P2.17 PLANETARY BOUNDARY LAYER HEIGHTS: LIDAR AND RADIOSONDE BASED OBSERVATIONS

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1. INTRODUCTION

The lowest portion of the troposphere, where most of our daily activity takes place, is the planetary boundary layer (PBL). This layer is directly influenced by friction and solar heating from the earth's surface (Minto and Pleva, 2002). Within the PBL, significant turbulent mixing from solar heating carries moisture and heat upward. This convective activity is responsible for the diurnal development and evolution of the planetary boundary layer height and the formation of clouds and eventually precipitation. A well-mixed PBL indicates a region where the capping inversion is broken and convective storms are initiated given the right atmospheric conditions. Therefore the study of the PBL height gives meteorologists a sense of the convective activity.

Lidars (LIght Detecting And Ranging) are now being used to investigate the PBL. These instruments measure the concentrations of aerosols and water vapor at various heights in the atmosphere. Lidars use lasers of very short wavelength that are sent into the atmosphere where the light energy interacts with the atmospheric constituents (in this case water vapor and aerosols/dust). The emitted signal from this interaction is recorded at the surface using telescopes and other holographic collecting surfaces (Goodman, 2000). The PBL can be determined by looking at the rate of decrease of the intensity of the water vapor or the aerosols scattering ratio. A fast and objective way of doing this is using a wavelet analysis (Davis et. al, 2000).

This study attempts to develop a method of assessing PBL parameterization using Lidar observations. These lidar-based PBL heights will be compared with PBL heights calculated from radiosonde data collected during the International H_2O Project (IHOP). This validation will be used in the future to evaluate different PBL parameterizations used in regional models.

2. INTERNATIONAL H_2O PROJECT (IHOP)

IHOP was a field experiment located in the panhandle of Oklahoma, Southern Great Plains from May 13 to June 25, 2002. This field project was aimed at understanding the 4-dimensional characterization of water vapor in the atmosphere. Water vapor is carried up in the atmosphere by turbulent eddies, where it then condenses to form clouds. Thus, understanding water vapor in the PBL is the first step in addressing the convective initiation matter for quantitative precipitation forecasting.

Of the many instruments used during this field experiment, three were used for this study. These instruments are radiosondes, SRL, and HARLIE lidars. The SRL lidar measures water vapor backscatter, and the HARLIE lidar measures aerosol concentration.

From all the IHOP data, one case study, May 22, 2003, was chosen from Homestead, OK. This day was ideal for a case study because a dryline moved back and forth over this region in the afternoon, and around 2349 UTC (6:49 pm) it passed through Homestead. As the dryline passed there was a drop in moisture (q), and a shift in wind speed (u) and direction. In addition, the potential temperature (θ) increases

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3. METHODOLOGY

Two methods were used for the analysis of the lidar and radiosonde data sets. To calculate the PBL heights for radiosonde observations a virtual potential temperature method was used from Stull (1988). This method takes the temperature, pressure, and humidity from the radiosondes and calculates the virtual potential temperature. For the lidar observations a wavelet method (Davis et. al., 2002) was used to calculate the PBL heights. Then the PBL heights were compared with the radiosonde PBL heights.

3.1 Radiosonde Data

Five radiosonde launches were conducted using the GPS/ Loran Atmospheric Sounding System (GLASS) Vaisala RS 80-15GH, which uses a GPS receiver (Susedik, 2000). In addition to the receiver, the radiosondes host pressure, temperature, and relative humidity sensors. This data is transmitted to the receiver using a 402 MHz transmitter. Of the five launched on this day, three were used for this analysis.

Once the data were obtained, the hypsometric equation was used to calculate the height for each sonde reading. Then the potential temperature was calculated using

$$\theta = T\left(\frac{p_1}{p_2}\right)^{R/C_p} \qquad (1)$$

where T is the temperature at p_2, p_1 is the pressure at the surface, C_p is the specific heat at constant

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pressure 1005 $Jkg^{-1}K^{-1}$, and R is the gas constant for dry air 287 $Jkg^{-1}K^{-1}$. Then the virtual potential temperature, was calculated using

$$\theta_v = \theta(1 + 0.61q) \quad (2)$$

where θ is the potential temperature, and q is the specific humidity, which can be calculated from the relative humidity. Then plots of the virtual potential temperature versus height of sonde readings were constructed using Splus, a statistics software package. From these plots the PBL were extracted by the gradient of the virtual potential temperature.

3.2 HARLIE Lidar Data

One type of lidar that was used to measure the PBL height is the HARLIE lidar. This lidar scans conically at a 45° angle in the vertical and measures aerosol scattering ratio. It uses a holographic optical element to collect and focus the light. From the lidar the return signal the backscatter profile is obtained. Then using a Haar function (Davis et al., 2000)

$$h\left(\frac{z-b}{a}\right) = \begin{cases} -1 : b - \frac{a}{2} \le z \le b \\ 1 : b \le z \le b + \frac{a}{2} \\ 0 : elsewhere \end{cases} \quad (3)$$

where z is the distance in the vertical, a is the dilation, and b is the translation, the wavelet method is analyzed for each profile. Dilation accounts for the frequency change in the analysis and translation accounts for the convolution of the backscatter profile. After the wavelet analysis was conducted, the PBL height was extracted from the aerosol backscatter profile.

