Environment and Natural Resources Trust Fund
2015 Request for Proposals (RFP)

Project Title: **ENRTF ID: 104-E**

Lake and River Spray Impacts on Minnesota Climate

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

Total Project Budget: $ 516,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2015 - June 2018

Summary:

Breaking water waves emit chemically complex ultrafine droplets, which grow into atmospheric aerosol particles. Studying regional implications of particles on cloud formation will improve Minnesotas air quality and climate models.

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Natural and human activities on the surfaces of lakes and rivers release aerosols into the atmosphere, impacting both regional air quality and climate.

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

PROJECT TITLE: Lake and River Spray Impacts on Minnesota Climate

I. PROJECT STATEMENT

The presence of nanometer sized aerosol particles (nanoparticulates) in our atmosphere impacts regional temperatures and precipitation, due to changes in solar radiation adsorption and in cloud properties. As the climate changes, these particles are predicted to dramatically alter regional precipitation, leading to intense storming events separated by longer dry periods. Well-studied sources of these particles include natural sources from plants and trees and anthropogenic sources from cars, ships and smoke-stakes. One source of pollution that has until recently been neglected is from larger bodies of water. It has been shown that along ocean coastlines, water wave induced sprays and bubble releases have a strong influence on atmospheric aerosol formation, leading to tens of millions of nanoparticulates per cubic meter released into the air. This aerosol formation can be further enhanced through commercial and recreational boating activities.

Unique amongst the 50 states, Minnesota contains more than 13 million square acres of lakes, rivers, streams and wetlands (making up 23% of the state's total area), and water activities and air quality are hence intrinsically linked within the state. Nonetheless, nanoparticulate release due to natural and human activities in and around water bodies is considered neither in regional weather and climate models, nor in any of Minnesota's Ambient Air Quality Standards (Minnesota Administrative Rules, Chapter 7009). This is an issue which merits further investigation; the chemistry of Minnesota's water bodies differ substantially from the better-studied case of oceans (which release primarily salt particulates), and the chemicals released by water activities may be detrimental to both human health and the environment. They also have an influence on local climate: depending on their chemical composition, nanoparticulates in the air may uptake water (water molecules from the air condense onto the surface of the nanoparticulates, causing them to grow orders of magnitude in size), leading to cloud formation, and influencing both annual rainfall and snowfall throughout the state.

In order to accurately predict Minnesota's changing climate, it is essential to understand to what extent Minnesota's water bodies influence its air quality. Our multidisciplinary five person research team will use a combination of state-the-art water quality and air quality field measurements, laboratory scale experiments, and fluid mechanical models, which will result in the information necessary to improve the accuracy of Minnesota's air quality and climate models.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Air and Water Quality Monitoring near Lake Superior* **Budget: $80,000**

Over one month period in the summer of 2016, we will monitor the daily concentrations of heavy metals, salts, and organics in a Lake Superior coastal site, and simultaneously monitor the concentrations of these chemical compounds in aerosol particles collected in the same region. We will also monitor the size distributions of aerosol particles and new particle formation events a coastal site. Subsequently, we will be able to develop climate models which account for lake spray aerosols.

Outcome	Completion Date
1. Determination of daily variation in species concentrations in Lake Superior water	*08/2016*
2. Determination of daily variation in species concentrations in Lake Superior air	*08/2016*
3. Completion of data analysis and construction of air quality/climate model	*08/2018*

Activity 2: *Aerosol Particle Formation due to Recreational Boating* **Budget: $80,000**

Using real-time measurement equipment, we will monitor aerosol particle formation in engine exhaust from a recreational boat operating on Lake Minnetonka. Subsequent data analysis over the course of a year will enable us to estimate nanoparticulate production rates due to recreational boating.

