Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-547

Proposal Title: Winter Precipitation Prediction to Support Minnesota Forest Resilience

Project Manager Information

Name: Lian Shen

Organization: U of MN - St. Anthony Falls Laboratory

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Project Basic Information

Project Summary: This project will develop physics-based methods to predict forest-damaging wet snow and freezing rain in Minnesota, providing scientific guidance to protect forests, wildlife habitat, and energy infrastructure.

ENRTF Funds Requested: $475,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Resiliency (A)

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.

Minnesota forests and infrastructure are vulnerable to winter precipitation, especially wet snow and freezing rain, which rapidly load branches and power lines when temperatures hover near freezing. Minnesota's winters have seen near-freezing temperatures more often in recent years, leading to more mixed-phase precipitation events. In December 2023, freezing rain followed by heavy wet snow destroyed nearly 20,000 acres of forest in Pine and Carlton Counties, snapping young aspen and pine trees, eliminating wildlife habitat for grouse, woodcock, and deer. Ice accumulation on power lines routinely causes widespread outages; blizzard winds on ice-laden lines snapped hundreds of poles in southern Minnesota in 2023, leaving over 38,000 residents without power for days.

These events often develop when cold air outbreaks interact with moist, storm-bearing air masses, creating near-freezing atmospheric conditions favorable for wet snow, sleet, or freezing rain. Whether that precipitation falls as snow or freezing rain depends on the microphysics of cloud droplets and ice crystals. Current weather prediction models poorly represent these processes, making it difficult to forecast whether a winter storm will bring manageable snow or destructive ice. The limited ability to forecast freezing precipitation types makes it difficult for Minnesotans to prepare for winter storms.

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

This project will develop a prediction tool for winter precipitation by modeling the microphysics of ice crystals and cloud droplets in turbulent atmospheric boundary layers. We will perform computer simulations by coupling Large-Eddy Simulation of air turbulence with a Lagrangian Cloud Model that tracks cloud droplets and ice crystals as they nucleate, grow, and settle through the atmosphere. This innovative hybrid computational approach, pioneered by our group, captures the stochastic microphysical processes that determine whether precipitation reaches the ground as snow, freezing rain, or ice.

The project builds on validated capabilities that have successfully captured cold-weather turbine-icing impacts in Minnesota and validated mixed-phase cloud microphysics against a DOE field campaign in Alaska. Our computational tool has also been employed and validated for fog lifecycle prediction, demonstrating its ability to capture droplet-scale physics in the turbulent atmosphere.

In this project, our modeling approach will be applied to representative Minnesota winter storm scenarios spanning the range of cold air outbreak conditions, atmospheric stability, and moisture availability that produce freezing precipitation. The deliverable is a prediction methodology with lookup tables that stakeholders, for example, state agencies, forest managers, and energy utility operators, can consult to assess ice risk from incoming winter storms.

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?

This project will produce four outcomes: (1) a validated ice microphysical model for predicting winter precipitation type and intensity in Minnesota winter storms; (2) precipitation-type predictions for 40+ representative cold air outbreak scenarios spanning Minnesota's winter weather range, with sensitivity analysis identifying which conditions produce destructive ice versus manageable snow; (3) prediction tables relating weather conditions to expected ice accumulation severity for use by MN DNR forest managers, rural electric cooperatives, and other stakeholders; and (4) an assessment of how warmer winters may affect the frequency of freezing precipitation events in Minnesota.

Activities and Milestones

Activity 1: Develop an ice microphysical model for Minnesota winter storm precipitation prediction

Activity Budget: $115,000

Activity Description:
This activity builds the core prediction framework. In our computer simulations, high-resolution Large-Eddy Simulation of air turbulence will be coupled with a Lagrangian Cloud Model that tracks cloud droplets and ice crystals through the atmospheric boundary layer. The particles and droplets will evolve according to local temperature, supersaturation, and aerosol environment, with ice nucleation computed from both homogeneous and heterogeneous pathways. The Lagrangian approach captures the stochastic variability of ice formation that conventional models miss, which is critical for correctly predicting whether precipitation reaches the ground as snow or freezing rain.

The atmospheric boundary layer is modeled with wind shear, temperature inversions, and turbulence profiles derived from ERA5 reanalysis fields representative of Minnesota's cold-season conditions. Large-scale atmospheric advection and subsidence tendencies are incorporated to maintain dynamical consistency with the evolving synoptic weather environment.

Key parameters in our studies include air temperature (−35 to 35 degrees), wind speed (5 to 30 mph), moisture availability, aerosol ice-nucleating particle concentrations, and atmospheric stability (stable, neutral, convective). The result will be a computational framework capable of predicting precipitation type, intensity, and ice accumulation potential for a given set of storm conditions.