3.3 SRL Lidar Data

The SRL lidar data was also used to calculate the PBL height for this case study. This lidar consists of two different two scanning techniques: a single scanning mechanism and a motorized scanning mechanism (Goodman, 2001). For the purpose of this study, we used the motorized scanning technique because it can obtain atmospheric profiles while scanning continuously form horizon to horizon. From the returned water vapor backscattered profiles a wavelet analysis was conducted as described above. Next, a plot of water vapor mixing ratio as a function of height and time was constructed. Then the PBL was extracted from the gradient of the water vapor mixing ratio.

4. RESULTS AND DISCUSSION

The evolution of the PBL over an 8-hour period was seen in all three data sets studied. Looking at the HARLIE lidar observations for May 22, 2002, at 1944 UTC (2:44 pm) the PBL was 1900 m (Figure 1a). About four hours later at 2331 UTC (6:31 pm), the height of the PBL extends up to 3400 m (Figure 1b). In the late evening, 0140 UTC (8:40 pm) the PBL reaches about 2300 m (not shown). The PBL height increased in the afternoon and decrease in the evening after sunset as expected.

This same pattern was seen in the SRL lidar data although no data was collected at 1944 UTC (2:44 pm). The height of the PBL is evident where the gradient of the water vapor mixing ratio is strongest. For 2331 UTC (6:31 pm) the PBL height was found to be about 3300 m and for 0140 UTC (8:10 pm) it was 1900 m (Figure 2). In the late afternoon, the PBL was at its maximum height, and it decreased in the evening.

The three radiosonde launches also revealed the development and decay of the PBL. The first launch was at 1944 UTC (2:44pm), and the PBL height for this time was about 2500 m (Figure 3a). The PBL then increased to 3800 m at 2331 UTC (6:31 pm) (not shown). Then by 0140 UTC (8:10 pm) it decreased to 2600 m (Figure 3b). These findings are summarized in Table 1.

Time (UCT)	Sonde (m)	SRL (m)	HARLIE (m)
1944	3200		1900
2331	3800	3300	3400
0140	2600	1900	2300

Table 1: PBL heights in meters from radiosonde, HARLIE, and SRL Lidars for three times on May 22, 2002.

The PBL heights from the HARLIE and SRL lidars were different from the radiosonde data. Some of this difference accounted for in the height of Homestead site, which is about 860 m above sea level. To adjust the readings to sea level, 860 m was subtracted from the radiosonde PBL heights. When this difference is taken into account, the PBL heights from the radiosonde launches look closer to the SRL and HARLIE lidars.

Time (UTC)	Sonde (m)	SRL-Sonde diff (m)	HARLIE-Sonde (m)
1944	2340		-440
2331	2940	360	460
0140	1740	160	560

Table 2: Radiosondes PBL heights adjusted to sea level and SRL – radiosonde differences, and HARLIE-radiosonde differences are also shown for May 22, 2002 at Homestead OK.

The adjusted PBL heights show that both HARLIE and SRL Lidars overestimate the PBL height in general. The differences between the SRL and radiosonde PBL heights and the HARLIE and radiosonde PBL heights are relatively small (Table 2). The SRL radiosonde differences are smaller than the HARLIE radiosonde differences. Another reason for this difference is the heights are being estimated from the gradient of the virtual potential temperature, water vapor mixing ratio, and aerosol concentration for the radiosonde, SRL and HARLIE respectively. This estimation may be slightly different for each person.

5. CONCLUSION

This analysis was conducted to validate the use of water vapor backscatter data from Goddard's Scanning Raman Lidar (SRL) and aerosol backscatter data from the Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE lidar) to calculate PBL heights. We found that both SRL and HARLIE lidar-based PBL heights were successfully compared to the radiosonde- based PBL heights. Results showed that the SRL derived PBL heights compared better than the HARLIE derived PBL heights