Outcome	Completion Date

1. Determination of particle sizes and concentrations emitted from boat exhaust	*08/2017*
2. Completion of data analysis and construction of air quality/climate model	*08/2018*

Activity 3: *Cloud Forming Potential of Water-Generated Nanoparticulates* **Budget: $178,000**

Through a combination of thermodynamic models and laboratory scale experiments in the Particle Technology Laboratory, we will determine to what extent the water generated particulates grow to become cloud condensation nuclei.

Outcome	Completion Date
1. State-of-the-science measurements of water uptake by laboratory generated particles	*06/2018*
2. Development of a predictive thermodynamic model of water-uptake by particles, implementable in air quality and climate models	*06/2018*

Activity 4: *Computer Simulation and Experimental Corroboration of Water Induced Particle Formation* **Budget: $178,000**

Using high performance computation and the best available models of liquid-gas simultaneous motion, we will develop prediction models for nanoparticulate formation rates based upon local wind speeds, and directly test such models through experiments at the Saint Anthony Falls Laboratory.

Outcome	Completion Date
1. Development of aerosol formation rate model	*06/2018*
2. Model validation through laboratory scale experimentation	*06/2018*
3. Model validation using field data collected at Lake Superior and Lake Minnetonka	*06/2018*

III. PROJECT STRATEGY

A. Project Team/Partners

The project activities will be carried out by the laboratory groups of Professors Cari Dutcher (PhD Chemical Engineering, UC Berkeley), Chris Hogan (PhD in Environmental Engineering, Washington University), and Lian Shen (ScD in Fluid Mechanics, MIT), who are all presently tenure-track/tenured faculty in the Department of Mechanical Engineering at the University of Minnesota, and will include two post-doctoral scholars. Uniquely, the project will involve faculty associated with both the Particle Technology Laboratory, and the Saint Anthony Falls Laboratory, two centers which have a history of successful research on aerosols and environmental fluid mechanics, respectively.

B. Project Impact and Long-Term Strategy

The proposed studies will be the first to directly examine interactions between water related activities on air quality in a non-oceanic environment, which will be an important step toward improved understanding of our state's lake and river rich environment, allowing for a unified treatment of the environmental-quality, as opposed to isolated air and water quality standards. The proposed work will lead to data which can be directly input into regional air quality and climate models, which predict both aerosol concentrations and cloud formation rates. All data collected will be made freely available via a website managed by the University of Minnesota. Beyond the 36 month funded period, the project investigators will seek to expand this project to investigate water, air, and soil interactions through the establishment of a National Science Foundation supported Engineering Research Center (ERC).

C. Timeline Requirements

The proposed activities will be completed over a 36 month period, with the field study portions completed in the first 24 months, and laboratory scale experiments as well as modeling efforts, which are dependent on field study results, completed at the end of 36 months.

