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Regional vs. Local Impact of Wind on Glaciers in the Andes Mountains

Derek Ferris

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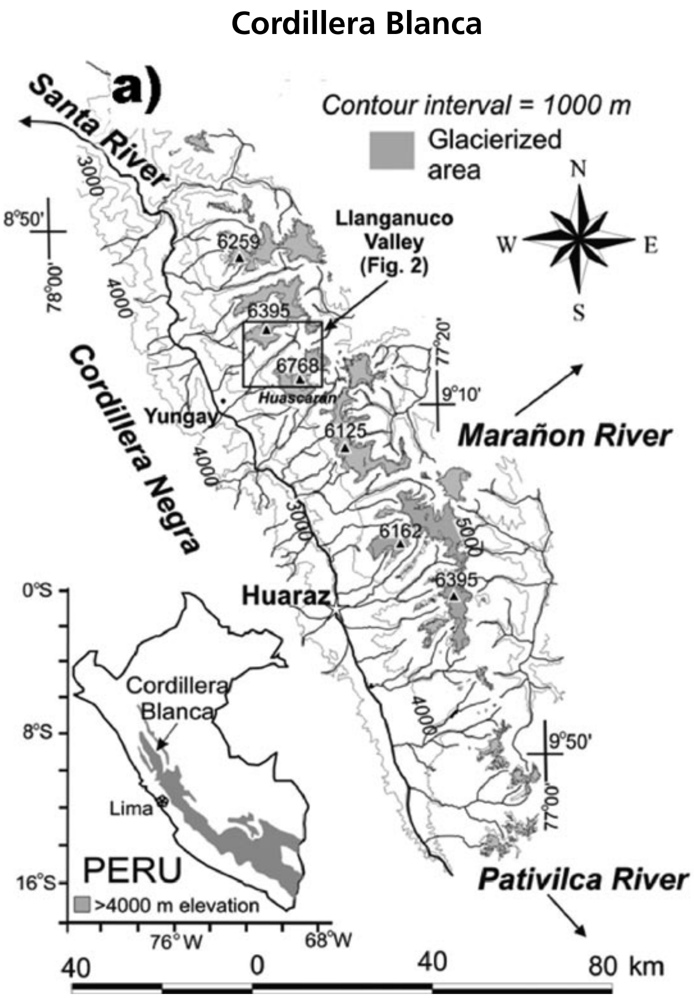
Northern Peru will face critical water resource issues in the near future as permanent ice in the Andes Mountains continues to rapidly melt. Ironically, the melt-water from these glaciers supports the culture of 100s of thousands of people living at lower elevations, particularly during the dry season, and predictions suggest some glaciers may be gone in less than 100 years. The impact of local warming of "U" shaped valleys running down the dryer western slope of the Andes range is largely disregarded in current climate model predictions because of the complexity of simulating the complex topography. Studies that compare the influence of regional and local warming factors are lacking, particularly in the Peruvian Andes. This project will use automatic weather station data within the Llanganuco Valley and archives of weather maps to determine the importance of local winds that funnel warm air up toward the glaciers.

1. Introduction

The Andes Mountains are located in western South America, most notably in the countries of Ecuador, Peru and Chile. Peru (Fig. 1a) is a nation facing critical water resource issues (Bradley et al., 2006). The area of focus for this project is the Llanganuco Valley, located in the Cordillera Blanca (White Mountains) in northern Peru. The steep, high-altitude topography creates sub-freezing temperatures above 5000 meters elevation and this leads to permanent ice cover (glaciers) in the highest portions of the mountains. The typical climate is warm throughout the year and distinct dry and wet seasons. The dry season, most dominant June, July and August, is their winter, and the wet season, in December, January and February, is their summer (Higgins, 2008). These glaciers essentially supply all the freshwater for agriculture and drinking during the dry season. Observed past increases in air temperature and changes in moisture have enhanced glacial melt in this portion of the world (Bradley, et al. 2002).

