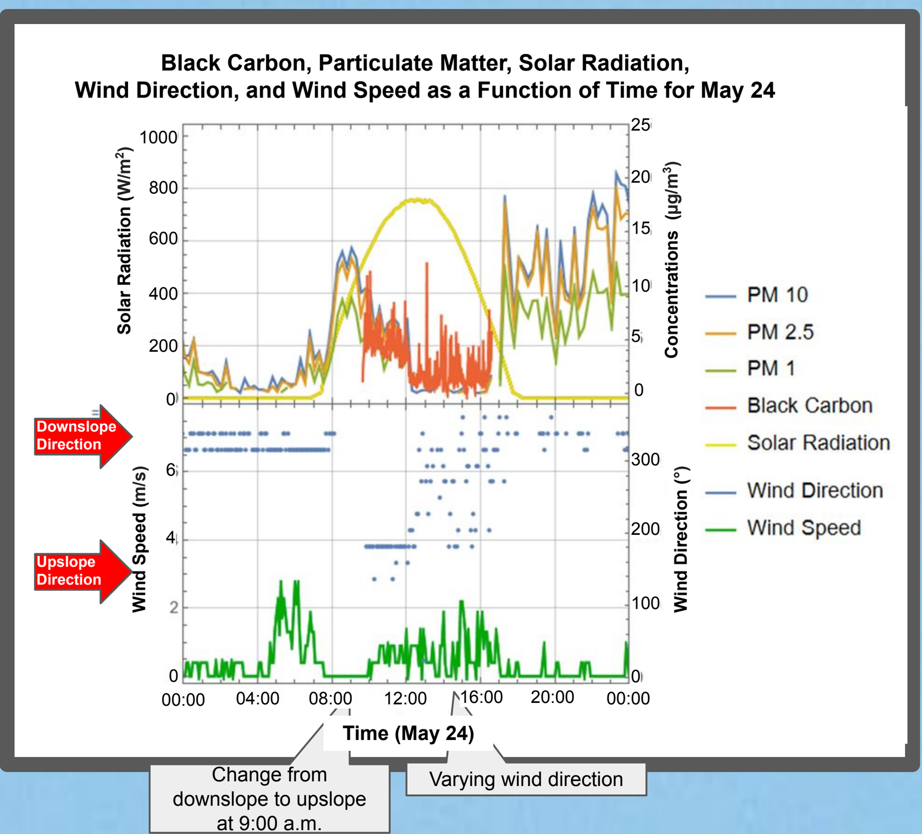
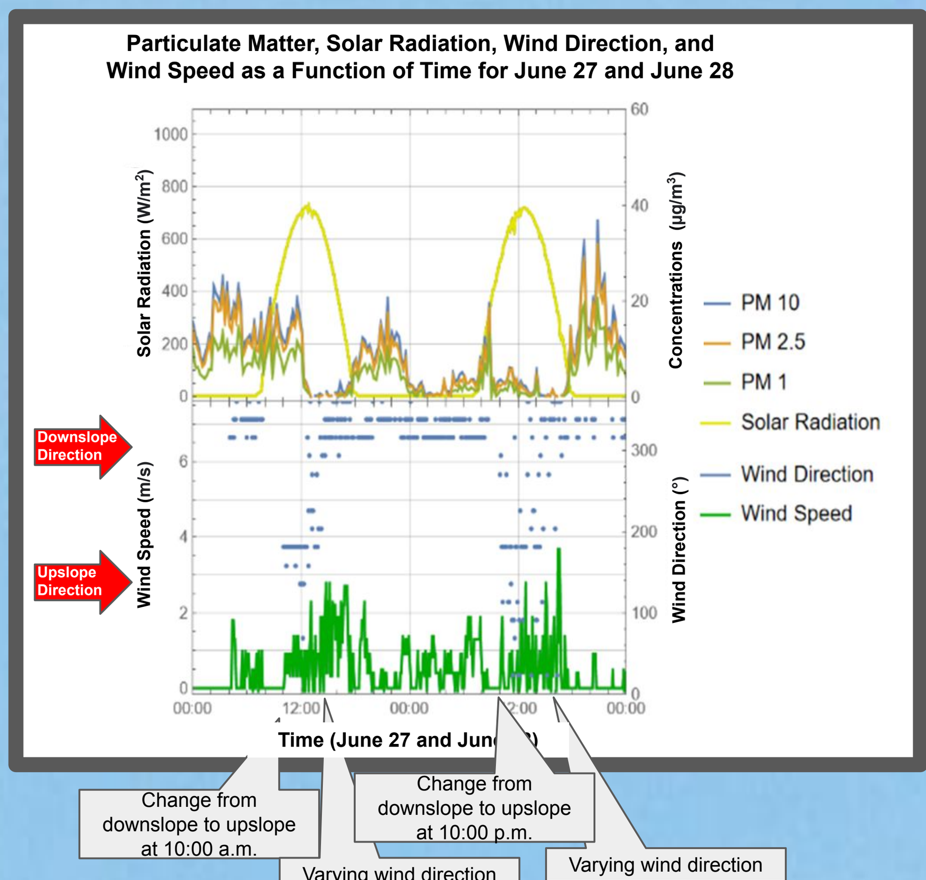
Transportation of Particulate Matter from La Paz to Chacaltaya Mountain

