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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1. SUMMARY OF RESEARCH ACTIVITIES

a) Near-freezing winter precipitation type in complex terrain

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

Research summary:

This project focused on analysis of mesoscale forecasts of precipitation type in near-freezing conditions. The research was led by two graduate students, Matthew Seymour and Megan Schiede; the results are detailed in their respective theses (Seymour 2021; Schiede 2024).

The first of these projects (Seymour 2021) focused on the mesoscale predictability of two near-freezing precipitation events in and around the Hudson and Mohawk Valleys: 6–7 February 2020 and 23–24 March 2020. These were selected in consultation with NWS focal points. Weather Research and Forecasting (WRF) model simulations were conducted for both events. The control simulation for each used a HRRR-like model configuration. A suite of planetary boundary layer (PBL) and microphysics (MP) experiments were conducted to determine how uncertainty in PBL and MP processes contribute to forecast uncertainty. An initial and boundary condition (IC/BC) ensemble was also run, with IC/BCs supplied by each of the 21 Global Ensemble Forecast System (GEFS) members, to investigate the role if IC/BC uncertainty. Results from all simulations were evaluated against ASOS and NYS Mesonet observations, mPING reports, and ERA-5 reanalysis datasets.

Results were used to diagnose the mechanisms associated with forecast uncertainty, such as temperature advection by terrain-channeled flow, whereby minor synoptic uncertainties translated differences in surface p-type. Variability in the PBL and MP ensembles was relatively modest, but both ensembles had highly biased precipitation type forecasts due to a warm bias. This warm bias was caused by subtle errors in the position of synoptic features, such as the surface low pressure center, leading to a reversal in the modeled valley-wind direction and thereby a reversal in the sign of the temperature advection. The IC/BC ensemble featured more variability and less of a warm bias than the physics ensembles, and synoptic-scale features were more adequately represented. Differences between the outcomes of the two ensembles were attributed to how differences in the representation of synoptic features affected mesoscale circulations and to differences in initialization datasets between the two sets of experiments. These results point to the importance of characterizing modest synoptic-scale storm evolution uncertainties in ensemble forecasts when forecasting precipitation type transitions in valley locations.

The second of these projects (Schiede 2024) focused on the mesoscale predictability of freezing drizzle aloft during a storm that led to substantial supercooled large drop aviation icing (with abnormally warm cloud-top temperatures) near the New York – Ontario border region on 7–8 March 2022. Observed thermodynamic and microphysical conditions aloft during this case were characterized using airborne observations collected as part of the NSF-sponsored Winter Precipitation Type Multi-scale Experiment (WINTRE-MIX) field campaign. For this event, the performance of operational HRRR forecasts was characterized and additional HRRR-like experiments were conducted to isolate sources of HRRR biases.

Results revealed that HRRR and the control HRRR-like WRF simulation simulated snow and ice hydrometeors at flight level, which contrasts with observations of freezing drizzle and supercooled large drop icing at flight level. The presence of simulated snow hydrometeors throughout the vertical column suggests that seeding from an upper-level cloud inhibited collision-coalescence and freezing drizzle formation in the model, as frozen hydrometeors serve as ice nuclei or lead to the evaporation of liquid through the Bergeron-Wegener-Findeisen process. Two sensitivity experiments were performed by removing moisture above 5 km and between 4 km and 6 km to explore the influence of seeding from the upper-layer cloud. This resulted in a reduction of snow mixing ratios and improvements to rain mixing ratios at locations of observed icing, demonstrating the biases introduced by the model's erroneous seeding. These results suggest a need to further investigate and improve the representation of seeding from upper-level clouds for accurate forecasts of supercooled large drop aviation icing.

NWS Interactions:

Throughout the project, in-person and virtual meetings were held between UAlbany researchers and NWS WFO staff feedback and communicate results. Results were also conveyed to the operational community and conferences and workshops including the Northeast Regional Operational Workshop, the New York State Mesonet Forum.

Training:

This funding supported the studies of two graduate students: Matthew Seymour and Megan Schiede. Both students conducted research that involved model evaluation against mesoscale observations for events with uncertain p-type under the advisement of PI Minder. Both students participated in conferences and workshops where they presented their research. Mr. Seymour completed a MS thesis based on his CSTAR research in August 2021 (Seymour 2021). After graduation, Mr. Seymour took a job as a private sector forecaster at WeatherWorks LLC. More recently, starting in May 2024, he has been employed as a research support specialist in the Center of Excellence in Weather and Climate Analytics at UAlbany. Ms. Schiede completed a MS thesis based on her CSTAR research in August 2024 (Schiede 2024). She is currently continuing her studies to pursue a PhD at UAlbany under the advisement of PI Minder.

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

Graduate students: Brennan Stutsrim, Rachel Eldridge
PI and co-PI: Brian Tang, Robert Fovell
NWS focal points: Tom Wasula (ALY), Joe Dellicarpini (BOX)
NOAA contributors: Hayden Frank (BOX), Kat Hawley (NESDIS)

Research summary:

Several goals were accomplished to better understand severe convective events in complex terrain. The first goal was to study factors conducive to back-building convection that could lead to excessive rainfall in the New York Capital and Hudson Valley regions. We identified about 70 convective cases from 2015 to 2020, during the months of June, July, and August. Based on subjective radar analysis, the cases were tagged as having or not having back-building behavior. High Resolution Rapid Refresh analyses were obtained of these cases, and thermodynamic and kinematic variables of interest were extracted and computed in the pre-convective environment. We then used a decision-tree framework to assess what variables distinguished back-building and non-back-building events. Thereafter, the decision-tree framework was used to stratify cases into correctly forecasted and falsely forecasted back-building events (false positives) to compare cases that were similar in character, i.e., simulating challenging scenarios that a forecaster might encounter.

Comparing these cases,

- Both correctly forecasted and false positive cases had large CAPE (> 2000 J kg^{-1}), so instability and low-level moisture were not strong distinguishing factors.
- False positive cases had stronger southwesterly winds through most of the troposphere, and stronger wind shear, resulting in faster storm propagation and upscale growth.
- On the other hand, correctly forecasted cases had weaker westerly winds and shear, resulting in a multi-cellular mode with back building that often occurred on the southwest side of the multi-cellular line, anchoring the heavy precipitation over a local area.

Figure 1 shows composite soundings of correctly forecasted and false positive back-building cases, which serves as a useful reference to compare against forecast and observed soundings. Such a comparison may aid situational awareness of the possibility of back-building convection and excessive rainfall.

