1. TITLE PAGE:

Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain

Proposal submitted in response to NOAA-NWS-NWSPO-2019-2005754: Collaborative Science, Technology, and Applied Science (CSTAR) Program

Proposal to address the areas of:

- Utilizing convection-allowing models and storm-scale ensemble systems to advance Warn-on-Forecast capabilities (1a)
- Improving application of numerical weather prediction information in the forecast and warning process at various time scales (1b)
- Improving the use of ensemble prediction systems in order to enable more effective forecaster assessment of uncertainty and historical context of potential high-impact events (1c-i)
- Developing improved surface analyses using data fusion to aid in the identification and characterization of high-impacts events in complex terrain (1d)

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Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain

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Improved Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain

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Total Proposed Cost: $450,000
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2. ABSTRACT:

This proposal responds to the opportunity provided by the Collaborative Science, Technology, and Applied Research (CSTAR) Program Federal Funding Opportunity (FFO) to improve the forecast and warning capabilities of the operational meteorological community by applying scientific research findings to the development of products and services. The proposed research is expected to lead to increased scientific understanding and improved forecast lead time, and accuracy, of high-impact weather events, including heavy snowfall and mixed-phase precipitation accumulations, damaging convective-scale winds, severe hail, and tornadoes, which have the potential to cause substantial societal and economic disruption. The weather events chosen will be addressed in the context of the FFO's *Research Priority #1, Improving lead time and accuracy of forecasts and warnings for high-impact weather events*, by focusing on the following challenging forecast problems: 1) severe convection in complex terrain and across different severe-weather environments, and 2) winter-precipitation type in regions of complex terrain. Emphasis will be placed on exploring the representation of these high-impact weather events in current, and future, convection-allowing numerical weather prediction models (CAMs) compared to observations, understanding model biases related to poorly-resolved physical processes, and developing real-time data fusion products combining CAM output with observations to highlight areas of enhanced forecast uncertainty. Although our projects are focused on cold-season cyclones and convective weather events in the eastern U.S., our scientific methods and operational diagnostics will be formulated as to be transferrable to other regions of hazardous weather in complex terrain across the country.

Our research efforts on high societal impact weather systems are designed to facilitate the transfer of research findings into operations (R2O) by taking advantage of the well-established programmatic assets and research infrastructure in the Department of Atmospheric and Environmental Sciences (DAES) at the University at Albany (UAlbany), and by enabling the participation of a significant number of National Weather Service (NWS) personnel on CSTAR-related research. In order to achieve this objective, we will build upon the framework for NWS participation and R2O that has been adopted in our current and previously funded CSTAR grants, which allows for the cost-effective generation of new scientific understanding and improved Warn-on-Forecast (WoF) capabilties to protect life and property. These efforts will be conducted in collaboration with multiple Eastern Region NWS offices and the New York State Mesonet (NYSM), as well as NOAA's Storm Prediction Center (SPC), Weather Prediction Center (WPC), and Earth System Research Laboratory (ESRL). These new and continuing R2O partnerships will: 1) ensure the development of conceptual models, forecast checklists, and decision trees at the completion of each project, 2) support promising visualization, diagnostic, and machine learning techniques to be formally evaluated in operational testbeds, and 3) ensure model biases and potential improvements are effectively communicated to developers.

3. RESULTS FROM PRIOR RESEARCH:

The objective of the current and previous UAlbany–NWS ALY CSTAR grants has been to improve the prediction of warm- and cool-season high-impact weather events in the Northeast United States (see *http://cstar.cestm.albany.edu* and *https://vlab.ncep.noaa.gov/web/albany-cstar*). To accomplish this goal, we have conducted multiscale studies designed to advance scientific understanding and transfer these advances to operations. Each study has involved the participation of a UAlbany graduate student jointly advised by the PI, Co-PIs, and NWS staff members, referred to as NWS "Focal Points", who have also assumed a critical role in coordinating the transfer of research to operations.

Below, we document research progress on the three studies conducted under the present UAlbany CSTAR grant, *Development of Improved Diagnostics, Numerical Models, and Situational Awareness of High-Impact Cyclones and Convective Weather Events*. A list of all previous UAlbany–NWS ALY COMET Partners, COMET Collaborative, and CSTAR grants, theses, former UAlbany advanced degree recipients currently employed in NOAA laboratories or by the NWS, refereed publications, and conference preprints/presentations may be found at *http://www.atmos.albany.edu/facstaff/kristen/CSTARVII/CSTAR_CumulativeResearch.pdf*.

1. Forecast and model diagnostics for severe convective weather events in complex terrain

Co-PI Dr. Brian Tang and Dr. Lance Bosart, working together with graduate student William Flamholtz, investigated how terrain channeling affects convective severity in major Northeast U.S. valleys. This work is in collaboration with Focal Points at NWS Albany, model developers at ESRL, and forecasters at SPC.

The first goal of the project was to update a database of high-impact, low-predictive-skill severe weather events in the Northeast, which had marginal, regional-scale signals for severe weather (e.g., high shear and low CAPE, or low shear and high CAPE), but ultimately had a large number of storm reports, using the methodology of Vaughan et al. (2017). The database extends cases into the NYSM era to allow use of the data for analysis. We examined representative cases and found evidence of terrain-induced mesoscale boundaries providing foci for severe weather.

The second goal of the project was to determine if there are particular regions of the shear–CAPE parameter space where terrain-channeling effects, through local increases in the low-level wind shear and storm-relative helicity, play a prominent role in potentially enhancing the risk of severe weather, particularly severe wind, above the background value. Using the Weather Research and Forecasting (WRF) model with High-Resolution Rapid Refresh (HRRR)-like physics, realistic and idealized simulations were conducted in order to isolate terrain-channeling effects on convection. It was determined that terrain-channeling effects are more important when the background CAPE and shear are anomalously high. This understanding increases situational awareness of scenarios and areas where the risk of severe weather may be enhanced due to terrain channeling.

2. High-resolution numerical forecasts of lake-effect snowstorms: Model performance, physics sensitivities, and synoptic predictability

This work focused on quantifying and understanding sources of uncertainty in CAM simulations of lake-effect storms (LeS), and was led by Co-PI Dr. Justin Minder, Dr. Ryan Torn, and Dr. Daniel Keyser, working with graduate student Massey Bartolini. Collaboration with the operational community was through Focal Points at NWS Albany and Buffalo, as well as HRRR model developers at ESRL.

This research focused on events from the Ontario Winter Lake-effect Systems field campaign. Case study simulations were run using the WRF model configured similarly to the HRRRv3. Sensitivity experiments were conducted by systematically varying the model initial and boundary conditions (IC/BCs) and physical parameterization schemes (microphysics and surface/boundary layer turbulence). Findings show substantial variations in snow band position due to IC/BC uncertainty and large (factor of two) variations in snowfall intensity due to physics parameterization uncertainty. Detailed field observations have been used to evaluate the accuracy and physical realism of the simulations, revealing poor representation of key processes in some schemes. Parameter perturbation experiments have revealed some of the elements within schemes that strongly affect the simulation of LeS. The results have been communicated through meetings with the HRRR development team, nine presentations at regional and national conferences, and are the subject of two manuscripts that will be submitted to American Meteorological Society (AMS) journals in Spring 2019.

3. Applying forecast track and intensity diagnostics to high-impact Northeast winter storms

Co-PI Dr. Andrea Lang, PI Dr. Kristen Corbosiero, and Dr. Ryan Torn worked together with graduate student Tomer Burg on a project focused on an application of forecast track and intensity diagnostics to high-impact Northeastern winter storms. This work was conducted in collaboration with Focal Points at NWS Weather Forecast Offices (WFOs) in Albany, Boston, and Gray.

The project methods included developing an objective cyclone identification and tracking algorithm to capture the array of Northeast U.S. cyclones lifecycles, as well as the creation of case composites categorized by forecast bias. The cyclone identification and tracking algorithm was applied to the 0–5-day forecast lead times of 516 Northeast U.S. cyclone cases available in the Global Ensemble Forecast System (GEFS) reforecast data. An analysis of the forecast biases (e.g., left vs. right of track, along vs. across track, slow vs. fast track, intensity) of these cyclones was conducted and the forecast bias trends were calculated. A series of metrics is currently being developed that will improve a forecaster's situational awareness of the likely biases that exist in a real-time forecast of Northeast U.S. storms. This project has funded the MS degree of Tomer Burg who will defend his thesis in Spring 2019. It is anticipated that this work will result in at least one manuscript submitted to an AMS journal in 2019.

4. PROJECT DESCRIPTION

The proposed project, with a focus on the development of improved analyses, numerical models, and situational awareness of high-impact weather events, responds directly to the research opportunities presented in the 2019 CSTAR FFO, as well as in NOAA's WoF Initiative. Building upon our current and previously funded CSTAR research (summarized in Section 3), the proposed project will address the following program priorities listed under Section B1 of the FFO (*Improving the lead-time and accuracy of forecasts and warnings of high-impact weather, water, and climate events*):

a) *Utilizing convection-allowing models and storm-scale ensemble systems to advance Warn-on-Forecast capabilities*
b) *Improving application of numerical weather prediction information in the forecast and warning process at various time scales*

c) *Improving the use of ensemble prediction systems in order to enable effective forecaster assessment of uncertainty and historical context of potential high-impact events*
d) *Developing improved surface analyses using data fusion to aid in the identification and characterization of high-impact events in complex terrain*

Consistent with the objective of this proposal to increase scientific understanding and improve situational awareness of high-impact weather events, we will investigate the structure, evolution, and predictability of mixed-phase precipitation and severe weather events, and their interaction with the topography of the northeastern United States. Our rationale for focusing our research efforts on the NWS Eastern Region (ER) is twofold: 1) to support the NWS mission to protect the lives of the over 45% of the United States population that lives in the ER and states bordering the Great Lakes (2010 US Census), and 2) to mitigate the risk to infrastructure and significant economic disruption that occurs whenever a high-impact weather event is forecast, even if the event does not ultimately occur. Highlighting this latter point, emphasis will be placed on exploring the predictability of cold-season mixed-phase precipitation and warm-season convective weather events in current and future CAMs, investigating biases related to poorly-resolved topography and model physics, and developing operational analyses and tools to improve lead-time and forecast accuracy of significant weather events. To this end, we anticipate that the diagnostics developed and methodologies employed in the course of our research can be applied to weather events across the country, with potential improvements to CAMs benefiting the meteorological community as a whole.