According to the World Bank, some lower altitude glaciers within the Cordillera Blanca could completely disappear within ten years. This is caused by a rapid increase in surface temperature. There are currently eighteen glaciers that exist in Peru, of which twenty two percent has been lost over the past thirty years. Glacial loss such as this is occurring across the globe (World Bank, 2008). The IPCC indicates as of 2007 that this glacial retreat is directly related to the increase in surface temperatures. Glacial retreat in the Peruvian Andes will have a profound affect on the water supply in surrounding cities



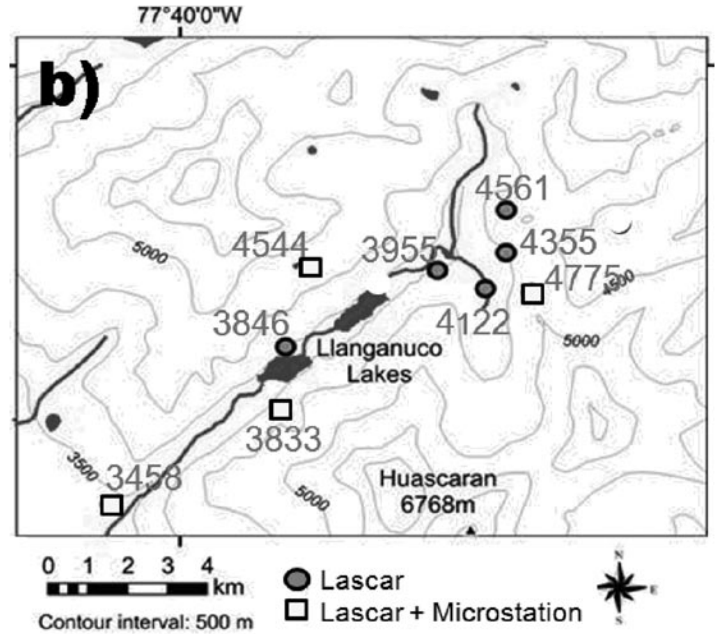


Figure 1: a) Cordillera Blanca located in the Peruvian Andes. b) AWS within the Llanganuco Valley and their elevations (m).

of the Andes. The glacial melt water supplies citizens with their fresh water supply. The culture of northern Peru critically relies on water for survival, both directly and indirectly through agriculture and hydroelectric power generation (Bradley, et al. 2006). With the glaciers melting as rapidly as they are, there is a growing concern of a new source of fresh water for the next generation. A lack of fresh water limits a cities ability to maintain vital local economies (World Bank, 2008).

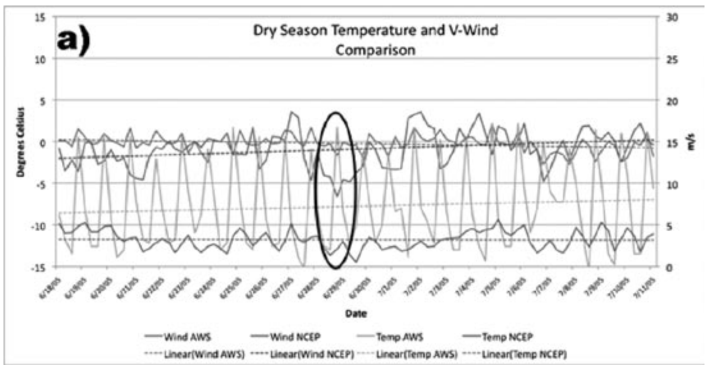
The freezing level height in the mountains of the tropical Andes is an essential part in understanding the hydrological cycle within the mountain range. Research has found that freezing levels have been rising over the past fifty years, which means, glaciers are retreating. This rise in freezing levels is directly related to a rise in sea-surface temperature (Bradley et al 2009). This shows that melting is occurring in this mountain range, but understanding the dynamics of what is occurring within the valleys of these mountains may give an indication as to why these glaciers are rapidly melting.

