Title Page

Principal Investigator (PI): Dr. Bassill **Date: November 18th, 2020**

Name: Nick P. Bassill
Title: Director of Research & Development
Organization: Center of Excellence, University at Albany, State University of New York
Telephone Number: (518) 442-6375
Email Address: nbassill@albany.edu
Mailing Address: LC SB-28, 1400 Washington Ave., SUNY, University at Albany, NY 12222

Co-Principal Investigators (Co-PIs, alphabetized): Dr. Stern, Dr. Sutton, Dr. Thorncroft

Name: Eric K. Stern
Title: Professor of Political Science and 2020-21 Faculty Chair
Organization: College of Emergency Preparedness, Homeland Security and Cybersecurity, University at Albany, State University of New York
Telephone Number: (434) 964-6223
Email Address: ekstern@albany.edu

Name: Jeannette Sutton
Title: Associate Professor
Organization: College of Emergency Preparedness, Homeland Security & Cybersecurity, University at Albany, State University of New York
Telephone Number: (303) 587-0498
Email Address: jsutton@albany.edu

Name: Christopher Thorncroft
Title: Director, Atmospheric Sciences Research Center & Director, NYS Mesonet
Organization: Atmospheric Sciences Research Center, University at Albany, State University of New York
Telephone Number: (518) 944-0534
Email Address: cthorncroft@albany.edu

Institutional Representative:

Name: Ms. Jessie L. Beauharnois
Title: Associate Director, SPA
The Research Foundation for the State University of New York
1400 Washington Ave, MSC 100A, Albany, NY 12222-0100
Telephone Number: (518) 437-3833
Email address: jbeauharnois@albany.edu

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Abstract Page

TITLE: Improving analysis and communication of extreme temperatures across the New York City metropolis using a dense network of in situ observations.

Principal Investigator (PI):
- Nick Bassill, University at Albany, State University of New York

Co-Principal Investigators (Co-PIs), alphabetized by last name:
- Eric K. Stern, University at Albany, State University of New York
- Jeannette Sutton, University at Albany, State University of New York
- Christopher Thorncroft, University at Albany, State University of New York

Abstract: When one imagines deadly weather conditions, hurricanes, snowstorms or tornadoes are generally the first phenomena to come to mind. However, extreme heatwaves (and extreme temperature in general) are significantly more deadly on an annual basis. Extreme temperature impacts are also modulated by a variety of factors both socioeconomic (e.g. access to air conditioning) and geographic (e.g. proximity to water bodies, sea-breezes, etc.). Despite these characteristics, extreme temperature products issued by the National Weather Service (NWS) are rarely more granular than county-sized. The New York City (NYC) urban environment is the embodiment of many of these challenges given its high-density population, varied urban landscape features, proximity to many water bodies, and the presence of socially vulnerable groups.

A primary mission of the NWS is the protection of citizens through accurate forecasting and effective messaging of hazards. Therefore, improving the accuracy and communication of extreme temperature products in urban settings would logically benefit the NWS mission. This proposal will produce a real-time Extreme Temperature Dashboard by utilizing several networks of opportunity that fill gaps in the commonly used ASOS observational network. In total, these networks of opportunity comprise nearly 50 weather stations across NYC. This network will be used to create granular analyses of extreme temperatures and also will allow more localized bias and error correction to forecast data based upon weather regime. This product, and its accompanying research efforts, has the potential to improve risk decision making and communication to vulnerable populations in the study area and beyond.

Strong partnerships with the New York, NY NWS office as well as NYC Emergency Management will be instrumental to the success of this proposal. Through this partnership, we will integrate this research and these products into their daily operations, as well as evaluate more actionable temperature products such as wet bulb globe temperature. Once completed, this project will produce a range of societal benefits. Improved forecasts – and dissemination of those forecasts – will save lives. More localized situational awareness and forecast products will also increase child safety when participating in outdoor sporting events, recess, or walking to/from school. These more granular forecasts can also improve forecasts of energy demand and reduce strain on electric grids. Finally, this dense network of observations will help us examine the representativeness (or lack thereof) of the current ASOS network and help inform whether additional sensors are required to reproduce this work for other urban environments.

1. Problem Statement:

Extreme temperatures across urban environments pose a variety of challenges ranging from increased risk of injury and death, to strains on power grids due to increased air conditioning during heat waves, to particular vulnerabilities associated with outdoor athletic activities and sporting events, and even impacts to education if schools close due to extremes of heat or cold. Forecasting and communicating risks associated with extreme temperatures is challenging as a result of many ancillary dependencies which may induce sharp spatial and temporal gradients in local conditions and impacts. Motivated by this, it is important to improve our ability to observe and predict temperature extremes in an urban environment and to ensure that they are communicated efficiently and effectively to key stakeholders including the general public.

This multi-disciplinary team seeks to leverage multiple novel weather networks as well as strong collaborations between the New York, NY National Weather Service (NWS) office and New York City (NYC) Emergency Management (NYCEM) to improve the analysis of extreme temperatures in NYC, improve the understanding of where forecasts may be deficient, and improve the communication of extreme temperature hazards. Through this collaboration, the NWS will benefit from having better tools for monitoring and predicting extreme temperatures in the urban NYC environment as well as improved risk communication tools decision support services.