The focused research effort on predictability studies of high-impact weather systems will allow us to take advantage of R2O partnerships with ER NWS offices, the NYSM, SPC, WPC, and ESRL. The partnerships will facilitate a two-way feedback such that the research knowledge gained improves operational products, and operational priorities direct the research as it evolves. We propose to work with our partners to facilitate the transfer of knowledge through: 1) conceptual models and forecast checklists that NWS forecasters can readily use; 2) visualization, diagnostic, and machine learning techniques that can be evaluated in operational testbeds; and, 3) communication of model biases and potential improvements to model developers.

a) Proposed research

Overview and identification of forecast problems

Some of the largest predictability challenges for forecasters generally, and numerical weather prediction (NWP) in particular, come from situations when the forecast environmental support for high-impact weather is marginal and/or varies over short distances. For instance, during the warm season, forecasts of severe convection can be challenging when the convective available potential energy (CAPE) and/or vertical wind shear (VWS) are spatially heterogeneous or marginal for severe convection (e.g., Sherburn et al. 2016; Vaughan et al. 2017). Additionally, during the cold season, forecasts of precipitation type (p-type) can be challenging if temperatures are near 0°C, where a wide diversity of liquid and frozen precipitation types are possible (e.g., Reeves et al. 2014; Stewart et al. 2015).

In both of these examples, modest changes in thermodynamic conditions may drastically alter the sensible weather and associated impacts. Accordingly, the predictability of such events can be shaped by an array of factors, including uncertainties in: the synoptic-scale flow evolution, mesoscale terrain-influenced circulations, land-surface conditions, and parameterization of subgrid-scale processes such as near-surface turbulence and cloud/precipitation microphysics. Characterizing and constraining these sources of uncertainty to provide sound and well-calibrated probabilistic forecasts of high-impact warm- and cold-season weather remains a crucial challenge for the forecasting community. The scientific merit of our proposed work will stem from advancing the understanding of these issues by focusing on the above-mentioned examples of summer severe convection and winter p-type, specifically over the complex terrain of the northeastern United States. The practical impacts of the work will be contributions to improved use of both high-resolution NWP (e.g., CAMs) and "data fusion" products that blend NWP and observations for probabilistic prediction of these phenomena.

Background and motivation

Precipitation type

Diverse processes, acting on synoptic to microphysical scales, determine p-type at the surface. Thermodynamic profiles of temperature and humidity exert fundamental controls on the melting, supercooling, and refreezing of hydrometeors. The evolution of synoptic features plays a crucial role in determining these profiles (e.g., Bosart and Sanders 1991; Robbins and Cortinas 2002; Durran et al. 2013); however, they may also be shaped by local, mesoscale, terrain-modified flow (e.g., Bell and Bosart 1988; Roebber and Gyakum 2003; Minder and Kingsmill 2013), as well as surface and boundary-layer processes. Thermodynamic feedbacks associated with melting, evaporation, sublimation, and refreezing can also modify the profile, and in turn the p-type, especially where flow is constrained by terrain (e.g., Bosart and Sanders 1991; Lackmann et al. 2002; Minder and Kingsmill 2013; Thériault et al. 2015). Even for a given thermodynamic profile, p-type may vary depending on microphysical properties (e.g., Stewart et al. 2015; Reeves et al. 2016). Poor representation of any of the above processes may degrade a forecast.

Objective p-type forecasting may use NWP output indirectly or directly. Indirect methods usually rely on predicted thermodynamic profiles to diagnose p-type (e.g., Bourgouin 2000; Mankin 2005) and are used by WPC to generate probabilistic winter precipitation products. In contrast, direct approaches use numerical parameterizations of microphysical processes to explicitly predict p-type (e.g., Reeves et al. 2016; Barszcz et al. 2018). Hybrid approaches, combining direct and indirect methods, are used by the Rapid Refresh (RAP) and HRRR models for high-resolution, short-term forecasting. (e.g., Benjamin et al. 2016).

Room for improvement remains in prediction of p-type. For instance, a U.S. Weather Research Program workshop working group agreed that, "the most serious problem with wintertime quantitative precipitation forecasting is the accurate determination of p-type when the surface temperature is near freezing" (Ralph et al. 2005). In bulk statistics, models are generally accurate in discerning between rain versus snow (e.g., Benjamin et al. 2016), though this accuracy can decline in situations where forecast conditions are close to freezing or in regions of complex terrain. Discerning between freezing rain and ice pellets is a particularly difficult challenge (Reeves et al. 2014; Barszcz et al. 2018). In response to these issues, testing of methods for p-type forecasting was a focus of the recent 2017–2018 Hydrometeorological Testbed–WPC Winter Weather Experiment.

Severe convection

The risk for severe weather may be locally modified where there are meso-gamma scale (2−20-km) interactions between the background flow and major river valleys or mountain ranges. Such interactions include areas of upslope and downslope flow (Wasula et al. 2002; Markowski and Dotzek 2011; Murray and Colle 2011), channeling of the low-level flow

(LaPenta et al. 2005; Bosart et al. 2006; Geerts et al. 2009; Kovacs and Kirshbaum 2016), and the formation of air masses with differing low-level moisture and thermal properties (Riley and Bosart 1987; Tang et al. 2016). These mesoscale inhomogeneities can affect convection by creating preferential areas for convective initiation and locally increasing convective severity. For example, channeling of low-level flow can locally increase the VWS and storm-relative helicity (SRH), and terrain-induced, low-level convergence can locally increase the low-level moisture and CAPE (Katona et al. 2016). Mesoscale boundaries between terrain-influenced air masses can also form, leading to stationary or dry-line-like boundaries, which can subsequently provide a focus for convective initiation or increase the severity of convection as it interacts with the boundary (Atkins et al. 1999; Tang et al. 2016).

Predictive skill is hampered due to deficiencies in representing any of a number of factors in high-resolution NWP models. First, there may be deficiencies in representing synoptic-scale triggers for convection, particularly if these triggers are uncertain or weak (Lombardo and Colle 2011; Hurlbut and Cohen 2014), or are dependent on antecedent convection (e.g., Trier and Davis 2007). Second, there may be deficiencies in boundary layer (BL) schemes representing the evolution of the BL depth and mixing of momentum, and energy, through the BL (e.g., Cohen et al. 2015, 2017; Evans et al. 2018). Owing to inappropriate assumptions of flatness and homogeneity (e.g., Epifanio 2007; Muñoz-Esparza et al. 2016), there may be substantial errors/biases when employing BL schemes in environments of complex terrain with relatively inhomogeneous environments that have a potential mosaic of stable, neutral, and unstable BLs. This second deficiency applies to both warm- and cold-season high-impact weather.

A practical example of BL sensitivity is illustrated in Figure 1, which shows the total snowfall difference field between two Nor'easter simulations that vary by the magnitude of BL moisture mixing. The differences (up to 250 mm or 10") result from a combination of factors, including subtle changes in cyclone motion, moisture-driven variations of warm sector CAPE, and surface-layer stability shifts over both land and water areas. This case is an example of uncertainty, as there is little direct information regarding which BL scheme produces the most realistic mixing, and motivates the stochastic parameter perturbations (SPP) strategy, especially on vertical moisture mixing. Serafin et al. (2018) suggested that inadequacies in model physics design owing to these, and other model assumptions, could be addressed via SPP.

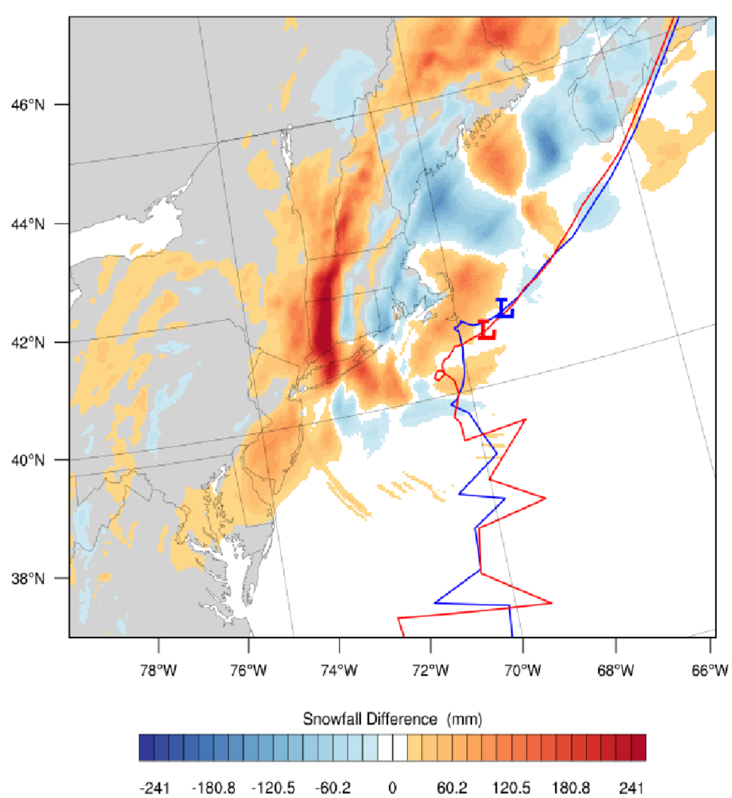

Figure 1*: Storm total snowfall depth difference (mm) between two simulations of the 26–29 January 2015 Nor'easter using BL scheme variants that differ with respect to vertical moisture mixing. Bold "L"s represent cyclone center locations at 0600 UTC 28 January 2015 and solid lines denote cyclone tracks.*

Data fusion

For both local and national NWS forecasters, an ever-increasing wealth of information is available in real-time. This information includes model forecasts with a variety of temporal and spatial resolutions, high-resolution satellite, radar, in-situ (e.g., surface and radiosondes) data, and many others. In critical situations with significant time constraints, properly interpreting these data can be challenging (Morss and Ralph 2007). Ideally, forecasters can compare model forecast data with current observations to assess the validity of those models. Accomplishing this can be made difficult, however, by the sheer volume of both model forecasts and observations. A potential path forward is the creation of tools or products that optimally combine high-resolution model data with observations to improve short-term (1–12-h) forecasting. Such tools would use machine learning to assess what model forecast factors determine the relative outcome of both severe weather forecasts and precipitation uncertainties, and then provide benchmarks in real-time for forecasters to evaluate against observations to help determine the most likely verifying outcome.

