Proposal for a Partners Project

Title: Development and Assessment of Blowing Snow Guidance for an IDSS Situational Awareness Display

Date: 29 October 2019

Signatures for University	Signatures for NWS
University Name: University of North Dakota Address: Twamley Hall 100 264 Centennial Dr Stop 7306 Grand Forks, ND 58202-7306	NWS Office: Grand Forks/Bismarck, ND Address: FGF: 4797 Technology Circle Grand Forks, ND 58203 BIS: 2301 University Dr. #27 Bismarck, ND 58504
Principal Investigator Name: Aaron Kennedy Telephone number: 701-777-5269 Address: 4149 University Ave. Stop 9006 Clifford Hall Room 454 Grand Forks, ND 58202-9009 Email: aaron.kennedy@und.edu	MIC/HIC (FGF / BIS) Name: Ryan Knutsvig (FGF) Telephone number: 701-772-0720 Name: Jeff Savadel (BIS) Telephone number: 701-223-4582
Department Official Name: Michael Poellot Title: Department Chair Telephone number: 701-777-3180	SSD Chief (CRH) Name: Bruce Smith
University Official Name: Jamie Mitzel Title: Senior Pre-Award Officer Address: Tech Accelerator Room 2050 4201 James Ray Dr Stop 8367 Grand Forks, ND 58202-6026 Telephone number: 701.777.4146 Email: jamie.mitzel@UND.edu	Regional Director (CRH) Name: Christopher Strager
Co-Principal Investigator Name: Gretchen Mullendore Telephone number: 791-777-4707 Email:gretchen.mullendore@und.edu	

SUMMARY OF BUDGET REQUEST:
COMET FUNDS: Year 1 $14984
NWS FUNDS: FY 1 $2084 FY 2 $2900

Project Budget Page

	COMET Funds	NWS Contributions
University Senior Personnel		
1.		**NA**
2.		**NA**
Other University Personnel		
1. Graduate Research Assistant (Spring/Summer)	**8052**	**NA**
2.		**NA**
Fringe Benefits on University Personnel	**644**	**NA**
Total Salaries + Fringe Benefits	**8696**	**NA**
NWS Personnel		
1. Tommy Grafenauer (NWS Grand Forks, ND)		**40 hours**
2.Chauncy Schultz (NWS Bismarck, ND)		**40 hours**
Travel		
1. Research Trips		
2. Conference Trips	**2084**	**2084**
3. Other		
Total Travel	**2084**	**2084**
Other Direct Costs		
1. Materials & Supplies		**NA**
2. Publication Costs (put in the NWS column if a co-author will be an NWS employee)	**0**	**2900**
3. Other Data		
4. NWS Computers & Related Hardware	**NA**	
5. Other (specify)		
Total Other Direct Costs	**10780**	**4984**
Indirect Costs		**NA**
1. Indirect Cost Rate	**39%**	
2. Applied to which items?	**All items**	
Total Indirect Costs	**4204**	**NA**
Total Costs (Direct + Indirect)	**14984**	**4984**

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

November 27, 2019

To Whom it May Concern,

The purpose of this letter is to express my endorsement for the COMET Partners project proposal titled "Assessment of Blowing Snow Guidance over the Northern Great Plains to Guide Development of a Situational Awareness Display for IDSS" (with the University of North Dakota). Having previously worked in North Dakota, I have first-hand experience with blowing snow over the Northern Plains. I am confident this project will help the National Weather Service improve its forecasting and messaging of this wintertime hazard.

Sincerely,

Christopher S. Strager
Director
National Weather Service Central Region

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		Summer 2019 (multiple dates)
2. Did NWS office consult Scientific Services Division (SSD) staff?	X		Summer 2019
3. Was Statement of Work and budget formulated as a team effort between university and NWS staffs?	X		Fall 2019
4. Was proposal submitted to SSD for review?	X		11/12/19
5. Did SSD forward copies of proposals dealing with WSR-88D data to Radar Operations Center (ROC), Applications Branch Chief for review?	NA		
6. Did SSD forward copies of proposals dealing with hydrometeorology to the Senior Scientist of OHD for review?	NA		
7. Did SSD review the data request for project to ensure its scope and criticality for proposal?	NA		
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?	X		
9. Does budget include publication charges and travel costs for NWS employees to present results at scientific conferences?	X		10/29/19
10.Does budget separate NWS costs into fiscal year costs and university costs into calendar year costs?	X		10/29/19
11.Does proposal include a separate justification for university hardware purchases which are usually not funded by the COMET Outreach Program?	NA	X	
12. Have the following people signed off on the proposal cover sheet: - MIC/HIC? - SSD Chief? - Regional Director?	X		11/15/19
13. Is a letter of endorsement signed by regional director attached?			11/27/19

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		12/6/2019
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.			

Abstract

Blowing snow causes adverse impacts across the Northern Great Plains (NGP) and continues to be a forecast challenge. The lack of this process in operational models prohibits direct investigation of model data and forces forecasters to use empirical techniques to determine impacts on visibility and whether blizzard criteria will be met. At the present time, regional offices use the Canadian Blowing Snow Model (CBSM) while national efforts have expanded the use of the Winter Storm Severity Index (WSSI). This product also includes guidance for blowing snow, and it is unclear how this compares to the CBSM. The relatively sparse observations in the region suggest that high-resolution model data must be incorporated into systems such that decisions can be made in areas without verification data.

