Sensing the Atmospheric Boundary Layer in New York

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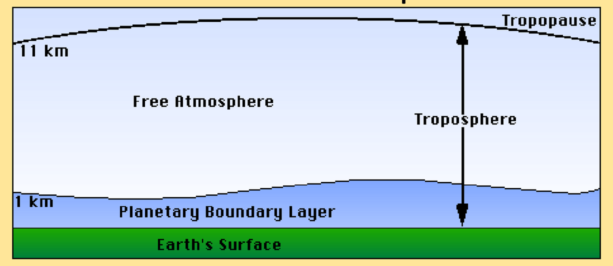
Abstract

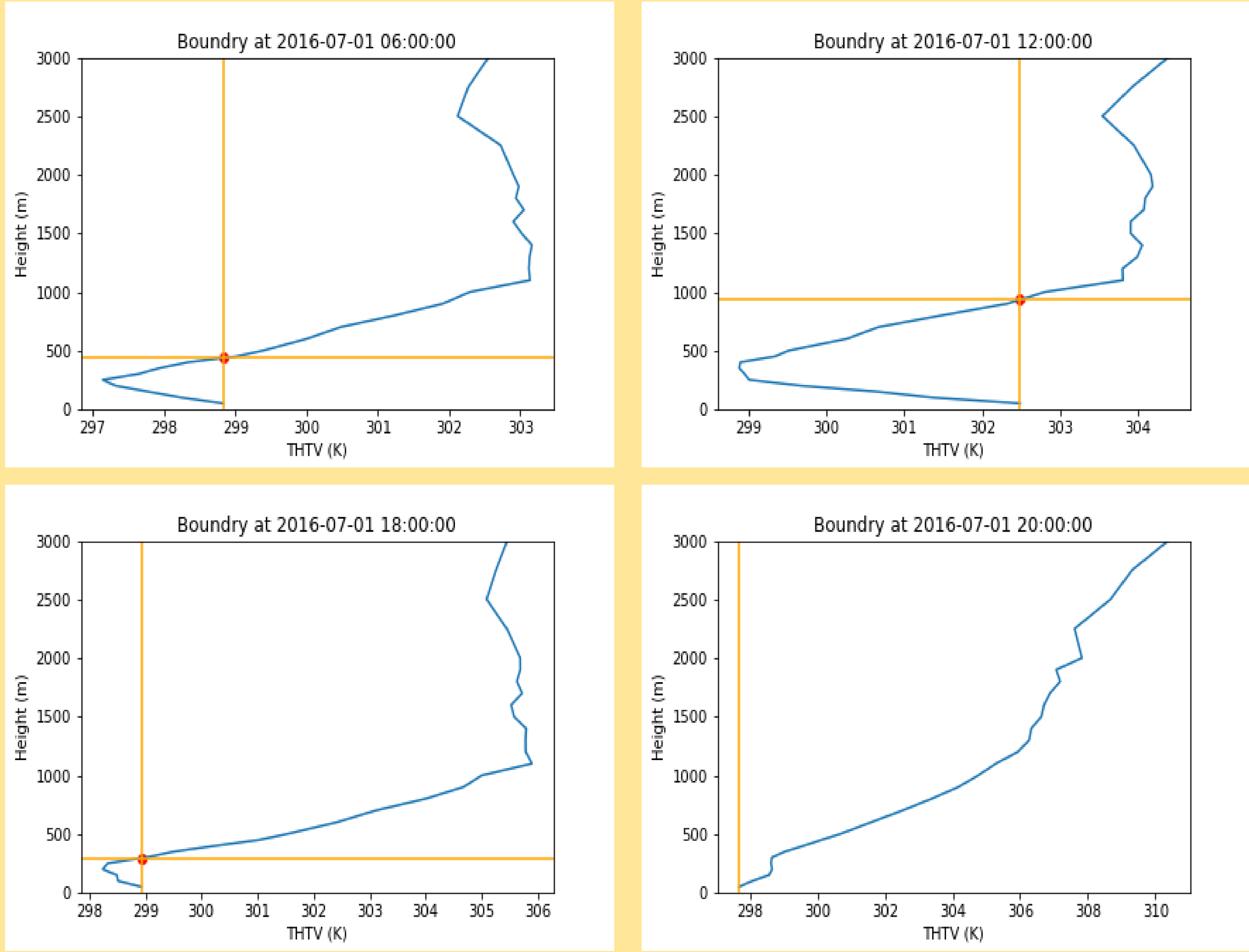
This study focuses on a phenomenon called the atmospheric boundary layer (ABL). The ABL resides at altitudes between 500m and 3000m in the earth's troposphere depending on several factors including time of day and temperature. The ABL can be in one of two states: stable and unstable. This research project focuses on the unstable state of the boundary layer, how it is affected by time of day and temperature, and how its altitude affects pollution in New York City. This happens typically during the day when the sun heats the ground, and therefore the air directly above it. Without an excess of sunlight, the troposphere's potential temperature increases with altitude, however with enough sunlight and materials that are more easily heated, the temperature near the surface becomes higher. This causes convection in the form of large plumes of rising hot air. These plumes rise until the air around them reaches their own potential temperature. The unstable ABL contains convection systems underneath it along with pollutants. Understanding the way in which this happens is of vital importance to air quality management, as the ABL plays a major role in the transport and dispersal of pollutants. The goal of this study is to better understand how the atmospheric boundary layer changes over time, as well as how it affects environmental hazards such as pollutants.