Scientific objectives

Our scientific objectives center on improving understanding and forecasting of p-type and severe convection in regions of complex topography, and in the face of model uncertainty. We focus on New York State as a testbed for our ideas because: (1) it experiences high-impact events of both types, which are modified by modest, but complex, topography, and (2) it is home to the NYSM, described below, which provides a uniquely-detailed observational dataset for model evaluation and data fusion efforts. Additionally, we expect the knowledge and tools gained from this project will be broadly applicable to areas outside of NYS.

Our research addresses the following scientific objectives for terrain-influenced winter p-type and summer severe convection:

- Evaluation of the factors that limit practical predictability in CAMs, including the relative roles of uncertainty in synoptic-scale initial and boundary conditions (ICs/BCs) and in parameterized model physics.
- Evaluation of the ability of CAM microphysics (MP) and turbulence parameterizations to adequately represent key physical processes. Identification of key biases that should be accounted for or corrected.
- Evaluation of the utility of multi-physics and single-physics SPP approaches for accounting for physical-process uncertainty in CAM ensembles for probabilistic forecasting.
- Evaluation of data fusion, post-processing tools that combine both dynamical model output and diverse operational observations using modern machine learning.
- Use of targeted field observations to aid in understanding and reducing forecast uncertainty and forecast bias.

Data and methods

New York State Mesonet

The New York State Mesonet (NYSM; *http://www.nysmesonet.org*) is a sophisticated and unique mesoscale observing system recently deployed with funding obtained in the wake of Hurricane Sandy (2012). The network consists of 126 standard stations, which are distributed as

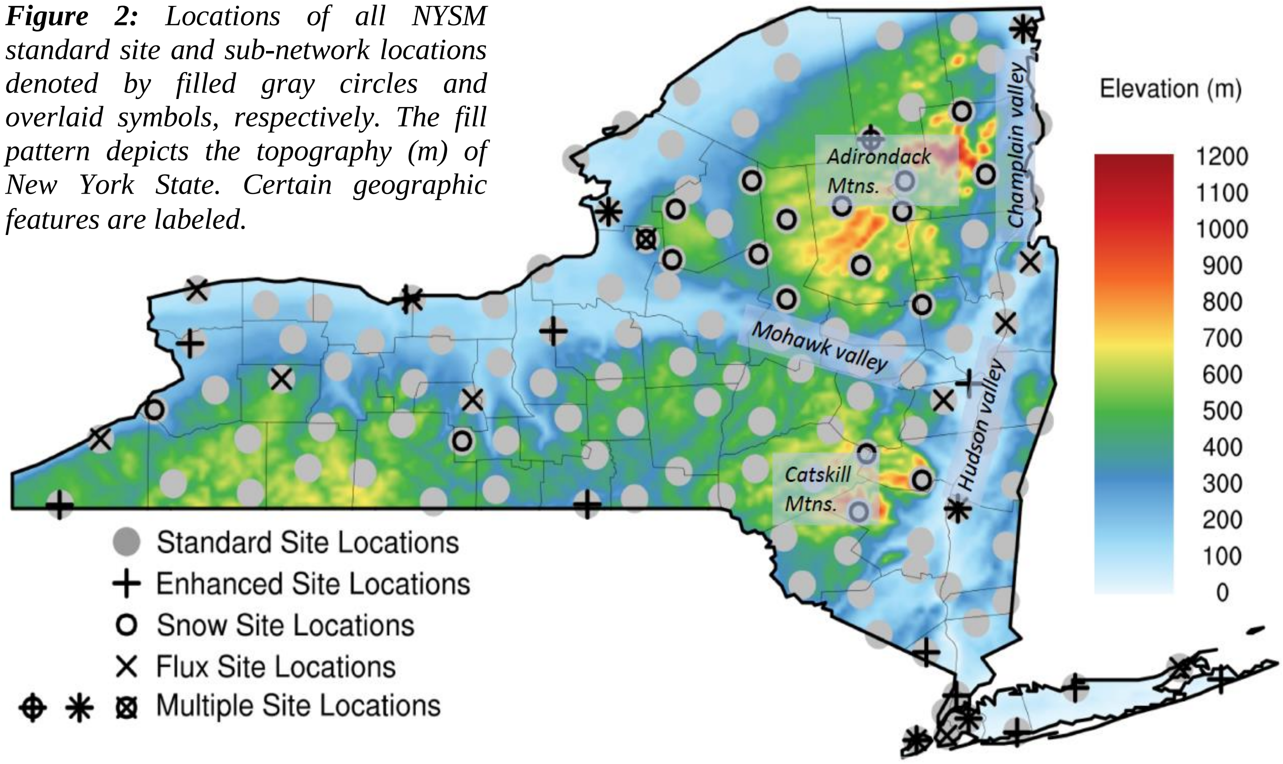

Figure 2: *Locations of all NYSM standard site and sub-network locations denoted by filled gray circles and overlaid symbols, respectively. The fill pattern depicts the topography (m) of New York State. Certain geographic features are labeled.*

evenly as is feasible across the state, while also maintaining a minimum of one per county (Figure 2). The stations measure a wide variety of standard meteorological variables (e.g., 10-m wind, 2-m temperature, precipitation, pressure, etc.) in addition to less common variables (e.g., snow depth, 9-m temperature, soil temperature and moisture, camera images, etc.). The network also consists of three sub-networks (Fig. 2): 20 "snow" sites that measure snow–water equivalent; 17 "enhanced" sites equipped with microwave radiometers, LiDARs, and sky imaging sun radiometers; and, 17 "flux" sites that further measure surface energy budget components, including turbulent and radiative fluxes. All data is collected within 5 minutes of measurement, and undergoes extensive automated and manual quality control.

Methodology

Below, we outline the general methodology that will be used to study high-impact winter precipitation and summer severe convective events (project specific details follow):

1) Identify and characterize low-predictive skill and/or high-impact events in consultation with NWS collaborators at Eastern Region Focal Points (see Section 4b).
2) Conduct retrospective simulations of selected events with the UAlbany high-resolution (UAHR) model suite with HRRR(E)-like and High-resolution Ensemble Forecast (HREF)-like physics (Table 1). Similar physics combinations are currently being evaluated for the CAM–FV3 (Gallo et al. 2018), so these simulations will also be applicable to FV3 development. We will begin by using WRF as the dynamical core for the UAHR and then transition to a stand-alone-regional (SAR) version of FV3 once it is available to the university research community. The initial, baseline WRF configuration is similar to a configuration that is being used in current CSTAR research led by Co-PIs

Minder and Tang. There are three domains, with the innermost domain covering the entire Northeast with a horizontal grid spacing of 3 km. The physics of our control configuration are chosen to emulate the HRRR model, including Thompson (THOM; Thompson and Eidhammer 2014) microphysics and MYNN boundary layer turbulence (Nakanishi and Niino 2009).

3) Explore the role of physics uncertainty with sensitivity experiments that alter BL or MP parameterizations to create ensembles. UAHR_BL and UAHR_MP experiments will generate multi-physics ensembles, analogous to the approach used in HREF. UAHR_BL_SPP and UAHR_MP_SPP will apply SPP to the MYNN and THOM schemes, an approach under development for use in the HRRRE (e.g., Jankov et al. 2018). Physics experiments will be initialized 6 h prior to convective initiation or precipitation onset, and will use RAP analyses for ICs and BCs to focus on errors associated with model physics.

4) Explore the role of IC/BC uncertainty with UAHR_ICBC experiments that will generate ensembles forced by GEFS or HRRRE output. These will be initialized at multiple times to explore how spread varies with lead time.

Table 1: *Proposed UAHR model suites.*

UAHR suite	Members	Physics or ICs/BCs	Notes
UAHR_BL	4	BL: MYNN, YSU, MYJ, EDMF	Emulates HRRR, HREF, and FV3 BL choices
UAHR_MP	7	MP: THOM, WSM6, FERR, MYAU, P3, NSSL, GFDL	Emulates HRRR, HREF, and FV3 microphysics choices (plus select others)
UAHR_BL_SPP	8	MYNN with stochastic physics perturbations applied	Emulates possible, future HRRRE component
UAHR_MP_SPP	8	THOM with stochastic physics perturbations applied	Emulates possible, future HRRRE component
UAHR_ICBC	9–21	ICs/BCs from HRRRE or GEFS	

5) Determine circumstances (e.g., synoptic-flow regimes and environmental factors) when physics-type, physics-parameter, or IC/BC uncertainty dominates in event outcomes. Compare the structure and character of ensemble spread generated by each approach.

6) Compare model-simulated fields with observations, including the NYSM, to assess simulation accuracy, characterize and constrain uncertainty in physics schemes, and understand how performance varies between schemes and across environments.

7) Conduct small-scale field experiments of opportunity, launching soundings and deploying instruments ahead of, and during, events that have the potential to be high impact, in order to collect data to compare with HREF, HRRR(E), and CAM–FV3 forecasts, particularly where they show significant differences.

8) Devise data fusion products, taking HREF, HRRR(E), and CAM–FV3 output and combining it with NYSM, radar, and GOES-16 observations to highlight areas where impacts are likely, forecasts are uncertain, and/or models are exhibiting errors/biases.

Project 1: Near-freezing winter precipitation type in complex terrain

Lead: Justin Minder

Members: Robert Fovell, Andrea Lang, Nick Bassill

Cases will be drawn from the past three years (with the addition of interesting events that occur during the lifetime of the grant) in order to effectively leverage data from the NYSM. We will catalog significant near-0˚C precipitation events that occur throughout upstate NY, with a focus on the Hudson, Mohawk, and Champlain Valleys, where terrain influences are likely important (Fig. 2). Events will be selected using archived observations and input from our collaborators at the NWS, and will be classified based on the observed p-type, thermodynamic profile, and synoptic setting. We will also consider forecast skill, comparing to guidance, high-resolution NWP, and official WPC forecasts. With input from NWS Focal Points, we will select a handful of high-impact and difficult to forecast cases for further study, sampling a range of observed p-types, synoptic settings, and thermodynamic conditions. The selected cases will be simulated using the above-described UAHR_BL, UAHR_BL_SPP, UAHR_MP, UAHR_ICBC, and UAHR_MP_SPP configurations. Simulated p-type will be diagnosed following the methodology used for the HRRR (Benjamin et al. 2016).