The purpose of this project is to perform forecast verification for blowing snow events and evaluate how datastreams should be used in a situational awareness display for Impact-Based Decision Support Services (IDSS). Surface and satellite observations, model data from the High-Resolution / Rapid Refresh (HRRR/RAP), and two types of blowing snow guidance (CBSM / WSSI) developed from model output will be compared. An evaluation will be compared for the winters of 2018-2019 to 2019-2020. An active winter in 2018-2019 (8 blizzards within the Grand Forks NWSFO CWA) assures that an ample number of cases will be tested. Quantitative evaluation of model data (winds, temperatures) and blowing snow guidance (visibility) will be undertaken by the University of North Dakota (UND). The Bismarck, ND and Grand Forks, ND NWSFOs will provide qualitative feedback on the comparison. Feedback will also be sought on optimal visualization of the products. The efforts of this work will pave the way for an eventual real-time IDSS display for blowing snow that can be incorporated nationally into efforts such as the Multi-Radar Multi-Sensor (MRMS) project and/or within the Advanced Weather Interactive Processing System (AWIPS II), thus supporting the Collaborative Forecast Process (CFP).

Project Description

1. Justification and Objectives

1.1 Climatology and impact of winter hazards

High-latitude regions of the globe including the northern tier of the United States are subject to adverse conditions during the winter including snowfall, high winds, and varying precipitation type depending on temperatures. In the North-Central US (MN, ND, NE, and SD), hazards include blizzards (blowing snow, hereafter BLSN), winter storms, and freezing rain. Of these hazards, BLSN is arguably the most significant process due to its frequency and personal, societal, and economic impacts. Investigation of the National Centers for Environmental Prediction (NCEP) Storm Events Database has revealed that this region is climatologically the most favorable for blizzards in the United States (Schwartz and Schmidlin 2002, Coleman and Schwartz 2017, Fig. 1).

Collaborative work by PI Kennedy and the Grand Forks NWSFO have made progress in characterizing blizzard events in this region. Overall, this CWA averages 2.5 blizzards per year, with the majority of blizzards occurring between December and March (Fig. 2). Over this region, the causes for these events are largely tied to three types of events: Alberta Clippers, Arctic Fronts, and Colorado Lows (Fig. 2). Other events contain characteristics of multiple patterns and have been coined hybrids. While Colorado Lows and Alberta Clippers typically bring fresh snow in tandem with strong winds (stereotypical blizzards), Arctic Fronts are associated with strong winds well removed from precipitation. This pattern is typically responsible for ground blizzards (purely BLSN vs falling snow), and whether one occurs depends on the lag between precipitation and strong winds and the properties of the preexisting snowpack.

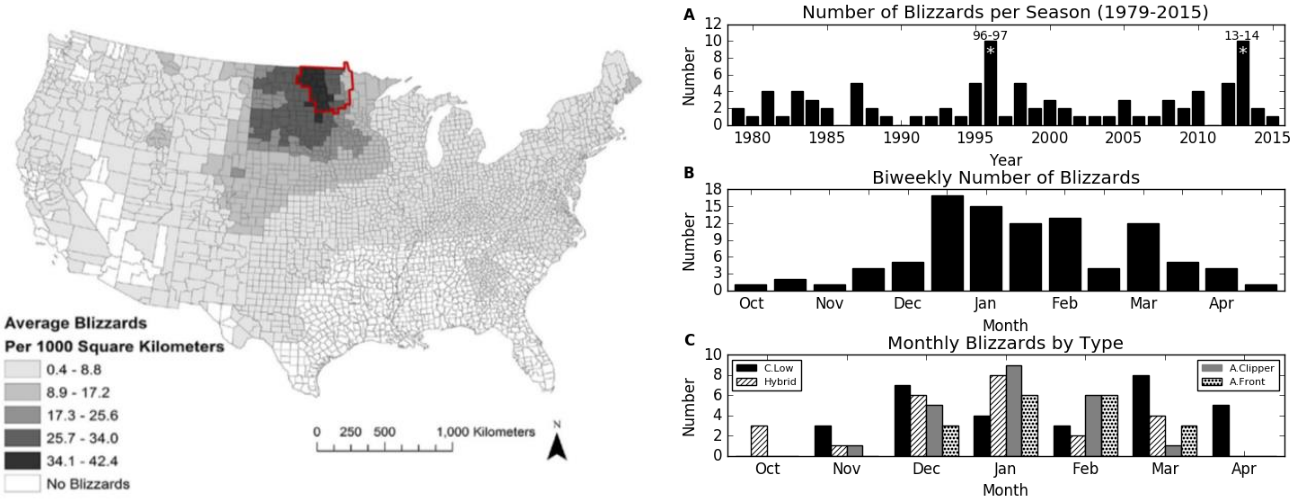

Figure 1. Left: Geographical distribution of blizzards (1959-2014) in the NCEP Storm Events Database from Coleman and Schwartz (2017). The red polygon indicates the Grand Forks NWS County Warning Area (CWA). Right: Characteristics of blizzards within the Grand Forks CWA from 1979-2015.