Activity Milestones:

Description	Approximate Completion Date
Computational framework configured for Minnesota cold-season atmospheric profiles	March 31, 2028
Lagrangian ice nucleation microphysics integrated and tested	September 30, 2028

Activity 2: Validate the prediction framework against Minnesota and other cold regions' observational data

Activity Budget: $165,000

Activity Description:
This activity validates the prediction framework developed in Activity 1 using two independent data sources. First, predictions of ice crystal formation and mixed-phase cloud evolution will be compared against the DOE ARM ISDAC campaign, a well-documented benchmark intercomparison dataset for Arctic mixed-phase clouds that the project manager's group has experience with. Agreement with ISDAC data will confirm that the framework correctly captures ice nucleation microphysics in cold environments. Second, predicted precipitation type and ice accumulation will be compared against Minnesota ground weather observations from documented ice storm events, such as the December 2023 ice/snow event in Pine and Carlton Counties, the freezing precipitation events during the January 2026 cold wave, and other winter storms in Minnesota during the project. Agreement with observed precipitation type, duration, and surface accumulation will confirm that the prediction framework correctly translates cloud-level microphysics into surface precipitation predictions under Minnesota conditions. Discrepancies identified in either validation step will be used to refine model parameters before the framework is applied to Minnesota scenario predictions in Activities 3 and 4.

Activity Milestones:

Description	Approximate Completion Date
Validation against ARM ISDAC mixed-phase cloud benchmark	December 31, 2028
Validation against Minnesota ice storm surface observations	March 31, 2029
Framework refinements completed based on validation results	June 30, 2029

Activity 3: Predict winter precipitation under representative Minnesota cold air outbreak scenarios

Activity Budget: $155,000

Activity Description:
This activity will apply the validated framework to generate winter precipitation predictions across the range of weather conditions Minnesota experiences during cold air outbreaks. The goal is to answer the practical question: under which combinations of temperature, moisture, wind, and atmospheric stability conditions does a winter storm produce destructive freezing rain rather than manageable snow?

A matrix of 40+ scenarios will be constructed from combinations of: air temperature profiles (warm nose vs. cold column), surface temperature (above vs. below freezing), wind speed and direction, moisture availability, and atmospheric stability. For each scenario, our computational framework will predict the precipitation type (snow, freezing rain, ice pellets), the ice accumulation rate on exposed surfaces, and the duration of icing conditions.

Sensitivity analysis will rank the factors that control the snow-to-ice transition, identifying which meteorological parameters most reliably predict destructive ice events. These results will detect which weather conditions most urgently require protective action for forests and power infrastructure.

Activity Milestones:

Description	Approximate Completion Date
Scenario matrix defined with MN DNR and utility input	March 31, 2028
Precipitation-type predictions completed for all 40+ scenarios	September 30, 2029
Sensitivity analysis identifying dominant ice-risk factors	December 31, 2029

Activity 4: Deliver prediction tables and disseminate to stakeholders

Activity Budget: $40,000

Activity Description:
This activity translates the prediction results from Activity 3 into formats usable by MN DNR forest managers, rural electric cooperatives, and other stakeholders for preparedness planning. Results will be organized into prediction tables that relate weather-forecast parameters to the expected severity of ice accumulation.

Prediction tables will present expected ice accumulation indexed by temperature profile, wind speed, and moisture availability. These tables will indicate whether a given set of forecast conditions is associated with low, moderate, or high ice-accumulation potential, helping managers decide when to prepare for possible damage to forests and power lines.

An assessment of how warmer winters may affect the frequency of ice-producing storms in Minnesota will accompany the prediction tables. Multiple briefings to stakeholders will be provided to explain the methodology, its utilities, and how to interpret the tables.

Activity Milestones:

Description	Approximate Completion Date
Draft prediction tables delivered to MN DNR for review	November 30, 2029
Stakeholder briefings completed	March 31, 2030
Final prediction tables and summary report delivered	June 30, 2030

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
We will ensure that data and results generated by the project are communicated broadly and effectively to stakeholders.

Scientific and technical dissemination includes: (1) Peer-reviewed publications: Results regarding the development and validation of the ice microphysical model will be submitted to scientific journals for publication. (2) Conference presentations: Findings will be presented at professional conferences to ensure visibility and encourage collaboration. (3) Technical reports and policy briefs: We will summarize outcomes and environmental tradeoffs.

Stakeholder engagement and communication efforts will include: (1) Agency briefings to share prediction tables and key findings of winter precipitation with MN DNR forest managers, rural electric cooperatives, and other stakeholders for preparedness planning. (2) Partnerships with MN DNR forest managers and rural electric cooperatives to refine the prediction tables based on their feedback. (3) Two-way knowledge exchange through meetings and webinars so that stakeholder input can help guide interpretation, application, and future use of project results.