Objective

The objective of this research project is to observe the changes in the height of the boundary layer over time and how they affect the concentration of pollutants in New York City. Data will be collected about the unstable boundary layer by measuring temperature, humidity, and pressure at different heights. The change of the boundary layer will be compared with readings taken by a separate research group studying the concentration of pollutants in New York City. Particularly that of PM 2.5: particulate matter with a diameter of 2.5 or less microns. By comparing this data with the height of the atmospheric boundary layer, a better picture of how to predict where and when pollutants will be most prominent can hopefully be built.

Finding the Boundary Layer

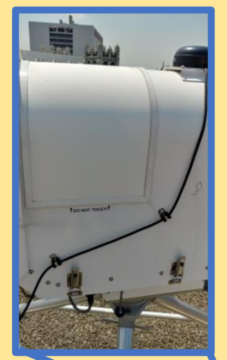


Methodology

The atmospheric boundary layer temperature, pressure, and humidity at different heights in the troposphere were measured using a microwave radiometer on the roof of the Groove School of Engineering. With this information, we were able to derive potential temperature, which was the raw data used in this project. The potential temperature is then graphed with respect to height. From there, a computer program written in Python finds which height the potential temperature above the surface matches that of the air near the surface. In some cases, particularly early in the morning and at night, the unstable boundary layer is nonexistent, in which case the program returns 'NaN' (not a number). These values are then graphed with respect to time.

This sensor is used to indicate the presence of rain. Liquid water changes the resistance of the circuit and indicates rain.

The radiometer does the bulk of the readings at multiple frequencies in the microwave light.



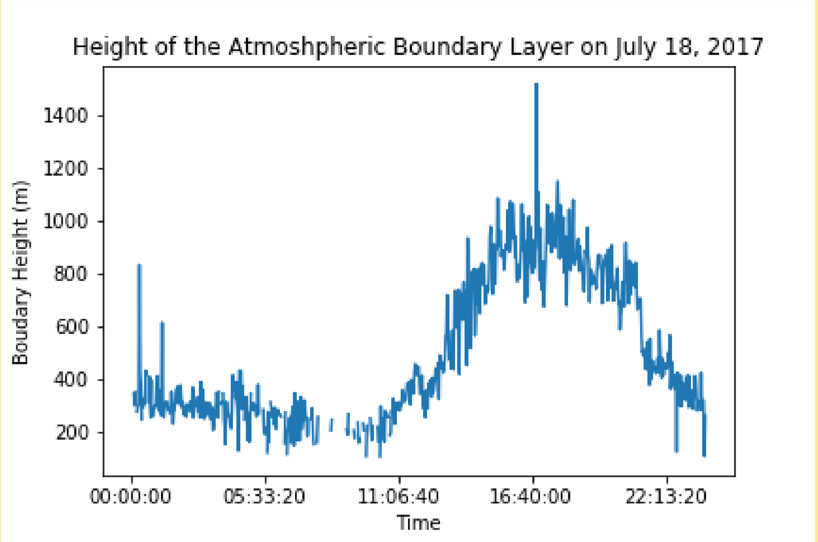
An infrared sensor is used to collect information about the cloud base.

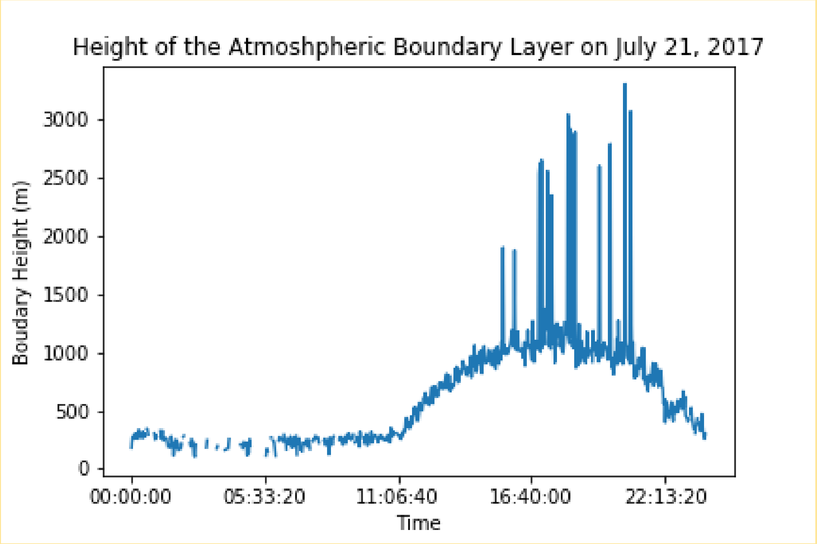
vs.