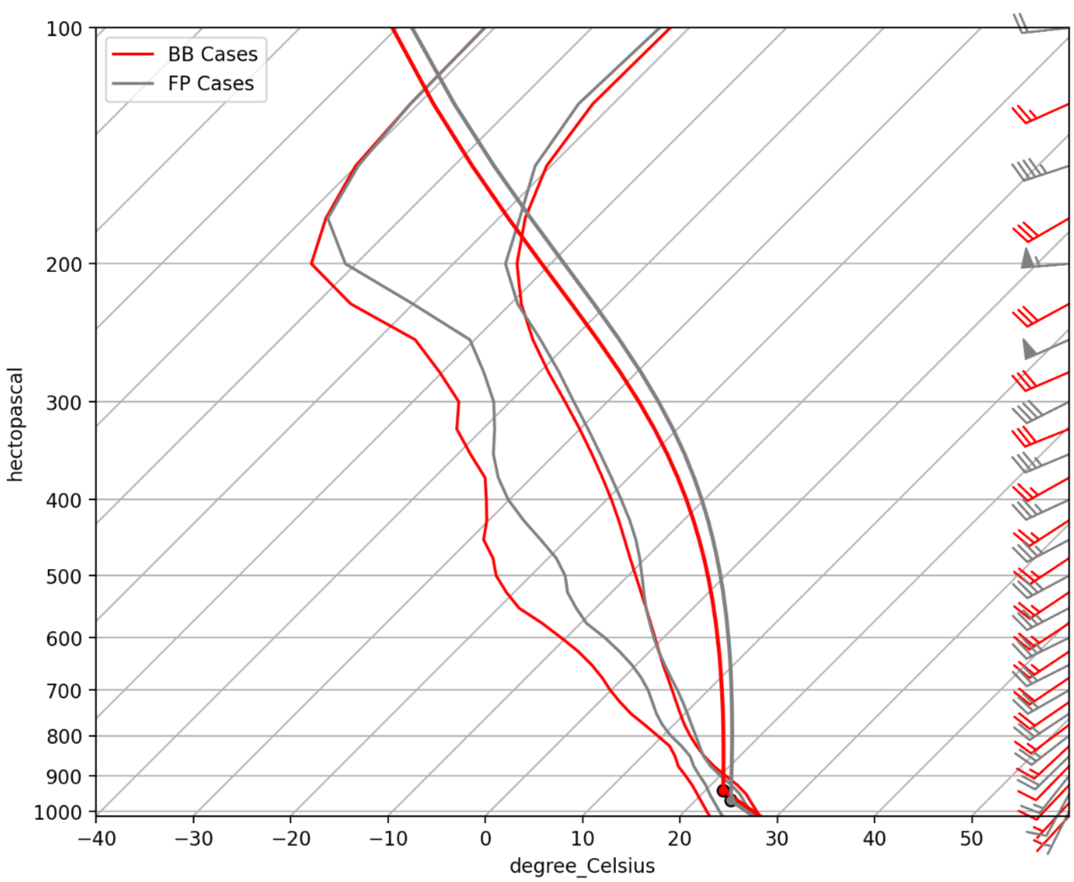

Figure 1. *Composite, area-averaged soundings of correctly forecasted back-building (BB) cases (red) and falsely forecasted back-building (FP) cases (gray). On the skew-T, log-p diagram, thick profile is the temperature, thin profile is the dewpoint, and barbs show the vertical profile of the wind. 1800 UTC HRRR analyses are used to compute the area-averaged soundings in the Hudson Valley region.*

The second goal was to assess HRRR model forecasts of the pre-convective environment. Errors and biases were calculated by comparing HRRR forecast output to New York State Mesonet (NYSM) observations. A major finding is that the HRRR model consistently had a warm and dry bias. Figure 2 shows these biases at Voorheesville, NY, which were consistent across different parts of the warm season and for clear versus convective days. Warm biases were largest during the latter part of summer and on days with widespread convection. We hypothesized that these biases were the result in errors in how the HRRR handled shortwave radiation, because we found a consistent positive difference between HRRR and NYSM surface shortwave values. Very late in the project, however, we discovered that there were issues with the NYSM standard-site pyranometers that caused an underestimation of the shortwave radiation, and our hypothesis was refuted. Thus, we were not able to ascertain the causes of the warm and dry bias in the HRRR. Nonetheless, this warm and dry bias can delay convective initiation and alter the convective evolution (e.g., coverage, movement, and mode), so is important for forecasters to be aware of when using the HRRR for forecasting convection.

