COMET Partners Proposal:

Development of operational products from the New York State Mesonet to aid forecasts of high-impact weather events by National Weather Service Forecast Offices

1. Project Overview

Mesonets consisting of weather stations established to collect data over concentrated areas have been developed in many areas of the United States over the past few decades (Schroeder et al. 2005, McPherson et al. 2007). A primary purpose of these mesonets is to aid forecasters and researchers with diagnosing a wide range of atmospheric phenomena by providing them with a dense network of reliable and highly-accurate weather observations. The construction of the New York State (NYS) Mesonet began in 2015 and was completed April 1st, 2018. Its goal is to provide a high spatial and temporal-resolution network of observations for the state (Brotzge et al, 2016). 126 "standard" stations were installed in New York, with each station measuring temperature (2 and 9 m), relative humidity, wind speed and direction (with redundant sensors), precipitation, solar radiation, atmospheric pressure, snow depth, and soil moisture and temperature at three depths (5, 25, and 50 cm) at 5 minute intervals. Each station is also equipped with a camera. The NYS Mesonet also consists of three additional "sub-networks": 17 "profiler" stations are outfitted with LIDARs and microwave radiometers to provide vertical profiles of the atmosphere, 20 "snow" stations provide snow-water-equivalent measurements, and 17 "flux" sites measure a wide variety of additional variables such as 4-component radiation fluxes, latent and sensible heat fluxes, and others.

The National Weather Service Forecast Offices (NWS WFOs) located at Brookhaven, Albany, Buffalo, and Binghamton, New York and Burlington, Vermont are responsible for producing accurate forecasts, warnings and decision support related to high-impact weather events in NYS. It has long been understood that meteorologists engaged in these endeavors can potentially benefit from having access to high temporal and spatial data sets such as those produced by the NYS Mesonet (Sanders and Doswell, 1995, Bosart 2003). Therefore, meteorologists at the NYS Mesonet and the National Weather Service (NWS) are motivated to work together to find the most effective ways for forecasters to utilize the data. This proposal describes a potential collaborative effort between the NYS Mesonet and the NWS to enhance the usage of data from the mesonet into the NWS forecast, warning and decision support activities.

2. Objectives

The objectives of this project are to develop products from data produced by the NYS Mesonet that will aid forecasts, warnings, and decision support from the NWS. These products will be available in real-time with a temporal resolution of approximately 5 minutes. The types of high-impact weather events covered in the proposal are as follows:

a) Flash Flooding

The NYS Mesonet provides forecasters with real-time measurements of rainfall and soil moisture at 5, 25 and 50 cm depths at 5 minute temporal resolution. Figure 1 gives an example of what this soil moisture data depicts. The relationship between flash flooding and rainfall can vary depending on factors such as topography and antecedent conditions, and is provided to forecasters at WFOs by River Forecast Offices through the dissemination of Flash Flood Guidance. Relationships between rainfall and soil moisture, and between antecedent soil moisture and flash flooding have also been examined. For example, Jessup and DeGaetano (2008) examined a data set of heavy rain events in New York and Pennsylvania and determined that the most significant difference between flash flood vs. non-flood events in their data set was the antecedent soil moisture. Based on findings such as this, it is hypothesized that the soil moisture data provided by the NYS Mesonet could be an invaluable tool for forecasters wishing to diagnose flash flood potential, along with the obvious benefits of the real-time rainfall measurements. However, forecasters at NWS WFOs are not typically well-versed in the use of real-time soil moisture data (B. Westergard, personal communication, March 7, 2019). Therefore, one of the objectives in this project will be to develop a better understanding of the soil moisture data, and how it can be used to diagnose flash flood potential. Research will be conducted on a data set of cases spanning the period 2017 to present (when NYS Mesonet data has been available), to determine the relationship between rainfall and soil moisture, and the relationship between soil moisture and flash flood occurrence. Once relationships between these factors are determined, graphical products will be developed by the staff at the mesonet to help forecasters to better visualize flash flood potential based on rainfall and soil moisture measurements from the mesonet.

