Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-232

Proposal Title: Study of fog in Minnesota climate and environment

Project Manager Information

Name: Lian Shen

Organization: U of MN - St. Anthony Falls Laboratory

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Project Basic Information

Project Summary: We will study the generation of fog and its life cycle in Minnesota environment, its effects on snow melting, climate change influences, and traffic and health hazards caused by fog.

Funds Requested: $340,000

Proposed Project Completion: June 30 2025

LCCMR Funding Category: Air Quality, Climate Change, and Renewable Energy (E)

Project Location

What is the best scale for describing where your work will take place?

Statewide

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Fog can affect human being's safety and health. Poor visibility leads to injuries and deaths in traffic accidents on roads, and is a dominant factor determining the safety of airplanes and boats. While the weather pattern in Minnesota usually keeps air pollution below the unhealthy level, it is known that fog leads to pollution growth by trapping the pollutants and hazardous particles. The abundance of water resources in Minnesota contributes greatly to the formation of fog. Minnesota currently experiences about 100 foggy days every year. With climate change, the occurrence of foggy days will increase when the winters are warmer.

To improve our prediction capabilities for fog, we need to understand how fog forms, develops, and disappears. The fog life cycle is influenced by the local weather and land topology. Because the weather conditions in Minnesota are different from many other parts of the United States, the fog research being conducted elsewhere in the country is not applicable to Minnesota. Therefore, there is a critical need for the study of fog in Minnesota climate and environment.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

The proposed work will be performed in parallel with another project of Professor Lian Shen, in which marine fog will be studied in the North Atlantic, Yellow Sea, and Arctic (https://cse.umn.edu/safl/news/safl-director-involved-new-75m-dod-muri-project). In that work, we will be developing models for the prediction of fog over oceans. In the present proposal, we aim to study Minnesota-specific weather and geographic conditions to develop models for local fog predictions. We will also study the correlation between fog and ice melting. We will use a combination of laboratory experiments, computer simulations, and field measurements. Fog can be of different types, and ice fog and freezing fog are common in Minnesota in winters. The condensing of fog droplets on snow surfaces can accelerate the snow melting. We will investigate which type of fogs are more likely and where in Minnesota as the winter warms, and how the fog affects the rate of snow and ice melting. We will also investigate local air pollution on fog and the probability of creating health hazard. We will develop models that will improve fog forecasting and help Minnesotans by warnings of fog related hazards in time.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

The outcome of this project will be: (1) models for local fog predictions for Minnesota weather conditions, (2) predictions of fog frequency and fog life in future for warmer winters, (3) quantification of the effect of fog on snow and ice melting, (4) identification of regions in Minnesota where severe fogs are more likely and where fog can create health hazards. The project outcomes will provide a guidance to Minnesota health, aviation, transportation and agriculture agencies for them to be better prepared to handle fog related events.

Activities and Milestones

Activity 1: Conduct field investigation and laboratory experiments to collect data and develop computer simulation models

Activity Budget: $150,000

Activity Description:
The Saint Anthony Falls Laboratory (SAFL) is renowned in environmental and geophysical fluid flow studies. It has an innovative experiment facility called CloudIA (Cloud of Inertial Aerosol), which is unique in the world and is ideal for studying the microdroplets of fog in atmosphere turbulence. Meanwhile, the Saint Anthony Falls in the Mississippi River next to SAFL is a natural fog generation machine. The water falls produce numerous small water droplets, which serve as the nuclei for fog formation.

We will first perform laboratory experiments in CloudIA for a wide range of environmental conditions under controlled settings and study how fog cycle is influenced by the size of nuclei. Field experiments will be taken near the Saint Anthony Falls on foggy days to measure the temperature, humidity, wind speed, and nuclei size distribution. These measurements will be crucial to developing and validating our computer simulation tools. Subsequently, we will run computer simulations for the past fog events to test and further improve the models in simulations.

