Determination of Planetary Boundary Layer Heights from Doppler Wind Lidar

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Background

Aerosol particles tend to congregate within the planetary boundary layer (PBL), this makes accurate measurements of the PBL height a valuable tool in air pollution forecasting, and air pollution dynamics. Due to this congregation, a sharp gradient in aerosol concentration occurs at the top of the boundary layer, making it measurable by observing signal to noise ratio (SNR) profiles. Although, aerosol concentration is not the only factor that experiences this sharp gradient; it can be seen by analyzing other profiles, like wind speed or wind velocity variance.

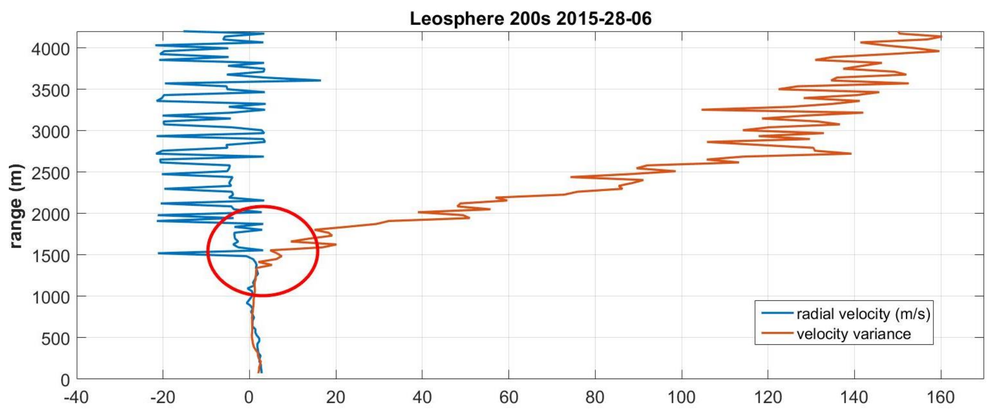

Figure 1. Velocity variance gradient sharply increasing at the location of the PBL.

Covariance Wavelet Transform

Haar Wavelet:

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

h = vertical distance or altitude in application
a = spatial extent or dilation of the function
b = center of the Haar function

Covariance Wavelet Transform of Haar Wavelet:

$$W_f(a,b) = a^{-1}\int_{z_b}^{z_t} f(z)\, h\left(\frac{z-b}{a}\right) dz$$

z_b and z_t: top and bottom altitudes in profile
f(z): profile as a function of altitude
a^{-1} : inverse of dilation factor

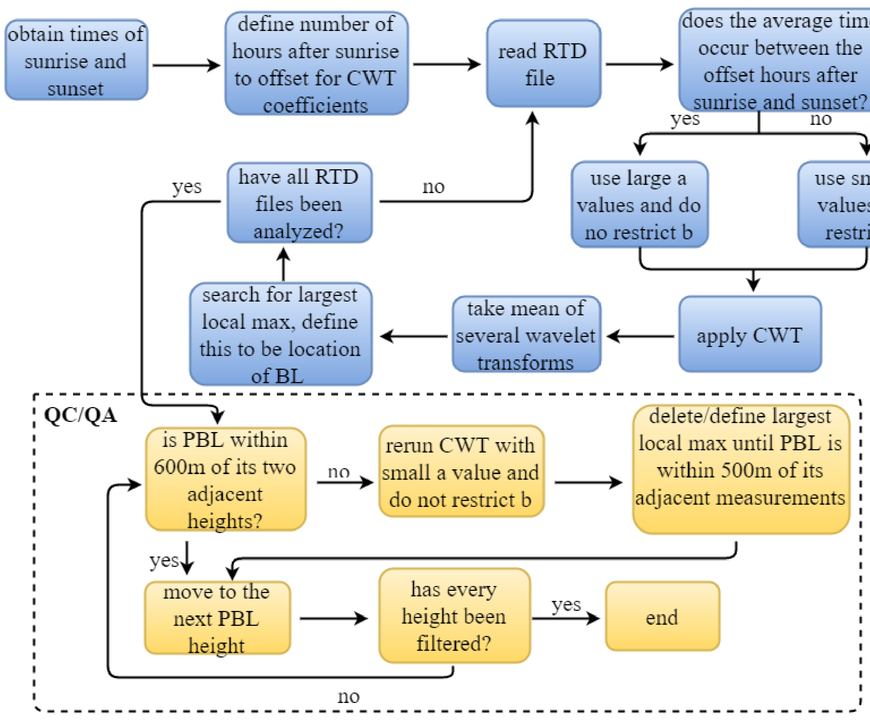

Figure 2. Covariance Wavelet Transform algorithm.

