# 24th Northeast Regional Operational Workshop (NROW)
# November 14–15, 2023 | Albany, New York



**<u>Co-Sponsored by</u>:**

**National Weather Service at Albany & University at Albany–SUNY:**

**Department of Atmospheric and Environmental Sciences**

**<u>Cooperating Organizations:</u>**

**American Meteorological Society**

**National Weather Association**

# A Night Shift Derailed: Lessons Learned from the High-Profile Train Derailment in East Palestine, OH

*Shannon Hefferan*
*NOAA/NWS/WFO Pittsburgh, Pennsylvania*

On a quiet, chilly night in early February, a freight train carrying hazardous material derailed, caught fire and began leaking highly toxic vinyl chloride in the small Ohio town of East Palestine, about 40 miles northwest of Pittsburgh. Forecasters at National Weather Service (NWS) Pittsburgh first became aware of the derailment by monitoring social media across the region. Recognizing the potential impacts the weather pattern could have on the response, forecasters proactively sprang into action to provide Decision Support Services (DSS) for the incident.

Over the next two weeks, numerous coordination and service challenges were uncovered during the incident, which occurred approximately 1000 feet from the Ohio/Pennsylvania state line — the dividing line between two US Environmental Protection Agency (EPA) regions and two Federal Emergency Management Agency (FEMA) regions. A total of eleven state and federal agencies were involved in service coordination during the East Palestine incident.

This presentation will highlight the services provided by NWS Pittsburgh throughout the East Palestine train derailment, as well as the service challenges revealed and how they have been addressed. We also will discuss the new partnerships that were developed in the aftermath among the NWS and the various responding agencies, as well as ongoing collaborative training to better prepare for future incidents.

# Extensive Flash Flooding of 29 September 2023 in the New York City Metro Area

*David Stark and James Tomasini*
*NOAA/NWS/WFO New York City/Upton, New York*

Extensive flash flooding occurred across the New York City Metro on September 29, 2023. A widespread rainfall of 3 to 6 inches was recorded, with localized amounts of 7 to 9 inches. Rainfall rates were generally around 1 inch per hour, but at times around 2 inches per hour locally. Many major roads and highways were closed due to flash flooding, leaving numerous motorists stranded and necessitating water rescues. The New York City Subway system, Metro- North Railroad, and Long Island Railroad experienced significant service disruptions. The John F. Kennedy Airport recorded 8.05 inches of rain for September 29th, breaking several records, including the daily rainfall for the 29th, daily rainfall for any calendar day in the month of September, and any calendar day year-round. There was also significant flooding at the LaGuardia Airport also witnessed significant flooding. Several rivers, streams, and creeks exceeded their banks, exacerbating the flooding in the NYC metro area.

This presentation will focus on the scientific aspects of the event from several days before the event to its aftermath, as well as review the Impact Decision Support Services (IDSS) provided. The IDSS included an on-site deployment of an NWS Meteorologist to the New York City Emergency Management (NYCEM) office, which helped the city's rapid response as the event unfolded.

# An Overview of the June 2023 NYC Smoke Event

*David Radell[1] and Lukas Walters[2]*
*[1]NOAA/NWS/WFO New York City/Upton, New York*
*[2]State University of New York at Brockport*

The combination of an unusually active fire season across eastern Canada, along with a blocking upper-level weather pattern across the northeastern US, resulted in a multi-day "smoke" event across much of the northeast. While the NYS Department of Environmental Conservation is responsible for producing public air quality forecasts, NWS New York (OKX) forecasts restrictions to visibility as part of its public and aviation forecast programs. The resulting smoke episode reduced visibilities at the surface for several days, peaking on Wednesday, June 7th, 2023. This impacted aviation traffic flow across the busy northeast corridor, reduced the surface air quality for several days across the northeast, and even impacted surface temperatures due to reduced solar radiation. Visibilities across the NYC metro area were less than 1.0 mile for several hours during the peak of the smoke on June 7th, and airport delays for inbound aircraft to LGA were extensive. The forecast staff at NWS New York, NY made use of NYS Mesonet and NYC Micronet data during the event, including the cameras, LIDAR plots, soundings, and surface observations to better assess the movement of the smoke and the potential for vertical mixing of the smoke toward the surface in near real-time. This presentation will review the event, including HRRR/RAP model guidance, satellite imagery, and the integration of NYS Mesonet/Micronet/Sounding data into forecast operations on this day.

# Machine Learning-Driven Detection of Road Surface Conditions in Department of Transportation Camera Images

*Carly Sutter[1], Kara J. Sulia[2], Nick P. Bassill[3], Christopher D. Thorncroft[2], Vanessa Przybylo[1], [4]Christopher D. Wirz, [4]Mariana Goodall Cains, [5]Jacob T. Radford, [1]David Aaron Evans*
*[1]Department of Atmospheric and Environmental Science, University at Albany, State University of New York*
*[2]Atmospheric Research Center, University at Albany, State University of New York*
*[3]Center of Excellence, University at Albany, State University of New York*
*[4]National Center for Atmospheric Research*
*[5]Cooperative Institute for Research in the Atmosphere, Colorado State University, NOAA/Global Systems Laboratory*

The New York State Department of Transportation (NYSDOT) has a large network of publicly available roadside cameras (511ny.org) that are used by both the public and NYSDOT to monitor road conditions, especially during winter storms. In an effort to automate the manual task of monitoring cameras, convolutional neural networks are trained to classify images into one of six road surface categories: severe snow, snow, wet, dry, poor visibility, or obstructed. These road-surface models are successful at identifying the road conditions on unseen images (the validation dataset) when all cameras and dates are represented in model development (the training dataset), achieving validation accuracy of ~90%. However, validation accuracy drops to ~60% when evaluated on new dates or cameras, indicating the need to explore additional methods to achieve model generalizability. Improving model generalizability is crucial in developing a tool that can be used in future winters to inform resource allocation and driving safety across the state of New York on thousands of new cameras in different and changing environments.

The model's ability to generalize to unseen data is impacted by each decision made in the model development process, such as: sampling and labeling images, selecting cameras to include in training, including pre-processing techniques. A set of baseline experiments were run to understand how each of these decisions impacts model performance from the perspective of improving model generalizability. This presentation will share the design and results from these experiments with an emphasis placed on model performance on new cameras, and it will include an outlook on future work needed for eventual model use across New York State.

# The Melting Pot Paradox: Ensuring Equitable Response for All New Yorkers

*Joseph E. Trujillo-Falcón*[1,2,3]
[1]*Cooperative Institute for Severe and High-Impact Weather Research and Operations, The University of Oklahoma, Norman, OK*
[2] *NOAA National Severe Storms Laboratory, Norman, OK*
[3] *NWS Storm Prediction Center, Norman, OK*

The United States is known as "The Great Melting Pot", for the wide variety of communities, cultures and languages from around the world present in the country. In the state of New York, approximately 2.5 million (or just over 12% of all) New York residents are considered to have Limited English Proficiency (LEP) (i.e., they speak English less than "very well"). This problem is recognized by leaders in New York, as high up as Attorney General Letitia James, stating that "the next severe weather event is a matter of when, not if. It is critical that this potentially lifesaving information be transmitted to the millions of New Yorkers — and Americans nationwide — who are not proficient in English." Government agencies' efforts to translate weather information into multiple languages are limited, leaving a significant service coverage gap. To achieve its goal of a Weather Ready Nation, the NWS must better understand the diverse communities it serves and how they use information for effective response.

Starting from the earliest recorded instance where a death was attributed to language inequities, I will offer an in-depth examination of how multilingualism has created obstacles to achieving effective disaster response. Personalizing demographic data to the state of New York, I will showcase interactive GIS maps that introduce strategies to reach the most underserved groups. Resources developed by NOAA, NWS, and FEMA will be shared to attendees so they feel empowered to diversify their risk communication to multiple audiences.

# Disconnected by Choice: Ongoing Efforts across the National Weather Service to Protect Life and Property in the Amish/Plain Communities

*John Banghoff and Jonathan Guseman*
*NOAA/NWS/WFO State College, Pennsylvania*

A defining characteristic of Amish and Plain communities is their selective use of technology. The Amish believe that technology, if left untamed, will interfere with traditions and separate close-knit communities. The choice to reject internet access and television in particular renders many common sources of weather information inaccessible and makes them especially vulnerable to hazardous weather. Over the last year, several National Weather Service offices have teamed up as the Weather Awareness for a Rural Nation (WARN) Task Force to address some of the gaps in service from the NWS for Amish/Plain communities.

This presentation will give a background of the Amish way of life, discuss the vulnerabilities of these communities, and focus on two main areas of current and future work by the WARN Task Force: improved dissemination given technological constraints and education/outreach activities with these communities. In order to provide accurate and timely forecasts and warnings, multiple NWS offices have developed novel ways to provide forecasts via phone recordings for Amish communities, the WARN Task Force is helping with the development of a NOAA Weather Radio for the Amish/Plain community, and NWS State College is piloting the use of AlertPA to notify Amish families of impending weather. To improve preparedness for and response to impactful hazardous weather events, the WARN Task Force developed weather safety handouts that can be delivered to Amish and Plain communities through both in-person engagement and print media sources that these communities trust.

# The Influence of Social Media User-Type on Informational Behaviors and Hazard Adjustments during Hurricane Dorian

*Amber Silver and Brandon Behlendorf*
*College of Emergency Preparedness, Homeland Security, and Cybersecurity,*
*University at Albany, State University of New York*

In this research, we disseminated a questionnaire to residents of Atlantic Canada immediately following Hurricane Dorian (2019) to explore whether and how social media influenced their information seeking and sharing behaviors, as well as their decisions to take protective action. The results demonstrate that users' on-line behaviors (e.g., searching, sharing) were closely related to what actions, if any, they took during the storm. For example, respondents who both searched for and shared information were highly proactive users who disseminated information about evacuations, recommended protective actions, and other official guidance more so than others. These respondents were also the most likely to heed official guidance in terms of their own preparedness (e.g., tying down furniture, purchasing supplies) and response (e.g., evacuation, seeking shelter) activities. In contrast, those respondents who only shared information OR searched for information were also motivated to take action by information they saw on-line, albeit at lower rates than conduits. Lastly, the results demonstrate that social media users can be positively influenced by information they see on-line even if they do not actively engage with it. Taken together, the results of this study suggest that social media users may interact with storm-related information in more nuanced and complex ways than previously understood.

