Routine Planetary Boundary Layer (PBL) Height Value Added Product (VAP) Development Using Radiosonde Measurements

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Motivation

Planetary boundary layer (PBL) depth is important to a wide range of atmospheric processes including cloud formation, aerosol mixing and transport, and chemical mixing and transport. Errors in the determination of the PBL height in models can significantly impact the formation and maintenance of low-level clouds. Numerous instruments and algorithms have been used for PBL height detection, each with their own strengths and weaknesses. In the first version of the PBL height Value Added Product (VAP) three methods for determining PBL using radiosondes have been implemented. In the next step of VAP development, methods for estimation of PBL height using ceilometer and lidar datasets will be implemented.

Radiosonde Methods

Heffter Method:

The Heffter (1980) method is a well-established method that examines potential temperature gradients to find elevated inversion layers. The PBL height is then identified as the lowest height (z) at which the which the potential temperature (θ) and temperature difference between the base and top of the inversion layer meet both of the following two criteria:

1) $\Delta\theta/\Delta z \geq .005$ K/m

2) $\theta - \theta \geq 2$K

Liu-Liang Method:

The method of Liu and Liang (2010) first identifies the likely status (convective, stable, neutral) of the PBL using near-surface temperature gradients. For convective and neutral boundary layers, potential temperature differences and gradients are used to identify the PBL height. For stable boundary layers, the PBL height is defined as the top of the bulk stable layer from the ground or the level of the low level jet, if present.

Bulk Richardson Method:

In this method, the mixing-layer depth (or PBL height) is defined as the height at which the bulk Richardson number surpasses a critical value beyond which the atmosphere is considered decoupled (Seibert et al. 2000). The bulk Richardson method is the standard approach used in many atmospheric models.

Ceilometer/lidar Methods

For the ceilometer and lidar data, we will implement the structure of the atmosphere (STRAT-2D) method described in Haeffelin et al. (2011). This algorithm estimates PBL height based on vertical and temporal gradients in attenuated backscatter using a wavelet covariance analysis.

Results using the Heffter and Liu and Liang method with convective and stable boundary layers:

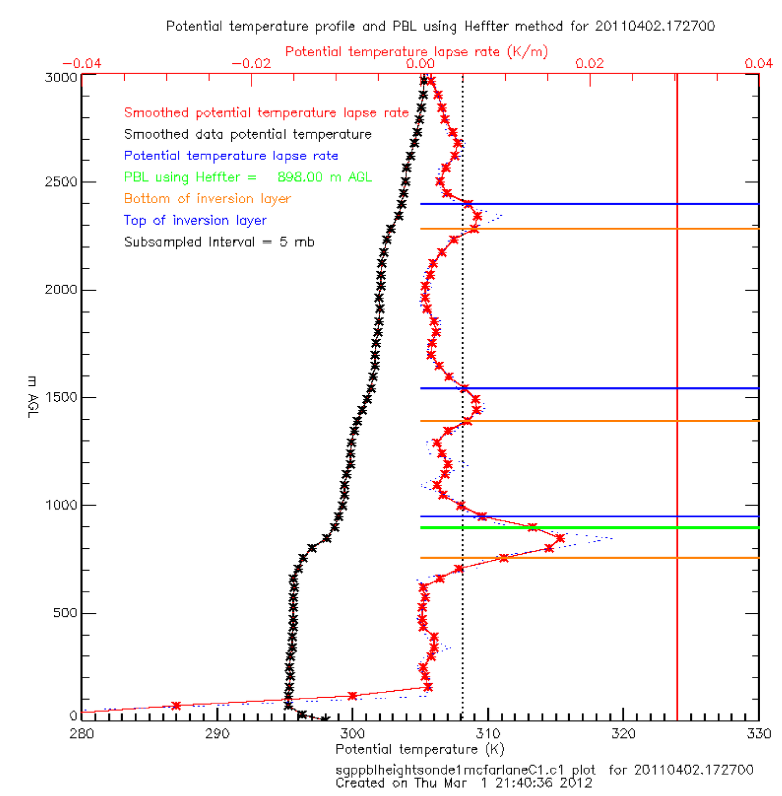

Figure 1: PBL determination using Heffter method when the profile was subsampled and smoothed at 5 mb and 15 mb respectively at SGP on April 02, 2011.

