month in the Northeast U.S., and many of the events had underlying science and forecasting challenges that directly relate to the aforementioned research ideas. We decided to use these events as motivation and basis to begin our investigation. There were 11 days with hail, tornado, and/or wind reports during August 2019 in the Northeast (NOAA 2019a). Figure 1 shows a sample of severe weather events that affected the NWS Albany and surrounding CWAs. The Storm Prediction Center (SPC) convective outlook categories for these days ranged from general thunderstorms to a slight risk of severe weather (Fig. 1; NOAA 2019b).

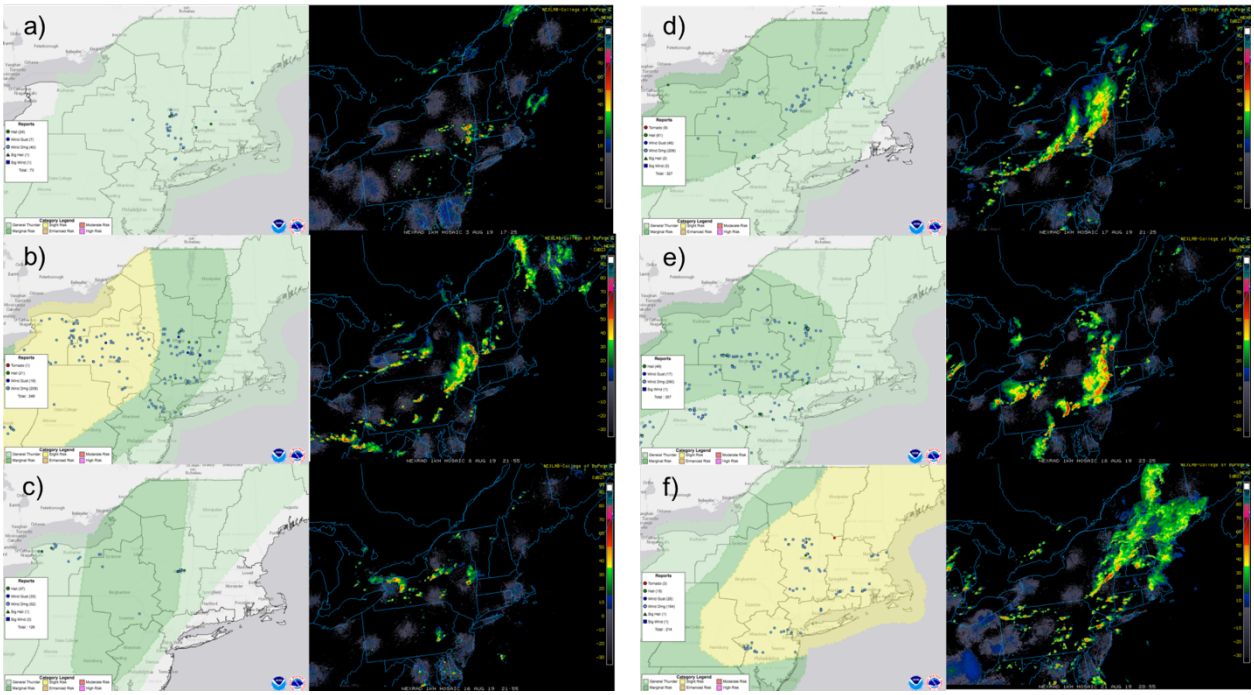

Figure 1. *NOAA SPC storm reports overlaid on 1300 UTC convective outlooks (first and third columns) and radar mosaic snapshots (second and fourth columns), from the NCAR image archive, for (a) 3 August, (b) 8 August, (c) 16 August, (d) 17 August, (e) 18 August, and (f) 21 August 2019.*

Brennan first investigated the background synoptic and convective environments for each event. The synoptic environment was analyzed through maps of 300-hPa winds and 500-hPa vorticity, using fields from the Climate Forecast System Reanalysis. The events were often characterized by weak synoptic forcing, moderate to high convective available potential energy, and weak to moderate vertical wind shear. Such weakly forced events, along with marginal environments for severe convection, present a challenge to forecasters, because large-scale signals for severe weather are not as apparent (Thompson and Grams 2008).

