Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID:** 195-E

Prediction of Inversions for Air-quality in Cold Weather

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

Sub-Category:

Total Project Budget: $ 304,984

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

Use experiments and models to reveal the relationships between inversions and air pollution in cold weather, and provide tools to help reduce air pollution.

Name: Lian Shen

Sponsoring Organization: U of MN

Job Title: Dr.

Department:

Address: 2 Third Avenue SE
Minneapolis MN 55414

Telephone Number: (763) 203-5867

Email shen@umn.edu

Web Address:

Location:

Region: Statewide

County Name: Statewide

City / Township: Minneapolis

Alternate Text for Visual:

Figures show examples of cold weather in Minnesota, as well as an accompanying inversion layer trapping pollution in Minneapolis, and how to predict air quality by modeling.

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _______ TOTAL _____%

PROJECT TITLE: PREDICTION OF INVERSIONS FOR AIR-QUALITY IN COLD WEATHER

I. PROJECT STATEMENT

The objective of the present proposal is to study inversions in the atmosphere using precise measurement data and high-fidelity modeling, to investigate the effects of inversions on the quality of the air in Minnesota, and to develop a mitigation strategy for air pollution. Inversions typically occur in the mornings and cold winters, and are characterized by a layer of cold air near the surface of the Earth that is trapped by a layer of warm air above it. Due to the inability of this trapped air to escape the warm layer, the amount of pollutants in the lowest level of the atmosphere increases as it is unable to enter the higher regions of the atmosphere. This region of high pollution, which is typically in the lowest 20 feet of the atmosphere, directly affects the quality of the air that is inhaled by residents of Minnesota. According to a study performed in 2018, inversions were recorded to occur in over 90% of the days measured in various Minnesota cities. The formation of inversions is governed by a wide variety of environmental variables and for this reason they are often difficult to detect and predict.

While the air quality of Minnesota on average is good when compared to many other areas, there are still regions in Minnesota that are linked to poor air quality. According to the Minnesota Pollution Control Agency 2019 report on air quality, around 2000 deaths per year are linked to the effects of air pollution, with hundreds of additional hospitalizations. Additionally, it was found that 32% of the population was found to live in regions where air pollution is above the risk guidelines. This value gets even worse for communities of color and indigenous communities where 91% of the population is living in regions of air pollution above the risk guidelines. Due to the direct effect of inversions on the quality of the air we breathe, it is important to better understand when and where these inversions occur and be able to provide valuable insights to ensure Minnesotans breathe the cleanest air possible.

The goal of this project is to use measurement data as well as highly accurate models to guide people on where and when strong inversions are likely to occur. Using the extensively developed and tested simulation tools developed at the Saint Anthony Falls Laboratory, it will be possible to accurately recreate the weather conditions, pollutant sources, and geography in which inversions occur. With access to modern supercomputers, it will be possible to rapidly replicate a wide variety of scenarios that occur naturally all throughout Minnesota without having to wait for these conditions to occur. From these simulations, insight into the causes of inversions and their severity, as well as the areas of greatest likelihood for inversions will be gained.

Based on the proposed study, it will be possible to use the information discovered to improve the quality of air in Minnesota. For example, it has been shown that fertilizing crops during inversions increases the amount of fertilizer that is trapped in the air, and drifts into surrounding areas. The detrimental effect is so severe that the Environmental Protection Agency has instructed farmers to refrain from fertilizing their crops during times when inversions are present. However, it is often difficult for the farmers to identify when inversions are present. The proposed research could be used to provide a powerful tool for farmers to use when they are identifying the best times to fertilize their crops.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1 Title: Collect data from field experiment
Description: The first phase of the project will be to use previous atmospheric data, together with wind and temperature data in Minnesota, to find out the relationship between air pollution and inversions. Also, air quality monitoring devices will be installed in the city, as well as other locations of interest to get a distribution of air quality in different horizontal layers, and its change over time of a day. By doing so, we will get a general understanding of air quality variance which can be used independently to study inversions, as well as for a tool to validate the simulations that are developed later in the project.

ENRTF BUDGET: $152,492

Outcome	Completion Date
1. Use previous data to analyze the relationship between air pollution and inversion.	*June 30, 2021*
2. Install devices to monitor the detailed air quality distribution over different layers.	*Oct. 31, 2021*
3. Obtain a general description of inversion layer's effect.	*March 31, 2022*

Activity 2 Title: Develop modeling capabilities
Description: The second phase will involve establishing a model capable of accurate simulation of inversions. The model will first be validated to ensure they are capable of accurately predicting inversions. After the validation, it will be used to conduct a broad study of many different weather scenarios responsible for inversions. We will be able to conduct an extensive study on different weather conditions and pollutant levels. Lastly, these results will be analyzed to identify trends that will allow for development of new and more effective methods of predicting the severity and frequency of inversions.

