FINAL REPORT

University: Montana State University

Name of University Researcher Preparing Report: Eric Sproles

NWS Office: Glasgow

Name of NWS Researcher Preparing Report: Tanja Fransen

Type of Project (Partners or Cooperative): Partners

Project Title: *Mapping and quantifying river ice to improve streamflow forecasting using Neural Networks and unmanned Aerial Vehicles*

UCAR Award No.: SUBAWD002072 MSU

Date: June 11, 2021

Section 1: Summary of Project Objectives

Near-term

1. Develop and test NN algorithms to map river ice and jams using MODIS and Sentinel 1 & 2 satellite imagery.
    1.1. Map and measure river ice using UAVs for training and validation of NN algorithms [MSU].
    1.2. Apply 3D reconstructions from UAV measurements to calculate the volume of river ice in study reaches [MSU].
    1.3. Develop, test, and refine the ability to map river ice using NN algorithms [MSU].

Longer-term

2. Integrate ML-based river ice data into testing of existing streamflow forecast models and the National Water Model (in an offline mode).
    2.1. First- (Alpha) and Second-phase (Beta) based upon refinements in the NN data [MSU & Agency Partners].
    2.2. Implement these tests in collaboration with the three National Weather Service offices in Glasgow, MT; Billings, MT; and Bismarck, ND; the Missouri Basin River Forecast Center; National Water Center; and the US Army Corps of Engineers [MSU & Agency Partners].
3. Present the techniques and applications described in goals 1 & 2 in a workshop for partner agencies [MSU & Agency Partners].
4. Transition these data and techniques into a lab exercise for an upper division course at Montana State University (Geospatial Analysis of Snow and Water Resources), [MSU & Potentially COMET_ED].

Section 2: Project Accomplishments and Findings

In the first year of this project, we were able to effectively refine our methodology and collect initial field data. This included site visits to establish our primary field site in Glendive, MT and (Fig 1). We were able to conduct ice-free baseline flights, and well as ice-on flights in 2020 and 2021. During these visits to the field we also established strong working relationships with the Dawson County (Glendive) Disaster and Emergency Services Coordinator (DES).

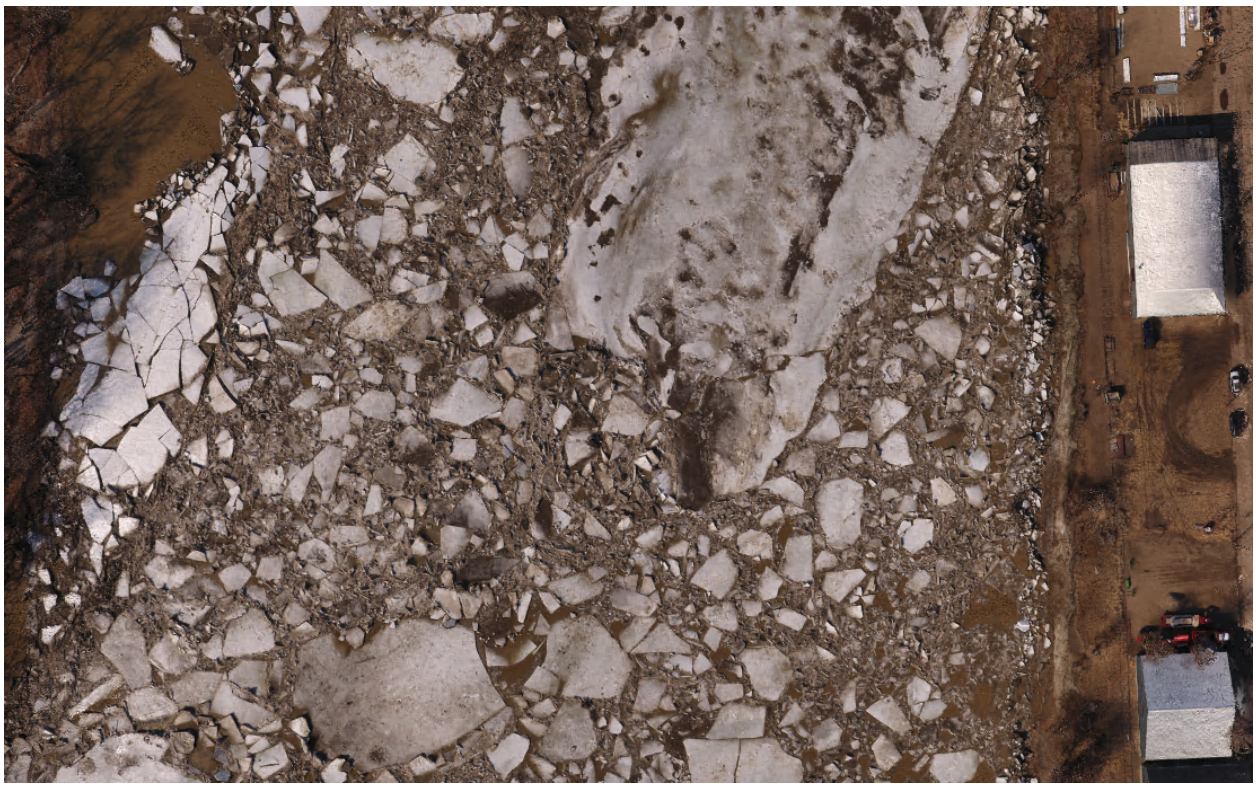

Figure 1 - River ice on the Yellowstone River at Glendive, Montana on March 5, 2020. For scale, note the vehicles on the right-hand side of the picture.

