ADCPs Aid Pioneering Study of How Glaciers Melt

Unmanned Vehicle Deploys ADCP Mooring near Calving Ice Cliff

Teledyne RD Instruments

Instruments

Products
Sentinel V & Workhorse ADCPs

Application
Study melting of ocean/glacier interface

Organizations
Oregon State University (OSU)
University of Alaska
University of Oregon

Sponsors
US National Science Foundation (NSF)
National Geographic Society

Principals
Profs. Jonathan Nash & Erin Pettit

Data Collection Date
Summer, 2018

Location
LeConte Glacier, SE Alaska

Overview

Global concern about rising sea levels has thrust increasing loss of glaciers and ice sheets into public attention. A key uncertainty in projections of sea level rise is the rate of ice loss at the seaward margin of glaciers.

The glaciers of Greenland and Alaska that reach the sea have therefore received increased scientific notice. Yet the ways in which warm ocean water interacts with and erodes the face of these glaciers have been largely unobserved.

Operating near an ice cliff that is actively calving icebergs—above and below the water line—is both difficult and dangerous. Icebergs, sized as big as football fields, can shoot to the surface at 300 m from the glacier's face.

A variety of ocean processes, ranging from mixing to circulation, are stimulated at a glacier's terminus. As well as local dynamics at the ice/ocean boundary, the melting is influenced by remote factors. Examples include weather conditions farther inland and deep-water temperatures farther seaward.

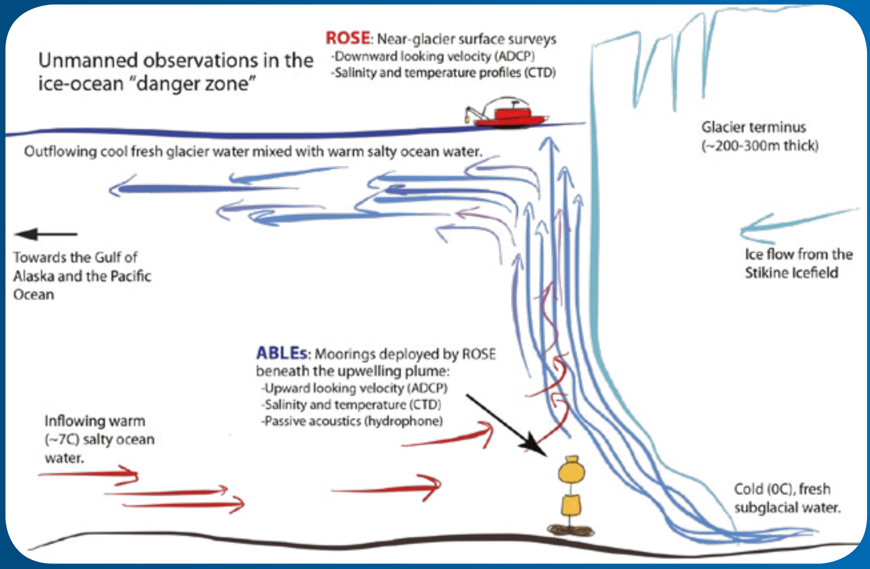
In the summer of 2018, a team of scientists from Oregon State University and University of Alaska deployed an extensive and innovative observational program to study ocean processes at the face of LeConte Glacier in Southeast Alaska.

Teledyne RDI ADCPs were installed on moored and moving platforms, and so played two different roles in the study. Upward-looking ADCPs were fitted to several moorings that had a variety of purposes, including recording ascending motions near the face of the glacier and measuring deep horizontal currents. These currents carry warm seawater toward the glacier.

In a second role, ADCPs were mounted on remotely controlled kayaks developed by OSU. These unmanned vehicles were used to deploy moorings in dangerous yet critical locations adjacent to the glacier's calving ice cliff. As well, the vehicles performed spatial surveys around the fjord.

LeConte Glacier, one of the most active glaciers in Southeast Alaska.

Credit: J. Nash (Oregon State University)



Buoyant plume of subglacial meltwater and its associated fjord-scale circulation.