This proposal identifies the dual priorities of "Obs-1: Extreme Temperatures" and "Obs-8: Harnessing data sets of opportunity" as primary fits with the outlined priorities, with a secondary fit corresponding to "Obs-9: Other areas of interest." The results of this work will produce an easily adaptable framework for other urban locations across the United States. This proposal team combines needed expertise in meteorological observations and numerical weather prediction alongside expertise in risk communication and emergency preparedness. Indeed, the team has significant experience with projects benefitting NOAA and NWS and their partners:

- PI Bassill is an active PI for "Development of operational products from the New York State Mesonet to aid forecasts of high-impact weather events by National Weather Service Forecast Offices" (2020-01-01 to 2021-01-01, UCAR subaward SUBAWD001611, NOAA award SUBAWD001611) and co-PI for "Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain" (2019-06-01 to 2022-05-31, NOAA award NA19NWS4680006) - both of which depend upon analysis of mesonet data, forecasts, and other data sources to produce actionable NWS products.
- Co-PI Sutton has conducted NOAA-funded research on risk communication over social media channels, where she investigated the use of Twitter by local Weather Forecast Offices across the U.S. (9/2016-9/2017 and 9/2018-9/2019 NOAA supplements to National Science Foundation award CMMI-IMEE 1645471). She is currently the PI on "Eye-Tracking the Storm: Information Processing of Visual Risk Communication" (9/2019-8/2021, NOAA-OWAQ, VORTEX SE NA19OAR4590211) to study how the public interacts with tornado warning messages.
- Co-PI Thorncroft was recently funded by NOAA (2015-05-01 to 2019-04-30, NA15NWS4680005) to work on "Exploitation of Ensemble Prediction System Information in support of Atlantic Tropical Cyclogenesis Prediction."
- Co-PI Eric Stern has a broad portfolio of basic and applied work focusing on crisis decision-making and emergency management. Recent projects include supporting

FEMA's efforts regarding *Building Cultures of Preparedness*, the OECD and UK MET on preparedness for extreme space weather events, and the NY State Division of Homeland Security and Emergency Services on crisis leadership.

Although hurricanes, blizzards, and tornadoes are frequently the first phenomena one considers when thinking of hazardous weather conditions, extreme temperatures consistently lead to more fatalities nationwide than any other type of weather. Exact attribution is sometimes difficult due to the cumulative nature extreme temperature impacts can have, but the NWS lists the 30-year average for heat-related deaths at 138 per year, and the equivalent cold-related deaths at 27 per year[1]. This cumulative 165 fatality yearly average exceeds flood fatalities (88 per year over the same period), tornado (68), and all other categories. Conversely, the Center for Disease Control & Prevention lists a significantly higher annualized average of 618 fatalities due to extreme heat[2]. A rigorous study of excess deaths associated with heat impacts in NYC estimated a median warm season total of 121 between 1997 and 2013 (Matte and coauthors, 2016). Regardless of the exact magnitude of fatalities, extreme heat in particular is a significant concern.

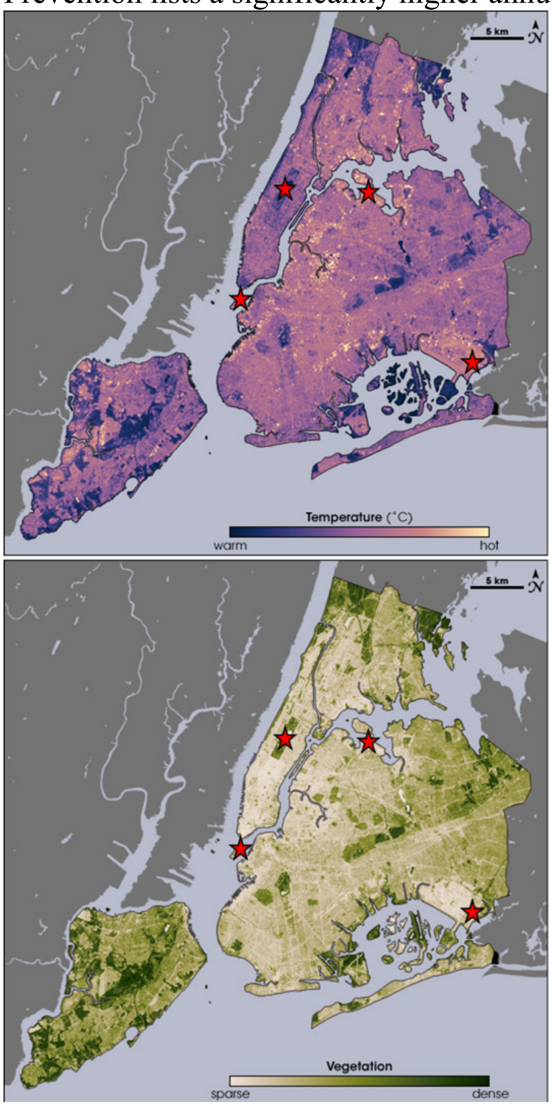

Figure 1 shows a schematic adapted from Landsat imagery taken 2002 August 14, with current ASOS locations denoted by stars.

Hawkins and coauthors (2017) recently summarized many of the forecasting and communication challenges the NWS faces inherent specifically to extreme heat. Effectively communicating the hazards of extreme temperatures is complicated by their dual dependence on factors both socioeconomic and geographic, as well as how that communication may be received. Underlying health conditions, occupation, access to air conditioning or greenspace, and even political ideology (Cutler and coauthors, 2018) affect public receipt of- and response to- threat communication. Decision makers' unfamiliarity with the meaning of extreme temperature metrics such as heat index, wet bulb globe temperature, and wind chill may further hamper effective communication. Importantly, the protective actions various thresholds of these variables should trigger for specific populations at risk is often even more poorly understood (or not explicitly stated).

The urbanization and geography of NYC presents further challenges to forecasting extreme temperatures. As of the 2010 census, NYC had a population density above 10000 people/km^2, which

[1] https://www.weather.gov/media/hazstat/80years.pdf
[2] https://www.cdc.gov/disasters/extremeheat/heat_guide.html

placed it above every United States city with a population of 75000 or greater[3]. The resultant changes in land-use can have significant impacts on estimated temperature which the current ASOS network is unable to directly observe, as the LANDSAT[4] schematic shown in Fig. 1 suggests. Finally, NYC is adjacent to a variety of water bodies (depicted in Fig. 1 as blue), including the Atlantic Ocean to the south, Long Island Sound to the northeast, the Hudson River, and a variety of other bays and inlets throughout the city. The proximity to water further modulates temperature, humidity, and wind speed through the development and movement of land-sea breezes. A variety of modeling studies have demonstrated the significant variability these breezes can impart - particularly during heat waves (Bauer, 2020; Meir and coauthors, 2003; Novak and Colle, 2006). Despite these factors, only four weather monitoring sites maintained by NWS are within NYC. Thus, significant opportunity exists to exploit additional dense weather network to improve NWS and NYCEM operations.

