Proposal for a Partners Project

Title: Exploration of Near Surface Vorticity in Operational Numerical Weather Prediction
Date:

Signatures for University

University Name: University of North Dakota
Address: Twamley Hall 100
264 Centennial Drive Stop 7306
Grand Forks, ND 58202-7306

Catherine A. Finley Digitally signed by Catherine A. Finley DN: cn=Catherine A. Finley, o=University of North Dakota, ou=Dept. of Atmospheric Science, email=catherine.finley@und.edu, c=US Date: 2020.08.20 13:59:07 -05'00'

Principal Investigator
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10/8/2020

University Official (usually dept. chair)
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Jamie Mitzel Digitally signed by Jamie Mitzel Date: 2020.10.08 09:04:04 -05'00'

University Official
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Signatures for NWS

NWS Office: Des Moines, IA
Address: 9607 NW Beaver Drive
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8/27/2020

Principal Investigator(s)
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MIC NWS Des Moines
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SSD Chief (CRH)
Name (typed): Bruce Smith

STRAGER.CHRISTOPHER.S.1040261962 Digitally signed by STRAGER.CHRISTOPHER.S.1040261962 Date: 2020.08.26 09:56:08 -04'00'

Regional Director (CRH)
Name (typed): Christopher Strager

SUMMARY OF BUDGET REQUEST:

COMET FUNDS: **$14,990**
NWS FUNDS: **$6,600**

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service, Central Region Headquarters
7220 NW 101 Terrace
Kansas City, MO 64153

August 25, 2020

MEMORANDUM FOR: COMET Proposal Review Board

FROM: Christopher S. Strager
NOAA/NWS Central Region Director

SUBJECT: Exploration of Near Surface Vorticity in Operational Numerical Weather Prediction

I have reviewed the COMET proposal titled: ***Exploration of Near Surface Vorticity in Operational Numerical Weather Prediction***, submitted by the University of North Dakota and the National Weather Service (NWS) Forecast Office in Des Moines, Iowa.

This is an important topic, since these near surface processes frequently help determine which thunderstorms become tornadic while others do not. The project has the potential to help NWS warning meteorologists better understand and anticipate the near surface kinematic processes important to tornadogenesis. This will have a direct impact on the issuance of timely and accurate tornado warnings, which will subsequently help the National Weather Service further its mission to issue warnings for the protection of life and property.

I fully endorse this proposal.

Project Budget

	COMET Funds	NWS Contributions
University Senior Personnel		
1. **Cathy Finley**	**(no monetary funds requested)**	**NA**
Other University Personnel		
1. **Graduate Research Assistant (Spring/Summer)**	**$8,052**	**NA**
2. **Undergraduate research assistant**		**NA**
Fringe Benefits on University Personnel	**$644**	**NA**
Total Salaries + Fringe Benefits	**$8,696**	**NA**
NWS Personnel		
1. **Alex Krull**	**NA**	**4hr/week (approx. 208 hr total)**
2. **Mike Fowle**	**NA**	**2hr/week (approx. 104 hr total)**
Travel		
1. Research Trips (focus groups)	**$814**	**NA**
2. Conference Trips (NWA, AMS, AGU, or ICA)	**$1,121**	**$2,500**
3. Other	**NA**	**NA**
Total Travel	**$1,935**	**$2,500**

Other Direct Costs		
1. Materials & Supplies (Software license)		
2. Publication Costs (put in the NWS column if a co-author will be an NWS employee)		**$4,100**
3. Transcription services		
4. Tuition (for Graduate Assistant)		
5. Other (specify) – Survey subject recruitment and focus group incentives		
Total Other Direct Costs		**$4,100**
Indirect Costs		**NA**
1. Indirect Cost Rate	**41%**	
2. Applied to which items?	**All Items**	
Total Indirect Costs	**$4,359**	**NA**
Total Costs (Direct + Indirect)	**$14,990**	**$6,600**

NWS Checklist for Submitting a COMET Outreach Proposal

Actions Before Proposal is Submitted to COMET	YES	NO	DATE
1. Did NWS office staff and university staff meet to discuss and form outline and scope of project?	X		07/06/2020
2. Did NWS office consult Scientific Services Division (SSD) staff?	X		08/06/2020
3. Was Statement of Work and budget formulated as a team effort between university and NWS staffs?	X		07/06/2020
4. Was proposal submitted to SSD for review?	X		08/06/2020
5. Did SSD forward copies of proposals dealing with WSR-88Ddata to Radar Operations Center (ROC), Applications Branch Chief for review?	n/a	n/a	n/a
6. Did SSD forward copies of proposals dealing with hydrometeorology to the Senior Scientist of OHD for review?	n/a	n/a	n/a
7. Did SSD review the data request for project to ensure its scope and criticality for proposal?	n/a	n/a	n/a
8. Is all data for the project being ordered by NWS offices through the National Climatic Data Center's (NCDC) Research Customer Service Group free of charge?	n/a	n/a	n/a
9. Does budget include publication charges and travel costs for NWS employees to present results at scientific conferences?	X		07/06/2020
10.Does budget separate NWS costs into fiscal year costs and university costs into calendar year costs?	X		07/06/2020
11.Does proposal include a separate justification for university hardware purchases which are usually not funded by the COMET Outreach Program?	X		07/06/2020
12. Have the following people signed off on the proposal cover sheet: - MIC/HIC? - SSD Chief? - Regional Director?	X		08/18/2020
13. Is a letter of endorsement signed by regional director attached?	X		08/18/2020