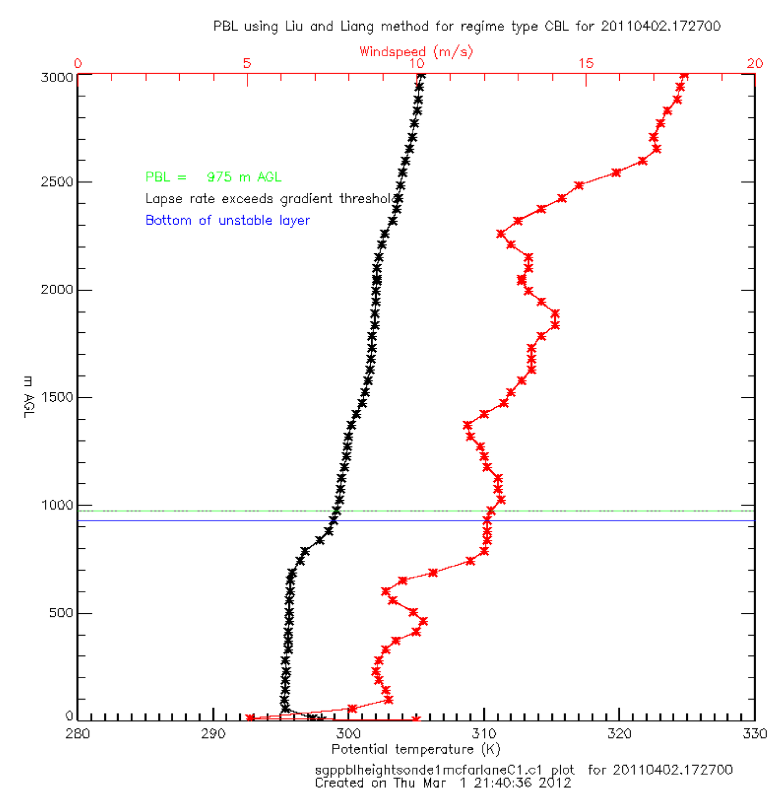

Figure 2: PBL and regime determination using Liu and Liang method when the profile was subsampled at 5 mb at SGP on April 02, 2011. This is an example when the boundary layer was determined to be convective.

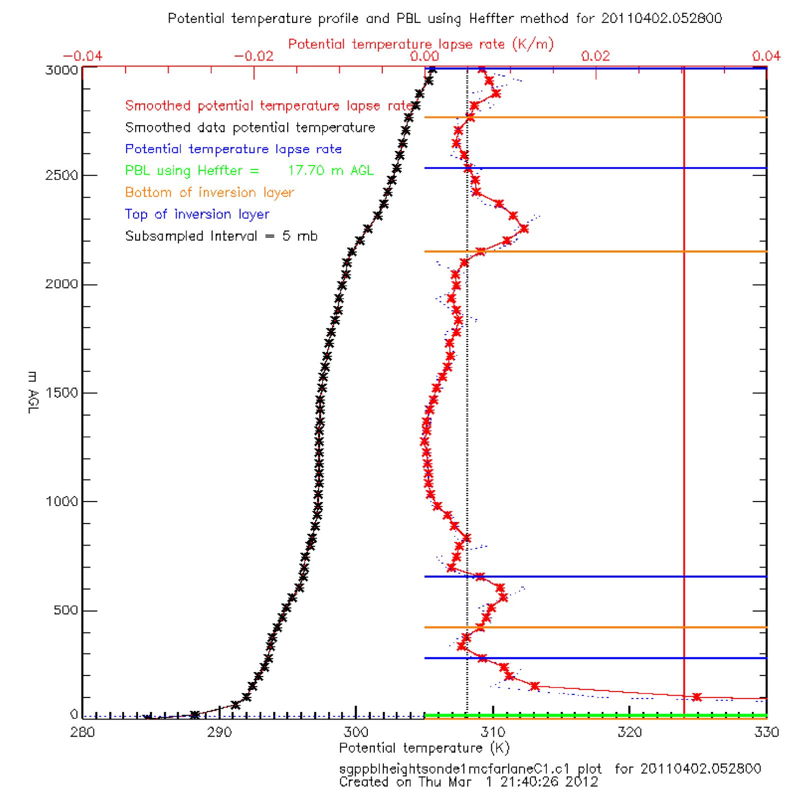

Figure 3: PBL determination using Heffter method when the profile was subsampled and smoothed at 5 mb and 15 mb respectively at SGP on April 02, 2011 when Liu and Liang method determined that the boundary layer was determined to be stable.