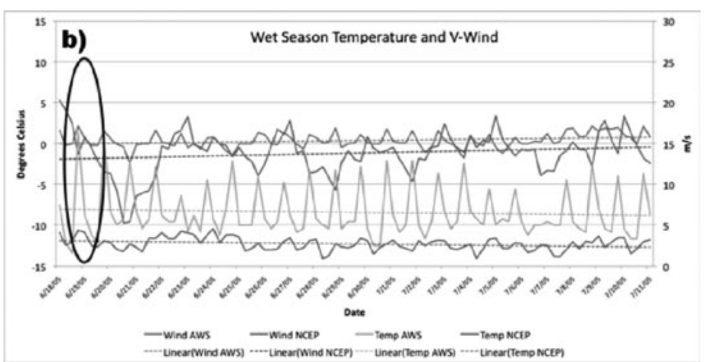
Understanding the microclimate that may or may not exist within the valley is the goal of this research. Little is known of how this microclimate affects glacial loss in this mountain range because few weather instruments have been set up to accurately assess how microclimate is affecting glacial loss. Using Automatic Weather Stations (AWS) set up within the valley allowed a better understanding of how wind and other factors affect temperatures within the valley (Fig 1b). Measurement that were taken at these weather stations includes; air temperature, relative humidity, geopotential height, solar radiation, vertical winds (V-Winds) and horizontal winds (U-Winds). Information available through the National Center for Environmental Predictions (NCEP) provided a synoptic overview of temperature, winds, relative humidity and Geopotential height. Comparing the data gathered using both of these sources also provided a better understanding of the microclimate within the valley. Based on the evidence from the AWS and NCEP data, the microclimate that exists within the glacier could affect glacial loss in the Llanganuco Valley.

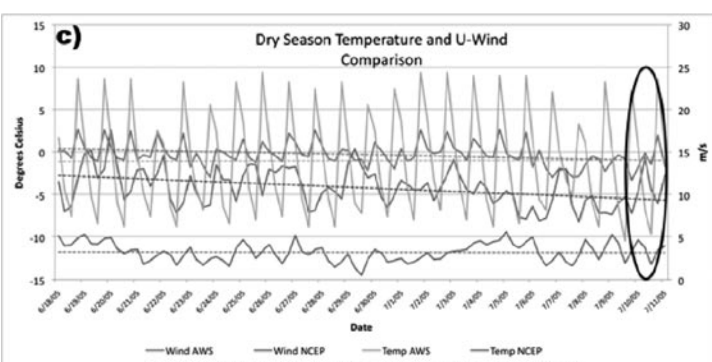
2. Methods and Results

After gathering AWS and NCEP data, interpreting the data and creating graphs was a pivotal point for this research. Graphs were produced in Microsoft Excel and were made to demonstrate the differences in the data acquired from AWS and NCEP. More specifically, time series, wind roses, and lapse rates (temperature profile).

A time series graph was produced to show changes in temperature over the courses of the dry and wet seasons. Figure 2a illustrates information from both AWS and NCEP comparing temperature and wind within the valley. In this case, temperature and vertical wind are observed during the dry season. There is a great daily change in temperature during the dry season as depicted with the green line. The NCEP data shows a less drastic temperature change during this period as shown with the purple line. The vertical winds, which are represented but blue (AWS) and Red (NCEP) lines also show differences in information. Figure 2a also displays an unusual event where the temperature and wind data from AWS conflicted with one another on June 28, 2005. Based on observing the data from the wind roses and information such as relative humidity, wind speed and solar input, it was determined that a weather system must have created a disturbance in the upper atmosphere creating this unstable pattern.