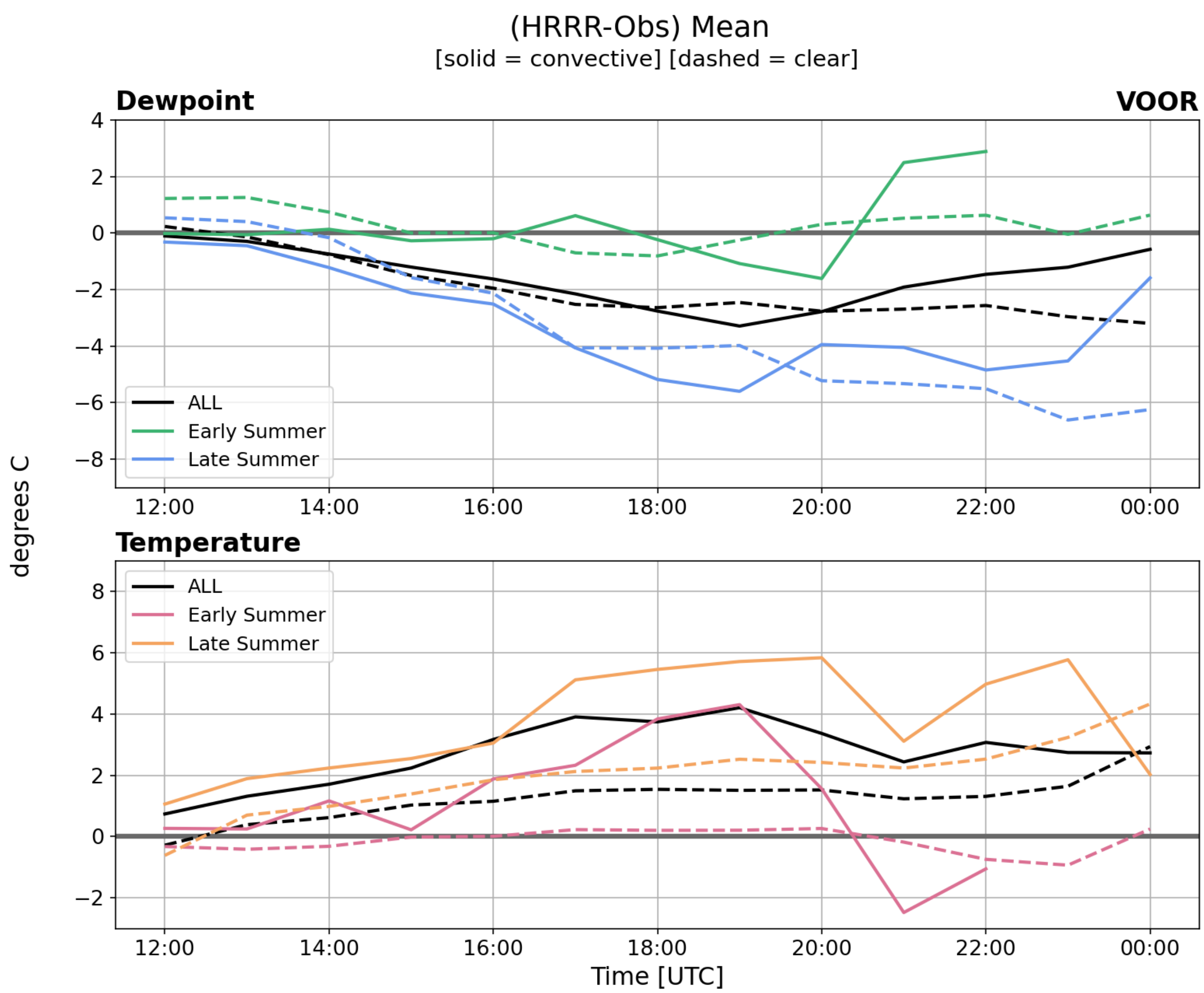

Figure 2. *Mean HRRR biases in the 2-m dewpoint and 2-m temperature, compared to NYSM observations at Voorheesville, NY. Biases are separated into convective days (solid) and clear-weather days (dashed). Additionally, biases are shown for the early summer (green and pink lines) and late summer (blue and orange lines), along with all cases (black lines).*

A third goal, supporting the first two goals above, was a small field project that we carried out called Investigation of Convective Environments in the Capital Region with Expanded Atmospheric Measurements (ICECREAM). We conducted radiosonde launches on 11 days during the summer of 2023. These days featured different types of high-impact weather – including heavy rainfall, high winds, and hail – along with null events where severe weather was possible but did not materialize. The highlight day was 13 July 2023, where we launched three radiosondes at Ft. Hunter, NY in the Mohawk Valley to study the evolution of the lower troposphere ahead of a line of severe convection. Figure 3 shows a comparison of the radiosonde observations with HRRR forecast soundings and hodographs below 700 hPa. The HRRR underestimated the low-level shear and storm-relative helicity early in the day and was too quick to erode the low-level stable layer. We found, consistent with the comparison with NYSM observations, that the HRRR forecast boundary layer tended to be too warm, dry, and deep compared to radiosonde observations, particularly on the moist side of terrain-influenced mesoscale boundaries.

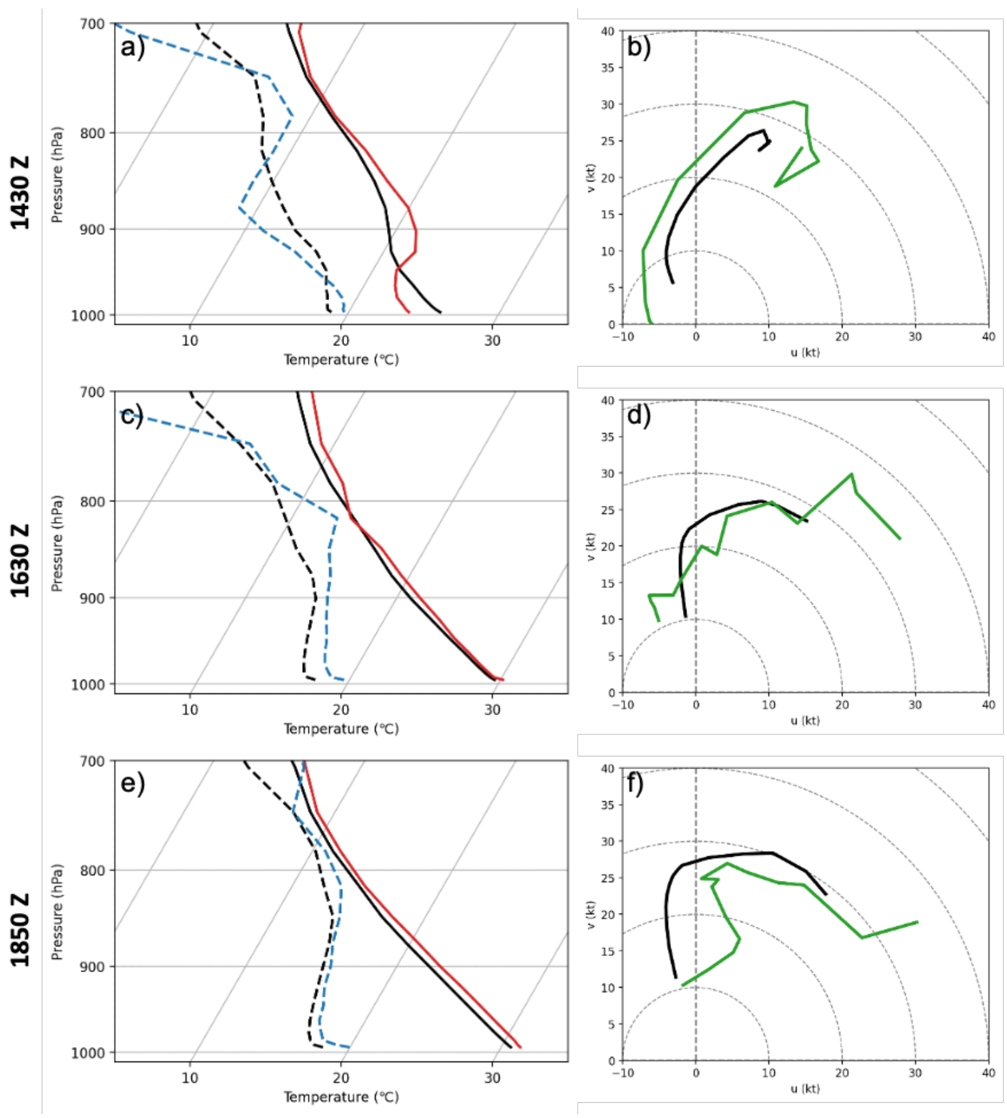

Figure 3. *Observed (color) versus HRRR forecast (black) variables from the surface to 700 hPa at Fort Hunter, NY on 13 July 2023 at (a, b) 1430Z, (c, d) 1630Z, and (e,f) 1850Z. Left column shows skew-Ts of temperature (solid) and dewpoint (dashed), and right column shows hodographs.*

NWS interactions:

We coordinated with NWS Albany during ICECREAM to let them know when we planned to launch radiosondes and to send the data to them. During the summer of 2023, NWS Albany was still setting up and testing their radiosonde infrastructure from the University at Albany ETEC building, so the radiosonde data was valuable for filling the gap on high-impact weather days. The data was cited in NWS Albany area forecast discussions and mesoscale discussions by SPC and WPC. For example, the radiosonde we launched on 12 August 2023 was used by SPC to justify not issuing a severe thunderstorm watch over the Albany area, given the severe weather parameters and drying aloft appeared unfavorable. The decision ended up being a good one.

