Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID: 047-AH**

Mapping and Mitigation of Strong Winds in Cities

Category: H. Proposals seeking $200,000 or less in funding

Sub-Category: A. Foundational Natural Resource Data and Information

Total Project Budget: $ 198,839

Proposed Project Time Period for the Funding Requested: June 30, 2022 (3 yrs)

Summary:

We will collect data of wind in street canyons with high winds, develop models for forecasting wind speed, and make executable plan to mitigate high winds in streets.

Name: Zixuan Yang

Sponsoring Organization: U of MN

Title: Researcher

Department: St. Anthony Falls Laboratory

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Motivation: high wind breaks trees, injure pedestrians, and damage vehicles. Street canyon accelerates wind speed. We will conduct experiments to make executable plan to mitigate high winds in streets.

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

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

_____ Capacity Readiness _____ Leverage _______ TOTAL ______%

____ If under $200,000, waive presentation?

PROJECT TITLE: Mapping and mitigation of strong winds in cities

I. PROJECT STATEMENT

The objective of this study is to **monitor and mitigate high winds in Minnesota cities**. Our goals are to: (1) identify streets with high winds, and collect building and wind information of these streets, (2) develop fast prediction model of city wind, and (3) make an executable plan to reduce wind speed in the high-wind streets.

In Minnesota, wind storms take place every year. **Strong wind can break trees, damage buildings and vehicles, and injure pedestrians.** Scientific reports indicate that the situation is even more severe in urban areas with **street canyons**, defined as the streets with tall buildings on both sides. When the wind is parallel to the street, the street canyon acts as a contraction channel to accelerate the wind speed. Monitoring and mitigating strong winds in the cities is important for environmental, safety, and economic reasons. If the buildings of the cities are well designed, citizens can be better protected against wind storms, and pedestrians and bikers can feel much more comfortable when they walk and ride in the streets. Many cities in United States have projects to improve their wind conditions. For example, with the help of an MIT research group, Boston has added infrastructures to reduce the wind in street canyons. In Minnesota, it is more urgent to mitigate high winds because of the severe winter conditions here. However, in comparison with many other regions in the States, we are lagging behind in the study and practice in this urgently needed area.

Weather forecast can provide wind information at high altitudes, typically 10 m above the ground level. However, more relevant to our daily life, **the near-ground wind in streets cannot be predicted by the present weather forecasting models**, because of the low spatial resolution in these models. In the urban area, the wind direction and wind speed can be drastically different from the weather forecast due to the effect of near-ground turbulence and buildings. To protect the environment and residents of urban areas against wind storms, it is urgent to develop a reliable fast prediction tool to **forecast near-ground wind**, and to make an executable plan to **reduce the wind speed in street canyons.**

Using the unique resources at the St. Anthony Falls Laboratory, we will generate a comprehensive wind map of major cities of Minnesota. The wind map will show the wind speed and wind direction at every street of the city corresponding to the wind condition at higher altitude given by the weather forecast. We will **identify the streets** most likely to have high wind speeds, and **collect the *in situ* wind information** in representative streets. We will also provide a **fast prediction model** based on machine learning, also known as artificial intelligence. The fast prediction model will report if a new building near the street will potentially reduce or enhance the wind speed. Based on the fast prediction model, we will provide an **executable method** by only slightly changing the perimeters of buildings and/or by adding small wind fences to effectively reduce the wind speed in the streets with high winds.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Identify streets with high winds

We will collect wind information of representative street canyons (for example, the S 9th St between Nicollet Ave and S Marquette Ave, Minneapolis). The data collection will also be carried out in streets with high winds reported by volunteers. We will also use in-house-developed software to simulate the wind field of cities in Minnesota. The powerful SAFL parallel computer will be used to run high-resolution simulations to establish a comprehensive database of wind speed and wind direction in the streets with high winds.

ENRTF BUDGET: $77,139

Outcome	Completion Date
1. Identify streets with high near-ground winds	October 2020
2. Collect wind information of streets with high near-ground winds	December 2020
3. Run virtual wind simulations of major Minnesota cities	June 2021
4. Establish database of wind field in the streets with high near-ground winds	January 2022

Activity 2: Develop fast forecast tool for near-ground winds

We will develop a fast forecast tool to predict near-ground winds based on neural network, a mature and broadly used technique in the context of data-driven artificial intelligence. The comprehensive database collected in Activity #1 will be used to train the fast prediction model. This model will then be extensively validated using more data collected in the rest periods of this program. Once the training and validation are finished, the fast-prediction model will be used to forecast the near-ground wind speed of every major locations.