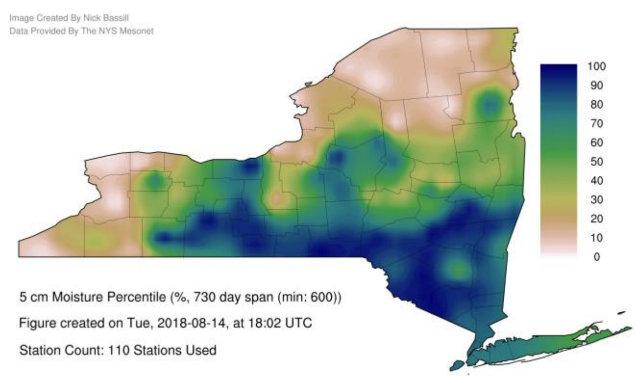

Figure 1: Sample soil moisture percentile plot made by the NYS Mesonet.

b) Freezing Rain

The NYS Mesonet provides forecasters with real-time measurements of soil temperature at 5, 25 and 50 cm depths at 5 minute temporal resolution. Additionally, each flux site is equipped with a four-component radiation sensor, which allows the NYS Mesonet to crudely estimate skin temperature using the Stefan-Boltzman law. The NYS Mesonet currently attempts to extrapolate this estimate to all sites using relationships derived automatically between soil temperature, 2 m temperature, solar insolation, (and others) as seen in Figure 2. Recent research has revealed the relationship between the potential for ice accumulation and several factors such as precipitation rate, wind and surface wet-bulb temperature (Sanders and Barjenbrunch, 2016). Forecasts of ice accumulations are important, however perhaps equally important are forecasts of potential impacts from freezing rain. For example, freezing rain will sometimes accumulate on surfaces that result in tree damage and / or power outages while having less impact on road surfaces and transportation. In other cases, freezing rain will have much more impact on travel than on trees and power lines. We are hypothesizing that one of the factors that leads to these variations of impact may be ground temperature, and that soil temperature, 2 m temperature, and flux-estimated skin temperature from the NYS Mesonet may be a good way for forecasters to assess these potential impacts. However, similar to soil moisture, forecasters are not particularly well-versed in evaluating ground temperatures as part of their forecast process, probably due to the fact that this data has not historically been widely-available. Therefore, we propose to examine a data set of cases spanning the last two years to find relationships between ground temperatures measured on the mesonet, and impacts from freezing rain as reported in the NWS's storm data publication.   Once these relationships have been determined, graphical products will be developed to help forecasters relate ground temperatures to impacts from freezing rain.

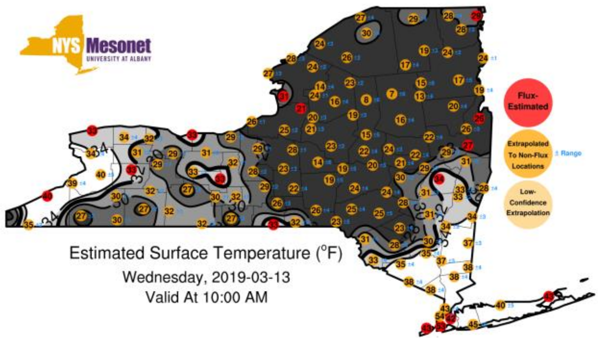

Figure 2: Sample NYS Mesonet-estimated skin temperature. Flux site observations (red) are used to estimate all other sites (orange).

c) Severe Convection

The NYS Mesonet can provide forecasters with a wide range of meteorological data in real time related to surface temperature, moisture, wind and pressure and as such can help forecasters to diagnose the strength and movement of frontal systems.   Previous research has indicated that the occurrence of severe weather is often related directly to the existence, strength and movement of large-scale frontal systems. For example, Wasula et a (2008) examined a high impact severe weather case over eastern New York and western New England and identified a strong gradient of equivalent potential across the region prior to the event. Evans (2010) found that the strength and speed of the eastward progression of large-scale forcing for upward vertical motion is critical for determining the magnitude of low-CAPE high shear convective events in New York and Pennsylvania. Lombardo and Colle (2011) also found direct relationships between characteristics of severe weather-producing storms and their spatial relationship to frontal systems.   More recently, Stuart and Cebulko (2018) examined the role of low-level forcing in cases of significant severe weather outbreaks in the eastern U.S., and determined that the strength of the low-level frontal zone can play a critical role in determining the magnitude of severe convective events.   Given that data from the NYS Mesonet is well-suited for forecasters who wish to diagnose the strength and movement of frontal systems, we

