Exhibit A - Statement of Work

This Research Statement of Work is made and entered into effective the 1st day of July, 2015 by Eversource Energy Service Company, for itself and as agent for its affiliates, having principal offices at 107 Selden Street, Berlin, CT 06037 ("Company") and UNIVERSITY OF CONNECTICUT ("University") pursuant to the terms of the SECOND AMENDED AND RESTATED SPONSOR RESEARCH AND SERVICES AGREEMENT between Company and University dated May 1st, 2015 (the "Sponsor Research Agreement").

Both Parties agree to participate in Research to be conducted in accordance with the terms and conditions of the Sponsor Research Agreement and this Research Statement of Work, provided however, that in the event of a conflict between the terms and conditions of the Sponsor Research Agreement and this Research Statement of Work, the terms of the Sponsor Research Agreement shall be controlling.

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Date: 9/18/2015

The Connecticut Light and Power Company doing business as Eversource Energy

By:

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Final - Sept. 15, 2015

Research/Project Description: Next Generation Predictive Storm & Damage Modeling Enhancements for Preparedness and Emergency Response Support

Lead(s): E.N. Anagnostou (PI), Marina Astitha and Dave Wanik

A. Problem Statement

Severe weather is the leading cause of damages to the overhead electric distribution grid, and recent weather events like Storm Irene (2011), the October nor'easter (2011), and Hurricane Sandy (2012) have shown a need for improved disaster preparedness, response and mitigation strategies. Adequate planning before these disasters can ameliorate many issues by giving better predictions of storm damages and the expected length of time before power is restored. Such preparation can help Eversource Energy to allocate equipment and personnel more efficiently, and the public can better manage their expectations about when the power will return. Another aspect of disaster preparedness is proactive management of the distribution grid, which entails such strategies as enhanced vegetation management and selective infrastructure hardening improvements. Understanding how the different resilience strategies contribute to improving system vulnerability can provide insight into which strategies can provide the greatest benefit customers and enhance electric reliability.

Modeling power grid distribution damages is a complex topic due to the different interactions involved (e.g. combination of weather effects, tree conditions, soil saturation, infrastructure age) and an assortment of methods have been used; including data mining, parametric, semi-parametric and non-parametric methods. Specifically, such models include: generalized linear models (GLMs) (Cerruti and Decker 2012; Li et al. 2010), spatial and non-spatial generalized linear mixed models (GLMMs) (Guikema and Davidson 2006; Liu et al. 2008), generalized additive models (GAMs) (Han et al. 2009a,b), classification and regression trees (CART) (Quiring et al. 2011), Bayesian additive regression trees (BART) (Nateghi et al. 2011), and hybrid approaches that combine methods into two stages (Guikema and Quiring 2012).

Each of the aforementioned models has relative strengths and weaknesses. Among the different methods data mining techniques like CART and BART have proved effective at predicting outages and damages when implemented as individual models, averaged ensemble (traditional ensemble), or as part of a hybrid two stage model. In the past year we researched the application of such models for Connecticut (Connecticut Light & Power Company, dba as Eversource Energy "Eversource") service territory evaluating their predictions of spatial damage patterns and their ability to perform statistical inference (Wanik et al. 2014, 2015; He et al. 2015). Our research so far has targeted three important questions:

- how accurate are the various nonparametric models in providing point estimates for a range of storm severities and types?
- how efficient are these models in evaluating the prediction uncertainty (i.e. prediction intervals)? and

- how well dynamic components of the power grid system (e.g. vegetation management, electric system hardening, etc.) can be represented in the models?