# Improving Communication With Highly Vulnerable Societal Groups: Results from Interviews and a Survey

*Josef Moses[1], Brian A. Colle[1], Christine Gilbert[1,2], and Ruobing Li[2]*
*[1]Department of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY*
*[2]School of Communication and Journalism, Stony Brook University, Stony Brook, NY*

Stony Brook's CSTAR project "Improving Communication With Highly Vulnerable Societal Groups Through Partnerships, Audience Analysis, Crowd-Sourced Information, and Workshops." is motivated by the challenges in hazard communication, especially for vulnerable communities, as evident with tropical storm Ida's flash flooding across New York City in 2021 The communication of extreme weather forecasts (e.g., heatwaves, extreme precipitation) is a challenge for weather forecasters and emergency managers who are tasked with keeping residents safe during often unprecedented situations. It is unclear the role that community-based organizations and super-local governmental entities play or may play during weather events in transmitting weather information and providing assistance.

Interviews were conducted with 26 New York City community leaders across all boroughs except Staten Island. Community leaders interviewed included representatives from community based service organizations, community boards, civic associations, and others. These interviews suggest that local organizations often act as intermediaries, passing on official weather information to members of their audience, regardless of the mission statement of their organization (n=13). Email (n=19) and social media (n=17) were identified as the most common forms of communication between community leaders and members. Common challenges for communities in responding to extreme weather include lack of access to information (n=12), language barriers (n=9), and insufficient resources (n=9). Additionally, despite not specifically asking about it, Hurricane Sandy was still frequently mentioned or discussed by many participants (n=17).

# “Hangover” Currents? The Challenges of Spanish Language Rip Current Outreach

*Jase Bernhardt*
*Hofstra University, Hempstead, New York*

Rip currents are poorly understood by the public and thus a leading cause of weather-related fatalities in the United States. Individuals who speak languages other than English, such as Spanish-speaking communities, have been historically underserved by National Weather Service (NWS) risk communication efforts for natural hazards and thus are at additional risk from rip currents. In response to that issue, the NWS recently released rip current informational brochures translated into Spanish, though their efficacy has not been systematically tested. We therefore surveyed members of the Spanish-speaking community in Nassau and Queens Counties, New York during the summer of 2022 to gain insights into how the brochures are working and possible improvements to be made. Survey results indicate that while the Spanish-language brochure is somewhat effective, several changes could be made to improve clarity and relatability. For example, the translation of the term Rip Current itself used by the NWS was found to be confusing by Spanish speakers of certain ages and dialects. Therefore, we ran a second survey in 2023 to clarify which translation of Rip Current makes the most sense to Spanish speakers. The results of these surveys can be used directly by the NWS and other agencies to improve their Spanish risk communication tools, and also as a guide when translating hazard information into other languages.

# Although What Happens in Vegas Stays in Vegas, What Happens Over the North Pacific (NPAC) Definitely Does Not Stay over the NPAC

*Lance Bosart, Tyler Leicht, and Alexander Mitchell*
*Department of Environmental Science, University of Albany, State University of New York*

Drought-alleviating heavy rainfall occurred across California in late December 2022 and early January 2023. Given that this heavy rainfall was not anticipated in subseasonal forecasts, this presentation will focus on the physical and dynamical processes that drove this extreme weather event. High latitude blocking across Alaska and the Chukchi Sea, repeated cold surges from Asia, frequent western and central North Pacific cyclogenesis, frequent eastward-directed trans-North Pacific (NPAC) subtropical atmospheric river (AR) moisture surges, and a trans-NPAC subtropical jet stream (STJ) collectively sustained a "fire hose" of deep tropical moisture directed toward California.

High-latitude ridging in mid-December culminated in the formation of a Rex block over Alaska and the Chukchi Sea. A series of amplified 500-hPa troughs moved eastward from eastern Asia into the WPAC equatorward of this Rex block. One trough deepened southeastward and became a very strong cutoff cyclone near 30 N and 160 W. This deep trough enabled tropical moisture to surge northeastward along atmospheric rivers (ARs) and reach the West Coast of North America in late December. A strong trans-NPAC STJ served as a conduit for successive trans-NPAC trough passages and associated ARs that produced episodic heavy rainfall in California.

The NPAC cyclones that reached California and contributed to the episodic heavy rain there moved inland across the Great Basin and redeveloped as lee cyclones east of the Rockies and moved northeastward toward the Great Lakes. This observed storm track persisted for much of winter 2022–2023 in conjunction with a La Nina Pattern that transitioned to an El Nino pattern in spring 2023. This observed storm track also contributed to an anomalously wet and warm pattern over the Northeast to the detriment of snow lovers.

## National Weather Service Snowfall Forecast Spatial Bias in Northeast Cyclones

*Joseph Villani and Michael Evans*
*NOAA/NWS/WFO Albany, New York*

It has been noted by NWS forecasters that snowfall associated with some east coast winter storms seems to trend farther north and west in the forecasts leading up to the event. The goal of this study was to determine if this trend occurs with certain types of storms. This was done by investigating possible spatial biases in National Weather Service (NWS) snowfall forecasts with regards to Miller Type A and B cyclones (*Miller, 1946*), comparing the 24 hour NWS forecast to observed snowfall. Miller Type A cyclones are characterized by a cold anticyclone covering most of the CONUS east of the Rocky Mountains, with a cyclone developing near or along the east coast. Miller Type B cyclones are characterized by an occluding or occluded primary cyclone in the Great Lakes region with a secondary cyclone developing along the east coast.

The research leveraged the NWS GAZPACHO program (available to NOAA VLab users through redmine) to create visual graphics of NWS forecasts from the National Digital Forecast Database and observed snowfall from the National Operational Hydrologic Remote Sensing Center. Due to data limitations, the study encompassed 14 significant snowfall events spanning December 2020 to March 2023. This was done by selecting significant snowfall events (10 or more NWS forecast zones verifying Winter Storm Warning criteria) in eastern New York & western New England and then categorizing each cyclone as Type A or Type B.

To assess forecast bias, polygons mapping out maximum snowfall areas were drawn for both the 24 hour NWS forecast and observed snowfall data. Then the centroids of these polygons were computed using ArcGIS, allowing for the measurement of the distance and direction between them to be calculated for each event that displayed a distinct trend.

Preliminary results indicated that out of the 14 events studied, 4 of the 6 Type B cyclones exhibited a northward component in the bias of maximum snowfall location, while none (0) of the 8 Type A events displayed such a bias. This finding persisted despite the absence of any discernible shift in the forecast storm tracks (700 mb and mean sea-level pressure from the HREF).

Future research efforts intend to incorporate additional events over the upcoming winter seasons (2023-24, 2024-25) to validate these initial findings and explore the possibility of uncovering new findings.

# Analyzing the Development and Movement of Mesoscale Snow Bands in Eastern U.S. Significant Snow Storms Between 2002-2022

*Neil Stuart*
*NOAA/NWS/WFO Albany, New York*

Mesoscale snowbands are associated with enhanced snowfall rates, sometimes as much as 3-6 inches per hour, which can cause significant impacts to roads, highways and the ability for plows and emergency vehicles to reach their destinations. Kenyon et al. (2020) studied the development and evolution of mesoscale snow bands, identifying 4 types: laterally translating, hybrid, laterally quasi-stationary and pivoting. This study will focus on the laterally quasi-stationary and pivoting mesoscale snow bands, the types of mesoscale snow bands that are associated with the most favored region of heavy precipitation accumulation (Novak et al 2004).

Radar data from snowstorms during the period of 2002-2023 were analyzed for the presence of mesoscale snow bands. Storms were selected by searching through the online Northeast Snowstorm Impact Scale (NESIS) database at the National Centers for Environmental Information web site. Locally archived snowstorm data from the NWS office in Albany, NY, along with snowstorms as listed in Stuart and Grumm (2006), were also used in selecting 38 total storms for this study. The storms occurred over the domain of the eastern region of the National Weather Service from the Carolinas to New England..

Kenyon et al. (2020) and Novak et al. (2006) concluded that the development, evolution and movement of mesoscale snow bands were critical in determining where the heaviest snow and the greatest impacts were observed. They also concluded that low to mid-level frontogenesis within a zone of moisture and weak, moist symmetric instability would often aid in determining where and when mesoscale snow bands would develop. Band motion could then be determined using features in the environment near a frontogenesis region.

This study supports Kenyon et al. (2020), showing that the laterally quasi-stationary and pivoting mesoscale bands in the storms between 2002-2022 were well-correlated with the axis of 700-500 hPa layer frontogenesis. The mesoscale snow bands were also observed where the layer frontogenesis was correlated with the maximum omega within the dendritic growth zone (DGZ). It will be shown that the coincident layer frontogenesis and maximum omega within the DGZ contributes to the development and evolution of mesoscale snow bands, similar to what is described in Novak et al. (2004 and 2006) and Evans and Jurewicz (2009). Rapid growth and clustering of dendrites within the DGZ increases snow to liquid ratios within the saturated column, resulting in large amounts of large dendrites and extreme snowfall rates.

Radar depiction of mesoscale snow bands, corresponding 700-500 hPa frontogenesis and equivalent potential vorticity will be shown. Forecast model time sections and cross sections, showing moisture, omega, and thermal profiles in the vicinity of where mesoscale snow bands were observed, will also be shown. Analyzing the coincidence of the layer frontogenesis, DGZ and maximum omega through the saturated layer could increase confidence in predicting the overall formation, timing and movement of mesoscale snow bands. This could lead to adjustment of predicted snow to liquid ratios, improving snowfall and snow rate forecasts.

