Satellites and citizen science: Predicting Alaska's spring breakup

By Grace Veenstra

If you fly to the remote Alaska village of Sleetmute in winter, it's likely you'd be greeted by the sight of the Kuskokwim River through the frosted window of your bush plane. Half the year, this river on the doorstep of Sleetmute has its surface frozen solid, the ice over a foot thick. But come back several months later, and this river is a different sight.

Sleetmute is one of dozens of Alaska communities that have experienced flooding due to the breakup of ice along Alaska's rivers.

"We've had several minor floods that have simply displaced items in our yards," said Angela Hayden, a teacher in Sleetmute. "The most recent flood, last year in 2022, caused more severe damage because the water level rose to the bottom of some of the houses, ruining their foundations and the insulation under the houses."

In spring of 2023, severe flooding hit numerous communities, including Circle and Eagle on the Yukon River and Crooked Creek on the Kuskokwim. In Circle, water levels reached historic heights. Dozens of homes were destroyed or suffered major damage. In response, Alaska Gov. Mike Dunleavy issued a disaster declaration to help communities respond to the severe and widespread flooding throughout the state. As of May 24, community members could apply for the state's individual assistance program for relief.

Like so many communities in river country, Sleetmute, Eagle and Circle know about the consequences of flooding and the importance of predicting it.

But how is that done?

What causes floods during breakup?

In Alaska, spring flooding results from ice jams, which occur when floating chunks of ice accumulate and clump together. Ice jams can significantly reduce water flow and cause upstream flooding and, in some cases, downstream flooding as backed up water spills over the riverbank.

There are two types of breakup. The first is known as thermal breakup, where the ice becomes soft and weak thanks to slowly increasing temperatures and breaks apart without resistance. This type of breakup is unlikely to form an ice jam since the ice is not solid enough to jam together.

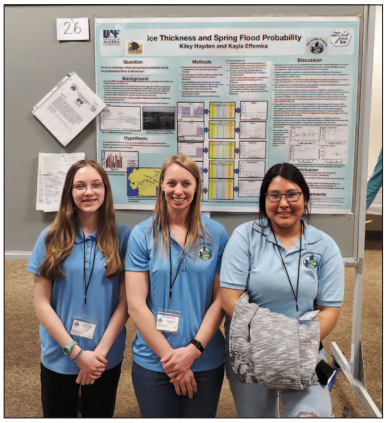
However, the second type of breakup, known as dynamic or mechanical breakup, is the one forecasters and communities need to watch out for. In a dynamic breakup, the ice remains hard and resistant to breaking. Dynamic breakup can result from high levels of snowpack, significant ice thickness and a rapid increase in temperatures.

When the ice does begin to break in a dynamic breakup, it typically remains in large sheets that are easily snagged on sandbars, bridge pilings or in slower-moving water close to shore. River ice jams typically occur at pinch points, such as at sharp bends and places where the channel constricts. Like trying to shove a square peg in a round hole, the ice piles up and prevents water from moving downstream. Water upstream of the jam can rise rapidly, flooding communities.

Aside from the rising waters, the ice itself can be a hazard. Large sheets of ice can be carried on shore and bulldoze anything in their path, leveling trees and buildings. In 2009, the Yukon River community of Eagle experienced a major flood. Some buildings had water up to the second story, and house-sized chunks of ice swept through the small town.

Ice jams cannot be prevented, so Alaska's many remote river communities focus attention and resources on preparation, prediction and response.

An aerial photograph of the 2023 Circle flood on May 14, 2023, showing the ice onshore and damaged houses. PHOTO BY APRFC PHOTO VIEWER



Kayla (right) and Kiley (left) with their teacher Angela Hayden (center) stand in front of the students' poster at the GLOBE Student Science Symposium. PHOTO BY ELENA SPARROW

Drone footage of the 2022 Sleetmute flood on May 8, 2022, showing the water overtaking the houses and flooding the community. PHOTO BY ZAC SMITH AND FRESH EYES ON ICE

Car-sized chunks of solid ice were brought into the community of Eagle during the 2009 spring break up flood event. PHOTO BY NATIONAL PARK SERVICE

Forecasting Flooding

An arm of the National Weather Service, the Alaska-Pacific River Forecast Center is the cornerstone to predicting flooding in Alaska.

"Year-round, we're responsible for flood forecasting and providing watches, warnings and advisories for all communities in the state of Alaska," said Celine van Breukelen, a service coordinator at the forecast center. "We work with the individual communities themselves, because they know what's going on in their backyard, how the winter has been and how things are progressing."

The forecast center is responsible for alerting communities to their flood risk a few weeks in advance of breakup so they have time to prepare. In 2023, the entire state had an above average risk for spring breakup flooding due to the high snowpack and unusually cold April.

"As the breakup season moves into being more active, we'll have people who are flying in small aircraft over the communities and reporting directly to those communities along with emergency managers," van Breukelen said. "We're also in the office looking at satellite imagery, looking at hydrographs and scraping data wherever we can get it."

The forecast center also works with a variety of partners to be able to predict flood events. Satellites are among their biggest assets.

"We use a lot of satellite imagery, and that's become more and more available in recent years," van Breukelen said.