This project will significantly enhance the existing UConn's storm damage model adding functionality and performance accuracy. Specifically, UConn's storm damage modeling work so far has combined utility-specific infrastructure and land cover data, aggregated around overhead lines, to build damage prediction models for Connecticut (Eversouce CT) service territory. To calibrate the model UC have used the state-of-the-art Weather Research and Forecasting (WRF; Skamarock et al. 2008) atmospheric model to provide high-resolution analyses for more than 110 storm events, which span a decade (2005 – 2014), occurred during different seasons and represent varying severities (from hurricanes to isolated thunderstorms). Two prediction systems, one that combines four decision tree-based models (Wanik et al. 2014) and a second based on BART and GLM (He et al. 2015) have been used in our research. We have shown that models forced with combination of weather, infrastructure and land cover data is superior to simpler models, especially in terms of predicting the spatial distribution of damages. A case study highlighting the town-by-town predictions of damages from the more complex models was presented for Storm Irene (2011) and Hurricane Sandy (2012) in Wanik et al. (2014) and He et al. (2015).

This first generation storm damage prediction model has been implemented in an operational forecasting system (https://dpm.engr.uconn.edu), which since August 2014 has been used by Eversource for storm emergency preparedness functions within the Eversouce CT service territory. Performance evaluation of the operational system in the past several months has shown a satisfactory performance for events triggered in the late summer to fall period, but exhibited biases in two recent winter events, i.e. blizzard Juno and Feb 7th coastal storm. Preliminary investigation on those cases has shown that forecast biases are attributed to the weather forecasting uncertainty (particularly in the Juno case where we showed sensitivity of the WRF forecasts to NOAA's initial and boundary conditions) and the choice of DPM forcing parameters (particularly for the Feb 7th coastal storm where we showed significant dependence of DPM output on the choice of weather parameters).

Furthermore, given that land cover has generally been used to represent the trees around the overhead lines, we believe that incorporating additional tree-related data around the overhead lines could improve the representation of tree hazard potential in damage prediction model (connection with vegetation management project proposed by J. Volin et al.).

Although there is a sizeable amount of research devoted to vegetation management (VM), right-of-ways (ROWs) and transmission lines, there is considerably less effort devoted to distribution networks. However, the general consensus is that VM can decrease outages for storm and fair-weather days. Utilities cannot trim everywhere because VM must be done with a limited budget (delivering electricity at low rates while being proactive is a difficult compromise). Specifically, Eversource CT employs two trimming treatments: standard maintenance tree trimming (SMT) that usually occurs in lower risk areas, and a more aggressive form of VM known as enhanced tree trimming (ETT), which is used in areas with higher risk. Arguably, using the vegetation management information available by Eversource (e.g. ETT and

SMT) in the DPM modeling could significantly improve the model's forecasting accuracy relative to the current DPM model that does not account for vegetation management effects. Furthermore, this modeling framework can be applied to demonstrate the benefit of using attributes of the overhead lines (for example, percentage of bare or covered wire; percentage of backbone or lateral circuit). Random forest and BART models will be used for this purpose. Five model forcing complexities will be evaluated by selecting models with the most improved error metrics. The output of the enhanced model will be used in impact assessment studies for the ETT and SMT vegetation management plans of Eversource based on retrospective analysis of past major and minor events.

Finally, utilities must evaluate whether they are prepared for future emergency management scenarios, including those impacts related to climate change. The general consensus is that, under current emissions scenarios, the severity of storms may intensify in future climate conditions (IPCC, 2014). ***This project will build on the DPM by adding a new vegetation management parameterization allowing the Company to develop and utilize functionality that assists in investigating the impact of potential future-climate storm scenarios (e.g. hurricanes) on the electric grids of the Connecticut service territory.*** For example, future climate hurricane tracks have been developed by altering large-scale thermodynamics conditions associated with global climate change (Lackmann, 2014). Our initial results comparing electric grid damages from hurricane Sandy (representing Category 1) to a potential future hurricane track from Lackmann's simulations (representing a Category 3 hurricane) yields a five times increase in damages within Eversource CT. The increased resilience planning of Eversource CT and other utilities is expected to reduce the impact of major storms, which is an aspect to be investigated in the proposed research.

