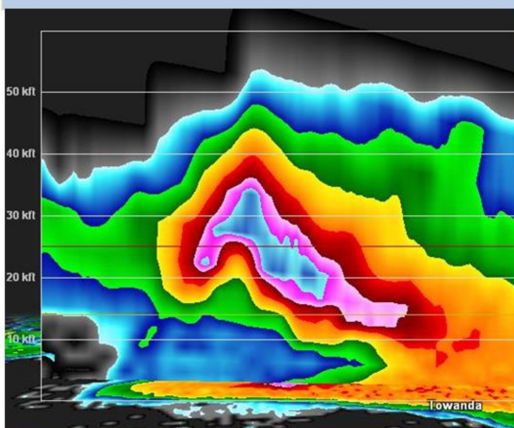
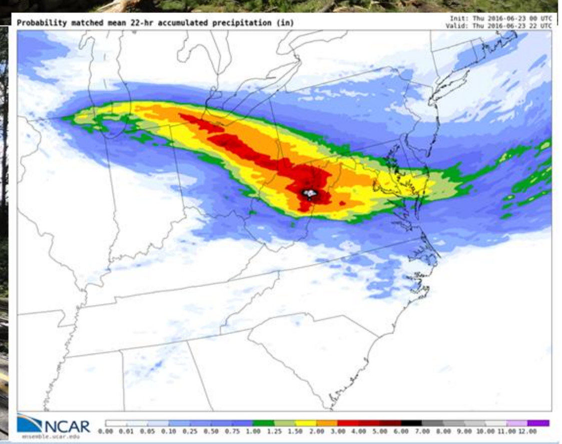
Northeast Regional Operational Workshop XVII

November 2-3, 2016

Albany, New York





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National Weather Service

SUNY-University at Albany's Department of Atmospheric and Environmental Science

American Meteorological Society

Agenda
Northeast Regional Operational Workshop XVII
Albany, New York
Nano South Conference Center, Room 103, 255 Fuller Road
Wednesday, November 2, 2016

8:30 am
Welcoming Remarks & Conference Logistics
Raymond G. O'Keefe, Meteorologist In Charge
Thomas A. Wasula, NROW XVII Steering Committee Chair
National Weather Service, Albany, New York

Session A – Extreme Weather Event(s)

8:45 am
The 10th Anniversary of the Valentine's Day Storm of 2007
John S. Quinlan
NOAA/NWS Weather Forecast Office, Albany, New York

9:05 am
Regime-Dependent Predictability of Extreme Weather Events: Characteristic Regime Types
Andrew C. Winters
Department of Atmospheric and Environmental Sciences
University at Albany, State University of New York, Albany, New York

9:25 am
Regime-Dependent Predictability of Extreme Weather Events: Representative Cases
Lance F. Bosart
Department of Atmospheric and Environmental Sciences
University at Albany, State University of New York, Albany, New York

9:45 am
Factors Contributing to the Heavy Rainfall in the Catskill Mountains Associated With Hurricane Irene (2011)
Luke J. Lebel
Department of Atmospheric and Environmental Sciences
University at Albany, State University of New York, Albany, New York

10:05 am
Ensemble Variability in Rainfall Forecasts of Hurricane Irene (2011)
Molly B. Smith
Department of Atmospheric and Environmental Sciences
University at Albany, State University of New York, Albany, New York

10:25 am
Break

Session B – Winter Weather/Cool Season Case Studies

10:40 am
Changes in the Winter Weather Desk Forecasts and Experimental Forecasts at the Weather Prediction Center (WPC)
Dan Petersen
NOAA/NWS/NCEP Weather Prediction Center, College Park, Maryland

11:00 am
The Elevation-Dependence of Snowfall in the Appalachian Ridge and Valley Region of Northeast Pennsylvania
Michael Evans
NOAA/NWS Weather Forecast Office, Binghamton, New York

11:20 am
A GIS-Based Winter Storm Impact Index (WSII) for a Weather-Ready Nation
Andy Nash
NOAA/NWS Weather Forecast Office, Burlington, Vermont

11:40 am
A Multiscale Analysis of Major Transition Season Northeast Snowstorms
Rebecca B. Steeves
Department of Atmospheric and Environmental Sciences
University at Albany, State University of New York, Albany, New York

12:00 pm
An Examination of the Rare Winter Tornado Event of 24 February 2016
Joe Ceru
NOAA/NWS Weather Forecast Office, State College, Pennsylvania

12:20–1:50 pm
Lunch

Session C – Severe Weather I

1:50 pm
The Nocturnal Severe Weather Outbreak of 25 February 2016 in Southern New England
Frank M. Nocera
NOAA / NWS Weather Forecast Office, Boston, Massachusetts

2:10 pm
An Unusual Morning Severe Weather Event in September: A Review of September 11, 2016
Justin Arnott
NOAA/NWS Weather Forecast Office, Gray, Maine

2:30 pm
Demonstrating an Effective End-To-End Warning Process: The Concord, MA Early Morning EF-1 Tornado of 22 August 2016
Joseph W. DelliCarpini
NOAA/NWS, Weather Forecast Office, Boston, Massachusetts

2:50 pm
Severe Thunderstorm Wind Damage Criteria – Is It Time For A Change?
Joseph P. Villani
NOAA/NWS Weather Forecast Office, Albany, New York

3:10 pm
Examining Methods to Accurately Predict Significant Severe Thunderstorm Wind Damage during the 2016 Severe Weather Season in Upstate New York
Brian J. Frugis
NOAA/NWS Weather Forecast Office, Albany, New York

3:30 pm
Break

Session D – Heavy Rainfall and Flash Flooding

3:50 pm
Improving Situational Awareness for Flash Flood Forecasting in a Small Urban Catchment by Integrating Meteorological Analysis into a Geospatial Framework
John M. Goff
NOAA/NWS Weather Forecast Office, Burlington, Vermont

4:10 pm
A Model Review of the Historic and Devastating West Virginia Floods of 23 June 2016
Rich H. Grumm
NOAA/NWS Weather Forecast Office, State College, Pennsylvania

4:30 pm
A Synoptic Comparison of Two High-Impact Predecessor Rainfall Events: Tropical Storm Lee/Hurricane Katia of September 2011 and Hurricane Joaquin of October 2015
Michael L. Jurewicz Sr.
NOAA/NWS Weather Forecast Office, Binghamton, New York

4:50 pm
The Ellicott City, Maryland, Flash Flood of 30 July 2016: Where Meteorology, Hydrology and Geography Collide
Steven M. Zubrick

NOAA/NWS Weather Forecast Office, Sterling, Virginia

5:10 pm
Wrap up
Thomas A. Wasula

5:15 pm
Adjourn

6:30–9:30 pm
CSTAR Dinner at Brown's Brewing Company (Trojan Room) for participants in UAlbany–NWS CSTAR VI
417 River Street, Troy, New York
518-273-2337

Agenda
Northeast Regional Operational Workshop XVII
Albany, New York
Nano South Conference Center, Room 103, 255 Fuller Road
Thursday, November 4, 2016

8:00 am
Opening Remarks
Raymond G. O'Keefe, Meteorologist In Charge
Thomas A. Wasula, NROW XVII Steering Committee Chair
National Weather Service, Albany, New York

Session E – Decision Support Services, Testbeds, and Data Networks

8:05 am
The Evolution of Impact-Based Decision Support Services (IDSS) at the Boston CWSU
Scott Reynolds
NOAA/NWS Center Weather Service Unit, Nashua, New Hampshire

8:25 am
Severe Weather Testbed Activities in Southern New England
Joseph W. DelliCarpini
NOAA/NWS, Weather Forecast Office, Boston, Massachusetts

8:45 am
"Living on the Edge": Communicating Uncertainty for the 23–24 January 2016 Blizzard in southern New England
Frank M. Nocera
NOAA/NWS, Weather Forecast Office, Boston, Massachusetts

9:05 am
Medium Range Forecasting at the Weather Prediction Center (WPC):
An Ensemble Effort in Big Data
Tony Fracasso
NOAA/NWS/NCEP Weather Prediction Center, College Park, Maryland

9:25am
New York State Mesonet
Jerry Brotzge
Atmospheric Science Research Center, Albany, NY

9:45am
Break

Session F – Ensembles

10:00 am
Toward Operational Convection-Allowing Ensembles over the United States
Craig Schwartz
National Center for Atmospheric Research, Boulder, Colorado

10:20 am
Verification of Multi-Model Ensemble Forecasts of North Atlantic Tropical Cyclones and an Analysis of Large Track Error Cases
Nicholas Leonardo
School of Marine and Atmospheric Sciences
Stony Brook University, Stony Brook, New York

10:40 am
A Review of the CSTAR Ensemble Tools Available for Operations
Brian A. Colle
School of Marine and Atmospheric Sciences
Stony Brook University, Stony Brook, New York

11:00-11:45 am

Round Table Discussion: Current Use of Ensembles in Operations

11:45 am
Lunch

Session G – Lightning, Heat, and Wind

1:15 pm
Use of High-Resolution Lightning Potential Forecasts for Vermont Utility Applications
Rob D'Arienzo
Vermont Electric Power Company, Rutland, Vermont

1:35 pm
Lightning Jumps as a Predictor of Severe Weather in the Northeastern United States
Pamela Eck
Department of Atmospheric and Environmental Sciences
University at Albany, State University of New York, Albany, New York

