Global warming and changing water resources: glacier retreat in mountain regions
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We are four anthropologists who form a research group on the perceptions of and responses to glacier retreat. The massive retreat of mountain glaciers during the twentieth century is one of the most visible and high confidence level indicators of global warming. Melting glaciers create a period of greater water availability, followed by a period of greater water scarcity when they have shrunk. The effects of climate change on the seasonal distribution and year-to-year variability in water supply are also of importance. Changing water availability interacts with local water management systems, the integration of local systems in regional and larger systems, and the effects of climate change programs and policies on water management. We draw on a variety of methods (ethnography, survey research, archival work) to understand how people associate glacier retreat with changing water availability. Our work is ongoing and is being carried out in three sites (the North Cascades of Washington State, the Cordillera Blanca in Ancash, Peru, and the South Tirol in the Italian Alps). Each site contains two to four villages or towns, all with populations less than 1000. In all areas, water is important as an economic resource (supporting agriculture, livestock raising, hydropower production and tourism); water-related hazards, particularly floods and mudflows, are also significant. In addition, water is a key element in cultural landscapes; its presence in many forms – ice, snow, springs, rivers, lakes – is a crucial element of regional identities.

Climate and means of livelihood vary in the three sites. The North Cascades are the most densely glaciated mountains in the contiguous United States. A temperate maritime climate and orographic enhancement produce abundant precipitation, averaging over 2000mm on the densely forested west slopes, most of which falls during the winter. Until the 1970s, logging and mining were the main industries in the study towns of Glacier and Concrete, situated on the Nooksack and Skagit Rivers respectively. Today residents look to recreation and tourism to boost local economies. The Cordillera Blanca holds the largest contiguous area of tropical glaciation in the world. The study community, Copa Grande, was established following the agricultural reform in the 1970s that dissolved large privately owned land parcels and deeded the land to the indigenous families who continue to live and farm there. Between October and May, Copa Grande receives approximately 500mm of precipitation annually; however, during the dry season life depends entirely on glacial meltwater or reservoirs. The South Tirol is a German-speaking area of Italy that was part of the Habsburg Empire until the defeat of Austria-Hungary in World War One. The municipality of Stilfs/Stelvio is a small alpine valley that drains into a major river, the Etsch/Adige, and receives about 900mm of precipitation annually. It contains three small settlements which formerly depended on agriculture and livestock raising, and now have an economy centered on family-based tourist enterprises such as guest houses and restaurants.

Glacier-fed rivers are a source of hydropower in all three sites. In addition, North Cascades rivers support salmon runs and a large bald eagle population that feeds on them and attracts tourism. Some of the most fertile farmland in the world lies in the deltas at their mouths. The abundant snowfall feeds a watershed that supports recreation throughout the year. The Rio Santa, which flows from the Cordillera Blanca, is a nationally important watershed that also provides water for local domestic needs, irrigation and agriculture, industry throughout the region, large and small-scale mining operations and many growing coastal cities. Glacial melt serves as a

critical buffer during the dry season months, making up roughly 60% of stream flow. In the South Tirol, streams and rivers also provide water for tourist enterprises and the irrigation of small-scale farms and pastures. The glaciers in the area support skiing throughout the year, a major attraction.

The glaciers in all three regions, like glaciers elsewhere in the world, have been retreating. This process was under way by the 1970s in our sites in the Alps and Andes. As a result, stream flow during the dry season has declined. In the North Cascades, rising temperatures have contributed to a 40-60% decrease the volume of glaciers since 1984, increased stream flow in the winter months, and a declining snowpack. As a result of the latter, summer stream flow has declined. The decline is less in more glaciated basins, due to enhanced glacier melting. Over 40 years of glacial monitoring in the Cordillera Blanca shows a 23% decline in glaciated area. As a result, stream flow has increased in some areas temporarily.

Preliminary results from our research indicate that the level of concern about glacier retreat varies greatly between sites. It is lowest in the North Cascades, where recent heavy winters, and the fact that residents of Concrete do not have a view of the glaciers, diminish their concerns. Some of those interviewed consider glacier retreat to be part of "natural" climate "cycles." In Glacier, skiers are concerned that rising snow levels will affect their activities, but admit that their own lifestyle (many residents commute to work in larger cities to the west) is part of the problem. Concern is highest in the Cordillera Blanca, where almost every person interviewed observed that glaciers have receded significantly in their lifetime. Most are sure that the glaciers will indeed disappear in the near future. They clearly connect glacier recession with the water they use to live, and worry that the water will dry up causing conflict over access and eventually large-scale death. Many feel as though there are no solutions; they know that glaciers are melting, and they believe that no amount of money or technology will help. In the South Tirol, residents fear that the loss of the glaciers will make the local landscapes "ugly," so that tourists will not come. The great fear of the villagers is not the loss of income in the near future, but the outmigration of their children and grandchildren, who will have few employment opportunities if tourism declines.

Other concerns related to climate change and water availability present strong challenges as well. In the North Cascades, residents' concerns about floods and mudslides caused by extreme precipitation events and high freezing levels during the winter outweigh those about glacier retreat. In the Cordillera Blanca, residents note that seasonality, which so marks the agricultural and cultural calendars, is now much more chaotic and often damaging. Plagues and diseases among crops, livestock and humans are also said to have increased. The residents of the South Tirol, concerned about the outmigration of the young, also worry about the arrival of immigrants from elsewhere in the European Union, disturbing the close-knit mountain communities. They also recognize other environmental hazards, such as landslides and avalanches, which may grow more common.

Initial efforts at adaptation to changing water availability also vary between sites. In the North Cascades, efforts at adaptation to climate change have been initiated at both the state and county government levels and by the hydropower companies, but with little input from local residents. These efforts focus mainly on reducing greenhouse gas emissions and increasing energy

efficiency and do not address changing water availability, although studies are planned. In Copa, where concern is highest, the management of water is not shifting to reflect the new realities that are rapidly approaching. At the community level, some leaders and elders claim that there is nothing to be done, while others argue that they do not have the knowledge or expertise needed to approach such problems. Even though the issues are recognized and feared, little or no action has been taken to adjust. However, several organizations are identifying and responding to climatic change in nearby communities, while the regional and national governments are working towards larger-scale mitigation and adaptation policies. In the South Tirol, many households weigh the potential of new forms of tourism, while others hope that agriculture might continue as a viable source of income. Some new museums and ski lifts also bring hope of a positive future for tourism. The residents have experienced a number of changes in policy in Italy and in the European Union which have favored minority populations, including themselves as German-speakers within Italy, and hope that future policies will also support them.

We look forward to continuing collaboration as we complete our research. By comparing across sites, we hope to learn more about what contributes to level of concern and how adaptation strategies are related to it and to other factors. We plan on sharing the results with a variety of actors—local communities, NGOs, government agencies, international organizations, and scientific research organizations, and hope that our research will help inform adaptation strategies that address local concerns.