B. Proposal Objectives

The primary scope of the proposed project is to develop the next generation storm based damage prediction model by investigating sources of DPM uncertainty and through research findings and analysis

(1) significantly improve the functionality and ability of the system to provide more accurate damage predictions and outage durations,
(2) better characterize forecast uncertainty in the operational damage prediction system, and
(3) enhance and extend Eversource ability to conduct extreme weather vulnerability analysis studies.

The project tasks proposed to address the scope of work and associated project deliverables along with dates are discussed next.

C. Methodology – Project tasks

The scope of work will be accomplished by performing the following three major tasks:

- The first task will focus on the development of improved tools for weather-based damage prediction on the overhead electric grid and optimal repair crew allocation.
- The second task will use DPM model to produce grid system vulnerability to a range of major weather events (Cat 1-3 hurricanes, blizzards, Nor'easters) based on different vegetation management (tree trimming) and assets hardening planning scenarios.
- The third task will continue integration of new operational capabilities of DPM model on UConn's High Performance Computing (HPC) system and providing real-time forecasts for the Connecticut service territory.

The model may continue to expand in future years to include additional Connecticut partners working with the Center, provided additional funds become available from these resources.

The proposed project tasks are described below:

Task 1: Development of improved forecasting accuracy of the damage prediction model through the following components:

1.1. *Enhance Damage Prediction Model (DPM) through improved forcing parameters and calibration*

We will start this task with an exhaustive investigation and analysis of the current damage prediction model's (Wanik et al. 2014; He et al. 2015) sensitivity to a number of factors including the selection of weather forcing parameters, vegetation information and infrastructure hardening information. Currently, the model uses a range of spatially distributed weather parameters (i.e. maps at 2-km grid resolution) including the magnitude of sustained wind at 10 meters height, duration of wind speed exceeding different thresholds, the mean and maximum values of gust wind and duration of gusts exceeding different thresholds, precipitation accumulation and precipitation rate during the max sustained wind duration, snow accumulation, an ice/freezing-rain parameter, soil moisture, near-surface air temperature and local vorticity. Preliminary results presented at the March 30th 2015 update meeting have shown sensitivity in the DPM predictions to the above weather parameters are used in the model. For example we have shown variability in the model outputs to varying combination of parameters: use of all parameters vs. sustained wind parameters alone or gust wind parameters alone. We are going to investigate those weather parameter dependences to converge to an optimal models for different weather types (e.g. snow storms/blizzards, rainfall/high-wind storms, summer thunder storms, coastal systems, Nor'easters and tropical cyclones) and seasons associated with different leaf conditions (winter-leafs off; summer-leafs on; transition months-leafs partial off). In case of no clear optimal model, combination of the various DPM forcing parameter combinations will represent an ensemble model prediction and the forested variability would constitute the DPM prediction uncertainty.

In addition, we plan to investigate regionalization of model parameters according to Area Work Centers and incorporation of dynamic information on system hardening as model parameter. This addition is expected to account for potential spatial and temporal changes in the system resilience due to selective hardening actions; information that could partially explain prediction errors in the current model. Improvements based on the different model development efforts described above will be demonstrated using recent major and minor storms (2011 to current).

1.2. *Include vegetation management information currently provided by Eversource into the new enhanced DPM model and evaluate potential improvements in forecast accuracy.*

Incorporating tree trimming information in DPM will allow us to represent dynamic changes in the system's vulnerability to weather-based tree damages. Preliminary results presented at the March 30th meeting have shown that such information can significantly improve model prediction accuracy especially in areas where vegetation management has altered the tree conditions. In this project component we will continue this effort to process the most up-to-date vegetation management information available for the Connecticut service territory (currently available in annual shapefile summaries) and use this information to calibrate the DPM models based on storm and vegetation management data since 2011. The new DPM model with the vegetation management parameterization addition will be updated on a quarterly basis to account for changes in the tree conditions around the Connecticut power grid due to vegetation management plans.