1:55 pm
A Synoptic Climatology of Excessive Heat Events in the Philadelphia Area
Lance Franck
NOAA/NWS, Weather Forecast Office, Mount Holly, New Jersey

2:15 pm
High Wind Events in Western New York: An Expanded Study and Development of Potential Impact Tables
Shawn Smith
NOAA/NWS, Weather Forecast Office, Buffalo, New York

2:35 pm
A Case Study of Five Unwarned Microbursts across Central New York
Paul Fitzsimmons
NOAA/NWS, Weather Forecast Office, Binghamton, New York

2:55 pm Break

Session H – Severe Weather II

3:15 pm
A Multi-Scale Analysis of the 1 July 2016 Null Tornado Watch across Eastern New York and Western New England
Thomas A. Wasula
NOAA/NWS, Weather Forecast Office, Albany, New York

3:35 pm
The 8 June 2016 Severe Weather Event in the Mid-Atlantic Region
Jared R. Klein
NOAA/NWS, Weather Forecast Office, Mount Holly, New Jersey

3:55 pm
Examination of Recent Mini-Supercell Tornadic Events in the Tri-State
Patrick Maloit
NOAA/NWS, Weather Forecast Office, New York, New York

4:15 pm
Assessing the Utility of Normalized Rotation in Detecting Tornado Development in the Allegheny Front
Dylan T. Cooper
NOAA/NWS Weather Forecast Office, Charleston, West Virginia

4:35 pm
The Utility of Incorporating Dual-Polarization Radar Signatures into the Tornado Warning Process: ZDR/KDP Separation Considerations in Supercells
Michael L. Jurewicz, Sr.
NOAA/NWS, Weather Forecast Office, Binghamton, New York

4:55 pm - Wrap Up
Thomas A. Wasula

5:00 pm – Adjourn

NROW XVIII is scheduled November 1–2, 2017

At the Nano South Conference Center, Room 103, 255 Fuller Road
On the Campus of the College of Nanoscale Science and Engineering
State University of New York, Albany, New York

The 10th Anniversary of the Valentine's Day Storm of 2007

John S. Quinlan
NOAA/NWS Weather Forecast Office, Albany, New York

The Valentine's Day storm of 2007 was one of the heaviest snowfalls to have ever occurred across the Mohawk Valley and Adirondacks of New York State. This storm was even featured in the December 2010 issue of Adirondack Life Magazine as one of the 10 greatest North Country weather disasters. What separated this storm from many other snowstorms that impacted the region over the years was the very intense band of heavy snow which yielded snowfall rates of 4 to 6 inches per hour and lasted for up to 6 hours. The entire snowstorm in most areas was over in 18 hours.

This presentation will focus on the forecast leading up to the storm including a discussion of SREF and MREF model data, a look at some of the key parameters which contributed to producing the heavy snowfall, the radar data including the intense band which formed as well as output from the snow accumulation algorithm, and a GIS analysis of the snowfall, snow water equivalent and snow to liquid ratio from the storm. Some pictures of the snowfall will be presented including a time lapse video of 6 inch per hour snowfall at North River, NY as well as photos showing snow drifts to 14 feet. In total there were 6 locations in the Albany Forecast area which received 40 inches or more of snowfall.

Regime-Dependent Predictability of Extreme Weather Events: Characteristic Regime Types

Andrew C. Winters, Daniel Keyser, and Lance F. Bosart
Department of Atmospheric and Environmental Sciences
University at Albany, State University of New York, Albany, New York

Extreme weather events (EWEs) during a single season can contribute disproportionately to temperature and precipitation anomaly statistics for that particular season. This disproportionate contribution suggests that EWEs need to be considered in describing and understanding the dynamical and thermodynamic processes that operate at the weather–climate intersection in order to improve operational probabilistic medium-range (8–10 day) temperature and precipitation forecasts. On the basis of this suggestion, a methodology to objectively identify EWEs over the continental United States will be presented. For this investigation, extreme will be defined on the basis of observations and in terms of percentiles, and events will be defined on the basis of the contiguous spatial coverage and duration of extreme temperatures and precipitation.

Following their identification, EWEs will be stratified into event types based on the state of the North Pacific jet stream 3–7 days prior to the development of an EWE. Subsequently, event-based composites will be constructed for each event type to examine the governing atmospheric flow patterns that are essential to the evolution of each event type. Knowledge of the governing atmospheric flow patterns characteristic of each event type has the potential to alert forecasters to the possibility of EWEs within the 8–10 day period. Motivated by this potential, we will present a real-time North Pacific jet phase diagram as an operational tool to characterize the state and evolution of the upper-tropospheric flow pattern over the North Pacific.

Regime-Dependent Predictability of Extreme Weather Events: Representative Cases

Lance F. Bosart, Andrew C. Winters, and Daniel Keyser
Department of Atmospheric and Environmental Sciences, University at Albany, State University of New York, Albany, New York

Extreme weather events (EWEs), defined by occasions of excessive precipitation or periods of well above or well below normal temperatures, can pose important predictability challenges on medium-range (8–16 day) time scales at the weather-climate intersection. Moreover, these EWEs can contribute disproportionately to observed precipitation and temperature anomalies on weekly and monthly time scales. EWEs usually occur in conjunction with highly amplified flow patterns that permit the extensive latitudinal exchange of tropical and polar air masses. Highly amplified flow patterns over North America typically develop in response to the evolution and reconfiguration of the large-scale upstream flow over the North Pacific Ocean.

This presentation will focus on the analysis of precipitation- and temperature-related EWEs over the CONUS that are challenging to predict on medium-range time scales. These EWEs owe their origin to the evolution and reconfiguration of the large-scale flow pattern over the North Pacific Ocean. Large-scale flow patterns that result in the formation of amplifying Rossby wave trains (RWTs) that propagate downstream and reach North America are especially likely to be associated with EWEs. Amplifying RWTs across the North Pacific Ocean may be triggered by the interaction of tropical and mid-latitude disturbances with the North Pacific jet stream (e.g., recurving and transitioning tropical cyclones, and longitudinally varying organized deep convection associated with an active MJO), by the interaction of mid-latitude and polar disturbances with the North Pacific jet stream (e.g., mid-latitude baroclinic disturbances associated with strong cold surges off the Asian continent and tropopause polar disturbances of arctic origin). Examples of challenging to predict EWEs that impacted the CONUS subsequent to the generation of upstream RWTs arising from tropical-mid-latitude and polar-mid-latitude interactions with the North Pacific subtropical jet stream will be illustrated.

Factors Contributing to the Heavy Rainfall in the Catskill Mountains Associated With Hurricane Irene (2011)

Luke J. LeBel and Brian H. Tang
Department of Atmospheric and Environmental Sciences
University at Albany, State University of New York, Albany, New York

Forecasting the rainfall associated with tropical cyclones (TCs) is challenging. This is especially true in the northeastern United States, where complex terrain and extratropical transition (ET) can combine to produce rapidly evolving rainfall distributions. In this study, Hurricane Irene (2011) was examined as a case study of this forecast challenge. Irene brought widespread rainfall totals of over 100 mm to the Albany, New York area, with locations in the Catskill Mountain region receiving in excess of 250 mm. An ensemble of WRF simulations initialized at 0000 UTC 27 August was utilized in order to determine the factors that contributed to the heavy rainfall totals over the Catskill region.

Track had the greatest influence on the rainfall totals in the Catskill region. When the ensemble members that produced the highest and lowest rainfall totals in the Catskill region were compared, it was found that the wetter simulation had a track much farther to the west. This farther west track – inland over New Jersey into the Catskill region – favored heavy rainfall in the Catskill region, and was tied to a slower progression of the upstream upper-level trough.

It is also interesting to note that a Predecessor Rain Event-like feature was evident in the wetter simulation. Each of the five wettest members also had similar PRE-like features, while the five driest members did not. This is evidence that the wetter members interacted more favorably with the upper-level trough, as PRE development requires strong synoptic forcing.

When track was removed as a factor and two members with nearly identical tracks were compared, the rainfall totals in the Catskill region became more sensitive to the details of Irene's ET. Specifically, we hypothesize that an earlier and stronger interaction between Irene and a southern stream upper-level PV anomaly resulted in differences in the early distribution of convection associated with the TC. The earlier and stronger interaction favored more convection to the northwest of Irene. This distribution of convection affected the progression of the upstream upper-level trough, as increased convection resulted in increased upper-level outflow to the northwest, slowing the trough progression. The differences in trough progression then resulted in differences in synoptic forcing for rainfall. When the trough stalled farther west due to enhanced outflow, it interacted more weakly with Irene at the time of heaviest rainfall over the Catskill region, resulting in lower rainfall amounts.

Ensemble Variability in Rainfall Forecasts of Hurricane Irene (2011)

Molly B. Smith[1], Ryan D. Torn[1], Kristen L. Corbosiero[1], and Philip Pegion[2]
[1]University at Albany, State University of New York, Albany, New York
[2]CIRES, Boulder, Colorado

As tropical cyclones (TCs) move from the tropics into the midlatitudes, they are often associated with extensive regions of heavy precipitation. This precipitation can lead to widespread flooding events, such as occurred with Hurricane Irene (2011) over the northeastern United States. Despite the high-impact nature of these events, there are relatively few studies that explore the sensitivity of precipitation forecasts to model initial conditions, instead focusing on the variability in TC track.