NWS Checklist for Submitting a COMET Outreach Proposal

Actions after Endorsement by NWS	**YES**	**NO**	**DATE**
1. University submits proposal to the COMET Program.	X		10/08/20
2. Proposal acknowledgment letter sent by the COMET Program to submitting university with copies to SSDs and NWS office.			
3. COMET review of proposal (internal review for Partners Project proposals and formal review for Cooperative Project proposals).			
4. The COMET Program sends acceptance, rejection, or modification letters to university with copies to SSD, NWS office, and OST12.			
5. The COMET Program allocates funds for university.			
6. OST12 obligates funds for NWS offices.			
7. SSD/NWS office orders data from NCDC.			
8. NWS office or SSD calls OST12 for accounting code for expenses.			
9. NWS office sends copies of all travel vouchers and expense records to OST12.			
10. NWS office or SSD sends copies of publication page charge forms to OST12.			
11. NWS office keeps SSD informed of progress on the project and any results or benefits derived from the project.			

1. Background Summary, Problem Identification, and Basic Approach

In supercell environments, operational meteorologists analyze low-level vertical wind shear to assess the potential for tornadogenesis with severe storms. Early work such as Davies-Jones et al. (1990), Thompson et al. (2003), and Rasmussen (2003) indicate that analyzing the 0-1 km bulk wind shear vector or storm relative helicity (SRH) provides skill in discriminating tornadic vs. non-tornadic supercell environments. In some cases, using an effective storm inflow layer provides improvement to the forecast (Thompson et al. 2007). Over the last 5-10 years, high resolution idealized simulations using cloud resolving models, such as Orf et al. (2017), have been pointing to even shallower layers being critical in tornadogenesis. The use of 0-500 m SRH in the significant tornado parameter (STP; Thompson et al. 2012) over 0-1 km layer demonstrates superior skill in discriminating tornadic vs. non-tornadic environments (Coffer et al. 2019).

The **Problem**: The aforementioned idealized supercell simulations are frequently conducted on numerical model domains with vertical grid spacing on the order of just 10s of meters. This can provide at least 7 grid points, if not more, in the 0-500 m near surface layer. However, operational convective allowing models (CAMs) used by forecasters do not provide the same level of vertical detail in this near surface layer. Typically, the hybrid isobaric-sigma coordinates in operational CAMs (e.g. HRRR, Benjamin et al. 2016) will provide 3 to 4 grid points in the 0-500 m above ground layer. This issue is highlighted by low-topped supercell work completed by the Des Moines National Weather Service (NWS) Weather Forecasting Office (WFO), presented at the 2019 Northern Plains Weather Workshop. Concerns regarding winds within the planetary boundary layer (PBL) of CAMs are also noted in Coffer et al. 2018 & 2019. While forecasters are able to look at the values of 0-500 m SRH from operational CAM solutions, 3 to 4 vertical grid points is likely insufficient to adequately qualify and quantify the stream-wise component of horizontal vorticity available for tornadogenesis in severe environments. This work creates an R2O initiative to address to this issue.

Another complexity in interpreting model predictions of 0-500m SRH is that storms themselves modify their inflow environment in such a way that can increase low-level shear. This is documented in special soundings taken during VORTEX2 (Parker 2014) and high resolution idealized numerical simulations (Brooks et al. 1994; Weisman et al. 1998; Nowotarski and Markowski 2015). More recently, Kerr et al. (2019) investigates convective modifications to the storm environment using a WRF-based CAM ensemble. Their results suggest there is a positive feedback between storm induced increases in the 0–1-km SRH in the storm inflow and mesocyclone strength. However, none of these studies examine the extent to which storms modify the 0-500 m SRH in their inflow region, or how model resolution affects this process in forecasts. From a forecasting perspective, storm modification of the low-level environment begs two questions: 1) Is there value to the forecaster in knowing how the storm might alter its inflow environment – particularly the 0-500 m layer? 2) If not, at what distance from the storm does a meteorologist get a true undisturbed environmental forecast sounding?

Basic Approach and **Operational Relevance**: To transition these idealized simulation findings to the operational forecasting realm, previous impactful convective weather events will be simulated using the Weather Research and Forecasting (WRF) model version 4.1. The WRF will provide governing dynamic equations, microphysical parameter schemes, and lateral boundary conditions comparable to those used with current operational CAMs. In addition, the WRF can be initialized with operational CAM analysis to feed in environmental data that forecasters used during the actual event. Our approach is advantageous over idealized simulations, because idealized model configurations commonly use parameters not available in operational CAMs, and also are initialized by artificially perturbing the base-state environment to generate convective storms. Using the method examined in Daniels et al. (2016), vertical grid resolution will be increased by using a nested domain. Within the child domain, there will be 7 to 8 grid points in the 0-500 m near surface layer. The availability of 7 to 8 grid points within this layer is expected to make characterizing the stream-wise component of horizontal vorticity in these environments feasible. The horizontal grid spacing within the nested child domain will be adjusted to ensure a reasonable aspect ratio with the vertical; however, the horizontal grid resolution will not need to be on the order of tens of meters as will be needed in the vertical for the purpose of this study. The environmental hodographs from the WRF simulations will then be compared to the hodographs and storm-relative helicity values from CAM output from the actual events. This will assess the value added in characterizing the stream-wise component of horizontal vorticity in the near surface layer when additional grid points are available. Further details are specified in the objectives.