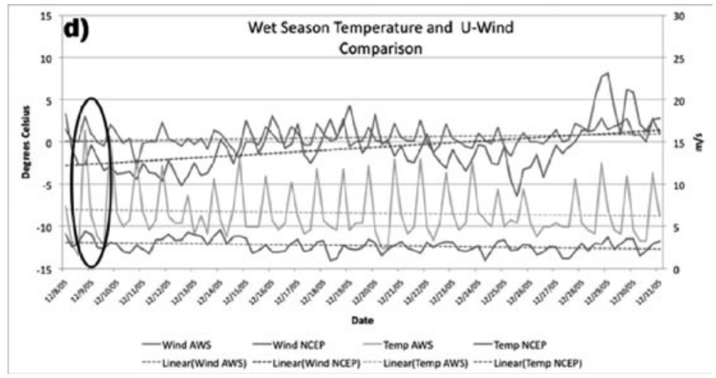


Figure 2: a) Dry Season temperature and vertical wind comparison. The black circle represents a special case where data from both AWS and NCEP conflicted with one another. b) Wet Season temperature and vertical wind comparison. c) Dry Season temperature and U-Wind comparison. d) Wet Season temperature and U-Wind comparison.

While these differences are not as drastic as the temperature differences are, the correlation with the temperature is different between the two data sources. The blue line and the green lines from AWS data correlate very well; when winds increase within the valley, so to does the temperature increase. NCEP data shows differences within it's own information. There is no direct correlation between its wind and temperature information, which may suggest that wind has no impact on temperature difference within the valley. Figure 2b shows the wet season comparison between temperature and wind. The changes in temperature during the wet season are less drastic but the correlation between the AWS data and the NCEP data did not change (Figure 2b). Time series graphs were also created for temperature and U-wind comparisons. Figures 2c and 2d also show the correlation in the AWS data and the inversely correlated NCEP data.

Wind Roses show differences in wind intensity and direction over the course of time. The wind roses that were created show the differences in wind speed and direction within the four time periods that we selected which were: 00Z (1900), 06Z (0100), 12Z (0700) and 18Z (1300). The time period that is of particular interest to this study is 18Z because it is the only time period observed during the day. Daytime weather systems are the most unstable systems throughout the day as shown in figure 4a-d. Figure 3 is an illustration of the daily cycle of winds in a mountain terrain (Whiteman, 2000). Figure 4a is a wind rose from data gathered from AWS during the dry season. Most of the strong winds during this period come from the northeast, while some of the lighter winds come from the southwest. This suggests that most of the time, wind from the bottom of the valley is blowing upslope and toward the glaciers. With an increase in surface temperature due to global

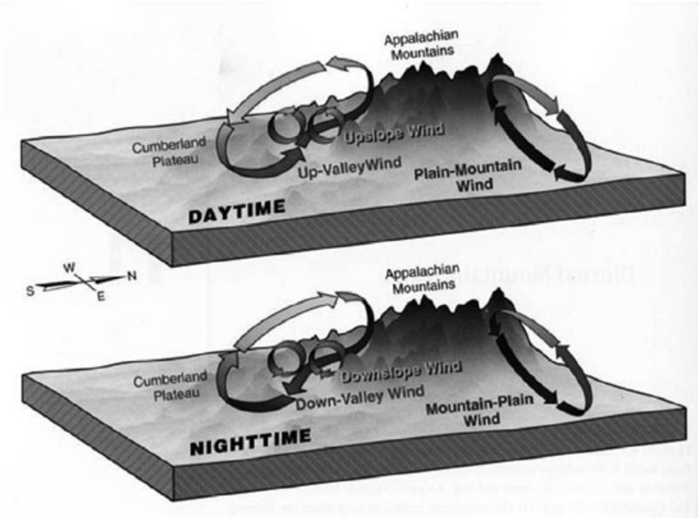


Figure 3: Illustration of wind dynamics within mountain ranges during the daytime and nighttime.