The goal of this work is to understand what modulates precipitation forecasts over the northeastern United States during Hurricane Irene. This is investigated using the 3 km Weather Research and Forecasting (WRF) model to downscale members of the Global Forecasting System ensemble prediction system, initialized at 0000 UTC 27 August 2011. The ensemble members that forecast the largest precipitation totals (i.e., wet members) over the Catskill Mountains of New York State (where over 15” of rain were observed) are then compared to the members that predicted the least precipitation (i.e., dry members), in order to diagnose the processes that lead to the rainfall differences. Results indicate that the amount of rainfall is tied to storm track, with wetter members clustered on the western side of the track envelope, and drier members on the east.

Due to the influences of terrain, however, the WRF ensemble members feature a more complex relationship between precipitation and storm track than a simple east–west correlation. The wettest members are characterized by lower-tropospheric winds that are directed perpendicular to the northeastern face of the Catskills (where the heaviest rainfall occurred), allowing maximum upslope forcing during the period of highest rainfall rates. The wet members also feature greater horizontal moisture flux convergence over the region in the hours prior to Irene’s landfall, which provided the water vapor required for sustained heavy rainfall. It is interesting to note, however, that the drier eastern members have the greatest synoptic forcing for vertical motion in the Catskills. Their lower rainfall totals may be due to the fact that the eastern members positioned the bulk of the available moisture too far east for that forcing to produce large rainfall amounts.

Changes in the Winter Weather Desk Forecasts and Experimental Forecasts at the Weather Prediction Center (WPC)

Dan Petersen, NOAA/NWS/NCEP/WPC, College Park, Maryland

Changes to the 2016-17 WPC winter weather desk and product suite are discussed in this presentation, including changes in the calculation of freezing rain accumulations, the membership of models/ensembles used to derive snow/freezing rain probability forecasts, and the implementation of the experimental days 4-7 probabilistic winter weather forecasts on the National Digital Forecast Database at http://digital.weather.gov/.

Sanders and Barjenbruch (2016) http://journals.ametsoc.org/doi/abs/10.1175/WAF-D-15-0118.1 studied freezing rain accumulations and found ice to liquid ratios had a median of 0.72:1, with a 25th percentile of 0.50:1 and a 75th percentile of 1.0:1. The authors derived a Freezing Rain Ice Accumulation Model (FRAM) and the Weather Prediction Center will adopt a simplified version of the FRAM, which will result in about a median 28 percent reduction in forecast ice accumulations (last year we used a 1:1 ice to liquid ratio, and the study median was 0.72:1) for each model/ensemble used in the freezing rain probability forecasts.

The WPC produces 24, 48, and 72 hour probabilistic winter weather forecasts for snow and ice accumulation across the 48 contiguous states http://origin.wpc.ncep.noaa.gov/pwpf/wwd_accum_probs.php?fpd=24&ptype=snow&amt=1&day=1&ftype=probabilities , now displayed using ESRI map backgrounds). The forecast models and ensembles used to derive the probability distribution will now include the convection-allowing models (WRF ARW/NMMB) and increase the number of Global Ensemble Forecast System (GEFS) ensemble members from 5 to 10 members. This increases the number of ensemble members to compute snow and freezing rain probabilities and percentiles to 70 for 2016-17.

In 2014-15, WPC provided experimental Day 4-7 forecasts of the probability of 0.25" liquid equivalent precipitation in the form of snow and sleet for NWS Weather Forecast Offices (WFOs). The WPC Quantitative Precipitation Forecast (QPF) for the Day 4-7 period was used, as well as temperature profiles from multi-model ensembles.

In 2016-17, the Experimental Day 4-7 Winter Weather Outlook will be issued, depicting the probability of winter precipitation (snow/sleet) exceeding 0.25 inches water equivalent over a 24-hour period (Valid Time 12z-12z). The product is comprised of 4 separate grids containing the forecast for Days 4, 5, 6 and 7, and will be shown at http://origin.wpc.ncep.noaa.gov/wwd/pwpf_d47/pwpf_medr.php?day=4. The product is updated daily at approximately 0900 UTC and 1930 UTC. More details on the Experimental Day 4-7 Winter Weather Outlook product are available in the Product Description Document: https://products.weather.gov/PDD/ExplDay4to7WinterWeatherOutlookinNDFD.pdf

The Elevation-Dependence of Snowfall in the Appalachian Ridge and Valley Region of Northeast Pennsylvania

Michael Evans[1], Michael L Jurewicz Sr[1] and Rachel Kline[2]
[1]NOAA/NWS Weather Forecast Office, Binghamton, New York
[2]State University of New York at Binghamton

Northeast Pennsylvania including the cities of Wilkes-Barre and Scranton is located in an area typical of the Appalachian Ridge and Valley Region, characterized by long northeast-to-southwest oriented ridges running parallel to broad valleys. Snowfall in this area often varies considerably in short distances due to differences in elevation; however there are times when elevation does not appear to substantially affect snowfall totals. In order to study the impact of elevation on snowfall in this region, a collection of 40 snow events in northeast Pennsylvania from 2005-2014 was studied. The median high-elevation versus low-elevation snowfall ratio for the 40 events in the study was 1.25, however, several events were identified that departed substantially from the average. The primary goal of this study is to give forecasters an understanding of factors that modulate the impact of elevation on snowfall in the Appalachian Ridge and Valley Region, including northeast Pennsylvania.

In order to illustrate factors that helped to determine differences in the dependency of snowfall on elevation for this area, nine events with a large elevation dependency were compared to twelve events with a relatively small elevation dependency. Examination of model forecast soundings showed that large elevation dependency was most likely for events with strong lower-tropospheric winds. Large elevation dependency was also most likely when surface temperatures at Avoca, Pennsylvania exceeded 30°F. A relatively weak, inverse correlation was found between elevation dependence and lower-tropospheric stability. The Froude number, which is a function of wind speed, wind direction and stability, was shown to be a useful parameter for determining the impact of elevation on snowfall. A regression equation was developed to aid forecasters with determining the impact of elevation on snowfall. A brief case study is shown that compared the output of the equation to forecasts from a high resolution model ensemble and observations. It was shown that output from the regression equation can be used in conjunction with high resolution model guidance to realistically assess the impact of elevation on snowfall in northeast Pennsylvania.

A GIS-Based Winter Storm Impact Index (WSII) for a Weather-Ready Nation

Andy Nash, NOAA/NWS Weather Forecast Office, Burlington Vermont
Nathan Foster, NOAA/NWS Weather Forecast Office, Las Vegas, Nevada
Michael Muccilli, NOAA/NWS Weather Forecast Office, Baltimore/Washington DC

Beginning with the 2013-14 winter season, the National Weather Service (NWS) Weather Forecast Office (WFO) in Burlington, Vermont has been producing, in real-time, a Winter Storm Impact Index (WSII). The goal of this demonstration project is to use a geographic information system (GIS) to depict the spatial distribution of potential impacts from winter storms beyond what can be conveyed through legacy NWS warning and advisory products. The WSII combines real-time official forecast information from the NWS National Digital Forecast Database (NDFD) with non-meteorological datasets, such as land use type, climatology, and population to produce a nationwide depiction of the potential severity of a winter storm. The WSII is scaled from 1 to 5 where 1 is a limited potential impact and 5 is an extreme impact. WSII is determined through 7 sub-component index calculations: total snowfall amount, snow accumulation rate, snow loading, blowing snow, flash freeze, ground blizzard, and ice accumulation. Snowfall amount and accumulation rate are normalized with respect to climatology to account for differing societal responses given the same meteorological conditions (e.g., 1 inch of snow in Atlanta versus 1 inch of snow in Chicago). Land use datasets are used to address higher impacts of blowing snow in open areas compared to heavily forested areas, and higher snow loading in urban and heavily forested areas than in grasslands. The WSII has the potential to be used internally by NWS forecasters to aid in situational awareness and to provide enhanced impact-based decision support services (IDSS) which is part of the NWS' Weather-Ready Nation initiative. External users, such as emergency managers, members of the media, and the general public, could potentially leverage WSII output to better understand the risk of disruption for more specific locations. This presentation will focus on how WSII is calculated, WSII evaluation for the past three winter seasons, and initial external partner feedback.

A Multiscale Analysis of Major Transition Season Northeast Snowstorms

Rebecca B. Steeves, Daniel Keyser, and Andrea L. Lang
Department of Atmospheric and Environmental Sciences
University at Albany, State University of New York, Albany, New York

Major transition season Northeast snowstorms have the potential to cause widespread socioeconomic disruption in the form of transportation delays, infrastructure damage, and widespread power outages. Because heavy, wet snow tends to occur in transition season Northeast snowstorms, lesser accumulations can result in greater disruption than if the same accumulation occurred in winter season Northeast snowstorms. Motivated by the opportunity to improve scientific understanding and operational forecasting of major transition season Northeast snowstorms, we are conducting a multiscale analysis of this class of snowstorms that focuses on documenting: 1) the planetary-to-synoptic-scale flow patterns occurring prior to and during major transition season Northeast snowstorms, with emphasis on the role of moisture transport occurring within atmospheric rivers in the formation and evolution of this class of snowstorms, and 2) the synoptic-to-mesoscale flow patterns in the extratropics occurring prior to and during major transition season Northeast snowstorms, with emphasis on the formation and maintenance of regions of lower-tropospheric cold air that coincide with areas of heavy snowfall.