For all experiments, simulated surface p-type will be evaluated against ASOS and crowd-sourced Meteorological Phenomena Identification Near the Ground (mPING) observations (Elmore et al. 2014). Accumulated liquid equivalent precipitation and snow depth will be evaluated against ASOS, COOP, and NYSM observations. Potential observational biases will be considered (e.g., Rasmussen et al. 2012; Reeves et al. 2016).

Results from the UAHR_ICBC experiments will be used to investigate how synoptic-scale forecast uncertainties limit predictability by comparing thermodynamic profiles and p-types across ensemble members and lead times. Spread across the UAHR_ICBC ensemble members will be related to variations in synoptic-scale flow features (as in Durran et al. 2013) and also interpreted in terms of mesoscale-terrain influences on airflow and thermodynamic feedbacks.

Results of the various physics experiments will be used to understand how uncertainties in parameterized processes limit predictability. In addition to comparing simulated p-types against observations, we will conduct process-focused evaluations to characterize how well the simulations capture important mechanisms. ASOS and NYSM surface observations will be used to evaluate near-surface air temperature and humidity, as well as ground temperature and snow cover. Operational sounding observations will be used to evaluate thermodynamic profiles. NYSM surface winds and LiDAR-observed BL wind profiles will be used to evaluate mesoscale and boundary layer circulations. Operational, dual-polarization, WSR-88D data will be used to evaluate microphysical conditions aloft via hydrometeor classification algorithm output, objective melting layer detection (e.g., Giangrande et al. 2008), and refreezing layer signatures (e.g., Tobin and Kumjian 2017).

Project 2: Severe convection in complex terrain and across severe-weather environments

Lead: Brian Tang

Members: Robert Fovell, Ross Lazear, and Nick Bassill

Cases will be chosen from a database of Northeast severe weather events (Vaughan et al. 2017) and events identified by NWS Focal Points, with an emphasis on events that have occurred since 2016 to effectively leverage data from the NYSM. We will classify cases based on synoptic-flow direction (e.g., 500-hPa southwesterly, westerly, and northwesterly flow), regionally-averaged convective environment characteristics (CAPE and 0–6-km VWS), storm reports (wind, hail, and tornadoes), and convective mode(s) in order to provide historical context and match events of similar character. We may choose to focus on a select combination of these classifiers (e.g., 500-hPa southwesterly flow, low-CAPE, high-VWS, and severe wind-producing quasi-linear convective systems) to focus on low-predictive-skill cases that are common to the Northeast (e.g., Lombardo and Colle 2013).

The selected cases will be simulated using the above-described UAHR_BL, UAHR_BL_SPP, and UAHR_ICBC configurations, so that we may focus on BL physics and IC/BC uncertainties. We will compare the mesoscale environments across UAHR members, with a focus on BL variables, such as the BL height, 0–1-km VWS, 0–1-km SRH, CAPE, BL-average and surface temperature, and BL-average and surface water vapor mixing ratio. At locations in the pre-convective environment where there is a relatively large spread in these variables, we will compare the evolution of model forecast soundings of temperature, moisture, and wind to identify reasons for these differences. For example, a BL scheme that has less mixing intensity (e.g., a local-mixing scheme) may tend to be slow in diurnally mixing out weak capping inversions that typify valley areas, leading to increased/prolonged flow channeling (higher VWS and SRH), lower temperatures, and higher moisture. On the other hand, if there is little spread among the UAHR_BL/SPP members, but a larger spread among the UAHR_IC members, this result would suggest IC uncertainty dominates over BL physics uncertainty.

We will analyze how differences in mesoscale environments affect the simulated convective evolution and severity through conventional proxy metrics for severe weather, such as simulated composite reflectivity, 2–5-km updraft helicity, surface wind speed, surface vorticity, and column-maximum vertical velocity. Comparison of UAHR members will be performed with cross sections and trajectories, which will allow differences in surface and BL properties to be analyzed in both Eulerian and Lagrangian frameworks.

For recent cases that occur within the NYSM network, we will compare the model forecast data to NYSM surface and profiler data in pre-convective environments. The NYSM data will be used to calculate verification statistics (e.g., root mean squared errors, biases, and rank histograms) of wind, temperature, and moisture variables at the surface and in the lower troposphere. The verification statistics will allow an objective assessment of the circumstances under which different BL schemes perform better, when IC spread dominates, and whether SPP improves spread-error ratios in complex terrain, similar to Cohen et al. (2017) and Jankov et al. (2018). We will also perform the same verification on the HREF, HRRR, and experimental HRRRE and CAM–FV3, so that comparable members/ensembles in the UAHR model suites can be compared to their operational/experimental counterparts.

Project 3: Observational and data fusion applications to assess forecast uncertainty and improve analyses

Lead: Kristen Corbosiero

Members: Nick Bassill, Andrea Lang, and Ross Lazear

The above projects focus on CAM forecasts of winter p-type and summer severe convection in complex terrain. This project focuses on integration and application of existing observational data with the methodologies and outcomes from preceding projects. The goal of this project is to use data fusion techniques with observational and model data to assess forecast uncertainty and real-time analysis of conditions in periods of high-impact weather.

We will identify high-impact weather events associated with uncertain p-type and severe convection in regions of complex terrain from cases compiled in previous UAlbany CSTAR projects, including days with severe weather in the Northeast, high-impact transition-season and cool-season snowstorms[1], as well as the knowledge of relevant cases from NWS Focal Points. From these cases, we will use archived ensemble forecast data sets (e.g., GEFS reforecast version 2, HRRRE) to quantify uncertainty in p-type and severe weather outcome forecasts at 0 to 2 day lead times. Next, a subset of the model data (70%) will undergo statistical post-processing using a machine-learning algorithm known as a random forest (e.g., Gagne et al. 2014, 2017; Herman and Schumacher 2018). Random forests can identify patterns and nonlinear interactions in data, attributes that have the ability to correct for various kinds of model biases (e.g., Herman and Schumacher 2018). The remaining data (30%) will be used to evaluate forecast skill gained by using the random forest prediction.

Table 2: *Potential variables for successful prediction of p-type, severe weather, or both. Observed surface variables are **bold**. The list is not exhaustive and subject to change.*

Severe Weather		Both	Precipitation Type	
Surface/ML/MU CAPE	**Lifting condensation level (LCL)**	**Surface (2-m) dew point (depression)**	Critical thicknesses (1000–500 hPa, 1000–850 hPa)	**Skin temperature and/or soil temperature**
Surface/ML/MU CIN	Level of free convection (LFC)	**Surface (2-m) Temperature**	**Surface (2-m) wet bulb temperature**	Dendritic growth layer depth
Lapse rate (low-/mid-level)	Helicity (0–1,0–3 km)	Freezing level height	850 & 925-hPa temperature	Positive & negative areas[1]
Bulk shear (0–1,0–3,0–6 km)	Solar insolation (e.g., heating)	**Total hourly precipitation**		*[1]Bourgouin (2000)*
		Elevation		
		Boundary layer height & depth		

Once the model data-only random forest prediction is evaluated, a second set of random forests will be created using observational data (e.g., NYSM, satellite, and radar). These observation-only forests will be evaluated for the p-type and severe weather and cases. Finally, a third set of random forests will be created, and evaluated, to include both model and observational data. Some examples of the quantities to be evaluated are listed in Table 2, although these are subject to change upon initial results and availability. The evaluation of the random forest predictions will involve the calculation of contingency tables and a comparison of the biases in the raw model data and post-processed forecasts.

[1] *See VLab: https://vlab.ncep.noaa.gov/web/albany-cstar*

A benefit of using the random forest is that it provides a quantification of variable importance. We will use this information for identifying observations of interest, and launch soundings, collect p-type observations, and deploy optical disdrometers for targeted, low-predictability, high-impact events associated with wintertime p-type and summertime convective hazards. For summer observations, the goal will be to collect pre-convective observations in specific areas where CAMs show significant differences in BL evolution due to terrain and/or mesoscale features, and where there is no NYSM profiler data (e.g., the Mohawk Valley). For winter observations, the goal will be to collect observations ahead of, and throughout, the precipitation event in valley areas where CAMs show significant differences in thermodynamic profile or p-type. Observations collected will be used to highlight areas where mesoscale BL features, terrain effects, and physics uncertainty may enhance forecast uncertainty of severe weather and p-type, and to evaluate NWP forecast errors.

The assessment of variable importance from the random forest and case study analysis will likely reveal that some important variables are easily observed across a large geographic footprint in near real-time (e.g., 2-m temperature), while others are difficult to observe across a widespread region (e.g., 0–3-km helicity). Thus, multiple variables will be utilized in the development of weather-hazard specific products to minimize the possibility of important variables being unavailable to a forecaster in real-time. The UAHR suite created for various historical events with significant terrain influence will be used for testing purposes toward product generation.

In an operational mode, derived data fusion products will leverage multiple high-resolution CAMs in predicting areas of forecast uncertainty. For each hazard, the available forecasts will be ranked according to the severity (or uncertainty) within their forecast for the location of interest. For instance, forecasts of summertime convection would be ranked based upon the likelihood/size of hail, strength of updraft helicity, and significant surface winds. For p-type, forecasts would be ranked according to metrics such as time- and area-integrated snowfall (and/or freezing rain or sleet). Once available models have been ranked, the variables of greatest importance will be assessed for each forecast hour leading up to the event. This assessment will determine which meteorological variables are most significantly related to the likelihood of future severe weather or wintertime precipitation. These variables can then be plotted on a map of the region corresponding to specific timeframes.

An example is provided using a severe weather case as a thought experiment. If available high-resolution models suggest possible severe weather in the Albany WFO, model forecasts would be ranked according to their forecast synthetic severe reports. Afterward, significant severe weather variables would be assessed for each of these forecasts at earlier forecast times and ranked in order of importance to future severe weather. If the available forecast models suggest possible severe weather in between 1900 and 2200 UTC, a hypothetical product would highlight observable weather predictors at earlier forecasts times. This product would highlight geographic regions that met certain thresholds and critical times, as shown in Figure 3. For example, 2-m dew point temperature in excess of 18°C over southern NY at 1400 UTC, integrated daily solar insolation of 10 MJ over the lower Hudson Valley by 1500 UTC, and most unstable CAPE of 1000 J kg^{-1} across western and central NY by 1600 UTC. Such a product would allow local forecasters to assess which forecast scenario was most likely to occur by comparing observed data to provided benchmarks.