Societal and economic impacts of winter hazards are numerous (business disruptions, property loss, emergency services, etc.). Nationally, winter storms were associated with \$8.5 billion in insured losses from 1950-1997 (Changnon 2003), while Munich RE (2015) found winter storm losses averaged \$1.2 billion per year. Coleman and Schwartz (2016) have reported that federal disaster declarations for blizzards have increased over the past half century, with more than 50% of the declarations occurring in the 21st century alone. Locally, archived news stories yield a number of headlines dedicated to blizzards- in fact, they are of such importance that the Grand Forks Herald actively names these events. More recently, a blizzard caused unanticipated costs during the search for the next University of North Dakota (UND) president due to rearranged travel plans (Burleson 2016).

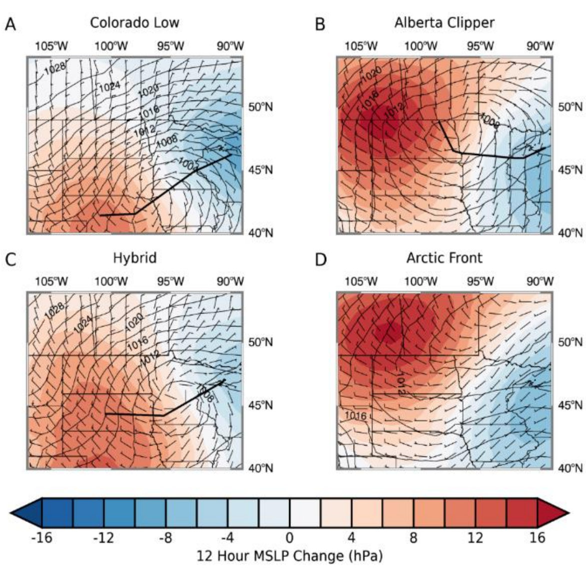

Figure 2. Composite meteorological patterns associated with blizzards in the Grand Forks NWS CWA. MSLP 12 hours prior to the event is contoured with 12-hr MSLP change filled. Thick black lines denote the mean stormtrack during the duration of blizzard events. Figure from Kennedy et al. (2019).

1.2 Forecasting challenges of BLSN

BLSN is one of several factors that lead to the reduction of visibility in winter storms. NOAA models such as the **High-Resolution Rapid Refresh (HRRR) do not contain the process of BLSN.** Instead, forecasters need to rely on either pattern recognition (Fig. 2) or empirical techniques to forecast this process. Currently used techniques and products are explained in Section 2.

The lofting of snow is dependent on snowpack conditions such as temperature and age (Li and Pomeroy 1997). As a result, threshold wind speeds for

BLSN can vary by these factors. Generally speaking, the frequency (and resultant threshold wind speed) of BLSN decreases with warming snowpack temperatures and age as the snowpack experiences the freeze-thaw cycle associated with the diurnal radiation budget along with the process of compaction. This process leads to the cohesion of snow particles that forms a crust (Hobbs and Mason 1964, Hosler et al. 1957, etc.). Higher winds are required to break this crust and loft snow, and and this poses a difficult challenge to regional forecasters given lack of research into this problem. Land type directly impacts whether blowing snow occurs; areas with more trees increase the roughness length of the surface, potentially weakening winds below thresholds required for blowing snow to occur. Empirical determination of BLSN risk is dependent on accurate forecasts of winds, knowing the condition of the snow-pack, and being cognizant of land-cover.

1.3 Usage of current NOAA models

Forecasters now have access to a variety of modeling tools at their disposal including high-resolution and ensemble modeling systems. These models have shown numerous improvements for warm season forecasts of precipitation and convective risks (e.g. Schwartz et al. 2015, Sobash et al. 2016, Clark et al. 2018). NOAA programs such as the NOAA Hazardous Weather Testbed (HWT) Spring Forecast Experiment (SFE) have demonstrated the utility of these modeling tools at the convective forecast desk (Clark et al. 2012, Clark et al. 2018). **Given the investment NOAA has made in present and future modeling efforts such as high-resolution models and ensembles, more knowledge is needed to understand how these predictive systems can improve forecasts for wintertime hazardous events**.

Literature is sparse for ensemble prediction of winter hazards. Of the studies that do exist, the focus has been on the Northeast US. For example, Novak and Colle (2012) investigated the skill of physics-varying ensemble for the prediction of three snowstorms in the Northeast US. While the system aided in the differentiation of high to low predictability events, there was significant uncertainty for the exact location of snowbands. More recently, Greybush et al. (2017) assessed the ensemble predictability of January 2015 and 2016 East Coast winter storms. They utilized the GEFS to downscale WRF simulations to determine where forecast errors originated. Locally, PI Mullendore served as advisor to Peterson (2016) who ran a 10-member physics-based ensemble for several Alberta Clipper events over the Northern Great Plains. Ensemble cyclone track, wind, and precipitation forecasts were verified against observations and reanalysis data. The study found the ensemble provided useful guidance and advocated for extending the analysis to varying initial conditions (i.e. GEFS) and additional cases.

Despite progress from these studies, there is still considerable uncertainty in how ensemble and high-resolution model data can be used to effectively make decisions for winter hazards. Currently, forecasters use the National Blend of Models (NBM) that eventually forms the NDFD to diagnose BLSN risk. This includes the empirical guidance developed by the Grand Forks / Aberdeen / Bismarck offices recently implemented in the ForecastBuilder / Graphical Forecast Editor (GFE) tool within AWIPS-II for NWS Central Region. BLSN probabilities were built upon cases within these select CWAs (Makowski and Grafenauer 2016). As a result, forecasters in other regions are unsure how these results translate to other areas especially those with different land surfaces (e.g. forested areas). In part for this reason, forecasters have expressed interest in **having explicit output from models that included both ensembles and high-resolution systems.** This information could then be combined to produce probabilistic products within the NBM. A survey conducted by the PIs for prior NOAA CSTAR proposal submissions found that the primary emphasis (need) requested from forecasters is for information within

48 hours of events that includes nowcasting style products such as the Multi-Radar/Multi-Sensor System (MRMS). These requests form the goals of the proposed project.

