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

Project Title: **ENRTF ID: 245-FH**

Prediction of Ice Shove in Lakes in Minnesota

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

Sub-Category: F. Methods to Protect, Restore, and Enhance Land, Water, and Habitat

Total Project Budget: $ 199,584

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

Summary:

A prediction model and an alert system of ice shove will be developed based on the data collected from field experiments and numerical simulations to prevent damages.

Name: Bingqing Deng

Sponsoring Organization: U of MN

Title:

Department: St. Anthony Falls Laboratory

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Thin ice on lakes in spring can be pushed onshore to form ice shoves that damage near-shore houses and shorelines. We will build an alert system to predict it.

_____ 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: Prediction of Ice Shove in Lakes in Minnesota

I. PROJECT STATEMENT

The objective of this proposal is to create an alert system to protect trees, roads, buildings, and residents near lakes in Minnesota against **ice shove**. Our goals are to: (1) identify lakes in Minnesota with high possibility of ice shove events, (2) collect information of ice, wind, water, and land topography near the identified locations, and conduct numerical experiments of ice shove based on the collected data, and (3) develop a fast prediction system to alert ice shove at the lakeshores of Minnesota.

What: In spring and autumn, the ice on the lakes can be thin, and may be easily broken and pushed ashore by a strong wind. Large broken blocks of ice can **pile up to feet high** on the shore rapidly, **eroding the shorelines of lakes and damaging bank vegetation**. Small broken ice can **ride up to the shore and advance up to hundred feet inland**, **damaging everything in their path**, including trees, sod, fences, homes, etc. The onshore pile-up and ride-up of ice are known as ice shove.

Why: In Minnesota, there are thousands of lakes, the lake water can be frozen with various depth of ice depending on the season, and the land is relatively flat so that wind storms can arrive without any block. These **geological features of Minnesota determine that we are living in a state that ice shove happens frequently**. Unfortunately, **it is difficult to forecast the ice shove**. The process is too complex to be predicted by the present weather forecast models, because the motion of ice cannot be solved in these models. The present forecast of ice shove relies on the experience of meteorologists. A veteran meteorologist Paul Huttner at Minnesota Public Radio predicted minor ice drifts on Mille Lacs Lake in 2013. However, after the surge, he blogged: "I had no idea it would be this bad" and added that we should come up with a new type of warning for future shoves. Therefore, **there is a critical need to develop a reliable and fast prediction tool to forecast ice shove events**.

How: Using the expertise and unique resources at the St. Anthony Falls Laboratory, we will collect data through field observations and numerical experiments, to **identify the lakes in Minnesota having high risk of ice shove attack**. In the laboratory, we will use a well-developed and broadly-used numerical software WRF to collect the wind condition near 5 representative Minnesota lakes (including Lake Superior and Mille Lacs Lake) to study as canonical cases. In the field, we will monitor the ice thickness of these lakes. Based on the above laboratory and field studies, we will identify locations along the lakeshore with high possibility of ice shove events. We will collect information of land and underwater topography of these areas, and conduct numerical experiments using the collected data. Based on the results of the experiments, we will apply the computation to other sites, and **a comprehensive database on the pile-up height and ride-up inland distance of ice shoves with respect to various wind and ice conditions** will be established. The database will be used to **develop a fast prediction model**.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Identify regions with high possibility of ice shove events **ENRTF BUDGET: $71,556**

We will incorporate the historical weather conditions in March, April, and November to simulate the wind condition of five representative Minnesota lakes using the software WRF. The powerful supercomputer at SAFL will be used to conduct the numerical experiments. We will identify the regions where the wind direction is often perpendicular to the shoreline. With the guidance of the WRF results, we will monitor the ice and wind conditions at selected locations along the shoreline of these lakes. Based on the above studies, we will identify the locations with high possibilities of ice shove events.

Outcome	Completion Date
1. Use WRF to simulate wind conditions near 5 Minnesota lakes	June 2020

2. Monitor ice thickness, wind speed, and wave condition of 5 Minnesota lakes	December 2020
3. Identify and list locations with high possibilities of ice shove events	January 2021

Activity 2: Establish database of ice motion **ENRTF BUDGET: $61,515**

We will collect the information of topography at the locations identified in Activity #1. We will then import the land information into a novel software package WOW developed in-house at SAFL to simulate the ice shove. The WOW software has an unprecedented capability of simulating the coupled motions of wind, water, ice, and waves. The numerical experiment will then generate a comprehensive database of the height and inland distance of ice shove at various wind, ice, and topography conditions. The results will be compared and validated with field measurement data.