Over the course of this project, we interacted with NWS focal points both virtually and in-person. The students working on the project gave overviews to NWS Albany forecasters to inform them about the research progress and findings. We also collected feedback on what research directions and applications would be most useful to operations. Additionally, the research summarized above was presented at workshops and conferences attended by NWS forecasters, including the Northeast Regional Operational Workshop, New York State Mesonet Symposium, and the Northeastern Storms Conference. Lastly, a quick reference overview of the back-building events was made available on the NOAA Virtual Laboratory.

Training:

This project enabled multiple students to advance their educational goals. Brennan Stutsrim and Rachel Eldridge both completed their M.S. Brennan then worked for UAlbany's Center of Excellence in Weather and Climate Analytics, making products to support both private and New York state entities on weather-related decisions. Additionally, a larger group of undergraduate and graduate students participated in ICECREAM, giving them practical experience in forecasting for and executing the field project, including hands-on experience launching radiosondes.

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

Graduate student: Brian Filipiak
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:

Winter mixed-precipitation events are associated with multiple hazards and create forecast challenges that are due to the difficulty in determining the timing and amount of each precipitation type. In New York State, complex terrain enhances these forecast challenges. The goal of this project was to create a random forest machine learning algorithm to generate probabilistic winter precipitation type forecasts.

In order to achieve this goals, Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) daily observations from trained reporters between January 2017 to September 2020 were used to identify precipitation events that included rain, snow, freezing rain, and sleet. The data associated with the timing of these mixed precipitation events were collected from the New York State Mesonet, National Weather Service upper air soundings, High-Resolution Rapid Refresh model (HRRR), and North American Mesoscale forecast model with a 4-km resolution (NAM 4km).

A random forest machine learning algorithm was trained and tested on the identified cases from the CoCoRaHS reports. This algorithm was then implemented to make new nowcasts and forecasts. The first major step completed was verifying the NYSM and upper-air, NYSM and upper-air reduced, and NAMNEST products. All three sets of forecast guidance were verified from 1 November to 31 March 31 for the 2020–2021 and 2021–2022 winter seasons. The forecast guidance was compared to ASOS and mPING reports at or around the valid forecast time. The ASOS and mPING reports were matched to the nearest RF forecast location to compare the forecast both deterministically and probabilistically.

Starting with the deterministic verification, Figure 4 displays the confusion matrix for the entire two-winter period for each of the three forecasting datasets. The NYSM and upper-air dataset over forecasted sleet across all categories (Fig. 4a). There were 20,256 sleet predictions over the two-winter period compared to 970 rain, 328 freezing rain, and 8,864 snow predictions. The NYSM and upper-air reduced dataset provided a much-improved forecast compared to the original NYSM and upper-air dataset (Fig. 4b). The darker red colors along the top left to bottom right diagonal indicate more accurate forecasts. The NAMNEST confusion matrix (Fig. 4c) also showed success at predicting precipitation type. It captured mixed precipitation (freezing rain or sleet) better than either NYSM or upper-air products. Although, it had a slight over prediction of freezing rain, it at least identified sleet and freezing rain observations more than 75% as some form of mixed precipitation.

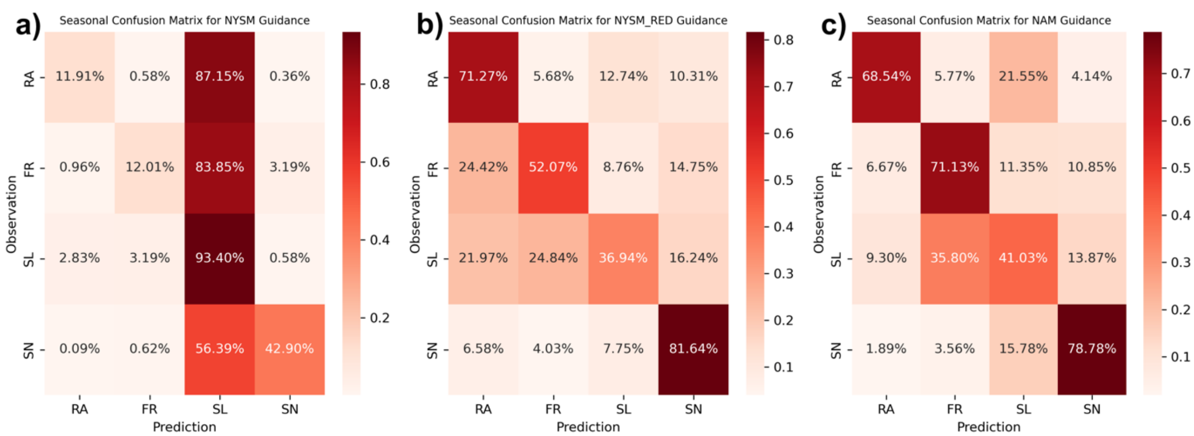

Figure 4. *Confusion matrices for NYSM and upper-air (a), NYSM and upper-air reduced (b), and NAMNEST (c). The numbers show the percentage of observations that occur in each of the boxes for the two-winter evaluation period. Darker red boxes indicate a higher percentage of observations in that box.*

Evaluating the RF in a probabilistic manner allows for understanding of what the probabilities displayed truly represent, which is important because it allows forecasters to understand what probability values are significant and how often they verify. Figure 5 shows this for the NAMNEST product. Fig. 5 not only indicates how many predictions were made and verified for each precipitation type, but for the probability bin distribution, what percent of cases in that bin verified correctly. For example, 70–75% is the highest probability bin for freezing rain, but that bin verifies 89% of the time. This result indicates that that probabilities in this bin verify more often than the probabilities would imply, so this can be used to tune the RF output. The probability bin distributions also allow for a quick check to make sure the RF is outputting a normal range of probabilities.

In addition to verifying the three sets of forecast guidance, a web archive was developed to host previous year forecasts and the verification plots associated with them. This archive is available through the main web page and is open access. It will be updated with this winter's forecast in quasi-real time.

In addition to the NAM, a HRRR-based dataset for the RF to process and make precipitation type forecasts was also created. This dataset was developed because during the previous two winter seasons, it became apparent that a denser spatial distribution of vertical model profiles would allow for more accurate and representative profiles.

