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

Project Title: **ENRTF ID: 063-AH**

Temperature and Ice Phenology Information for Lake Management

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

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

Total Project Budget: $ 194,704

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

Summary:

Develop cloud based image processing methods to map lake ice/snow phenology (snow, ice cover onset, thickening and disappearance) and lake surface temperature using satellite optical and all weather radar data.

Name: Leif Olmanson

Sponsoring Organization: U of MN

Job Title: Dr.

Department:

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Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Maps and graphs showing lake-ice and surface temperature from radar and thermal satellite data. Field excursions showing snow and ice phenology validation. Essential data for fish habitat and HAB modeling.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%

PROJECT TITLE: Temperature and Ice Phenology Information for Lake Management

I. PROJECT STATEMENT

This project will enhance fisheries and water quality management by implementing and validating automated approaches using Google's Earth Engine (GEE) cloud-based infrastructure to provide lake temperature and ice phenology assessments from satellite observations. Ice phenology, including ice cover onset, snow cover and ice disappearance, are important since it sets up the thermal structure of lakes and is needed for reliable modeling of lake temperature, which in turn is needed for fish habitat, algal growth, and harmful algal bloom (HAB) occurrence modeling. Lake surface temperature is important since it can be used as a measure of lake temperature on a regional basis and to calibrate and validate lake temperature models.

This project is a compelling opportunity as it leverages the archive of publicly available optical and radar data from current operational Earth observation satellites and the no-cost high performance computing and storage resources of GEE. **Radar data has the advantage of not being affected by cloud cover**, which can be persistent especially during the winter. The Sentinel 1 C-band Synthetic Aperture Radar (SAR) collects data at 3 to 6-day intervals. Meanwhile, Landsat-8 and Sentinel-2 provide multispectral data every 3 to 5 days and should allow for ice phenology validation when combined with concurrent SAR measurements. Further, the Landsat satellites have the unique feature of measuring thermal radiance of the surface and will allow for mapping lake surface temperatures. With the launch of Landsat 9 scheduled for December 2020, the combined use of these sensors can produce data every 8 days.

Ice phenology and surface temperature of inland lakes are new applications that will require significant research and development. For this project, we will conduct exploratory research to understand the potential for a multi-sensor (optical and radar) approach to map ice phenology (including snow, ice cover onset and disappearance, and water retrievals), potentially ice thickness and lake surface temperature. We will use GEE to conduct preliminary evaluation by querying all available Landsat and Sentinel 2 optical imagery and Sentinel-1 SAR data over several sub-regions throughout Minnesota. These sub-regions will span from southern to northern portions of the state and include lakes with varying levels of phytoplankton and color as well as variations in size and depth. From a multi-sensor approach, spectral and optical observations from Landsat-8 and Sentinel-2 multi-spectral data will be used in combination with the SAR imagery to discern snow and ice characteristics. The ability to manipulate all these datasets in a single GEE environment will be explored to extrapolate developed models to a regional scale and ultimately to over 10,000 Minnesota lakes.

During the winter 2018 we conducted two field campaign to measure optical properties and collect lake ice and snow measurements. For the second trip, we collaborated with under ice Limnologists from NRRI and LLO at the University of Minnesota Duluth who collected limnological parameters from six lakes with varying levels of phytoplankton and color. For these trips, we used GEE to process all available SAR imagery throughout Minnesota to target areas where the backscatter signal was different than other lakes in the area, so we could get data from a range of lake ice conditions. Those trips made it clear that there is some important information that can be identified with this data such as differences in ice thickness, areas with thin ice and water due to springs, clusters of fish houses and ice road to name a few. Since the SAR data is collected at an angle there are some systemic differences across the imagery that need to be corrected. These corrections to normalize the imagery will be a part of our preprocessing steps that will allow for consistent ice thickness measurements over large regions. The optical and radar data time series allows us to visualize ice onset, thickening, melting and disappearance. For this project, we are planning to collect field data each year of the project during February and early March for lakes within the sub-regions discussed above. Snow/ice surface sampling will consist of in situ frozen lake surface reflectance using field spectrometers and ice thickness using an auger and measuring stick. Snow pits and ice cores will be collected at a subset of locations to determine snow and ice structure. The field data will be supplemented with ice thickness and snow data collected by state and local agencies and will be used to calibrate and validate different approaches to identify open water, ice, ice thickness and snow using clear Landsat 8, 9 and Sentinel 2

imagery and Sentinel 1 SAR data implemented in GEE. This proposal was developed in cooperation with staff from state water management agencies and is designed to support their management needs.

