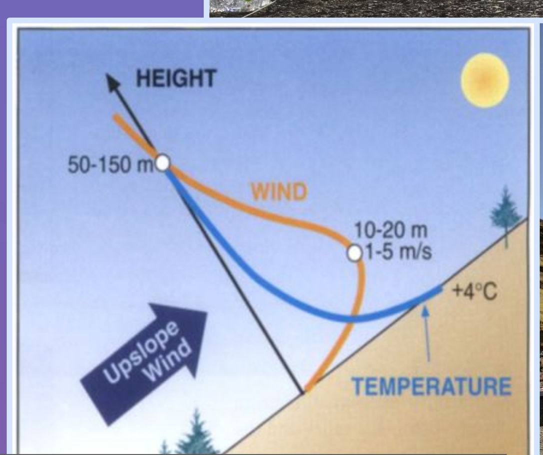
The Effect of a Mountainous Environment on Aerosol Transport from La Paz

Introduction

The rate at which glacier has melted has increased since the industrial revolution. The increase has caused rising sea levels, a decrease in the already limited freshwater sources, enhanced natural disasters, and more. One contributor to glacial melt was particulate matter (PM), specifically black carbon (BC). BC is a small semi-crystalline form of carbon produced by the incomplete combustion of hydrocarbons, which can melt ice by darkening ice and absorbing solar radiation. BC are produced from burning biofuels such as gasoline, campfires, or using a gas stove, which, although damaging to the environment are necessities in developing countries such as Bolivia, making it a prime research location. Bolivia was also attractive due to its particular geography; La Paz and El Alto are built on a plateau and are the highest and two of the fastest-growing cities in South America. With the glaciers melted on mountains close to La Paz/El Alto, it was a suitable location to investigate how PM travels to reach glaciers. The topic of how PM travels to and affects glaciers has yet to be sufficiently researched, and the project aimed to shine more light on the subject.

The hypothesis was that PM traveled up the mountain of Chacaltaya primarily via the mountain chimney effect (MCE). It was assumed that in the data collected by the campaign, all instruments that were used were accurate and no major issues occurred during the measurement period.

NOAA Weather balloon string tied down using spread out water bottles for slowed descent nearing end of ascent to prevent string break at Site Curva Uno due to lack of access to electricity.
Photo taken by Dr. David Whiteman



MCE Diagram by Dr. David Whiteman
Displays the increased temperatures at lower height due to heated ground layer by the sun in blue. The temperature also decrease as height increases, which are attributes of an unstable air layer. The diagram also show predicted wind speeds in the upward direction due to MCE.
Paper URL: https://doi.org/10.1175/BAMS-D-21-0150.1

Bolivian Campaign 2022, picture of members holding NOAA Balloon at balloon launch location, Site Curva Uno.
Photo taken by Isabel Moreno.
Paper URL: https://doi.org/10.1175/BAMS-D-21-0150.1