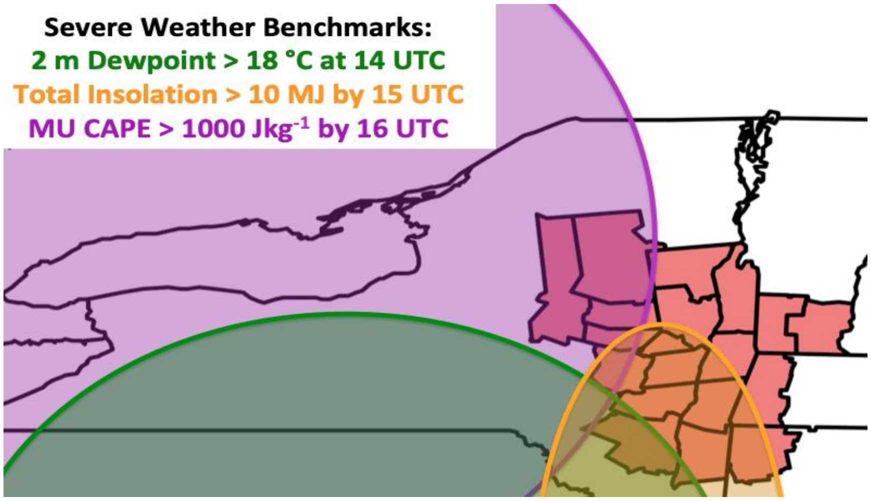

Figure 3: *Potential data fusion product. In this hypothetical case, severe weather in the ALY WFO (highlighted in pink) would be most dependent on benchmark values of parameters available in the model guidance. The parameters, and their location- and time-dependence, would be unique to each forecast.*

Timeline

Year 1:

- **Projects 1 & 2:** Identify and characterize events of interest. Conduct physics and IC/BC experiments and characterize uncertainty. Evaluate experiments against observations.
- **Project 3:** Create a database of recent cases of a) severe weather outbreaks in complex terrain; and, b) mixed-phase weather events. Train the random forest to identify the most important observational and forecast variables in predicting the significant hazards.

Year 2:

- **Projects 1 & 2:** Conduct SPP physics experiments. Evaluate experiments against mesoscale observations. Participate in field experiments.
- **Project 3:** Conduct field experiments on two cases of low-predictability severe convection and two cases of low-predictability mixed-phase precipitation events.

Year 3:

- **Projects 1 & 2:** Complete any outstanding experiments. Complete evaluation against observations. Synthesize results. Prepare and submit publications.
- **Project 3:** Generate operational products and conceptual diagrams highlighting important variables in predicting severe weather and mixed-precipitation weather events.

b) Framework for Cooperative Research with the NWS

NWS Focal Points, Contributors, and Collaborative Projects *(from NWS SOO Mike Evans)*

The proposed research projects have been designed to facilitate the transfer of research findings into the NWS operational warning and forecast environment to improve situational awareness and scientific interpretation of high-impact weather events. Each project involves one UAlbany graduate student jointly advised by UAlbany team members and NWS Focal Points. The Focal Points advise students on operational perspectives, and may provide datasets/cases, or participate actively in the research and publication processes. They collaborate and coordinate with their assigned graduate student(s) and ensure operational aspects of the project remain in focus. The Focal Points first conduct an initial meeting with the student where the operational significance of the project is discussed and regularly scheduled meetings (minimum of four per year) follow. The Focal Points provide input for six-month reports and develop a recorded presentation, journal article, or technical attachment based on the work. In addition, each project includes a list of one or more NWS participants, referred to as NWS Contributors, who will support the Focal Points in ensuring a meaningful R2O process occurs at the end of the project.

Project 1: Near-freezing winter precipitation type in complex terrain
Focal Points: Mike Evans (ALY) and Frank Nocera (BOX)
Contributors: Dan Thompson (ALY) and Jared Klein (BGM)

Project 2: Severe convection in complex terrain and across severe-weather environments
Focal Points: Tom Wasula (ALY) and Joe Dellicarpini (BOX)
Contributors: Dan Thompson (ALY), Hayden Frank (BOX), and Kat Hawley (NESDIS)

Project 3: Data fusion applications to assess forecast uncertainty and improve analyses
Focal Points: Christina Speciale, Joe Cebulko, and Neil Stuart (ALY)
Contributors: Kat Hawley (NESDIS)

In order to increase the participation of NWS personnel in complementary research outside of the three major projects, our framework incorporates an additional category, NWS Collaborative Projects, the rationale for which is to take advantage of interest on the part of NWS staff members in conducting CSTAR-related research that extends beyond the scope of the three proposed research projects. NWS–UAlbany undergraduate student interns and independent research students participate in these projects for full academic years, or summer sessions.

1) Improvement of tornado detection and lead time
Joe Dellicarpini (BOX) and Christina Speciale (ALY).

2) Warm-season QPF challenges: Identifying situations when model precipitation areal coverage, location, and maximum amounts will be skillful
Justin Arnott (GYX)

3) Recent dual-polarization radar techniques to support severe weather operations
Mike Jurewicz (CTP)

4) Using GLM lightning data in operations for severe weather forecasting and enhanced DSS
Jared Klein (BGM) and Mike Jurewicz (CTP)

5) Using GAZPACHO to verify high-resolution model snowfall forecasts from 2017–2019
Joe Villani and Mike Evans (ALY)

6) Examination of significant hail events: expand the project across the Northeast U.S.
Tom Wasula (ALY)

7) The role of the strength of large-scale low-level forcing on severe weather event magnitudes
Neil Stuart and Joe Cebulko (ALY)

8) Factors that determine the skill of tornado watches in the ALY County warning area
Joe Cebulko (ALY)

UAlbany–NWS Liaison

As an additional means to facilitate R2O, Ross Lazear will continue his role as the liaison between UAlbany and the NWS. In this capacity, Mr. Lazear will build upon R2O efforts begun in CSTAR VI. A page on the NOAA VLab was developed and made publicly available in order to centrally store and disseminate succinct, operationally relevant research results and completed M.S. theses from the primary CSTAR projects (see *https://vlab.ncep.noaa.gov/web/albany-cstar*). CSTAR-related teletraining modules, conceptual diagrams, and operationally relevant results from new CSTAR projects, as well as those from CSTAR I–V, will continue to be added to VLab. Conceptual diagrams and concise research results will be linked to operations through keywords via the AWIPS Interactive Reference utility. A major R2O focus moving forward will be integrating primary CSTAR results into web-based products. A new page for such products will be developed and housed on the VLab.

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NYS Mesonet
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To whom it may concern,

The New York State (NYS) Mesonet enthusiastically supports the goals of the CSTAR proposal "Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain". The primary mission of the Mesonet is to save lives and reduce the economic impacts from high-impact weather, and this CSTAR proposal is a major step towards utilizing Mesonet data for improved warning operations. In particular, CSTAR will accelerate research-to-operations in two ways: (1) Assist with interpretation and direct integration of data into NWS warning operations, and (2) Use of Mesonet data for numerical model evaluation and improvement. The Mesonet works closely with NOAA and individual NWS Weather Forecast Offices across the Eastern Region, and this CSTAR proposal builds upon that collaboration.

On January 7, 2014, the governor of New York State, Governor Cuomo, announced the formation of the New York State Early Warning Weather Detection System - an advanced, statewide early warning weather detection system or Mesonet. Funded by FEMA, this $30.5 million network is the first of its kind in New York and consists of 126 surface weather stations and 54 non-standard sites that detect weather phenomena across the entire state. Deployment of the Mesonet, operated by the State University of New York at Albany (SUNY-Albany), facilitates improved spatial (30 km spacing) and temporal (5-min) observing capability across a large and diverse region, providing real-time access to high-resolution data and analyses.

Each of the Mesonet's 126 Standard weather stations measures air temperature, relative humidity, wind speed and direction, precipitation, solar radiation, barometric pressure, snow depth, and soil moisture and temperature at three depths (5, 25, and 50 cm). In addition, 17 "profiler" sites are outfitted with LiDARs and microwave profilers, providing wind, temperature, and moisture profiles in the vertical. Another 17 sites are equipped with flux measurement systems, estimating the surface energy budget, and yet another 20 sites measure snow water equivalent. All of these data are transmitted in real-time to a central location, where the data are quality controlled and archived, and then disseminated to a variety of users, including our research partners. For more information, see http://nysmesonet.org.

The NYS Mesonet will provide to the project all quality-controlled data from its 180 station network as needed. These data will include both the Standard and Profiler site observations. NYS Mesonet data made available to project PIs will be restricted for use on this project, and all Mesonet data will remain subject to the NYS Mesonet data policy. The NYS Mesonet data policy restricts sharing, selling or redistributing Mesonet data and associated derived products. The NYS Mesonet acknowledgement statement, data policy and terms of use are available on its website at http://nysmesonet.org/research/. NYS Mesonet personnel will work closely with project PIs to ensure careful use and application of the Mesonet data.

The execution of this project will be a high priority for our organization. The New York State Mesonet strongly supports the scientific goals presented in the CSTAR proposal and is eager to participate in its success.

Sincerely,

Jerald A Brotzge

Jerald Brotzge, PhD
Program Manager, New York State Mesonet

UNITED STATES DEPARTMENT OF COMMERCE
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December 7, 2018

Christopher Hedge
NOAA/NWS
1325 East-West Highway, Room 15328
Silver Spring, MD 20910-3283

Dear Mr. Hedge:

I am offering my support for the CSTAR proposal "**Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain**" submitted by faculty at the University at Albany–SUNY.

This proposal focuses on studying high impact severe convective weather and wintertime precipitation events in complex terrain through high resolution numerical modeling and data collection/fusion efforts. The proposed work aims to build upon previous CSTAR efforts to improve the lead-time and accuracy of forecasts and warnings for high-impact weather events. Given the success of UAlbany in establishing and maintaining productive collaborative interactions with forecasters at NWS Forecast Offices and NCEP Centers, including SPC, this effort should continue to build upon these collaborative relationships.