Data from the European Space Agency's Sentinel satellite is among the most used at the forecast center, with the satellite providing high-resolution images and products accessible by the public. Among these products are the true color product, which is similar to what the human eye would see from space, and false color products, which assign different colors — such as dark blue for snow or cyan for cloud cover — to highlight different land features.

Sentinel is just one information source used by the forecast center. They also make use of data and products from other satellites.

William Straka III works at the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin. He develops algorithms that process satellite data and turn it into products that forecasters such as van Breukelen can use. Despite being over 2,000 miles from Alaska, Straka's work is very relevant to Alaska communities.

"Ground-based instruments provide a local point-based set of information, whereas satellite data can provide you a very, very large-scale observation of an area," Straka said.

Straka works with the river forecast center to provide daily notes on the satellite data during breakup. One of the products he looks at is the "VIIRS River Flood" product, which is produced by the Geographic Information Network of Alaska at UAF. Sanmei Li of George Mason University developed this satellite product partly in response to the 2013 Galena, Alaska, flood. That Yukon River flood displaced nearly all 472 residents as 7 to 9 feet of water overtook homes and businesses.

"The VIIRS Flood product measures how moist the land within a pixel is compared to normal," Straka said. "The more moisture that you see, the more likely it's flooded. If you're getting upward of 60 to 90% moisture in a pixel, you probably don't have mud there, you have water there."

With the aid of satellite imagery from Sentinel and the VIIRS River Flood product, the forecast center can

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see far more of the state.

Community-Based Observations

Facebook has many public and private groups of community members from across Alaska who share information about the behavior of the ice. One of these groups belongs to Fresh Eyes on Ice, a project from the University of Alaska Fairbanks that focuses on improving observations and understanding of freshwater ice.

Fresh Eyes on Ice uses a variety of tools such as buoys and satellite data, much like the forecast center, to understand freshwater ice. But one of its most notable features is their citizen science and community-based monitoring teams.

"The community-based monitoring teams are comprised of educators, long-term community members and youth who work together to make monthly measurements of ice thickness," said Katie Spellman, an assistant professor at the International Arctic Research Center at the University of Alaska Fairbanks. Spellman specializes in citizen science and is part of Fresh Eyes on Ice.

One of these community-based monitoring teams is in Sleetmute. During the winter, Angela Hayden takes her students out to measure the Kuskokwim River ice.

"Fresh Eyes on Ice helps the students realize they are a part of something bigger and that their citizen science skills benefit their community and the world," Hayden said. "It also helps them be aware of the environment around them and makes them feel like they are a part of the future."

The tools Hayden's class uses for ice monitoring aren't complex instruments. They can be bought at a general store in town.

"Ice augers and rulers, that's pretty much it," Spellman said.

Aside from recording measurements of ice thickness, Fresh Eyes on Ice is also an avenue for community members to share photos of the ice outside their homes. Those photographs are shared with the river forecast center and National Weather Service.

"There's so much more people power in inviting everyone to the table to submit photos of changing ice conditions," Spellman said. "That's why community and citizen science is a good approach, because everybody has a phone now and everybody can take a picture."

Whether through the Fresh Eyes on Ice Facebook page or photo-submission form, these photos are vital to predicting break up flood events. They help communities in the present by informing others upstream or downstream of a potential flood hazard and help with predicting flooding in years to come.

For example, Straka uses the photos submitted through Fresh Eyes on Ice to improve the satellite products he works on. "That's very important," Straka said. "The algorithm's good, but you want verification and validation of the algorithm. If you don't validate your algorithm, you don't know how accurate it is."

It's not just people like Straka or the forecast center trying to predict breakup flooding either, it's also the communities themselves.

Student-Based Science

Kayla and Kiley are two high school students from Sleetmute who witnessed the impact the 2022 flood had on their community. The girls were on a class trip at the time of the flood but upon their return they could see the flood's impact.

"The dump got flooded, and there was trash a quarter mile away," Kayla said. "I could also see scratches on the trees from the ice."

Kiley said the water rose until it was a couple feet from the steps of her house, and she spent time picking up her dad's wood that had floated away with the water. They also had a neighbor's old outhouse float away from its foundation, and another neighbor had an ATV whose engine was flooded.

Due to the 2022 flood, the girls wondered if they could predict the probability their community would flood based on ice thickness measurements. Using a historical record of spring flood events in Sleetmute collected by resident Susan Hubbard and ice thickness measurements from the National Weather Service for other communities along the Kuskokwim, the girls compared how ice thickness correlated with floods. They found a weak relationship between ice thickness and flood probability and concluded that using ice thickness measurements alone had limited use in predicting flood likelihood.

The two presented their findings several times, including at the GLOBE Student Science Symposium in Fairbanks, alongside many other youth community members with their own projects.

Sleetmute escaped breakup flooding in 2023, though other communities such as Circle and Crooked Creek were not so fortunate. Many Circle residents are staying elsewhere, and people from the State Emergency Operations Center and Red Cross have begun flying out to affected communities to survey the damage or provide supplies.

For communities like Circle, the recovery will take months. Meanwhile, Straka will continue to refine his models, and the forecast center will continue to monitor the river over the summer and inform Alaska of how its rivers are behaving.

"Our goal at the end of the day is to give communities the best possible information so they can make the best decisions," van Breukelen said.

Grace Veenstra is a student at the University of Alaska Fairbanks and is employed by the Geographic Information Network of Alaska at the UAF Geophysical Institute.