Brennan also analyzed the radar reflectivity of these cases and noted some interesting convective behavior. In some cases, the convective mode changed from an ordinary, discrete mode to a multicellular, quasi-linear, or marginally supercellular mode. These mode changes occurred as convection moved from the Catskill Mountains down into the Hudson Valley. Some cells also exhibited quasi-stationary or back-building behavior in the Hudson Valley, which differed from the surrounding convection over higher terrain. The more organized convection (multicellular, quasi-linear, and marginally supercellular) was associated with the damaging wind and hail reports, motivating convective mode change in complex terrain as a relevant research-to-operations topic.

We plan to further analyze these cases over the next six months. Brennan will use a HRRR-like configuration of the WRF model to conduct both real and idealized simulations. Real simulations will be initialized from model analysis fields. Idealized simulations will be based off the methodology of CSTAR VI work conducted by William Flamholtz. Additionally, we will examine forecast fields from the HRRR and HREF members to assess how operational models performed in these cases. We also plan to use archived New York State Mesonet observations to study the mesoscale evolution of each event.

NWS Interactions:

Brennan presented his initial research interests to NWS focal points at the Fall CSTAR Meeting on 8 November 2019. There was a discussion with the focal points and NWS forecasters about what forecast challenges they have identified when forecasting severe weather in the Albany CWA. Forecasters mentioned that the location and timing of convective mode changes are relevant forecast challenges. Convective initiation was also brought up as a challenging forecast issue.

There was also discussion of the August 2019 severe weather events, and forecasters expressed interest in collaborating on case studies of these events. Tom Wasula shared his preliminary analysis of these events in a poster that he presented at the 2019 Northeast Regional Operational Workshop, so there is opportunity for collaboration.

Brennan plans to meet with the NWS focal points in January to discuss research plans in order to ensure that the project has operational relevance.

References:

NOAA Storm Prediction Center, 2019a: *Interactive Local Storm Reports Display*. https://spc.noaa.gov/exper/reports. Accessed 12 Dec 2019.

NOAA Storm Prediction Center, 2019b: *Convective Outlooks Archive*. https://spc.noaa.gov/products/outlook. Accessed 12 Dec 2019.

Saha, S., et al., 2012: *NCEP Climate Forecast System Reanalysis (CFSR)*. Research Data Archive at the National Center for Atmosphere Research, Computational and Information Systems Laboratory. https://doi.org/10.5065/D69021ZF. Accessed 12 Dec 2019.

Thompson, R., and J. Grams, 2008: *Synoptic Environments and Convective Modes Associated with Significant Tornadoes in the Contiguous United States*. NOAA Storm Prediction Center. https://www.spc.noaa.gov/publications/thompson/envimode.pdf. Accessed 12 December 2019.

c) Data fusion applications to assess forecast uncertainty and improve analyses

Graduate student: TBD

PI and co-PIs: Kristen Corbosiero, Nick Bassill, Andrea Lang, and Ross Lazear

NWS focal points: Christina Speciale (ALY) and Neil Stuart (ALY)

Research summary:

During the six-month reporting period, we have undertaken a series of key tasks in preparation to begin our research. First, we are recruiting a graduate student with the necessary meteorological and technical skillset to perform the anticipated research and analysis, with a start date of Fall 2020. Second, we are archiving high-resolution numerical model output from convection-permitting models such as the operational HRRR and 3-km NAM. To this end, we have collected 18 months of hourly, HRRR model output and nine months of 3-km NAM output. Concurrently, we are compiling a list of topographically-influenced warm season convection cases, as well as mixed-precipitation events for New York State and surrounding regions. Finally, we are beginning preliminary work utilizing NYS Mesonet observations for the purposes of evaluating high-resolution model forecasts for mixed precipitation events (Figure 2), as an initial means to assess potential model bias for key events.

