Project acronym: AMAGSUM

Project title: Acoustic monitoring of submarine melting at Arctic glaciers

Project leader: Hari Vishnu, National University of Singapore, Singapore

Discipline: Earth Sciences & Environment: Marine science/Oceanography

Station(s): Polish Polar Station, Hornsund (Svalbard/Poland)

Studying the components of ice-loss at tidewater glaciers, including submarine-glacier-melting (SGM) at the glacier terminus, how it is affected by subglacial discharge of melt-water from the base of the glaciers, and how it relates to calving, is a key knowledge gap to bridge to quantify climate-change impacts. These processes produce sound which can be sensed using passive-acoustics. In this campaign, we undertook field deployments to Hans and Paierl glaciers in Hornsund fjord in collaboration with researchers from Polish Academy of Sciences and Scripps Institution of Oceanography. Previously in 2019, our group had recorded the sound-field in this glacial bay using a small array of sound-sensors, and showed that passive-acoustics can be a promising technique for monitoring the ice-loss processes.

In the current campaign, we improved on the study done in the past campaign by making more advanced measurements and using more powerful instruments.

We instrumented the bay with longer hydrophone arrays (both in vertical and horizontal configurations) to study the SGM-induced sound in the bay in more detail adding to previous studies with higher resolution and clarity, including studying the sound's horizontal variability across the glacier face.This will also be used to study the sound produced by subglacial-discharge and ground truth it with water current measurements, which has never been undertaken before. This is the first time a long array is being used for this purpose. These measurements were done in the same bay that other complementary measurements were taken, hence allowing us a comparison against measurements of the same location using different sensing modalities to get a full perspective of climate change impacts in this region. Recordings using a vertical array of hydrophones with a longer aperture than used in our 2019 campaign to this region, and at distances closer to glacier. This allows us to take a closer look at the terminus with more resolution. We also made video recordings of the surface ice in the glacial bay,allowing us to better evaluate the effect of this on the acoustics Our passive-acoustic array measurements were done at 2 glaciers separated by 4 days, allowing us to examine correlation between acoustics and melt activity, and compare it to our findings from 2019.

One of the most path breaking aspects of the research undertaken in this campaign is that we used a small remote-controlled surface-vehicle named GLAMOR (Glacial Ablation MOnitoring Robot) to study the thermohaline-structure and acoustics near the glacier-terminus by instrumenting it with stand-alone acoustic recorders named PULSARs (Passive Ultra Light Stand-Alone Recorders), temperature-salinity sensors and cameras. These helped us study the terminus up close, which is otherwise impossible to do due to the safety concerns. We believe this is the first time this study is being done at such a close range to the glacier, and in that sense, it is groundbreaking. These measurements near the terminus can help establish the distortion of sound as it crosses the turbulent water region near the glacier terminus, and how the sound sensed in the bay can be used to quantify the SGM using passive-acoustic-monitoring. This validates the paradigm of using robots to sense the glacier terminus which is otherwise dangerous for humans to access.

The GLAMOR robot recorded thermohaline parameters via conductivity-temperature-depth (CTD) casts down to 20 m which will allow us to study the water mixing and variability of oceanographic parameters in the otherwise-unknown near-terminus region. We also captured underwater videos near the terminus, and captured a high density of bubbles in the water column at depths of up to 20m, giving new insight on the near-terminus region.

We used aerial drones to video the glacier terminus, helping us to reconstruct the terminus shape using structure-from-motion technique, for the 1st time at Hans glacier. We also used handheld cameras as well as cameras mounted on the GLAMOR robot to video/photograph large ice pieces in the glacier bay to try and reconstruct their shape/geometry/volume using structure-from-motion. These will be complementary to measurements done by our colleagues at Scripps, who tested a direct melt-rate measurement technique for floating icebergs.

Another exciting aspect of this campaign is that our collaborators at the station undertook complementary measurements at the same glaciers, which can be compared with ours to get a more holistic understanding of climate-change effects at Hornsund fjord glaciers. These studies included:

- acoustic recordings to measure calving activity at 3 glaciers, including a long-term mooring installed by Polish Academy of Sciences
- GoPro camera visual systems installed for long-term camera monitoring of glaciers
- laser-scanning of glacier terminus

- active acoustic scans of the glaciers using multibeam sonar to study water-mass mixing, subglacial outflow and bubble density in the water column
- a new instrument to directly measure iceberg melt, as well as fine-structure temperature measurement sensors to sense the temperature microstructure near melting ice.
- Acoustic Doppler Current measurements of current velocities in the bay and near the glacial sills.

These were all done in close coordination in the same region. Our initial analyses show that there are overlapping validations of similar phenomena at these glaciers.

All these studies together have the potential to complement existing studies and work towards long-term persistent methods of quantifying ice-loss at Arctic glaciers.