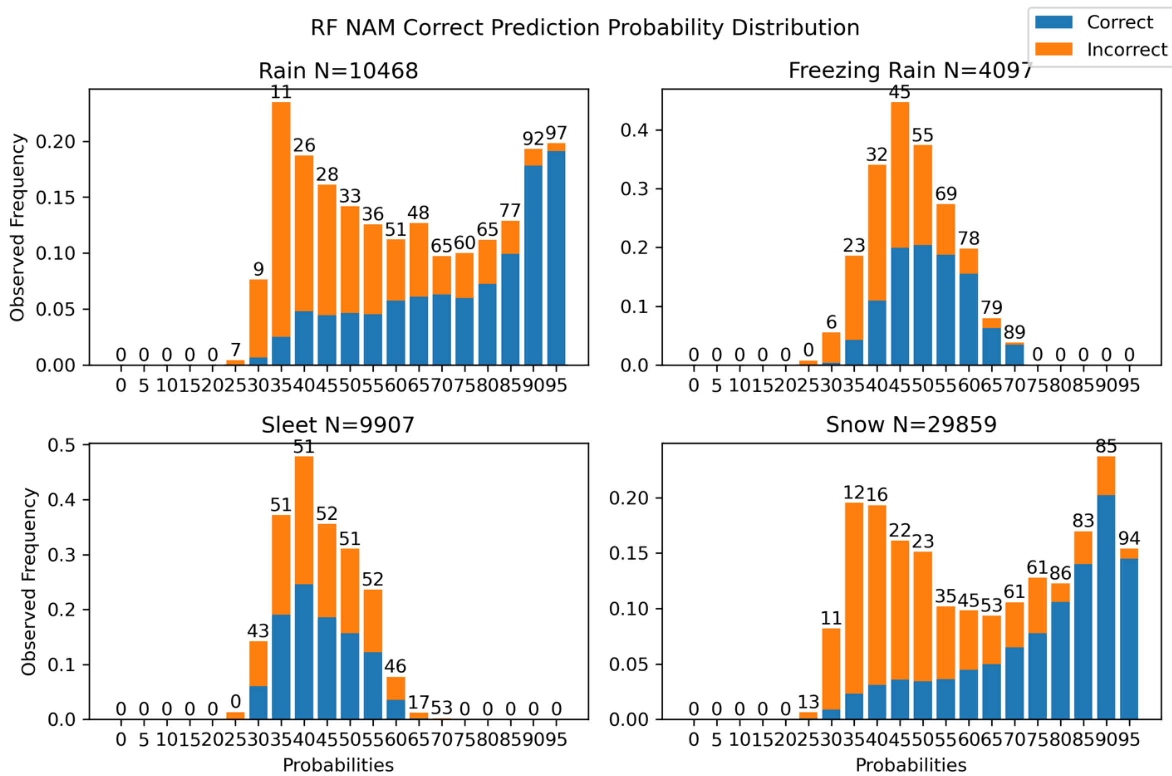

Figure 5. *Observed frequencies for the probability distribution of correct and incorrect predictions of NAMNEST product. N is number of predictions for each type of precipitation in the two-winter period. The number on the top of the frequency bars represents the percentage of correct predictions in each bin.*

Figure 6 shows the distribution of NAMNEST and HRRR vertical profiles; it is clear the proposed HRRR sounding grid (40-km spacing, blue circles) provides more representative profiles especially when considering the complex terrain of New York. The HRRR dataset will be implemented through both a forecasting and a nowcasting product. The HRRR forecasting product is initialized every 3 h and generates 12 h of lead time (same as the NAMNEST product except it is initialized every 6 h) once it becomes available. For the nowcasting product, the HRRR combines NYSM surface observations with the HRRR vertical profiles to allow for combining accurate surface observations with relative accurate model profiles. This product is the first operational product combining model data with surface observations.

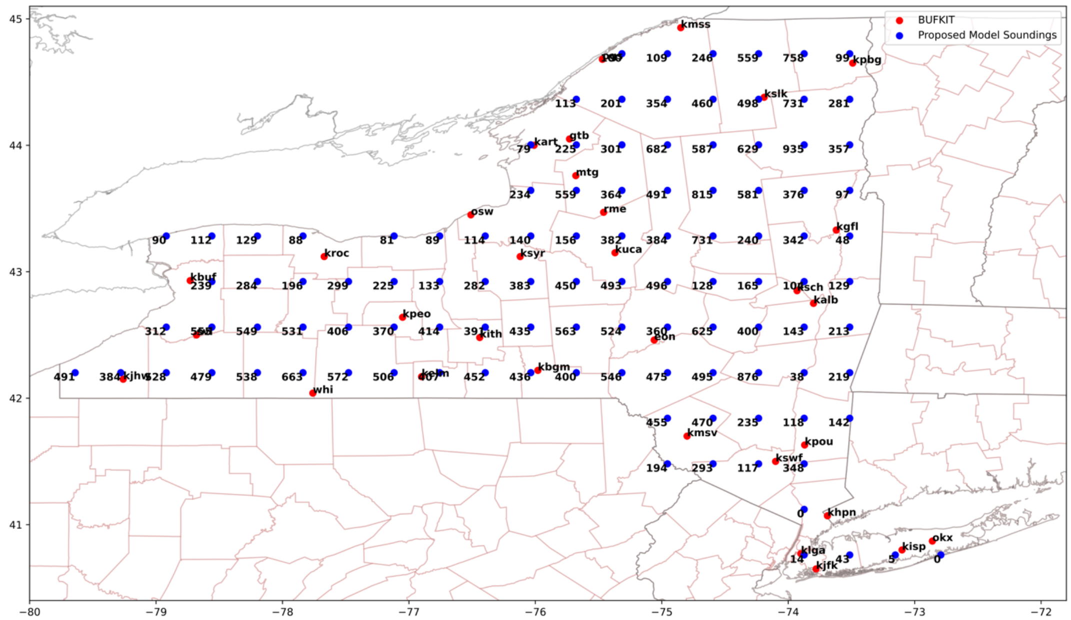

Figure 6. Map of New York displaying locations of NAMNEST (red circle) and HRRR profile sites (blue circles). Numbers next to blue circles are elevations in meters.

Finally, an evaluation of the RF NAMNEST algorithm compared to the operational HRRR and NAM analysis precipitation type output was completed. As seen in Figure 7, the NAMNEST algorithm performed well over the two-winter period making precipitation type forecasts for model forecast hours 0–9. Compared to the operational numerical models HRRR and NAMNEST, the RF underperforms at predicting rain and snow, but shows significant improvement of at least 24% and 11% for freezing rain and sleet, respectively. This result shows how the RF algorithm can complement the HRRR and NAMNEST precipitation outputs. This finding provides validation that this technique and application in the RF algorithm can provide benefits to the end users.