Our project goals are to: 1) **develop remote sensing methods to permit routine measurement of lake ice/snow phenology and lake surface temperature in Minnesota's waters**; 2) **apply methods to our 10,000 lakes and large rivers to create a database and corresponding maps**.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Build advanced methods for measuring lake ice/snow phenology and lake surface temperature in surface waters of Minnesota **Budget: $154,704**

Physically-based predictive relationships will be developed to measure lake ice/snow phenology and lake surface temperature using available remote sensing data from satellites. Methods will be established and validated with field data collected from lakes within sub-regions distributed throughout the state. Applications of the methods will be used to gain information for all lakes and large rivers.

Outcome	Completion Date
1. Measure ice thickness and snow depth at multiple lakes and locations within sub-regions throughout the state to obtain a data set for developing predictive relationships	*March 2023*
2. Gather field ice and snow measurement data from state and local agencies	*June 2022*
3. Analysis of field and satellite data to develop predictive relationships to permit routine monitoring ice/snow phenology and lake surface temperature in the state's waters	*January 2023*
4. A method for ice/snow phenology and lake surface temperature for Minnesota's 10,000 Lakes	*January 2023*

Activity 2: Dissemination in web-accessible mapping tool and application for lake and fisheries management **Budget: $40,000**

Information gained in Activity 1 will be used to construct a web-accessible statewide database of lake ice onset, snow cover and ice disappearance and lake surface temperature during the late summer that will be available to the public, researchers and state agencies. This information will also be used to create animations from select areas of ice phenology and lake temperature to illustrate seasonal changes. Results will be disseminated to water resource managers, and stakeholders via presentations at local meetings.

Outcome	Completion Date
1. Integrate project results into a publicly accessible web accessed database/mapping tool	*June 2023*
2. Two peer reviewed publications, and numerous presentations on methods & applications	*June 2023*

III. PROJECT PARTNERS AND COLLABORATORS:

The project team consists of the Principal Investigator (PI) Leif Olmanson and Co-I Benjamin Page who are based at the University of Minnesota and unfunded collaborator Christopher Crawford from the U.S. Geological Survey Earth Resources Observation and Science (EROS) Center.

IV. LONG-TERM IMPLEMENTATION AND FUNDING:

This project directly addresses LCCMR funding priorities in Water Resources and Foundational Natural Resource Data and Information. In collaboration with University of Minnesota Duluth and USGS scientists, we are seeking funding from the NSF for a complementary project exploring the effects of snow/ice phenology on under ice limnology in different optical water types. The results from this project will be of immediate use to the DNR for fish habitat modeling and prioritization of resources and could be implemented in a HABs occurrence model.

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Leif Olmanson
Project Title: Temperature and Ice Phenology Information for Lake Management
Organization: Regents of the University of Minnesota
Project Budget: $194,704
Project Length and Completion Date: 3 years 6/30/2023
Today's Date: 4/9/19

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 164,904	$ -	$ 164,904
Leif Olmanson PI (76,600) 74% salary 26% fringe 28% FTE			
Ben Page (88,304) 74% salary 26% fringe 40% FTE			
Professional/Technical/Service Contracts			
	$ -	$ -	$ -
Equipment/Tools/Supplies			
Snow measurement kit to measure snow properties and microstructure for remote sensing modeling/validation	$ 500		$ 500
Deployable field tent to block wind and provide cover from extreme temperatures	$ 500		$ 500
Lake ice thickness kit to measure ice thickness for remote sensing validation	$ 800		$ 800
High quality near infrared camera to image snow and ice microstructure	$ 500		$ 500
$500 lab fees and $500 misc per year for 3 years	$ 3,000	$ -	$ 3,000
Snow mobile rental $3,000 per year	$ 9,000		$ 9,000
Capital Expenditures Over $5,000			
Lake Ice coring system to measure air bubblies and ice microstructure for remote sensing modeling	$ 8,000		$ 8,000
Fee Title Acquisition			
	$ -	$ -	$ -
Easement Acquisition			
	$ -	$ -	$ -
Professional Services for Acquisition			
	$ -	$ -	$ -
Printing			
	$ -	$ -	$ -
Travel expenses in Minnesota - in accordance with UMN Travel Policy	$ 7,500		$ 7,500
$796 (plus milage 1,372.5 at $0.58) per year. Total for 3 years $2,388			
Lodging for field crew ($105 a day per 8 days)			
Per Diem: 8 days per year for 2 persons at $54 = $1372: per 3 years			
Other			
	$ -	$ -	$ -
COLUMN TOTAL	$ 194,704	$ -	$ 194,704