The SPC looks forward to working with UAlbany and NWS Eastern Region Forecast Offices in examining and studying severe convective weather and mixed-phase precipitation events in complex terrain. The research emphasis on mesoscale weather is of great importance to SPC and can play a role in improving NWS severe and winter weather services; therefore, I recommend funding of this proposal.

Sincerely,

Russell Schneider

Dr. Russell S. Schneider
Director, SPC

UNITED STATES DEPARTMENT OF COMMERCE
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7 December 2018

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Silver Spring, MD 20910

CSTAR Program Officers and Reviewers,

I am writing to strongly support the CSTAR proposal, 'Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain" by PI Kristen Corbosiero and Co-PIs Andrea Lang, Justin Minder, Brian Tang, Ross Lazaer, Nicholas Bassill, and Robert Fovell of the University of Albany. Convection allowing ensemble forecasts provide a promise to be a vital part of the future of operational Numerical Weather Prediction (NWP). The convective allowing models possess the capability of explicitly resolving mesoscale features such as squall lines, banding features in winter cyclones, and terrain interactions. Therefore, the ability to forecast such high impact phenomena hinges on accurate depiction by convective permitting numerical models.

This proposal aims to develop and test convective allowing ensemble forecasts of high-impact weather events in the northeastern US. They aim to utilize convection-allowing models and storm-scale ensemble systems to advance Warn-on-Forecast capabilities. Of interest to WPC, the group will work on wintertime precipitation type in complex terrain as well as working to identify and collecting, observations for use in real-time data fusion applications for assessment of forecast uncertainty and improved surface analyses.

The proposal activities laid out in the proposal offer a framework in which to achieve their goals. Understanding the sources of uncertainty can help explain the role ensembles have in creating the envelope of potential solutions for a variety of parameters. And fusing this with a comprehensive observational database will help identify areas more prone to uncertainty in complex terrain.

The PIs are looking to extend on their current CSTAR project titled: "Development of Improved Diagnostics, Numerical Models, and Situational Awareness of High-Impact Cyclones and Convective Weather Events".

The WPC strongly supports this activity and enthusiastically endorses funding of this proposal. The proposed work has direct relevance for probabilistic snowfall and precipitation type products and how best to communicate this information to the public. We expect to be an active participant in their research, and look forward to starting this important collaborative work.

Sincerely,

James A Nelson Jr

James Nelson
Branch Chief – NCEP/NWS/WPC Development and Training Branch
5830 University Research Court – Rm 4633
College Park, MD 20740

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Earth System Research Laboratory
325 Broadway – David Skaggs Research Center
Boulder, Colorado 80305-3337

10 December 2018

To:
Dr. Christopher Hedge
Office of Science and Technology
NOAA/National Weather Service
1325 East-West Highway, Suite 15328
Silver Spring, MD 20910

I acknowledge that the goals in the CSTAR proposal entitled, "Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain" help support the Global Systems Division (GSD) mission. There are two projects in the proposed work: 1) severe convection in complex terrain and across different severe-weather environments, and 2) numerical forecasts of winter precipitation type in complex terrain. The two projects will foster collaboration between GSD and investigators/graduate students at the University at Albany to improve the use of high-resolution models for forecasting high-impact weather events in both the warm and cold seasons. The High-Resolution Rapid Refresh (HRRR) model is used operationally to forecast both severe convection and winter precipitation and GSD scientists are working to improve the representation of the mesoscale environment prior to and during these events. The collaboration will aid in HRRR (and its Unified Forecast System successor) model development by increasing the evaluation of existing physics parameterizations and verification of HRRR forecasts along with improving strategies for stochastic parameter perturbations being evaluated in the HRRR ensemble. GSD scientists will work with the PIs to share code and archived model output and facilitate the research-to-operations transfer of knowledge so that the lessons learned from this project will have direct gains in improving operational models.

Sincerely,

Curtis R. Alexander

Dr. Curtis R. Alexander
Acting Chief, Assimilation Development Branch
Global Systems Division
curtis.alexander@noaa.gov
303-497-4725

7. CURRICULA VITAE

On 20 November 2018, CSTAR Program Manager, Dr. Hedge, approved a request to use web links for the CVs of the UAlbany CSTAR team. The use of online CVs allows the proposal to remain under the 25-page limit, while including a large number of participants, spanning multiple areas of expertise, and increasing the research potential of the UAlbany–WFO ALY CSTAR team. Links to the CVs of the PI, Co-PIs, and UAlbany–NWS liaison appear below.

a. Kristen L. Corbosiero:
http://www.atmos.albany.edu/facstaff/kristen/CSTARVII/Corbosiero_CSTAR_CV.pdf

b. Nicholas P. Bassill:
http://www.atmos.albany.edu/facstaff/kristen/CSTARVII/Bassill_CSTAR_CV.pdf

c. Robert G. Fovell:
http://www.atmos.albany.edu/facstaff/kristen/CSTARVII/Fovell_CSTAR_CV.pdf

d. Andrea A. Lopez Lang:
http://www.atmos.albany.edu/facstaff/kristen/CSTARVII/Lang_CSTAR_CV.pdf

e. Justin R. Minder:
http://www.atmos.albany.edu/facstaff/kristen/CSTARVII/Minder_CSTAR_CV.pdf

f. Brian H. Tang:
http://www.atmos.albany.edu/facstaff/kristen/CSTARVII/Tang_CSTAR_CV.pdf

g. Ross A. Lazear:
http://www.atmos.albany.edu/facstaff/kristen/CSTARVII/Lazear_CSTAR_CV.pdf

8. DATA MANAGEMENT PLAN

We will archive model output from numerical simulations of identified high-impact warm- and cold-season events. These model data will be archived on disks maintained by the Data Center at UAlbany. The data will be stored in NetCDF format, following Climate and Forecast metadata conventions, and will include all information necessary to reproduce our experiments. The data fusion tools will utilize machine learning packages freely available in Python. These data and information will be made available to any individual who makes a request to use the code for their own research or operational purposes. Furthermore, if the project results in modifications or additions to the model codes, these will be offered to the code developers, for possible adoption, and to others upon request. We will also provide data and documentation needed to reproduce figures, tables, and other representations of the data in publications and presentations to those who request it. Also upon request, data will be disseminated using the UAlbany Thematic Real-time Environmental Distributed Data Services (THREDDS) server, which "provides metadata and data access for scientific datasets, using a variety of remote data access protocols." The methodology and code will be documented in VLab, as well as uploaded to an open source platform (e.g., GitHub) when applicable. Operationally relevant data, training materials, and documentation will be disseminated using our NOAA VLab page (*https://vlab.ncep.noaa.gov/web/albany-cstar*).

The PI, co-PIs, and graduate students will each participate in the archival and dissemination of data, and we have included adequate resources to achieve this task in our budget. Mr. Kevin Tyle, a university-funded, computer support specialist with additional expertise in data management, will aid in the archival and dissemination of our large datasets.

9. CURRENT AND PENDING

I. Kristen L. Corbosiero

A. Currently Funded

1. **Development of Improved Diagnostics, Numerical Models, and Situational Awarness of High-Impact Cyclones and Convective Weather Events** - *PI*
   NOAA/NWS/CSTAR NA16NWS4680005 .50/.50/.50 $450,000 5/1/16-4/30/19
2. **Investigating Tropical Cyclone Intensity Change due to Trough-induced Vertical Wind Shear** - *PI*
   NASA NNX17AG95G 1 / 1 / 1 $299,997 2/24/17-2/23/20
3. **Physics and Dynamics of the Tropical Cyclone Cirrus Canopy** - *Co-PI*
   NSF AGS1636799 1 / 1 / 1 $574,752 4/17/17 - 3/31/20
4. **Investigating Ventilation Processes and Effects on Tropical Cyclones** - *Co-PI*
   NSF AGS1748779 1 / 1 / 1 $397,626 3/15/18-2/28/21

B. Pending

1. **Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain -** *PI*
   NOAA/NWS/CSTAR- *this proposal* .50/.50/.50 $450,000 5/1/19-4/30/22

II. Nicholas Bassill

A. Currently Funded **None**

B. Pending

1. **Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain -** *Co-PI*
   NOAA/NWS/CSTAR- *this proposal* .50/.50/.50 $450,000 5/1/19-4/30/22

III. Robert Fovell

A. Currently Funded

1. **Collaborative Research: S12-SSI: Big Weather Web: A Common and Sustainable Big Data Infrastructure in Support of Weather Prediction Research and Education in Universities** - *PI*
   NSF 1450195 .50/.50/.50 $246,111 8/1/15-9/30/19
2. **Physics and Dynamics of the Tropical Cyclone Cirrus Canopy** - *Co-PI*
   NSF AGS1636799 1 / 1 / 1 $574,752 4/17/17 - 3/31/20
3. **Assessing Wind Hazards Associated with the October 2017 Northern California Wildfires** - *PI*
   Pacific Gas and Electric Company 3 $240,000 10/1/18-9/30/19

B. Pending

1. **Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain -** *Co-PI*
   NOAA/NWS/CSTAR- *this proposal* .50/.50/.50 $450,000 5/1/19-4/30/22

IV. Andrea Lang

A. Currently Funded

1. **Development of Improved Diagnostics, Numerical Models, and Situational Awarness of High-Impact Cyclones and Convective Weather Events** - *Co-PI*
   NOAA/NWS/CSTAR NA16NWS4680005 .50/.50/.50 $450,000 5/1/16-4/30/19

2. **A Climatological and Forecast Perspective on the Lower Stratospheric Environment During Synoptic Waveguide Perturbation Events**
   NSF AGS1547814 1 / 1 / 1 $361,907 7/1/16-6/30/19
3. **A Categorical Assessment of Forecast Skill, Uncertainty, and Biases in Extended-Range Ensemble Forecasts of Stratospheric Regime Changes** - *PI*
   NOAA NA16OAR4310068 1 / 1 / 1 $363,882 7/1/16–6/30/19
4. **Understanding the Role of the Stratosphere in Sub-Seasonal-to-Seasonal Variability and Predictability of Arctic Weather Systems** - *PI*
   ONR NN000141812199 1 / 1 / 1 / 1 / 1 $620,078 3/1/18-2/28/23