1.4. Scientific objectives

The overarching goal of this project is to improve forecasts of BLSN that will improve Impact-Based Decision Support Services (IDSS) provided by the Grand Forks (FGF) / Bismarck (BIS), ND offices. Provided the scope of this program, a case study approach will be taken to investigate blowing snow events for the winter of 2018-2019 to 2019-2020. This project has the following components:

1. Selection of BLSN cases and null events
2. Quantitative analysis of HRRR and RAP surface variables at sites across the BIS and FGF CWAs
3. Generation and evaluation of CBSM and WSSI BLSN guidance generated from HRRR/RAP analyses
4. Exploration of visualization strategies for a BLSN IDSS system

2. Description and delegation of tasks

<u>Objective 1: Selection of BLSN cases and null events</u>

The Grand Forks and Bismarck NWS offices will provide a list of cases that include blizzard events, BLSN events that did not reach blizzard criteria, and null events. An active winter in 2018-2019 (8 blizzards within the Grand Forks NWSFO CWA) assures that an ample number of cases will be available for the objectives regardless of the outcomes of the 2019-2020 winter.

<u>Objective 2: Quantitative analysis of HRRR and RAP surface variables at sites across the BIS and FGF CWAs</u>

To understand model biases in variables known to physically impact the process of BLSN and to provide insight into the performance of high-resolution models over the Northern Great Plains, HRRR and RAP forecasts will be compared to surface observations across the BIS and FGF CWAs. Provided the short-fuse nature of this project, forecasts will focus on the sub 24-hr timeframe. The quantitative analysis will focus on temperature and wind speed while precipitation will be considered subjectively (the focus is on the process of lofted snow).

Ms. Elizabeth Sims, a current graduate teaching assistant, will download and analyze the data for the cases. RAP data will be obtained from NOAA directly while archived HRRR forecasts will be downloaded from the University of Utah archive (Blaylock et al. 2017). Surface observations (in accessible data formats) will be downloaded from the Iowa Environmental Mesonet. To expedite the analysis, Ms. Sims will use code already written by the PI to investigate the BLSN/blizzard event of 24 February 2019 (Kennedy and Jones 2019, Figure 3). Further, Ms. Sims has experience analyzing surface variables to MRMS fields as part of a Research Experience for Undergraduate (REU) experience at the U. of Oklahoma.

<u>Objective 3: Generation and evaluation of CBSM and WSSI BLSN guidance from HRRR/RAP analyses</u>

Two efforts (one regional, one national) are ongoing to provide BLSN guidance. It is important to note that both of these efforts are not applied to raw model output. Rather, probabilities or risks due to blowing snow are based on winds provided from the National Digital Forecast Database (NDFD) which is also subject to biases.

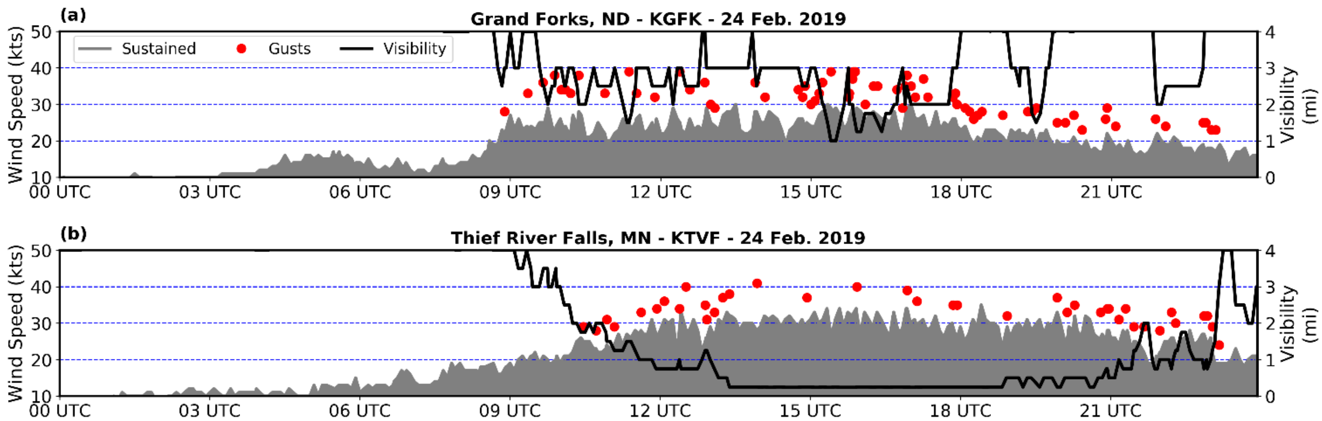

Figure 3. Timeseries of surface meteorological properties on 24 February 2019 including 10 m sustained winds (shaded grey area), 10 m wind gusts (red dots), and visibility (black lines) for (a) KGFK – Grand Forks, ND and (b) KTVF – Thief River Falls, MN.

