Glacial Flooding & Disaster Risk Management
Knowledge Exchange and Field Training
July 11-24, 2013 in Huaraz, Peru
HighMountains.org/workshop/peru-2013

Sampling of light absorbing particulates on the glaciers of the Cordillera Blanca, Peru

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Abstract

Glaciers in tropical regions have been losing mass at an extremely high rate since the 1950s. This can be caused by several factors. The temperature in tropical regions has been shown to be increasing and is predicted to continue to increase due to global climate change. Weather patterns may also change significantly due to climate change. A third factor that could be leading to higher glacier melt rates is increased dust and black carbon loads on the surface of the glaciers. The research presented here investigates this third factor. During the dry season of 2011 and 2012, the American Climber Science Program (ACSP) sampled light absorbing particulates on glacier surfaces in the Cordillera Blanca mountain range in the Peruvian Andes. One hundred and fifty samples have been collected and filtered during two field seasons by volunteer climbers working with scientists in the field. Glacier snow and ice was collected on thirteen peaks throughout the range at altitudes from 4800 to nearly 6800 meters. After collection, snow samples were rapidly melted and then immediately filtered through 0.7 micron quartz fiber filters in the field. The particulates captured on the filters have been analyzed for their bulk heat absorption properties. Results show that glaciers that are close to human population centers can have up to five times more light absorbing particles than remote glaciers. Results indicate that snow age and altitude all play a significant role in the amount of contaminants. Multiple locations have been sampled during both expeditions as well as at different times during the same climbing season. The 2012 results show similar trends to the 2011 results. Sampling will continue in the 2013 climbing season with additional measures to better quantify the black carbon amounts directly resulting from pollution.

1. Introduction

Understanding water availability and how this availability will change with ongoing climate change will help policy makers to design policies supporting local and regional sustainability. The glaciers of the Cordillera Blanca mountain range in Northern Peru have been receding rapidly (Rabatel et al, 2013). There are several possible factors affecting the glacier loss in the tropical Andes. The most evident is temperature increase over the globe caused by the increase in greenhouse gasses in the atmosphere. The temperature increase in the tropics is estimated to be approximately 0.1C per decade over the last 70 years. A second possible factor is that this temperature increase has significant additional impact on atmospheric circulation patterns. Weather patterns may have shifted causing a decrease in precipitation in the region. Seidel et al. (2008) showed that the tropical belt is widening due to the strengthening of the Hadley circulation in the tropics. To date, significant precipitation alterations have not been observed in the tropical Andes, but as the tropical environment continues to evolve with climate change, this could change. Land use changes in the surrounding regions can also significantly influence precipitation timing and location. Finally, the topic of this study, snow contamination by the introduction of increased amounts of light absorbing particulates, can also result in increased melt rates. This study reports on recent measurements of light absorbing materials sampled on the glaciers of the Cordillera Blanca mountains in Peru.

Sources of black carbon and dust in the Cordillera Blanca are numerous. Our emphasis is to understand the change in the anthropogenic contribution because these changes are important to understanding human impacts. Contaminants include black carbon which is a product of incomplete combustion of carbon based fuels. Obvious sources of black carbon include industry, transportation (especially diesel fuel), and agricultural burning. One interesting question is whether or not there is a significant impact in the Cordillera Blanca from agricultural burning or long-range transport of ash from forest clearing by fire in the Amazon basin. Increases in dust can be caused by increased traffic on dirt roads as well as from mining activities. Because there are several dirt roads through the Cordillera Blanca that receive heavy traffic as well as several open pit mines in the region, increased dust load on the glaciers could be a significant factor.

With population growth, populations have adapted to the natural cycle of glacier runoff. Seasonal water availability has led to choices in agricultural practices as well as reservoir size in order to maintain a constant supply of water for agricultural, municipal, and hydroelectric power uses. As the glacier melt rates have increased, water flow rates have likely increased as well. In the future, as glacier mass continues to decrease, the semi-constant water contribution from glacier melt will start to decrease. Understanding the ice melt rates will enable better policy decisions to be made to facilitate sustainable water use in the future.