We leveraged the data collected from the initial field visit to support a 3-year NASA proposal, "Remotely-sensed approaches to quantify river ice and ice-jam vulnerability in continental rivers", which was funded. This will support Ross Palomaki, a PhD student working with Sproles, for the duration of his graduate training.

While the scope of work has not changed, we were able to reallocate funds. Based upon approval from the COMET Program Managers, we reallocated funds from this grant funding to purchase a UAV dedicated to this project.

Palomaki has identified and collected Sentinel-1 and Sentinel-2 satellite imagery that correspond to aerial photography collection dates. With the acquisition of NASA funds for this project comes the opportunity to access Planet Labs satellite products (including PlanetScope daily imagery at 4 m spatial resolution). Work to incorporate this imagery into the project is ongoing.

Processing aerial photosets from the dedicated UAV into 3-dimensional surface models is also ongoing and expected to be completed by July 2021. Once this step is complete we can begin to validate the Sentinel-1, Sentinel-2, and PlanetScope imagery using the UAV-based surface models. Next steps for this aspect of the project are to compile a neural network training dataset of satellite imagery from the appropriate platform(s).

Section 3: Benefits and Lessons Learned: Operational Partner Perspective

The NWS office in Glasgow, MT has struggled for decades to best prepare and warn communities for a low to moderate probability, but high impact event. While we as an agency are improving on severe weather warnings, ice jams present an entirely different threat that has little skill in prediction. After multiple ice jam events in the last decade flooded roads, cut off access to neighborhoods and threatened and damaged numerous homes, we actively sought ways to improve:

1.) How we communicate in advance the potential flash flood/ice jam threat;
2.) Real-time identification of flash flood/ice jam threats by increasing reports on the ground as well as "seeing" it from satellites, and;
3.) warning for the threat of flash flooding due to ice jams.

This project fostered collaborations with the researchers from MSU-Bozeman and initiated new collaborations with the NOAA/NWS National Water Center in Tuscaloosa, AL. This team is actively working in a research-to-operations paradigm. It has brought renewed attention to the issue of ice jams, and increased the number of people watching our region and collaborating with what they are seeing from hundreds to thousands of miles away during our primary ice jam season in late Winter and early Spring.

During the ice jam season, communications are now conducted through the creation of the Yellowstone River Ice Jam Task Force. This group includes the three NWS offices in the basin, the NWS Missouri Basin River Forecast Center, the National Water Center, local emergency response partners, the MSU-Bozeman researchers and other federal agencies involved in water management such as the USGS, the USBOR Upper Great Plains Region and the USACE Omaha District. This formalized communication did not exist prior to coming together to work on this project.

One of challenges has been in finding research done on ice jams, very little has been published, and an even smaller percentage of that tackles the prediction of ice jams. We continue to seek opportunities in this area, but having half our staff forced into telework this past year has slowed some of those inner-office collaborations.

Another challenge was the warmer winter across the region and lack of snow cover really didn't produce ideal conditions for ice jams this year. We had ice move through, and utilized the task force as designed, but thankfully for the communities, ice was not a major threat this year.

We look forward to continuing our partnership with MSU-Bozeman, connecting them with the National Water Center and the Missouri Basin River Forecast Center to find ways to get the observed data from the UAV's and satellite imagery into river forecast predictions that will someday allow us to extend the lead time of our warnings.

Section 4: Benefits and Lessons Learned: University Partner Perspective

This project has generated interest within the university and research communities. Sproles was awarded internal funding from Montana State to develop a citizen-science app for smartphones to map river ice. A prototype was developed during the winter of 2021, and will be further augmented during upcoming winters.

We also look forward to working with NOAA and other federal partners to integrate our tools into an operational modality. This includes a hands-on workshop during 2023.

Section 5: Publications and Presentations

Palomaki, RT, 2021: Measuring and monitoring river ice using UAV and satellite imagery. Invited presentation on 2021-04-07; Montana Institute on Ecosystems; available at https://youtu.be/t_2Gc1nMLB0.

Palomaki, RT and EA Sproles, 2020: Measuring and monitoring river ice using UAV and satellite imagery. *Fall Meeting 2020*; Virtual conference; Amer. Geophys. Union; Oral presentation.

Section 6: Summary of University/Operational Partner Interactions and Roles

Sproles manages the overall project, with a tremendous amount of support from Palomaki. Fransen serves as scientific and logistics counsel. As a scientist Fransen helps frame the goals of the project into a format that is relevant to the mission of NOAA. As a facilitator, Fransen coordinates relationships with partners within the federal government and in communities affected by river ice.

Fransen, Palomaki, and Sproles are in frequent contact during the winter (2-3 times monthly), and as needed during ice-free periods.