<u>Pilot Work</u>: The work of Coffer et al. 2018 & 2019 is the initial source of motivation to further explore the operational utility of using 0-500 m SRH (or even shallower layers) in severe convective nowcasting. However, WFO Des Moines realized that the large focus of previous literature on this subject has been on traditional supercell environments, with high shear and high CAPE. In studies that have examined high-shear low CAPE environments, the focus is generally on quasi-linear convective system (QLCS) storm mode. In Fall 2019, WFO Des Moines reviewed three medium impact low-topped (mini) supercell cases to assess the use of 0-500 m SRH for tornadic potential with this storm mode. In select instances, the 0-500 m SRH demonstrates enhanced ability in discriminating tornadic vs non-tornadic low-topped supercells compared to 0-1 km and effective inflow layer SRH. This indicates the importance of near-surface vorticity sources for tornadogensis, in both traditional and non-traditional supercell environments. However, the use of archived High Resolution Rapid Refresh (HRRR) hodographs reveals the weakness of only having 3 to 4 grid points in the 0-500 m SRH layer. The stream-wise component of horizontal vorticity is difficult to characterize and visualize on the hodograph plot. Thus after completing this work, the next step is to conduct this project increasing the number of vertical grid points to provide better visualization and characterization of this parameter in a variety of severe storm environments.

2. **Objective Statements**

The following objectives will work toward the overarching goal to determine if numerical models configured with an operational framework have the ability to provide forecasters the same details about near surface sources of vertical vorticity as theoretically idealized simulations have done. This will begin an R2O initiative to bring the latest in tornadogenesis theory to NWS severe weather operations.

<u>Objective 1</u>: **Qualitatively and quantitatively assess the stream-wise and cross-wise component of horizontal vorticity in the 0-500 m AGL vs 0-1 km across severe convective environments of all storm modes and types.**

Tornadic hodograph climatologies referenced by operational forecasters and warning meteorologists are largely predicated on the 0-1 km layer. However, there are notable examples recently in which there are elevated values of 0-1 km storm-relative helicity, but within the 0-500 m layer, the bulk of the vorticity is cross-wise and subsequently tornadogenesis is not observed. Conducting simulations of tornadic events with WRF, differences in hodograph shape and length between the 0-500 m and 0-1 km layer will be examined. Using non-idealized, operationally based data and model initial conditions, this will further qualitatively assess if generally stream-wise vorticity in the 0-1 km layer with primarily cross-wise vorticity in the first 0-500 m is a signal for non-tornadic vs tornadic storms. Additionally, this may provide an opportunity to visually associate low-level hodograph characteristics to a specific storm mode (traditional supercell, low-topped supercell, QLCS), working to enhance hodograph climatologies. These values will be compared to the work of Thompson et al. 2012 and Coffer et al. 2019.

Objective 2: **Determine if an increase to ~8 vertical grid points in the 0-500 m layer enhances forecaster's ability to characterize the stream-wise component of vorticity over current operational CAMs with generally 3 or 4 vertical grid points.**

The pilot work by NWS Des Moines found that the 3 to 4 grid points in the 0-500 m layer makes it extremely difficult to characterize low-level hodograph characteristics. This additionally leads forecasters to question the quality of the model computed 0-500 m wind shear and SRH if only 3 to 4 points are available to sample and perform computations. These operationally based WRF simulations will assess if increasing the number of vertical grid points in the model domain adds value to characterizing the stream-wise vs cross-wise components of low-level horizontal vorticity. Generally, more sample points will increase forecaster confidence that a particular atmospheric field is properly being represented in the model domain. This will be critical to determining whether or not operational numerical models are robust enough to provide forecasters a sufficient level of detail in shallow, near surface layers as idealized models are able to do.

Objective 3: **Qualitatively and quantitatively assess the extent to which storms modify the 0-500 m SRH in their inflow region in CAM forecasts.**

Kerr et al. (2019) found in their CAM ensemble forecasts of supercell events that there is a positive feedback between storm modifications to the 0-1km SRH in the inflow region, and forecast mesocyclone strength. The timescale for this feedback mechanism is approximately 60 minutes for the midlevel mesocyclone, and approximately 30 minutes for the low-level mesocyclone. Thus, there may be some value in examining storm modifications to the SRH in short-term forecasts. Storm modifications to the 0-500 m SRH could play an even larger role in discriminating between tornadic/non-tornadic storm potential, but this has not been previously examined. To explore this topic, the WRF model simulations described above in Objectives 1 and 2 will be rerun ‘dry’ (i.e., convection will not be allowed to develop in the model) to eliminate the convective impacts on the forecasts. These runs will be compared with the full-physics runs to determine to what extent the storms modify the 0-500 m SRH in the inflow region, how far this modification extends into the storm environment (which is likely a function of CAPE), and to what extent the model vertical grid resolution affects this process. These comparisons will also be used to determine if the storm modified 0-500 m SRH provides any forecast value in discriminating between tornadic/non-tornadic events compared with using the undisturbed forecast environmental hodographs.