Examples of inconsistent accuracy in predictions and analysis of mesoscale bands from recent storms between 2020-2023 will be presented, along with some examples of IDSS to communicate real-time evolution of the mesoscale bands and the impacts. Better predictions of mesoscale snow bands, their evolution and impacts would improve IDSS to all user groups, including snow removal companies that serve the marginalized and underserved communities.

# A Multiscale Analysis of the 29 April–2 May 2023 Winter Storm in Michigan's Upper Peninsula

*Daniel Thompson*
*NOAA/NWS/WFO Marquette, MI*

An historic late-season winter storm impacted Michigan's Upper Peninsula (UP) 29 April–2 May 2023. Snowfall occurred in two distinct rounds; the first occurring mainly 29–30 April affecting the western UP, and the second mainly 1–2 May affecting the northern UP. Storm total snowfall was mainly 9–18" over the western UP, and 24–48" over the northern UP (although amounts varied considerably based on elevation and distance from Lake Superior). These totals broke a multitude of May records at the National Weather Service (NWS) office near Marquette, including greatest calendar day and two-day snowfall (19.8" and 26.2", respectively), greatest snow depth (20"), and snowiest May on record (26.2"). Additionally, the cooperative observer in Herman recorded a 4-day storm total of 52" and a single-day total of 27" on 2 May, which set a new record for the greatest one-day May snowfall east of the Mississippi River. Storm-total liquid equivalent precipitation in the north-central UP totaled 4–8", with approximately 3.5–6.5" falling as snow in the favored snow belts, leading to snow-to-liquid ratios of 4–8:1. The quantity and density of snow resulted in extremely difficult clean-up efforts and hazardous travel conditions despite the high May sun angle. In addition, winds gusted to 30–50 miles per hour during and just after the storm. The high winds and heavy, wet snow led to extensive tree and powerline damage and at least 10,000 customers losing power. Finally, temperatures warming into the 50s and 60s during the week following the storm led to minor flooding due to snowmelt.

This presentation examines synoptic to mesoscale characteristics of the storm while addressing predictability and messaging challenges. A highly amplified and blocked synoptic-scale upper level flow pattern across North America led to the slow movement of an anomalously strong cutoff low over the Great Lakes region. The slow movement, coupled with rich moisture wrapping westward into the system from an atmospheric river extending from the Gulf of Mexico into southern Quebec, provided a favorable environment for an extreme precipitation event. Strong north to northwest flow in the surface to 925 mb layer, coupled with the anomalous moisture, resulted in a prolonged period of moderate to heavy orographically enhanced precipitation focused on the higher terrain south of Lake Superior. Backward trajectories show that air parcels in the lowest 500 m of the atmosphere originated near Hudson Bay where the air in that layer was slightly below freezing, and this airmass was modified little by a cold Lake Superior. Latent cooling due to evaporation and melting of hydrometeors and cooling due to dynamic lift were also factors that led to the dominant precipitation type being snow.

The predictability of the relevant synoptic-scale features and their associated impacts was generally good leading up to this storm. NWS Marquette began to highlight the potential for hazardous weather in the Hazardous Weather Outlook and social media posts as early as 27 April. Convective-allowing models depicted extreme snowfall and liquid equivalent precipitation amounts, as well as high winds. This allowed NWS Marquette staff to use strong wording to highlight the expected impacts of the storm, and compare it to another historical May snowstorm. Communicating potential impacts was complicated by the sharp gradient in snowfall totals around the largest population center in the UP.

# A Holiday Period for the History Books: Part One
# A Forecaster's Perspective of the Deadly Christmas Blizzard of 23-27 December 2022

*Robert Hamilton*
*NOAA/NWS/WFO Buffalo, New York*

What was billed as a “once in a generation storm” turned out to be more like a once in a century event, as a historically intense area of low pressure that passed over the lower Great Lakes ‘bombed out’ to less than 968 hPa over western Quebec. While the anomalously deep cyclone was setting low pressure records across parts of eastern Canada, 60 to 70 knot winds in its wake pummeled areas east of Lakes Erie and Ontario with 50 inches of blinding lake-effect snow and wind chill values as low as 35 degrees below zero.

As if this were not enough to ingrain the storm into the minds of winter hardened western New Yorkers, the long duration blizzard occurred at the worst possible time of the year, in the days immediately leading up to Christmas. Nearly a million people were forced to take shelter in their homes for multiple days, and several airports and significant stretches of interstate were shut down to holiday travelers. Despite the deadly tempest being accurately forecast well in advance with an average lead time of 84 hours for the winter storm watches and over 36 hours for the blizzard warnings, nearly fifty people tragically lost their lives.

This presentation will show how pattern recognition and longer range forecast ensembles played a crucial role in getting an early jump on the evolution of the holiday storm. It will also demonstrate how local expertise enabled forecasters to uniquely heighten the awareness of the pending hazards in their forecast products and social media posts.

# A Holiday Period for the History Books: Part Two
# A Historical Perspective of the Crippling Metropolitan Buffalo Blizzard of 23-27 December 2022

*Michael Fries*
*NOAA/NWS/WFO Buffalo, New York*

Meteorologists tend to use the terms "historic" or "generational" very judiciously, whether for fear of sounding alarmist or so as not to seem dismissive of past events in the record. Days ahead of the metropolitan Buffalo Blizzard of 23-27 December 2022, it became clear the events that were likely to unfold in and around Buffalo during the holiday period would take on both monikers.

As a prolonged period of rain and mild conditions came to a close on the morning of 23 December, a bomb cyclone was developing and advancing through the central Great Lakes. The passage of its associated cold front heralded the almost immediate dawn of a lake effect blizzard in Buffalo that would last an unabated 37 hours as temperatures sank into the single digits and winds gusted in excess of hurricane force downtown. This presentation will look at the system that drove this hellacious blizzard in light of historical comparisons to the 20-25 December 1878 Christmas Blizzard that left Buffalo reliant on sleigh transportation for nearly a week, the locally notorious Blizzard of 1977 that left behind drifts of snow up to 20 feet in depth, as well as the historic snowfall that occurred just one month prior.

**Buffalo Television Meteorologists Preparation & Coverage of the 2022 Christmas Blizzard**

*Elyse Smith[1], Carl Lam[2], and Mike Doyle[3]*
*Former WGRZ - NBC Affiliate, Buffalo, New York. Currently with KTRK - ABC Affiliate Houston, TX[1]*
*WGRZ - NBC Affiliate, Buffalo, New York[2]*
*WIVB Buffalo, New York[3]*

This presentation will show how broadcast meteorologists from WGRZ and WIVB (NBC and CBS affiliates for Buffalo, NY, respectively) and the station readied the public for the impending Christmas Blizzard a week in advance. We will discuss the storm coverage and how we got the public ready for the blizzard.

We will also discuss how we covered the blizzard with very limited staff throughout the Christmas weekend because most of the staff couldn't make it to the station because of the life threatening conditions.

Lastly, we will discuss what we learned from this event and how we could improve our storm coverage for the next big storm.

# Variability of Cool Season Precipitation Structures Within the Cyclone Comma Head

*Phillip Yeh[1], Brian A. Colle[1], Laura Tomkins[2], and Sandra Yuter[2]*
*[1]School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY*
*[2]College of Natural Resources, Center for Geospatial Analytics, North Carolina State University*

The Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) is a field campaign operated by NASA to understand the structure of mesoscale snowbands. While significant research has explored single (primary) bands in the cyclone comma head, few studies have included the broader spectrum of precipitation structures that may not fit the current rigid categories of primary or multibands. The current conceptual model of precipitation bands as described in Houze (2014) also does not account for findings from more recent field campaigns. An updated precipitation band climatology around the cyclone would allow one to better understand the environmental conditions that favor the spectrum of precipitation structures within the comma head within the context of lifting mechanism, stability, moisture, and shear.

This talk will highlight a new algorithm developed to identify mesoscale precipitation structures in extratropical cyclones, building on work done by Ganetis et al. (2018). Unlike older approaches that objectively identified structures relative to a single background radar reflectivity threshold for a large region (e.g., Northeast U.S.), this algorithm divides a stitched reflectivity domain into several smaller boxes and computes the upper sextile reflectivity in each box, to focus on enhancements relative to the background. Image processing techniques such as image morphology and watershed segmentation are also utilized to further separate regions of enhanced precipitation into discrete objects. The thermodynamic environment is computed in a cyclone-relative frame for each case from ERA-5 reanalysis.

Preliminary results show that a locally defined threshold improves object detection by separating large, amorphous regions and picking up several lower reflectivity objects, compared to older methods in the literature, although there is some sensitivity to thresholds chosen. In the cyclone-relative frame, more quasi-linear objects are most frequently found north/northeast of the cyclone center, in an environment of mid-level frontogenesis and slantwise instability. In particular, the distribution of objects is close to an exponential curve and does not appear to be separated into distinct regions of primary or multibands. These results will be compared against several winter storm cases sampled by the IMPACTS field campaign during the 2020, 2022, and 2023 deployments.

# Investigation of Convective Environments in the Capital Region with Expanded Atmospheric Measurements (ICECREAM) Field Project

*Brian H. Tang*, *Rachel Eldridge, Ross Lazear, and Robert G. Fovell*
*Department of Environmental and Atmospheric Science, University at Albany, State University of New York*

Past research has shown that severe weather environments in the Capital Region are influenced by the local terrain and mesoscale boundaries, resulting in spatial inhomogeneities of severe weather parameters. These inhomogeneities, and their evolution, may influence convective initiation, mode, and severity. The overarching goal of the ICECREAM field project was to study severe weather environments, as part of the NOAA Collaborative Science, Technology, and Applied Research (CSTAR) program, and support NWS operations.