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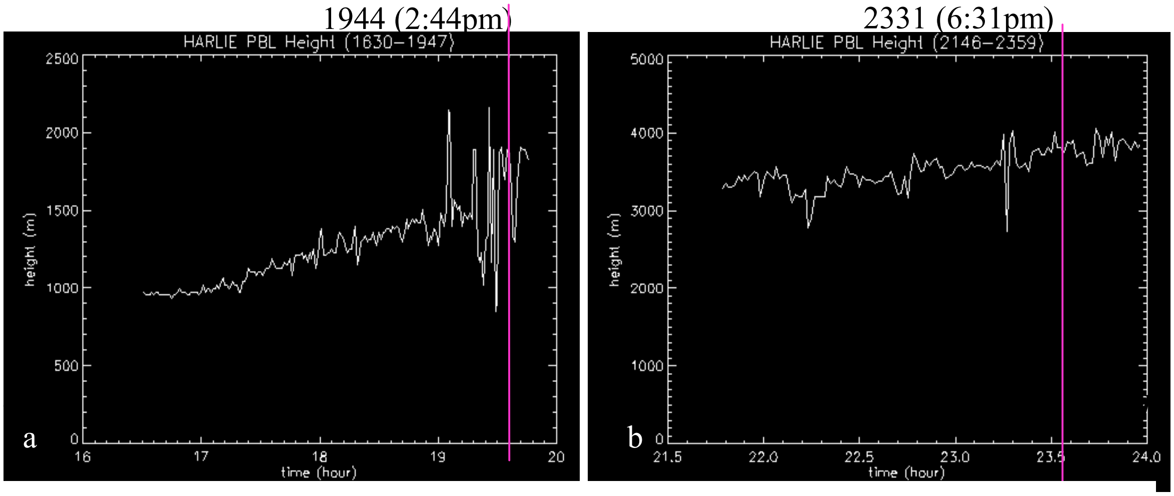


Figure 1: PBL height from HARLIE Lidar for a. 11:30 am –2:47 pm and b. 4:50- 6:59 pm for case study on 22 May 2002.The pink line indicates the times when the PBL height was compared with sonde and the SRL lidar.

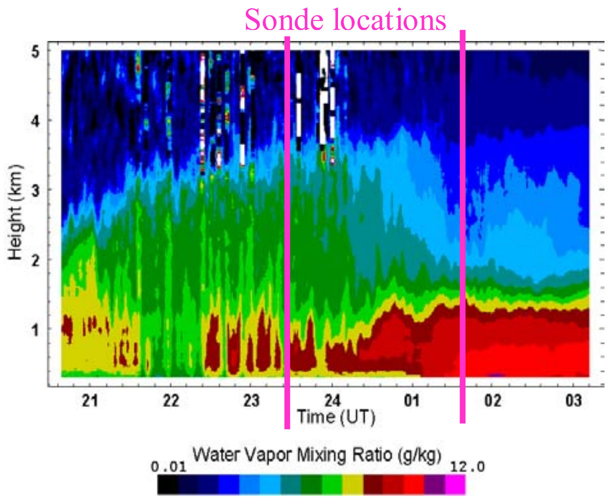
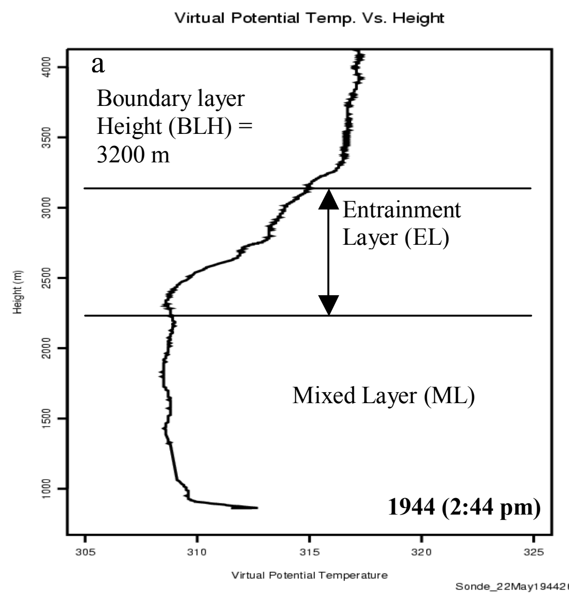


Figure 2: PBL height from SRL lidar for 4:00- 10:00 pm. The pink lines indicate the time when the PBL heights were compared with sonde and HARLIE lidar 2331 and 0140 UTC (6:31 and 8:40 pm).



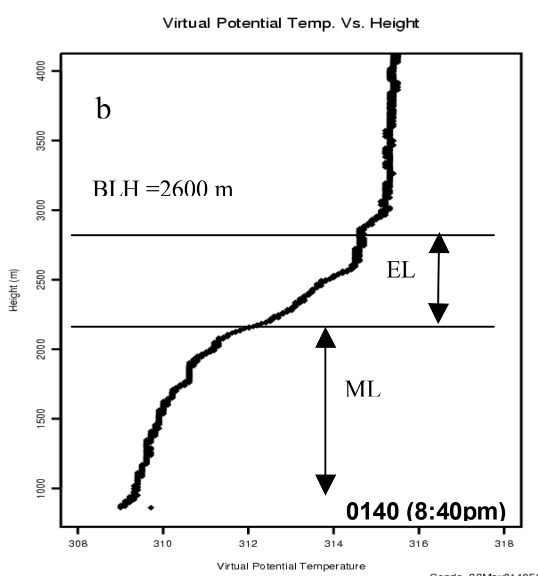


Figure 3: PBL heights from Radiosonde for two times a) 1944 UTC and b) 0140 UTC for May 22, 2002 at Homestead, OK.