SURVEYING ON ICE: SONTEK RIVERSURVEYOR S5 PROVIDES INSIGHT ON GLACIAL STREAMS

Greenland

Global climate change has thrust receding glaciers into the public eye, but little is known about the dynamics of water storage and conveyance on these massive rivers of ice.

Meltwater runs fast and cold on the surface of an ice sheet. Slippery conditions, unstable banks, water temperatures of just 0.5 to 1.0 degree Celsius and velocities of up to three meters per second over nearly frictionless bottoms make glacial streams a dangerous work environment. So does the fact that many glacial streams are abruptly swallowed by seemingly bottomless crevasses, creating powerful hydraulics on even low-gradient streams.

These are not like temperate, terrestrial rivers. That's why first-hand measurements of how they work are vital to understanding how glaciers melt.

"Glacial melting has been recognized as a key contribution to rising sea levels associated with global climate change," notes Brandon Overstreet of the University of Wyoming Department of Geography, one of the researchers on the project. "Our group is interested in better understanding the fate of meltwater on the Greenland Ice Sheet to better constrain estimates of how much and how quickly meltwater is conveyed through the hydrologic system of the ice sheet to the ocean.

"The big-picture goal is to develop a water budget for the Greenland Ice Sheet," he adds.

A grant from the U.S. National Aeronautics and Space Administration (NASA) Cryosphere Program is yielding fascinating data on glacial stream dynamics from the Greenland Ice Sheet. Correlating lake and stream bathymetry data with imagery from the WorldView2 satellite will help scientists to produce bathymetric maps that will allow them to estimate the volume of water that is stored in melt ponds and conveyed through stream channels on the surface of the Greenland Ice Sheet, says Overstreet. Eventually, they hope to create a budget of ice and water under a full array of conditions.

National Team

Laurence C. Smith of the University of California, Los Angeles (UCLA) is principal investigator for the project, titled "Towards Hydrologic Understanding of the Greenland Ice Sheet." Co-PI Asa K. Rennermalm of Rutgers brings an East Coast crew to the effort, and second Co-PI Carl Legleiter and Ph.D student Overstreet bring perspective from the University of Wyoming.

UCLA graduate student Lincoln Pitcher and University of Wyoming graduate student Brandon Overstreet measuring discharge in a supraglacial ice river on top of the Greenland Ice Sheet, immediately following record melting in July of 2012.

In July, 2012, the team set up shop at the Kangerlussuaq International Science Support facility in southwest Greenland. Every day, the team commuted to the ice sheet's ablation zone – as far as 120 kilometers from base – by helicopter.

Their arrival coincided with a massive melt event that involved 97 percent of the ice sheet and caused catastrophic flooding – both a thrill and a nightmare for the team. There was no doubt that their methodology and equipment would be put to the test.

The team used two primary tools on the ice. A drone boat was outfitted with an echo sounder, GPS and spectroradiometer to measure the depth and optical characteristics of glacial lakes and slow-moving streams. A SonTek RiverSurveyor S5 acoustic Doppler profiler (ADP) on a HydroBoard and cable system provided depth and velocity measurements – and computed discharge – from streams moving too fast for the drone boat.

"We had been using the RiverSurveyor S5 to make measurements on shallow terrestrial rivers for several years," says Overstreet. "During this time, we found the system to be extremely versatile. We have even developed a system for deploying the system from a whitewater kayak in the fast-moving water of the Snake River in Grand Teton National Park."

The Wyoming team recognized features that could keep them safe in the dangerous environment of the ice sheet, Overstreet adds. Among them were the robust radio telemetry connection and RiverSurveyor Live software package that allow the operator to control the instrument and collect the data via mobile phone.

"The ability to control the RiverSurveyor system via mobile phone allowed us to keep the operator safely away from the water's edge when working in Greenland, which was ideal for the hazardous conditions we experienced there," he says.

Tough Day at Work

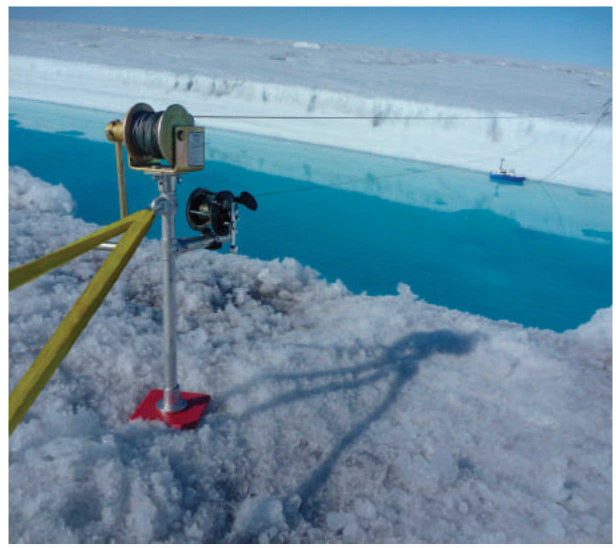
Once on the ice sheet, the team would locate a sampling location. An anchor system was established on one bank using a vertical mast secured to the ice using a series of ice screws. Team members flew across the stream by helicopter and received a weighted fishing line thrown across the stream. The line allowed them to pull a cable across the river and anchor it to a second mast anchored to the opposite bank. The cable system was then tightened with a hand crank.