A total of 11 severe-weather days from June through August were sampled by radiosondes released by a team of faculty and students. Most of the launches were conducted from ETEC, and we performed three launches from Fort Hunter, NY in the Mohawk Valley. We provide an overview of some of more interesting aspects in the collected data, such as characteristics of convective initiation, the passage of a moisture boundary, and profiles conducive to heavy rain events. We also conducted a preliminary comparison between HRRR forecast and observed boundary-layer structures, showing that the HRRR tends to produce boundary layers that are too warm and dry in pre-convective environments.

# Evaluating HRRR Model Forecasts of Impactful Severe Weather Events in Upstate New York

*Rachel Eldridge, Brian H. Tang, and Robert G. Fovell*
*Department of Atmospheric and Environmental Science, University at Albany, State University of New York*

Forecasting severe convection can be more challenging in areas of complex terrain, such as in and around the valleys and mountains of Upstate New York. Biases in numerical weather prediction models, related to the lack of resolution of the terrain and errors in physical parameterizations, can affect forecasts of convection. The main goal of this research is to assess biases in the High-Resolution Rapid Refresh (HRRR) pre-convective environment that could contribute to deficiencies in the forecasted convective evolution.

We investigate how the HRRR model performed during several notable severe weather events that affected the New York Mohawk Valley and Capital Region. These events were characterized by their intense line of thunderstorms that resulted in numerous wind damage reports across the region. HRRR model output was compared to New York State Mesonet (NYSM) surface observations, NYSM flux data, and NEXRAD reflectivity data for these events during the period they passed over the Mohawk and Hudson valleys. Surface moisture variables, temperature, heat fluxes, and downward shortwave were analyzed across multiple HRRR model runs. Preliminary results show discrepancies between the model forecast and surface observations in the hours leading up to the convection. The HRRR model forecasts tend to have a warm bias, especially in the early morning. There also tends to be a seasonal difference in the moisture and temperature biases of events that occurred in May versus the late summer. Sensible and latent heat fluxes show similar trends however they do differ by location. The HRRR model also consistently overestimates shortwave down at multiple mesonet sites across the region on both convective and clear days. To further explore the case-to-case variability in the forecasts of these variables and the convective evolution of these events, we have begun running WRF simulations that mimic the HRRR model to diagnose where these biases are originating from, and how they might be corrected. The first goal of these simulations is to try and correct the underlying biases that occur in the HRRR model on clear days. Further exploration and experimentation of cases and HRRR biases will inform forecasters and may lead to better warnings in this populated and economically important region.

# The April 1, 2023 Mid-Atlantic Severe Weather Outbreak: How Mesoanalysis and Knowledge of Quasi-Linear Convective System Tornadogenesis Aided the Operational Performance of Weather Forecast Office Philadelphia/Mount Holly

*Cameron Wunderlin, Lee Robertson, Matthew Brudy, and Alex Staarmann*
*NOAA/NWS/WFO Philadelphia/Mount Holly*

The Philadelphia/Mount Holly (PHI) Weather Forecast Office (WFO) serves a diverse range of counties across New Jersey, Pennsylvania, Delaware, and Maryland, all situated within the Mid-Atlantic region. On April 1, 2023, a significant severe weather outbreak occurred, causing extensive wind and tornado damage. This event spawned a total of nine tornadoes within the County Warning Area, resulting in both fatalities and widespread damage.

This study examines the synoptic and mesoscale dynamics that underlie the weather event on April 1st and its forecasted evolution. The main goal of the analysis is to understand the factors that contributed to the event and to gain insights that could aid in understanding similar events in the future. This event featured a strong mid-upper level jet, unseasonably strong instability, high shear, high storm relative helicity, and strong updraft helicity tracks, all of which contributed to the enhancement of tornado activity.

This study also presents a review of how mesoanalysis and meteorological knowledge regarding quasi-linear convective system (QLCS) tornadogenesis allowed WFO PHI to perform operationally. Mesoanalysis undertaken by staff leading up to and during the event ultimately aided WFO PHI's performance. WFO PHI issued eight Tornado Warnings, 17 Severe Thunderstorm Warnings, and six Special Marine Warnings during the event, achieving a 92% Probability of Detection, 32% False Alarm Ratio, with an average lead time of 24 minutes for all reports. Notably, tornado warnings were in effect for eight of the nine tornadoes, with just one tornado event eluding detection due to the challenging linear storm mode. Eight of the tornadoes which occurred on April 1st were QLCS tornadoes. Seven of the eight of these QLCS tornadoes were warned on as staff utilized environmental information from mesoanalysis and the three-ingredients methodology for QLCS tornadogenesis.

## Predicting Weather Related Power Outages in the Northeast United States

*Brian Filipiak, Diego Cerrai, and Emmanouil Anagnostou*
*University of Connecticut*

When high impact storms occur, millions of people lose power in the densely populated and vegetated northeastern United States. Developing models for predicting the number and location of power outages and their estimated restoration time helps the utility providers, residents, and federal government save hundreds of millions of dollars for each major storms and contributes to reducing the consequences of prolonged outages. In conjunction with Eversource Connecticut, the University of Connecticut Outage Prediction Model (UConn OPM) was developed over the last 10 years. It consists of four modules, one for each major storm type or severity: (i) thunderstorms, (ii) extratropical, (iii) tropical, and (iv) winter storms. The OPM has been continuously improved over time, and now has been extended to four major utilities across eleven states in the Eastern United States. In this presentation, an overview of outage prediction modeling will be presented, with a focus on the key components for model development. Model performance will then be compared across service territories, with an emphasis on the Eversource service territory located in Connecticut, Massachusetts, and New Hampshire. Lastly, the role of information from and communication with the NWS will be discussed as it relates to conveying the potential outage forecasts to utility operators.

# HRRR Wind Forecast Verification Against NYSM and Public Utility Observations

*Robert G. Fovell*
*Department of Atmospheric and Environmental Sciences, University at Albany, State Univeristy of New York*

Accurate weather forecasts on short and medium timescales are needed by public utilities to properly assess threats, especially those involving wind in the fire-prone western United States. We focus on operational HRRR forecasts averaged across observation networks and for individual stations, using data from the NYSM, ASOS, RAWS, and California public utility networks.

Regarding network-averaged winds, we demonstrate that the HRRR provides very good forecasts for 10 m sustained winds at ASOS stations across the CONUS but tends to overpredict winds in other networks (such as the NYSM, RAWS, and public utility mesonets) by up to 50%. These other networks may mount anemometers closer to the ground, tend to be placed in more complex environments (mountain slopes, urban areas, forests), and/or may employ different hardware (propeller and cup anemometers instead of sonics), all of which can lead to systematic errors. In all networks, there is a marked tendency for winds to be overestimated at stations where measured winds are slow and under-forecast where they are fast. The latter can lead to underestimation of the wind threat.

We identify the proximate cause of this station bias and present a method for extracting high-quality forecasts at NYSM and public utility stations.

# NROW Day 2 -
## Wednesday 15 November 2023

# The Northeast Drought Early Warning System: History, Activities and Opportunities

*Silvia Reeves*
*NOAA National Integrated Drought Information System Northeast Drought Early Warning System*

The Northeast Drought Early Warning System came into existence just after the 2016-17 northeast drought. NOAA's National Integrated Drought Information System focused its expansion into the region by partnering with the NWS offices in the area, the Northeast Regional Climate Center and state drought response committees who were seeking support. A Strategic Action Plan was developed and evolved as guidance for regionally specific drought response and mitigation work, as well as an assessment of data and research needs. In the last few years, a robust community of practice has developed along with decision support dashboards, state drought information pages on Drought.gov and venues for the exchange of response planning strategies and messaging tools.

This presentation will provide additional background on NE DEWS history, current activities and opportunities. Work with regional partners at the Federal, Tribal, State and local levels will be highlighted. A recap of research projects and outcomes will be shared. Most importantly, there will be an opportunity to explore next steps in the launch of improved NWS Drought Information Statements, regional drought status updates and other drought monitoring strategies. This real-time exploration will be facilitated by the presenter in the form of a "One, Two, Three - All" discussion session that allows for audience inputs and idea generation. Inputs and new ideas will be collated and integrated into future NE DEWS projects and research.

# Rain Without End - A Review of Summer 2023 in New Hampshire and Western Maine

*Justin Arnott and Sarah Jamison*
*NOAA/NWS/WFO Gray/Portland, Maine*

After two summers of moderate drought in the northeastern United States, a dramatic change of the warm season pattern occurred in 2023 which resulted in above normal precipitation and an unprecedented number of flooding events. According to the National Centers for Environmental Information, New Hampshire had its wettest summer on record with Maine having its second wettest. The National Weather Service in Gray, Maine issued 84 flash flood warnings, nearly double the previous annual record. After a widespread heavy rain event to begin the month of May, convective flash flood events occurred with increasing frequency in June and especially July. Over 150 independent flash flood events were reported to the office and three requests for national disaster declarations were made by New Hampshire and Maine.

In this presentation, we will review the pattern responsible for this anomalous amount of rainfall and flooding during the summer of 2023. We will then dig deeper into some of the more noteworthy flash flood events, examining forecast tools, warning decisions, and the subsequent impacts these events had on the public.

# A Hydrologic Perspective of the Historic July 9-11, 2023 Vermont Floods

*John Goff*
*NOAA/NWS/WFO Burlington, Vermont*

The State of Vermont experienced severe to catastrophic flash and riverine flooding from July 9-11, 2023. The impacts were varied, but in some areas they were similar, if not worse, to those of Tropical Storm Irene which affected the state less than 12 years prior. Preliminary estimates suggest total damages to infrastructure may exceed $400 million. Over 70 landslides were documented by state geologists with more than 100 state and federal highways closed during the event's peak. A total of 26 Flash Flood Warnings and 34 Flood Warnings were issued by NWS Burlington during the period with a federal disaster declared for 9 of the state's 14 counties to aid in flood damage recovery. The hardest hit areas were along an approximately 100 mile long, 40 mile wide south-to-north axis along the Green Mountain spine, where reliable rainfall estimates of 5 to 9 inches were observed. While flash flooding posed the immediate threat to life, severe riverine flooding heavily damaged portions of Montpelier and Johnson, Vermont. This presentation provides a brief overview of this extreme event from a hydrologic perspective, with highlights focusing on antecedent conditions, pre-storm meteorological signatures and resultant impacts.