This DPM development with the vegetation management parameterization will support vulnerability analysis research to be discussed in a subsequent task.

1.3. *Improving weather/wind forecasting functionality and characterization of uncertainty*

As pointed out by many studies the near-surface (10 meter) wind speed and wind gust is among the most important meteorological variables responsible for storm-related outages. Within this context, accurate forecasting of surface wind speeds is crucial to the development of accurate tools for prediction of damages to the power distribution network. Weather and wind forecasts in the current operational system is based on the state-of-the-art Weather Research and Forecasting (WRF) model implemented at high resolution (2-km grid) and model parameterizations optimized for the storms that develop in the Northeast US. *This research aims at improving WRF modeling of surface winds by investigating mathematical and ensemble forecasting approaches that allow reduction of biases in the forecasted fields and characterization of the random error.*

Accurate forecasting of near surface wind speed magnitude and location is challenging especially when computational resources are limited. The surface wind and other surface process are resolved by parametrizations for which the level of sophistication depends on the computational affordability (Dudhia, 2014). The most typical approaches to improving wind forecasting combining cost and performance are parametrization advances, probabilistic forecasting, including post-processing techniques and model ensembles, and data assimilation (Hu et al., 2010; Delle Monache et al., 2011; Jones et al., 2007; Erickson et al., 2012; Lee et al., 2012; Muller, 2011; Wyszogrodzki et al., 2013).

Probabilistic forecasting provides probabilities of future outcomes derived from Probability Density Functions (PDF), which can also be used to derive uncertainties to a single-value prediction (Alessandrini2015). In statistical post-processing, several methods can be used to derive PDFs and uncertainties, e.g., Model Output Statistics (Glahn1972), Bayesian Model Averaging (Raftery2005), and Analog Ensemble (Dellemonache2011). Within the extent of this project, one of our goals is to develop a new methodology for deriving PDFs and uncertainties for WRF forecasts. Specifically, this task seeks to improve WRF driven numerical weather prediction of surface wind speeds for the Eversource service territory, during events that impose a threat to the electricity distribution network. We propose to explore feasible solutions and alternatives, in that we can derive an optimal forecast given the available computational resources. This objective is to be accomplished in three stages: (1) Evaluation of multiple NWP parametrizations' accuracy in representing wind fields during past events of low, medium and high impact; (2) Development a post-processing technique to estimate the wind speed uncertainty of the deterministic model arrangement defined in (1); (3) Analysis of the Damage Prediction Model (DPM) response when accounting for wind speed uncertainties, derived with the method developed in (2), versus a traditional method for generating forecast ensembles.

1.4. Develop new Coastal flooding modeling functionality in DPM

We propose to expand DPM to include coastal flooding from storm surges based on a model that is under development for coastal towns of Connecticut. The model will provide flooding levels that account for surge, high and low tides and will update those forecasts daily based on NWS surge predictions for the Long Island Sound.

1.5. Develop new optimized crew allocation module integrating damage predictions from DPM and damage estimates from peak customer outages

The storm restoration duration (SRD, hours) is the time it takes for a utility to restore power, the time between when the peak numbers of customers are affected and when 99.5% of those customers were restored. In this study, we will relate actual damage and restoration crews to predict damage the SRD for events that impacted the Connecticut service territory by using empirical and machine learning regressions (namely, artificial neural network and support vector machine). Our initial results show that crew efficiency, the average time it takes for a crew to repair a trouble spot, increases as the total number of damages increases, which may be associated with severe damage (snapped poles) or organization challenges that stem from the management of outside crews. Initial results from an empirical model and a machine learning model are shown to be acceptable. Further, we will investigate how systematic and random errors from i) our trouble spot prediction models and ii) crew efficiency estimates can subsequent SRD predictions.