Outcome	Completion Date
1. Collect information of topography at the locations identified in Activity #1	March 2021
2. Conduct numerical experiments to establish the database of ice shove	September 2021

Activity 3: Develop fast prediction model to alert ice shove **ENRTF BUDGET: $66,513**

We will use the database established in Activity #2 to build a fast prediction model based on the neural network, which is a mature and broadly used artificial intelligence technique of data-driven machine learning. The model will be able to predict the ice shove events one day in advance, with the wind and temperature information given by weather forecast as an input. We will then test the fast prediction model using the historical events of ice shove. Once the model is validated, it will be used to forecast the ice shove events. An alter system will be developed to forecast ice shove events using the model, and a map that shows potential ice shove events in the next 24 hours will be published and updated online.

Outcome	Completion Date
1. Develop the fast prediction model using the database established in Activity #2	February 2022
2. Validate the model using ice shove events recorded in the history	April 2022
3. Establish an alert system to forecast ice shove events using the fast prediction model	June 2022

III. PROJECT PARTNERS:

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

The proposed project will be the pioneering work on the forecast of ice shove. In the long term, the forecast tool developed in this project will greatly benefit the residents in the state of Minnesota. We will launch a program that is convenient for the residents in Minnesota to report ice movements near lakes for the long-term monitoring purpose. The valuable data collected will be shared with state agencies through a user-friendly web interface to be used for future research. We will help agency members familiarize with the prediction tool developed in this project. The prediction tool can also be further embedded as a module in the present widely-used weather research and forecasting model for accurate prediction of ice shoves. We will publish the alert system and the ice shove map through a well-designed website, so that residents living near the lakes can be aware of incoming ice shove events and make full preparation to protect their lives and properties.

V. TIME LINE REQUIREMENTS:

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

VI. SEE ADDITIONAL PROPOSAL COMPONENTS:

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

2019 Proposal Budget Spreadsheet

Project Title: Prediction of ice shove in lakes in Minnesota

IV. TOTAL ENRTF REQUEST BUDGET: 3 years

BUDGET ITEM	AMOUNT
Personnel:	$ 186,084
Dr. Bingqing Deng, Project Manager, 50% FTE for each of 3 years, 82% salary, 18% benefit ($95,683)	
Co-investigator Prof. Lian Shen, 4.2% FTE for each of 3 years, 75% salary, 25% benefit ($32,464)	
Postdoctoral Associate, experiment and modeling research, 12.5% FTE for each of 3 years, 82% salary, 18% benefit ($23,919)	
IT Research Staff, data analysis and model development, 10% FTE for each of 3 years, 75% salary, 25% benefit ($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: Cost for the purchase of velocimetry for the meansurement of wind speed ($3,730), sona for the meansurement of ice thickness ($3,250), minitoring ice movement near the lakeshore ($2,410), hard disks for saving big data ($1,240), and developing altering system ($1,370).	$ 12,000
Acquisition (Fee Title or Permanent Easements): N/A	$ -
Travel: 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 1000 miles =$545; Incidental expense during travel $200; Lodging $755.	$ 1,500
Additional Budget Items: N/A	$ -
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 199,584

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).	$ 107,775	Secured
Past and Current ENRTF Appropriation: Prof. Lian Shen is a co-investigator of the project "Enabling extracting of solar thermal energy in Minnesota" (ML 2017, Chp. 96, Sec. 2, Subd 07a) from 7/1/2017 to 6/30/2020 (Project Manager Fillippo Coletti, co-investigators Jane Davidson and Lian Shen). The total budget is $250,000. Prof. Shen's portion of budget is approximately $74,000.	$ 74,000	Secured
Other Funding History: N/A	$ -	N/A