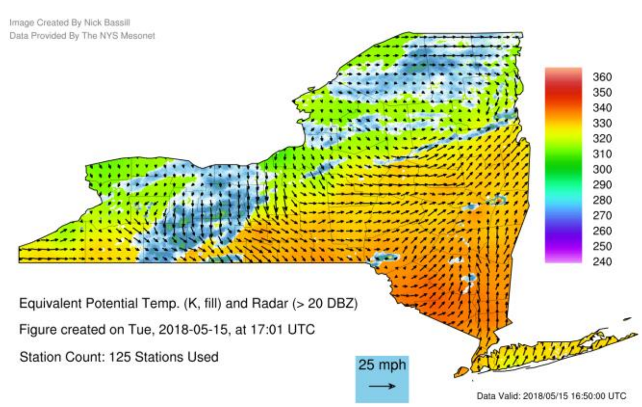

Figure 3: Example NYS Mesonet theta-e, 10 m wind, and NEXRAD radar data preceding a significant severe weather outbreak.

hypothesize that data from the NYS Mesonet can help forecasters anticipate the magnitude of severe convective events by aiding with the diagnosis of frontal systems. We propose to examine a data set of convective cases spanning the last two years, examining characteristics of any associated low-level frontal zones. Fronts can be characterized by factors such as the gradient of equivalent potential temperature across the frontal zone (as shown in Figure 3), the speed of movement of the front, and mean sea-level pressure changes ahead of and behind the front. The high spatial- and temporal-resolution of the mesonet data will allow us to examine these factors in greater detail than what has been possible previously in this area. Once these relationships are better understood, graphical products can be generated by NYS Mesonet staff that will help forecasters to better anticipate the magnitude of convective events based on the characteristics of associated frontal systems.

3. Tasks

Our research group will divide the work for this project into three sub-projects, with each sub-project consisting of work related to one of the three high-impact weather event types listed in the objectives (flash flooding, freezing rain, and severe weather). Each of these sub-projects will have a collaborative team consisting of a NYS Mesonet employee and one or two NWS forecasters, along with undergraduate students from the State University of New York at Albany.

The following section lists the tasks needed to accomplish the objectives in this proposal, along with who will be working on each task.

a) **Select case study examples for each sub-project.** For each sub-project, NWS forecaster(s) will select 2 to 3 case examples that will serve as prototypes for products to be created by the NYS Mesonet. The examples should represent cases that forecasters believe would have benefited from enhanced situational awareness that could have been provided by products created by the NYS Mesonet. High-impact, null and poorly forecast events will all be considered for case selection.

b) **NWS forecasters forward cases to NY mesonet participants.** After the case examples have been selected, the forecasters will forward written summaries or power point presentations of the cases to the NY mesonet participants that will be working on their sub-project. The summaries or presentations should include some thoughts on how enhanced information from the NYS Mesonet could have helped them with their forecasts and warnings. This will give time for the NYS Mesonet participants to become familiar with the cases, and to begin to formulate ideas for what types of products may have helped the forecasters, prior to meeting with the NWS participants.

c) **NWS forecasters meet with NYS Mesonet participants.** A meeting will be scheduled between the NWS forecaster(s) and the NYS Mesonet participants for each sub-project. During this meeting, the NWS forecasters and NYS Mesonet participants will discuss their ideas for product development, and agree on some products going forward. Products could include displays of purely observational data, or data derived from a blend of observations and short-range model forecasts from sources such as the High resolution rapid refresh (HRRR) model.