Objective 4: **Develop documentation to provide forecasters training on appropriate use of shallow layer SRH analysis and forecasts.**

The overarching goal of this work is to transition the latest in tornadogenesis theory in the idealized model realm to operational nowcasting and storm warning issuance. These simulations will provide rationale for using 0-500 m SRH (and potentially even shallower layers), while also describing limitations of using the 0-500 m layer with current CAMs. This will be able to help forecasters better message tornadic potential, and allow the NWS to provide enhanced Impact-Based Decision Support Services (IDSS).

Objective 5: **Foster Development of the Next Generation of Near Storm Mesoscale Analysis**

The results of this work will be an important contribution to SPC's continuous development of tools pertinent to severe weather nowcasting. This will provide further understanding of limitations and strengths of current model forecasts and analysis that largely constitute the current SPC Mesoanalysis page.

3. Tasks Completed by National Weather Service Des Moines

3a. Develop List of Severe Weather Events to Simulate in WRF

NWS Des Moines will select ~10 cases from severe weather events across the Central Great Plains and the Upper Midwest. The list of cases will contain a variety of convective modes and storm types. This will include traditional supercells, low-topped (mini) supercells, and QLCS events. Both tornadic and non-tornadic events will be included in this list. Of particular interest, will be events where the tornado threat was perceived high, but supercell thunderstorms did not result in tornadogenesis. For the set of cases with tornadic supercells, there will be variety with respect to the intensity of the events with long-track violent tornadoes (EF-4 to EF-5), considerable tornadoes (EF-2 to EF-3), and weak tornadoes (EF-0 to EF1). The goal is to include greater diversity in event type than typically utilized in idealized supercell simulations.

3b. Select Initialization Source for WRF Simulations

The benefit to using WRF is the ability to initialize and configure the model run with operationally-based, realistic atmospheric conditions. This is unlike idealized simulations, which generally artificially perturb the environment by creating a warm buoyant bubble, releasing a cold air dam block, or placing a heat sink/source into the model domain. For cases selected later than January 2016, the HRRR forecast and analysis will be utilized for initial boundary conditions of the WRF simulations. The HRRR is an operational CAM widely used among operational meteorologists when forecasting severe weather environments, and will be able to provide realistic atmospheric parameters across the Central Great Plains and Upper Midwest. HRRR data is available from the Utah Meso West Group (Blaylock et al. 2017). For events where archived HRRR data is not available, WRF will be initialized with data from Rapid Refresh (RAP) analysis and forecasts. The RAP is another short term forecasting model widely used by operational meteorologists for mesoscale meteorological analysis.

3c. Post Processing of WRF Output

Alex Krull from NWS Des Moines will utilize Python to read in the netCDF4 output from the WRF simulations. The MetPy module developed through Unidata will largely be used to compute atmospheric variables that are not directly output by the WRF simulations. MetPy will also be utilized to plot appropriate Skew-T soundings and hodographs from the simulations. Where appropriate or beneficial, WRF output from a select point will be output to a CSV file that can be read by SHARPpy to produce a sounding, hodograph, and calculate values of parameters pertinent to severe weather. The SHARPpy interface in particular will provide a format that atmospheric scientists are largely familiar with viewing. MetPy will be used in conjunction with Cartopy to create 2D plots of atmospheric parameters. Statistical analysis will also be done in Python, utilizing the SciPy package to view data point distribution, assess distribution over a specified confidence interval, and pinpoint outlier points that may need further examination. The bulk of the post-processing will be handled by NWS Des Moines, though UND will conduct some post-processing for quality control as simulations are being conducted.

3d. <u>Provide Operational Perspective On Analysis of WRF output</u>

NWS Des Moines will work with forecast staff at the office, and across other local WFOs in the agency to assess the value and determine how model output with increased vertical grid resolution can be used in nowcasting and warning operations with severe convective environments. This will be critical in completing the transition from the theoretical, idealized supercell simulations to operational meteorology. This will guide the dialogue between the NWS and UND academic partners.

3e. <u>Develop Training for NWS forecasters</u>

NWS Des Moines will work with NWS Central Region science chief and the personnel at the Warning Decision Training Branch (WDTB) on the utility of the 0-500 m SRH for tornadic supercell nowcasting. This training will highlight the strengths and limitations of using current operational CAM output. Working with WDTB will incorporate analysis techniques into the intensive interactive training courses that new NWS hires complete as part of the on-boarding process.

4. Tasks Completed by the University of North Dakota

4a. <u>Provide Access to Computer Cluster and Data Storage</u>

The University of North Dakota will provide access to high performance computing resources to conduct the WRF simulations. UND has a high performance computing center on campus that is available to faculty members for use. UND will also provide local storage or nearby storage to easily access WRF output data for the duration of the grant's active time period. UND will provide user accounts to NWS personnel to access the data and complete the post-processing tasked to the NWS.

4b. Compile and house WRF Code, Conduct WRF Simulations

UND will load and execute the appropriate files and libraries to set up WRF on the high performance computing cluster they are providing. The source code for WRF will be housed and maintained by UND. The NWS will work with UND to determine appropriate namelist settings to be utilized in simulations, such as microphysical schemes, grid resolution, output parameters, frequency of model output and model time step. UND will be able to provide guidance on the best parameters to use based on prior numerical weather prediction experiences. Finally, UND will submit the batch jobs to the high performance computing center to run the WRF simulations.