Task 2: Use DPM model to produce grid system vulnerability to a range of major weather events (Cat 1-3 hurricanes, blizzards, Nor'easters) based on different vegetation management (tree trimming) and assets hardening planning scenarios.

The task will focus on three primary activities: (1) Evaluate the Connecticut electric grid vulnerability to historic severe weather events and future storm projections (e.g. future Cat 1-3 hurricanes); and (2) Evaluate impacts of tree-trimming management practices on the number of outages and outage duration in Connecticut. In this task, we will use storm tracks from future climate Hurricane Sandy simulations developed by altering large-scale thermodynamics that are consistent with global climate change (Lackmann, 2014). Our initial results using the current Sandy simulation (Cat 1 hurricane) as calibration and future Sandy track (Cat 3) as a model test yields a five times increase in damage (see Figure 1 below).

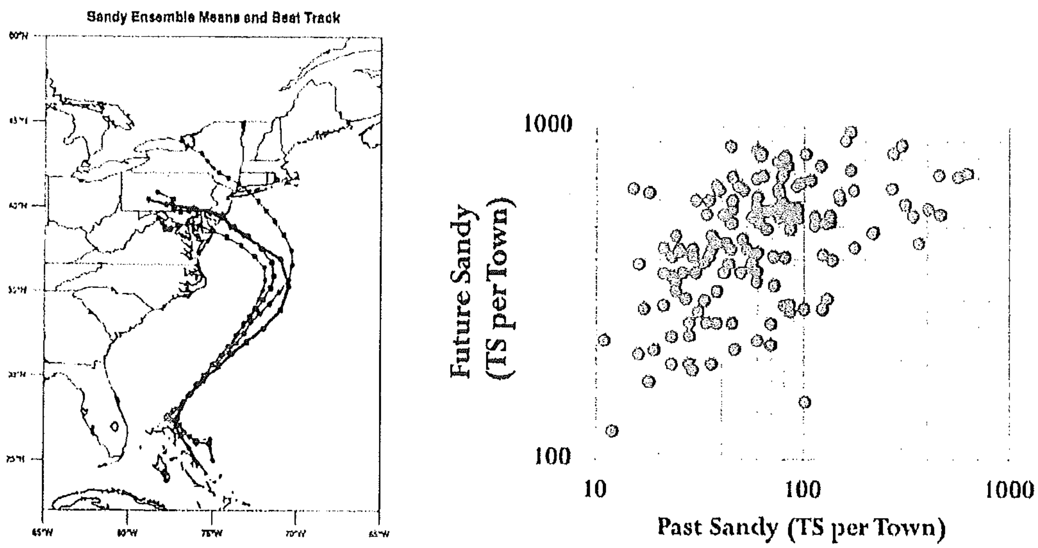

Figure 1: (Left) Different Sandy Tracks (green = past, black = actual, blue = actual prediction, red = future track) and (right) the predicted increase in damage per town in Connecticut service territory for past and future Hurricane Sandy simulations.

Task 3: Integrate new operational capabilities of DPM model on UConn's High Performance Computing (HPC) system and provide real-time forecasts for the Connecticut service territory.

The operational system is a critical component of this project as it supports the emergency decision making based on the latest and most updated DPM models. This task includes (1) continuing the development of the operational system to maximize efficiency and data dissemination, (2) transferring improved DPM models from previous tasks on a frequent basis, and (3) establishing an automated process for triggering the operational system based on multiple data sources (weather forecasts, external weather reports, other models).

D. Data Requirements

The main data requirements are the trouble spot reports, vegetation management (tree trimming) and infrastructure changes.

