Environment and Natural Resources Trust Fund
2014 Request for Proposals (RFP)

Project Title: **ENRTF ID: 138-E**

Wind Energy from Gravity Waves and Nocturnal Jetstreams

Category: E. Air Quality, Climate Change, and Renewable Energy

Total Project Budget: $ 191,779

Proposed Project Time Period for the Funding Requested: 3 Years, July 2014 - June 2017

Summary:

This project examines gravity waves and nocturnal jetstreams for wind turbine energy generation. Results will help Minnesota meet the 25% renewable energy requirement by 2025 and will improve air quality.

Name: Timothy Griffis

Sponsoring Organization: U of MN

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Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ Employment	_____ TOTAL _____%

PROJECT TITLE: Wind Energy from Gravity Waves and Nocturnal Jetstreams

I. PROJECT STATEMENT

Why this project is important: Minnesota law requires that 25% of its electricity production come from renewable energy sources, such as wind, by 2025. Recent emphasis on developing wind turbine technologies to meet these demands has prompted research regarding the trends, patterns, and statistical properties of wind. In this project, we aim to quantify and model gravity waves, nocturnal jetstreams, and wind velocities at turbine height to provide new knowledge for planning future wind turbine design and wind farms in Minnesota. These research activities have the potential to help Minnesota meet the 25% renewable requirement, thereby, offsetting the State's greenhouse gas emissions through fossil fuel burning and improving air quality.

As recently reported in the Star Tribune (http://www.startribune.com/local/north/207136111.html?refer=y), energy companies are in need of wind data and wind forecasts ***"on the nose of the wind turbine",*** which are typically installed at heights of about 80 m. The intent of this proposal is to help meet that challenge by producing new measurements and model forecasts of wind properties across Minnesota. Wind speeds at turbine height often reach a maximum velocity at night, while the surface observations reveal calm conditions. This phenomenon is related to the development of gravity waves and the formation of nocturnal jetstreams. The results from this study will have implications for understanding the available energy at these altitudes, turbine and structural designs, siting wind farms, as well as understanding other meteorological processes such as damaging wind gusts and intensification of precipitation events, which are linked to nocturnal jetstreams.

Goals of the project:

- Analyze 7-years of high frequency (i.e. 10 measurements per second) wind and turbulence data to assess the diurnal and seasonal dynamics of wind speed and wind energy potential for Minnesota;
- Gain new knowledge regarding the development and occurrence of nocturnal gravity waves and jetstreams and assess their influence on wind energy;
- Test the accuracy of the Weather Research and Forecasting (WRF) model in predicting wind statistics above the surface layer to assess if it can reliably estimate the potential wind power production at the **nose of the wind turbine** and map the optimal location of future wind farms in Minnesota.

How to achieve the goals: From 2007 to present our research team has been measuring wind and turbulence characteristics at heights ranging from 3m to 200 m at the University of Minnesota Rosemount Research and Outreach Center tall tower facility in order to study the carbon, water, and nitrogen budgets for our region. These long-term datasets will prove powerful in assessing the wind energy potential for Minnesota and the fluid dynamics that influence wind speeds at these altitudes. We will use the WRF model to test its ability to forecast the wind profile through the atmosphere and will use it to assess optimal locations of future wind farms.

II. DESCRIPTION OF PROJECT ACTIVITIES

Activity 1: Observe and Analyze Wind, Gravity Wave, and Nocturnal Jetstream Behavior **Budget: $76,800**

We will use our long-term tall tower observations to quantify wind velocities and identify gravity waves and nocturnal jetstreams and determine their influence on potential wind energy production.

Outcomes	Completion Date
1. 3 dimensional wind fields obtained at 3 m to 200 m levels on tall tower	Aug 1, 2014
2. Compile data sets and perform quality control	Oct 1, 2014
3. Phase 1 data products: basic wind statistics, patterns, and trends for 2007-present	Jan 1, 2015

4. Phase 2 data products: identify and describe gravity waves and nocturnal jets	July 1, 2015
5. Phase 3 products: scientific publications related to Phase 1 and Phase 2 activities	Dec 1, 2015

Activity 2: Model and Forecast Wind, Gravity Wave, and Nocturnal Jetstream Behavior **Budget: $76,800**

We will validate the Weather Research and Forecasting model using our observations and then extend the model forecast to the entire state at high resolution (a few meters to a few kilometers).

Outcomes	Completion Date
1. Phase 1 model products: model testing and parameterization	April 1, 2016
2. Phase 2 model products: comparisons of model simulations to long-term field data	July 1, 2016
3. Phase 3 products: scientific publications related to Phase 1 and Phase 2 activities	Jan 1, 2017

Activity 3: Identify Optimal Locations for Future Wind Farms **Budget: $38,400**

We will use a combination of measurements and model forecasts over multiple years to help determine the optimal sites for future wind farms.