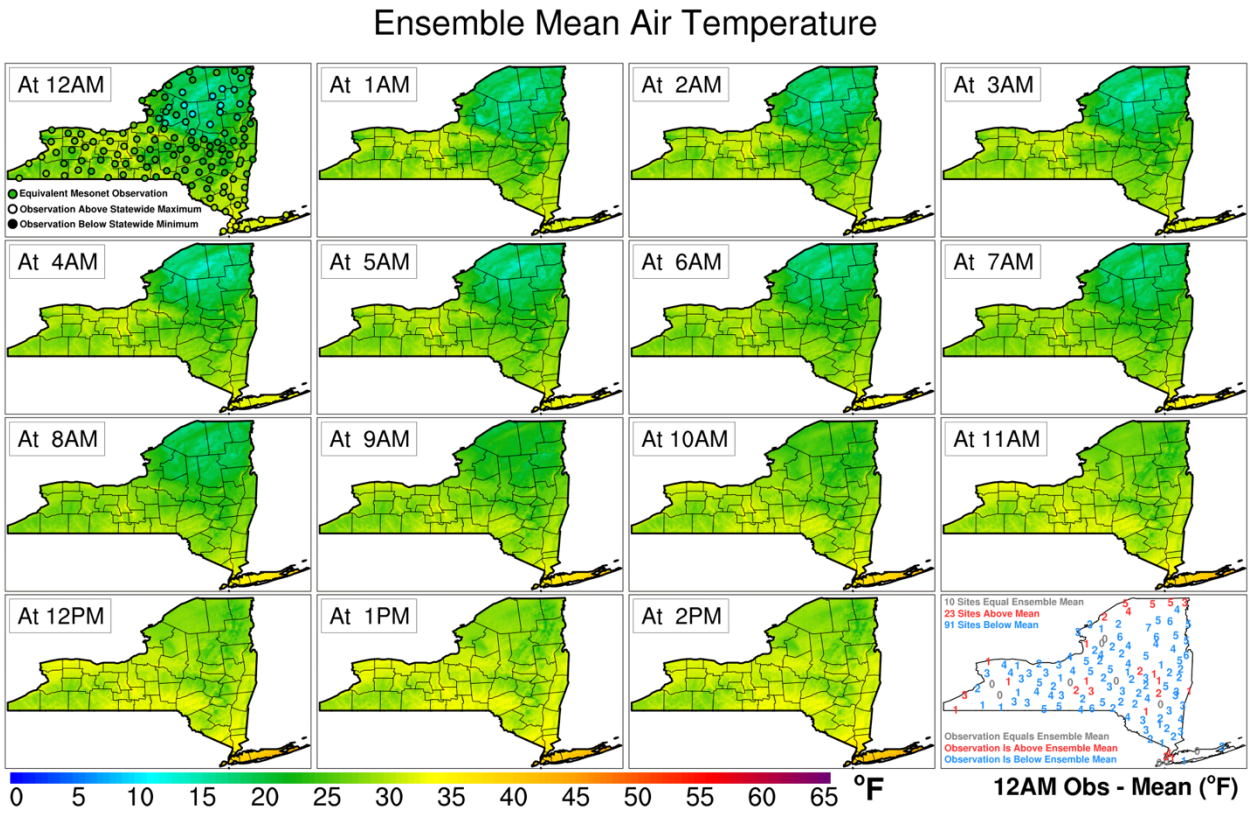

Figure 2. *An example of an automatically-generated, time-lagged, HRRR ensemble created 17 December 2019 for a potential icing event in southeastern NY. The difference between forecast and NYS Mesonet observations for 12 AM (0500 UTC) are depicted in the lower right, highlighting the generally below-forecast temperatures in the lower Hudson Valley. Significant freezing rain accumulation occurred over the subsequent 18 h in this location.*

2. CSTAR VII PROJECT THESES, PRESENTATIONS, AND PUBLICATIONS

(For a complete list of UAlbany–NWS Albany CSTAR project publications, please see *http://www.atmos.albany.edu/facstaff/kristen/CSTAR/CSTAR_CumulativePublications.pdf*.)

a) Theses completed

None

b) Presentations

None

c) Refereed publications

None

3. RESEARCH TO OPERATIONS

Ross Lazear and Vasil Koleci (NWS Albany) maintain an active Virtual Lab (VLab) community page for Albany CSTAR results, teletraining, conference agendas, and grant reports. Recent changes to the page include a new training modules subpage, and the addition of two recent

modules (*High-impact, low-predictive skill severe weather events in the Northeast U.S.,* and *Warm season cut-off lows in the Northeast U.S.*). The VLab page continues to be monitored through Google Analytics in order to more easily track traffic to each page.