# NWS Flood Inundation Mapping: A New Tool in the WFO Albany Hydrology Toolbox

*Britt Westergard*
*NOAA/NWS/WFO Albany, New York*

On September 26, 2023, the National Weather Service (NWS) began a multi-year effort to implement new experimental Flood Inundation Mapping (FIM) services to deliver a new generation of water prediction services, providing actionable information that allows emergency managers, decision makers and the public to view and access real-time inundation maps. FIM provides approximate estimates of where flood impacts may occur based on modeled forecast river flows and latest conditions. The NWS Albany forecast area is included in the first phase of the national rollout for the experimental FIM that includes 10% of the U.S. population. Three unique maps will be available in near-real-time, including National Water Model derived hourly inundation analysis of latest conditions, National Water Model based five-day inundation forecast, and River Forecast Center based five-day inundation forecast.

This presentation will describe the basics of how NWS FIM is created, a description of the public products available for the "first 10%" area, how these products can be accessed by the public and the timeline for these experimental products to be rolled out to the rest of the U.S.

# The Crucial Role of Flood Inundation Mapping (FIM) in the July 2023 Montpelier, VT Flood Damage Assessment

*Evan Belkin*
*NOAA/NWS Northeast River Forecast Center*

The NOAA National Water Center (NWC), in collaboration with the National Weather Service River Forecast Centers (NWS RFCs), implemented Flood Inundation Mapping (FIM) services to -approximately ten percent of the United States population on 26 September 2023. Over the next 3 years, the NWC will work in coordination with the NWS RFCs and other federal partners to release FIM services to the remainder of the nation. As part of this effort, the NWS Northeast RFC is working to evaluate the accuracy of Categorical FIM (CatFIM). CatFIM is a static FIM layer generated using the Height Above Nearest Drainage Method corresponding to established NWS river stage categories that result in minor, moderate, and major flood impacts. This evaluation compares the accuracy of the CatFIM against the inundation extent of FIM to the NWS Flood Impact Statements.

The July 2023 Vermont Floods provided an opportunity to evaluate the performance of CatFIM as part of a Flood Damage Assessment in partnership with the Burlington, VT, Weather Forecast Office. Catastrophic river flooding occurred along the Winooski River at Montpelier (NWS Forecast point "MONV1") on 10 July 2023. The river crested at a stage of 21.35 ft, which is 3.85 feet above major flood stage, provisionally the second highest crest on record at that location. The city of Montpelier, including the state office buildings, were inundated with several feet of water for nearly eighteen hours. CatFIM played a critical role during the flood damage assessment surveys and paved the way for deciding which portions of Montpelier to survey, i.e., locations with the greatest FIM extent at major and record flood stages. There were several areas within the city where the FIM extent was very accurate. This presentation will show the value of FIM for informing Impact-Based Decision Support Services (IDSS) in the future.

# Exploring a New Dimension of Impact-Based Forecast Products: Duration of Impacts

*Dana Tobin[1], Joshua Kastman,[2] and James Nelson[1]*
*[1]Cooperative Institute for Resarch in Environmental Science, NOAA/NWS Weather Prediction Center*
*[2]Weather Prediction Center*

The duration of expected impacts due to adverse weather conditions can be incredibly informative in impact-based decision support services (IDSS) provided by the National Weather Service (NWS). Whereas communicating the severity of expected impacts is an important aspect of IDSS, the duration over which that level of severity is expected to be sustained can also be crucial for end users. The duration of impact severity can be used to help decide which mitigation efforts should be taken, and also provide context for how long recovery efforts may take in the wake of the storm, or even clue decision-makers into how recovery efforts will need to be delayed. The duration of impact severity also goes above and beyond current forecast information provided by the NWS – such as the start and end time of snowfall – by communicating how long the worst part of the storm is expected to last.

The prototype Winter Storm Severity Index (WSSI) Travel is an hourly impact-based forecast tool that provides an ideal structure to explore the concept of impact duration. This concept will be demonstrated for the first time for a number of high-impact winter weather events where the extended severity of weather conditions exacerbated the total impacts from the storm and hindered recovery efforts afterwards. The pre-Christmas 2022 blizzard in the Buffalo, NY area is one such highly-impactful storm event in which duration played a crucial role in the overall severity of the storm, and will be highlighted with this work to explore the potential utility of the concept to aid in future IDSS.

# Collaboration of Winter Storm Watches

*Bryan Jackson*
*NOAA/NWS Weather Prediction Center (WPC)*

An effort for WPC to lead collaborative Winter Storm Watches has been in the works for several years, after being first discussed at the 2016 NROW. In the winter of 2022-2023, live testing of a prototype concept was conducted for three separate groups of WFOs, including one in the Northeast U.S. (CAR, GYX, BTV, ALY, BOX, OKX, BGM, BUF) from February 6 to March 3, 2023. Two events were handled in this proof-of-concept exercise in the Northeast, February 23 and March 4. These two cases will be discussed briefly. Another live proof-of-concept test is scheduled for this winter for the same Northeast offices, so a look ahead to this effort will be made. In this discussion for the upcoming season, an update on the probabilistic information used by the Weather Prediction Center (WPC) to inform winter watch decision products will be provided.

# The Weather Prediction Center's Winter Weather Experiment: Past Successes, Ongoing Challenges, and Future Plans

*W. Massey Bartolini[1], James Correia, Jr.[1], Sarah Trojniak[1], Kirstin Harnos[2], James Nelson[2]*
*[1]Cooperative Institute for Research in Environmental Sciences,*
*NOAA/NWS Weather Prediction Center*
*[2]NOAA/NWS Weather Prediction Center*

During the past 13 years, the Weather Prediction Center - Hydrometeorology Testbed (WPC-HMT) has led the annual Winter Weather Experiment (WWE). The WWE examines forecast challenges associated with heavy snowfall and mixed precipitation during the cool season, across a variety of scales from mid-latitude cyclones to lake-effect snow bands. In past years, the WWE has examined forecast cases of interest either in real-time or retrospectively. Key findings and results from WWE include enhancements to the National Blend of Models, testing of improved snowfall accumulation variables and winter specific verification metrics for convection allowing models (CAMs), all while strengthening collaboration between WPC and individual Weather Forecast Offices (WFOs).

Currently, WPC-HMT is focused in large part on the evaluation of ongoing CAM deterministic and ensemble forecast development with the Rapid Refresh Forecast System (RRFS) ensemble. However, numerous challenges remain for evaluation of experimental CAM forecasts of winter weather. For example, gridded analyses of snow often have large uncertainties, and point observations of snowfall and precipitation types must be carefully quality controlled and contextualized to be useful for model verification. Snowfall is especially difficult to verify due to processes such as melting and settling affecting observations.

In this presentation, the recent history and successes of the WWE are reviewed along with ongoing forecast evaluation challenges. The remainder of the presentation focuses on aspirational goals to continue refining the WWE to meet the needs of WPC, WFO meteorologists, and the CAM ensemble development community. This will include highlighting ongoing projects that will expand the scope of WWE activities into forecast messaging and impacts of heavy winter precipitation on transportation.

# Examining the Performance of the National Blend of Models During High Impact Winter Weather in New England

*Christopher Gilberti*
*Department of Atmospheric and Environmental Science, University at Albany, State University of New York*
*NOAA/NWS/WFO Gray/Portland*

This research project examines the performance of the National Blend of Models (NBM) during high impact winter weather events in New England. The NBM is a state-of-the-art weather forecasting system developed by NOAA that combines multiple numerical weather prediction models as a part of the Weather Ready Nation initiative. The goal of which is simplifying forecasting for National Weather Service (NWS) forecasters, allowing them to devote more time to providing critical decision support services during high impact weather. NBM v4.1 became operational in January 2023, so this evaluation primarily focuses on its performance during high-impact winter weather in New England. Additionally, this project involves a comparative analysis between the current version and its predecessor, NBM v4.0 for the impactful December 2022 Winter Storm that led to a blizzard in the Buffalo, NY region.

To complete this evaluation, data was collected for numerous impactful winter weather events during the 2022-2023 winter season. This includes NBM forecasts and corresponding observations for key variables including temperature, dew point, wind speed, quantitative precipitation forecast (QPF), snowfall, precipitation type, and snow-to-liquid ratio. This analysis was done by examining spatial and temporal forecast errors to identify systematic biases or regional variations. Biases and errors associated with various meteorological setups such as cold air damming, arctic frontal passages, near freezing temperatures, and more were documented. NWS forecasters have gained some understanding through their own forecasting experience of how the NBM performs in certain situations. Through the results of this examination and collaboration with forecasters at NWS Gray, it was determined how forecasters in New England NWS offices could change their approach to utilize the NBM most effectively when making forecasts.

The findings of this project contribute to a better understanding of the NBM's strengths and weaknesses in providing forecast guidance before high impact winter weather events in New England. This research provides insights for NWS meteorologists and informs efforts to enhance the accuracy and reliability of the NBM, particularly during extreme weather conditions.