Outcomes	Completion Date
1 Phase 1 model products: 3 dimensional maps illustrating the optimal heights and spatial locations of future wind turbines and wind farms	April 1, 2017
2. Transfer data and knowledge to stakeholders	June 1, 2017

III. PROJECT STRATEGY

A. Project Team/Partners

1) Tim Griffis, Micrometeorologist, Professor, Dept. Soil, Water, and Climate, University of Minnesota, will oversee all aspects of the project. He will take the lead role in maintaining the tall tower wind observations, data quality control, and will organize the WRF modeling activities.
2) John Baker, Micrometeorologist, USDA-ARS and Professor, Dept. Soil, Water, and Climate, University of Minnesota, will oversee all of the surface wind and turbulence measurements and analyses conducted at 3 AmeriFlux sites in Minnesota with observations obtained at approximately 3 m above the ground.
3) Dylan Millet, Atmospheric Chemist, Associate Professor, Dept. Soil, Water, and Climate, University of Minnesota, will assist with all of the atmospheric modeling activities and optimal wind farm location analyses
4) Mark Seeley, Extension Climatologist, Professor, Dept. Soil, Water, and Climate, University of Minnesota, will assist with project outreach and incorporating research findings into his extension program.

B. Timeline Requirements

A three-year project duration is estimated based on the extensive data analyses and modeling activities outlined above.

C. Long-Term Strategy and Future Funding Needs

The proposed project is heavily leveraged against National Science Foundation and Department of Energy Funding, which allowed us to establish these measurement systems at the Rosemount Research and Outreach Center of the University of Minnesota. The focus of those previous studies was on the greenhouse gas budgets of Minnesota's agricultural sector. We are now leveraging those datasets and pursuing new funding to exploit their use in improving clean renewable wind energy for Minnesota. Our long-term goal is to provide a high temporal and spatial resolution wind forecast as a means to assess potential wind energy and establish optimal siting of future wind farms. Funding through LCCMR can help us meet those important goals.

2014 Detailed Project Budget

Project Title: *[Wind Energy from Gravity Waves and Nocturnal Jetstreams]*

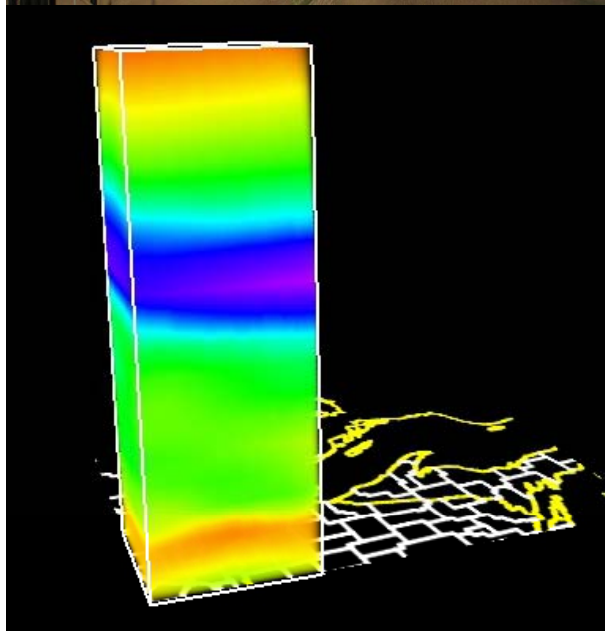
IV. TOTAL ENRTF REQUEST BUDGET *[3]*

BUDGET ITEM *(See "Guidance on Allowable Expenses", p. 13)*	**AMOUNT**	
Personnel: Tim Griffis and Dylan Millet hold 9-month appointments at the University of Minnesota. They are each requesting approximately 0.25 months of summer salary in each year of the project. Griffis will oversee all aspects of this project. Millet will assist with the wind modeling component of this study and will also help supervise the PhD student. Griffis is requesting a total of $3,492 plus $232 fringe. Millet is requesting $2,957 plus $196 fringe. Seeley and Baker hold 12-month appointments and are not requesting funds.	$	20,630.00
PhD student (to be named) will analyze the data and assist Griffis/Millet with the modeling component of this project. The student salary will be $66,118 plus $53, 830 fringe for the three year study period. They will join the Graduate program in Land and Atmospheric Science.	$	119,949.00
Contracts: We will rent space from Minnesota Public Radio to maintain our equipment on their communications tower at the University of Minnesota, Rosemount Research and Outreach Center - also known as UMORE park. The cost is $700 per month and includes electricity. Total cost is for the three year study period.	$	25,200.00
A professional tower climbing team will maintain our equipment on the tall tower facility i.e. the sensors located at 100 m and 200 m. Estimated cost for the climbs is $2000 per year.	$ 6,000.00	
Equipment: A sonic anemometer will be replaced/repaired at the tall tower 200 m level. The cost of the sonic anemometer is $20,000. This instrument has a lifetime of about 10 years and will serve as a research and teaching instrument beyond the years of this project.	$	20,000.00
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	**$191,779**	