An objectively developed list of major transition season Northeast snowstorms that occurred during fall and spring from 1983 through 2013 was constructed using National Centers for Environmental Information monthly Storm Data Publications. This list was used to construct composite analyses for categories based on characteristic patterns of lower-tropospheric cold air that coincide with areas of heavy snowfall and to perform illustrative case studies of the categories. The composite analyses and case studies will be used to document the planetary-to-mesoscale flow patterns occurring prior to and during major transition season Northeast snowstorms and to consider the hypothesis that atmospheric rivers play a key role in the formation and evolution of this class of snowstorms. We will address this hypothesis by applying an objective atmospheric river detection algorithm. We also will document moisture transport along parcel trajectories to diagnose moisture sources for areas of maximum snowfall, as well as to diagnose the evolution of selected thermodynamic quantities and moisture variables along the trajectories for selected case studies. While performing the composite analyses and case studies, we will diagnose processes that contribute to the formation and maintenance of regions of lower-tropospheric cold air that coincide with areas of heavy snowfall.

An Examination of the Rare Winter Tornado Event of 24 February 2016

Joe Ceru and Richard H. Grumm
NOAA/NWS Weather Forecast Office, State College, Pennsylvania

A surge of unseasonably warm moist air and strong southerly flow produced a widespread severe weather event over the eastern United States on 24 February 2016. The event produced over 540 reports of severe weather and 32 tornadoes. The two northernmost tornadoes were observed in Pennsylvania. The two tornadoes in Pennsylvania were the first reported tornadoes since 1990 doubling the tornado climatology for the month of February.

Tornadic events are rare in the winter and require rather unique meteorological conditions. A review of the literature revealed that there was a widespread severe weather event with at least 3 tornadoes in Pennsylvania in February 1887. The twentieth century re-analysis data was used to compare the 1887 synoptic setup to the 2016 event. In both cases strong southerly flow and unseasonably high precipitable water appeared to play a role in the event.

In addition to the pattern which produced the severe weather event over the eastern United States, radar data is used to show the evolution of the severe weather in Pennsylvania. It will be shown that this event evolved from a quasi-linear convective system to one with at least one supercell thunderstorm along the line. It was this supercell produced the Whitehorse tornado in Lancaster County, PA.

The Nocturnal Severe Weather Outbreak of 25 February 2016 in Southern New England

Frank M. Nocera
NOAA/NWS Weather Forecast Office, Boston, Massachusetts

An anomalous late winter severe weather outbreak affected southern New England during the early morning hours of 25 February 2016. Widespread wind damage was reported with a fine line of low-topped severe convection that produced wind gusts of 50 to 70 mph, and as high as 83 mph at the Blue Hill Observatory in Milton, MA. There were many reports of downed trees, power lines, and a loss of power to tens of thousands of customers.

The severe weather outbreak was a result of a strengthening low pressure system that tracked across the eastern Great Lakes and brought an unusually warm and moist airmass into New England ahead of an approaching cold front. The elevated instability coupled with very strong jet dynamics produced a line of thunderstorms from the Mid-Atlantic States into New England.

Ensemble and operational model guidance showed the potential for an anomalous severe weather event in the days leading up to February 25. Forecasters at the National Weather Service (NWS) in Taunton conveyed the potential for severe weather in email briefings to core partners, Area Forecast Discussions, and social media posts as early as February 22. That evening, Severe Thunderstorm Watches were issued by the NWS Storm Prediction Center. This was the first time Watches were issued for parts of New England in February since SPC began keeping records in 1970. A total of 14 Severe Thunderstorm Warnings were issued by NWS Taunton for this event, all of which verified with an average of xx minutes of lead time. It had been nearly 20 years (1997) since the office issued Severe Thunderstorm Warnings in February.

This presentation will focus on the science behind this anomalous event, including a review of the unusual environment that was in place over New England that evening. Radar data and mesoscale analyses will show the role thunderstorms played in bringing very strong winds aloft down to the surface, which resulted in widespread damage. Several examples of messaging from NWS Taunton used to convey the threat will also be shown.

An Unusual Morning Severe Weather Event in September: A Review of September 11, 2016

Justin Arnott
NOAA/NWS Weather Forecast Office, Gray, Maine

A strong cold front moved through New England on the morning of September 11, 2016. Along this cold front, a line of convection produced over three dozen damaging wind reports in the WFO Gray forecast area. A review of the September severe weather climatology in the WFO Gray forecast area reveals that while events of similar magnitude are not unprecedented in September, the fact that the entire event occurred during the morning hours was highly unusual. In fact, eight of the ten severe thunderstorm warnings issued occurred between 8 and 11 am EDT, the greatest number during that span over the past decade.

In this presentation, we will review the climatological, synoptic and mesoscale aspects of this event including the skill of probabilistic and deterministic guidance in anticipating it. Despite its highly anomalous nature, situational awareness was high leading up to the event, with over 40 hours of lead time in the Hazardous Weather Outlook text product. This, along with upstream damage reports, resulted in accurate and timely warnings despite relatively weak radar signatures.

Demonstrating an Effective End-To-End Warning Process: The Concord, MA Early Morning EF-1 Tornado of 22 August 2016

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On 22 August 2016 a rare early morning tornado struck Concord, Massachusetts. The tornado was rated EF-1 with maximum winds of 100 mph, had a path length of one-half mile, and maximum path width of 400 yards. There was significant tree damage and some damage to homes in a small portion of the town. It was only the third tornado to have occurred in Massachusetts between midnight and 6:00 am (the last one was in July, 1970). Despite having occurred in the middle of the night there were no fatalities or injuries, largely due to the fact that Wireless Emergency Alerts (WEA) received on cell phones woke people up and gave them adequate time to get to safe shelter.

This event was an excellent example of how the end-to-end warning process should work as part of a Weather Ready Nation. The Massachusetts Emergency Management Agency (MEMA), considered one of the office's "Deep Relationships" partners, hosts its annual Spring Workshop where NWS Boston forecasters present topics on severe weather and provide training to their staff. Local research on environments that are favorable for these short-lived tornadoes, which are typical for New England, was applied in the days leading up to the tornado and led to very high situational awareness. IDSS information was communicated not only through NWS products such as Area Forecast Discussions and Hazardous Weather Outlooks, but also through social media in order to raise awareness of this low probability but high-impact event. That night, new technology was utilized (Meso-SAILS 3 and MRMS) and a Severe Thunderstorm Warning was issued for the storm 29 minutes ahead of time and mentioned the possibility of a tornado. It was upgraded to a Tornado Warning 19 minutes before the tornado touched down in Concord. Later that day, MEMA assisted the office with the storm damage survey by providing contacts with the Concord Fire Department and access to closed-off areas that sustained the most damage.

This presentation will review the end-to-end warning process, from the expectation two days prior to communication of the potential hazards and warning issuances, which helped to save lives.

Severe Thunderstorm Wind Damage Criteria – Is it Time for a Change?

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In the Eastern Region of the National Weather Service (NWS), tree damage is the primary source of wind verification for Severe Thunderstorm Warnings (SVRs). However, there is a conflict between the NWS issuance criteria for SVRs and the NWS mission statement. The criteria for issuing a SVR due to wind is to determine if a thunderstorm is producing wind gusts equal to or greater than 50 kt. The NWS mission for SVRs is protecting lives and property. The conflict arises since damage to trees is possible at wind speeds less than 50 kt.

Scientific studies (Frelich and Ostuno 2012 and McDonald and Mehta 2006) have proven that damage to trees and limbs can and does occur with wind speeds less than 50 kt. Tree condition (rotting/diseased) and other factors (drought) play a significant role in determining what wind speeds can cause damage to trees and tree limbs.

NWS Meteorologists base SVR decisions on radar signatures expected to produce winds equal to or greater than 50 kt. However, most storms that produce damage to rotted/diseased trees occur with more subtle signatures, which leads to several missed reports. In 2016 (through 13 September), 96% of missed reports due to thunderstorm wind damage at NWS Albany were from tree(s) or wires down. Furthermore, the rationale for determining the issuance criteria of SVRs is outdated (1970) and was initially intended for aviation safety. These factors bolster the impetus for lowering the wind speed issuance criteria for SVRs. Evidence will be presented for adopting the need to change the issuance criteria of SVR based on wind damage to trees.

Examining Methods to Accurately Predict Significant Severe Thunderstorm Wind Damage during the 2016 Severe Weather Season in Upstate New York

Brian J. Frugis
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The Storm Prediction Center (SPC) considers severe thunderstorms that produce measured or estimated wind gusts of at least 65 knots (74.8 mph) or hail two inches in diameter or greater to be significant. Between 2012 and 2015, the Northeast (New England, New York, New Jersey and central and eastern Pennsylvania) saw 174 severe thunderstorm reports that were either significant or produced injuries or fatalities. This is nearly double the number of tornadoes that were reported over the same time period (95). Many of these significant severe thunderstorm wind damage reports had a much larger societal impact as compared to the tornadic events as well. Considering the National Weather Service's implementation of Impact-Based Warnings, knowledge of a severe thunderstorm's damage potential is critical information for forecasters to have when issuing severe thunderstorm warnings.