d) **NYS Mesonet participants develop products associated with each sub-project.** NYS Mesonet participants will develop prototype products, and test them on the case examples. They will be encouraged to contact their NWS counterparts whenever they have anything to discuss, or for any questions that come up.

e) **NWS forecasters and NYS Mesonet participants will meet for a demonstration and discussion of the new products**. A meeting will be held where the NYS Mesonet participants will demonstrate the utility of their newly developed products to the NWS forecaster(s). This likely will result in the NWS forecasters suggesting some refinements. Ultimately, after one or more of these meetings, an agreement will be reached on the final form of the products.

f) **NYS Mesonet participants will evaluate their products for a larger number of representative cases.** For each sub-project a data set of cases will be selected from the period of time during which the NYS Mesonet has been operational (2017-present). These cases will be selected as part of a combined effort between the NWS and the NYS Mesonet. The products proposed in the previous task will be created for each case, and analysis will be done to quantitatively evaluate relationships between values of parameters generated by the products and the weather associated with the cases.

g) **Research to operations.** Once these products have been developed and evaluated, they will be made operational on a webpage hosted by the NYS Mesonet. These products will then be available for routine use by NWS forecasters who will be increasingly tasked to perform mesoanalysis to provide enhanced decision support services in short-range forecasts of high-impact weather events to core partners. Routine use of these products will likely spur forecasters to notice new features not previously noticed until the execution of the project, which will result in continued beneficial two-way collaboration between the forecasters and the NYS Mesonet.

h) **Conferences and workshops.** During the fall of 2019, a representative of the NYS Mesonet will visit the NWS forecasts offices at ALY, BGM and BUF and will provide an overview of the project and updates on the development of the products. Depending on the progress of this project, updates will also be given at the Northeast Regional Operational Workshop in Albany in November, and may be ready for national conferences in 2020.

4. **Time schedule**

Time Period	**Task**
July – August 2019	a) NWS participants select 2 to 3 case study examples for each sub-project.
August 2019	b) NWS forecasters forward cases to NYS Mesonet participants.
September 2019	c) NWS forecasters meet with NY mesonet participants.
October 2019 - January 2020	d) NYS Mesonet participants develop products associated with each sub-project.
January 2020	e) NWS forecasters and NYS Mesonet participants will meet for a demonstration and discussion of the new products.
January 2020 – May 2020	f) NYS Mesonet participants will evaluate their products for a larger number of representative cases.
May 2020 -	g) Research to operations
November 2020 -	h) Conferences and workshops

5. **Curricula Vitae**

Dr. Nick Bassill has worked with the NYS Mesonet since it's inception to develop products and work on projects designed to facilitate the use of NYS Mesonet data. His Curriculum Vitae is attached separately.

Michael Evans earned high earned his Bachelor's of science degree in Meteorology from Penn State University in 1985. He worked as a forecaster at Accu-Weather Inc. in State College, Pa from 1985-1988, then earned a Master's Degree in Atmospheric Science at the State University at Albany in 1991. Mike began his National Weather Service career as a meteorologist intern in Charleston West Virginia in 1992, worked as a forecaster at the WFO in White Lake Michigan from 1994-1998, and worked as a lead forecaster at the WFO in State College, Pennsylvania from 1998-2002. Mike was been the Science Operations Office at the WFO in Binghamton, New York from January, 2002 – October 2017. During that time he has led the office science and training programs, gaining extensive knowledge and experience in forecasting all kinds of meteorological phenomena in central New York, including severe weather, mixed precipitation and heavy precipitation. During Mike's time in Binghamton, he led the office's participation in successful COMET partner's projects with Cornell University on flash flooding, and Hobart and William Smith Colleges on lake-to-lake connections associated with lake effect snow forecasting. Mike moved to Albany, NY to become the Science and Operations Officer at that NWS office, in October 2017. In addition to leading that office's science and training programs since 2017, Mike has also led the collaborative relationship between the NWS office and the Atmospheric Science Department at U Albany, which has included participation in a successful CSTAR project covering a wide range of research to operation forecast topics.