4c. Post Processing and Analysis of Forecast Storm Modifications to the 0-500 m SRH

UND will complete the analysis of the storm-induced 0-500 m SRH changes. Graduate student Ben Remington will assist in this work which will include: looking at difference fields between dry and full-physics model runs to determine the extent to which storms modify the environment, extracting model soundings to look at differences in the hodographs between the storm-modified inflow and the undisturbed environment, and calculating 0-500 m storm-induced SRH changes in the storm inflow region. The storm modified values of 0-500 m SRH will be compared with the undisturbed environmental values to determine if the modified 0-500 m SRH has value in discriminating between tornadic/nontornadic events. Comparisons will also be made between the model runs with coarser and enhanced vertical resolution to determine how enhanced vertical resolution affects these results.

4d. Provide Theoretical/Research Oriented Angle on the Analysis

The overarching goal is to establish an R2O initiative. While the NWS Des Moines provides insight on the operational utility, UND will contribute to the dialogue with their deep understanding of high-resolution idealized simulations from recent literature. This will be critical to complete the transition from research to operations, and also allow feedback to flow from operations into research.

5. Approximate Timeline

Month 1: Procurement of access to high performance computing cluster and data storage. Load and compile source code for WRF. Develop list of cases to simulate in WRF. Install appropriate Python distribution and install appropriate modules and packages needed for post-processing. Finalize namelist settings and model parametrizations to select in WRF.

Month 2: Procurement of HRRR and RAP analysis data that will be utilized as initial boundary conditions for WRF simulations. Ensure quality and integrity of the data prior to initialing the model.

Month 3-7: Submit batch jobs to run WRF simulations. After completion of each event, post-process WRF output and begin analysis.

Month 7-9: Continue to post-process as necessary. Compare the inter-experiment simulations. Begin to develop hodograph climatology based on storm type. Compare WRF simulations to the operational RAP and HRRR forecasts of the actual event, determining enhancements provided by the increased number vertical gird points. Compare dry and full physics WRF simulations to determine convective influences on the SRH in the storm inflow and its potential utility in short-term forecasting.

Month 10-12: Prepare manuscript for peer-reviewed journal article. Prepare abstract for AMS and/or NWA conferences, symposiums, and workshops. Develop training plan for operational meteorologists based on findings.

6. Brief PI Description

Alexander (Alex) J. Krull is a meteorologist with NWS Des Moines. Alex has been with the NWS for over 2 years. He has actively been involved with the Science and Operations Team at WFO Des Moines to develop training related to severe weather. Specific tasks accomplished have included training for the latest release of SHARPpy, and how a dedicated mesoanalyst can provide value during severe weather operations. The aforementioned pilot work was led by Alex, as he has been delving deep into the literature regarding sources of near surface vorticity in supercell thunderstorms. He presented this work at the 2019 Northern Plains Weather Workshop in St. Cloud, MN, and as a NWS Central Region Guest Speaker Series presentation. Prior to joining NWS, Alex was a member of the Severe Storms Research Group led by Dr. Adam Houston at the University of Nebraska-Lincoln.

Michael Fowle is the Science & Operations Officer at NWS Des Moines, and has held this position since 2015. Previously he was a Science and Operations Officer with NWS Aberdeen for 7 years and has also worked as a meteorologist at NWS Milwaukee/Sullivan and NWS Phoenix. Mike received his B.S. in Meteorology at Saint Louis University and a M.S. in Atmospheric Science/Mathematics at the University of Wisconsin-Milwaukee. Mike's research interests are varied and have included published research on high resolution convective allowing model (CAM) guidance, significant wind-driven hail events, and an analysis of the record Vivian, SD hailstone. He has also led research projects on soil temperatures and snowfall accumulation, traffic accidents and the association with winter storms, and downslope winds with subtle topography. He has participated in numerous hazardous weather experiments at the NOAA/NWS Hazardous Weather Testbed and has been a reviewer for AMS and NWA journal manuscripts.

Dr. Catherine (Cathy) Finley is an Assistant Professor of Atmospheric Sciences the University of North Dakota in Grand Forks. Dr. Finley obtained her Ph.D. in Atmospheric Science from Colorado State University where she used the Regional

Atmospheric Modeling System (RAMS) to simulate supercells and associated tornadoes in realistic 3-D environments. Her current research focus is very high-resolution numerical modeling of supercells and tornadoes, with the aim of better understanding the processes contributing to tornadogenesis and maintenance of long-track tornadoes. Dr. Finley is currently a PI on an NSF-funded collaborative research grant titled ‘Collaborative Research: Understanding Tornado Development and Maintenance in Supercells with an Emphasis on "High-End" Events’ and was a Co-PI on a recently completed NSF-funded high performance computing grant titled ‘PRAC: Understanding the Development and Evolution of Violent Tornadoes in Supercell Thunderstorms’. She has also co-directed several field projects, collecting data around supercell storms in order to improve our understanding of the connection between storm downdrafts/boundary features and tornadogenesis.

Budget Justification

Direct Costs

Section A: Personnel

One M.S. student will be supported during the project during the spring/summer semesters of 2021. Salary for graduate students typically cover a year-round (12-mo) research assistantship with base rates in year one of $24,157 for a M.S. Four months are budgeted at a rate of $8052.

Section B: Fringe Benefits

Fringe benefits are calculated at a rate of 8% ($644) for graduate student assistantships. Only actual salary and fringe benefit costs will be charged to the project.