B. Pending

1. **IGE: Collaborative Research: Community Achieving Reproducible Data Science (CARDS) -** *PI*
   NSF 1 / 1 / 1 $155,000 7/1/19-6/30/22
2. **Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain -** *Co-PI*
   NOAA/NWS/CSTAR- *this proposal* .50/.50/.50 $450,000 5/1/19-4/30/22

V. Justin Minder

A. Currently Funded

1. **CAREER: The Mesoscale Climate Dynamics of Rocky Mountain Snowpack Depletion -** *PI*
   NSF AGS1349990 1 / 1 / 1 / 1 / 1 $581,396 3/1/14–2/28/19
2. **Development of Improved Diagnostics, Numerical Models, and Situational Awarness of High-Impact Cyclones and Convective Weather Events** - *Co-PI*
   NOAA/NWS/CSTAR NA16NWS4680005 .50/.50/.50 $450,000 5/1/16-4/30/19

B. Pending

1. **Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain -** *Co-PI*
   NOAA/NWS/CSTAR- *this proposal* .50/.50/.50 $450,000 5/1/19-4/30/22

VI. Brian Tang

1. **Development of Improved Diagnostics, Numerical Models, and Situational Awarness of High-Impact Cyclones and Convective Weather Events** - *Co-PI*
   NOAA/NWS/CSTAR NA16NWS4680005 .50/.50/.50 $450,000 5/1/16-4/30/19
2. **Intensity and Frequency of Severe Hailstorms** - *PI*
   Bermuda Institute of Ocean Sciences .50 / 0 $52,032 8/22/16-7/31/19
3. **Investigating Tropical Cyclone Intensity Change due to Trough-induced Vertical Wind Shear** - *Co-PI*
   NASA NNX17AG95G 1 / 1 / 1 $299,997 2/24/17-2/23/20
4. **Investigating Ventilation Processes and Effects on Tropical Cyclones** - *PI*
   NSF AGS1748779 1 / 1 / 1 $397,626 3/15/18-2/28/21

B. Pending

1. **Improving Analyses, Numerical Models, and Situational Awareness of High-Impact Severe Convective and Mixed-Phase Precipitation Events in Complex Terrain -** *Co-PI*
   NOAA/NWS/CSTAR- *this proposal* .50/.50/.50 $450,000 5/1/19-4/30/22

10. BUDGET TABLE

	Yr1 Sum	*2% increase Yrs 2-3*				Year 1	Year 2	Year 3	Total
						5/1/19-4/30/20	5/1/20-4/30/21	5/1/21-4/30/22	5/1/19-4/30/22
Senior Personnel	Mo Salary	Yr 2	Yr 3	#of mon					
PI - Kristen Corbosiero	9,860	10,057	10,258	0.50	Sum mo	4,930	5,029	5,129	15,088
Co-PI - Nicholas Bassill	8,588	8,760	8,935	0.50	Cal mo	4,294	4,380	4,468	13,142
Co-PI - Robert Fovell	14,070	14,351	14,638	0.50	Sum mo	7,035	7,176	7,319	21,530
Co-PI - Andrea Lang	9,162	9,345	9,532	0.50	Sum mo	4,581	4,673	4,766	14,020
Co-PI - Justin Minder	9,682	9,876	10,074	0.50	Sum mo	4,841	4,938	5,037	14,816
Co-PI - Brian Tang	9,162	9,345	9,532	0.50	Sum mo	4,581	4,673	4,766	14,020
Other Personnel	Mo Salary			#of mon					
Ross Lazear - Extra Service	6,215	6,339	6,466	0.50	extra service	3,108	3,170	3,233	9,511
Nathan Bain -Sr. Programmer	8,077	8,239	8,404	0.50	Cal mo	4,039	4,120	4,202	12,361
3 Graduate Students TBD	2,335			3	Sum mo	21,015	21,015	21,015	63,045
TOTAL Salaries and Wages						**58,424**	**59,174**	**59,935**	**177,533**
Fringe Benefits	Yr 1	Yr 2	Yr 3						
PI and Co-PI	14.0%	14.0%	14.5%			3,636	3,708	3,917	11,261
Bassill and Bain	40.0%	42.0%	43.0%			3,333	3,570	3,728	10,631
Ross Lazear-Extra Service	62.48%	63.02%	66.61%			1,942	1,998	2,154	6,094
Graduate Students	16.0%	18.0%	18.5%			3,362	3,783	3,888	11,033
TOTAL Fringe Benefits						12,273	13,059	13,687	39,019
TOTAL Salaries, Wages and Fringe Benefits						**70,697**	**72,233**	**73,622**	**216,552**
Travel - Domestic									
6 People per year to attend AMS or other professional conference									
$600 Airfare Albany, NY to Washington, DC						3,600	3,600	3,600	10,800
$270 /day per diem for 5 days in Washington, DC ($1,350 each)						8,100	8,100	8,100	24,300
$50 /person ground transportation						300	300	300	35,100
$350 /person conference registration						2,100	2,100	2,100	6,300
TOTAL Travel - Domestic						**14,100**	**14,100**	**14,100**	**42,300**
Supplies									
3 Desktops/laptops solely for project $3,005 each						9,015			9,015
Annual supplies						1,000	999	450	2,449
Launch Soundings @$325/launch (7 launches yrs 1-3)						2,275	2,275	2,275	6,825
Disk space							1,680	840	2,520
TOTAL Supplies						**12,290**	**4,954**	**3,565**	**20,809**
Other Direct Costs									
2 Publications in the AMS journal ($145 * 20 pages = $2,900 each)						-	5,800	5,800	11,600
TOTAL Other Direct Costs						**-**	**5,800**	**5,800**	**11,600**
Total Direct Costs						**97,087**	**97,087**	**97,087**	**291,261**
Indirect Cost Base						*97,087*	*97,087*	*97,087*	*291,261*
Total Indirect Costs	54.50% MTDC					**52,913**	**52,913**	**52,913**	**158,739**
TOTAL COSTS						**150,000**	**150,000**	**150,000**	**450,000**

11. BUDGET JUSTIFICATION

PERSONNEL Total: $177,533

Name & Title	Amount of support years 1–3	Yr1	Yr2	Yr3	Total
Kristen Corbosiero, PI	.50 summer month	$4,930	$5,029	$5,129	$15,088

Lead the Data Fusion project and oversee the overall coordination of the grant

Nicholas Bassill, Co-PI	.50 calendar month	$4,294	$4,380	$4,446	$13,142

Provide NYSM and synoptic meteorology expertise to all three projects

Robert Fovell, Co-PI	.50 summer month	$7,035	$7,176	$7,319	$21,530

Provide modeling expertise to the Precipitation Type and Severe Convection projects

Andrea Lang, Co-PI	.50 summer month	$4,581	$4,673	$4,766	$14,020

Provide synoptic and machine learning expertise to Precipitation Type & Data Fusion projects

Justin Minder, Co-PI	.50 summer month	$4,841	$4,938	$5,037	$14,816

Lead the Precipitation Type project creating a case-study database and overseeing modeling

Brian Tang, Co-PI	.50 summer month	$4,581	$4,673	$4,766	$14,020

Lead the Severe Convection project creating a case-study database and overseeing modeling

Ross Lazear, Extra Service	.50 calendar month	$3,108	$3,170	$3,233	$9,511

Extra Service Compensation for Instructional Support Specialist, Ross Lazear, of .50 calendar month at approximately 112 hours over the course of 12 months (outside of normal hours) in years 1–3 is requested. Mr. Lazear will serve as the primary liaison between the department and National Weather Service (NWS), including the duties of coordinating the undergraduate internship program, drafting research summaries for distribution to the NWS, and developing conceptual models and forecast checklists for transfer of research into operations. He will also be responsible for providing weather forecasts for the Data Fusion project field experiments.

Nathan Bain, Sr. Programmer	.50 calendar month	$4,039	$4,120	$4,202	$12,361

Provide NYSM data quality control support for the project

A 2% increase is assumed for all salaries above in years 2–3.

3 Graduate students	3 sum. months $2,335/mon.	$21,015	$21,015	$21,015	$63,045

Research assistantships are requested for three graduate students, one assigned to each of the three projects, who will work on this grant during the summer in years 1–3. The students will process and analyze data, run numerical models, and create forecast products for R2O.

FRINGE BENEFITS Total: $39,019

	Year 1			Year 2			Year 3		
Name	**Salary**	**Rate**	**Total**	**Salary**	**Rate**	**Total**	**Salary**	**Rate**	**Total**
PI and Co-PI	$25,968	14%	$3,636	$26,489	14%	$3,708	$27,017	14.5%	$3,917
Bassill and Bain	$8,333	40%	$3,333	$8,500	42%	$3,570	$8,670	43%	$3,728
Lazear	$3,108	62.48%	$1,942	$3,170	63.02%	$1,998	$3,233	66.61%	$2,154
3 Grad Students	$21,015	16%	$3,362	$21,015	18%	$3,783	$21,015	18.5%	$3,888

TRAVEL Total: $42,300

Domestic Travel:	**Per Year**
1 trip x 6 people @ $600 airfare to Washington, DC	$3,600
5 days per diem x $270/day ($201/$69) x 6 people	$8,100
Conference registration $350 per person	$2,100
Ground transportation $50 per person	$ 300
Total:	$14,100

Support is requested in years 1–3 for six people to attend one American Meteorological Society, (or other professional) conference to present research findings, or to participate in NOAA workshop activities (e.g., the SPC Spring, or WPC Winter Weather, Experiment). Since the locations are not known at this time, the Washington, DC rates are being used as an estimate.

SUPPLIES Total: $20,809

In year 1, three desktop and/or laptop ($3,005 each) computers are requested for the graduate students. They will use the computers solely for this project to log into the departmental servers to process and analyze data, run numerical models, and prepare figures for publication. Also requested is disk space for data related to this project only, which will be stored on the departmental server ($1,680 year 2 and $840 year 3). Annual supplies include computer software, printer cartridges, and computer supplies needed for conducting the proposed objectives of this research project, and the preparation of publications and reports related to this project only ($1,000 year 1, $999 year 2, and $450 year 3). Materials for the launching of soundings are requested for seven launches per year @ $325 ($2,275/year).
Purchases will be made through the Purchasing Office at the New York State Contract prices.