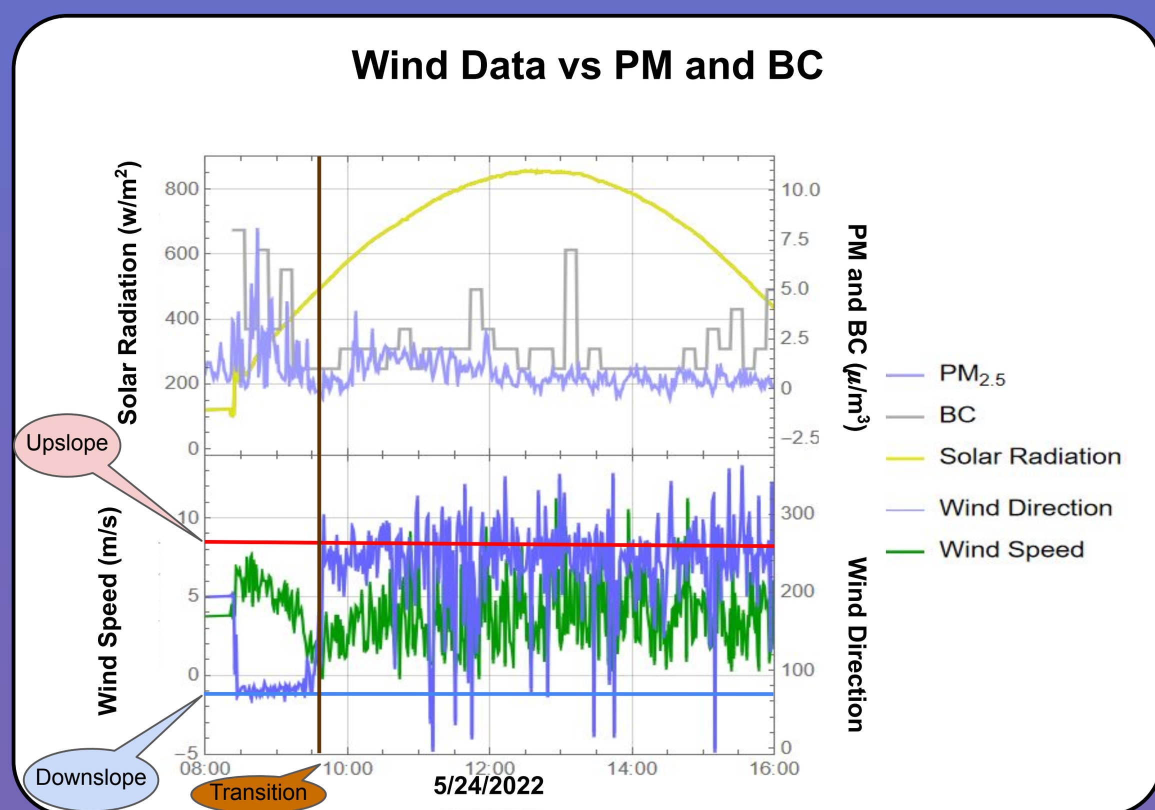
Method

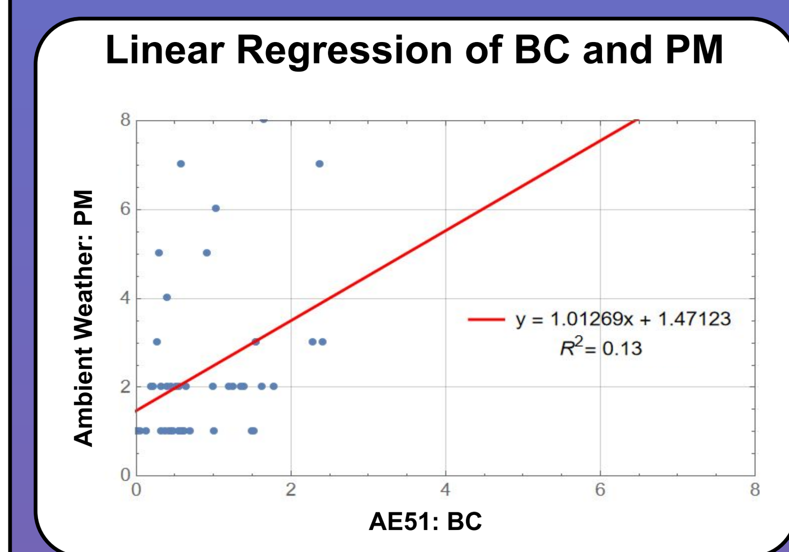
- Downloaded data measured from the Student Bolivia Campaign of 2022, Site Curva Uno
  - The data analysis contained the data from the AE51 micro aethalometer (BC), Ambient Weather WS5000 sensor (PM, Wind, Solar Radiation), and a iMet RadioSonde (Wind, Temperature, Pressure, Humidity, Altitude) attached to a NOAA weather balloon from the campaign on May 24, 2022. Although both cities are producers of PM, only La Paz (~3705m a.s.l.) contain a site (Site Fabrica Forno). The other site is located slightly higher up (~4124m a.s.l.) in the mountain (Site Curva Uno), which was focused on.
- Downloaded Mathematica
- Charted Wind, PM, BC, and Temperature Data
  - Imported the data files into Mathematica via the "Import" function.
  - Assigned variables to each column of data via a list ordered from left to right separated by comma.
  - Converted time from the form, year:month:day:hours:minutes:seconds, to absolute time (Time shown in seconds since January first, 1900, the standard time keeping method for mathematica) using the "AbsoluteTime" function.
  - Combined each variables with time by using the "Thread" function
  - Used "DateListPlot" function to plot ordered pairs of variable and time on a graph
  - Used "Overlay," "Show," "PlotGrid," and "ResourceFunction" functions to combine the time graphs for comparison.
  - Used "ResourceFunction" to form graphs not using time on the x axis.
- Used LinearModelFit for Linear Regression of PM and BC
- Examined Charts were for possible correlation and explanation for behavior.