Results

Comparison of Doppler Wind LIDAR PBLH to Radiosonde PBLH

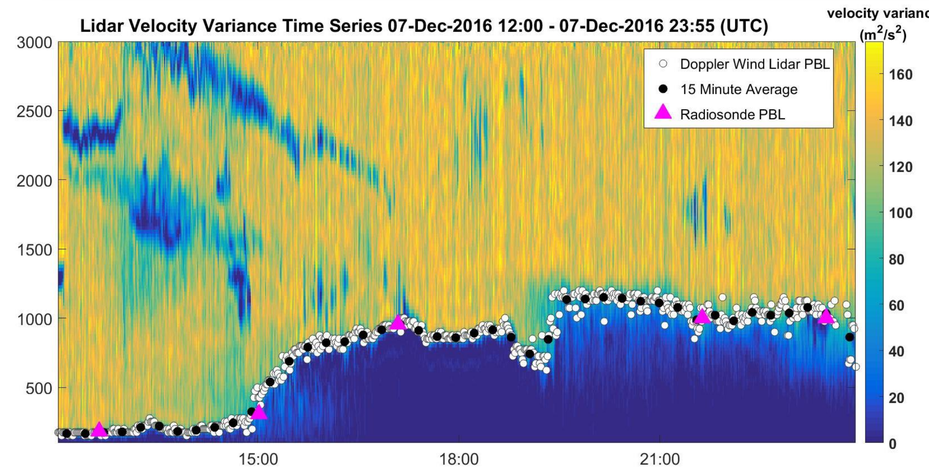

Figure 3. Doppler wind LIDAR time series for 12:00UTC - 23:55UTC on 12-07-2016, Baltimore, MD.

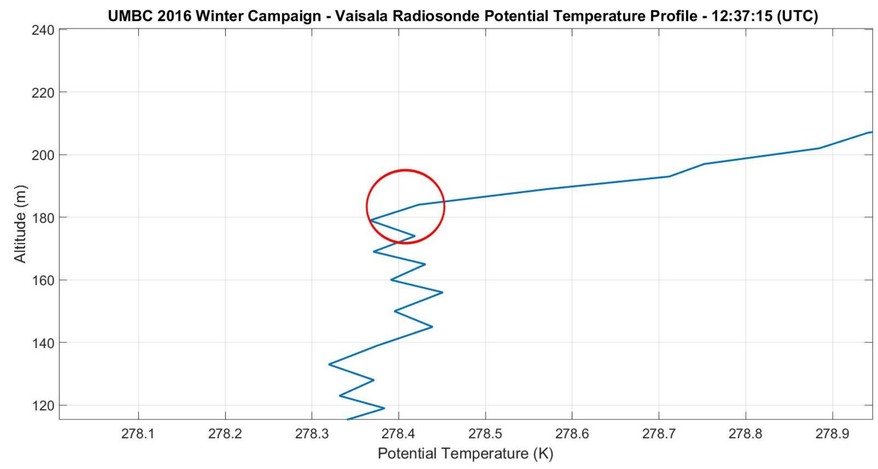

Figure 4. Potential Temperature profile for 12-07-2016, 12:37 UTC, Baltimore, MD

Correlation between LIDAR PBLH to Radiosonde PBLH

56 Radiosondes were launched during UMBC's 2016 Winter Campaign. Shown below is a linear regression of the Radiosonde PBLH to the Doppler Wind LIDAR PBLH.

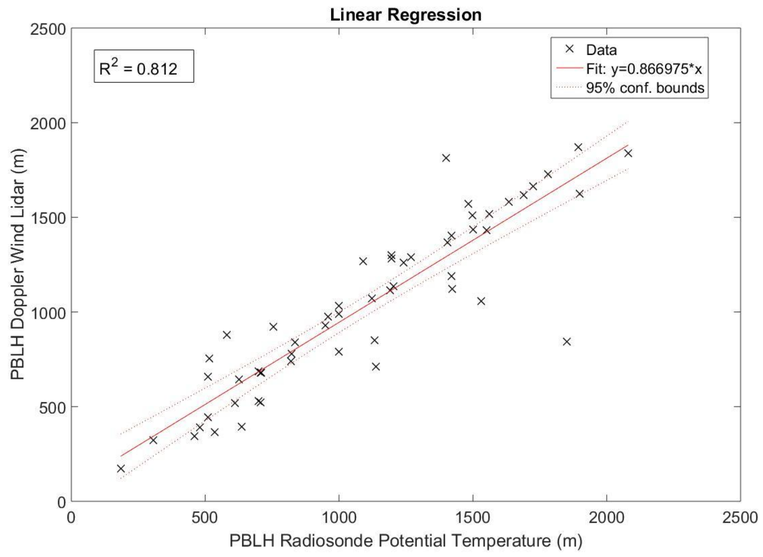

Figure 5. Linear regression for Doppler Wind LIDAR PBLH and Radiosonde PBLH

Discussion

- PBLH accuracy varies based on the day
  - In general, days with higher aerosol concentrations will have more accurate measurements
  - Days with low aerosol concentrations tend to have very scattered results , but oftentimes, the 15 minute average PBLH is close to actual value
  - Difference in day-to-day accuracy causes outliers in linear regression between radiosonde PBL and LIDAR PBL

Future Plans

- Use of peak-thresholding method and cluster analysis method, compare results with CWT method to determine most accurate.

References

[1] Jaime C. Compton, Ruben Delgado, Timothy A. Berkof, Raymond M. Hoff, Determination of Planetary Boundary Layer Height on Short Spatial and Temporal Scales: A Demonstration of the Covariance Wavelet Transform in Ground-Based Wind Profiler and Lidar Measurements
[2] Thomas Rieutord, Automatic detection of the boundary layer using Doppler LIDAR measurements

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