Section C: Travel

Travel is budgeted for the M.S. student to attend the 2021 Severe Storms and Doppler Radar Conference in Ankeny, IA. The estimated costs of this trip is $1121 based on $450 airfare, 3 nights of hotel stay at the government rate of $109/night, 4 days of per diem at the government rate of $61/day, and $100 for conference fees.

Travel is also budgeted for 1 research trip for Dr. Finley to visit the NWS office in Des Moines. The estimated cost of the trip is $814 based on the government mileage rate of $0.575/mile for 1120 miles, 1 night of hotel stay at the government rate of $109/night, and 1 day of per diem at the government rate of $61/day.

Indirect Costs

The indirect cost rate of 41% is a federally approved research rate based on modified total direct costs (excluding equipment greater than $5,000 and subcontracts in excess of the first $25,000 for each award and tuition remission).

The cognizant federal agency and officer is Robert W. Lee (415-437-7820) at the DHHS/HHS Division of Cost Allocation Western Region

References

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COLLEGES AND UNIVERSITIES RATE AGREEMENT

EIN: 45-6002491

ORGANIZATION:
University of North Dakota
Budget
264 Centennial Drive
Stop 8233
Grand Forks, ND 58202-8233

DATE: 10/22/2019

FILING REF.: The preceding agreement was dated 07/25/2019

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.	07/01/2018	06/30/2019	39.00	On-Campus	(A) Org. Res.
PRED.	07/01/2019	06/30/2023	41.00	On-Campus	(A) Org. Res.
PRED.	07/01/2018	06/30/2023	26.00	Off-Campus	(A) Org. Res.
PRED.	07/01/2018	06/30/2019	50.50	On-Campus	(A) EERC (1)
PRED.	07/01/2019	06/30/2023	51.00	On-Campus	(A) EERC (1)
PRED.	07/01/2018	06/30/2023	26.00	Off-Campus	(A) EERC (1)
PRED.	07/01/2018	06/30/2020	35.60	On-Campus	(C) Oth Spo Pro
PRED.	07/01/2020	06/30/2023	35.00	On-Campus	(C) Oth Spo Pro
PRED.	07/01/2018	06/30/2023	26.00	Off-Campus	(C) Oth Spo Pro
PRED.	07/01/2018	06/30/2019	17.00	On-Campus	(C) HNRC (2)
PRED.	07/01/2019	06/30/2023	18.00	On-Campus	(C) HNRC (2)
PRED.	07/01/2018	06/30/2019	43.90	On-Campus	(C) Instruction
PRED.	07/01/2019	06/30/2023	43.00	On-Campus	(C) Instruction
PRED.	07/01/2018	06/30/2023	26.00	Off-Campus	(C) Instruction
PRED.	07/01/2018	06/30/2019	39.50	On-Campus	(B) Org. Res.
PRED.	07/01/2019	06/30/2023	42.00	On-Campus	(B) Org. Res.
PRED.	07/01/2018	06/30/2023	27.50	Off-Campus	(B) Org. Res.
PRED.	07/01/2018	06/30/2019	51.50	On-Campus	(B) EERC (1)

TYPE	FROM	TO	RATE(%)	LOCATION	APPLICABLE TO
PRED.	07/01/2019	06/30/2023	52.00	On-Campus	(B) EERC (1)
PRED.	07/01/2018	06/30/2023	27.50	Off-Campus	(B) EERC (1)
PROV.	07/01/2023	Until Amended		(D)	

*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.

(1) Energy and Environmental Research Center
(2) Human Nutrition Research Center

(A) Facilities and Administrative Cost Rates
(B) Facilities and Administrative Cost Rates - DOD Contracts Only
(C) (A) & (B) apply

(D) Use same rates and conditions as those cited for fiscal year ending June 30, 2023.

SECTION I: FRINGE BENEFIT RATES**

TYPE	FROM	TO	RATE(%)	LOCATION	APPLICABLE TO
FIXED	7/1/2019	6/30/2020	28.00	All (1)	EERC-Permanent Employees
PROV.	7/1/2020	6/30/2023	28.00	All (1)	EERC-Permanent Employees

** DESCRIPTION OF FRINGE BENEFITS RATE BASE:

Direct salaries and wages excluding other fringe benefits.

(1) Vacation, holiday, and sick leave rate

SECTION II: SPECIAL REMARKS

TREATMENT OF FRINGE BENEFITS:

This organization charges the actual cost of each fringe benefit direct to Federal projects. However, it uses a fringe benefit rate which is applied to salaries and wages in budgeting fringe benefit costs under project proposals. The fringe benefits listed below are treated as direct costs:
SOCIAL SECURITY, HEALTH/LIFE INSURANCE, WORKERS COMPENSATION, UNEMPLOYMENT INSURANCE, RETIREMENT (STATE, TFFR, OR TIAA/CREF), DISABILITY INSURANCE, AND EMPLOYEE ASSISTANCE PROGRAM

TREATMENT OF PAID ABSENCES

Except for EERC Employees, vacation, holiday, sick leave pay and other paid absence are inlcuded in salaries and wages and are charged to federal projects as part of the normal charge for salaries and wages. Separate charges for the cost of these absences are not made.

