Glacier Lake Outburst Flood Research at Imja Lake, Nepal

Glaciers have long been studied as indicators for the global climate change. When the climate is globally cooler, glaciers gain ice, and as the climate warms glaciers will lose ice. With the recent rise of anthropogenic climate change, we have witnessed a large-scale loss of mass in our planet's glaciers. It is important to understand how climate change is affecting the planet now and what changes and risks we can expect in the future. One of these risks is glacier lake outburst floods or GLOFs for short. As a glacier melts and recedes, much of the melt water may gather to form a lake at the terminal moraine. Many times this dam is stable and is able to adequately hold the newly made lake. Sometimes it is not. The subsequent flood is what the science community terms a GLOF.

GLOFs can be initiated in many ways including snow/ice avalanches into the lake, self-destruction (hydrostatic pressure on the dam or buried ice in the dam melting and thus causing a dam failure), blocking of subsurface water channels, or other dynamic events upstream from the glacial lake such as a rock fall. Since no two glaciers are alike, each risk manifests differently depending on glacier dynamics and environment characteristics.

The glacier we were studying is the Imja glacier, located high in the Khumbu Valley of the Sagarmatha province of Nepal. This valley is popularized by celebrities like Everest, Lhotse, Ama Dablam, and other renowned peaks. It is one of the most heavily touristed areas of Nepal and likewise is home to many thousand locals. Imja glacier itself is located south-east of Mt. Everest at the base of popular trekking peak, Island Peak. Imja glacier has been receding at a rate of approximately 45-50 meters annually. Because this glacier is covered by insulating debris, it deflates only 1 meter per year. This glacier has received much attention internationally because of the birth of the glacial melt lake at the base which holds many millions of gallons of water. The potential for flood is great, and such a flood would be catastrophic. Duly, the science community has given this glacier much attention in order to understand if and when such a flood would pose the greatest risk.

Our group is starting a project whose aim is to categorize which glaciers pose the greatest risk of flooding, and which of those floods could potentially cause the greatest harm. There are many glaciers that are located in heavily populated areas that pose no risk of flooding, while conversely, there are also many glaciers that are in imminent danger of having a major GLOF, but pose no threat to human inhabitants due to their remote location. The future of this project is to characterize and categorize each glacier at risk of their likelihood to cause a GLOF and to also analyze which glacier would pose the greatest risk to human inhabitants living down-valley of each glacier.

In a rare and unbelievable circumstance, our group was actually able to witness a relatively small GLOF which broke through the ice of the Lhoste glacier on June 12, 2016. The flood lasted over 8 hours and caused severe erosion and trail damage to supply trails downstream, but luckily did not cause much damage to the lodges at the down-stream village of Chukung and nobody was hurt.

Upon arrival at our base camp, our first priority was to collect data from last-years trip and to set up new data collection instruments in preparation for the upcoming year. This is necessary in order to keep our computer models up to date and to compare our data from previous years with the data

collected with new method or instruments. We first installed an in-situ weather station that monitors precipitation rates, air temperature, wind speed, and solar radiation. This was located on the glacier in a stable area that would not be affected by the frequent rock-slides, avalanches, and melt ponds that may form on the surface of the glacier. The weather station collects data and stores it on a hard-drive located on the weather station until next year's expedition comes to retrieve the data.

Another on-going project is to record how quickly the glacier is receding. To help us understand this, we set up a time-lapse camera using a game camera commonly used for hunting. This enabled us to capture long term glacier calving images across the entire front of the glacier.

In order to accurately characterize Imja glacier, it is important to measure and update characteristics of the glacier in order to input these measurements into sophisticated models which can help project future changes in climate and glacier dynamics. One characteristic we measured was ice thickness. We used a type of ground penetrating radar which sends electromagnetic waves through the ice medium and reflects once it reaches the underlying rock-bed in order to record ice thickness. We recorded thicknesses ranging from 80m to over 130m.

One of the most memorable experiences was when we used a kayak and sonar to record the bathymetry, or topography of the bottom of the lake. Our pattern of measurement included crossing the lake longitudinally and again transecting the lake across the front of the glacier. This was done with haste due to the constant barrage of falling ice and impending threat of a large ice calving event from the glacier. We then weaved our way through icebergs in zig-zags to capture the depth of the lake. This ranged anywhere from 45m in the shallower areas to over 180 meters deep!

Our final objective was to increase local knowledge and risk preparation in the populations inhabiting the valley immediately in the pathway of a potential GLOF. Interestingly enough, we found many newly installed signs and maps which directed passer-bys of safe areas in case of a GLOF. Unfortunately, they were only in areas of high tourism and written only in English, which does little for the local communities who may speak little English. In order to better help these communities we must first learn what the perceived biggest threats are. Through many extensive and varied community meetings, we were surprised to find that among the 10+ villages which participated in these community meetings, GLOFs were ranked consistently among the top 3 perceived most pressing threats to both communal safety and livelihood.

The outcome of our project will include a categorization of each of the hazardous glaciers throughout the Himalaya and will be expanded to include the rest of the Himalaya in Nepal, India and the Kingdom of Bhutan. This will include many follow-up expeditions and years of data processing. It will be highly important to work with and among locals in order to be most effective in this mission to mitigate the risk of glacial lake outburst floods.