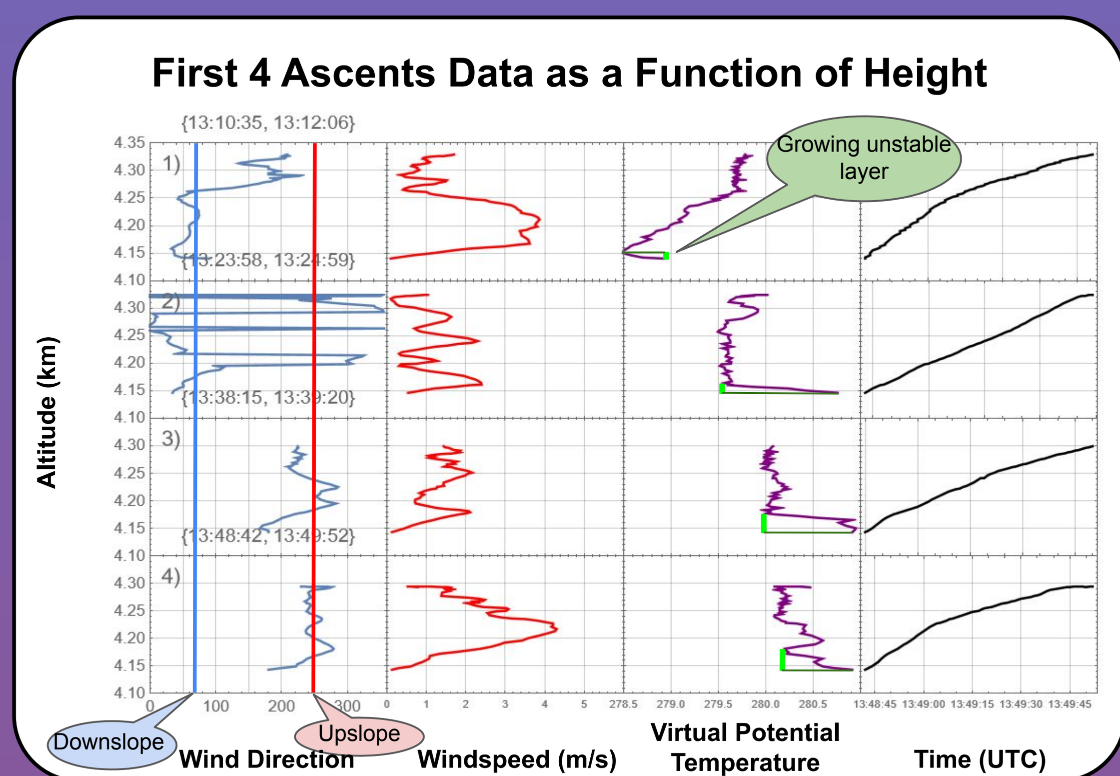
Findings

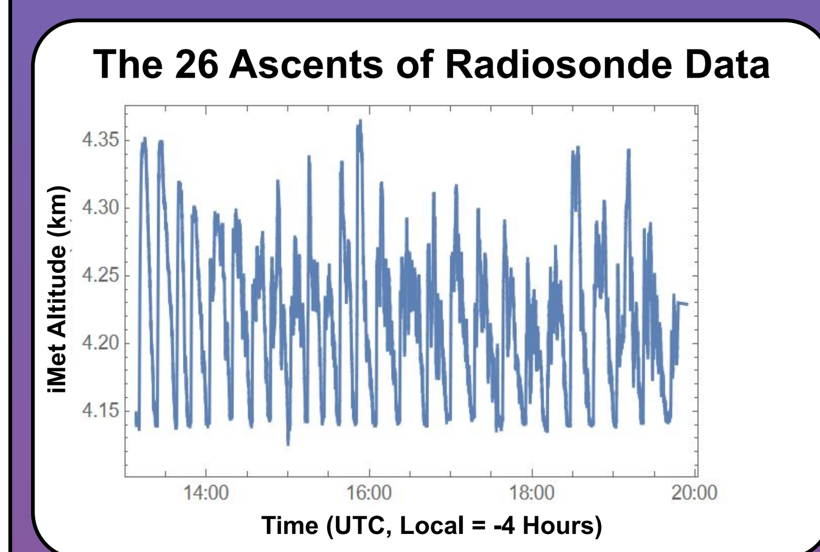
At around 9:30 a.m. on the Wind Data vs PM and BC graph, the wind direction rapidly changed from downslope to upslope, while wind speed dropped significantly at the change as indicated on the graph in brown. This coincided with a drop in PM and BC measurements at the drop, which then increased after the transition. There was also convection observed in the atmosphere after the change to upslope flow as indicated by the rapid fluctuation in wind direction after 11:00 am. The BC to PM linear regression graph indicated there was more measured PM than BC (1:1.01 BC to PM ratio), which was expected. The weak positive R^2 value, however, was cause for concern as BC was a part of PM and expected to be correlated. No other statistical analyses were applicable as the nature of atmospheric science prevented repeated controlled sets of tests.

As for the Ascent Radiosonde data, the NOAA balloon was attached to a string with sensors mounted. Once the ascent was sufficiently slowed by the water bottle method, the balloon was pulled back down. However, only the four rises showed a pattern which was shown in the graph below. The accents were around 15 minutes apart and showed the clear transition from stable downslope flow (ascent 1), to convected upslope and downslope flow (ascent 2), to unstable upslope flow (ascent 3), and lastly to stable upslope flow (ascent 4). The observed layer of unstable air also grew in height from ascent to ascent. Unstable air was characterized by decreasing virtual potential temperature with height increase. This layer of decreasing temperature grew in height as shown in light green in First 4 Ascents Data graph.









Conclusion

The MCE determined the wind direction and wind speed on the mountain. However, aerosol measurements were opposite of what was expected if the MCE was the primary method of travel. If the MCE was the main form of travel for the aerosols, it was expected that an increase in aerosols would coincide with an upwards wind direction and a reduction in aerosols in the downward wind direction. However, the opposite behavior was measured which disproved the hypothesis. In other words, although the MCE held true and impacted winds, it did not seem to impact aerosols in the way predicted by the MCE. The convection mentioned before may influence the aerosol travel, theorized as the rising planetary boundary layer.

The experiment seemed to show MCE but aerosol measurements did not follow the pattern.

The project could be improved if aerosols could be marked or have traceable material with similar properties as BC as a means to show the path of travel of BC and other PM. A BC sensor on the radiosonde would also help to determine BC levels through the atmosphere. In the future, there would be a shift in focus to the rise in planetary boundary layer and its effect on aerosols.

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