For EERC employees, the cost of vacation, holiday, sick leave pay, and other paid absences (and associated other fringe benefits) are included in a fringe benefit rate and are not included in direct charges for salaries and wages. Charges for salaries and wages must exclude those paid to EERC employees for periods when they are on vacation, holiday, or sick leave, or are otherwise absent from work.

DEFINITION OF OFF-CAMPUS
An off-campus activity is defined as that activity performed by University employees at locations other than the main campus and not using the University's operation and maintenance facilities.

Activity such as short term (less than one month's duration) travel by employees to an off-campus site where office space is maintained on campus in their absence shall be considered on campus activity for the purposes of applying the indirect cost rates. Travel in excess of one month's duration will be reviewed and classified on or off campus on a case by case basis.

Activity performed by other than University employees through contractual arrangements is normally considered on campus with only the first $25,000 subject to the on campus indirect cost rate.

DEFINITION OF EQUIPMENT

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 $5,000.

NEXT PROPOSAL DUE DATE

An indirect cost proposal based on actual costs for fiscal year ending 06/30/22, will be due no later than 12/31/22.
A fringe benefit proposal based on actual costs for fiscal year ending 06/30/19, will be due no later than 12/31/19.

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:

University of North Dakota

(INSTITUTION)

(SIGNATURE)

Jed M. Shivers
Vice President for Finance & Operations/COO
University of North Dakota

(NAME)

(TITLE)

30 October 2019

(DATE)

ON BEHALF OF THE FEDERAL GOVERNMENT:

DEPARTMENT OF HEALTH AND HUMAN SERVICES

(AGENCY)

Arif M. Karim -S

Digitally signed by Arif M. Karim -S
DN: c=US, o=U.S. Government, ou=HHS, ou=PSC, ou=People, cn=Arif M. Karim -S, 0.9.2342.19200300.100.1.1=2000212895
Date: 2019.10.26 17:10:48 -05'00'

(SIGNATURE)

Arif Karim

(NAME)

Director, Cost Allocation Services

(TITLE)

10/22/2019

(DATE) 7110

HHS REPRESENTATIVE: Karen Wong

Telephone: (415) 437-7820

UNIVERSITY OF NORTH DAKOTA
FACILITIES AND ADMINISTRATIVE COST RATES
FOR THE PERIOD JULY 1, 2018 THROUGH JUNE 30, 2023

	ORGANIZED RESEARCH					
	JULY 1, 2018 - JUNE 30, 2019			JULY 1, 2019 - JUNE 30, 2023		
		ON-CAMPUS	OFF-CAMPUS		ON-CAMPUS	OFF-CAMPUS
BUILDING DEPRECIATION		1.30%			2.50%	
BUILDING INTEREST		0.00%			0.10%	
EQUIPMENT DEPRECIATION		2.70%			2.00%	
OPERATIONS & MAINTENANCE		7.80%			9.20%	
LIBRARY		1.20%			1.20%	
GENERAL ADMIN	7.20%			6.10%		
DEPT ADMIN	14.60%			15.70%		
SPON PROJ ADMIN	4.20%			4.20%		
STUDENT SERV ADMIN	0.00%			0.00%		
ADMIN COMPONENTS	26.00%	26.00%	26.00%	26.00%	26.00%	26.00%
TOTAL		39.00%	26.00%		41.00%	26.00%

	ENERGY & ENVIRONMENTAL RES CTR (EERC)					
	JULY 1, 2018 - JUNE 30, 2019			JULY 1, 2019 - JUNE 30, 2023		
		ON-CAMPUS	OFF-CAMPUS		ON-CAMPUS	OFF-CAMPUS
BUILDING DEPRECIATION		1.40%			1.40%	
BUILDING INTEREST		1.20%			0.70%	
EQUIPMENT DEPRECIATION		1.20%			2.00%	
OPERATIONS & MAINTENANCE		18.80%			19.20%	
LIBRARY		1.90%			1.70%	
GENERAL ADMIN	6.00%			6.00%		
DEPT ADMIN	16.50%			16.70%		
SPON PROJ ADMIN	3.50%			3.30%		
STUDENT SERV ADMIN	0.00%			0.00%		
ADMIN COMPONENTS	26.00%	26.00%	26.00%	26.00%	26.00%	26.00%
TOTAL		50.50%	26.00%		51.00%	26.00%

REFLECTS PROVISIONS OF APPENDIX III TO PART 200 OF UNIFORM GUIDANCE - INDIRECT (F&A) COSTS IDENTIFICATION AND ASSIGNMENT, AND RATE DETERMINATION FOR INSTITUTIONS OF HIGHER EDUCATION (IHEs), C.8 DATED SEPTEMBER 10, 2015.

CONCUR:

Jed M. Shivers
(SIGNATURE)

Vice President for Finance & Operati[illegible]
University of N[illegible]
TITLE

30 October 2019
DATE

UNIVERSITY OF NORTH DAKOTA
FACILITIES AND ADMINISTRATIVE COST RATES
FOR THE PERIOD JULY 1, 2018 THROUGH JUNE 30, 2023

DOD CONTRACTS ONLY

	ORGANIZED RESEARCH					
	JULY 1, 2018 - JUNE 30, 2019			JULY 1, 2019 - JUNE 30, 2023		
		ON-CAMPUS	OFF-CAMPUS		ON-CAMPUS	OFF-CAMPUS
BUILDING DEPRECIATION		1.00%			2.00%	
BUILDING INTEREST		0.00%			0.10%	
EQUIPMENT DEPRECIATION		2.00%			2.00%	
OPERATIONS & MAINTENANCE		7.80%			9.20%	
LIBRARY		1.20%			1.20%	
GENERAL ADMIN	7.70%			6.10%		
DEPT ADMIN	15.10%			16.90%		
SPON PROJ ADMIN	4.70%			4.50%		
STUDENT SERV ADMIN	0.00%			0.00%		
ADMIN COMPONENTS	27.50%	27.50%	27.50%	27.50%	27.50%	27.50%
TOTAL		39.50%	27.50%		42.00%	27.50%