**Using Airborne Measurements to Evaluate HRRR Forecasts of Freezing Drizzle Aloft: Results from the WINTRE-MIX Field Campaign**

*Megan Schiede and Justin Minder*
*Department of Atmospheric and Environmental Science, University at Albany, State University of New York*

Supercooled large drop (SLD) icing poses a serious threat to aviation, however, forecasting SLD occurrence is challenging, due in part to limitations in numerical weather prediction models. One goal of the Winter Precipitation Type Research Multi-scale Experiment (WINTRE-MIX) was the evaluation and improvement of numerical forecasts of precipitation type (p-type). Research flights were conducted during WINTRE-MIX with the National Research Council of Canada Convair-580 aircraft to investigate precipitation processes in winter storms with near-freezing surface conditions. The High-Resolution Rapid Refresh model (HRRR) is commonly used in the meteorological community for its 3-km resolution along with its short temporal data assimilation of one hour, thus, making it an ideal model for mesoscale events such as winter storms. The HRRR uses the Thompson–Eidhammer bulk microphysics scheme to represent clouds and precipitation processes. This study investigates a WINTRE-MIX intensive observing period that took place on 07–08 March 2022 and coincided with a warm frontal passage through northern New York and into southern Quebec from 1600 to 2000 UTC. During initial ascent, the Convair observed widespread freezing drizzle (FZDZ) with cloud-top temperatures as cold as -15℃. Cloud-top temperatures observed with FZDZ are typically greater than -12℃, making this flight of interest from a microphysical perspective.

The aim of this study is to evaluate HRRR forecasts against Convair-580 observations. To characterize icing conditions, ice detector frequency, liquid water content (LWC), cloud droplet number concentration, hydrometeor particle size distribution, and maximum droplet diameter (Dmax) are examined and compared between in situ aircraft observations to their model-simulated equivalent. Using the method presented by Tessendorf et al. (2021), Dmax is calculated using HRRR data and compared to measurements from a 2D-Stereo probe. The inclusion of Dmax allows for the distinction between freezing rain (FZRA) and FZDZ. Additionally, we compare the observed and simulated occurrence of ice particles to evaluate HRRR's ability to predict the transition between FZDZ and snow. Thermodynamic conditions and cloud structure are compared between aircraft and model simulations to evaluate the capabilities of the HRRR to represent the observed development of SLD. These comparisons are supported by the use of airborne W-band and X-band radar profiles collected by the Convair-580 along with soundings made across the WINTRE-MIX domain.

# Better Utilization of Ensembles in Operations Through Clustering and Ensemble Sensitivity Analysis

*Brian A. Colle[1], Austin Coleman[2], James Nelson[2], and Travis Wilson[3]*
*[1]School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY*
*[2]NOAA/NWS Weather Prediction Center*
*[3]NOAA/Global Systems Laboratory*

Operational ensembles help forecasters determine the uncertainties of various weather phenomena, which need to be communicated to the public and various stakeholders. However, the standard ensemble mean and probability plots do not help forecasters communicate potential scenarios from the model ensembles. One solution to this issue is to cluster ensemble members into groups, which reduces the amount of data that needs to be assessed while providing the forecaster with a representative view of the ensemble data.

A clustering approach, which was originally developed for a NOAA-CSTAR collaboration, has been made more operational at the Weather Prediction Center (WPC). It utilizes ensemble-spread characteristics as represented by the leading Empirical Orthogonal Function (EOF) patterns of the spread for 500-hpa geopotential height. The EOFs are calculated across the model ensemble member dimension (GEFS+CMC+EC ensembles or 100 members). The leading principal components (PCs) are the projections of the dominant EOF patterns onto the difference between each of the ensemble members and the ensemble mean. The first and second PCs for the ensemble members are used as input into a K-Means clustering routine, which is utilized to group ensemble members with similar forecast scenarios. This clustering has recently been included in the NWS Dynamic Ensemble-based Scenarios for IDSS (DESI) software, which now runs in many NWS forecast offices. One can create weather scenarios by examining the probability of each cluster spatially, and display many more variables (precipitable water, surface CAPE, cloud cover, etc) using histograms, plume diagrams, and box-and-whisker plots.

Forecasters have requested more information and tools to understand how the atmosphere needs to evolve in the proceeding days for a particular cluster scenario to come to fruition. This talk will also describe a new project involving an ensemble sensitivity analysis (ESA) tool that will be implemented at WPC and hopefully DESI. This tool uses the patterns in the ensemble spread of SLP to calculate upstream sensitive regions for high impact weather, which can help forecasters better understand the origin of the ensemble uncertainty. Overall, this presentation will review the clustering and ESA approaches with a storm event and highlight the new DESI software that forecasters have access to. Some of the benefits to forecasting and stakeholder communication will be highlighted as well as some potential future directions based on forecaster survey feedback. The web page for this project at WPC is:
https://www.wpc.ncep.noaa.gov/wpc_ensemble_clusters/day_3_9_plus_esa/view.php

# Using Ensembles to Establish High Confidence in Historic Wind Chills During February 2023 in Maine

*Todd Foisy*
*NOAA/NWS/WFO Caribou, Maine*

The blast of Arctic air on February 4, 2023, was extreme even by Maine standards. Wind chills were as low as -62°F in Northern Maine, making them the coldest wind chills observed in over 30 years in some areas. These extreme conditions had significant impacts. The confidence in predicting the extreme wind chills was notably high, primarily due to strong agreement among ensembles a week in advance. This high confidence was communicated to partners well in advance through briefings and one-on-one communication.

Tools such as DESI (Dynamic Ensemble-based Scenarios for IDSS), National Blend of Models (NBM) Whole Story Uncertainty & Probabilities (WSUP) Viewer, Ensemble Situational Awareness Tables (ESAT), and ECMWF Extreme Forecast Index (EFI), played a crucial role in assessing the high confidence associated with this extreme weather event.

# AI Coastal Upwelling Detection in the Mid-Atlantic Bight

*Andrea John*[1] *and Travis Miles*[2]
[1]*Rutgers University, Department of Environmental Sciences*
[2]*Rutgers University, Department of Marine and Coastal Sciences*

Using a combination of AI technology, ocean data, and numerical weather prediction models, we can better predict wind speed and direction for offshore wind energy. Upper ocean temperatures play a critical role in the characteristics of the marine boundary layer, particularly in regions of offshore wind development that experience coastal upwelling. To detect these ocean features and increase the accuracy of these models, we use deep-learning methods. This includes using a convolutional neural network that uses sea surface temperature satellite images from the NASA Geostationary Operational Environmental Satellite 16 (GOES-16). One of the more imperative instruments on the GOES-16 is the ABI: the Advanced Baseline Imager with 16 spectral bands, which has a spatial resolution of 0.5-2.0km with the ability to scan the Western Hemisphere in 15-minute intervals. This is why spatiotemporal models produced by the AIRU-WRF (AI-powered Rutgers University Weather Research & Forecasting) are important to fuse numerical weather predictions with hourly observations. Here, we focus on the Mid-Atlantic Bight (MAB) enclosing the region between the north of Cape Cod, Massachusetts, and the south of Cape Hatteras, North Carolina, bisected by the Hudson Shelf Valley extending from the mouth of the Hudson River Valley. We distinguish the effects of upwelling from other transient features to develop automated detection tools for upwelling and provide those outputs to numerical weather prediction models. With these combined systems we hope to better understand the processes and behaviors of offshore wind and ocean observing methods to harness a potential 22 GW of wind capacity energy.

# A Retrospective Look at 50 Years of Severe Weather Forecasting

*Steven Weiss*
*Retired - NOAA/NWS Storm Prediction Center, Norman, Oklahoma*

National severe weather forecasting science, technology, and services have advanced substantially during the last 50 years. In the mid-1970s, operational analysis and prediction as practiced by the SELS (Severe Local Storms) Unit of the National Severe Storms Forecast Center mirrored closely the pioneering techniques developed in the 1940s and 1950s by the U.S. Air Force and U.S. Weather Bureau. Improvements in operational severe weather forecasting in subsequent decades resulted from a series of focused and transformative research-to-operations (R2O) efforts that are highlighted in this presentation.

These advances include: 1) more timely receipt and effective display of observational and NWP model data through the implementation of several generations of interactive workstations, 2) advances in understanding severe storm physical processes and multi-scale interactions between convective storms and the mesoscale environment, informed by special observational field programs and high-resolution idealized cloud modeling studies, 3) large improvements in data assimilation and regional and global NWP modeling systems facilitating the incremental extension of severe weather forecasts from day 1 out to day eight, 4) innovations in short-range convection-allowing models and ensemble systems providing unique high-resolution guidance on explicit thunderstorm characteristics such as timing, mode, intensity, and uncertainty that is inherent in convective-storm prediction, 5) more recent applications of AI/ML techniques providing promising approaches to the creation of probabilistic storm hazard guidance, and 6) the development and growth of the Hazardous Weather Testbed as a unifying vehicle to foster community-wide R2O collaborations and to accelerate science-based advances into SPC operations.

This presentation documents the evolution of national severe weather forecasting from the perspective of SELS/SPC forecasters during the last 50 years. It highlights selected decade-by-decade key events, activities, and decisions that influenced forecasting techniques and resultant improvements in severe weather products and services for the protection of life and property across the U.S.

# New York and New England Significant Hail Climatology
# Part I: Climatology and Case Studies

*Thomas Wasula and Michael Main*
*NOAA/NWS/WFO Albany, New York*

Significant hail events are relatively rare across New York (NY) and New England. The National Centers for Environmental Prediction, Storm Prediction Center, considers a severe thunderstorm to be significant if it produces measured or estimated wind gusts of at least 65 knots (74.8 mph), hail of two inches (5.0 cm) in diameter or greater, or a tornado rated EF2 or greater. A climatological analysis of significant hail reports from January 1, 1950, to June 30, 2023, sourced from the National Climate of Environmental Information Storm Data, revealed a total of 273 events in NY and New England (each report corresponds to an event). New York recorded 138 events, with 53 occurring in the area covered by the National Weather Service at Albany Weather Forecast Office and 85 across the rest of the state. New England experienced 135 significant hail events, with 43 in Massachusetts, 36 in Maine, 22 in Vermont, 17 in New Hampshire, 15 in Connecticut (CT), and two in Rhode Island.