2015 Detailed Project Budget

Project Title: *Assessing Water-Air Quality Interactions in Minnesota*

IV. TOTAL ENRTF REQUEST BUDGET *3* **years**

BUDGET ITEM *(See "Guidance on Allowable Expenses", p. 13)*	**AMOUNT**
Personnel:	
Prof. Cari Dutcher, Project Manager, lab-scale experiments and thermodynamic modeling, 1.5 months of salary and benefits, 8.3% of total salary, 75% salary, 25% benefits	$ 21,565
Prof. Chris Hogan, Project Manager, field studies and data analysis, 1.5 months of salary and benefits, 8.3% of total salary, 75% salary, 25% benefits	$ 22,243
Prof. Lian Shen, Project Manager, fluid dynamics modeling and spray aerosol production, 1.5 months of salary and benefits, 8.3% of total salary, 75% salary, 25% benefits	$ 22,339
2 Full-time Postdoctoral Research Associates, Data collection and analysis, 36 months of salary and benefits each, 100% FTE, 77% salary, 23% benefits	$ 360,085
Contracts	
Trailer and space rental on the Lake Superior shore for a three week measurement study	$ 5,000
Boat rental on Lake Minnetonka for a three week measurement study	$ 10,000
Equipment/Tools/Supplies:	
Funds to contruct an electrodynamic balance for laboratory scale studies of particles	$ 20,000
Funds to support operation of flumes for experiments at Saint Anthony Falls Laboratory; flumes are artificial channel in which lake spray events can be simulated, and used to construct models of Lake Spray events.	$ 10,000
Funds for sampling tubes, tubing systems; entirely stainless steel tubing systems will be constructed for field and laboratory scale measurements of particles, the use of plastic tubing is known to lead to chemical interferences in measurements.	$ 3,768
Funds for Gas Cylinders used in both field studies and laboratory experiments; speficially Nitrogen and Argon are required for the operation of Mass Spectrometers used in chemical analysis of water and air samples.	$ 1,000
Funds for an Inductively Coupled Plasma Mass Spectrometer (ICP-MS) to be used in field measurements; ICP-MS instruments enable detection of metal compounds in both air and water samples, in particular those which are toxic and particularly harmful to the environment	$ 25,000
Acquisition (Fee Title or Permanent Easements):	N/A
Travel:	
Lodging and equipment transport for three week field study on Lake Superior shore	$ 15,000
Additional Budget Items	N/A
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 516,000

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ To Be Applied To Project During Project Period:	N/A	
Other State $ To Be Applied To Project During Project Period:	N/A	
In Kind Services: Both field studies and laboratory scale measurements will make use of instruments available in the Particle Technology Laboratory at the University of Minnesota, including mass spectrometers and scanning mobility particle sizers.	N/A	
Funding History:	N/A	
Remaining $ From Current ENRTF Appropriation	N/A	

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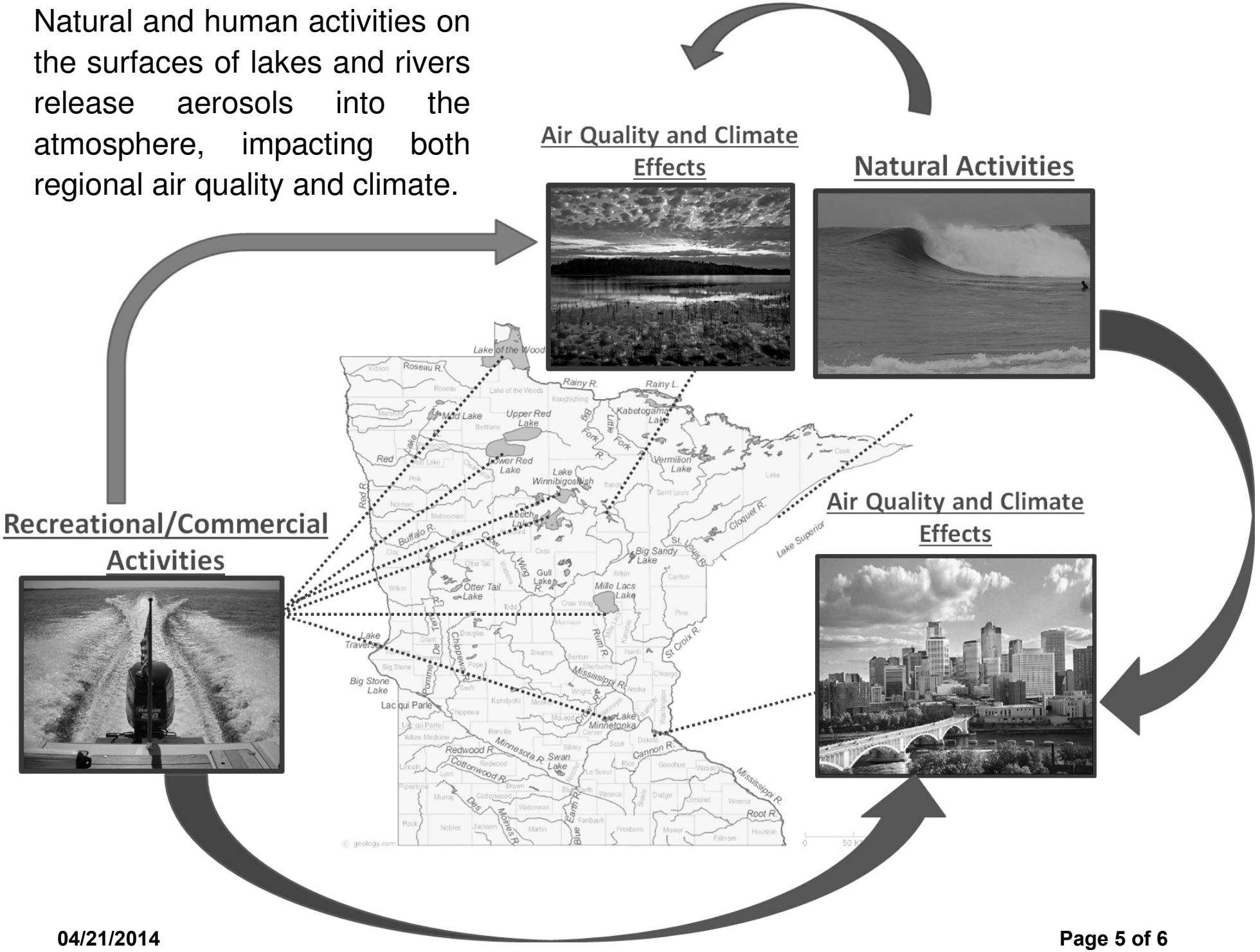