Unfortunately, the expected impacts of climate change add urgency to improving extreme temperature analysis, forecasting, and communication. The *New York City Panel on Climate Change 2015 Report* (Rosenzweig and Solecki, 2015) suggests mean annual temperatures across NYC may increase approximately 2.5-5 C and the prevalence of heat waves could increase by a factor of 3 by the 2080s (although the incidence of cold waves is expected to decrease). An analysis of regional changes in heat waves between 1981-2015 by Schoof and coauthors (2017) found that the northeastern United States has already experienced an increase in heat wave days. Although this proposal seeks to improve analyses and forecasts for both warm and cold events, the significant (growing) impacts from heat waves necessitate a primary focus on extreme heat.

Hence, we propose to address four key questions (**Q**) and create one product suite (**P**):

Q1) Does a combination of multiple networks of opportunity improve the analysis of spatial and temporal variability during extreme temperature events in relation to the ASOS network?

Q2) Are available numerical weather prediction models and forecasts capable of simulating the observed spatial and temporal variability of extreme temperature at lead-times of hours to days?

Q3) How accurately do extreme temperature metrics (such as heat index, wind chill, wet bulb globe temperature) map onto observed impacts and/or contribute to effective decision support?

Q4) How can the conclusions from (1), (2), and (3) best improve the communication of extreme temperature events to key stakeholders such as emergency management?

P5) We further propose to create a real-time high-resolution analysis and forecast product for NYC built using these observations and forecasts for all stakeholders to use.

The remainder of this proposal will describe key proposed outputs and products, expected outcomes and impacts from these endeavors, as well as the scientific methods needed to be successful. Finally, a proposed timeline is provided, along with a description of our commitment to outreach, education, diversity, and inclusiveness. A data management plan is also provided.

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[3] https://www.census.gov/programs-surveys/decennial-census/decade.2010.html

[4] Adapted from: https://earthobservatory.nasa.gov/images/6800/new-york-city-temperature-and-vegetation

2. Project Outputs, Products, and Readiness Levels

i) Products and Outputs

The following products and outputs are proposed:

- ***Extreme Temperature Dashboard:*** A dashboard that publicly displays high resolution real-time meteorological analyses and bias-corrected forecasts for NYC of temperature, wind chill, heat index, wet bulb globe temperature, and any other requested temperature metrics from our NWS and NYCEM collaborators. The dashboard will also have the ability to overlay important ancillary data such as cooling centers, parks, water, and appropriate socio-economic data. The dashboard will be supplemented by a static webpage that provides decision-aids for NWS core partners to effectively communicate risk to vulnerable populations. One possible display template may be the Heat Vulnerability Index map[5]. NWS will consider integrating this into their existing public heat page[6].

- ***Forecast Error And Historical Bias Characteristics:*** Additionally, current forecast errors (as calculated from a dense network of observations) from high resolution, widely used forecasting systems such as the National Blend of Models (NBM) and High-Resolution Rapid Refresh (HRRR) will be displayed for the most recent available output time. Historical biases will also be calculated and displayed for NWS forecasters to aid in forecasting. Additional statistics such as the duration a station has exceeded certain criteria (e.g. heat index of 95F) will also be displayed. These analyses, errors, and biases will be developed from a pre-existing dense network of roughly 50 high-quality weather stations across NYC (described below in **Methods and Activities**).

- ***Documentation:*** Project outputs also include the documentation of analysis products and training for end users. These and results from field research and the usability study will also be shared with core partners through a series of webinars at the end of the project.

- ***Professional Presentations:*** Finally, in addition to the dashboard products, and education and outreach with partners, we will publish this research in peer-reviewed journals (such as the *Bulletin of the American Meteorological Society; Weather Climate and Society*; *Weather and Forecasting, and the Journal of Applied Meteorology*), and present this work at conferences including the annual meeting of the American Meteorological Society, the Natural Hazards Workshop, and the National Weather Association. The proposal budget includes money for these endeavors.

ii) Proposed current and final readiness levels

Proposed current readiness level: RL5

A combination of factors contributes towards this estimate. We will utilize four high-quality observational networks (described below) that are currently installed and overseen by dedicated teams of experts. However, there is no current prototype for integrating the networks and a current network outage has temporarily affected one of the four networks due to COVID-19 maintenance restrictions. The proposal PI has existing experience creating a wide variety of real-

[5] http://a816-dohbesp.nyc.gov/IndicatorPublic/VisualizationData.aspx?id=2191,719b87,107,Map,Score,2018
[6] https://www.weather.gov/okx/excessiveheat

time, operational analyses and has developed integrated forecast dashboards for educational, utility, transportation, and NWS partners within NY. There are existing communication products, but little research has been done to assess their usability and effectiveness.

Proposed final readiness level: RL8

At the conclusion of this research, we aim to produce a real-time analysis and forecast display system (the Extreme Temperature Dashboard) that has been created through significant coordination with NWS, NYCEM, and other expected operational users to highlight all relevant information in an actionable and user-friendly format. Further, successful completion of this project will necessarily entail detailed documentation for the analysis products as well as training on its usage where appropriate. The New York, NY NWS office has explicitly suggested these products may be linked to their existing extreme temperature office webpages for use within their user environment the results of the usability study will be applicable to all weather forecast offices (WFOs) communicating extreme temperature.