On August 13, 2016, a cold front moving towards a warm and extremely humid air mass led to several rounds of thunderstorms over upstate New York. Many of these thunderstorms were severe, producing wind damage to trees and power lines. A few of the storms produced significant damage, especially around the Pine Lake campground in the southern Adirondacks of northwestern Fulton County, where seven injuries occurred to fallen trees. Newspaper media reported about 200 trees were estimated to have fallen at the campground, which damaged at least 59 structures and 18 vehicles. The total estimated cost of damage was around 1 million dollars. Wind gusts were likely at least 65 knots with this storm based on photographic evidence of damage.

Pinpointing which particular severe thunderstorms will produce significant wind damage can be a difficult challenge for the warning forecaster. Out of the 80+ storm reports received by the Albany Weather Forecast Office (WFO) on August 13th, only a small handful of reports were considered significant or produced injuries. However, these particular storms had a major impact on the lives of many people in the region. Doppler radar radial velocity data may not always provide a clear picture on the scope of the storm, due to inherent problems regarding the radar beam's height and angle. This study will attempt to examine some other sources of guidance in addition to traditional velocity data, including lightning data, dual-polarization radar products, and mesoscale parameters to help provide better guidance on when a thunderstorm will have to potential to produce significant wind damage.

Improving Situational Awareness for Flash Flood Forecasting in a Small Urban Catchment by Integrating Meteorological Analysis into a Geospatial Framework

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The susceptibility of flash flooding in Burlington, VT is examined through meteorological analysis and the examination of two recent events affecting the city. Integration of geospatial data within a broader historical framework reveals most of the recent flooding has occurred along a subtle northeast to southwest oriented ravine, largely buried due to urban development over the past 150 years. The link between episodic flash flood events in this small watershed and high intensity, short duration (HISD) rainfall shows the best correlation among various meteorological elements examined. Recent availability of WSR-88D dual-polarization precipitation intensity data has added value in identifying HISD rainfall events and enhanced situational awareness for the potential of flash flooding. While HISD rainfall events are likely the dominant meteorological cause of flooding within the city, potential anthropogenic sources are also examined including 1) watershed urbanization and 2) drainage inefficiencies in the sewer/storm water collection system. Improvements to the drainage system and hydraulic/hydrologic modelling software by the Burlington Public Works Department were completed in 2014 with the aim of mitigating the impacts of future heavy rain events in the city.

A Model Review of the Historic and Devastating West Virginia Floods of 23 June 2016

Richard H. Grumm
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A large scale frontal system with flow over a strong subtropical ridge set up a nearly classic Maddox frontal rainfall event over the Ohio Valley on 23 June 2016. The larger scale pattern was relatively well predicted in the NCEP global forecast systems and thus these models showed a signal for a potential rain event. However, lacking the ability to produce convection these models failed to produce the precipitation amounts relative to observed extreme rainfall. These models also exhibited large spatial and temporal issues. Several Convection Allowing Models (CAMS) produced significantly higher QPF amounts in closer proximity to the general locations where the heavier rainfall was observed. The probability matched mean products produced from the CAMS models showed great promise in forecasting future extreme rainfall events.

The large scale pattern favoring heavy rainfall is presented along with forecasts from traditional NCEP models and ensemble forecast systems. Short range forecasts from CAMS are also presented. In this event, the CAMS provided insights into the potential for an extreme rainfall event over the portions of Kentucky and West Virginia. The High Resolution Rapid Refresh Model (HRRR) also created a cold pool as the event progressed and thus indicated a reduced threat of additional flash flooding during the late morning and evening hours of 24 June 2016.

This paper will show how CAMS and emergent CAM ensembles should improve 0-24 hour forecasts of convective driven flash flood events with strong synoptic forcing. The ability to correctly leverage the power of rapid updating CAMS and CAM ensembles should be a key training focus to improve the forecasting and warning of heavy rainfall and flash flooding in the near future. These data, if effectively employed, have significant potential to improve short-term forecasting during the warm season relative to models that employ convective parameterization schemes.

A Synoptic Comparison of Two High-Impact Predecessor Rainfall Events: Tropical Storm Lee/Hurricane Katia of September 2011 and Hurricane Joaquin of October 2015

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John Forsythe, Andy Jones, Stan Kidder, Dan Bikos, Ed Szoke, CIRA/Colorado State University

Predecessor Rainfall Events (PRE) are coherent areas of heavy rainfall (generally 4 in/100 mm or greater rainfall centroids per 24 h or less) that occur at distant ranges from the centers of tropical cyclones, yet are still indirectly related to these systems, usually through a connected plume of deep tropical moisture. This presentation will focus on two PRE events over the eastern U.S., both extremely high-impact in nature, due to record rainfall and catastrophic flooding.

In early September 2011, a plume of deep moisture associated with the remnants of Tropical Storm Lee spread northward across the eastern U.S., while its remnant circulation slowly decayed as it tracked through the Tennessee and Ohio Valleys. At the same time, distant Hurricane Katia well off the Southeast U.S. coast slowly moved northward. The combined effects of these two systems on the large-scale and mesoscale environments were instrumental in forcing a nearly stationary band of excessive rainfall over MD, PA, and NY on 7-8 Sep. In early October 2015, a slow moving closed upper low formed near the eastern Gulf Coast. At the same time, a plume of deep moisture emanating from Hurricane Joaquin was directed towards the Carolinas. The stagnant nature of the large-scale pattern and the significant roles of both Hurricane Joaquin and the closed upper low were integral in the formation of a persistent area of excessive rainfall over SC from 1-4 Oct.

Key synoptic-scale similarities between these events will be discussed, including the effects of the two distant tropical cyclones (Katia and Joaquin). Newer satellite derived datasets will also be used to illustrate the moisture contributions of Hurricanes Katia and Joaquin, most notably the CIRA Layered Precipitable Water product.

The Ellicott City, Maryland, Flash Flood of 30 July 2016: Where Meteorology, Hydrology and Geography Collide

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A statistically-rare heavy precipitation event developed during the evening hours of Saturday, 30 July 2016, affecting an area of Central Maryland from Montgomery County through Howard County to the City of Baltimore. While significant impacts were observed throughout the impact zone, the most noteworthy impacts occurred in the historic district of Ellicott City, Maryland, with two fatalities, damage of numerous buildings and infrastructure, and necessitating the closure of much of Main Street in Ellicott City for a period several months.

The flash flooding occurred on a typically busy Saturday night, with the downtown section filled with many visitors. Social media documented the extreme flash flooding that occurred along Main Street, including numerous vehicles being swept down the street, and harrowing life-saving rescues by citizens of those trapped in partially-submerged vehicles.

At time durations of 5 minutes to 3 hours, observed rainfall at the Hydrometeorological Automated Data System (HADS) Ellicott City rain gauge (ELYM2-located ~2 km from downtown area that was impacted by flooding) has a probability of occurrence of less than or equal to 1/1000.

Although the rainfall – nearly six inches in two hours – would have created major impacts in almost any populated area, unique hydrologic and geographic features exist in Ellicott City, including multiple small streams feeding into a large river, and significant elevation changes. These create a complex situation, and played a substantial role in the severe damage which occurred. The thunderstorms that produced the incredible rainfall exhibited back-building and low lightning flash rates.

The National Weather Service (NWS) Weather Forecast Office (WFO) in Sterling, Virginia, (LWX), issued a flash flood warning, which included Ellicott City, at 7:18pm EDT (2318 UTC/30 Jul 2016). The first report of flooding near Ellicott City was in the Chatham area west of downtown at 8:01pm EST (0001 UTC/31 Jul). Based on video evidence and resident interviews, the most severe flooding occurred between 8:05pm and 9:00pm EST (0005 and 0100 UTC/31 Jul).

The event will be reviewed through a timeline of known events, with specific focus on the complex hydrologic elements in play and the geography of this very small watershed.

The Evolution of Impact-Based Decision Support Services (IDSS) at the Boston CWSU

Scott Reynolds
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The date was April 4, 1977. Southern Airways Flight 242, a DC-9 jet flying from northwest Alabama to Atlanta suffered hail damage and lost thrust in both engines as a result of an encounter with a severe thunderstorm. Flight 242 subsequently crashed in rural New Hope, Georgia. Over 70 people from the flight and on the ground perished as a result of the crash.
Acting on a recommendation from the National Transportation Safety Board's (NTSB) report on the accident, the Federal Aviation Administration (FAA) and the National Weather Service (NWS) agreed to create Center Weather Service Units (CWSU) in each of the 21 Air Route Traffic Control Centers (ARTCC).

We've come a long way since CWSU Boston opened in 1978. The CWSUs have always been in the ***Impact-based*** Decision Support Services (IDSS) "business" … and now more so than ever. We have long provided ARTCC Traffic Management Units (TMU) with critical information for them to make informed decisions on routing of aircraft in hazardous weather situations in the very near term (0-12 hour time frame). And at Boston ARTCC (ZBW), an added focus was always on hazardous weather that would be impacting Logan International Airport (KBOS).
In the past 5-10 years, our FAA partners have asked for, and demanded more information. The level of detail needed has never been higher, and it continues to increase. What is also changing is the level of detail that the NWS needs from our partners – more detailed knowledge of their operations. It's just not good enough to tell them "where and when"…it is truly all about the impacts of the weather and helping our partners mitigate those impacts quickly and efficiently. And we have to have more than just a basic level of knowledge of their operations in order to accomplish that mission.