During his career, Mike has researched and published studies on a wide range of meteorological phenomena. Topics include precipitation type forecasting, heavy snow banding within winter storms, lake effect snow, and low CAPE – high shear severe weather. Details on the publication of some that work are given below:

Evans, M.S., D. Keyser, L.F. Bosart, and G.M. Lackmann, 1994: A satellite-derived classification scheme for rapid maritime cyclongenesis. Mon Wea. Rev., 122, 1381-1416.

Evans, M.S., 1994: Two case studies illustrating a method for predicting severe weather thresholds of vertically integrated liquid in West Virginia, ER Technical Attachment 94-5A.

Evans, M.S., 1994: An examination of the characteristics of rain versus snow predictors at Charleson, West Virginia, ER Technical Attachment 94-3A.

Evans, M.S., 1996: A method for forecasting lake effect snow using synoptic-scale model forecasts of 850 mb temperature, 850/700 mb vertical velocity and 850/700 mb relative humidity, CR Technical Attachment 96-09.

Evans, M.S., 1996: A study on the relationship between CAPE, Storm-relative helicity and tornadoes in Michigan, CR applied research paper 18-06.

Evans, M.S. and R.B. Wagenmaker, 2000: An examination of an intense west-east oriented lake-effect snow band over southeast lower Michigan, Natl. Wea. Dig., 24, 67-78.

Evans, M.S. and R.H. Grumm, 2000: An examination of Eta model forecast soundings during mixed precipitation events, Natl. Wea. Dig., 24, 14-36.

Jurewicz, M.L., and M.S. Evans, 2004: A comparison of two banded, heavy snowstorms with very different synoptic settings, Wea. Forecast, 19, 1011-1028.

Evans, M.S. 2006: An analysis of a frontogenetically forced early spring snowstorm, Bull. Amer. Meteor. Soc., 87, 27-32. (A national winter WES case was also developed based on this work).

Evans, M.S. and R.A. Murphy, 2008: A proposed methodology for reconciling high-resolution numerical modeling guidance with pattern recognition to predict lake effect snow, Electronic J. Operational Meteor., 9, 1-55.

Schaffner, M., M.S. Evans, and J. Arnott, 2009: The June 19, 2007 Delaware County flash flood: A meteorological and hydrological anaylsis. ER Tech Attachment.

Evans, M.S., and M.L. Jurewicz, 2009: Correlations between analyses and forecasts of banded heavy snow ingredients and observed snowfall, Wea. Forecasting, 24, 337-350.

Evans, M.S., 2010: An examination of low cape / high shear severe convective events in the Binghamton, NY county warning area, Natl. Wea. Dig., 34, 129-143.

Evans, M.S., J. Constantino, B. Lambert and R. Grumm, 2012: A preliminary study of inverted-V soundings and downstream severe weather in New York and Pennsylvania, Natl. Wea. Dig., 36, 9-26.

Evans, M.S., M.L. Jurewicz and R. Balletine, 2012: A preliminary examination of the elevation dependence of snowfall in northeast Pennsylvania, NWA National meeting, 2012, extended abstract P1.28.

Evans, M.S., and R.A. Murphy, 2014: A historical analog-based severe weather checklist for central New York and northeastern Pennsylvania, J. Operational Meteor., 2, 214-232.

Gitro, C.M., M.S. Evans and R.H. Grumm, 2014: Two major heavy rain/flood events in the Mid-Atlantic: June 2006 and September 2011, J. Operational Meteor., 2, 152-168.

Evans, M.S., M.L. Jurewicz, and R. Kline 2017: The elevation dependence of snowfall in the Appalachian ridge and valley region of northeast Pennsylvania, J. Operational Meteor., 5, 87-102.