3. Outcomes and Impacts

Ultimately, one of the central missions of the NWS is the protection of life and property through timely, accurate, and actionable weather forecasts. As described in the **Problem Statement**, extreme temperatures – and heat in particular – kill more Americans than any other type of hazardous weather. Thus, this work directly addresses a critical need that will likely be exacerbated as a result of climate change in the coming years.

i) Key Outcomes

The ultimate expected outcome is an increase in the health and safety of the NYC populace through improved forecasting and situational awareness of extreme temperatures. This will occur through a cascading series of scientific endeavors, including better utilization of existing disparate observational networks of opportunity for situational awareness and better understanding of model error and bias characteristics which will lead to more accurate forecasts with better lead times. Another outcome is more granular forecasts during marginal events due to an improved understanding of micro-climates within NYC which will ultimately improve probability of detection while reducing false alarms of extreme temperatures. Enhanced coordination and dissemination of extreme temperature impacts and decision support between NWS, NYCEM, and their core partners including education and energy sectors is also a critical outcome. Ancillary outcomes include improved NYC governmental efficiency for activities like coordinating opening of cooling centers or warming shelters. A final implicit outcome is a better understanding of the value additional high quality observation networks provide over the conventional ASOS network.

ii) Key Beneficiaries:

There is a hierarchy of beneficiaries, beginning with the New York, NY NWS office via enhanced analysis and forecasting of extreme temperature events, as well as improved situational awareness of those events and increased decision support capabilities. NYCEM is a co-primary beneficiary as their mission entails disseminating key information to impacted groups and coordinating emergency response. Existing stakeholders primarily impacted by extreme temperatures including educational and energy sectors will benefit from improved dissemination of timely and accurate information, which promotes safety (e.g. children walking to school) and efficiency (e.g. improved estimates of energy demand). Ultimate beneficiaries include the greater

NWS and emergency management enterprise within the United States due to the transferability of the methods and visualization used here, as well as the field research and usability studies that will provide insights into decision making and risk communication for other similar organizations.

iii) Societal Benefits

This project will have a direct impact on the wellbeing of society; especially among populations facing increased heat risk. By utilizing a dense network of observations, we will identify geographical areas and populations that have the greatest vulnerability to extreme temperatures. The design and deployment of an integrated Extreme Temperature Dashboard will facilitate accurate assessment and prediction of heat stress, increasing the ability of NWS and its partners to effectively communicate heat severity, its impacts, and population-specific protective actions. The use of the dashboard may increase their ability to make effective decisions, thereby increasing lead time for opening shelters, reducing the loss of life. Finally, this will serve as a case study for other urban areas that face similar threats.

4. Methods and Activities

A successful project will require appropriate data, analysis, communication, and displays.

i) Observational data sources

Four observational networks will contribute to the proposed analyses. These networks, described below, are hereafter referred to as "ASOS," "NYSM," "ConEd," and "CUNY." When operating as intended, these networks collectively record nearly 50 independent measurements of temperature and humidity across or near NYC every few minutes. The NYSM and ConEd networks also measure solar irradiance, while the NYSM, ConEd, and ASOS networks measure wind speed. The site locations for these networks as depicted in Fig. 2 are fairly evenly distributed.

- **ASOS:** The Automated Surface Observing Systems (ASOS) is well-known observational network maintained by the NWS, Federal Aviation Administration, and the Department of Defense[7]. Four of these sites are in NYC, while three more are nearby.

- **NYS Mesonet:** The New York State Mesonet (NYSM) is a sophisticated $30M network of observing stations installed across New York in the wake of Hurricanes Irene (2011) and Sandy (2012) (Brotzge and coauthors, 2020). This data is rigorously quality controlled and instruments are replaced or calibrated as needed. The portion of this network in NYC consists of five sites on rooftops (Brotzge and coauthors, in press). The NYSM have provided a letter of support for this endeavor.

- **Con Ed:** The NYSM, in coordination with the electric utility Consolidated Edison also operates the ConEd Micronet (ConEd). As of this writing, this network of 17 sites is nearing completion. All sites are located on or near Consolidated Edison property, with a goal of monitoring changing climate conditions and their effects on utility infrastructure[8]. Sixteen of these sites measure temperature and humidity.

[7] https://www.weather.gov/asos/asostech
[8] https://www.albany.edu/news/94295.php

- **CUNY:** The New York Urban Hydrometeorological Testbed (CUNY) is a network of 19 weather stations across NYC operated by scientists at the CUNY Crest Institute[9]. CUNY scientists have committed to support this proposal (see attached letter of support).