When the cable was tight and the World View 2 satellite was overhead taking images, the HydroBoard carrying the RiverSurveyor S5 was attached to a cable system designed for the Wyoming team by a company called StreamCraft, a new start-up by University of Wyoming graduate student Chip Rawlins. The special cable setup was rigged to withstand the whitewater conditions, heavy slush flows, and standing waves that threatened to flip or sweep away the RiverSurveyor and its HydroBoard. The system worked perfectly. Though the HydroBoard would occasionally be pulled off a perfectly straight tangent by floating ice and slush, it never dove or flipped, and the instrument gathered its measurements as planned.

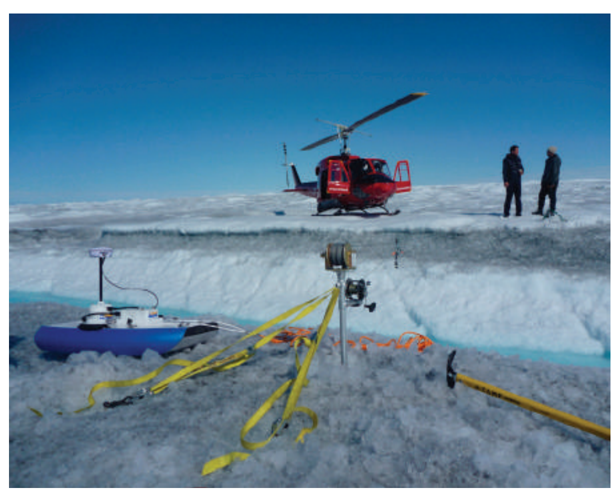
Those measurements will be vital to understanding the dynamics of glacial streams, Overstreet notes.

"We hope to use bathymetric data, water surface elevations and velocity measurements to produce hydraulic geometry relationships that can be used to estimate meltwater flux," he says. "Similar hydraulic relationships currently exist for terrestrial rivers, but very little work has been done on supraglacial streams due to the difficulty of collecting these types of hydrologic measurements."

The RiverSurveyor was operated via mobile phone while being slowly pulled across the stream.



One side of the cableway was secured to the stream bank using ice screws. The cable was tensioned using a hand crank and the RiverSurveyor was attached to the cable



A second operator was flown across the stream by helicopter and a second anchor system was installed.

Ultimately, the ground-level relationships will be correlated with reflectance data from satellite imagery to create a comprehensive view of bathymetry and discharge characteristics on the surface of the ice sheet.

Challenge: Ultra-Pure Water

The RiverSurveyor platform is built tough, ruggedized and sealed for punishing environments in rivers and streams around the world. Its SmartPulseHD system analyzes water depth, velocity and turbulence to automatically adjust pulse, frequency and cell size for optimum data collection in a wide variety of conditions – even fast-changing ones.

But one of the biggest challenges in deploying the RiverSurveyor in Greenland was the extreme purity of the glacial water, notes David Velasco, Product Line Manager for SonTek in San Diego, California, USA.

"The biggest question on everybody's mind was, 'is the system going to perform as it's supposed to in water that's basically as devoid of sediment as you can get in a natural environment?'" Velasco admits.

He explains that the acoustic signals from the RiverSurveyor S5's acoustic beams bounce off particles suspended in moving water. In nearly all natural environments, it's safe to assume that there are enough particles to provide good return signals to allow the system to measure the direction and velocity of water flow, and a stable enough bed to provide solid data on the bathymetry of the banks and bottom of the river.

However, the only particles in glacial streams are dust or ash blown onto the surface of the ice sheet or suspended ice crystals. It was difficult to confirm whether that light sediment load would be enough for the RiverSurveyor S5 to work – or whether the slushy, churning bed and banks of the icy rivers would yield accurate data on the geometry of the streams that are needed to compute discharge.

"Unfortunately, acoustics are one of those things where you just can't look at the water and tell whether it's good enough," Velasco notes. "You can't even test for turbidity, because that's an optical reading and we're working with acoustics. They took a real gamble."

Watching data feed into the operator's mobile phone as the RiverSurveyor S5 fought across the tumbling meltwater rivers, Overstreet and his colleagues realized their gamble had paid off – even in streams with discharges as high as 20 cubic meters per second, which is a significant volume for these type of streams.

"Surprisingly, we were able to collect quality data with no alterations to the operation of the instrument," Overstreet reports. "Despite the ultra-pure water, signal-to-noise ratios from the instrument were within acceptable ranges, and we were able to collect reasonable velocity measurements in all of the streams we worked on."

There were other challenges. For instance, the unstable and constantly moving streambeds required the researchers to rely on

Most supraglacial streams abruptly transition into deeply incised canyons with powerful hydraulics. Even low-gradient streams can spontaneously be captured by crevasses or form moulins

Dynamic surface streams convey large volumes of meltwater. In this study, stream widths up to 30 meters and depths exceeding 2 meters. Velocity exceeding 3 m/s in some measurement locations.

external references, such as GPS, for location and boat movement data instead of the traditional Bottom Tracking solution.
In the end, the RiverSurveyor S5 proved a success in some of the harshest deployment conditions on earth.

"The RiverSurveyor S5 has proved to be very versatile," says Overstreet, "and performed even better than I expected in the extreme conditions of the Greenland Ice Sheet."

Special thanks to Dr. Carl J. Legleiter and Brandon T. Overstreet for taking and providing all photos associated with this application note.

Brandon Overstreet and Dr. Carl Legleiter.

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Let's Solve Water

SonTek
9940 Summers Ridge Road
San Diego, CA 92121
Tel: +1 858 546 8327
Fax: +1 858 546 8150
Email: inquiry@sontek.com
Web: www.sontek.com