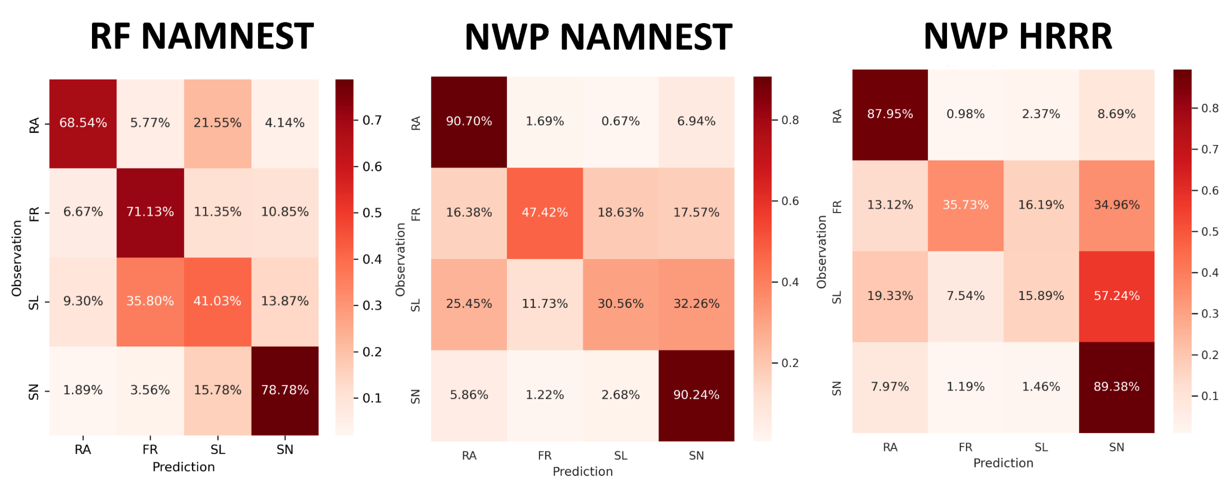

Figure 7. Confusion matrices evaluating all forecasts made by the RF NAMNEST (left), operational NAMNEST (center), and operational HRRR (right) during the winters of 2020–2021 and 2021–2022. Darker red colors indicate more correct predictions. The percentages shown are the values for the corresponding prediction observation pairing.

NWS Interactions:

Throughout the project, Brian met with NWS Focal Points regularly to maintain an open line of communication regarding updates and changes to the RF algorithm. He worked with the Focal Points to find clear and understandable ways to convey this information to other forecasters. In addition, he and his NWS Focal Points developed two slideshows showing forecasters what a sample RF forecast looked like for the 3–4 February 2022 event to collect feedback from them. The feedback was used to make updates and improvements to the RF forecasts.

Training:

This project enabled Brian Filipiak to advance his educational goals. Brian completed his M.S. and is now a PhD student at the University of Connecticut. Brian participated in numerous conferences, workshops, and NOAA webinars where he presented his research. He gained valuable experience working with big data and AI tools.

2. CSTAR VII PROJECT THESES, PRESENTATIONS, AND PUBLICATIONS

a) Theses completed

Seymour, M., 2021: Predictability issues associated with near-freezing precipitation type in complex terrain. Master of Science Thesis, Dept. of Atmospheric and Environmental Sciences, University at Albany/SUNY, 179 pp.

Stutsrim, B., 2021: A mechanism for upscale growth of convection in the complex terrain of the Northeast U.S. Master of Science Thesis, Dept. of Atmospheric and Environmental Sciences, University at Albany/SUNY, 111 pp.

Filipiak, B., 2022: Probabilistic forecasting of winter mixed precipitation types in New York State utilizing a random forest. Master of Science Thesis, Dept. of Atmospheric and Environmental Sciences, University at Albany/SUNY, 101 pp.

Eldridge, R., 2024: Examining the performance of the High-Resolution Rapid Refresh model during clear, isolated, and widespread convective days in the New York State Capital Region. Master of Science Thesis, Dept. of Atmospheric and Environmental Sciences, University at Albany/SUNY, 55 pp.

Schiede, M., 2024: Using airborne measurements to evaluate forecasts of freezing drizzle aloft. Master of Science Thesis, Dept. of Atmospheric and Environmental Sciences, University at Albany/SUNY, 93 pp.

b) Presentations

Seymour, M., 2020: Sensitivity of forecast precipitation type to WRF parameterizations over complex terrain. *National Weather Association Annual Meeting*, 14 September, Tulsa, OK.

Seymour, M., 2020: Characterizing uncertainty in forecast precipitation type in eastern New York during the 6–7 Feb 2020 winter precipitation event. *New York State Mesonet Forum*, 30 October, Albany, NY. (Virtual)

Seymour, M., 2020: Sensitivity of forecast precipitation type to WRF parameterizations over complex terrain. *21st Annual Northeast Regional Operational Workshop*, 5 November, Albany, NY. (Virtual)

Stutsrim, B., 2020: Modeling convective mode changes in complex terrain in the Northeast U.S.. *21st Annual Northeast Regional Operational Workshop*, 4 November, Albany, NY. (Virtual)

Stutsrim, B., B. Tang, and R. Fovell, 2021: A mechanism for upscale growth of convection in complex terrain. *National Weather Service Interior Northeast Science Webinar*, 20 April. (Virtual)

Stutsrim, B., B. Tang, and R. Fovell, 2021: A mechanism for upscale growth of convection in the complex terrain of the Northeast U.S. *46th Northeastern Storm Conference*, 23 April. (Virtual)

Seymour, M., 2021: Sensitivity of forecast precipitation type to WRF physics parameterizations during the 23 March 2020 winter storm in upstate New York. *46th Northeastern Storm Conference*, 24 April. (Virtual)

Filipiak, B., 2021: Data fusion: A machine learning tool for mixed precipitation. *New York State Mesonet Forum*, 7 May. (Virtual)

Filipiak, B., K. Corbosiero A. L. Lang, R. A. Lazear, and N. P. Bassill, 2021: Data fusion: A machine learning tool for forecasting winter mixed precipitation events. *First Annual New York State Mesonet Science Symposium,* 29 September, Albany, NY.

Filipiak, B., K. Corbosiero A. L. Lang, R. A. Lazear, and N. P. Bassill, 2021: Data fusion: A machine learning tool for forecasting winter mixed precipitation events. *22nd Annual Northeast Regional Operational Workshop*, 9 November, Albany, NY. (Virtual)

Filipiak, B., K. Corbosiero A. L. Lang, R. A. Lazear, and N. P. Bassill, 2021: Data fusion: A machine learning tool for forecasting winter mixed precipitation events. Albany Weather Forecasting Office Fall Meeting, 19 November, Albany, NY. (Virtual)

Filipiak, B., K. Corbosiero A. L. Lang, R. A. Lazear, and N. P. Bassill, 2021: Data fusion: A machine learning tool for forecasting winter mixed precipitation events. 2021-2022 NOAA Weather Prediction Center Winter Weather Experiment Seminar Series, 7 December, Albany, NY. (Virtual)

Lazear, R. A., and M. Evans, 2021: Collaborations between the NWS and the University at Albany before and after our move to the ETEC. *22nd Annual Northeast Regional Operational Workshop*, 9 November, Albany, NY. (Virtual)

Seymour, M., 2021: Initial and boundary condition uncertainty's role in predicting precipitation type in complex terrain. *46th National Weather Association Annual Meeting,* 22 August, Tulsa, OK.

Seymour, M., and J. Minder, 2021: Assessing the effects of initial and lateral boundary conditions on mesoscale predictability of precipitation type over complex terrain. *First Annual New York State Mesonet Science Symposium,* 29 September, Albany, NY.

Stutsrim, B., B. Tang, and R. Fovell, 2021: A mechanism for upscale growth of convection in the complex terrain of the Northeast U.S. *22nd Northeast Regional Operational Workshop*, 10 November. (Virtual)

Wasula, T., 2021: The 24 August 2020 Whitehall, NY flash flood. *First Annual New York State Mesonet Science Symposium,* 29 September, Albany, NY.