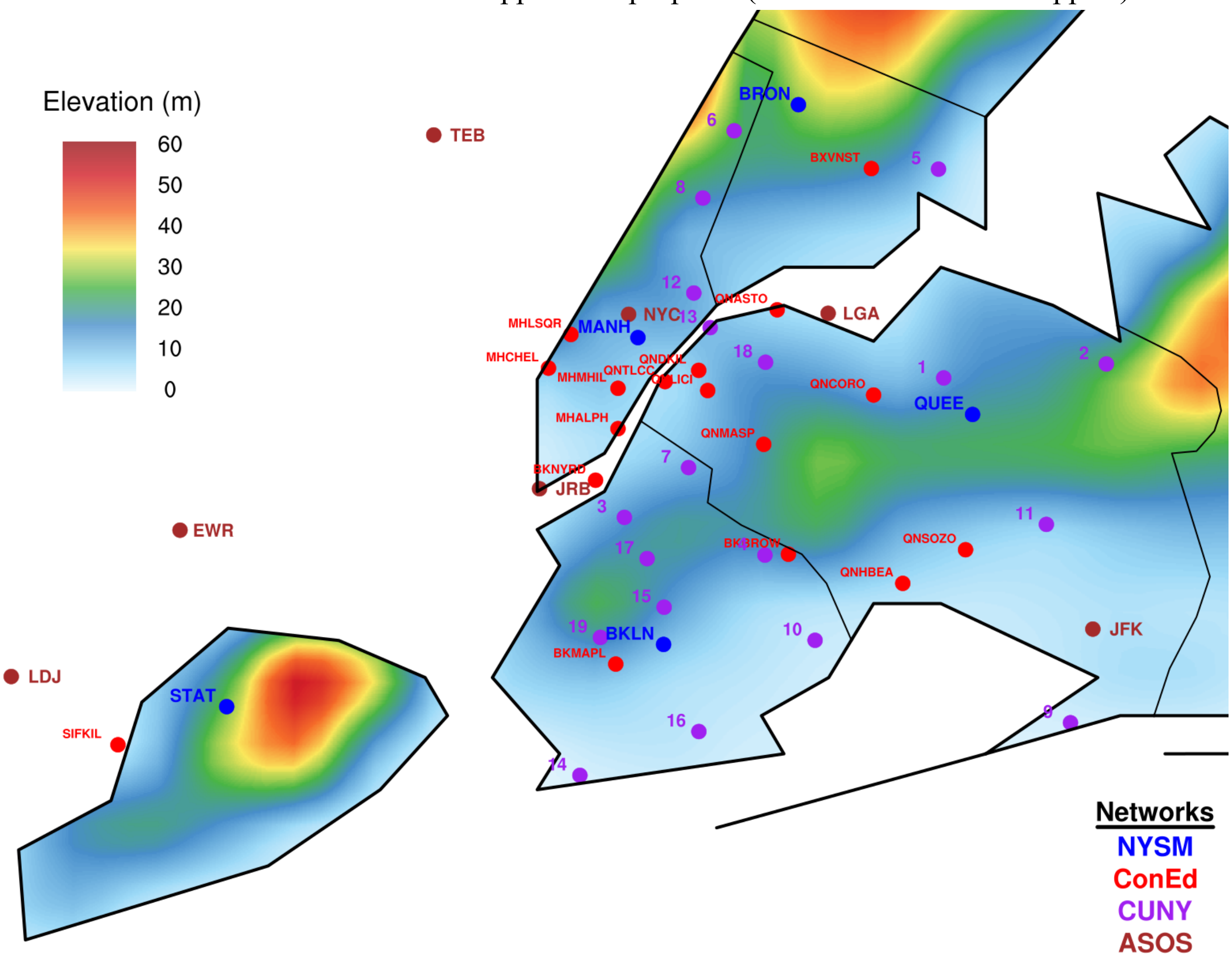

Figure 2 displays the four observational networks in or near NYC, each denoted by an identifier and colored according to network: ASOS (black), NYSM (blue), ConEd (red), and CUNY (purple). Approximate elevation (m) is depicted by the color fill.

ii) Forecast Data Sources

Two forecasting systems will be used for comparison and evaluation purposes. The first is the High-Resolution Rapid Refresh (HRRR) model (Benjamin and coauthors, 2016). This model serves a the backbone for short range forecasting for many operational centers, due in part to its high resolution (3km grid spacing) and frequent updates (new forecasts are produced hourly). The proposers have an archive of raw HRRR forecasts spanning the period of June 2018 to present. The second forecasting system is the National Blend of Models (NBM), which is a calibrated ensemble of multiple forecast models that is becoming increasingly valuable to NWS forecasters (Hamill and coauthors, 2017). The NBM has a horizontal resolution comparable to the HRRR. These two forecasting systems provide complementary and contrasting forecasts for comparison.

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[9] https://www.cessrst.org//uHMT/index.html

iii) Meteorological Analysis Methods

From these four networks, data will need to be gathered and normalized for important variables including temperature, humidity, irradiance, and wind speed. Irradiance and wind speed are currently available at a subset of sites within the collective network, and wind speed may be recorded at different heights. Certain data may have different temporal resolutions. Once observational data is normalized, key variables including heat index, wind chill, and wet bulb globe temperature at all locations will be calculated from these observations. Given the absence of certain critical variables (e.g. missing irradiance for wet bulb globe temperature) we will determine an optimal approach for filling important gaps (such as interpolation, nearest neighbor, etc.). It is likely that consistent small-scale variations in temperature and humidity will be more prevalent than variations in sunshine or mean wind speed, which is fortuitous in that every site has both temperature and humidity sensors to capture these small-scale variations. Once these variables are created for each site, mean forecast biases and errors at various lead-times for these variables at network locations in relation to the forecast data will be calculated and binned according to both regime type (e.g. offshore flow or onshore flow) as well as seasonality. These errors and biases will also be segregated by network type, in order to evaluate each network independently.

Next, gridded analyses of these key variables will be created. Multiple techniques will be evaluated, ranging from relatively straightforward Barnes objective analyses (Spencer and coauthors, 2007) to more complex techniques using numerical weather prediction models as first guesses (Tyndall and coauthors, 2007; Hamill, 2020). Ultimately, the effective grid resolution of even the highest resolution operational model may prove inadequate at providing an effective first guess field given the density of the observing network considered, and the sensitivity of high resolution models to the NYC environment (Gutiérrez, 2015). Once separate gridded analyses of temperature, humidity, wind speed, and irradiance are created, then heat index, wind chill, and wet bulb globe temperature gridded analyses can be created by combining the necessary variables.

Real-time data feeds will be initiated for these networks and forecast products in order to produce real-time analyses of key variables as well as real-time forecast error calculations. Historical regime type biases will also be provided, dependent on the type of regime identified from simple identifiers such as season and prevailing wind direction. Additionally, regime type biases will be provided for forecast intervals extending out to 72 hours. Quantitative success may be defined as a reduction in false alarms for extreme temperature warning and advisory products issued by NWS and an increase in the probability of detection, while qualitative success may be defined by improved forecaster confidence and use of the Extreme Temperature Dashboard.