ENRTF BUDGET: $141,994

Outcome	Completion Date
1. Development of modeling capabilities	*March 31, 2021*
2. Validation of the accuracy of the model	*June 30, 2022*
3. Using model to improve understanding of inversions	*Dec. 31, 2022*

Activity 3 Title: Educating and outreach to the community on findings
Description: The final phase of the project will be to use the information from the study to provide meaningful insights to a wide range of Minnesotans in a simple and effective manner. From the information gathered, it will be possible to locate regions of Minnesota, as well as times of the year, with a high probability of inversions. This information can then be relayed to the general population by creation of websites and apps that couple weather forecasting and geographic information to provide an easy tool for the average Minnesotan to understand the complicated nature of inversions in a simple, convenient method. These tools can then be used by many different industries and communities. The tools can be used by farmers to better understand safe times to fertilize crops, city planners to best understand regions where air pollution is likely to be of greater concern, and residents who simply want to know when the safest time is to enjoy the outdoors.

ENRTF BUDGET: $10,498

Outcome	Completion Date
1. Develop an app and website to inform citizens on inversions	*March 31, 2023*
2. Provide information to farmers on safe fertilization times	*June 30, 2023*

III. PROJECT PARTNERS AND COLLABORATORS:

IV. LONG-TERM IMPLEMENTATION AND FUNDING:
Air quality is a problem that affects many residents of Minnesota. By learning more about the occurrences of inversions and their effects on pollution, it will be possible to provide insight into many different industries and communities that make up Minnesota. In the future, the continued work of collecting measurement data and performing modeling will provide methods to test potential mitigation methods.

V. SEE ADDITIONAL PROPOSAL COMPONENTS:

A. Proposal Budget Spreadsheet
B. Visual Component or Map
F. Project Manager Qualifications and Organization Description

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Lian Shen
Project Title: Prediction of Inversions for Air-quality in Cold Weather
Organization: Regents of the University of Minnesota
Project Budget: $304,984
Project Length and Completion Date: 3 years; June 30, 2023
Today's Date: April 12, 2019