Credit: E. Pettit (University of Alaska) https://exploreice.org/sound-of-ice

Situation

Glaciers that extend through mountain valleys into oceanic fjords are termed "tidewater" glaciers. At the seaward terminus, the rock basement under these thick glaciers can be far below sea level. The jagged glacier face, which is an ice cliff above and below the water surface, erodes in two ways—by melting and by calving icebergs. Oceanographers focus on the submerged processes.

During their creep to the sea, glaciers melt at their upper surface. The resulting frigid water drains through the glacier to the underlying rock basement where this meltwater runs seaward below the glacier.

This fresh subglacial water, which enters the ocean far below sea level, has two dynamical effects at the glacier's terminus. First, the meltwater ascends because it is more buoyant than ambient seawater. Turbulent mixing associated with this rising plume entrains warmer seawater that, in turn, enhances melting of the adjacent glacier face.

In its second dynamical role, the buoyant plume also drives a larger fjord-scale vertical circulation cell. These motions unceasingly draw deep, warm seawater into closer proximity to the glacier face. Moreover, larger amounts of subglacial meltwater drive more vigorous circulation in the vertical cell.

LeConte Glacier creeps seaward at about 25 m/day. At times, extremely active calving of icebergs more than counters this rate. In fact, during the 1990s, LeConte was one of the fastest-retreating glaciers in the world—shrinking 1.5 km in 1998.

Solution

Measuring the challenging environment near a calving glacier face required a multifaceted solution. A team from Oregon State University and University of Alaska relied on unmanned aerial and surface vehicles. Even more impressive, the researchers used these robotic tools to deploy ADCP moorings from afar—hundreds of meters away.

The unmanned surface vessels named ROSE (the Robotic Oceanographic Surface Explorer) come from ongoing engineering work at OSU. These motorized kayaks carry a 300 kHz downlooking ADCP and a profiling CTD system.

Highlights:

- The face of a tidewater glacier erodes by melting and by calving icebergs
- The glacier terminus undergoes a dynamic balance—between seaward creep and landward retreat (due to facial erosion)
- A buoyant plume of frigid freshwater is injected into the oceanic fjord at the base of the glacier
- The ascending plume drives both turbulent mixing and circulation in the fjord that each act to bring warmer water to the glacier face

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The target of the project was to measure the plume of subglacial discharge ascending the face of LeConte Glacier. The vertical beam and remote measuring capability of an uplooking near-bed Sentinel V ADCP were well suited to this need—especially with some prospect of icebergs shooting upward and colliding with objects in the measurement region.

The researchers used a creative strategy to place the ADCP mooring near the face of the glacier and beneath the upwelling plume. This type of mooring named ABLE (acoustic bottom landing explorer) comes from ongoing engineering work at OSU. Other sensors on this short 15 m mooring included a CTD for measuring salinity and temperature as well as a hydrophone for recording passive acoustics. Popping bubbles indicate melting ice.

The team carefully laid out the ABLE mooring in a purpose-built raft that was towed into position by a ROSE. This towing and positioning operation was remotely controlled from a research vessel, standing-off from the glacier face.

After two weeks, scientists aboard a small boat sent acoustic commands to release the mooring from its anchor. The mooring was recovered after it had been carried by surface currents away from the glacier face.

Although the mooring had ascended at 1 m/s, there remained a 3 cm thick layer of glacial sediments atop the ADCP transducers. You can imagine researchers were delighted to see the ADCPs had profiled successfully despite the unintended sediment cover.

In all, the team deployed five moorings. Four were along the glacier face, and two of the four carried Teledyne RDI ADCPs. Another mooring—carrying a pair of 300 kHz Teledyne RDI ADCPs—was deployed farther into the fjord to record the larger-scale circulation.