Once retrospective cases have been identified (see below), the most appropriate relevant observational data (ASOS, etc.) will be determined, and time-series of temperature, heat index or wind chill (where appropriate) will be derived to assist in that analysis.

iv) Analysis of reference cases:

Historical analyses of extreme heat events have the potential to offer insight into gaps in observational data, metrics for analysis, and decision-making thresholds. In order to contextualize the current research on heat index, wet bulb globe temperature, and other heat stress measurements, we propose to conduct a series of counter-factual cases studies to be conducted by joint teams of atmospheric and social scientists. In collaboration with NWS, we will select a set of relevant extreme temperature cases that resulted in the issuance of heat or cold products and/or the activation of extreme temperature response plans from NYCEM and partners. We will conduct retrospective analyses of existing observational data as described above. The pre-existing data may be deficient in one or more metrics, such as insufficiently granular or missing key incalculable variables such as wet bulb globe temperature. This will be coupled with post hoc review of the content of decision support, advisories, emergency management guidance, public/media response, and estimated health outcomes (c.f. Parker et al, 2009; Stern, 1999). The case studies will include counter-factual analysis (Lustick, 2010; Tetlock and Belkin eds, 1996) of the potential contribution of state-of-the-art techniques and enhanced observational infrastructure in reducing extreme temperature harm. The outcome of the historical analysis will provide a benchmark of accessible data, modeling and decision-making in response to extreme temperature events. It will serve to contextualize and highlight the usefulness of dense observation networks and additional weather data for effectively communicating heat stress to NWS partners and vulnerable populations. Where deficiencies arise in the limited utility of pre-existing observational data (e.g. only heat index where wet bulb globe temperature would have been more actionable), these deficiencies will drive improvement in the operational products and outputs produced via this proposal.

v) Examine Real-time Decision Making During Extreme Temperature Events:

For the purpose of understanding real time decision making in extreme heat events, we will conduct systematic observations of extreme heat decision support activities undertaken by NWS New York as they occur in the NYC Emergency Operations Center. We will focus on how decision makers, emergency managers, and NWS core partners make use of forecast information using heat index, wet bulb globe temperature, and other products (Stallings, 2003). IRB approval will be received before beginning any human subjects research. For our field study, we will work with our collaborators to identify one significant heat event responses in the summers of 2022 and 2023. At the onset of the selected extreme heat event, we will rapidly deploy a team of 2-3 field researchers to the NYCEM Emergency Operations Center, where we will observe the daily briefings, interactions, and communication activities that take place with NWS New York over a 1-3-day period. Observations will be documented through structured field notes (Phillippi and Lauderdale, 2018) and the use of digital cameras to capture relevant visual images such as drawings on whiteboards or other images displayed related to meteorological forecasts and vulnerable populations, communicating risk messages to core partners, communicating risk messages to the public, and other issues that arise that may be relevant to decision making. At the conclusion of each day, field researchers will discuss key observations that emerge on each day of deployment (Janesick, 2007). Field notes will be typed up and discussed among the research team and partners at NWS New York to identify key datapoints and processes that were highly relevant to decision making during the extreme heat event (Bernard and coauthors, 2016). In the weeks following the response, the field team will brief NYC and NWS collaborators on their findings to evaluate and discuss key observations that may benefit future measurement, analyses, decision making, and communication.

vi) Usability of Excessive Heat Product Displays:

Excessive heat products (heat advisory and excessive heat warning) are developed through collaboration between NWS, forecasters, and researchers in universities and departments of public health (Hawkins and coauthors, 2017). Products are then issued based upon locally developed criteria. Within the NWS Eastern region, NWS offices make use of the heat index and the

"Kalkstein Procedures" (Fig. 3) and may soon add the wet bulb globe temperature. Each model determines heat stress using different criteria, some of which are correlated with health impacts and necessary risk messaging to prevent heat related illness and even death. While NOAA and individual WFOs host heat related information on their weather.gov webpages, there is a gap in knowledge about how core partners make use of the content for their own decision making and risk communication. Therefore, we propose to conduct a cognitively-based usability study with a set of WFO core partners in order to determine how decision makers understand and utilize the excessive heat information provided on WFO webpages for decision making and risk communication (Dumas and coauthors, 1999).

We will work with our NWS partner to identify a set of primary core partners that make use of NWS webpage information to accomplish public safety tasks (Kushniruk and coauthors, 1997). IRB approval will be received before beginning any human subjects research. We will then conduct a needs assessment with representatives of those user groups to determine (1) their public safety goals (i.e. to send a risk message, to initiate health checks with vulnerable populations, to open cooling centers) and (2) how they prefer to utilize heat information available to them on NOAA webpages (Kushniruk and coauthors,1997). Beginning with existing webpages that are currently published to weather.gov, we will conduct remote usability testing (using WebEx or other software) to assess the ability of participants to complete tasks previously identified in the needs assessment phase. We will collect think aloud data, observational notes, and participant written feedback on the content presented to complete identified tasks. Data will be coded for information content, comprehension of graphics and text, problems in navigation, and overall system understandability. Iterative input will be made to webpage design focusing on webpage content to improve risk visualizations, communication of public health impacts and public health recommendations, and risk messaging with successive testing. The concluding webpage will be incorporated into the Extreme Temperature Dashboard.

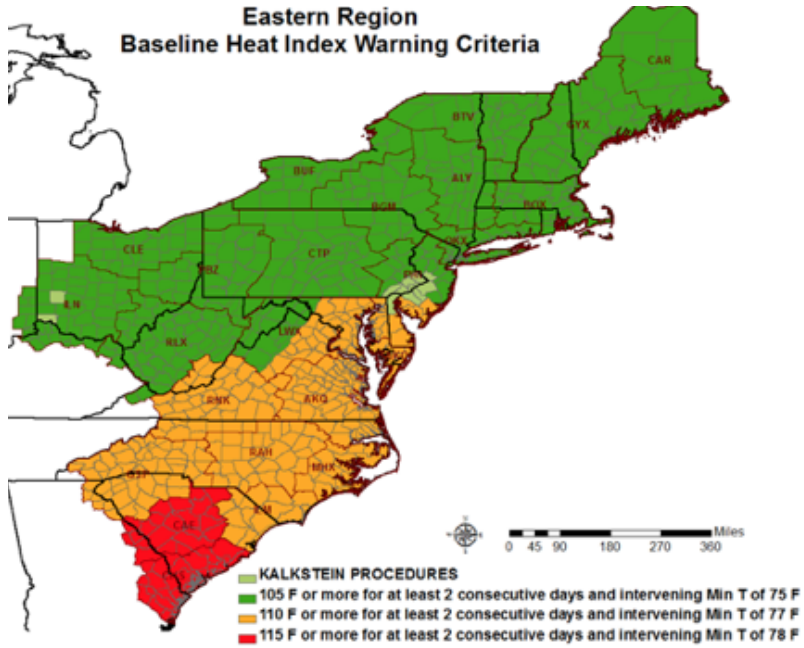

Figure 3 shows two types of heat index baseline warning criteria used by NWS Eastern Region on July 6, 2020; the Kalkstein Procedures, and the Heat Index.