Activity Milestones:

Description	Completion Date
Laboratory experiments to collect data required for the next activity	June 30 2023
Develop empirical models using data from laboratory experiments	June 30 2024
Test the numerical simulations against the historical fog events in Minnesota in different regions (urban, rural, north shore)	December 31 2024

Activity 2: Conduct statewide simulations to understand fog patterns and their potentials to create health hazards

Activity Budget: $100,000

Activity Description:
The fog occurrence is influenced by local weather and geographic conditions. We will perform computer simulations for different sites in Minnesota (urban, rural and the neighborhood regions of different lakes and rivers) to investigate the probability and severity of fog in those regions. Pollutants (particulates) and local humidity directly influence the fog formation, fog life, and fog dissipation. We will investigate the effect of local pollution and aerosol concentration in their expected range on the fog parameters such as their life and visibility. The simulations results will be analyzed to identify the types of expected fog patterns in different regions, their effect on snow melting, and their potentials to create health hazards.

Activity Milestones:

Description	Completion Date
Collect data of pollution at identified sites and record local weather conditions	December 31 2023
Run simulations and predict the probability of fog formation and the type of fog expected.	June 30 2024
generate maps of local visibility for local humidity and particulate concentration	September 30 2024
Run additional simulations to analyze the effect of fog on snow melting and snow cover.	December 31 2024

Activity 3: Develop models for fog forecasting

Activity Budget: $90,000

Activity Description:

Using the simulation database created in activity 2, we will develop models for fog forecasting. The model outputs will be fog type, fog life, and visibility in fog. The models will be customized for Minnesota urban, rural, and lakeside regions. We plan to use machine learning techniques in developing these models. We will also explore the possibility of simple models depending on the complexities in the data from activities 1 and 2. Machine learning requires training before it can be used for predictions. We will use data from activities 1 and 2 for training the machine learning models. We will run additional simulations to test and improve the machine learning models developed in this activity. As mentioned earlier in activity 1, the experimental facility CloudIA at SAFL can generate realistic conditions and in a controlled environment. We will test the developed models against the experiments in CloudIA and the field measurements at the St. Anthony Falls.

Activity Milestones:

Description	Completion Date
Analyze and sort data for fog forecasting model development	December 31 2023
Train machine learning model	June 30 2024
Run additional computer simulations to test and improve the forecasting models	December 31 2024
Test the forecast models against laboratory experiments and field measurements	June 30 2025

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?

This project will provide a guidance to Minnesota health and transportation departments on if they need to pay immediate attention to be ready for fog related hazards in near future. The project will provide better models for forecasting fog and related hazards in Minnesota and thus, has a potential of saving lives. The study on the effect of fog on snow cover has direct implications on local ecology, fishery, water resources, and agriculture. The project outcomes will also be shared with state agencies including MPCA, DNR and MDA.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Extraction of Solar Thermal Energy in Minnesota	M.L. 2017, Chp. 96, Sec. 2, Subd. 07a	$250,000
Assess and Develop Strategies to Remove Microscopic Plastic-Particle Pollution from Minnesota Water Bodies	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 04b	$300,000

Project Manager and Organization Qualifications

Project Manager Name: Lian Shen

Job Title: Professor and Director

Provide description of the project manager's qualifications to manage the proposed project.

Dr. Lian Shen is the Director of the St. Anthony Falls Laboratory and the Kenneth T. Whitby Professor in the Department of Mechanical Engineering at University of Minnesota, Twin Cities. He earned his Doctor of Science degree from Massachusetts Institute of Technology in 2001. After three years of postdoctoral training at MIT, he joined the faculty of Johns Hopkins University in 2004. In 2012, he was recruited by University of Minnesota to join its faculty. Dr. Shen is a world expert on the study of environmental fluid flows and renewable energy. He is currently serving on the national committee of ASCE Environmental & Water Resources Institute on CFD Applications in Water and Wastewater Treatment. He is also on the editorial boards of four internal academic journals. Dr. Shen has organized several national and international conferences and symposiums, and has participated in a large number of research projects funded by federal and state agencies, including the Minnesota Environment and Natural Resources Trust Fund. On wind energy research, Dr. Shen is currently serving as the Co-Chair of the Advisory Group of the National Offshore Wind Energy Research and Development Consortium, which has 40 organizations nationwide. At University of Minnesota, Dr. Shen has been serving as the Director of the EOLOS Wind Energy Research Center since 2015. Dr. Lian Shen served as the Associate Director for Research of St. Anthony Falls Laboratory in 2014-2017, and has been serving as its Director since 2017.