Regionally, the Grand Forks NWSFO has spent time investigating the abilities of the Canadian Blowing Snow Model (CBSM, Baggaley and Hanesiak 2005) that calculates the probability of blowing snow based on properties such as snow age, snow amount, temperature, and wind speed. Makowski and Grafenauer (2016) analyzed the performance of this model for 27 BLSN events within the Grand Forks CWA from 2006-2014 and found that from an operational perspective, CBSM provided useful output as probabilities of blizzard events were correlated with visibility observations, with stronger correlations for events associated with falling snow. Limits of the study included a lack of null cases, and confinement to the Grand Forks CWA. Based on these results, the Grand Forks NWSFO partnered with other regional offices to provide operational guidance within AWIPS-II via the NDFD.

Nationally, the Winter Storm Severity Index (WSSI) is managed by the Weather Prediction Center (WPC). The WSSI combines multiple impacts into one index to provide NWS forecasters with an indication of the level of severity of winter storms. Hazards include snow load, snow amount, ice accumulation, flash freeze, BLSN, and ground blizzards. Each of these hazards are associated with a 0-5 (none-extreme) index. For any given location, the WSSI is then defined as the maximum of the individual indices.

Within the WSSI, BLSN is defined as blowing/drifting snow that is associated with the combination of wind and accumulating precipitation while ground blizzards consider wind acting on preexisting snow. The algorithms are relatively simplistic. A numerical index for WSSI BLSN is calculated by multiplying a) wind gust category, b) 6 hour snow ratio, c) 6 hour snow amount, and d) a land use factor. The index for WSSI ground blizzards is found by multiplying factors for snow age, snowpack temperature, and wind speeds, along with land use. The numerical indices are then converted to a scale ranging from 'None' to 'Extreme'.

Similar to the regional guidance, the WSSI is dependent on gridded meteorological information from the NDFD. Additional information is provided from land type/use maps and snow analyses from the National Operational Hydrologic Remote Sensing Center (NOHRSC). Due to the experimental nature of this product, it is archived in a non-standard fashion; the simplistic nature of the product, however, means components can be calculated retrospectively for the case studies.

After completing Objective 1, Ms. Sims will be assisted by the PI to calculate the WSSI and CBSM output from HRRR and RAP surface fields. Depending on the results of the prior objective, some modifications to the algorithms may be made to adjust for biases in properties such as wind speed. For the 2019-2020 winter, the FGF and BIS offices will archive products generated from the NDFD so comparisons can be made to the guidance produced from raw model output.

Guidance will be evaluated analytically by Ms. Sims and the PI. This will include comparison of BLSN probabilities to visibility observations at select surface sites within the FGF and BIS CWAs. In addition to this comparison, guidance for select events (ground blizzards that occur under predominately clear skies) will be compared to composite imagery from Geostationary Operational Environmental Satellites 16 (GOES-16). Kennedy and Jones (2019) demonstrated that BLSN can be seen with imagery that composites the 0.86, 1.6, and 3.9 – 10.3 μm bands, and this has proven useful in the operational environment (Fig. 4). The NWS will provide subjective feedback on guidance and how it compares to the areal extent and frequency of BLSN seen in daytime GOES-16 imagery.

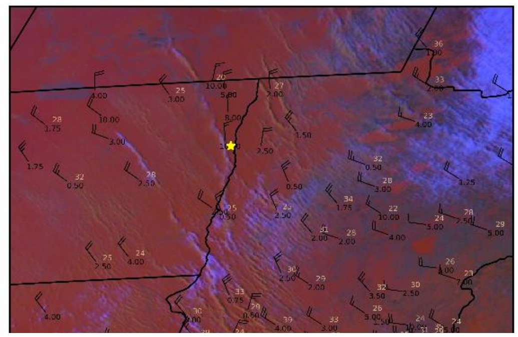

Figure 4. Example of a GOES-16 near-infrared composite image at 2137 UTC on 24 February 2019. Tan colors indicate areas of BLSN, seen as rows of horizontal convective rolls. Some purple bands are also BLSN, but topped by cloud. Visibility (mi) is indicated by black numbers (mi) while tan numbers are wind gusts.

<u>Objective 4: Exploration of visualization strategies for a BLSN IDSS system</u>

Objectives 2-3 will bring together a variety of data sources including remotely sensed (radar and satellite) observations, surface observations and the various model guidance. The amount of information poses issues for the operational setting where bandwidth and time considerations encourage efficient visualization strategies. A variety of visualization options will be tested for the case studies to understand forecaster preference. The NWS will provide subjective feedback on visualization strategies. This information will be used to guide future efforts that could entail incorporation into products such as the MRMS or determine panel confirmations within AWIPS-II.

3. Timeline of tasks

Objective 1: Cases will be compiled by the NWS during the winter of 2019-2020. UND will archive observations for these cases during this time.

Objective 2: UND will analyze model biases in the spring of 2020. This objective will be completed in the early summer.

Objective 3: Guidance will be created during the summer of 2020. The NWS will provide feedback on the guidance in the late summer/early fall.

Objective 4: Feedback from the NWS will be provided concurrently with Objective 3. After the conclusion of this objective, UND and NWS will jointly work on a manuscript to be submitted in the late fall of 2020.

4. References

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Peterson, B., 2016: Improving Forecasts Of Winter Storm Tracks Using A Local Ensemble, Thesis in Department of Atmospheric Sciences, University of North Dakota, 140 pp.