ENRTF BUDGET: $54,235

Outcome	Completion Date
1. Train the fast prediction tool based on the data collected in Activity #1	September 2021
2. Validate the tool using more data in the continuous study	December 2021
3. Publish the forecast wind map through the website	March 2022

Activity 3: Develop strategies to reduce wind speed

With the assistance of the fast forecast model developed in activity #2, we will identify the building conditions that are responsible for causing high winds in street canyons. The fast forecast model will also be used to make a plan by making slight change in the perimeter of buildings, or by adding small wind fences at certain locations, to effectively reduce the wind speed. The plan will then be examined carefully by conducting virtual experiments on SAFL supercomputers.

ENRTF BUDGET: $67,465

Outcome	Completion Date
1. Identify buildings that cause high winds, and develop strategies to reduce high winds	January 2022
2. Examine the plan with virtual experiments	March 2022
3. Publish the executable plan through the website of SAFL	June 2022

III. PROJECT PARTNERS:

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

This project will provide an effective and executable method to reduce the high wind speed in streets in Minnesota cities. It will provide a guidance to the state agencies on how to mitigate the high winds. The collected data will also be shared with state agencies through a user-friendly web interface, providing guidelines on future constructions. We will launch a program where volunteer pedestrians and bikers report high wind they have encountered when they are walking and riding in the streets. Additionally, we will hold virtual workshops to help agency members familiarize with the tools developed in this project. The research findings will be disseminated through presentations, workshops, and local media outlets. We will also publish the wind map through website of SAFL, so that citizens are able to know the wind condition in streets before they go outdoors during wind storms. With the aid of the fast forecast model, the wind map in the next few days will be updated automatically on the website. The citizens can use the wind map to design their routines, especially for the safety reason if they need to go outdoor during wind storms.

V. TIME LINE REQUIREMENTS:

This project is planned for 3 years beginning on July 1, 2019 and ending on June 30, 2022.

VI. SEE ADDITIONAL PROPOSAL COMPONENTS:

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

2019 Proposal Budget Spreadsheet

Project Title: Mapping and mitigation of strong winds in cities

IV. TOTAL ENRTF REQUEST BUDGET: 3 years

BUDGET ITEM	AMOUNT
Personnel:	$ 191,339
Dr. Zixuan Yang, PI, 33% FTE for each of 3 years, 75% salary, 25% benefits. ($77,018)	
Dr. Lian Shen, co-PI, 4.2% FTE for each of 3 years, 75% salary, 25% benefits. ($32,464)	
Postdoctoral Associate, experiment and modeling research, 25% FTE for each of 3 years, 82% salary, 18% benefits. ($47,839)	
SAFL IT Staff, data analysis and model development, 10% FTE for each of 3 years, 75% salary, 25% benefits. ($26,818)	
Undergraduate Assistant, measurement and data analysis, 1.5 months for each of 3 years, 100% salary. ($7,200)	
Professional/Technical/Service Contracts: N/A	$ -
Equipment/Tools/Supplies:	$ 7,200
Cost of the purchasing of velocimetry ($3,500) for outdoor wind measurement, facility setup for monitoring the wind at street canyons ($3,000), and developing interactive website for high-wind report ($700).	
Acquisition (Fee Title or Permanent Easements): N/A	$ -
Travel:	$ 300
Tranportation within Minnesota state for data collection and research meetings with other researchers in the state. Estimation of cost for 3 years: Mileage $0.545/mile x 400 miles =$218; Incidental expense during travel $82.	
Additional Budget Items: N/A	$ -
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 198,839

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

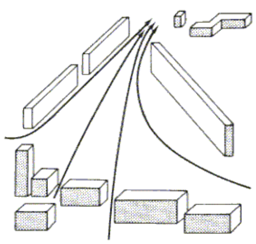
SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period: N/A	$ -	N/A
Other State $ To Be Applied To Project During Project Period: N/A	$ -	N/A
In-kind Services To Be Applied To Project During Project Period: The University of Minnesota does not charge the State of Minnesota its typical overhead rate of 54% of the total modified direct costs (graduate tuition and equipment are excluded).	$ 107,373	Secured
Past and Current ENRTF Appropriation:	$ -	N/A
Other Funding History: N/A	$ -	N/A