Pollution and dust on glaciers has been shown to significantly increase ice melt rates (Painter et al. 2012). Glaciers near population centers are particularly important to water supply. In addition to glacier mass loss from climate change, glaciers near population centers can have additional melting due to added light absorbing pollutants on ice surfaces. This paper reports on new measurements of dust and pollutants on the glaciers of the Cordillera Blanca mountains in Peru. The work is conducted as part of the American Climber Science Program which will be briefly discussed in section 2. Section 3 will discuss the analysis techniques and the results. Section 4 will discuss some of the implications of the findings from the first two years of measurements.

2. The American Climber Science Program Expeditions:

The American Climber Science Program (ACSP) is a citizen-science program designed to facilitate research opportunities for scientists in regions which are difficult to access. Scientists and climbers come together for expeditions to collect data for scientific projects and to share their enthusiasm for the mountains. Research expeditions are also designed to provide opportunities for non-scientists to learn about scientific practices as well as to instruct future scientists on safety in mountain regions.

During the dry season in the Cordillera Blanca region in 2011, the first ACSP scientific expedition was conducted with one of the scientific goal being the sampling of black carbon and dust in glacial snows. In 2011, 48 samples were collected and returned to the US for analysis. In 2012, the core team from 2011 along with a new group of volunteers returned to the Cordillera Blanca for the second ACSP expedition, collecting 100 samples for analysis. Samples were collected from glacial surfaces from an altitude of 4800 meters and at regular intervals up to 6800 meters. Several locations were sampled during both expeditions and multiple samples were taken from the walls of a crevasse on one occasion to identify long term trends.

Samples were collected by scooping snow into ziplock plastic bags. Hands, gloves, or ice tools were 'contaminated' with local snow before sampling to reduce potential contamination of samples. Approximately 1 kilogram of snow was collected at each site from both the surface (defined as the top 2.5 cm) and the sub-surface (deeper than 2.5 cm) at each site. Snow samples were packed together into backpacks and returned to basecamp for processing.

In camp, snow samples were melted one at a time by placing the ziplock bags into near-boiling water. Once melted, the melt water was drawn into 60 mL syringes and pushed slowly through 0.7 micron quartz fiber filters. Ten syringes of water were used per sample making a total of 600mL of water filtered per sample. Filters were removed from filter holders and placed into airtite coin collection coin holders and held in place with a thin foam ring. After each field session (generally approximately 7 days) the filters were returned to Huaraz where they were dried in the sun, then stored in a freezer until they were returned to the US.

3. Analysis and Results

The filters from the 2011 and 2012 expeditions have been analyzed to determine the heat absorption capacity of the captured particles. Each filter was suspended above a constant temperature surface (ice water) by placing it on two crossed threads. An infrared thermometer was used to measure the temperature of the filter. The ice water background assured that the infrared thermometer was aimed correctly. To determine the light absorption capacity of the materials, an incandescent light was turned on close to the filter. The particulates on the filter absorbed the radiation from the light causing the filter to heat up. The temperature of the filter was noted after fifteen seconds. The temperature increase ranges from 10C for an unused filter, to 40C for the most heavily contaminated filters. During analysis, after every ten filters, two control filters were tested to assure consistency in the setup. The control filters included an unused clean filter and a filter darkened with a sharpie pen which had higher absorption than any of the experimental filters.

The light absorption capacity of each filter can now be compared though the results have not been calibrated in an absolute sense. Even without absolute calibration, the relative results present a striking picture. Relative results are compared by assigning a heat absorption capacity value of zero for an unused filter and a heat absorption capacity value of 100 for the filter with the highest heat absorption capacity for each year. As there was a minor change in equipment used between the 2011 and 2012 seasons, each year's data has been scaled individually. Figure 1 shows the average heat absorption capacity for each of the valleys based on the filters collected for the 2011 and 2012 data. Only filters collected at altitudes higher than 5000 meters were used in the comparison in order to avoid influence from local dust sources. Data from both years show a distinct trend with the northern mountains being relatively clean compared to the mountains near Huaraz.