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: University of Minnesota Unrecovered Facilities and Administration Costs 54%	Pending	$ 100,800	$ -	$ 100,800
In kind: Value of Landsat satellite imagery from EROS Data Center. The estimated net value of 7 years (2017-2023) of Landsat imagery over the project period is $574,800 (958 images X $600/per image).	Secured	$574,800		$574,800

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

Temperature and Ice Phenology Information for Lake Management

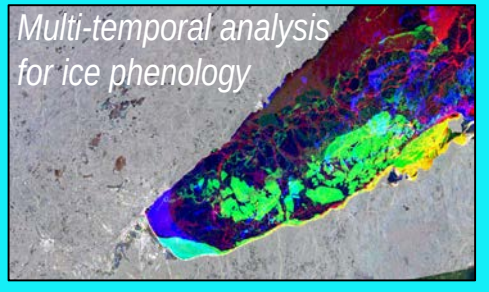
Satellite Data

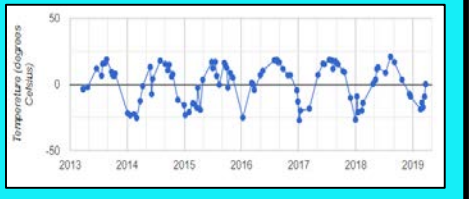
Sentinel-1 Radar
All weather data collection

Synthetic Aperture Radar (SAR)

Landsat-8 & 9

Thermal Infrared Sensor (TIRS)





Time-Series Analysis of Lake Thermal Properties

Google Earth Engine

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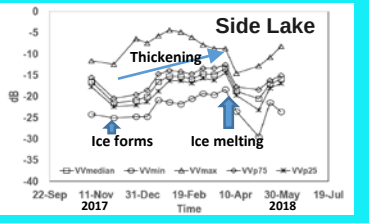
Field-Validated Methods

Optical Measurements

Snow Depth-Structure

Radar Backscatter



Ice Thickness-Structure

Essential Data for:

- Fish habitat modeling
- HAB occurrence modeling
- Under-ice limnology

05/12/2019

ENRTF ID: 083-AH

Temperature and Ice Phenology Information for Lake Management

Project Manager Qualifications and Organization Description

Leif Olmanson, PhD.
Project Principal Investigator (PI); Research Associate, Remote Sensing and Geospatial Analysis Laboratory, Dept. of Forest Resources, has over 20 years experience developing remote sensing applications to create temporally and spatially rigorous datasets of water and land resources for large area ecosystem characterization. He is particularly interested in developing field validated image processing methods implemented in automated geospatial analysis systems such as Google's Earth Engine and Minnesota Supercomputing Institutes supercomputers to gain a better understanding of the natural environment. He currently leads a team of researchers and computer scientists to build a near real-time water quality monitoring system for Minnesota's >10,000 lakes using satellite imagery to providing critical water quality information for lake management. He is the PI on a USGS project "Advancing remote sensing methods for lake water quality and ice phenology" for which he and collaborator Christopher Crawford have collected some preliminary field measurements of optical measurements, ice thickness and snow characteristics. He will provide overall leadership for the project and contribute to development of computer code for prototype image pre-processing and algorithms to derive ice/snow phenology and lake temperature products.

Benjamin Page, MS.
Co-I; Research Fellow, University of Minnesota's Water Resources Center. Ben's primary research is focused on calibrating/validating satellite data for aquatic applications in Minnesota. As a former NASA associate, he has experience with a wide variety of Earth observation platforms and is passionate about implementing remote sensing strategies for lake management. Currently he has been transferring conventional optical and radar image processing methods to cloud- and high-performance computing infrastructures for automated monitoring purposes.

Organization Description
All personnel are based at the University of Minnesota, one of the largest, most comprehensive, and most prestigious public universities in the US (umn.edu/twincities). The labs and offices of the investigators and collaborators are equipped with the necessary space and facilities needed for the proposed work.