Filipiak, B., K. Corbosiero A. L. Lang, R. A. Lazear, and N. P. Bassill, 2021: Data fusion: A machine learning tool for forecasting winter mixed precipitation events. 2021–2022 NOAA Weather Prediction Center Winter Weather Experiment Seminar Series, 7 December, Albany, NY. (Virtual)

Filipiak, B., K. Corbosiero, A. L. Lang, R. A. Lazear, and N. P. Bassill, 2022: Data fusion: A machine learning tool for forecasting winter mixed precipitation events." 102nd AMS Annual Meeting/31st Conference on Weather Analysis and Forecasting/27th Conference on Numerical Weather Prediction, 26 January, Houston, TX. (Virtual)

Eldridge, R., B. Tang, and R. Fovell, 2022: Evaluating HRRR model forecasts on the 15 May 2020 severe weather event in Upstate New York. 47th Northeastern Storm Conference, 13 March, Burlington, VT.

Creighton, E., R. Lazear, and B. Tang, 2022: Analysis of the 15 May 2018 severe weather event in Eastern New York. *23rd Northeast Regional Operational Workshop*, 3 November, Albany, NY.

Eldridge, R., B. Tang, and R. Fovell, 2022: Evaluating HRRR model forecasts of impactful severe weather events in Upstate New York between 2017 and 2020. *30th Conference on Severe Local Storms,* 28 October, Albuquerque, NM.

Eldridge, R., B. Tang, and R. Fovell, 2022: Evaluating HRRR model forecasts of impactful severe weather events in Upstate New York. *23rd Northeast Regional Operational Workshop*, 2 November, Albany, NY.

Filipiak, B., K. Corbosiero A. L. Lang, R. A. Lazear, and N. P. Bassill, 2022: Data fusion: A machine learning tool for forecasting winter mixed precipitation events. *New York State Mesonet Forum,* 15 April, Albany, NY.

Filipiak, B., K. Corbosiero A. L. Lang, R. A. Lazear, and N. P. Bassill, 2022: Data fusion: A machine learning tool for forecasting winter mixed precipitation events. *Second Annual New York State Mesonet Symposium*, 13 September, Albany, NY.

Filipiak, B., K. Corbosiero A. L. Lang, R. A. Lazear, and N. P. Bassill, 2022: Data fusion: A machine learning tool for forecasting winter mixed precipitation events. *23rd Annual Northeast Regional Operational Workshop*, 3 November, Albany, NY.

Filipiak, B., K. Corbosiero A. L. Lang, R. A. Lazear, and N. P. Bassill, 2022: Data fusion: A machine learning tool for forecasting winter mixed precipitation events. *Albany Weather Forecasting Office Fall Meeting*, 8 November, Albany, NY.

Speciale, C., 2022: The heavy mixed precipitation and localized ice storm on 3–4 February 2022 in eastern New York Part II: Warnings, communication of hazards, and verification. *23rd Northeast Regional Operational Workshop*, 2 November, Albany, New York.

Wasula, T., 2022: The heavy mixed precipitation and localized ice storm on 3–4 February 2022 in eastern New York Part I: Synoptic and mesoscale overview. *23rd Northeast Regional Operational Workshop*, 2 November, Albany, New York.

Creighton, E., R. Lazear, and B. Tang, 2023: Analysis of the 15 May 2018 severe weather event in eastern New York. *48th Northeastern Storm Conference*, 11 March, Burlington, VT.

Eldridge, R., B. Tang, and R. Fovell, 2023: Evaluating HRRR model forecasts of impactful severe weather events in Upstate New York. *48th Northeastern Storm Conference*, 11 March, Burlington, VT.

Filipiak, B., K. Corbosiero, A. L. Lang, R. A. Lazear, and N. P. Bassill, 2023: Data fusion: A machine learning tool for forecasting winter mixed precipitation events - Updates and performance. *103rd AMS Annual Meeting/22nd Conference on Artificial Intelligence for Environmental Science*, 12 January, Denver, CO.

Filipiak, B., K. Corbosiero, A. L. Lang, R. A. Lazear, and N. P. Bassill, 2023: Data fusion: A machine learning tool for forecasting winter mixed precipitation events - Updates and performance. *University of Connecticut Department of Civil and Environmental Engineering Seminar*, 24 March, Storrs, CT.

Filipiak, B., K. Corbosiero, A. L. Lang, R. A. Lazear, and N. P. Bassill, 2023: Data fusion: A machine learning tool for forecasting winter mixed precipitation events - Updates and performance. *WINTRE-MIX Workshop*, 22 May, Albany, NY.

Main, M. E., and T. A. Wasula, 2023: New York and New England significant hail climatology. *WFO Burlington Spring Workshop*, 21 April 21, Burlington, VT.

Wasula, T. A., and M. E. Main, 2023: New York and New England significant hail climatology. *48th Northeastern Storms Conference*, 12 March, Burlington, VT.

Main, M. E., and T. A. Wasula, 2023: New York and New England significant hail climatology Part II: Environmental Analysis. *24th Northeast Regional Operational Workshop,* 15 November, Albany, NY.

Wasula, T. A., and M. E. Main, 2023: New York and New England significant hail climatology Part I: Climatology and Case Studies. *24th Northeast Regional Operational Workshop,* 15 November, Albany, NY.

Wasula, T. A., and M. E. Main, 2023: Significant hail event across eastern NY on May 15, 2018. *3rd Annual New York State Mesonet Symposium,* 14 September, Albany, NY.

Schiede, M., J.R. Minder, 2023: Using airborne measurements to evaluate HRRR forecasts of freezing drizzle aloft: Results from the WINTRE-MIX field campaign. *24th Northeast Regional Operations Workshop*, 15 November, Albany, NY.

Eldridge, R., B. Tang, and R. Fovell, 2023: Evaluating HRRR model forecasts of impactful severe weather events in Upstate New York. 24th Northeast Regional Operational Workshop, 14 November, Albany, NY.

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c) Refereed publications

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Filipiak, B. C., N. Bassill, K. L. Corbosiero, A. L. Lang, and R. A. Lazear, 2023: Probabilistic forecasting methods of winter mixed precipitation events in New York State utilizing a random forest. *Art. Intell. Earth Sys*., **2**, 1–17.

3. RESEARCH TO OPERATIONS

Progress has continued on the Albany CSTAR Virtual Lab (VLab) community page, a publicly viewable repository for past and current CSTAR research projects. The page contains a list of ongoing projects, recent CSTAR reports, M.S. theses, CSTAR project-related web tools, operational training modules, and quick references—concise reports of student-led CSTAR projects which contain only the portions of the results that are most operationally relevant. These quick references are easily viewed by operational forecasters through the use of keywords within the AWIPS Interactive Reference (AIR) tool. Finally, the VLab community page also hosts past proceedings from the Northeast Regional Operational Workshop, held annually in Albany each fall.

The following projects were completed and operationally relevant results were made into quick references, as outlined below. Rachel Eldridge is finalizing her quick reference, which will be placed on the VLab page in the coming months.