Motivation for Mapping and Mitigating Strong Winds in Streets

Tree broken by strong wind falling on top of car

Pedestrians falling down in strong winds

Street Canyon Enhances Strong Wind

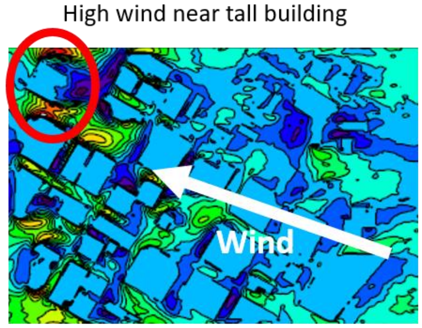


Left figure: when air flows from an open area into a street canyon, the wind is accelerated due to the constriction of flow channel. Right figure: street canyon at S 9th St, Minneapolis.

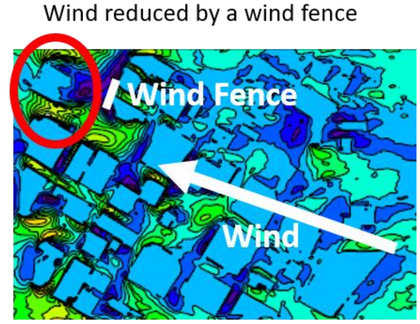
Numerical Experiments Provide Plan for Mitigating Strong Winds

3D Model of Minneapolis Downtown

High wind near tall building



Wind reduced by a wind fence



The left figure shows the 3D building model of downtown Minneapolis. The middle and right figures show the wind speed with and without wind fence, respectively. Red color means streets with high winds. The middle figure shows that the highest wind occurs near a tall building in the northwest of this area, which is a typical effect of street canyon. The high wind can be reduced by a wind fence as shown in the right figure.

PROJECT MANAGER QUALIFICATIONS

The proposed research will be led by Dr. Zixuan Yang, Researcher at the St. Anthony Falls Laboratory (SAFL) at the University of Minnesota, Twin Cities. Dr. Yang obtained his bachelor's and Ph. D. degrees from Tsinghua University (China) in 2007 and 2012, respectively. From 2013 to 2015, he was a postdoctoral fellow at the University of Manitoba (Canada). He joined the Department of Mechanical Engineering at the University of Minnesota in 2015, and is now a researcher at SAFL. Dr. Yang conducts research in environmental fluid mechanics, focusing on the urban atmospheric air flows, wind-structure interaction, and machine learning (artificial intelligence). He is an expert using advanced software to simulate turbulent flows past complex structures, such as buildings. Dr. Yang is part of the team that developed this simulation tool, and has extensive experience studying winds in urban and rural areas.

Dr. Lian Shen will also participate in this project. He is the Director of SAFL and a Professor in the Department of Mechanical Engineering at the University of Minnesota. 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. In 2012, he was recruited by University of Minnesota to join its faculty. Dr. Shen has performed extensive research on environmental water and air flows. He is currently serving on the national committee of ASCE Environmental & Water Resources Institute on CFD Applications in Water and Wastewater Treatment. Dr. Shen has also organized many 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 the University of Minnesota. SAFL is an interdisciplinary fluid mechanics research and educational institution. It has 21 faculty members and 37 research and administrative staff members. It 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 uses the powerful supercomputer equipped at SAFL. 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 our state-of-art measurement techniques and unique experimental facilities, our simulation-based expertise has uniquely positioned the laboratory to make far-reaching advances in the major societal problems of our time 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). It also has 240 cores of Paros-class interactive nodes provisioned via Openstack for interactive use. The storage associated with the clusters is a 262TB Lustre-based storage system with distributed metadata servers (MDS) and object storage servers (OSS), all connected via the IB network in order to handle high I/O needs of the programs. A secondary 400TB storage system based on Serial Attached SCSI (SAS-2) disks with redundant controllers serves the long-term storage and day-to-day needs of the cluster.