Despite the very aviation-focused nature of CWSU operations, we are uniquely positioned to help our fellow NWS offices in their IDSS evolution. This presentation will focus on how the changing scope of CWSU Boston's operations (past, present and future) can serve as an excellent resource for other NWS offices to utilize as we make our way down the IDSS and WRN paths. Several recent "high end" weather events to impact the Northeast Corridor will be used to show how we've adapted to changing customer needs, and how we're anticipating further enhancements to our services.

Severe Weather Testbed Activities in Southern New England

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The National Weather Service (NWS) in Boston began participation in three severe weather testbeds during the summer of 2016 which will continue through next year: NSEA (Near-Storm Environmental Awareness), ProbSevere (Probability of Severe), and TRENDSS (Thunderstorm Risk Estimation and Nowcast Development from Size Sorting).

Historically, the office's severe weather warning detection and lead time has been lower than the national average. The staff saw these testbeds not only as an opportunity to improve the office's severe weather detection and lead time, but to be able to provide feedback on emerging technology for areas not typically associated with frequent severe weather outbreaks (i.e., the Plains).

This presentation will describe each of the three testbeds and show how they have been integrated into forecast and warning operations at NWS Boston. Some initial results will also be shown.

"Living on the Edge": Communicating Uncertainty for the 23–24 January 2016 Blizzard in Southern New England

Frank M. Nocera
NOAA/NWS Weather Forecast Office, Boston, Massachusetts

The East Coast Blizzard of 23-24 January 2016 was the first threat of significant snowfall for southern New England since the winter of 2014-2015, when record-breaking snowfall occurred. Unlike the winter storms from that season, which had a direct impact on the region, this storm presented uncertainty with snowfall amounts since southern New England was expected to be on its northern edge. There were also concerns with precipitation type, damaging winds and coastal flooding.

As part of its Decision Support Services program, the National Weather Service (NWS) in Boston provided email briefings and conference calls to its core partners in the days leading up to the blizzard. However, there were challenges in communicating the uncertainty in the forecast, even 12 to 24 hours before the snow began.

This presentation will highlight the steps that forecasters at NWS Boston took leading up to the storm, in order to provide the most likely scenario but also convey the high uncertainty with reasonable "best" and "worst" case scenarios. In particular, the use of experimental probabilistic snowfall forecasts will be discussed, including the issues that arose from this particular event.

Medium Range Forecasting at the Weather Prediction Center (WPC): An Ensemble Effort in Big Data

Tony Fracasso
NOAA/NWS/NCEP/Weather Prediction Center, College Park, Maryland

The Weather Prediction Center (WPC) leverages a suite of international (American, Canadian, and European) deterministic and ensemble data to produce a medium-range forecast twice-daily from three to seven days into the future. The forecasters' challenge is to formulate a forecast "plan" and a preferred model/ensemble solution within the first 60 minutes of their shift. The strategy in times of high ensemble spread may be to use an ensemble mean or a blend of guidance, but when may that not be the best approach?

In recent years, an internal blended dataset has been used as a high benchmark for verification purposes of the WPC medium range grids. This blended dataset often scores highest in monthly and yearly averages by conventional metrics (mean absolute error, Brier skill score, etc.). However, in a recent study and regarding WPC medium range forecasts, Novak, et al. (2014) noted that "The quality added by humans for forecasts of high-impact events varies by element and forecast projection, with generally large improvements when the forecaster makes changes ≥8°F (4.4°C) to MOS temperatures." Can the human forecasters cruise on autopilot until a substantial change is warranted? Select recent cases will be presented.

In the future, a common starting point will serve as the starting point to the medium range forecast process. But what happens when a bifurcation in forecast scenarios yields an untenable blend? An example of this "forecaster's dilemma" will be highlighted. This evolving process by which WPC forecasters condense the vast amount of guidance into a final forecast is outlined in this presentation.

New York State Mesonet

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The New York State (NYS) Mesonet Early Warning Weather Detection System is a new advanced meteorological network that provides unprecedented weather information across the state. Designed primarily to facilitate emergency management, this network is the first of its kind in New York and will consist of 126 surface weather stations with at least one site located in every county and borough across the state. This weather detection system provides federal, state, and local communities with access to high-resolution, real-time data, and more robust predictive models. Funded by FEMA, the network is designed, implemented, and operated by scientists at the University at Albany with support from the New York State Department of Homeland Security and Emergency Services.

Each of the Mesonet's 126 weather stations measures surface temperature, relative humidity, wind speed and direction, precipitation, solar radiation, atmospheric pressure, snow depth, and soil moisture and temperature at three depths. In addition, 17 of the sites will be outfitted with LiDARs, microwave profilers, and sun photometers providing wind, temperature, and moisture profiles in the vertical. Seventeen sites will measure the surface energy budget, and another 20 of the sites will measure snow water equivalent for hydrological applications. All data are transmitted in real-time to a central location, where data are quality controlled and archived, and then disseminated to a variety of users. Real-time data along with graphical products are available to the public via website at http://nysmesonet.org.

This presentation will provide an update on site installations, network reliability, data quality, and new product development. Sample data will be reviewed, and the status of the enhanced, flux, and snow sites will be discussed in detail.

Toward Operational Convection-Allowing Ensembles over the United States

Craig Schwartz, Glen Romine, Ryan Sobash, and Kathryn Fossell
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Over the past few years, the National Center for Atmospheric Research (NCAR) has invested substantial efforts developing convection-allowing ensembles. These efforts led to daily, real-time, 10-member, 48-hr ensemble forecasts with 3-km horizontal grid spacing over the conterminous United States (http://ensemble.ucar.edu) that have been produced since April 2015. These computationally-intensive, next-generation forecasts have been embraced by both amateur and professional weather forecasters, are widely used by NCAR and university researchers, and receive considerable attention on social media.

This presentation will document performance characteristics of the real-time ensemble forecasts, including aspects related to winter weather predictability and severe weather forecasting over the northeast. Furthermore, results comparing 3-km ensemble forecasts to 1-km ensemble forecasts will be discussed. Finally, the unique design of NCAR's real-time analysis and forecast system will be briefly described and challenges of developing future operational convection-allowing ensemble systems will be discussed.

Verification of Multi-Model Ensemble Forecasts of North Atlantic Tropical Cyclones and an Analysis of Large Track Error Cases

Nicholas Leonardo and Brian A. Colle
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Medium-range (day 3-5) track forecasts of North Atlantic tropical cyclones (TC) have significantly improved over the decades. However, some TC's, such as Joaquin (2015), have still proven to be significantly less predictable within the recent several years. In such scenario's, even a multi-model consensus can produce abnormally large track errors. These cases can be especially problematic given the growing confidence and expectations in model guidance. They suggest the need for more probabilistic forecasts based on multi-model ensembles, the verification of which has been limited. They also raise the question of whether these events exhibit any commonalities in the patterns steering the TC. That is, are there any common synoptic features or physical mechanisms associated with the track errors that can be traced back to an earlier time in the forecast?

The first part of this study verifies the 2008-2015 track error forecasts of three global ensembles (51 ECMWF members, 23 UKMET members, and 21 GEFS members) and their combination ("grand ensemble") for the western North Atlantic. The results are compared with several other models, such as the deterministic ECMWF (ECdet), HWRF, GFDL, and the NHC's official forecast (OFCL. The grand ensemble probabilistic skill is quantified through Brier Skill Scores, using the ECdet and OFCL guised with its climatology-based cone as baselines. The NHC's best track data is used as the verifying analysis. In the second part of this study, the day 3-5 grand ensemble mean track forecasts are ranked from best to worst based on their track errors. The top and bottom quarter percentiles are categorized as large and small track error cases, respectively. The model fields from the 10 members with the largest track errors (BAD) are compared with the 10 members with the smallest track errors (GOOD), as well as the CFSR reanalysis.

All models exhibit a significant "slow" along-track bias beyond day 3, most of which is attributed to extratropical transitions. This bias improves throughout the sample period. The mean track errors of the grand ensemble are amongst the lowest of the models studied, comparable to the ECdet and OFCL. The probabilistic skill of the grand ensemble is superior to the ECdet and comparable to the OFCL cone-forecast. The large track error events for days 3-5 are most commonly associated with recurving TC's east of the U.S. East Coast, with the initial points for these forecast tracks clustered over and east of Puerto Rico. The large-scale flow with these cases is more amplified and sometimes more complex than small track error cases. Many of the large track error events grow exponentially beyond day 3 in response to differences in the phase and amplitude of an approaching upstream trough as well as the downstream ridge amplitude.

A Review of the CSTAR Ensemble Tools Available for Operations

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Forecasters need more tools to better understand the variability in ensemble solutions in operations. A major challenge is how to quickly extract useful information from a multi-model ensemble and to determine the right mix between ensemble automation (machine) and the forecaster interpretation of the models. Stony Brook has been developing diagnostics and tools to help increase the use of ensembles in operations by immersing the forecaster more into the data. One goal of this talk is to review the tools developed by our CSTAR, which includes an ensemble sensitivity tool, a fuzzy clustering tool, a tool for ensemble Rossby Wave packet (RWP) identification and tracking, and an ensemble cyclone tracking page that is calibrated based on past cyclone verification results. The ensemble clustering tool can help forecasters condense ensemble information by separating 90-member multi-model ensemble (GEFS+EC+CMC) into 4-5 different scenarios. It also allows model developers to verify the ensembles without the uncertainties introduced by cyclone and other feature-based tracking. Currently, we are developing an ensemble spread anomaly tool to complement the Situational Awareness Table (SAT), which can inform forecasters whether the ensemble spread is more or less than other similar anomalous weather events.