Budget

	COMET Funds	**NWS Contributions**
University Senior Personnel		
1. Nicholas Bassill	**$2,899**	**NA**
2.		**NA**
3.		
Other University Personnel		
1. Junhong (June) Wang	**$1,822**	**NA**
2. Nathan Bain	**$2,019**	**NA**
3. Undergraduate Student	**$2,334**	**NA**
Fringe Benefits on University Personnel **(Bassill, Wang, Bain 42%; Undergrad 5%)**	**$2,831**	**NA**
Total Salaries + Fringe Benefits	**$11,905**	**NA**
NWS Personnel		

1. Michael Evans (WFO ALY)	**NA**	**20 hours**
2. Neil Stuart (WFO ALY)	**NA**	**20 hours**
3. Joe Cebulko (WFO ALY)	**NA**	**20 hours**
4. Tom Wasula (WFO ALY)	**NA**	**20 hours**
5. Christina Speciale (WFO ALY)	**NA**	**20 hours**
6. Britt Westergard (WFO ALY)	**NA**	**20 hours**
7. Steve DiRienzo (WFO ALY)	**NA**	**20 hours**
8. Jared Klein (WFO BGM)	**NA**	**20 hours**
9. Mitchell Gaines (WFO BGM)	**NA**	**20 hours**
10. Heather Kenyon (WFO BUF)	**NA**	**20 hours**
Travel		
1. Research Trips		
2. Conference Trips		**$1500**
3. Other		
Total Travel		**$1500**
Other Direct Costs		
1. Materials & Supplies	**NA**	**NA**
2. Publication Costs (put in the NWS column if a co-author will be an NWS employee)	**NA**	**$3000**
3. Other Data	**NA**	**NA**
4. NWS Computers & Related Hardware	**NA**	**NA**
5. Other (specify)	**NA**	**NA**
Total Other Direct Costs	**$11,905**	**$3000**

Indirect Costs		**NA**
1. Indirect Cost Rate	**26%**	**NA**
2. Applied to which items?	**All**	**NA**
Total Indirect Costs	**$3,095**	**NA**
Total Costs (Direct + Indirect)	$15,000	**$4500**

References

Bosart, L. F., 2003: Whither the weather analysis and forecasting process?, Wea. Forecasting, **18**, 520-529.

Brotzge, J.A., 2016: The New York State Mesonet: A technical Overview, AMS annual meeting in New Orleans, LA, January 10-14, 2016.

Evans, M.S., 2010: An examination of low CAPE / high shear sever convective events in the Binghamton, New York county warning area. J. Operational Meteor., **34**, 130-144.

Jessup, S.M., and A. T. DeGaetano, 2008: A statistical comparison of the properties of flash flooding and non-flooding precipitation events in portions of New York and Pennsylvania. Wea. Forecasting, **23**, 114-130.

Lombardo, K., and B. A. Colle, 2011: Convective storm structures and ambient conditions associated with severe weather over the Northeast U.S, Wea. Forecasting, 26, 940-956.

McPherson, R. A., C. Fiebrich, K. C. Crawford, R. L. Elliott, J. R. Kilby, D. L. Grimsley, J. E. Martinez, J. B. Basara, B. G. Illston, D. A. Morris, K. A. Kloesel, S. J. Stadler, A. D. Melvin, A.J. Sutherland, and H. Shrivastava, 2007: Statewide monitoring of the mesoscale environment: A technical update on the Oklahoma Mesonet. J. Atmos. Oceanic Technol., **24**, 301–321.

Sanders, F and C. A. Doswell, 1995: A case for detailed surface analysis: Bull. Amer. Meteor. Soc., **76,** 505-521

Schroeder, J. L., W. S. Burgett, K. B. Haynie, I.Sonmez, G. D. Skwira, A. L. Doggett, and J. W. Lipe, 2005: The West Texas Mesonet: A Technical Overview. J. Atmos. Oceanic Technol,. **22**, 211-222.

Stuart, N.A., and J.E. Cebulko: 2018: Analyzing the role of low-level forcing in significant severe weather outbreaks in the eastern U.S., AMS severe storms conference, Stowe, VT, October 22-26, 2018.

Wasula, T. A., N. A. Stuart, and A. C. Wasula, 2008: The 17 February 2006 Severe Weather and High Wind Event across Eastern New York and New England. Preprints, 24th AMS SLS Conf., Savannah, GA, 13B.3.