OTHER DIRECT COSTS Total: $11,600

Publications: Page charges resulting from publication of research results are estimated for two publications in year 2 and 3 in the journals of the American Meteorological Society. The cost of the publication is estimated at $2,900 (20 pages @ $145 per page).

TOTAL DIRECT COSTS Total: $291,261

INDIRECT COSTS Total: $158,739

Indirect costs at the University at Albany are charged a rate of 54.5% MTDC in years 1–3. Tuition for the research assistant is excluded from the indirect cost base. Fringe benefits and indirect costs are charged according to The Research Foundation's negotiated indirect cost rate agreement dated 5/08/2018 per Cognizant F&A Cost Negotiator, Ryan McCarthy, Department of Health & Human Service, 26 Federal Plaza, New York, NY 10278, (212) 264-0918.

Total Indirect Cost Base	**$291,261**
Multiplied by Indirect Cost Rate 54.5%	
Total Indirect Costs:	**$158,739**
TOTALS – DIRECT AND INDIRECT COSTS	**$450,000**

COLLEGES AND UNIVERSITIES RATE AGREEMENT

EIN: 1146013200F3

ORGANIZATION:

RFSUNY and SUNY at Albany
35 State Street, 3rd Floor
Albany, NY 12207-2826

DATE:05/08/2018

FILING REF.: The preceding agreement was dated 01/10/2018

The rates approved in this agreement are for use on grants, contracts and other agreements with the Federal Government, subject to the conditions in Section III.

SECTION I: INDIRECT COST RATES

RATE TYPES: FIXED FINAL PROV. (PROVISIONAL) PRED. (PREDETERMINED)

	EFFECTIVE PERIOD				
TYPE	**FROM**	**TO**	**RATE(%)**	**LOCATION**	**APPLICABLE TO**
PRED.	07/01/2017	06/30/2019	54.50	On-Campus	Research
PRED.	07/01/2017	06/30/2019	26.00	Off-Campus	Research
PRED.	07/01/2017	06/30/2019	53.00	On-Campus	Instruction
PRED.	07/01/2017	06/30/2019	26.00	Off-Campus	Instruction
PRED.	07/01/2017	06/30/2019	58.50	On-Campus	Research DOD Contract
PRED.	07/01/2017	06/30/2019	30.00	Off-Campus	Research DOD Contract
PRED.	07/01/2017	06/30/2019	32.00	On-Campus	Other Sponsored Activities
PRED.	07/01/2017	06/30/2019	26.00	Off-Campus	Other Sponsored Activities
PRED.	07/01/2017	06/30/2019	6.00	All	IPA (A)
PROV.	07/01/2019	Until Amended			Use same rates and conditions as those cited for fiscal year ending June 30, 2019.

*BASE

Modified total direct costs, consisting of all direct salaries and wages, applicable fringe benefits, materials and supplies, services, travel and up to the first $25,000 of each subaward (regardless of the period of performance of the subawards under the award). Modified total direct costs shall exclude equipment, capital expenditures, charges for patient care, rental costs, tuition remission, scholarships and fellowships, participant support costs and the portion of each subaward in excess of $25,000. Other items may only be excluded when necessary to avoid a serious inequity in the distribution of indirect costs, and with the approval of the cognizant agency for indirect costs.

(A) See Special Remarks (5)

ORGANIZATION: RFSUNY and SUNY at Albany

AGREEMENT DATE: 5/8/2018

SECTION I: FRINGE BENEFIT RATES**

TYPE	FROM	TO	RATE(%)	LOCATION	APPLICABLE TO
FIXED	7/1/2017	6/30/2018	40.00	All	Regular Employees
FIXED	7/1/2017	6/30/2018	14.00	All	Summer Employees
FIXED	7/1/2017	6/30/2018	14.00	All	Graduate Students
FIXED	7/1/2017	6/30/2018	5.00	All	Undergraduate Student
FIXED	7/1/2018	6/30/2019	40.00	All	Regular Employees
FIXED	7/1/2018	6/30/2019	14.00	All	Summer Employees
FIXED	7/1/2018	6/30/2019	16.00	All	Graduate Students
FIXED	7/1/2018	6/30/2019	5.00	All	Undergraduate Student
PROV.	7/1/2019	6/30/2021	42.00	All	Regular Employees
PROV.	7/1/2019	6/30/2021	14.00	All	Summer Employees
PROV.	7/1/2019	6/30/2021	18.00	All	Graduate Students
PROV.	7/1/2019	6/30/2021	5.00	All	Undergraduate Student
PROV.	7/1/2019	6/30/2021	25.00	All	Post-Doctoral

** DESCRIPTION OF FRINGE BENEFITS RATE BASE:

Salaries and wages.

SECTION II: SPECIAL REMARKS

TREATMENT OF FRINGE BENEFITS:

The fringe benefits are charged using the rate(s) listed in the Fringe Benefits Section of this Agreement. The fringe benefits included in the rate(s) are listed below.

1. These Facilities and Administrative cost rates apply when grants and contracts are awarded jointly to Research Foundation for SUNY and SUNY at Albany.

2. For all activities performed in facilities not owned or leased by the institution or to which rent is directly allocated to the project(s), the off campus rate will apply. Actual costs will be apportioned between on-campus and off-campus components. Each portion will bear the appropriate rate.

3. The fringe benefit costs listed below are reimbursed to the grantee through the direct fringe benefit rates applicable to Research Foundation employees:

A. Retiree Health Insurance
B. Retirement Expense
C. Social Security
D. NYS Unemployment Insurance
E. NYS Disability Insurance
F. Group Health Insurance
G. Group Life Insurance
H. Long Term Dis. Ins.
I. Workers' Compensation
J. Dental Insurance
K. Vacation & Sick Leave*
L. Vision Benefits

*This component consists of payments for accrued unused vacation leave made in accordance with the Research Foundation Leave Policy to employees who have terminated, changed accruing status, or transferred. It also includes payments for absences over 30 calendar-days that are charged to sick leave.

The fringe benefit costs for State University of New York employees are charged utilizing the New York State fringe benefit rate for federal funds. This approved rate is contained in the New York State-Wide Cost Allocation Plan. This rate includes the following costs:

A. Social Security	E. Workers' Compensation	I. Vision Benefits
B. Retirement	F. Survivors' Benefits	
C. Health Insurance	G. Dental Insurance	
D. Unemployment Benefits	H. Employee Benefit Funds	

4. Equipment means tangible personal property (including information technology systems) having a useful life of more than one year and a per-unit acquisition cost which equals or exceeds the lesser of the capitalization level established by the non-Federal entity for financial statement purposes, or $5,000.

5. Treatment of Paid Absences: *Vacation, holiday, sick leave pay and other paid absences are included in salaries and wages and are claimed on grants, contracts and other agreements as part of the normal cost for salaries and wages. Separate claims for the cost of these paid absences are not made.

6. This rate applies to positions covered under the Intergovernmental Personnel Act (IPA) Mobility Program. This rate includes the applicable administrative costs only.

** Your next FB proposal based on actual costs for the fiscal year ending 06/30/2018 is due in our office by 12/31/2018.

** Your next IDC proposal based on actual costs for the fiscal year ending 06/30/2018 is due in our office by 12/31/2018.

This rate agreement updates fringe benefit rates only.

SECTION III: GENERAL

A. LIMITATIONS:

The rates in this Agreement are subject to any statutory or administrative limitations and apply to a given grant, contract or other agreement only to the extent that funds are available. Acceptance of the rates is subject to the following conditions: (1) Only costs incurred by the organization were included in its facilities and administrative cost pools as finally accepted: such costs are legal obligations of the organization and are allowable under the governing cost principles; (2) The same costs that have been treated as facilities and administrative costs are not claimed as direct costs; (3) Similar types of costs have been accorded consistent accounting treatment; and (4) The information provided by the organization which was used to establish the rates is not later found to be materially incomplete or inaccurate by the Federal Government. In such situations the rate(s) would be subject to renegotiation at the discretion of the Federal Government.

B. ACCOUNTING CHANGES:

This Agreement is based on the accounting system purported by the organization to be in effect during the Agreement period. Changes to the method of accounting for costs which affect the amount of reimbursement resulting from the use of this Agreement require prior approval of the authorized representative of the cognizant agency. Such changes include, but are not limited to, changes in the charging of a particular type of cost from facilities and administrative to direct. Failure to obtain approval may result in cost disallowances.

C. FIXED RATES:

If a fixed rate is in this Agreement, it is based on an estimate of the costs for the period covered by the rate. When the actual costs for this period are determined, an adjustment will be made to a rate of a future year(s) to compensate for the difference between the costs used to establish the fixed rate and actual costs.

D. USE BY OTHER FEDERAL AGENCIES:

The rates in this Agreement were approved in accordance with the authority in Title 2 of the Code of Federal Regulations, Part 200 (2 CFR 200), and should be applied to grants, contracts and other agreements covered by 2 CFR 200, subject to any limitations in A above. The organization may provide copies of the Agreement to other Federal Agencies to give them early notification of the Agreement.

E. OTHER:

If any Federal contract, grant or other agreement is reimbursing facilities and administrative costs by a means other than the approved rate(s) in this Agreement, the organization should (1) credit such costs to the affected programs, and (2) apply the approved rate(s) to the appropriate base to identify the proper amount of facilities and administrative costs allocable to these programs.

BY THE INSTITUTION:

RFSUNY and SUNY at Albany

(INSTITUTION)

Christopher J Wade

(SIGNATURE)

Christopher J. Wade

(NAME)

Senior Director of Finance

(TITLE)

5/23/18

(DATE)

ON BEHALF OF THE FEDERAL GOVERNMENT:

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Darryl W. Mayes -S

Digitally signed by Darryl W. Mayes -S
DN: c=US, o=U.S. Government, ou=HHS, ou=PSC, ou=People, 0.9.2342.19200300.100.1.1=2000131669, cn=Darryl W. Mayes -S
Date: 2018.05.31 13:03:24 -04'00'

(SIGNATURE)

Darryl W. Mayes

(NAME)

Deputy Director, Cost Allocation Services

(TITLE)

5/8/2018

(DATE) 5708

HHS REPRESENTATIVE: Ryan McCarthy

Telephone: (212) 264-2069