	ENERGY & ENVIRONMENTAL RES CTR (EERC)					
	JULY 1, 2018 - JUNE 30, 2019			JULY 1, 2019 - JUNE 30, 2023		
		ON-CAMPUS	OFF-CAMPUS		ON-CAMPUS	OFF-CAMPUS
BUILDING DEPRECIATION		1.40%			1.40%	
BUILDING INTEREST		1.20%			0.70%	
EQUIPMENT DEPRECIATION		1.20%			2.00%	
OPERATIONS & MAINTENANCE		18.10%			18.70%	
LIBRARY		2.10%			1.70%	
GENERAL ADMIN	6.30%			6.10%		
DEPT ADMIN	17.60%			16.90%		
SPON PROJ ADMIN	3.60%			4.50%		
STUDENT SERV ADMIN	0.00%			0.00%		
ADMIN COMPONENTS	27.50%	27.50%	27.50%	27.50%	27.50%	27.50%
TOTAL		51.50%	27.50%		52.00%	27.50%

REFLECTS PROVISIONS OF APPENDIX III TO PART 200 OF UNIFORM GUIDANCE - INDIRECT (F&A) COSTS IDENTIFICATION AND ASSIGNMENT, AND RATE DETERMINATION FOR INSTITUTIONS OF HIGHER EDUCATION (IHEs), C.8 DATED SEPTEMBER 10, 2015.

CONCUR:

Jed M. Shivers
(SIGNATURE)

Vice President for Finance & Operations/COO
University of North Dakota
TITLE

20 October 2019
DATE

UNIVERSITY OF NORTH DAKOTA
FACILITIES AND ADMINISTRATIVE COST RATES
FOR THE PERIOD JULY 1, 2018 THROUGH JUNE 30, 2023

	OTHER SPONSORED ACTIVITIES						INSTRUCTION		
	JULY 1, 2018 - JUNE 30, 2020			JULY 1, 2020- JUNE 30, 2023			JULY 1, 2018 - JUNE 30, 2019		
		ON-CAMPUS	OFF-CAMPUS		ON-CAMPUS	OFF-CAMPUS		ON-CAMPUS	OFF-CAMPUS
BUILDING DEPRECIATION		0.60%			1.20%			1.70%	
BUILDING INTEREST		0.00%			0.00%			0.00%	
EQUIPMENT DEPRECIATION		3.70%			1.90%			1.70%	
OPERATIONS & MAINTENANCE		3.80%			4.40%			7.30%	
LIBRARY		1.50%			1.50%			7.20%	
GENERAL ADMIN	7.00%			6.00%			6.00%		
DEPT ADMIN	14.70%			15.70%			12.80%		
SPON PROJ ADMIN	4.30%			4.30%			0.20%		
STUDENT SERV ADMIN	0.00%			0.00%			7.00%		
ADMIN COMPONENTS	26.00%	26.00%	26.00%	26.00%	26.00%	26.00%	26.00%	26.00%	26.00%
TOTAL		35.60%	26.00%		35.00%	26.00%		43.90%	26.00%

	HUMAN NUTRITION RESEARCH CENTER				INSTRUCTION		
	JULY 1, 2018 - JUNE 30, 2019		JULY 1, 2019 - JUNE 30, 2023		JULY 1, 2019 - JUNE 30, 2023		
		ON-CAMPUS		ON-CAMPUS		ON-CAMPUS	OFF-CAMPUS
BUILDING DEPRECIATION		0.10%		0.10%		2.00%	
BUILDING INTEREST		0.00%		0.00%		0.00%	
EQUIPMENT DEPRECIATION		0.00%		0.00%		1.30%	
OPERATIONS & MAINTENANCE		0.00%		0.00%		7.10%	
LIBRARY		1.00%		1.00%		6.60%	
GENERAL ADMIN	7.20%		6.00%		6.00%		
DEPT ADMIN	4.00%		6.30%		12.80%		
SPON PROJ ADMIN	4.70%		4.60%		0.20%		
STUDENT SERV ADMIN	0.00%		0.00%		7.00%		
ADMIN COMPONENTS	15.90%	15.90%	16.90%	16.90%	26.00%	26.00%	26.00%
TOTAL		17.00%		18.00%		43.00%	26.00%

REFLECTS PROVISIONS OF APPENDIX III TO PART 200 OF UNIFORM GUIDANCE - INDIRECT (F&A) COSTS IDENTIFICATION AND ASSIGNMENT, AND RATE DETERMINATION FOR INSTITUTIONS OF HIGHER EDUCATION (IHEs), C.8 DATED SEPTEMBER 10, 2015.

CONCUR:

(SIGNATURE) **Jed M. Shivers**

Vice President for Finance & Operations/COO

TITLE Univ[illegible]y o

20 October 2019

DATE