5. Timeline

A Gannt Chart is shown below with expected timelines. The research team will also conduct weekly online meetings to discuss research activities and progress. Collaborators from NWS and NYCEM will be invited to join our calls quarterly or more frequently as needed. Student Capstone projects may be at various times throughout the academic semester.

Listed Start Date: August 1, 2021	Begin At RL 5	Months 1-3			Months 4-6			Months 7-9			Months 10-12			Months 13-15			Months 16-18			Months 19-21			Months 22-24		
TASK	ASSIGNED TO																								
Literature Review	Thorncroft & Post-Doc	■	■																						
IRB Approval	Sutton & RA	■	■																						
Retrospective Case Analysis	Stern		■	■	■																				
Develop Observational Data Streams	Bassill & Post-Doc		■	■	■																				
Gather Forecast Data	Bassill & Post-Doc			■	■																				
Usability Study/Needs Assessment	Sutton & RA			■	■	■	■																		
Calculate Forecast Errors & Biases	Post-Doc					■	■	■																	
Evaluate Spatial & Temporal Variability	Post-Doc							■	■	■															
Usability Study/User Interaction	Sutton & RA							■	■	■	■	■	■	■											
Field Research Training	Sutton & RA									■	■														
Develop Historical Analyses	Post-Doc										■	■	■												
Field Research	Sutton & RA										■	■	■	■	■										
Develop Real-Time Analyses	Post-Doc											■	■	■											
Evaluate Real-Time Analyses	Post-Doc												■	■	■										
Advance To Readiness Level 6	All													■	■										
Develop Dashboard Display	Bassill & Post-Doc													■	■	■	■	■	■						
Usability Study/Data Analysis	Sutton & RA															■	■	■	■						
Field Research/Data Analysis	Sutton & RA															■	■	■	■	■					
Integrate Socioeconomic Display	Post-Doc																■	■	■	■					
Advance To Readiness Level 7	All																■	■	■	■					
Manuscript Development	All																■	■	■	■	■	■	■	■	■
Dashboard/Partner Feedback Loop	Sutton, Post-Doc, RA																	■	■	■	■	■	■	■	
Presentations & Webinars	All																			■	■	■	■	■	■
Integration Into Partner Operations	All																				■	■	■	■	■
Examine End User Engagement	Stern & Thorncroft																					■	■		
Examine Follow-up Work	All																							■	■
End At Readiness Level 8	All																							■	■

Figure 4 Shows An Expected Project Timeline In Gannt Chart Format

6. Outreach and Education

Outreach: Several activities will be undertaken to engage with scientific, policy, and public audiences. In addition to the end-user focused and scholarly activities discussed elsewhere, we will host a public facing webpage with integrated social media accounts on Facebook and Twitter. Tutorial videos explaining the use of the Extreme Temperature Dashboard will be created and hosted on YouTube. We will engage with popular weather, disaster, and emergency management podcast hosts (e.g. Weather Brains, Weather Hype, and EM Weekly) to share our findings in an audio format. We will host a series of virtual webinars to share project results with weather professionals and their core partners and host a virtual workshop for these partners to share results at the completion of the project. Further, the focused and direct engagement with NWS and NYCEM can serve as the template for a future extreme temperature testbed.

Education: While this project focuses primarily on observational networks, it has been designed to be interdisciplinary by including scholars in meteorology and social science. This has the benefit of training the next the generation of scholars about both the meteorological and the societal impacts of their work. Faculty PIs will expose and engage graduate and undergraduate students and interns in this research via client-oriented team-based Capstone Projects. Also, educational infrastructure in NYC will benefit even without direct engagement, as the improvements made to extreme temperature forecasting will promote safe practices for children walking to and from school, playing in outdoor athletics, or participating in outdoor recess.

7. Diversity and Inclusion

The proposed project proudly conforms with NOAA's commitment to diversity and inclusion. The Atmospheric Sciences Research Center, the Department of Atmospheric and Environmental Sciences as well as the College of Emergency Preparedness, Homeland Security and Cybersecurity (CEHC) have Diversity and Inclusion Committees to ensure that we are purposeful about establishing and promoting a diverse and inclusive community in our respective units. The lead PI of this proposal gladly serves on the former committee. In 2019, the Atmospheric Sciences program at UAlbany became an AGU Bridge Program member to improve our recruitment and support of students from underrepresented racial groups in our graduate program. We also engage with high school students from underprivileged areas within the New York Capital District to cultivate interest in the geosciences and encourage greater participation of underrepresented groups in STEM fields. Similarly, CEHC has been recognized as a campus leader in diversity and inclusion with multiple initiatives underway. Furthermore, the College is home to an NSF INCLUDES project (Minority SURGE) focusing on boosting representation of under-represented groups in emergency management and disaster research. UAlbany is one of 2019 Higher Education in Diversity (HEED) Award recipients. UAlbany is also recognized as a Hispanic Serving Institution. This UAlbany-led project includes a female faculty member in the leadership team (Dr. Sutton). Dr. Bassill and Dr. Sutton will actively recruit a Post-Doc and PhD student, respectively, who are members of an underrepresented group to serve on this project.

8. Data Management Plan

Data Sources and Types: All observational datasets required for this research are generated and stored by other groups; including the NYSM, the NOAA NWS ASOS Network and the CUNY Urban Hydro-Meteorological Testbed. All final research related data products produced from our research will be stored in the self-describing NetCDF format. All data to be collected as part of this project from human sources will be approved by the University at Albany Institutional Review Board prior to collection. Human subjects' data will be kept confidential to the extent permitted by law. All usability study participants will sign consent forms and data will be anonymized. Following collection, the data and consent forms will be stored in the Co-PI's office and on a password protected computer. Only officially designated personnel will have access to the data.