A state-by-state review of climatological trends for significant hail was conducted. The majority of these significant hail reports occurred during the months of May to August, accounting for approximately 96% of the total. Columbia County in eastern NY recorded the highest number of significant hail events (≥2" in diameter) with 13. Notably, some mountainous and sparsely populated counties in NY and New England have not reported any significant hail events.

This study aims to provide a comprehensive overview of significant hail climatology and discuss common synoptic and mesoscale features among these events. It also examines the pre-convective environmental analysis, focusing on real-time observational soundings to examine parameters such as 0-6 km deep shear, convective availability potential energy, freezing level and wet bulb zero heights, equilibrium levels, mid-level lapse rates, and the role of elevated mixed layers. In Part II, composites of various synoptic and mesoscale features will be discussed.

Finally, this presentation briefly examines two recent cases of significant hail events that occurred on May 15, 2018, and June 1, 2022. On May 15, 2018, there were eight reports of significant hail across the Catskills and the Mid-Hudson Valley in NY and northwest CT. During this event, six hailstones measured two inches (5.0 cm) in diameter, with one measuring up to 2.75 inches (baseball size) in Columbia County, NY. On June 1, 2022, three significant hailstones were observed near Binghamton in central NY from an isolated supercell, one of which was the size of tea cups or large apples, measuring 3 inches in diameter. Meteorological factors at various scales, along with observational data from the NYS Mesonet, including theta-e, irradiance, wind analyses, and surface convergence/divergence trends in 30 and 60 minute data, will be integrated into ) the analysis of these cases. NYS Mesonet profiler data will be applied in the environmental convective analysis.

# New York and New England Significant Hail Climatology
# Part II: Environmental Analysis

*Michael Main and Thomas Wasula*
*NOAA/NWS/WFO Albany, New York*

Significant hail events are rare in New York (NY) and New England but have shown an increased frequency over the past two decades. A significant hail event is defined by the National Centers for Environmental Prediction and the Storm Prediction Center as having at least one hailstone measuring at least two inches (5.0 cm) in diameter. This presentation is Part II of a study on the climatology of significant hail in NY and New England, aiming to analyze the synoptic and mesoscale features associated with these uncommon events.

Part I of this study presented a temporal and geographical analysis of the frequency of occurrence of significant hail events, examined mesoscale parameters associated with significant hail events, and investigated case studies of the May 15, 2018, event across eastern NY and western New England and an isolated supercell event near Binghamton NY on June 1, 2022. This presentation builds upon Part I of this study by focusing on the synoptic-scale environments and features associated with significant hail events through analysis of composite plots.

Significant hail events since January 1, 1950, were identified from Storm Data. The pre-convective environment for these events was assessed on various pressure levels using ECMWF Reanalysis v5 data to identify relevant synoptic-scale meteorological features. Initial results indicate upper-level ridging over the Rocky Mountains, troughing in southern Canada, and zonal flow over the northeastern U.S. The 300 hPa composite plots also show a mean jet streak over southeastern Canada, with its poleward entrance region situated over the northeastern U.S. The average 700 to 500 hPa lapse rates ranged between 6.5 and 7.0 °C/km, which is unusually steep for the Northeast U.S. This presentation will also investigate cases where the synoptic setup did not align with the composite pattern.

The second phase of this project, which will be presented as future research, will expand on the above results, incorporating all significant hail events in the climatology to increase the robustness of the findings. Furthermore, the environments associated with all significant hail events will be compared and contrasted with those associated with events that produced baseball or larger size hailstones.

## Beyond the Message: What to consider for Emergency Communications

*DeeDee Bennett-Gayle*
*College of Emergency Preparedness, Homeland Security, and Cybersecurity,*
*University at Albany, State University of New York*

Emergency communications are meant to be actionable, believable, and concise. But is this all that we should consider? During most disasters and incidents from natural hazards, individuals most at risk tend to have specific social, cultural, and economic challenges that impact their ability (or willingness) to comply with detailed requests. Throughout previous research, it appears these challenges may arise from the accessibility of technologies, historical and cultural precedents, discriminatory factors, misunderstanding/misinterpretation of what is being provided, digital divide issues, and the protection of one's mental health.

When considering the potential for increased vulnerability, it is essential to understand what exactly presents barriers to so many people. In this presentation, the audience is encouraged to contemplate what the layperson understands and the difficulties they may face. Through this brief presentation about literacy and mental health, audience members will get a glance at potential factors beyond the message that present a barrier to effective emergency communications.

This presentation topic is built from a meta-analysis of research regarding communications during disasters, user studies on the use of wireless emergency alerts among people with disabilities, focus groups across racial and ethnic minorities to discuss mobile apps disseminated for COVID-19, and survey data regarding use and perception of COVID-19 mobile apps across ages. The results indicate that we need to factor in literacy, numeracy, digital literacy, and accessibility when determining who can comply with emergency messaging. Additionally, avoidance may be a contributor to some people not complying.

# A Grassroots Effort Continues to Gain Traction: Year Three of the Snow Squall Safety Campaign

*John Banghoff, Jonathan Guseman, and Greg Devoir*
*NOAA/NWS/WFO State College, Pennsylvania*

Central PA has been the site of several multi-vehicle pile ups caused by snow squalls over the years due to the combination of location (downwind of Lake Erie), mountainous terrain, and significant commercial truck traffic on its interstate system. Now that several years have passed since the implementation of the Snow Squall Warning in 2018, educating the public about snow squall science, Warnings, and safety is paramount. To that end, NWS State College, with input from the other four NWS offices that serve Pennsylvania (Binghamton NY, Mt. Holly NJ, Pittsburgh, & Cleveland OH), embarked on an effort beginning in April 2021 to launch a coordinated safety messaging campaign with PennDOT, the Pennsylvania Turnpike Commission, Pennsylvania Emergency Management Agency (PEMA), and Pennsylvania State Police (PSP). These efforts originated from several years of successful coordinated awareness week campaigns for other hazards. The slogan for the snow squall safety campaign in Pennsylvania captures the essence of the dangers of snow squalls: There is no safe place on a highway during a snow squall.

Over the past few years, a team of representatives from the aforementioned agencies worked to create a variety of digital and print materials to educate the public (www.weather.gov/ctp/snowsquall). Annual press conferences have highlighted the inter-agency collaboration present in Pennsylvania and provided the public with a clear understanding of the dangers of snow squalls and how to stay safe. Facebook Live broadcasts hosted by NWS State College helped to further educate the public and field questions as the Awareness Week came to an end. Now in year three, new content has been developed as we learn more about gaps in public awareness including how to spot a snow squall in the distance, what to do if caught in a pileup, and how variable speed limit signs are being deployed to help mitigate the dangers of snow squalls. This presentation will also briefly preview some initiatives NWS State College is pursuing in order to collect information from the public about risk perception and knowledge of snow squalls. These collective efforts to improve awareness and identify knowledge gaps help foster a more Weather-Ready Nation in Pennsylvania and across snow squall-prone areas!

## Environmental Conditions and Forecast Error Evolution Associated with Synoptic Progressiveness Errors in GFS Forecasts

*Kevin Lupo and* Craig S. Schwartz
*National Center for Atmospheric Research*
*Center for Western Weather and Water Extremes, Scripps Institution of Oceanography, UC San Diego*

Cutoff lows are often associated with high-impact weather; therefore, it is critical that operational numerical weather prediction systems accurately represent the evolution of these features. However, medium-range forecasts of upper-level features using current and previous versions of NCEP's Global Forecast System (GFS) are often characterized by excessive synoptic progressiveness, i.e., a tendency to advance troughs and cutoff lows too quickly downstream. To better understand the processes associated with progressiveness errors in the GFS, this research jointly evaluates the environmental conditions that favor erroneously progressive cutoff lows in conjunction with the evolution of meso- to synoptic-scale forecast errors in the days preceding the diagnosed progressive displacement error. Feature-relative composite analysis of erroneously progressive cutoff lows over North America indicate that these displacement errors are preceded by the onset of negative 500-hPa geopotential height errors in the environment (i.e., heights that are too low) surrounding the composite feature, most notably through an under-amplification of an upstream ridge and heights that are too low poleward of the forecast feature. At the same time, mid-tropospheric wind speeds and cyclonic vorticity advection are too strong on the downstream and equatorward side of the forecast feature, consistent with greater forcing for height falls and faster downstream progression than verifying analyses. This composite behavior is most prominent in forecasts using GFS version 15 (June 2019–March 2021) and is corroborated by examination of individual cases of progressiveness errors. Further research is planned to identify and examine deficiencies in processes represented by the GFS, including parameterized physics, which may influence these errors.

# Evaluating Stochastic Parameter Perturbations in Convection-Permitting Ensemble Forecasts of Lake-Effect Snow

*Justin Minder*[1] *and W. Massey Bartolini*[2]
[1]*Department of Atmospheric and Environmental Science, University at Albany, State University of New York*
[2]*Cooperative Institute for Research in Environmental Sciences, NOAA/NWS Weather Prediction Center*

Lake-effect snowstorms, such as those occurring downwind of the Laurentian Great Lakes, can produce large, highly localized, snowfall accumulations that are challenging to simulate and forecast accurately. Effective forecasts need to include both expected snowfall and measures of forecast uncertainty. One type of numerical weather prediction forecast uncertainty for these events arises from the uncertainties associated with the parameterization of important sub-grid processes such as planetary boundary layer and surface layer turbulence (PBL/SL) and cloud and precipitation microphysics (MP). One way to represent the impact of physics scheme uncertainty is to design convection-permitting ensemble forecasts that use stochastic parameter perturbation (SPP) to vary individual uncertain parameters within physics schemes. The goal of this research is to evaluate and improve the utility of SPP for representing uncertainty in ensemble forecasts of lake-effect snow, with a focus on PBL/SL and MP parameterizations.