E. Project Deliverables and Timeline

Date	Activity Reports	DPM Enhancements (Versions) and New Module Releases	Related Tasks
10/2015	- Report results on DPM model improvement due to weather parameter forcing and regionalization of model calibration; - Report preliminary results on the dual weather model characterization of weather forecasting uncertainty	-	1.1, 1.4
01/2016	Report on improvements in DPM outage predictions from using improved weather forecasts based on: - the dual-weather forecasting development - high-resolution ensemble weather forecasts - including data from different weather vendors (e.g. Schneider Electric)	Release version 2.1 functionality improvement of DPM that includes regionalized model calibration and improved weather parameter forcing Implement the new DPM model on the Eversource Energy Center High Performance Computing cluster.	1.1, 1.3, 3
04/2016	- Report on the development of the freezing rain module of DPM; - Report on the development of the optimized crew allocation and outage duration prediction tool	-	1.1, 1.3, 1.5
07/2016	- Report results on DPM improvements from including additional data on infrastructure and tree trimming (e.g. WestCOG database; tree trimming database); - Report on the optimized crew allocation model	Release module 1.1, upgrade DPM to include (1) the freezing rain module and (2) the outage duration calculation tool.	1.1, 1.2, 1.5, 3

Date	Activity Reports	DPM Enhancements (Versions) and New Module Releases	Related Tasks
10/2016	- Report on the storm surge DPM module development; - Report on the operational DPM model improvements after one year of system improvements in DPM and weather forecasting.	Release version 2.2 functionality improvement to upgrade DPM model to dynamically include vegetation state (e.g. tree trimming, leaf area index) and infrastructure changes information.	1.1, 1.2, 1.4, 3
01/2017	- Evaluate improvements in DPM outage prediction accuracy from using LiDAR-derived potential tree hazard maps (information contributed from the Vegetation Management project); - Preliminary report on vulnerability analysis studies based on major past and future climate storm events	Release module 1.2, upgrade DPM to include (1) the storm surge component and (2) the dual-model ensemble weather forecasting component	1.1, 1.2, 2, 3
04/2017	- Report on the damage prediction uncertainty characterization by integrating the ensemble weather forecasting with the enhanced damage prediction model	Release module 1.3, to simulate outages from extreme weather events	1.1, 1.3, 3
07/2017	- Report updates on the vulnerability analysis studies; - Prepare all models for the next hurricane season;	Release module 1.4, upgrade the DPM model to (1) incorporate the final ensemble weather forecasting system, (2) vegetation management data and (3) infrastructure data in a dynamic way	2, 3
12/2017	Deliver final report that includes acceptance criteria and overall performance evaluation demonstration of the enhanced and new		3

Date	Activity Reports	DPM Enhancements (Versions) and New Module Releases	Related Tasks
	modulated DPM forecasting model including proposal for future improvements and further system development within the Eversource Center activities.		

F. Acceptance Criteria:

The DPM and vulnerability analyses deliverables will be presented at update meetings with EE Center leadership and through the operational use of our system by EE emergency response management. Our team will work on implementing feedback and comments from EE emergency response management team and EE Center leadership.

The acceptance of the enhanced model will be based on performance evaluation metrics (prediction error statistics) determined by comparing the DPM predicted outages to outage reports provided by Eversource. Error metrics will be reported for the various DPM model upgrades to demonstrate relative improvements and in the end of the project period after a two-year system operation to demonstrate the overall performance of the developed outage prediction system.

G. Project significance:

Knowing when to expect the power to come on after a major storm occurs allows the public and government agencies to appropriately prepare for prolonged power outages. Outages have direct and indirect consequences for businesses, government and social services; and all of these functions need reliable estimates of when the power will be restored in order to function. The State of Connecticut will be better prepared for natural hazards by using the tools and analyses that are under development in this continuing project; namely, creating models to predict storm damages and outage durations, evaluating the impacts of vegetation and its management on system reliability, and understanding the vulnerability of the grid to major events.

Some direct and indirect benefits from this project are listed below:

- Outages can be dramatically shortened (by improving crew and asset placement before a storm) and societal impact reduced.
- Ratepayer confidence could be boosted by:
  - Seeing projected local trouble spots in advance of a major storm, and take precautions.