Public communication and education efforts will include: (1) Plain-language summaries, fact sheets, and infographics explaining how mixed-phase cloud processes determine the precipitation types (e.g., freezing rain vs. snow) and their impact on Minnesota's ecosystem. (2) Presentations through public events, community outreach activities, and interactive visualizations to help make the science of winter resilience accessible to broader audiences.

Documentation and data management efforts will include: (1) Data archiving: All computational models, raw data, and final analyses will be deposited in a public repository (e.g., University of Minnesota Digital Conservancy) for open access and long-term preservation. (2) Standard formats: Data will be documented following open-science best practices to ensure usability by agencies, stakeholders, researchers, and the public.

In all the print and electronic media, publications, signage, and other communications of this project, we will acknowledge the Environment and Natural Resources Trust Fund through: (1) use of the trust fund logo, and/or (2) attribution language per the ENRTF Acknowledgment Guidelines.

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 work be funded?
The prediction tables will provide a reference that MN DNR and utilities can consult alongside standard weather forecasts without additional modeling. The methodology of this project will also establish a foundation for future work on additional winter storm types and lake-effect events of the Great Lakes, to be pursued through federal funding (e.g., NSF, NOAA, DOE). The University of Minnesota's existing computational infrastructure and the project manager's other projects on cold-region atmospheric processes ensure continued capability beyond the ENRTF funding period.

Project Manager and Organization Qualifications

Project Manager Name: Lian Shen

Job Title: Distinguished McKnight University Professor and Director

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Lian Shen is a Distinguished McKnight University Professor at the University of Minnesota. He also holds the Kenneth T. Whitby Professorship in the Department of Mechanical Engineering and serves as the Director of the St. Anthony Falls Laboratory. 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 at Johns Hopkins University in 2004. In 2012, he was recruited by the University of Minnesota to join its faculty. Dr. Shen is an internationally renowned expert in environmental fluid flows and renewable energy research, with over 160 journal publications. He also serves on the editorial boards of five academic journals. He has organized several national and international conferences and symposia, and he will host the 83rd American Physical Society Division of Fluid Dynamics Meeting, the world's leading fluid mechanics conference, in Minnesota in 2030. Dr. Shen has participated in many federally and state-funded research projects on environmental fluid flows.

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 the University of Minnesota. SAFL is an interdisciplinary fluid mechanics research and educational center. It has 21 faculty members and 28 research and administrative staff members. Each year, more than 100 postdocs and students conduct research at SAFL. SAFL is a world-renowned research laboratory specializing in environmental, geophysical, and engineering fluid mechanics. SAFL researchers have conducted numerous innovative environmental studies for Minnesota. Some of the projects were/are funded by the Minnesota Environment and Natural Resources Trust Fund. The proposed research leverages SAFL's unique and advanced capabilities for simulating and measuring environmental and geophysical flows, with 16,000 square feet of dedicated research space.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Project Manager		Oversee the whole project, supervise the project team, lead the study, and take responsibility for project reporting			38.5%	0.09		$37,440
Postdoctoral Associate		Develop and validate the ice microphysical model and develop the prediction tables			28.1%	2.7		$228,417
Graduate Student Assistant		Conduct large-eddy simulations with the Lagrangian cloud model, along with data analysis for a range of cold air outbreak conditions in Minnesota			28.9%	1.5		$148,246
Undergraduate Student Assistant		Assist with data collection and analysis			0%	0.36		$13,260
Computer Scientist		Data sharing and assist the computational setup			34.9%	0.42		$46,637
							Sub Total	**$474,000**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
							Sub Total	-
Capital Equipment								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								

	Miles/ Meals/ Lodging	Estimated number of trips: 10. Each trip is estimated for two persons and 120 miles on average, $0.725/mile * 120 = $87. Each trip is estimated to cost $13 for parking. Total cost of each trip: $100.	The in-state trips are for the project team members to conduct field observations and meet with stakeholders.					$1,000
							Sub Total	**$1,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$475,000**

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 the project will be carried out.	Secured	$251,471
			Non State Sub Total	**$251,471**
			Funds Total	**$251,471**

Total Project Cost: $726,471

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: f86451f5-63d.pdf

Alternate Text for Visual Component

Diagram showing an Arctic cold air outbreak advancing over Minnesota. In the north, sub-freezing air columns yield heavy snow. Further south, a warm nose of air creates hazardous freezing rain. In the south, temperature profiles dictate precipitation types, leading to ice accumulation that damages forests and power lines....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
University of Minnesota Authorization Letter	0bcd0c2d-d59.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I understand the UMN Policy on travel applies.

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

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?

No

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Ben Vargas, Sponsored Projects Administration

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

N/A