Introduction

Particulate matter (PM) plays a crucial role in Earth's radiative balance. Once it deposits on glaciers, it reduces the snow's albedo, causing them to absorb more solar radiation and melt faster. There is limited research into the transportation of PM in South America. La Paz, Bolivia is one of the fastest-growing cities in South America and a major producer of anthropogenic PM. The Chacaltaya mountain glacier, located next to the city, has completely disappeared. This is particularly problematic since many people and plants in the region relied on its water runoff.

An understanding of how PM reaches mountain glaciers is needed to better understand glacial melt in the future. This project was selected to analyze the mechanisms involved in the transportation of PM from cities to higher elevations on mountains. The PM was hypothesized to follow a diurnal pattern along a pollution corridor in accordance with the Mountain Chimney Effect (MCE), which would result in a daytime flow of PM from the city to higher elevations and a nighttime flow of cleaner mountain air to the city. To investigate this hypothesis, a field campaign was set up in 2022 in Fabrica Forno, located in La Paz. It was assumed that the instruments recorded the data properly and there were no mistakes in importing the data from the instruments into the software.





Method

The analysis of the data was done at Howard University's Beltsville Campus in Beltsville, Maryland.

Data collected by an AE51 Aethalometer (BC), AirNote (PM), iMet radiosonde(wind speed and direction), and Vantage Pro2 Weather Station (solar radiation) were downloaded from a shared Google Drive with Howard University's Beltsville Campus and onto an HP Pavilion x360 Convertible Laptop.

The data files stored on the laptop were imported into Mathematica software. Then, a variable was assigned to each column of data. The time for each day was converted from a year-month-day format to absolute time using the software's AbsoluteTime function.

The Thread function combined the variables with time to form ordered pairs. The DateListPlot function was used to plot the ordered pairs on a graph.

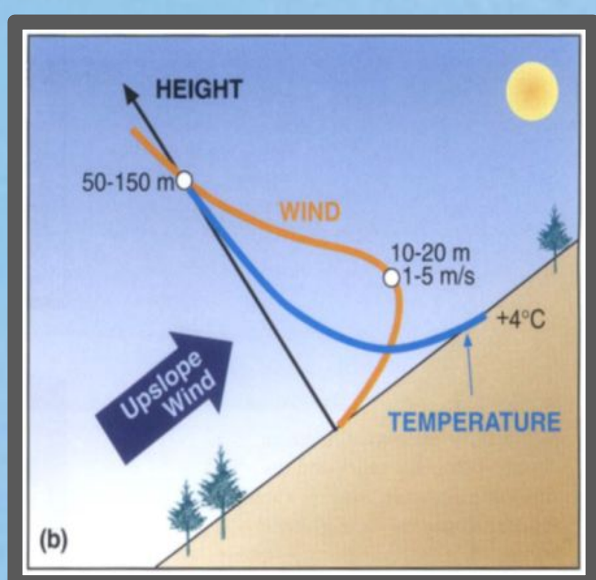
Linear regression and the FindPeaks function in Mathematica were used to find correlations between BC, PM 1, PM 2.5, PM 10, solar radiation, wind speed, and wind direction.

The findings were examined to determine whether the MCE hypothesis was applicable.