Examples will be shown on how these tools performed for some recent storm events in the medium range, which includes the ensemble tracks of recent hurricanes Hermine and Matthew. These examples also highlight some of the challenges using ensembles, such as the clustering by operational center and the associated under dispersion of cyclone tracks. The final goal of this talk highlights the feedback from forecasters on these ensemble tools from the WPC Winter Weather Experiment and our CSTAR listserve. Some feedback includes more training, a recommendation to reduce the complexity of interpreting these tools, thus allowing them to be used more effectively in operations, and more verification of the tools themselves. For example, is the ensemble sensitivity tool properly capturing the sensitive regions? We will summarize some of the progress in addressing these issues.

Use of High-Resolution Lightning Potential Forecasts for Vermont Utility Applications

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Operators of high voltage transmission lines consider lightning to be the most frequent cause of outages and interruptions. Today, close to one-third of all power outages are lightning-related which costs the nation roughly $1 billion annually. More specifically, power system faults caused by lightning can cost large commercial customers millions of dollars due to losses in production. The increasing trend of severe weather phenomena over the past few years has put electric utilities under high risk. In light of potential impacts, improving our ability to understand and forecast the potential for lightning is critical not just to ensure a reliable electric grid, but to our very ability to maintain a safe and functioning society.

Vermont's complex terrain and vast local variability coupled with large gaps in observational data pose many challenges from a weather forecasting perspective. In a collaborative effort to increase the resiliency of Vermont's electrical grid, Vermont Electric Power Company (VELCO) and statewide partners developed the Vermont Weather Analytics Center (VWAC) to increase grid reliability, lower weather event-related operational costs, and optimize the utilization of renewable generation resources.

The weather prediction component is powered by IBM's Deep Thunder, an advanced NWP model that is based, in part, on a configuration of the Advanced Research core of the Weather Research and Forecasting (WRF-ARW) model. Deep Thunder runs two 72-hour forecasts daily at 1 km horizontal resolution and outputs variables at 10 minute intervals. Vertical resolution is also high with 51 vertical levels in order to account for characteristics of the wind turbines. Deep Thunder uses RAP for background fields and NAM for lateral boundary conditions, as well as complex physics configurations to account for highly rural and urban environments. Deep Thunder's lightning output utilizes the Lightning Potential Index or LPI (Lynn & Lair, 2010) which represents the potential for charge generation and separation that produces lightning strikes within convective thunderstorms. The LPI is mathematically defined as the volume integral of the total mass flux of ice and liquid water within the charging zone of a developing thundercloud. Similar to the CAPE instability parameter, the LPI is measured in units of J/kg.

The presentation will first provide background information on how lightning impacts the transmission system. Synoptic and mesoscale forecasting challenges within Vermont will then be discussed followed by an overview of the VWAC project. Numerous case studies will then be presented comparing LPI forecasts to the observed Cloud-to-Ground (CG) lightning strikes during the event (via the NLDN). Finally, potential future work and applications of the operational weather model will be discussed, including outage/impact prediction, road weather forecasting, recreational forecasting, and climate change.

Lightning Jumps as a Predictor of Severe Weather in the Northeastern United States

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Severe weather events in the northeastern United States can be challenging to forecast, given the importance of interaction of convection with complex terrain. Complex terrain also poses challenges for the warn-on forecast due to the lack of surface observations in critical areas and radar beam blockage. To supplement existing observations, this study explores using lightning to forecast severe convection in areas of complex terrain in the northeastern United States. A sudden increase in lightning flash rate, or a lightning jump, is indicative of a strengthening convective updraft. Lightning jumps may key forecasters in on particular convective cells that have an increased probability of becoming severe.

This study assesses the value of using lightning jumps to forecast severe weather during the 2014 and 2015 convective seasons, defined as June–August, in the northeastern United States. Total lightning data from the National Lightning Detection Network (NLDN) is used to calculate lightning jumps using a 2-sigma lightning jump algorithm with a minimum threshold of 5 flashes min^{-1}. Following individual cells, lightning jumps are verified against severe weather reports from the Storm Prediction Center (SPC). If a lightning jump occurs within 45-minutes prior to a severe report, it verifies as a hit. If a lightning jump occurs with no corresponding severe report, it is classified as a false alarm.

There is a high probability of detection (POD; 75%) and a high false alarm rate (FAR; 55%) for severe-weather days during the 2015 convective season. Previous studies that applied a similar methodology to limited areas outside of the Northeast using lightning mapping arrays have a similarly high POD (79%), but a much lower FAR (36%). The anomalously high FAR of 55% for our sample is likely due, in part, to the location and timing of some convection, occurring in regions of low population density and/or overnight. These results suggest lightning jumps have limited value when used alone, but also suggest that storm reports have significant gaps.

A Synoptic Climatology of Excessive Heat Events in the Philadelphia Area

Lance Franck and Alan Cope
NOAA/NWS Weather Forecast Office, Mount Holly, New Jersey

Excessive heat is a significant hazard in the area covered by the National Weather Service (NWS) Forecast Office in Mount Holly, NJ (WFO PHI), especially for the city of Philadelphia and surrounding urbanized areas. During a typical summer season (June, July and August) several people die from heat-related causes. Records over the past 20 years show that excessive heat events have occurred, per county and per day, more frequently than any other type of Storm Data phenomenon. NWS forecasters use a variety of guidance for the issuance of Heat Advisories and Excessive Heat Watches or Warnings in advance of these events. The goal of this study is to develop additional guidance, including conceptual models that can be incorporated into the operational forecasting routine as best practices.

To provide further guidance and a better understanding of excessive heat, a synoptic climatology spanning thirty years (1987-2016) is being developed. In the WFO PHI area, most excessive heat days occur during meteorological summer (June, July or August) but a few occur in May or September. Using data from the Philadelphia International Airport (site PHL) such days have been identified and grouped according to (1) various combinations of temperature and dew-point, (2) various ranges of Heat Index, and (3) consecutive days with maximum temperature above 90 degrees F. Once identified, individual days or multiple consecutive days can be studied further by creation of reanalysis composite charts, backwards trajectory plots and air mass type frequency distributions. We hope to identify synoptic patterns and other signals associated with excessive heat events of varying magnitude and duration. Preliminary results such as these from our study will be presented at the conference.

High Wind Events in Western New York: An Expanded Study and Development of Potential Impact Tables

Shawn Smith
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High Wind Events are a common occurrence in the Great Lakes region from the late Fall through early Spring. These events frequently cause widespread infrastructure and property damage with monetary values ranging from thousands to millions of dollars. The frequency of these events is especially high across western New York. A tally of 2005-2014 cold season non-convective high wind warnings and wind advisories shows National Weather Service Buffalo issued the highest number of all Great Lakes NWS offices.

This study expands upon previous high wind research completed by Niziol and Paone (2000) with new information and findings in several areas. In addition to using a more recent dataset of 2004-2014 cold-season events, the new study sifted these events into three new categories to cover the full range of hazardous wind scenarios: Widespread, Limited and Advisory-only wind events. The coverage area of the study was also expanded to the entire NWS Buffalo county warning area along with development of new NARR model reanalysis composites of 500 hPa heights, Mean Sea Level Pressure (MSLP) and 850 hPa wind speed for each event. These were designed to improve forecaster pattern recognition of high wind events. While the track of a deepening surface low northwest of Buffalo, NY was identified as a key requirement for a high wind event in the previous study, this study discovered that a strong and persistent 850 hPa jet that tracks across western NY is also a key requirement for a widespread high wind event. Wind data following this new finding was used along with event MSLP data to develop a set of potential impact tables to help increase forecaster confidence in forecasting high wind events.

A Case Study of Five Unwarned Microbursts across Central New York

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The early part of the 2016 convective weather season was unusually quiet across central New York and northeast Pennsylvania. However, over the course of five days, July 14 – July 18, there were five unwarned severe storms across central New York, all producing damaging winds. In one case, numerous trees were uprooted, while in another an estimated 100 trees were brought down. A third snapped a telephone pole which then landed on a truck. Therefore the concern wasn't just that storms were missed, but that these were significant events. Also, none of these events occurred during major outbreaks, with only nine reports in total over this period. The radar and environment data for each storm was examined in order to try to better understand what happened in an effort to better warn for future storms of this type.

Forecasters at WFO Binghamton rely heavily on identifying reflectivity core heights when evaluating severe potential for convective storms. Specifically, local studies have shown that severe hail becomes likely when a 60+ dBZ core reaches the -20 ˚C level and/or a 50+ dBZ core reaches 5,000 feet above this level. While these thresholds were designed for hail, they are frequently used as criteria for severe weather in general. For each case, SPC mesoanalysis data were analyzed, in addition to model proximity soundings to assess the height of the 0 ˚C and -20 ˚C levels, as well as the values for key severe weather parameters. Radar data were also examined for severe wind signatures such as storm rotation, weak echo regions, and sharp low level reflectivity gradients. Finally, the most recent HWO and SPC outlooks issued prior to each case were examined to get a better idea of forecaster's situational prior to the events.