Robotic Operations

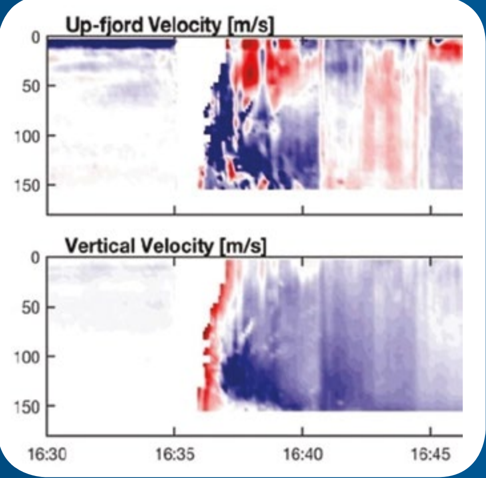
- Researchers used robotic tools to deploy ADCP moorings
- Unmanned motorized kayaks, each carrying an ADCP, operated near the calving glacier face and around the fjord's waters
- The vertical beam of a Sentinel V ADCP provided direct measurements of critical rising motions near the glacier face
- The ADCP mooring was dropped from an unmanned raft that had been towed to the measurement site by a ROSE vehicle
- An aerial drone supplied video to assist in remote control of the ADCP deployment

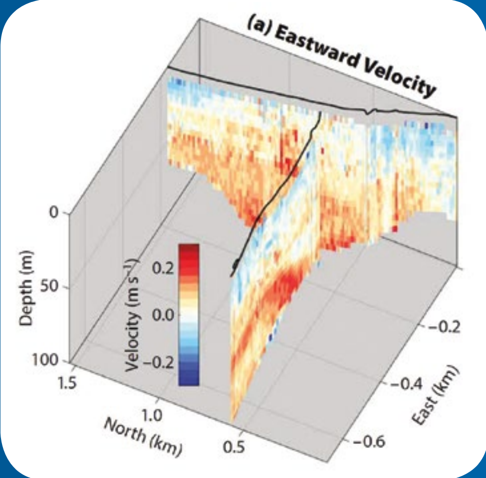
ADCP mooring was deployed using an unmanned raft towed by a ROSE vehicle (both designed/built by June Marion).

Credit: E. Pettit (University of Alaska)

Sentinel V ADCP during recovery after being deployed for two weeks near LeConte Glacier.

Credit: J. Nash (Oregon State University)





Left:

ADCP time series when a "shooting" iceberg calved from LeConte Glacier. Depth (m), Time (h:min), Speeds to ±1 m/s with RED positive, BLUE negative.

Credit: J. Nash (Oregon State University) https://goo.gl/5FodjB

Right:

ADCP transects showing fjord circulation near LeConte Glacier.

Credit: J. Nash et al., 2017 (Oregon State University). https://goo.gl/SXZkYT

Results

The team deployed ADCP moorings to observe water motions associated with melting of the glacier face. One ADCP happened to record a calving event of a submerged iceberg in which a huge piece of ice separated at the base of the glacier and ascended in the ADCP's vertical beam. The adjacent image shows impressive vertical speeds due to the rising iceberg.

This study is providing a ground-breaking 3-D picture of how subglacial meltwater intrudes into the fjord. Current measurements with a five-beam Sentinel V ADCP helped map the 3-D motion and distribution of the plume as well as the advancing deep warm water of the fjord. Information was also gleaned about how these patterns vary due to changes at the ice face.

As part of a 2017 study at LeConte Glacier, Nash's team collected ADCP transects in the fjord. Data from a 300 kHz ADCP fitted to the unmanned motorized kayak showed a classic two-layer circulation cell. Currents were stronger at depth and headed toward the glacier face whereas fresher and colder surface waters moved seaward, away from the glacier. The layered motions persisted for some distance away from the glacier face.

This fascinating research program at the face of LeConte Glacier captured much-needed observations of oceanic processes in a critical yet unknown region—the seaward margin of glaciers. These impressive results provide a new example of the benefits of the ADCP's remote sampling capability.

Other Key Contributors:

Rebecca Jackson, Jason Amundson, Dave Sutherland, plus technical support by June Marion, Jasmine Nahorniak, and Dylan Winters

References:

Nash, J.D., J. Marion, N.McComb, J.S.Nahorniak, R.H.Jackson, C.Perren, D.Winters, A.Pickering, J.Bruslind, O.L.Yong, and S.J.K.Lee. 2017. Autonomous CTD profiling from the Robotic Oceanographic Surface Sampler. Oceanography 30(2):110–112, https://goo.gl/SXZkYT

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