Organization: U of MN - St. Anthony Falls Laboratory

Organization Description:

This project will be performed at the St. Anthony Falls Laboratory (SAFL, http://www.safl.umn.edu) at University of Minnesota. SAFL is an interdisciplinary fluid mechanics research and educational institution. It has 22 faculty members and 37 research and administrative staff members. SAFL is a world-renowned research laboratory specialized in environmental and engineering fluid mechanics. SAFL researchers have been performing many innovative environmental studies for the state of Minnesota. Some of the projects were/are funded by the Minnesota

Environment and Natural Resources Trust Fund. The proposed research leverages on the unique and advanced capability of simulating and measuring environmental flows at SAFL, which has 16,000 square feet of space dedicated to research. The facility, which has recently been upgraded with a $16M renovation, has a wind tunnel and 15 general purpose flumes, tanks, and channels readily configurable to the needs of the projects.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Project Manager		Oversee the whole project and lead the research planning and reporting			27%	0.12		$36,508
Postdoctoral Associate		Design and establish computational model and carry out computer simulations			20.2%	3		$193,799
Undergraduate Student Assistant		Assist experiment data analysis and model validation			0%	0.75		$7,200
IT Staff		Assist computational model development			24%	0.54		$44,809
							Sub Total	**$282,316**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Equipment	Cost of 10 fog generators ($400 each)	To conduct laboratory and field measurements.					$4,000
	Tools and Supplies	Cost of materials for fabricating models to be tested in experiments.	To conduct laboratory and field measurements.					$2,934
							Sub Total	**$6,934**
Capital Expenditures								
		Cost of three fog monitors ($8,000 each) for fog droplet size distribution measurement, two present weather detectors ($7,500 each) for fog detection and measuring visibility, and two 3-axis ultrasonic anemometers ($5,500 each) for wind velocity vector and temperature measurements.	For measuring the size distribution of fog droplets, detecting fog, measuring visibility, and measuring wind speed in laboratory and field experiments.					$50,000
							Sub Total	**$50,000**

Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Field experiment	Miles and meals to conduct field experiments					$750
							Sub Total	**$750**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$340,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Unrecovered F&A	Support of SAFL facilities where research will be conducted.	Secured	$159,500
			Non State Sub Total	**$159,500**
			Funds Total	**$159,500**

Attachments

Required Attachments

Visual Component

File: 5179917c-105.pdf

Alternate Text for Visual Component

We will study the fog in Minnesota climate and environment, its consequences on traffic and health hazards and snow melting, and the effects of climate change on fog occurrence. Our study uses a combination of computer simulations, laboratory experiments, field measurements and machine learning....

Optional Attachments

Support Letter or Other

Title	File
Approval of proposal submission by University of Minnesota	0cb8d251-16e.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, or sale of products and assets?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

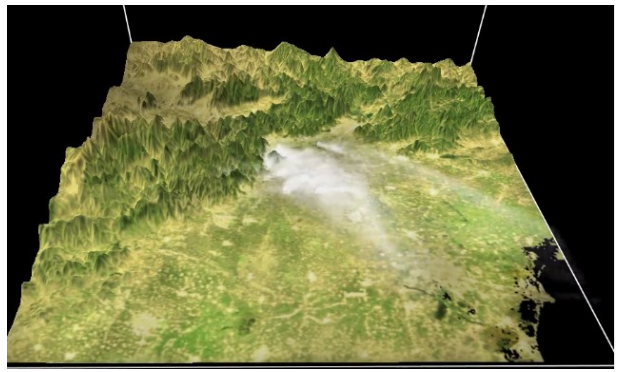
Study of Fog in Minnesota Climate and Environment

Laboratory experiment

Field measurement

Laboratory and Field Experiments

Small-scale simulation



Real topology simulation

Computer Simulations

Better fog prediction models for Minnesota weather and geographical conditions

Better understanding of the consequences of more foggy days in Minnesota with climate change on creating traffic and health hazards and changing snow cover