Schwartz, C. S., G. S. Romine, R. A. Sobash, K. R. Fossell, and M. L. Weisman, 2015: NCAR's experimental real-time convection-allowing ensemble prediction system. *Wea. Forecasting*, **30**, 1645–1654.

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Abbreviated Curriculum Vitae

Dr. Aaron Kennedy

Education and Training

University of Oklahoma	B.S. Meteorology	2004
University of Oklahoma	M.S. Meteorology	2006

Thesis: A Characterization of Descending Reflectivity Cores in Rear-flank Appendages of Supercells.

University of North Dakota	Ph.D. Atmospheric Science	2011

Dissertation: Evaluation of a Single Column Model at the Southern Great Plains Climate Research Facility

Post-doctoral research associate, Dept. of Atmos. Sciences, University of North Dakota.	2011-2012
NSF Post-doctoral Fellow, Dept. of Atmos. Sciences, University of North Dakota.	2012-2013

Research and Professional Experience

2019-Present	Associate Professor, Dept. of Atmospheric Sciences, University of North Dakota.
2013-2019	Assistant Professor, Dept. of Atmospheric Sciences, University of North Dakota.
2002-2004	Hail Forensics Worker, Weather Decision Technologies, Norman, Oklahoma

Publications Related to Proposed Project

Kennedy, A. and C. Jones, 2019: PICTURE OF THE MONTH: The 24 February 2019 Blowing Snow Event. *In prep for Mon. Wea. Rev.*

Kennedy, A., A. Trellinger, T. Grafenauer, and G. Gust, 2018: Climatology of Atmospheric Patterns Associated with Red River Valley Blizzards. *Climate, **7**, 66.*

Wang, J., X. Dong, **A. Kennedy**, B. Hagenhoff, and B. Xi, 2019: A Regime-Based Evaluation of Southern and Northern Great Plains Warm-Season Precipitation Events in WRF. *Wea. Forecasting*, **34**, 805–831.

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Professional Presentations (Selected Recent and Related)

"UND Research and Collaborative Opportunities", Northern Plains NWS Science Operations Officer (SOO) Community Meeting, Bismarck, ND (8/13/2019)

"Identifying Northern Great Plains Blizzards in the Past, Present, and Future", AMS 99th Annual Meeting, Phoenix, AZ (1/9/2019)

"Hazardous Convective Environments in the North American Regional Reanalysis", 16th NOAA Climate Prediction

Applications Science Workshop, Fargo, ND (5/22/18)

“Atmospheric Reanalyses: A Tool for Investigating Hazardous Weather Events.” U. of Arizona Dept. of Hydrology and Atmospheric sciences seminar (4/5/18)

“A Regime Based Climatological Assessment of WRF Simulated Deep Convection and Associated Precipitation”, 97th AMS Annual Meeting, Seattle, WA (1/24/17), *Presented by Brooke Hagenhoff, student oral presentation winner.*

Synergistic Activities

- Member of the American Geophysical Union, American Meteorological Society, and the American Association for the Advancement of Science
- In the past year, reviewer for: DOE, NSF, NOAA, Advances in Atmospheric Sciences, AGU JGR-Atmospheres, and the AMS Journal of Climate, AMS Weather, Climate and Society, MDPI Climate.
- 2016 Advances in Atmospheric Sciences Editor’s Award
- 2017: AAAS Climate Science Day on Capitol Hill Fellow
- 2017-Present: Center for Regional Climate Studies (CRCS) Assistant-Lead, and Stakeholders Advisory Board Organizer.

Dr. Gretchen Mullendore

Professional Preparation

Undergraduate Institution: University of California, Santa Barbara; Geophysics	B.S., 1998
Graduate Institution: University of Washington; Atmospheric Sciences	Ph.D., 2003
Postdoctoral Institution: UCLA; Atmospheric and Oceanic Sciences	2003-2007

Appointments

2019-current	Professor, University of North Dakota, Dept. of Atmospheric Sciences
2013-2019	Associate Professor, University of North Dakota, Dept. of Atmospheric Sciences
2007-2013	Assistant Professor, University of North Dakota, Dept. of Atmospheric Sciences
2007	Lecturer, University of California, Los Angeles, Dept. of Atmos. and Ocean. Sci.

Publications Related to Proposed Project

Starzec, M., G. L. Mullendore, and P. A. Kucera, 2018: Using Radar Reflectivity to Evaluate the Vertical Structure of Forecasted Convection. *J. Appl. Meteor. Climatol.*, 57, 2835–2849, https://doi.org/10.1175/JAMC-D-18-0116.1.

Barber, K.A., G.L. Mullendore, and M.J. Alexander, 2018: Out-of-Cloud Convective Turbulence: Estimation Method and Impacts of Model Resolution. *J. Appl. Meteor. Climatol.*, 57, 121–136, https://doi.org/10.1175/JAMC-D-17-0174.1

Xue, H., Q. Jin, B. Yi, G. L. Mullendore, X. Zheng, and H. Jin, 2017: Modulation of Soil Initial State on WRF Model Performance over China, *J. Geophys. Res. Atmos.*, 122. https://doi.org/10.1002/2017JD027023.

Mullendore, G. and M. Starzec, 2016: Forecast Model Activities for North Dakota Cloud Modification Project. *J. Weather Modification*, **48**, 93-98.

