Measurement of Wind Paths Due to the Mountain Chimney Effect

Introduction

The "mountain chimney effect" is observed when colder air flows downwards on a mountain as the hot air rises, creating a cycle-like movement where colder air dips and heats up to rise and then cools down creating this cyclic motion. Researchers hypothesized that the mountain chimney effect had a significant impact on the transportation of pollutants from nearby Bolivian cities, promoting glacial melt. By graphing altitude by wind direction and wind speed, researchers were able to observe an upslope and downslope trend. This trend implies that "the mountain chimney effect" might have contributed to the melting trend.

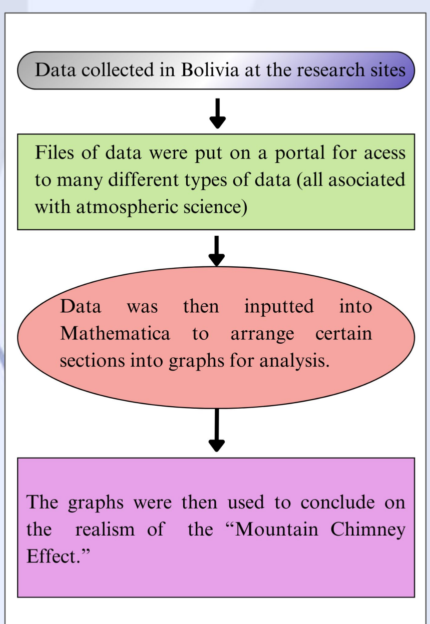
This study focused on this phenomenon by graphically analyzing pollutant distribution patterns surrounding the Chacaltaya mountain. Researchers chose to study this mountain because it is close to two high-altitude cities La Paz and El Alto. Researchers aimed to identify correlations and trends that either supported or refuted the hypothesis. In these high-altitude cities, people commute using cars that are very old which causes incomplete combustion of gasoline. This causes further complications involving high volumes of black carbon particles to increase in the country. These particles have the properties of absorbing ultraviolet radiation from the sun. By conduction, black carbon heats the airflow surrounding the glacier. Because of this, researchers identified black carbon as a main factor involved with the glacial melting in the Chacaltaya mountains.

Method

The data collected by researchers was taken in the Chacaltaya mountain range in Bolivia. Researchers from Howard University collected data during Bolivia's dry season of July 2023, which ensured ideal conditions for the instruments used. Researchers applied a radiosonde machine which recorded a large range of atmospheric data. For this study, researchers used the data from this machine that covered: day (in year month date format), time, altitudes (in kilometers), GPS wind speed (in m/s), and GPS wind direction (degrees). This was done by connecting the radiosonde device to a weather balloon and releasing it to ascend, tracking this data.

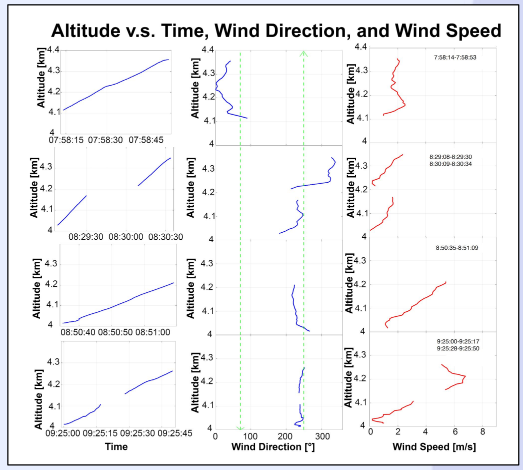
Procedures:

- Data collection was done in Bolivia, involving the use of weather balloons and radiosounding devices.
- Converted the collected day and time data into Universal Time (UT) using the absolute time function in Mathematica.
- Using the UT, 3600 seconds (or 4 hours) was then subtracted changing the time to Bolivian time (BOT).
  - This was done because the radiosonde device was tracking the time using the Eastern Time Zone.
- The profiles, or attempts, of ascent tracked in the data were identified by using Mathematica, to graph the altitude data against the converted time.
  - The profiles were found in the linear-like increasing parts of the graph aforementioned graph
- The profiles were used to create graphs of altitude as a function of wind speed and direction.
  - These graphs were used to analyze the "mountain chimney effect" looking for any upslope and downslope relations.



Findings

After analysis of the profiles, researchers found that the data supported the hypothesis. The graphs of altitude, as a function of wind direction and speed, revealed cyclical changes in wind direction and speed during the ascensions. The ascent graphs showed that as the day transitioned from early morning (low sunlight) and progressed to the latter part of the morning (with increased sunlight), the mountainous surface heated up. As the surface heated, the wind direction changed from a zero-degree direction, or upslope, to a 200°, downslope, direction with increased speed. Despite data inaccuracies, due to glitches from weather balloons not having free ascent, the following graphs, of altitude as a function of wind direction and wind speed, revealed an upslope-downslope relationship that would support "the mountain chimney effect". Statistical tests were not utilized in the research, as this study focused on graphic trends and real-world implications rather than hypothesis testing.



The first column highlights the four profiles (identified by altitude over time). The second column highlights the altitude over wind direction, identifying upslope and downslope relationships. The third column highlighted altitude over wind speed. Using the relationships between each of the graphs revealed "the mountain chimney effect."

- First Profile:
  - Wind Direction: Plotted data (on average) was observed closest to zero degrees or an upslope direction.
  - Wind Speed: Increased slightly but stayed around two meters per second, having prolonged winds.
- Next Two Profiles:
  - Each direction was closer to 250° or 270°, which indicated a downslope direction.
  - Wind speeds were shown to have increased in this section as well as the direction changes.
- Fourth Profile:
  - The fourth profile exhibits a downslope direction, following the trend of downslope winds, caused by the heating of the mountain slopes.
  - During downslope directions, speed increased to a value that was approximately 6.5 to seven meters per second.
- Complete Analysis:
  - "The Mountain Chimney Effect": In the early morning, with dimmer conditions, speeds were slower. As time progressed exposure to the sun increased, which caused the mountain surfaces to warm up. This resulted in downslope winds and an increased wind speed. But, as time progressed, it is inferred that colder temperatures on the mountain, would cause the winds to flow slower, and in an upslope direction.

Conclusion

When comparing the multiple profiles that depicted the trend of altitude changes over time, upslope downslope movement of the winds became apparent. This was observed by the cyclical changes in the wind, regarding its speed and direction. This further supported the hypothesis, identifying "the mountain chimney effect's" existence. Though the information about "the mountain chimney effect" could be true, understanding the air pollutants' transportation properties was a more complex topic to study and would have required further research. By synthesizing these findings, researchers obtained a clearer understanding of "the mountain chimney effect." This provided valuable insights for future research and environmental mitigation efforts. A proposed hypothesis (for further research efforts) could be that the geographical location of the mountains, such as canyons, would directly impact the cyclic patterns and paths of wind.

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Nehemiah Gray