Ross Lazear has been working with recent CSTAR VI, M.S. graduates, Massey Bartolini and Tomer Burg, in developing operationally relevant quick references from their research to add to VLab. The most operationally relevant results from both students' work is described as follows:

- Massey Bartolini created a table highlighting key differences in lake-effect snow band intensity, position, and graupel content when adjusting microphysics and boundary layer parameterization schemes for a lake-effect snow case from the Ontario Winter Lake-effect Systems (OWLeS) project. The table clearly depicts which parameterizations are used in current operational convection-allowing models.

- Tomer Burg created a phase-space diagram representing along- and across-track biases for Northeast cyclone tracks. Tomer also created a conceptual diagram showing longwave upper-tropospheric patterns conducive for large and small across-track variability, as well as biases expected for various teleconnection patterns.

The aforementioned quick references were discussed among the National Weather Service focal points for feedback, and will be placed on the VLab in the coming weeks.

4. NWS PERSPECTIVE ON CSTAR VI PROGRESS *(Michael Evans, SOO WFO ALY)*

NWS Albany hosted the Northeast Regional Operational Workshop on 6–7 November 2019. This workshop has historically served as a vehicle to enhance communications between the research community and operational forecasters, which has included presenting results of CSTAR-related research. This year marked the 20th NROW conference and included 34 presentations, including keynote presentations from Dr. David Novak and Dr. Louis Uccellini. Attendees represented the University at Albany, Stony Brook University, Hofstra University, Hobart and William Smith Colleges, the University of Utah, the New York State Mesonet, NCEP, NWS Headquarters, and forecast offices from Albany, Binghamton, Burlington, State College, Taunton, and CWSU Nashua.

The CSTAR semiannual meeting with NWS representatives and University at Albany faculty and students was held on 8 November. Presentations were given by graduate students Matt Seymour and Brennan Stutsrim on planned research on near-freezing winter precipitation and severe convection, respectively. Plans for continued migration of results from research-to-operations were discussed by Ross Lazear and Vasil Koleci, and plans for NWS participation in CSTAR VII, including upcoming meetings with students were discussed by Mike Evans.

Progress continues on the initiative to migrate CSTAR training materials and research findings to NOAA's VLab, in order to facilitate increased research-to-operations for our projects. Ross Lazear is working with our Information Technology Officer Vasil Koleci on the CSTAR VLab page, which now contains CSTAR reports, Master's theses, and web tools derived from previous and ongoing projects. In addition, cold-season and warm-season quick reference graphics and links to recorded training have also been added to the page, and a link to previous NROW presentations is being developed. Reference material from the research is also available to forecasters via the AWIPS Interactive Reference Tool. This tool allows operational forecasters to access VLab material with a mouse click on a product legend. This is an ongoing project, as there

are many references that have been added over the past several months, but many more remain to be added.

NWS focal points and participants have been selected for each of the three CSTAR VII projects. NWS focal points on the near-freezing winter precipitation type project are Mike Evans and Frank Nocera. Mike met with Matt Seymour at the CSTAR meeting and discussed the occurrence of a preliminary meeting this winter. The meeting will focus on the operational utility of the project. Potential case studies for the project will also be discussed. Mike has developed case studies on 2 March 2018 and 19 January 2019 that could be utilized in the project. These events could serve as interesting compare and contrast events, as the biggest challenge associated with the 2 March case was the near-freezing conditions in the boundary layer near Albany, while biggest challenge on 19 January 19 was near-freezing temperatures in an elevated warm nose.

NWS focal points for the severe convection project are are Tom Wasula and Joe Dellicarpini. Tom has closely examined the 21 August 2019 severe weather event in eastern NY as a case study, and gave a poster presentation on the event at NROW. Interesting aspects of this case included three small tornadoes and an impactful urban flash flood in the city of Troy. Tom and Joe will be meeting with Brennan Stutsrim to discuss the operational utility of the project as well as additional case studies.