We focus on a snowfall event observed during the Ontario Winter Lake-effect Systems (OWLeS) field campaign that occurred from 10–12 December 2013. We run nested simulations of the event down to 1.33-km horizontal grid spacing using the Weather Research and Forecasting (WRF) model configured similarly to the operational High-Resolution Rapid Refresh model.To understand the impacts of SPP, a suite of 20-member SPP ensemble simulations are run, including ensembles where SPP is applied only to turbulence or microphysics parameterizations, or where SPP applied to multiple parameterization schemes concurrently. To compare the effects of SPP relative to other sources of ensemble spread, additional simulations are run where perturbations to initial and boundary conditions (ICs/BCs) are applied instead of SPP, or where SPP and IC/BC perturbations are applied together.

Results from the ensemble forecasts are evaluated against observations from OWLeS. Results indicate that SPP perturbations produce substantial spread in simulated precipitation, despite having only modest impacts on the free tropospheric synoptic scale flow. They accomplish this by modulating lake-atmosphere fluxes, boundary layer characteristics, precipitation growth processes, and hydrometeor terminal fall speeds. The spread and skill of simulated precipitation from an ensemble using SPP alone is comparable to that from ensemble that uses IC/BC perturbations alone. The specific physical pathways whereby different SPP perturbations generate spread in simulated lake-effect precipitation are examined and discussed.

# The Development of Snow Multi-Bands in High-Resolution Idealized Baroclinic Wave Simulations.

*Nicholas Leonardo and Brian A. Colle*
*School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY*

Snowbands within the comma head of extratropical cyclones can cause locally enhanced snow accumulations, ice accretion on tree limbs and powerlines, and travel hazards. The small-scale nature of these bands makes them difficult to forecast. While single-band precipitation structures have been extensively studied in winter storms, multi-bands remain less understood. The mechanisms determining the development, growth, and longevity of multi-bands need to be further analyzed. During the Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS) campaign, several storms developed multi-bands within a wedge-shaped region to the east of a surface low and along a trough of warm air aloft (TROWAL) throughout a 9-18-hour period. However, the many complex factors occurring in these case studies make them difficult to analyze. This study thus uses the idealized baroclinic wave setup from the Weather Research and Forecasting (WRF; Skamarock et al. 2008) model (version 3.4.1). Inner nests down to 800-m grid spacing are added after 108 hours of simulation time, focusing on the comma-head region of the surface cyclone.

The 4-km WRF grid will be the focus of this talk as it produces multi-bands resembling the 800-m grid. The lifecycle of the banding activity and its relationship with changes in environmental conditions will be highlighted. Multi-bands develop within a wedge northeast of the low center by 120 h, resembling the observed case studies. The development of this wedge follows an increase in both 700-500-hPa potential instability and 600-500-hPa vertical wind shear over the same region. The individual bands start as cells triggered by low-level frontogenesis and organize into segments oriented from southwest-to-northeast, parallel to the vertical shear. The bands propagate northward with the mean flow, bounded by a TROWAL frontal structure to the east and drier more stable air to the west. The banding activity diminishes ~18 hours later (by 138 h), as the ambient potential instability is depleted by convection. The individual bands elongate northeastward due to interactions between their moist updrafts and the horizontal relative vorticity generated from the vertical shear. The updrafts tilt the horizontal vorticity, creating a positive vertical vorticity anomaly to the right of the shear vector and a negative anomaly to the left. At the same time, the updraft releases latent heat in between the two vorticity anomalies, thus corresponding to a potential vorticity (PV) dipole. The PV in the dipole is advected northeastward by the southwesterly winds aloft. Meanwhile, the PV dipoles perturbs the mean flow such that divergence develops aloft to the northeast of the original updraft, resulting in additional upward motion and precipitation extending along a band.

# Poster Session -
# Wednesday 15 November 2023

## Water Mass Transformation Induced by Tropical Cyclones

*Samantha Donner[1], Marlos Goes[2,3] Ana Vaz[2,4], Shenfu Dong[3], Hui Li[5], and Ryan Sriver[6]*
*[1]Rutgers University*
*[2]Cooperative Institute for Marine and Atmospheric Studies, University of Miami*
*[3]NOAA Atlantic Oceanographic and Meteorological Laboratory*
*[4]NOAA Southeast Fisheries Science Center*
*[5]National Center for Atmospheric Research*
*[6]Department of Atmospheric Science, School of Earth, Society & Environment, University of Illinois Urbana Champaign*

Tropical Cyclones leave heat anomalies within the subsurface layers of the ocean. This heat can be redistributed around the world's oceans through advection and mixing, and knowing how this heat is being redistributed can help scientists understand heat-driven ocean and atmospheric changes. The goal of this work is to study the subsurface pathways of the anomalies induced by tropical cyclones. We are interested in the salinity, temperature, and surface mixed layer depth changes as they can hold great importance in understanding water masses transformation and their impacts on weather and climate. To achieve this goal, virtual particles were released utilizing the Connectivity Modeling System (CMS), which is an open-source lagrangian model, to simulate the virtual particle dispersal. Particles were released in global ocean-only model experiments from the Community Earth System Model, with and without TC wind forcing, using three different horizontal ocean grid resolutions (high resolution 0.1deg and low-resolution 1deg). These particles were advected for 2 years on the low-resolution model, and for 1.5 years on the high-resolution model to represent the fate of water parcels under direct influence of TCs. The analysis focused on the West Pacific, North Atlantic, and Indian oceans. Results show that some subsurface pathways can lead to cross-basin transport, such that a tropical cyclone in the Indian Ocean might affect the Atlantic, and this influence is enhanced in the high resolution model. Some pathways, specifically in the Western Pacific, followed a pathway to the Equatorial Pacific at about 65m depth. This results in the warming of the Eastern Pacific, which can be a precursor for El Nino events. This is the first large-scale study that focuses on understanding how TCs may influence the transfer of the subsurface heat and salt anomalies throughout the globe, and with this process studied, scientists can better comprehend the remote impacts of TCs in the global ocean.

**Validation of Offshore Winds in the ERA5 Reanalysis, HRRR, and NOW-23 Analyses Using Two Floating LiDARs South of Long Island, NY**

*Christopher Fragano[1], Brian Colle[1], Jeffrey Freedman[2]*
[1]*School of Marine and Atmospheric Sciences, Stony Brook University, Stony Brook, NY*
[2]*University at Albany, State Univeristy of New York*

Wind forecasting over offshore waters is challenging given the lack of long-term, multi-level observations and the limitations of operational numerical weather prediction (NWP) models in predicting the marine atmospheric boundary layer. The use of model reanalyses for offshore wind power resource assessments can result in considerable wind errors, especially when low-level jets (LLJs) occur, which are an important warm season coastal wind in the New York Bight. This study uses approximately three years (4 September 2019 - 30 November 2022) of hourly vertical wind profiler data from two New York State Energy Research and Development Authority (NYSERDA) floating lidars in the New York Bight, as well as the ERA5 global reanalysis, NREL's NOW-23 Mid-Atlantic Offshore wind resource dataset (i.e., NOW-23), and the HRRR analysis. The goal is to understand how well these model winds compare against observations in the lowest 200 m ASL for the warm season months and LLJ events. NOW-23 is the Weather Research and Forecasting model version 4.2.1. initialized with ERA5 at 2-km grid spacing and 9 model levels in the lowest 200 m, while the HRRR analysis is at 3-km grid spacing and 5 model levels in the lowest 200 m.

The warm season (May-September) LLJ events were identified using the observed floating lidar wind profiles and a combination of three different types of LLJ detection algorithms in the literature, whose criterion have been slightly modified from their original usage in prior coastal LLJ studies. An event was included in the warm season LLJ dataset, if at least two out of the three different algorithms identified a jet. The ERA5 reanalysis underpredicts wind speeds by 1 – 9% through the lowest 200 m profile during spring and summer, with April through June having the largest negative bias of 9.5-17.5% (1.0 – 1.8 m s-1). In contrast, NOW-23 has a more similar 60 – 200 m wind profile compared to the observed, with average underprediction of -0.08 m s-1 (0.9%). NOW-23 overpredicts wind speeds by 0.5 – 1.8 m s-1 in June-September, especially from 2000 – 0800 UTC. During warm season LLJ events, the ERA5 was found to have the poorest performance in terms of LLJ detection (zero hours detected) and depiction of LLJ structural characteristics. The NOW-23 analysis performed most accurately out of all the model analyses, in terms LLJ detection and validation performance metrics. On average, the lidar observed LLJ profile had a jet nose maximum of 11.2 ± 0.4 m s-1 at 100 m ASL, while NOW-23 depicted a slightly weaker and elevated jet nose of 10.4 ± 0.5 m s-1 at 120 m. The ERA5 exhibited a more elevated and weaker maximum of 9.3 ± 0.4 m s-1 at 140-160 m. The HRRR analysis is on average 9.6 ± 0.9 m s-1 and also elevates the jet to 140-160 m. Overall, this work highlights the challenges in using analyses with the limited offshore observations available for data assimilation in offshore wind prediction and wind resource assessment. This presentation will also highlight the synoptic patterns and environmental conditions when exceptionally large wind speed profile errors occur in the New York Bight.

# Acknowledgements:

The NROW conference is a partnership between the National Weather Service (NWS) Weather Forecast Office in Albany, NY and the Department of Environmental and Atmospheric Science at SUNY Albany. The Steering Committee would like to thank all presenters for sharing their research, insights, and experiences with NROW attendees. The committee would also like to acknowledge the follow groups for their photos used on the front cover of the abstract booklet: NWS Albany, NWS Buffalo, NWS Boston/Norton, and the New York State Mesonet.

The NROW 2023 Steering Committee includes Steven DiRienzo, Andrei Evbuoma, Brian Frugis, Abigayle Gant, Christopher Gitro, Vasil Koleci, Kevin Lipton, Lee Picard, Christina Speciale, and Joseph Villani.