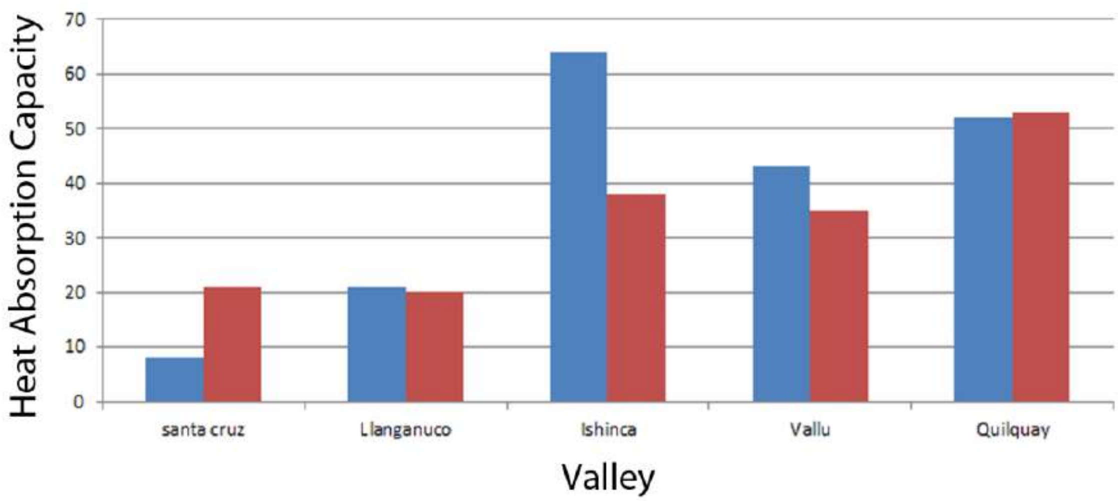

Figure 1: *Relative heat absorption capacity for particulates in snow sampled in the different valleys or individual mountains of the Cordillera Blanca. Blue bars represent measurements from 2011 and red represent measurements from 2012. The Santa Cruz and Llanganuco valleys (left) are north of Huaraz while the Ishinca and Quilcayhuanca valleys and Vallunaraju (right) are near Huaraz and therefore more polluted.*

There are several possible factors that could lead to the observed trends. Higher levels of pollution from the town of Huaraz as well as the higher abundance of dirt roads could contribute significantly. Mining activities are also more significant at the Southern end of the range. It should be noted that a storm moved through the region during the 2011 season immediately before climber-scientists sampled a subset of the mountains. Even though the entire range received fresh snow and the snow was sampled at several locations in the north and south of the range within 2-3 days of the storm, the trends shown in figure 1 were still present. Although the storm system may have had a significant load of dust, the snow may still have been influenced by local sources.

4. Implications and future work

Airborne and snowborne particulates can contaminate the surface of glaciers leading to reduced albedo and increased melting rates. Our measurements indicate that, in the Cordillera Blanca, particulates are significantly more abundant in the mountains near to Huaraz, the largest local population center. The implications of this are significant, as melt water is an important natural resource for the region for agriculture, drinking water, and hydroelectric power. It is well known that tropical glaciers are melting rapidly. With added pollutants from population centers, the glaciers nearby could be at significantly greater risk of melting rapidly. Local and regional planners need to be aware that glacier melt rates for highly used water sources could be melting at a significantly faster rate than more remote glaciers, potentially putting their water sources at even greater risk.

The ACSP is continuing to sample snow in the Cordillera Blanca in a 2013 expedition. With three years of data it will be possible to look at changes with respect to time. Additional sampling protocols are being implemented to better categorize the different types of pollutants on the glaciers in order to better understand the sources. A Droplet Measurement Technology (DMT) Soot Photometer – 2 (SP2) will be used to analyze samples from the 2013 for black carbon content for pollution size particles. With this information and co-located filter samples, it will be possible to use an integrated sandwich spectrometer setup (Grenfell, 2011) to separate black carbon from dust in all previous samples. These future results will enable environmental decision makers to better understand the challenges facing their glaciers. Possible mitigation activities include vehicle emission controls, agricultural burning limitations, or dust mitigation for dirt roads or mining operations.

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