Project Manager Qualifications:

All proposed activities will be performed by graduate research assistants (PhD students at the University of Minnesota-Twin Cities Campus) and full-time research associates (with PhDs) under the supervision of Professor's Cari Dutcher, Chris Hogan, and Lian Shen. All three are full-time faculty members in the department of mechanical engineering at the University of Minnesota, and collectively, in the past 5 years, they have served as principal investigators/co-investigators on federally sponsored research projects with over $2,500,000 in research funds. Prof. Dutcher (PhD in Chemical Engineering) specializes in the study of multiphase systems, including the formation and growth of multi-component aerosol particles. Prof. Hogan (PhD in Environmental Engineering) specializes in the development of instruments to analyze aerosol physical and chemical properties, as well as methods of mitigation for air pollution. Prof. Shen (PhD in Fluid Mechanics) specializes in the study of wind-wave interactions, and the development of computational techniques to study such interactions.

Organization Description:

The University of Minnesota-Twin Cities Campus is the oldest and largest campus of the University of Minnesota system, and with over 50,000 students it has the 6th largest main campus student body in the United States. Within UMN, the department of Mechanical Engineering (ME) is at the forefront of engineering graduate programs in the nation. The department's doctoral program was ranked 7th overall in the 2010 National Research Council (NRC) Assessment of Doctoral Research Programs. Considering ME departments at all public institutions evaluated by the NRC, no mechanical engineering department received both a higher R-ranking (research ranking) and "Students" rating (student quality and satisfaction) than the UMN mechanical engineering department.

The mechanical engineering department has 39 active faculty members, 164 PhD students, 139 MSME students, 8 postdoctoral associates, ~550 undergraduate students, and 46 staff members (including professional staff and research associates). The department is internationally renowned for its research in heat transfer, aerosol science and engineering, fluid & plasma technology, and energy. Since 2009, the department has collectively published ~550 peer reviewed scientific journal articles. In addition to success in research, the department has a strong record of placing PhD graduates into positions in industry, primarily within the state of Minnesota. Of the department's 250 most recent PhD graduates, ~74% have gone on to positions in industry, 21% are tenure-track or tenured faculty in engineering or physics departments in the US or abroad, and 5% are employed as post-doctoral associates.