When it came to estimating potential temperature at different altitudes, there were two different options, a weather balloon from Brookhaven National lab, and the radiometer mounted on top of the Grove School of Engineering. While the weather balloon provided more detailed data, it took readings only twice a day, and was not located in the city. The radiometer on the roof took reading every 90 seconds and was located inside of Manhattan.

Results

Groove School Data



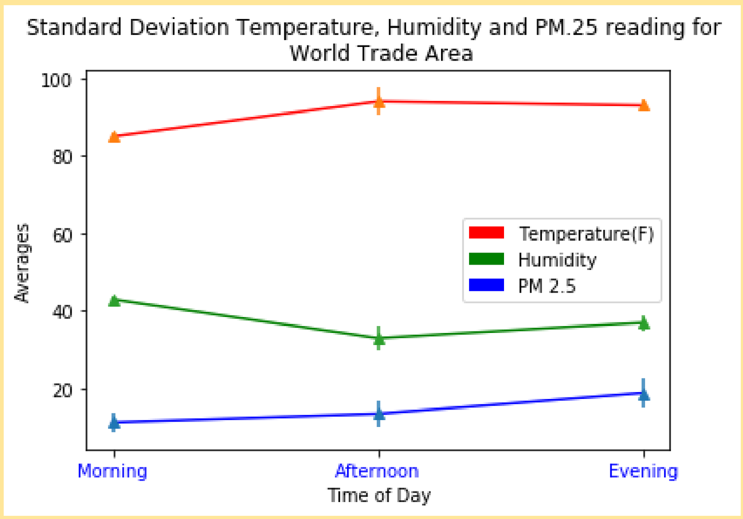


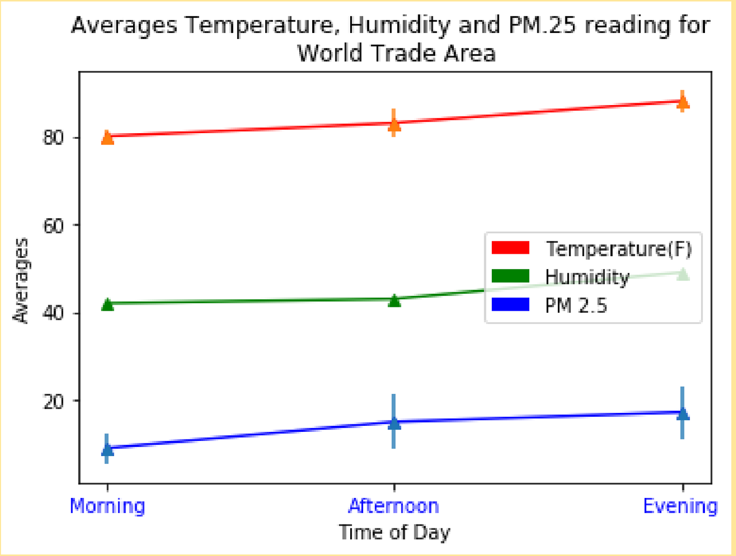
Data from Brookhaven is only available twice a day but since the radiometer gives us more points throughout the day, we can track changes in the boundary layer.

When comparing the change in the boundary layer, there appears to be a general correlation between the height of the boundary layer and the PM 2.5 concentration and temperature as well as the standard deviation of both values.

Note: In the Air-beam data, the PM 2.5 readings are in µg/m^3, and the humidity readings are in g of water per m^3.

Air-beam Data





Conclusions

The Atmospheric boundary layer consistently tended to increase in altitude in the afternoon and evening, then decrease in altitude shortly after. This was excepted as the ground is heated by the sun and generate plumes of hotter air later in the day, followed by a loss of heat in the nighttime.

While there was a direct correlation between the height of the Atmospheric boundary layer and the concentration of pollution over the day, this change in the PM 2.5 reading was more likely caused by temperature. Instead, the increase in standard deviation was more likely caused by the rise of the atmospheric boundary layer. With more room for air currents to flow, the pollution would be less consistent.

Future

One of the major cruxes of this experiment was the lack of data variety. With only one sensor mounted on one roof in Harlem it's difficult to get a full picture of the boundary layer. Many different locations would help build something of a map of the height of the boundary layer at different locations. These differences could then be compared with different pollution concentration readings taken with the Air-beam in order to better understand the correlation between the boundary layer and pollutants.

References

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Molina, Mario J, and Luisa T Molina. "Megacities and Atmospheric Pollution." wiki.esipfed.org/images/2/2c/MegaCityPollutionMolina.pdf.

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