Bigelbach, B. C., G. L. Mullendore, and M. Starzec (2014), Differences in deep convective trans- port characteristics between quasi-isolated strong convection and mesoscale convective systems using seasonal WRF simulations, *J. Geophys. Res. Atmos.*, 119, 1–11, doi:10.1002/2014JD021875.

Other Significant Publications

Hacker, J., J. Exby, D. Gill, I. Jimenez, C. Maltzahn, T. See, G. Mullendore, K. Fossell: 2016: A containerized mesoscale model and analysis toolkit to accelerate classroom learning, collaborative research, and uncertainty quantification. *Bull. Amer. Meteor. Soc.,* **98**, 1129–1138.

Starzec, M., C. R. Homeyer, G. L. Mullendore, 2017: Storm Labeling in 3 Dimensions (SL3D): A Volumetric Radar Echo and Dual-Polarization Updraft Classification Algorithm. *Mon. Wea. Rev.*, 145, 1127–1145, doi: 10.1175/MWR-D-16-0089.1.

Mullendore, G. L., Homann, A. J., Jorgenson, S. T., Lang, T. J., and Tessendorf, S. A., 2013: Relationship between level of neutral buoyancy and dual-Doppler observed mass detrainment levels in deep convection, *Atmos. Chem. Phys.*, 13, 181-190, doi:10.5194/acp-13-181-2013.

Synergistic Activities

- Instructor, UND ATSC 530, "Numerical Weather Prediction"
- Instructor, UND ATSC 405, "Numerical Methods in Meteorology"
- Lead Investigator, daily North Dakota forecast simulations, used by ND Atmospheric Resources Board (NDARB) summer field operations and Grand Forks NWS, 2012-current

Appendix 2: Current and Pending Support

Dr. Gretchen Mullendore

Current:

Principal Investigator, NDARB, "Forecast Simulations for Western North Dakota, 2019-2020", $48,988, 6/1/19-4/30/21, 0.25 MM

Senior Personnel, NSF, “REU Site: Interdisciplinary Renewable and Environmental Collaborative - IREC”, $339,501, 1/2018-12/2020, 0.0 MM

Co-Principal Investigator, NASA, “Dynamics and Convection of the Summer Stratosphere (DCOTSS)”, $445,336, 1/1/19-12/31/23, 1.0 MM

Pending:
Principal Investigator, NSF, EarthCube RCN: "What About Model Data?": Determining Best Practices for Archiving and Reproducibility, $143,199, 10/1/19-9/30/21, 1.5 MM

Budget Justification

Budget Justification

Section A: Personnel

One M.S. will be supported during the project during the spring/summer semesters of 2020. Salary for graduate students typically cover a year-round (12-mo) research assistantship with base rates in year one of $24157 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 and one NWS employee to attend an operationally oriented meeting.

Based on prior trips, costs for a meeting are estimated at $2084 per trip.

Description NOAA Meeting	Cost per person	Notes / Justification
Airfare	550	Delta.com / Prior experience
Hotel	750	$150/night, 5 nights
Per diem	534	$89/day * 6 days, Gov. rate
Local transit	50	Mass transit
Conference Fees	200	Estimated
Total	**2084**	

Other Direct Costs

Publication Costs

One paper is budgeted at an estimated rate of $2900 per article. This estimate comes from an estimated 15-page paper at the AMS rate of $120/page and an additional $1100 to make papers open-access.

Indirect Costs

The indirect cost rate of 39% 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 Thomas Suttles (578-893-8338) at the DHHS/OIG/Office of Audit Region VII.

UND UNIVERSITY OF NORTH DAKOTA

Proposal Transmittal Form

Five business days prior to the sponsor's due date, submit to Division of Research & Economic Development the following: 1) a completed transmittal

Division of Research & Economic Development | Tech Accelerator, Room 2050 | 4201 James Ray Drive, Stop 8367 | Phone: 701-777-2505

SECTION A: SUBMISSION INFORMATION

For e-submission email full proposal to: vpr.proposals@und.edu

Phone # to call for pickup: 701-777-5269

Project #:

Competitive Proposal: ☑ Yes ☐ No

Electronic Submission: ☑ Yes ☐ No

Due Date: No deadline

○ Pre-Proposal ◉ New Proposal ○ Renewal ○ Revision ○ Supplemental ○ Progress Report

SECTION B: PROPOSAL DATA

Principal Investigator Name:	Dept Name:	Dept #:	PI Phone #:	PI Email:
Aaron Kennedy	Atmospheric Sciences	2210	5269	aaron.kennedy@und.edu
Co-PI Name:	**Dept Name:**	**Dept #:**	**Co-PI Phone #:**	**Co-PI Email:**
Gretchen Mullendore	Atmospheric Sciences	2210	4707	gretchen.mullendore@und.edu

Proposal Title: Development and Assessment of Blowing Snow Guidance for an IDSS Situational Awareness Display

Start Date: 1/1/2020 End Date: 12/31/2020

Sal? due? yes yes

Effort - 5% minimum for PI and Co-PI (if applicable) per effort policy. *See Instruction, #9 for further requirements.