Finally, NWS focal points on the data fusion project are Christina Speciale and Neil Stuart. Neil discussed potential case studies with Nick Bassill during the Fall CSTAR meeting, and they will be meeting early in 2020 to choose cases and begin comparing NYS Mesonet data to high-resolution model output for the chosen events.

5. COLLABORATIVE AND ASSOCIATE PROJECTS *(Michael Evans and focal points)*

The eight collaborative projects associated with CSTAR VII are listed below, along with updates on progress from June through November 2019.

1. Improvement of tornado detection and lead time

Team lead: Joe Dellicarpini (BOX) and Christina Speciale (ALY)

No progress to report.

2. Warm season QPF challenges: identifying when model precipitation, areal coverage, location and maximum amounts will be skillful

Team lead: Justin Arnot (GYX)

No progress to report.

3. Recent dual-polarization radar techniques to support severe weather operations

Team lead: Mike Jurewicz (CTP)

No progress to report.

4. Using GLM lightning data in operations for severe weather forecasting and enhanced DSS

Team leads: Jared Klein (BGM) and Mike Jurewicz (CTP)

Mike and Jared studied several convective events over the northeastern U.S. from 2018–2019, and examined trends and rates of flash extent density. Their findings were similar to previous studies indicating an increase in flash extent density associated with convective

storms several minutes prior to tornadogenesis, and a decrease in flash extent density around the time of tornadogenesis. This work was given as an oral presentation at NROW 2019.

5. Using GAZPACHO to verify high-resolution model snowfall forecasts from 2017–2019

Team leads: Joe Villani and Mike Evans (ALY)

This study aims to identify relationships between the impact of topography on snowfall amounts, and high-resolution model snowfall forecast skill vs. environmental characteristics of events. To advance this study, University of Albany undergraduate Jamin Marino added data to a data base of environmental parameters associated with approximately 10 winter storms from 2018–2019. Jamin completed this work while serving as a student volunteer at WFO Albany during the summer of 2019. Results from this study were shown at poster sessions at the NWA meeting in Huntsville in September 2019 and NROW in November 2019.

6. Examination of significant hail events: expand the project across the Northeast U.S.

Team lead: Tom Wasula (ALY)

Nothing new to report.

7. The role of the strength of large-scale low-level forcing on severe weather event magnitudes

Team leads: Neil Stuart and Tom Wasula (ALY)

Neil Stuart and Tom Wasula are working with the New York State Mesonet on this project. They have identified several case studies and plan to work with the Mesonet to identify signatures in the data that will provide forecasters with a heads-up on the potential for severe convective winds.

8. Use of collapsing specific differential phase columns to predict significant severe thunderstorm wind damage across the Northeast United States

Team lead: Brain Frugis (ALY)

Brian added 51 null cases to his study and presented results in a poster at this year's NROW. In addition, Brian has written a paper on this project that is undergoing a review at NWS ER Scientific Services. Brian has also been in contact with Charles Kuster at CIMMS as they are currently involved in some similar research.

6. CSTAR PROJECT RESEARCH IN NWS AFDs

Thursday 6 June 2019

CSTAR research on Hudson–Mohawk convergence was cited in the near-term section of the NWS ALY AFD.

FXUS61 KALY 060519
AFDALY

AREA FORECAST DISCUSSION
National Weather Service Albany NY
119 AM EDT Thu Jun 6 2019

.NEAR TERM /THROUGH TONIGHT/...
With the passage of the midlevel wave, the rainfall should be isolated to widely scattered by 12Z today, but some shallow showers are still possible especially along and south of I-90 through the morning hours as the frontal boundary continues to sag through the forecast area. Clearing will gradually occur from south to north behind the frontal boundary, although it may take areas along and south of I-90 at least until mid-morning to see clearing. **Some high-res models indicating light QPF lingering from the mid-morning into the early afternoon hours due to what looks like a Hudson-Mohawk Convergence type signature (see CSTAR research).** Have retained slight chance PoPs for portions of the Capital District, Helderbergs, and eastern Mohawk Valley into the Catskills to account for this possibility. Otherwise, humidity values and cloud cover will be decreasing through the day with high temps near to a couple degrees above normal. Forecast soundings suggest mixing up to 850 mb where temps are around 10C on average.