Results of the study show that in all five cases, the core/height criteria described above was not met. Further, in two cases there was little to no expectation of severe weather as indicated by the latest HWO issuance. However, analysis of radar data show that two of these storms exhibited low level storm rotation. Two others exhibited cores of 65+ dBZ above the freezing level in an environment of high Downdraft CAPE (DCAPE) of 1100-1200 j/kg. From these results, lack of situational awareness and subsequent detailed storm interrogation appear to be contributing factors to these missed wind events. Based on these results recommendations are made that forecasters should increase monitoring of key environmental parameters favorable for damaging winds. If parameters are favorable then radar interrogation needs to include closely examining for wind signatures such as storm rotation, strong reflectivity gradients, and velocity convergence patterns (MARC, low level convergence).

A Multi-Scale Analysis of the 1 July 2016 Null Tornado Watch across Eastern New York and Western New England

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On 1 July 2016, a fairly widespread severe weather event occurred across much of eastern New York (NY), and portions of New England that extended southward into the Mid-Atlantic Region. The NCEP Storm Prediction Center posted an enhanced risk early that afternoon for much of eastern NY, northeast Pennsylvania (PA), northern New Jersey (NJ), and western New England. A tornado watch was issued shortly thereafter for much of eastern NY, northeast PA, northern NJ, Vermont, northwest Connecticut and western Massachusetts. There were no tornado reports that day in the Northeast. The NWS at Albany forecast area had 25 severe reports with a half dozen being marginal large hail (1.9 cm in diameter).

Observational data, as well as short range deterministic Rapid Refresh data suggested a significant severe weather outbreak would likely occur. A cyclonically curved upper-level jet was located well upstream of NY over the Great Lakes Region with an area of divergence migrating into the Northeast during the afternoon. Surface based convective available potential energy values were in the 500-1500 J kg^{-1} range with steepening mid-level lapse rates. The effective shear values were in the 35-45 knot range in the Tornado Watch box, suggesting the possibility of supercells with rotating updrafts capable of producing tornadoes. The shear was strongest in the 3-6 km layer over eastern NY and western New England, and the instability was more limited for locations north and east Albany.

This talk will focus on a detailed mesoscale and radar analysis of the event. Traditional base and derived WSR-88D radar products will also be shown in conjunction with some Dual-Pol data. The storm-scale analysis will focus on helpful forecast techniques, including applying results from a local 1-inch hail and tornado V-R Shear study to determine what produced the copious wind and large hail reports and contributed to the paucity of tornadoes. Also, the societal impacts concerning Tornado Watches in the Northeast will be briefly discussed.

The 8 June 2016 Severe Weather Event in the Mid-Atlantic Region

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A line of low-topped convection organized over the northern mid-Atlantic region during the late morning on 8 June 2016 before moving off the coast by the early afternoon. Widespread wind gusts of 60–75 mph were reported with the storms across southeastern Pennsylvania and southern New Jersey, causing extensive wind damage, including numerous downed trees and wires, and power outages to more than 90,000 customers. The strong winds also caused a large scoreboard at a high school football field in Gloucester Township, NJ, to topple over, the roof of a building on the Camden County College campus to blow off, and a partial collapse of an apartment building roof in Atlantic City, NJ. Additionally, there were several observations of 55–65 mph winds south of the convective line in northeastern Maryland and Delaware. In total, there were 90 severe thunderstorm wind events reported with a majority of these events occurring in the Mount Holly, NJ, National Weather Service Forecast Office County Warning Area (CWA).

Unlike typical environments associated with significant warm season severe thunderstorm events in the mid-Atlantic region, the airmass for the 8 June 2016 event was not particularly warm (surface temperatures from 20–23°C) or moist (surface dewpoints from 9–12°C) as a primary cold front had just moved through the area the night before. Accordingly, surface-based convective available potential energy (CAPE) values of < 300 J kg^{-1} were not very indicative of an ordinary severe thunderstorm setup. However, the presence of very strong deep-layer shear (0-6 km bulk shear values near 75 kt) and tropospheric-deep forcing for ascent accompanying a potent upper-level shortwave trough sufficiently compensated for the lack of instability to support an organized severe thunderstorm event in a high-shear low-CAPE (HSLC) environment.

The synoptic pattern and mesoscale environment will be examined using observational data to determine the key ingredients and mechanisms that lead to the severe weather. Radar data from Fort Dix, NJ (KDIX) WSR-88D radar will also be used to identify storm structure and discuss how the near storm environment may have been modified. A mechanism to vertically transport the strong mid-level winds downward to the surface is proposed, which has similarities to sting jets that have been previously documented in intense extratropical cyclones. A brief review of NWP and NWS operational forecast performance will be presented to reveal the forecast challenges associated with what was considered to be a low predictability event.

Examination of Recent Mini-Supercell Tornadic Events in the Tri-State

Patrick Maloit and Nelson Vaz
NOAA/NWS Weather Forecast Office, New York, New York

Two mini-supercell tornadic events occurred this summer in southeastern Connecticut and Eastern Long Island on August 11, 2016. A brief tornado traversed the North Haven community of New Haven CT, and was classified via an NWS storm damage survey as an EF-0 on the Enhanced Fujita scale. The second tornado on that day moved across Mattituck on the North Fork of Eastern Suffolk County, and was also classified as an EF-0 as well. The structure of these storms and the mesoscale environment had similarities to another mini-supercell tornadic event that occurred on July 27, 2014 in the Wolcott community of New Haven CT.

These tornadic events are not only rare but can be difficult to detect due to their low-top storm structure, lack of lightning development, and miniature or subtle tornadic signatures. Situational awareness of the synoptic and mesoscale environments; and vigilant monitoring of storm morphology and changes in the near and storm-scale environment are key to provide timely and accurate warning for these events.

Thankfully several new observational and radar tools are helping make this easier. SAILS/AVSET provide superior WSR-88D scanning strategies compared to just a few years ago. The inclusion of MRMS low-level rotational tracks in AWIPSII provides a very useful situational awareness and warning confidence tool in these type of shallow tornadic events. Additionally, five-minute resolution Automated Surface Observing System (ASOS) data and real-time mesonet surface observations, SPC's mesoscale analysis tools, and hourly high-resolution rapid refresh model data provide forecasters an excellent representation of the evolving critical mesoscale environment.

This presentation will show the value of the radar, observational, and forecast tools for identifying these hard to detect tornadoes.

Assessing the Utility of Normalized Rotation in Detecting Tornado Development in the Allegheny Front

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Compared to the Great Plains, tornadoes in and near the Allegheny Front region of the U.S. are less frequent, but their detection poses numerous challenges to operational forecasters. Diagnosing tornadogenesis using traditional radar data and interrogation strategies is further complicated by tornado occurrences from non-supercell storm modes and supercell variants.

To address some of these challenges, radar data were collected in the Jackson, KY; Charleston, WV; and Pittsburgh, PA National Weather Service (NWS) county warning areas (CWAs) for tornado events between 2006 and 2015. These events were sampled by the KJKL, KRLX, and KPBZ WSR-88D radars and the GR2Analyst radar analysis application was used to calculate normalized rotation (NROT). Maximum values of NROT were collected for five consecutive volume scans preceding tornado onset at the lowest three elevation angles (excluding 0.5° SAILS scans). The data were then stratified based on storm mode, and a basic statistical analysis was calculated.

Initial results indicate discrete supercells have consistently higher mean NROT values that increase more uniformly with time and appear to maximize at the radar scan nearest tornado onset. For non-supercell storm types, the magnitude of mean NROT is less, and greater variability is apparent in the data. Still, there is a discernible tendency for NROT values to cluster within a small range nearest to tornado onset. These results suggest that there is some utility in using NROT to diagnose developing tornadic circulations before they occur, specifically when used in conjunction with thorough environmental and radar analyses.

The Utility of Incorporating Dual-Polarization Radar Signatures into the Tornado Warning Process: Z_{DR}/K_{DP} Separation Considerations in Supercells

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Christopher M. Gitro, NOAA/NWS, Kansas City, Missouri

Prior research has investigated the potential usefulness of interrogating certain dual-polarization radar fields in tornadic situations. The two primary variables of focus were differential reflectivity (Z_{DR}) and specific differential phase (K_{DP}). It was shown that in tornadic events, areas of enhanced Z_{DR} typically resembled an arc-shaped configuration. These Z_{DR} arcs tended to form along the right inflow sides of the parent supercells, indicative of areas of preferentially large raindrops near the leading edge of the forward flank. In the meantime, regions of enhanced K_{DP} and lower Z_{DR} tended to develop much deeper into the storm, indicative of high liquid water content areas and the inclusion of smaller raindrops.

Building upon the above outlined results, this research investigated significant severe weather events, where both tornadic and non-tornadic supercells were featured. While previous dual-polarization studies were conducted in specific geographical regions of the United States, this study has looked at a number of cases that occurred east of the Rocky Mountains, in an effort to find a unified, geographically independent approach on using dual-polarization radar fields in the tornado warning decision-making process. The most important, specific features of note were the separation characteristics between Z_{DR} and K_{DP} maxima in the forward flank, as well as the behavior of the Z_{DR} arc. The implications of these signals with regards to drop size diameter distributions in certain supercell sectors, low-level storm-relative flow, storm-scale shear, and tornadogenesis potential will be discussed. We will also briefly introduce future plans to investigate separate dual-polarization signatures in the hook echo regions of supercells.

While the initial results look promising, it is hoped these findings stimulate additional research to further improve our ability to differentiate between storms that produce tornadoes, from those that do not.

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