Boundary Layer Heights in a Heterogeneous Landscape

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Introduction

The Planetary Boundary Layer (PBL) is the layer of the atmosphere, approximately one kilometer in height, which is directly influenced by earth's surface. At the Beltsville Center for Climate System Observation (BCCSO), air quality is one of the primary research focuses and PBL height is one important parameter in air quality forecasting, for example.

The height of the Planetary Boundary Layer (PBL) has been studied extensively in homogeneous environments; however, very few observational studies of PBL height in a heterogeneous landscape have been conducted. The BCCSO is ideal for this study because it is surrounded by distinct landscapes (**Figure 1**). A 31-meter flux tower and a ceilometer, both located at the BCCSO, provide the data needed for this study (**Figure 2**).

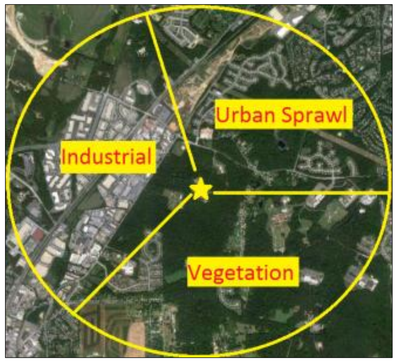

Figure 1: Aerial view of the BCCSO (marked with yellow star), with the surrounding landscapes identified.

Figure 2: The ceilometer (left) and 31-meter flux tower (right) used in this study. Both are located on site at the BCCSO.

Methods

The Lifting Condensation Level (LCL) is known to be a good proxy for the height of the PBL. In this study, the LCL is derived from surface point measurements of temperature and mixing ratio (dew point) taken from the 31-meter flux tower, while the height of the PBL is measured directly from the ceilometer using the cloud base height. The LCL is used to find PBL-bounded clouds from the ceilometer data set: only clouds within 750 meters of the LCL are assumed to be PBL-bounded clouds and therefore the measured height of the PBL.

The data provided by the tower and ceilometer covers a time period between February 2006 and July 2012. All data over this time period is first averaged into one-minute intervals and then divided and averaged by wind direction, in 15-degree intervals.

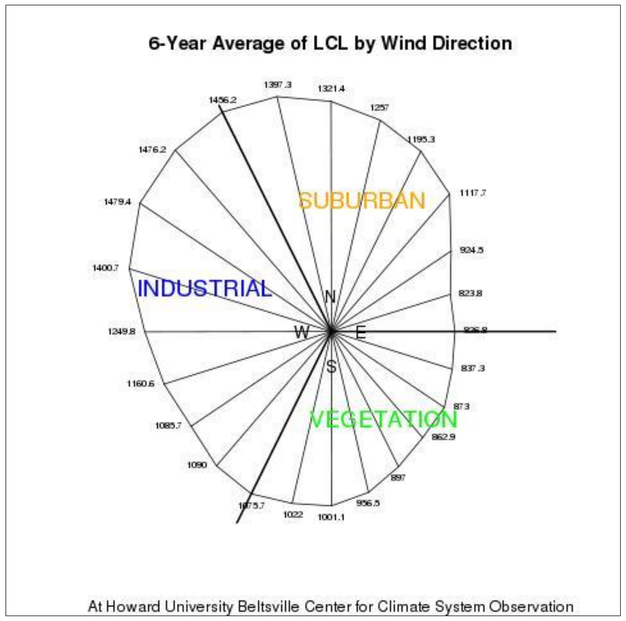

Figure 3: The six-average seasonal LCL height by wind direction. The sectors are noted for reference to Figure 1.

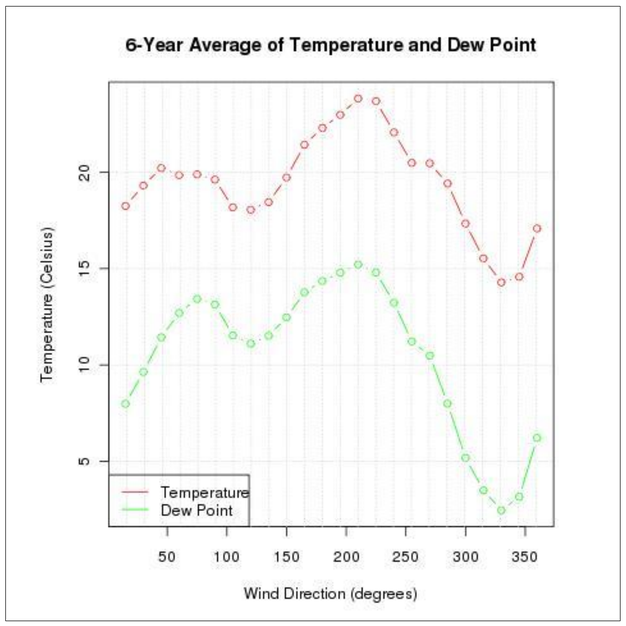

Figure 4: The six-year average of Temperature and Dew Point.

Results

There are noticeable variations in PBL heights across the different landscapes. The highest PBL heights, for example, are shown to come from the industrial area to the west-northwest of the BCCSO, while the lowest PBL heights are linked to the vegetation landscape that lies to the east-southeast of the research site (**Figure 3**).

Surface temperature and dew point are two key factors in determining the height of the LCL: increasing the temperature will increase the height of the LCL while increasing the amount of moisture in the air will decrease the height of the LCL. The larger the difference between the temperature and dew point, the higher the LCL (**Figure 4**).

Discussion

Industrial areas, compared to mostly vegetated areas, are generally warmer. This is because building materials such as concrete and asphalt absorb solar radiation better than naturally occurring surfaces such as grass and dirt. Additionally, industrial areas are drier than vegetated areas because soils and plants retain moisture much better than standard building materials such as those already described.

This process would explain the higher LCL (PBL height) in industrial regions compared to vegetated areas; however, the higher PBL heights occur in the industrial region for another reason. Even though the northwest is about eight degrees Celsius cooler than the southwest, the dew point is almost twelve degrees lower in the northwest compared to the southwest. This larger difference in the northwest explains why the PBL heights are higher there.

Future work on this study should investigate if these PBL heights are due to large-scale effects or local variations in landscape. For example, the Appalachian Mountains to the northwest and/or the Chesapeake Bay to the southeast could influence the PBL heights at the BCCSO (**Figure 5**).

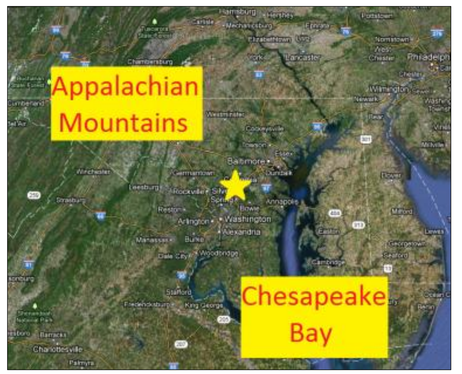

Figure 5: Satellite view of the BCCSO (approximate location marked with yellow star). The Appalachian Mountains and Chesapeake Bay are marked for reference.

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