- *Brian Filipiak*

  Much of Brian's work involved developing forecasting tools for operational staff during and prior to mixed-precipitation weather events in New York State. The quick reference first describes the methodology (random forest) used for probabilistic precipitation type forecast products, and then describes how a forecaster can interpret the products using a sample figure taken directly from the website. Brian also created a more technical *product description document*, linked from the website from the VLab, similar to documents created by WPC for new and/or experimental forecast tools.

- *Brennan Stutsrim*

  Brennan's quick reference includes a two-dimensional phase–space highlighting variables most important in forecasting backbuilding convection in the Hudson Valley (in this case, a lower lifted index and cooler surface temperatures). Additionally, mean soundings for back-building and false positive cases indicate the importance of weaker deep-layer winds and slightly reduced instability in cases where backbuilding is most likely. Finally, a decision tree enables a forecaster on shift to walk through a check list to determine the likelihood of backbuilding convection in the Hudson Valley.

- *Matthew Seymour*

  Matthew's quick reference focuses on situational awareness in cases of low forecast confidence for mixed precipitation type in complex terrain. Specifically, differences in planetary boundary layer (PBL) schemes and initializations result in temperature biases that result in varied precipitation-type forecasts.

- *Megan Schiede*

  Megan's operationally-relevant results focus on model prediction of supercooled large droplets (SLD), and that removal of upper-level clouds to inhibit cloud seeding, allows precipitation to form as supercooled large drops in the lower-troposphere.

Finally, the VLab page is being monitored through Google Analytics in order to more easily track traffic to each page, both via the web and through the AIR. Page visits continue to increase, with peak traffic occurring in conjunction with the Northeast Regional Operational Workshop, as well as the cold season when some of the most popular quick references are viewed.

4. NWS PERSPECTIVE ON CSTAR VII *(Timothy Humphrey, SOO WFO ALY)*

The National Weather Service benefited greatly from our relationship with UAlbany including collaborations done through CSTAR research grants, including CSTAR VII. During the past several years, the National Weather Service has been transitioning its operations towards an increased emphasis on decision support services for our partners within the emergency management community. This emphasis requires that NWS meteorologists focus less on the manual production of gridded forecasts of routine weather, and more on the application of the latest science to forecasts and warnings of high-impact weather events. The collaboration between NWS Albany and UAlbany has positioned our office to excel in this area by helping us to maintain a culture that emphasizes the benefits of applying science to our forecasts and warnings. In particular, the emphasis on high-impact weather events in CSTAR VII was the key to ensuring the operational relevance of this project to the NWS.

Benefits realized by the NWS Forecast office in Albany include the opportunities for professional growth provided by direct interactions with students and faculty during the execution of the projects. In addition, research associated with CSTAR VIU consistently provides much of the material for presentations at our annual Northeast Regional Operational Workshop (NROW), which in turn provides excellent opportunities for professional growth for both presenters and attendees. Along with benefits realized by the forecast office in Albany, activities associated with CSTAR VII have provided opportunities for professional enhancement across the entire National Weather Service, and especially at offices over the northeast U.S.. Findings from CSTAR VII have been placed on the National Weather Service's Virtual Laboratory so that they can be accessed by all offices within the NWS. Collaborative research projects motivated by research associated with CSTAR VII were undertaken by staff from several northeastern NWS offices including at Albany, and meteorologists from many Northeast U.S. forecast offices have attended and presented at NROW.

Research has been completed on the three Major Foci projects of CSTAR VII, and work to transition this research to operations is ongoing. As was stated above, the emphasis on high-impact weather was critical to ensuring the operational relevance of this work to the NWS. For the first major project on near-freezing winter precipitation type in complex terrain, the NWS focal points primarily contributed to this research activity in advisory capacity. This included providing the student researchers: feedback on early results, guidance on how researching findings could be applied to operations, and suggestions for future work. NWS Albany focal Lee Picard indicated that he was pleased to work on these research activities which leveraged his operational modeling experience and research to identify sensitivities in the NWS modeling suite. The results of Matthew and 's research activities were shared with NWS meteorologists from the local to the national level through the following venues: NWS Albany staff meetings, the New York State Mesonet Science Symposium, Northeast Regional Operational Workshop (NROW), and National Weather Association Annual Meeting.

The second major project included a wide variety of NWS interactions in association with severe convection. In terms of the student research projects, NWS focal points provided input to the students on operational forecasting challenges in forecasting severe convection in the Northeast. With respect to transitioning research to operations, Brian Tang participated in the 2022 NOAA Hazardous Weather Testbed Spring Forecasting Experiment. The testbed specifically focused on determining the utility of the Warn on Forecast System and machine learning for improving the skill of forecasting severe convection. Finally, radiosonde data collected during the

ICECREAM field campaign were used by forecasters for making operational forecasts of convection during the summer of 2023.

Finally, for the third major Data Fusion project NWS Albany focal points assisted Brian Filipiak in the development of a random forest machine learning algorithm to produce probabilistic forecasts of precipitation type by providing input on meteorological variables to consider including in the algorithm's decision trees. Additionally, they provided a list of mixed precipitation cases to train the algorithm on. After the random forest algorithm was trained, focal point interactions primarily were focused on the development of a website for meteorologists to view the probabilistic precipitation type forecasts. In addition to the interactions with NWS Albany, presentations at NROW and WPC's Winter Weather Experiment resulted in additional interactions with multiple NWS offices, including NWS Binghamton and NWS Charleston West Virginia.

The NWS participants encountered several challenges (the COVID-19 pandemic, staffing shortages, and budget constraints) which limited NWS interactions throughout CSTAR VII. Despite these challenges, CSTAR VII was a valuable collaboration with UAlbany that improved the scientific basis of NWS decision support services, forecasts, and warnings.

One of the most unique benefits of NWS participation in CSTAR VII, compared to previous CSTAR projects, was to fulfill a direct NWS operational need with soundings from the ICECREAM field campaign in the summer of 2023. During the field campaign, NWS Albany was in the process of establishing and testing the infrastructure needed to conduct radiosonde launches from their new location at UAlbany ETEC. This testing prevented NWS Albany from conducting upper air soundings to assess how favorable the atmosphere was for severe weather. The ICECREAM team coordinated with the NWS on their plans for upper air sounding operations and shared the data they collected with the NWS. These data were extremely valuable for NWS Albany, the Storm Prediction Center, and Weather Prediction Center to more confidently make short-term forecasts of deep convection on high-impact weather days during the summer of 2023.

The various biases of high-resolution weather models found as a result of the CSTAR VII major research activities are also extremely impactful on NWS operations. This is especially true for the biases associated with forecasts of precipitation type during the winter season. Incorrect forecasting and messaging of precipitation types can result in significant economic costs leading up to and during winter weather events. Combining a better understanding of model biases with probabilistic guidance of the precipitation types helps the NWS better inform partners on a range of forecast solutions and improve the likelihood of partners making cost effective decisions in preparing for winter weather.