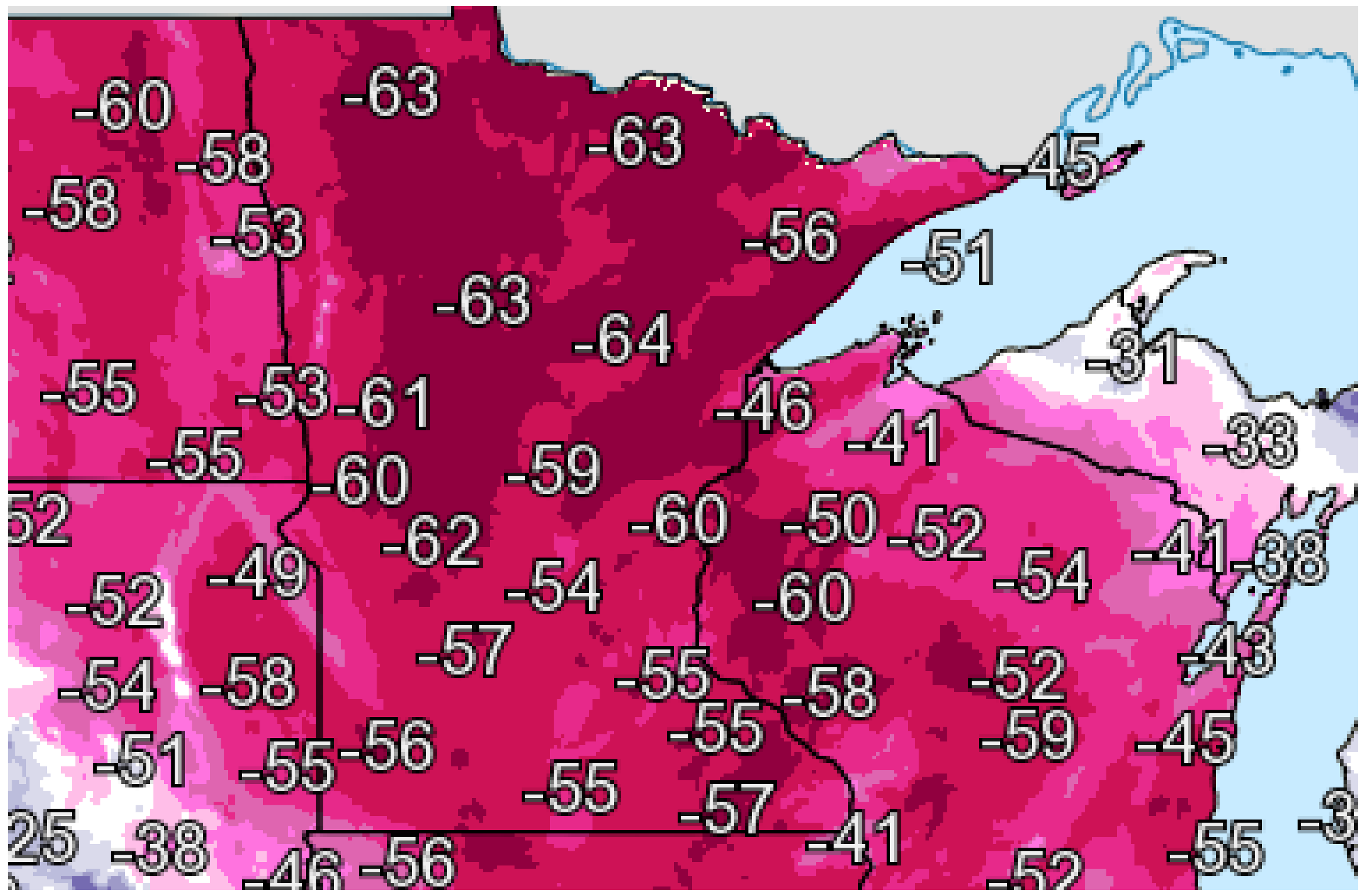
ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 298,234	$ -	$ 298,234
Lian Shen, Program Manager (74% salary, 26% benefits); 3.7% FTE, 0.33 month per year. ($34,656)			
Postdoctoral Associate, experiment and modeling research (80% salary, 20% benefit); 100% FTE for each of 3 years. ($192,098)			
Graduate student, modeling study (84% salary, 16% benefit); 3 summers month per year for 3 years. ($20,892)			
Undergraduate Assistant, measurement study (100% salary); 1.5 months for each of 3 years. ($7,200)			
IT staff, data analysis and modeling system design (85% salary, 15% benefit); 40% FTE for each of 3 years. ($40,026)			
Professional/Technical/Service Contracts			
	$ -	$ -	$ -
Equipment/Tools/Supplies			
Cost of three air-quality sensors ($1,000 each) and three meterological meausring packages ($1,000 each) for measurements at three locations simultaneously	$ 6,000	$ -	$ 6,000
Capital Expenditures Over $5,000			
	$ -	$ -	$ -
Fee Title Acquisition			
	$ -	$ -	$ -
Easement Acquisition			
	$ -	$ -	$ -
Professional Services for Acquisition			
	$ -	$ -	$ -
Printing			
	$ -	$ -	$ -
Travel expenses in Minnesota			
Tranportation within Minnesota state for field data collection and research meetings with other researchers in the state. Estimation of cost for 3 years: Mileage $0.58/mile x 500 miles =$290; Incidental expense during travel $60; Lodging $400.	$ 750	$ -	$ 750
Other			
	$ -	$ -	$ -
COLUMN TOTAL	$ 304,984	$ -	$ 304,984