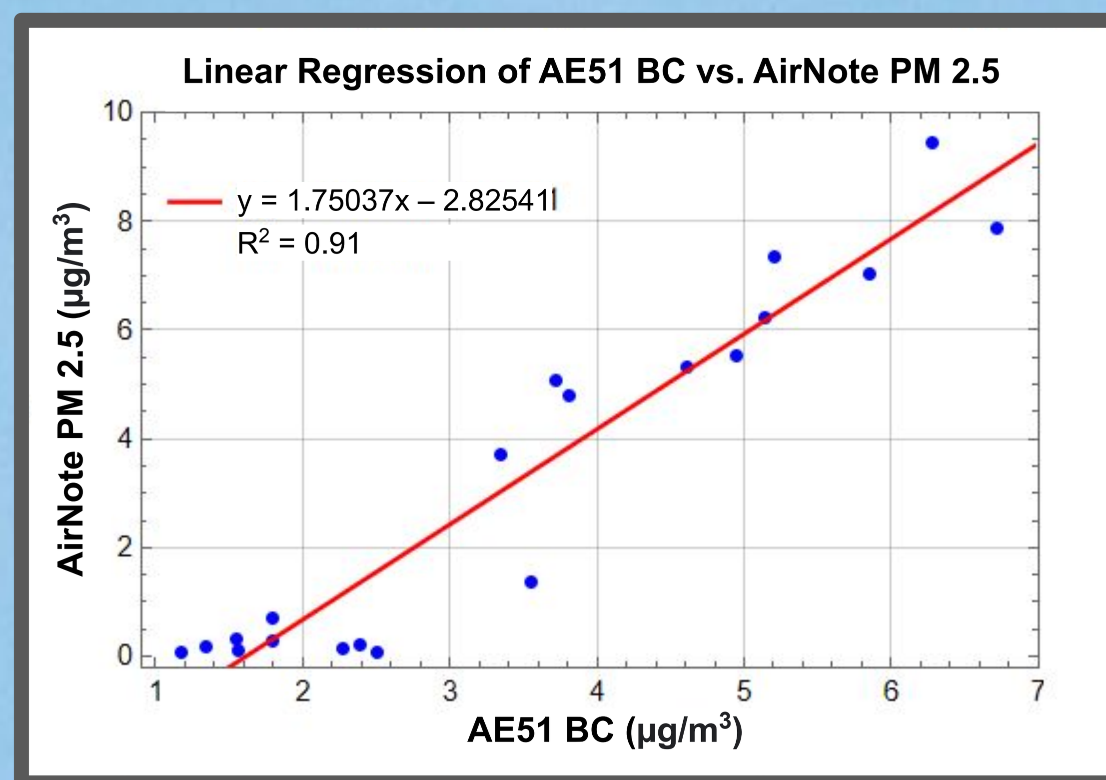
Findings

Before 9:00 a.m., Fabrica Forno had an established steady downslope flow that corresponded with a lower concentration of PM, as shown in the PM, solar radiation, and wind speed and direction graphs. As the solar radiation increased, the surface warmed causing the wind direction to change from a steady downslope flow to a steady upslope flow around 9:00 a.m., as indicated by the change in wind direction from nearly 320° to 140° in the PM, solar radiation, and wind speed and direction graphs. As the winds changed direction, there was a brief period where the wind speed decreased to nearly 0 m/s, and the black carbon (BC) and PM increased. Once there was an established steady upslope flow, around 11:00 a.m., the concentrations of BC and PM decreased. Around 6:00 pm, the wind speed slowed to nearly 0 m/s, and the wind direction changed from upslope to downslope, as indicated by the change in wind direction from nearly 140° to 320° in the PM, solar radiation, and wind speed and direction graphs. During the change, there was variability in the wind direction. After the change, BC and PM concentrations increased.

A linear regression was performed to find the correlation between the BC measured by the AE51 Aethalometer and PM 2.5 measured by a low-cost AirNote sensor to test the accuracy of the Airnote. The R^2 value was 0.91. Statistical tests were not conducted, since the atmosphere is always changing and there would have been no control variable to compare with the data.



Mountain Chimney Effect by C.D. Whiteman, 2000, Mountain Meteorology
The Mountain Chimney Effect (MCE) is a mechanism in which aerosols are transported to higher elevations in mountainous regions as a result of an upslope wind created by daytime solar heating of the mountain's surface.



The linear regression described the relationship between black carbon (BC) measured by an AE51 Aethalometer and particulate matter 2.5 (PM 2.5) measured by a low-cost AirNote sensor on May 24, 2022.

Conclusion

The R^2 value of 0.91 indicated that the AE51 Aethalometer and the low-cost AirNote sensor were highly correlated. The bunching of the AirNote PM 2.5 values below 1 μg/m^3 from the linear regression suggested that the AirNote was less accurate in measuring PM concentrations less than approximately 2 μg/m^3. The data collected from Fabrica Forno indicated that the MCE did occur, however, its effect on BC and PM was more complicated than hypothesized. The BC and PM concentrations appeared to be influenced by traffic and variations in wind direction, taken to be an indication of convection caused by a rising planetary boundary layer.

This project could have been improved by attaching sensors to a radiosonde that would measure the PM concentrations and the potential temperature of the atmosphere st various altitudes to observe the development of the planetary boundary layer and its effect on aerosols. This research will help future researchers identify the mechanisms involved in the transportation of PM to higher elevations and develop solutions to prevent PM from melting glaciers.

Acknowledgements

I would like to thank my mentor, Dr. David Whiteman at Howard University Beltsville Campus, for his dedication to this project. I would also like to thank Eleanor Roosevelt's internship coordinator, Dr. Yau-Jong Twu, for her guidance. Finally, I would like to thank my parents, Chineka Reid and Kim Reid, for their support.

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