Data Preservation and Access: All existing data used, and all derivative data products generated, during the course of this research will be archived in the research group's storage space within the University at Albany's Tier-3 Data Center. This NetApp based storage space is fully redundant ensuring the longevity of new research products generated through this project. All final data products generated through this research will be assigned a Data Object Identifier, or DOI, which is a persistent identifier to uniquely identify the research product as well product the intellectual property of the research team(s) involved in the generation of the data product.

Data Sharing and Access: Derivative NetCDF data products, and any ancillary non-NetCDF data required for research reproducibility, will be made available for public consumption through unrestricted HTTPS (web) access via a research web server located in UAlbany's Virtual Machine (VM) tenant space. We will initially provide public data access through a simple data URL link, but since we will be utilizing a web server, will have the ability to create an outward facing web interface for information dissemination as well as data access/download available for public consumption roughly one year from project start.

Software Licensing and Copyright: All software products developed by the research team shall be copyright works of the Research Foundation for the State University of New York (RFSUNY). Therefore, the RFSUNY copyright will remain with all software products for the lifetime of the software. To ensure the level of openness and collaboration required within the NOAA Data Management Plan while maintaining RFSUNY copyright, the permissive MIT open-source license[10] will be applied to all software and software documentation.

[10] https://opensource.org/licenses/MIT

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FY21 WEATHER PROGRAM OFFICE NOTICE OF FUNDING OPPORTUNITY

STANDARD FORM FOR ACKNOWLEDGEMENT OF NOAA COLLABORATION

DATE: November 5, 2020

MEMORANDUM FOR: NOAA/OAR Weather Program Office Competition Manager

FROM: David B, Radell, Science and Operations Officer, WFO New York, NY

SUBJECT: NOAA Collaboration on WPO Proposal

NWS WFO New York, NY (OKX) acknowledges NOAA collaboration with Principal Investigator(s) Nick Bassill on the development of proposal titled Improving analysis and communication of extreme temperatures across the New York City metropolis using a dense network of in situ observations The applicants have sufficiently coordinated the development of this proposal, including any relevant infrastructure costs and/or plans for proposed Testbed activities.

Our role in this collaborative project will include (check all that apply):

_x_ Providing (unfunded) research and development support

___ Providing equipment, office space, or computer access to non-federal PIs

_x_ Providing operational guidance to support the eventual transition of this project

___ Coordinating NOAA Testbed activities for this project

___ Other: ________________________________

Any major comments or concerns are listed below.

DB Radell

Science and Operations Officer
NWS New York, NY

Signature
(Name, Title, Organization)

NYC Emergency Management

Date: November 10, 2020

Subject: Memorandum of Support for University of Albany Extreme Temperature Study

1. New York City Emergency Management (NYCEM) is writing in support of the goals of University of Albany's research proposal to improve the analysis and communication of extreme temperatures across the New York City metropolis using a dense network of in situ observations.

2. NYCEM manages multiple emergency plans on behalf of the City of New York related to extreme temperatures and thus has a bona fide interest in coordinating on this project in collaboration with the New York National Weather Service office in Upton and the University of Albany. The need for such a study is imperative in New York given the relationship between extreme heat and public health, the variability of extreme temperatures in the urban environment, the lack of a dense network of weather observations throughout the city.

3. Please feel free to contact us at meteorology@oem.nyc.gov for questions or additional information.

Joshua Rapp
Meteorologist
NYC Emergency Management

The City College of New York / CUNY
Steinman Hall (T-107)
140th Street & Convent Avenue
New York, NY 10031

Dear Dr. Nicholas Bassill,

I am pleased to support the research proposal " 'Improving analysis and communication of extreme temperatures across the New York City metropolis using a dense network of in situ observations".

The CUNY Remote Sensing Earth System Technology (CREST) Institute engages in research, education and outreach programs that utilize remote sensing science and technology to meet pressing environmental and climate challenges. Emphasis is placed on recruiting, mentoring, and training graduate students in science, engineering and technology, with a special on traditionally underrepresented groups, to provide a diverse future workforce for NOAA, NOAA contractors, and other federal, state, and industrial stakeholders. Since our inception in 2002, over 300 students (75% underrepresented minorities) have participated at the high school, undergraduate, and graduate levels, and CREST had become a model for a comprehensive strategy for expanding the STEM 'pipeline'.

The proposed research topic is consistent with the mission of the CUNY CREST Institute to develop environmental information and technical capabilities needed for research on urban heat island, which continue to pose challenges for humanity's increasingly urban population. **We commit to providing available CUNY weather network data to support these efforts.** I believe the research caried out proposal will help us in mesoscale environmental research in New York City.

Sincerely,

Tarendra Lakhankar, PhD
NOAA-Center for Earth System Sciences and Remote Sensing Technologies
The City College of the City University of New York
ST-185, Steinman Hall, 160 Convent Ave, New York, NY 10031
Email: tlakhankar@ccny.cuny.edu
Office: 212-650-5815

NYS Mesonet
518/442-MESO

Lecture Center
Suite SB-28
1400 Washington Avenue
Albany, New York 12222

10 November 2020

Dr. Nick Bassill
Director of Research & Development, Center Of Excellence
LC SB-28, University at Albany,
1400 Washington Ave.,
Albany, NY 12222

Dear Dr. Bassill,

I am writing to express my support for your collaborative proposal entitled: "Improving analysis and communication of extreme temperatures across the New York City metropolis using a dense network of in situ observations."

If selected, the NYS Mesonet team is excited to collaborate with you on this to make it a success. We are particularly interested in the benefits that this collaborative work could provide with respect to improved quality control for the Con Ed sites, improved heat-related products for the city and the stronger ties with the NWS and EM in NYC.

Sincerely,

Jerald Brotzge

Jerald Brotzge, Ph.D.

Program Manager
New York State Mesonet
State University of New York at Albany
LC SB-28, 1400 Washington Ave.,
Albany, NY 12222