Ice Shove

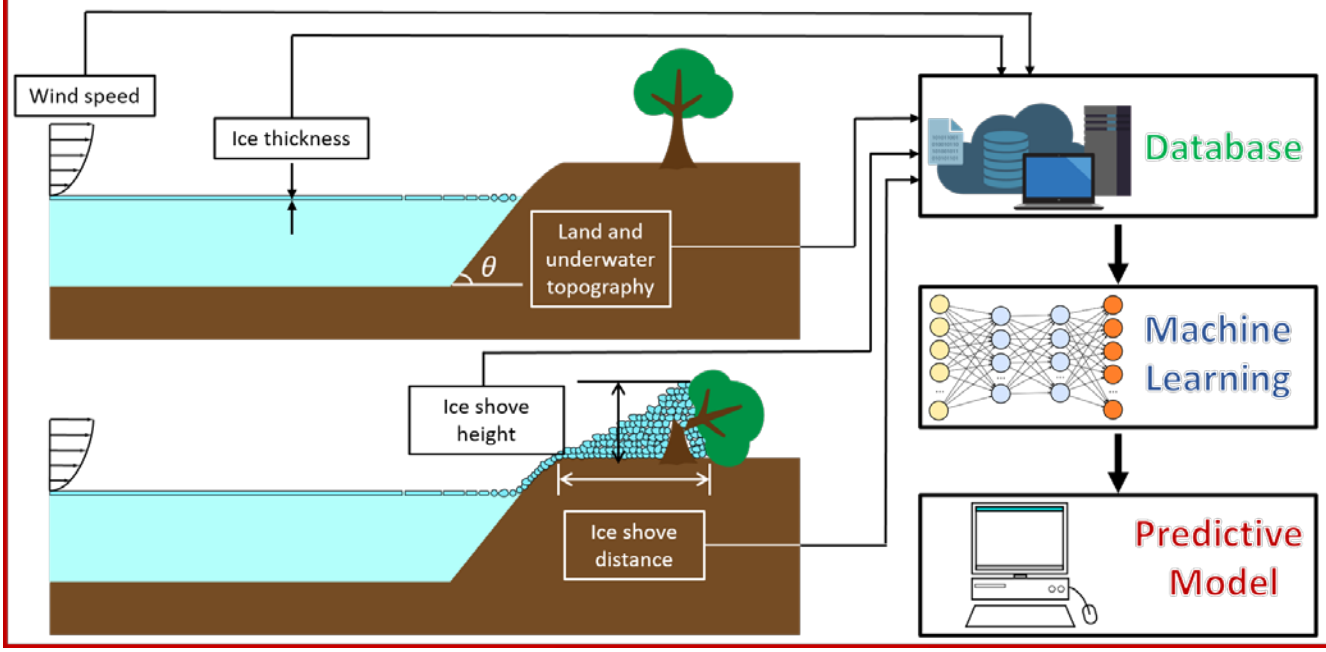
Melting ice in Lake Superior in spring

Strong winds push thin ice onshore

Damage

Ice shove on Mille Lacs Lake in 2013 damaged near-shore houses, trees, and shoreline…

Our project: predict ice shove



PROJECT MANAGER QUALIFICATIONS

This proposed research will be led by Dr. Bingqing Deng working in the St. Anthony Falls Laboratory (SAFL) at University of Minnesota. She received her bachelor's and Ph. D. degrees from Tsinghua University (China) in 2009 and 2014, respectively. Her Ph.D. thesis earned the outstanding thesis award at Tsinghua University. Dr. Deng joined the St. Anthony Falls Laboratory at University of Minnesota in 2014. Her research area at University of Minnesota is environmental fluid mechanics, including flows in the atmosphere boundary layer and surface mixed layer of oceans and lakes, interactions among wind, surface waves, and water flows, and applications of machine learning in fluid mechanics. Her research is conducted using both the field experimental results and the advanced in-house numerical tool developed by herself. She has extensive experiences and expertise in modelling practical environmental flows. Especially, the advanced in-house numerical tool she used can accurately capture the motions of solid bodies, e.g., ice in the proposed research, driven by wind or water flows. She has published many papers on the top journals in fluid mechanics and reviewed papers for the journal published by American Institute of Physics.

Dr. Lian Shen 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 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. 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 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. 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. 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 water flow, lake temperature, and surface and subsurface photography.

The powerful supercomputer equipped at SAFL supports 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). SAFL also has 240 cores of Paros-class interactive nodes provisioned via Openstack for interactive use.