    - Knowing that utilities are basing their storm preparedness decisions on quantitative data rather than guesses.
- Utility costs can be reduced by:
    - Faster power restoration
    - Better decision-framework requesting out-of-state repair crews.
    - Optimal selection of hardening strategies

H. Project Team:

The hydrometeorology team in the Environmental Engineering program of the University of Connecticut (***led by Professor Emmanouil Anagnostou, Eversource Energy Foundation Chair of Environmental Engineering***) has an extensive experience working with natural hazards research including severe weather, floods, hurricanes and lightning. The research group has been extensively funded by NASA, NOAA, the National Science Foundation and the private sector to research aspects of the water cycle predictability and applications in weather and water related hazards. We address this challenge through a multi-disciplinary research approach based on remote sensing, process based and statistical models and data assimilation frameworks to (i) understand variability at climatic scales, (ii) enhance predictability of weather/climate extremes (winds, precipitation, energy fluxes, floods, etc.) and (iii) study how changes on the frequency and intensity of extremes would affect infrastructure and human activities. In the energy sector our scientific interest has been to understand how extreme weather events like high winds, excessive precipitation or drought and unusual temperatures would affect the sector under current and future climate conditions.

The UConn team to be engaged in this project is listed below:

Emmanouil Anagnostou, Professor of Civil and Environmental Engineering, University of Connecticut, three months support to direct the Eversource Energy Center, lead the DPM project as PI, coordinate efforts on DPM model development and vulnerability analyses components of the project.

Marina Astitha, Assistant Professor of Civil and Environmental Engineering, University of Connecticut, one month support to lead the quantitative weather forecasting component of the project.

David Wanik, PhD, twelve months support for coordinating the operational system updates, lead research task 2 (optimized crew allocation modeling) and support research on damage modeling (Task 1)

Three PhD students will work on improving the accuracy of the damage prediction models and to use the models for vulnerability analysis studies.

One PhD student will support the weather forecasting improvements through data assimilation and characterize forecasting uncertainty and error propagation in outage prediction.

<u>One PhD student</u> will work with Dave Wanik to support the operational system.

<u>Partial (50%) HPC system administration</u> support for the Center

<u>Partial (50%) administrative assistant and web designer</u>

We will also seek support from two research consultants: One Prof. Brian Hartman on the improvements of DPM models, and the second is a researcher from NCAR (National Center for Atmospheric Research) for the ensemble based uncertainty characterization of weather forecasts.

I. Budget

The budget of this project is divided in a contract agreement for the total amount of ***$2,367,896 for a three-year period (July 1 2015 – December 31 2017)***; the budget includes ***costs for the Center management and operational outage forecasting system.***

The breakdown of costs per task is as following:

Project Activity	Resources / Expenses	Cost (direct+overhead)
Task 1 activities	E. Anagnostou salary (1.5 months per year) M. Astitha salary (1 month per year) D. Wanik partial support (6 month per year) B. Hartman one month support per year A graduate assistant on DPM modeling A graduate assistant on dual-weather forecasting and data assimilation A graduate assistant on error modeling and error propagation on damage prediction Travel to conferences and support of visits by international experts	$250,187 (2015) $478,825 (2016) $424,838 (2017)
Task 2 activities	E. Anagnostou (0.5 month per year) Dave Wanik partial support (2 months per year) One graduate student support	$0,0 (2015) $77,584 (2016) $157,530 (2017)
Task 3 activities	E. Anagnostou (1 month per year) D. Wanik partial support (4 months per	$442,885 (2015)

	year) One graduate student on high performance computing system implementation Web/IT work Partial High Performance Computing staff support HPC equipment purchase	$259,084 (2016) $276,963 (2017)

J. Project payment increments

Date	Payment
July 2015	$277,273
Nov 2015	$415,799
May 2016	$407,746
Nov 2016	$407,747
May 2017	$429,665
Nov 2017	$429,665

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