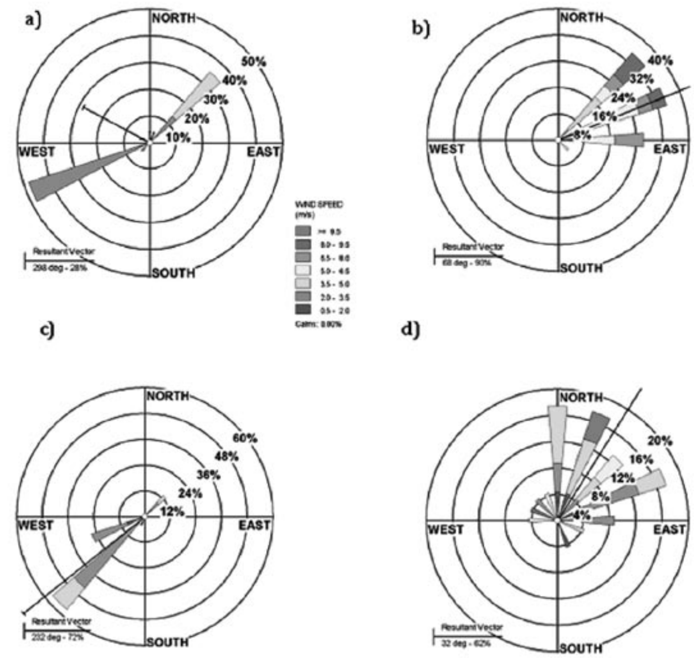


Figure 4: a)18Z Dry AWS. b) 18Z Dry NCEP. c) 18Z Wet AWS. d) 18Z Wet NCEP

climate change, melting of glaciers could be enhanced due to winds bringing warmer air to the summit. Figure 4b is an exact opposite model of figure 4a. It shows very strong winds from the northeast which would bring cool air from the summit, down the valley. This could perhaps cause glacial expansion, which is not occurring in this mountain range.

Figures 4c and 4d are from the wet season. Information from AWS shows almost all wind comes from the southwest while NCEP shows that almost all wind comes from the northeast. The NCEP data contradicts figure 3, which suggests that winds go upslope during the day and downslope during the night. NCEP data could be suggesting that there is some event that occurs at high levels of the atmosphere that changes model predictions. But with the data collected from NCEP, winds coming from the northeast would cause glacial expansion. With evidence suggesting that glaciers are melting in this mountain range, one would suggest a better way of gathering data for NCEP. The AWS data, which was strategically set up at different areas of the valley leading up to the summit suggests that surface warming and up-valley winds are causing glacial loss.

Discussion

The results demonstrate that there is a disconnect between the regional and local scale winds. AWS data and NCEP data contradict what one another says. This could be an indication that there are unusual events much like the one on June 28, 2005 that occur often in higher levels of the atmosphere. Or, there could be problems with instrumentation for both data sources. The fact is, glaciers in the area are melting rapidly and based on the data acquired from both sources, it seems as though AWS is a more reliable source because based on this data, one can conclude that glaciers would melt, whereas, NCEP data would suggest a glacial expansion. There are many valleys located in the Cordillera Blanca to which this data could be applied. Every valley seems to have its own microclimate, so concluding that what data was found here is found at every valley in the Cordillera Blanca is false but some of the same principles apply, therefore melting in these areas may be occurring for the same reasons.

Conclusion and Future Work

More recent data within the valley has been gathered. Using this new information more can be determined about the current state of melting within the valley. More equipment could also be used; such as setting up weather instruments on the glaciers to show exactly how fast the glaciers are melting. This could give an exact timeline as to when the glaciers will completely disappear and alternate sources of water resources that can be found within that time period, if any. Unfortunately, because there is a lack of instrumentation in some areas of the tropical Andes, the consequences for people living in lowland areas may be directly affected both socially and economically (Bradley et al 2009). More could also be done to determine what impact the sun has on the valley. Knowing its exact position and the amount of radiation in emits on the valley is pivotal in understanding how radiation affects the valley. Any upgrades in sensor information are helpful in the understanding of how and why this microclimate exists.

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