UND Personnel	UND Employee Name	Calculated Total %	% of Effort Paid By Agency	% of Effort Paid by Dept	If known, list the Local/Appropriated Funding Source currently paying salary
PI	Aaron Kennedy	5 0%	0%	~~0%~~ 5%	30005-2210
Co-PI	Gretchen Mullendore	5 0%	0%	~~0%~~ 5%	30605-2210
Key Personnel		0%			
Key Personnel		0%			
Key Personnel		0%			
Key Personnel		0%			

University Commitments - check all that apply

☐ Faculty Release Time Beyond Current Allocation ☑ Graduate Tuition Waiver ☐ Other

☐ Office/Lab Space Beyond Current Allocation ☐ Department Funds Used as Matching

Additional Information - complete all sections

		Yes	No
UND to issue subaward to external entity?	*If "Yes", see Instruction #11	☐	☑
Proposing new building construction, major renovations or building additions?	*If "Yes", route to Facilities	☐	☑
Creating a new course/curriculum for credit?	*If "Yes" route to VPAA for SBHE approval	☐	☑
Is Program Income anticipated from this proposal? Example: sale of an item(s) or charging registration fees		☐	☑
Is a department, other than the PI's department involved in this proposal?	*If "Yes", see Instruction #11	☐	☑
Has lobbying occurred in relation to the proposal?		☐	☑
Does this proposal focus in part or completely on Native American populations?		☐	☑
Did this proposal result from a Faculty Research Seed money (FRSM) grant?		☐	☑
Is support staff/clerical staff salaries proposed?	*If "Yes", be sure to justify in the budget	☐	☑

SECTION C: SPONSOR/PROGRAM DATA

Agency Type: Non-Profit Flow Through Type: SELECT Function: Research - Applied

Grand Challenge, if applicable: Primary: Big Data Secondary: SELECT

Agency Name: UCAR / COMET Flow Through Name:

Is there a limit on the number of proposals that can be submitted to the Agency from UND? ☐ Yes ☑ No

;SECTION D: BUDGET DATA

incurred are project related and in accordance with contractual terms, conditions and time frames, and ensuring the technical and reporting requirements of the project are satisfied.

What is UND's Indirect Cost rate for this proposal? 39.0%

Does the Agency restrict the Indirect Cost allowable in the budget? If "Yes", provide documentation ☐Yes ☑No

Agency approved Indirect Cost rate if lower than UND's approved F&A rate:

Was a request approved by the VPFO to waive UND's Indirect Cost rate? If "Yes", provide documentation ☐Yes ☐No

Direct Costs	Indirect Costs (F&A)	Total	Total + Cost Share
$10,780.00	$4,204.00	$14,984.00	$19,968.00

Equipment/Equipment Fabrication greater than or equal to $5,000 per unit? *If "Yes", see Instruction #21 ☐Yes ☐No

SECTION E: COMPLIANCE DATA

Animals: ☐Yes ☑No Inst. Animal Care & Use Committee (All Live Vertebrate Animals)	**Human Subjects:** ☐Yes ☑No Institutional Review Board	**Biohazard or Recombinant DNA:** ☐Yes ☑No Institutional Biosafety Committee
Radioactive Materials ☑Yes ☑No Radiation Safety & Hazardous Materials Committee	**Controlled Substances:** ☐Yes ☑No **Select Agents BSL Level 3:** ☐Yes ☑No	

Other Compliance Topics - complete all sections

Will any foreign nationals be working on this project? If unknown, choose No. ☐Yes ☑No

Are you aware of any publication restrictions on this project? ☐Yes ☑No

Are there plans to work with or travel to an international country? Country ☐Yes ☑No

Is it anticipated this project would result in new intellectual property? If unknown, choose No. ☑Yes ☐No

Will UND's existing intellectual property be utilized? Invention ID#: ☐Yes ☑No

Is it anticipated this project will use intellectual property not owned by UND? ☐Yes ☑No

Does this involve a confidentiality agreement, material transfer agreement or proprietary information? ☐Yes ☑No

Has the PI, Co-PI and Key Personnel filed Conflict of Interest Disclosure forms within the past 12 months? ☑Yes ☐No

Is this a PHS or PHS flow-through proposal? If "Yes", attach Page three of the proposal transmittal ☐Yes ☑No

Is proposal for STTR/SBIR (Small Business Technology Transfer/Small Business Innovation Research)? ☐Yes ☑No

Is a Small Business Subcontracting Plan required (contracts over $650,000)? ☐Yes ☑No

If NSF proposal, is Responsible Conduct of Research (RCR) training complete? ☐N/A ☐Yes ☑No

SECTION F: APPROVALS

By signing this transmittal form, you are certifying that 1) the information submitted herein is true, complete and accurate to the best of your knowledge, 2) any false, fictitious, or fraudulent statements or claims may subject you to criminal, civil or administrative penalties, 3) you agree to accept the responsibility for the scientific conduct of the project and to provide progress reports, and 4) PI and any other key personnel are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from current transactions by any federal department or agency.

Aaron Kennedy 9/23/19
UND Principal Investigator (Print & Sign) Date

Co-Principal Investigator Chair (Print & Sign) Date

9/23/19
UND Co-Principal Investigator (Print & Sign) Date

Co-Principal Investigator Dean (Print & Sign) Date

Michael Poellot 9-23-19
Principal Investigator's Chair (Print & Sign) Date

Bonnie Baumgartner 9/23/19
School/College - Admin./Finance (Print & Sign) Date

9/23/19
Principal Investigator's Dean (Print & Sign) Date

Karen Kath (Karen Kotrick) 10/4/19
Other (Print & Sign) Date

Campus Capital Proj & Planning (as needed) Date

Division of Research Authorized Official Date