V. OTHER FUNDS

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ Being Applied to Project During Project Period: *Indicate any additional non-state cash dollars to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.*	NA	
Other State $ Being Applied to Project During Project Period: *Indicate any additional state cash dollars (e.g. bonding, other grants) to be spent on the project during the funding period. For each individual sum, list out the source of the funds, the amount, and indicate whether the funds are secured or pending approval.*	NA	
In-kind Services During Project Period: *Griffis and Millet will each contribute 1% of in kind support per year.*	$ 8,250	*secured*
In-kind Services During Project Period: unrecovered IDC of 52% MTDC	$ 63,425	secured
Remaining $ from Current ENRTF Appropriation (if applicable): *Specify dollar amount and year of appropriation from any current ENRTF appropriation for any directly related project of the project manager or organization that remains unspent or not yet legally obligated at the time of proposal submission. Be as specific as possible. Describe the status of funds in the right-most column.*	NA	
Funding History: *The research site and tall tower facility to be used in this research project has been funded since 2004 by NSF, DOE, and USDA. Proposals are pending to continue the support.*	$ 2,250,000	past funding

Wind Energy from Gravity Waves and Nocturnal Jetstreams



1. Characterize gravity waves, jetstreams, and the potential wind energy at high altitudes using sonic anemometry

2. Model and forecast wind energy across the state of Minnesota

3. Provide new knowledge for planning Minnesota's wind farms, help reduce CO_2 emissions, and improve air quality using clean energy

Project Manager Qualifications

Dr. Tim Griffis is a professor in the Department of Soil, Water, and Climate at the University of Minnesota (www.biometeorology.umn.edu). He has been a faculty member at the University of Minnesota since 2002. He teaches courses in micrometeorology and climatology and specializes in boundary-layer meteorology and biometeorology. His research involves the use of boundary layer theory, isotope techniques, and land-atmosphere modeling to study atmospheric transport processes and the greenhouse gas budgets of natural and managed ecosystems at the field to regional scales. He has managed several large scale projects funded by the National Science Foundation, Department of Energy, and United States Department of Agriculture. In the proposed project he will oversee all of the wind measurement and modeling activities and will ensure that all reporting requirements are met and the project stays on schedule.

Professional Preparation

2002	NSERC Postdoctoral Fellow, Biometeorology, Univ, of British Columbia, BC, Canada
2000	Ph.D., School of Geography and Earth Sciences, McMaster University, ON, Canada
1995	B.Sc., Physical Geography, Brock University, ON, Canada

Appointments

2012-	Professor, Department of Soil, Water, and Climate, University of Minnesota- Twin Cities, USA
2006-2012	Associate Professor, Department of Soil, Water, and Climate, University of Minnesota-Twin Cities, USA
2002-2006	Assistant Professor, Department of Soil, Water, and Climate, University of Minnesota-Twin Cities, USA
2000-2002	Natural Sciences and Engineering Research Council Postdoctoral Fellow, Biometeorology and Soil Physics Group, University of British Columbia, Canada
1997-2001	Research Assistant, Canadian Land-Atmosphere Surface Scheme Project, Meteorological Service of Canada

Synergistic activities:

- Co-Director of Graduate Studies in Land and Atmospheric Science, Dept. of Soil, Water, and Climate, University of Minnesota, 2009-present
- Member of the National Ecological Observatory Network (NEON Inc.)- Fundamental Instrument Unit, Working Group, 2009-present
- Associate Editor, Agricultural and Forest Meteorology, 2008 to present
- Associate Editor, Journal of Geophysical Research-Biogeosciences, 2007 to 2011

Organizational Description

The proposed research will be conducted in the Department of Soil, Water, and Climate at the University of Minnesota in collaboration with the USDA-ARS group (Dr. John Baker, Unit Leader). The field research will take place at the Rosemount Research and Outreach Center of the University of Minnesota. This research site includes a number of micrometeorological stations and a tall tower facility that are part of the national and international AmeriFlux network (http://ameriflux.lbl.gov/SitePages/Home.aspx). All of the proposed data analyses and modeling activities will rely on the University of Minnesota Supercomputing Institute (https://www.msi.umn.edu/). All project personnel are members of the Land and Atmospheric Science program of the University of Minnesota. We will recruit one PhD student to assist with the data analyses and modeling activities proposed in this study. The student will be mentored by Griffis, Millet, Baker, and Seeley. All of the research will be performed within the guidelines of the University of Minnesota.