NEAR TERM...Thompson

Monday 10 June 2019

CSTAR research on warm-season cutoff cyclones was cited in the short-term section of the NWS ALY AFD.

FXUS61 KALY 100812
AFDALY

AREA FORECAST DISCUSSION
National Weather Service Albany NY
412 AM EDT Mon Jun 10 2019

.SHORT TERM /6 PM THIS EVENING THROUGH WEDNESDAY/...
The bulk of the rainfall, along with locally heavy rainfall, will occur tonight as lift/moisture increase substantially. Upper level heights will be decreasing as a sharp/progressive trough approaches from the upper Great Lakes. At the surface, an occluded front with a weak wave of low pressure along it, will focus the rainfall. What is most impressive with the system is the forecast high precipitable water values/anomalies. Both NAM/GFS indicating PWATs approaching 2 inches from around Albany southward. These values may break the daily maximum PWAT at Albany for June 11 (1.84"), and across the region PWAT anomalies of +2 to +4 STDEV are forecast from the GEFS. Moisture/forcing components concerning for heavy rainfall. **However, local CSTAR III research indicates the progressive movement of the upper trough**

(as opposed to a closed upper low), limited instability, and the absence of a downstream upper jet max should generally preclude a widespread flash flood threat. That being said, minor flooding of urban/poor drainage areas will be possible along with isolated flash flooding. Some elevated instability will result in embedded convective elements with isolated thunder. Any areas that encounter persistent/repeated convective rainfall would have an isolated flash flood threat. Since expected flash flood occurrence is isolated at this time, we will not issue a flood watch. However, we will continue to mention the possible threats in the HWO.

SHORTTERM...JPV

Tuesday 6 August 2019

CSTAR research on severe weather events with low-predictive skill was cited in the near-term section of the NWS ALY AFD.

FXUS61 KALY 060805
AFDALY

AREA FORECAST DISCUSSION
National Weather Service Albany NY
405 AM EDT Tue Aug 6 2019

.NEAR TERM /UNTIL 6 PM THIS EVENING/...
By early to midafternoon, scattered convection is expected to develop as large scale ascent increases ahead of the upper level disturbance, in an increasingly unstable air mass. SBCAPE values of around 800-1500 J/Kg are forecast from the HREF mean, which will lead to thunderstorm development. Deep layer shear looks to be weak and generally < 20 kt. However, the forecast DCAPE (downdraft CAPE) may approach 1000 J/Kg in parts of the area today once sufficient surface heating occurs and low level lapse rates steepen. **So, while the threat for organized/severe storms is low, a rogue storm or two may produce severe wind gusts due to downdraft potential (as shown by previous CSTAR research).**

NEAR TERM...JPV

Sunday 24 November 2019

CSTAR research on mesoscale snowbands was cited in the near-term section of the NWS ALY AFD.

FXUS61 KALY 240839
AFDALY

AREA FORECAST DISCUSSION
National Weather Service Albany NY
339 AM EST Sun Nov 24 2019

.NEAR TERM /UNTIL 6 PM THIS EVENING/...
Due to transitioning precip types, snow accumulations will vary greatly with the highest amounts over the mountains of the eastern Catskills and Helderbergs. We are noting a strong signal in the latest model guidance, with regards to an area of strengthening 850- 700mb F-Gen to the north and west of the 700mb low/deepening surface cyclone by late this morning into early afternoon. **Previous CSTAR research has shown this to be favorable for mesoscale banding.** Hi-res guidance such as the NAMNest/HREF focusing bands of moderate/heavy snow across the eastern Catskills and Helderbergs during this time. This is the area we have increased snowfall totals to around 3-6 inches. Warm nose aloft is still expected to progress northward across the Taconics, Litchfield Hills, Berkshires and eventually southern VT from this morning into this afternoon. So in these areas we have increased ice slightly due to freezing rain, with slightly less snow and greater potential for sleet into early afternoon.

NEAR TERM...JPV