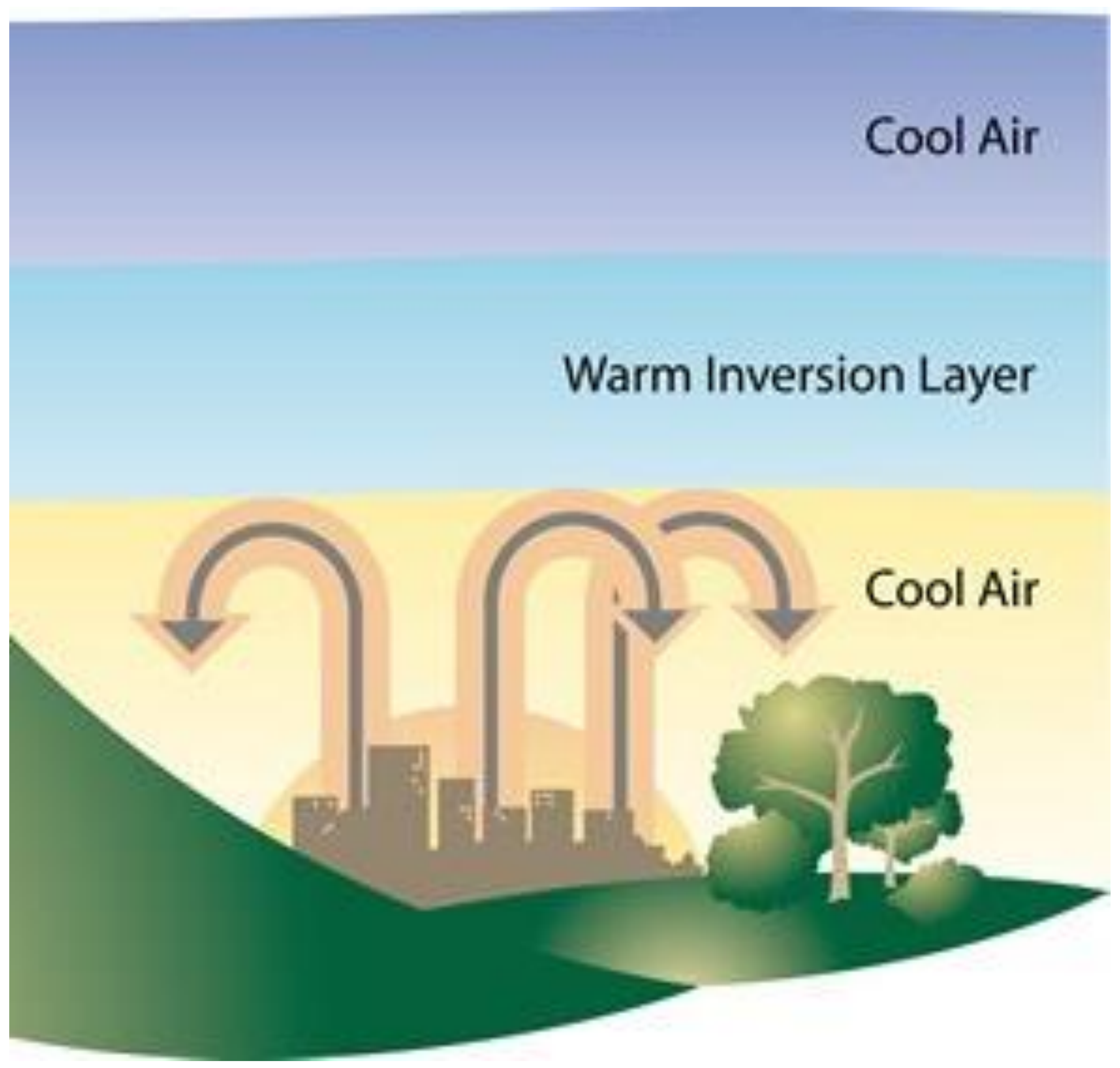
SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: The University of Minnesota does not charge the State of Minnesota its typical overhead rate of 54% of the total modified direct costs.		$ 164,691	$ -	$ 164,691

Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
		$ -	$ -	$ -

Prediction of Inversions for Air-quality in Cold Weather

Motivation





As a result of the cold weather in winter and early spring in Minnesota ...

… the near ground inversion layer has a significant impact on contaminant trapping such as small particles, fog, and smog.

Plans

Data Collection

Code Developing

Results Delivering

Developing a tool to model the inversions in cold weather and predict the air-quality …

Expected outcomes

… provides agricultural and industrial guidance to Minnesotans.

PROJECT MANAGER QUALIFICATIONS

This project will be led by Professor Lian Shen as program manager. Prof. Shen is the Director of the St. Anthony Falls Laboratory and a 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 (MIT) in 2001. After three years of postdoctoral training at MIT, he joined the faculty of Johns Hopkins University (JHU) in 2004. At JHU, he performed extensive research on environmental water and air flows. In 2012, he was recruited by University of Minnesota to join its faculty.

Prof. Shen is a world expert on the study of environmental fluid flows. 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 three internal academic journals. Prof. Shen has been active in professional societies, including American Geophysical Union, American Society of Civil Engineers, American Society of Mechanical Engineers, and Association of Environmental Engineering and Science Professors. He has organized several national and international conferences and symposiums.

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 35 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 advanced capability of measuring environmental flows at SAFL, which has 16,000 ft^2 of research space dedicated to physical modeling and experimentation. 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 projects. SAFL field research is as broad as its laboratory work and includes establishing long-term monitoring sites as well as developing new methods and techniques for observing, measuring, logging, and communicating environmental processes. SAFL has tremendous experience in developing a field approach for a range of applications, such as remoting measurement of atmospheric and aquatic fluid flows and temperature.

The powerful cluster computers equipped at SAFL support the numerical modelling in the proposed research. Driven by the exponential growth of computational power, scientific computing is now radically transforming our research philosophy by enabling the simulation of many complex flow phenomena across a broad range of scales in natural and engineered systems with an unprecedented degree of realism. Coupled with the state-of-art measurement techniques and unique experimental facilities, SAFL's simulation-based expertise has uniquely positioned the laboratory to make far-reaching advances in the major societal problems in energy, the environment, and human health. SAFL has two High Performance Computing (HPC) Beowulf-style computer clusters with execution and compute nodes connected by low-latency/high-throughput local interconnects (InfiniBand).