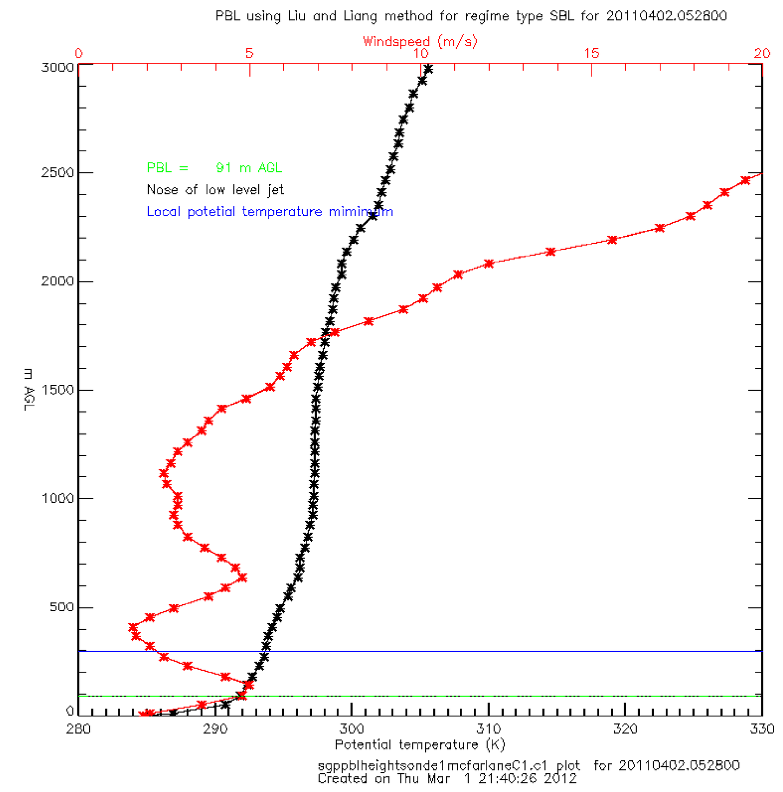

Figure 4: PBL and regime determination using Liu and Liang method when the profile was subsampled at 5 mb at SGP on April 02, 2011. This is an example when the boundary layer was determined to be stable.

Case Study

The Midlatitude Continental Convective Cloud Experiment (MC3E), a joint field program involving NASA Global Precipitation Measurement Program and ARM investigators, was conducted in south-central Oklahoma during the April to May 2011 period. Due to the frequent (4-8/day) sonde launches and importance of boundary layer development to convective initiation, this period has been chosen for initial evaluation of the VAP results.

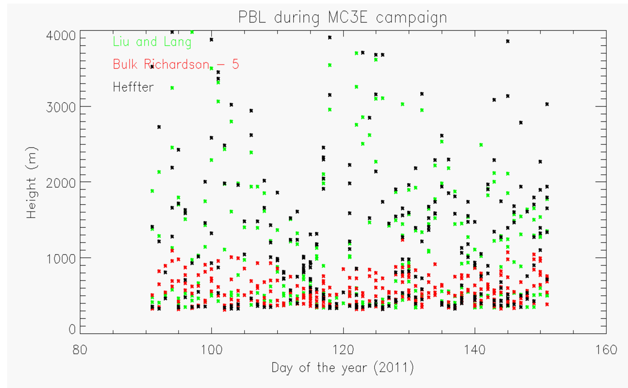

Figure 5: Results showing the time series of PBL height determination using Heffter, Liu and Liang, and the Bulk Richardson methods during the MC3E campaign.

The bulk Richardson method never retrieves PBL height greater than 1000 m AGL, while the other two methods allow elevated layers. We will examine the sensitivity of the bulk Richardson method to sonde resolution and choice of critical threshold.

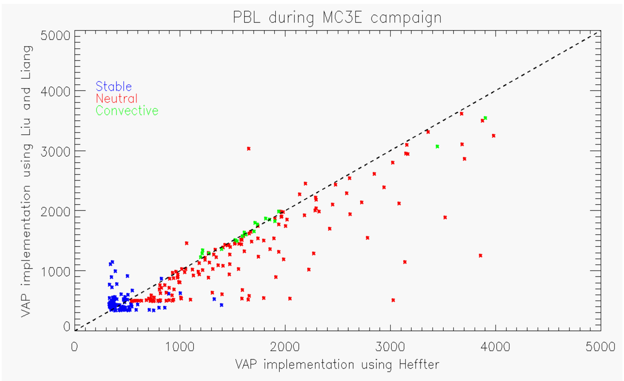

Figure 6: A comparison of PBL heights as determined by the VAP using Heffter and Liu and Liang methods during the MC3E campaign. PBL heights are categorized by the regime types from the Liu and Liang method.

The convective boundary layers show the best agreement between the two methods, while the stable and neutral boundary layers show larger differences. For the stable cases, differences are likely due to use of the low level jet information in the Liu/Liang method. For the neutral cases, some of the large differences may be due to multiple inversion levels being present in a profile.

Preliminary Evaluation

To understand the impact of choices made in the implementation of the Heffter method, the PBL height from the VAP was also compared to Marc Fischer's implementation of the Heffter method for April 2004.

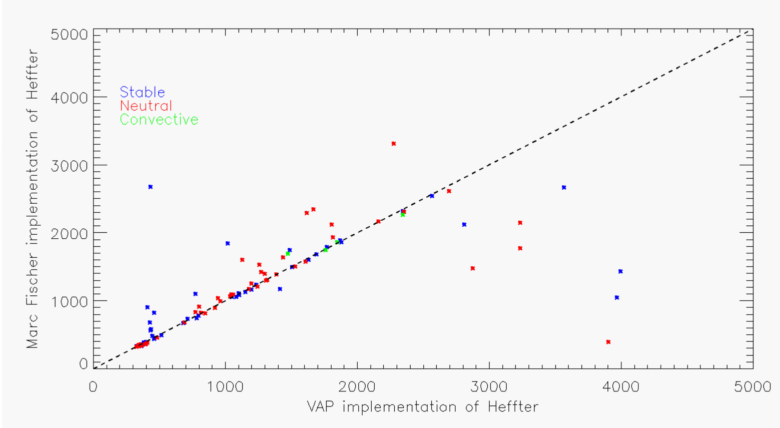

Figure 7: A comparison of the VAP implementation of Heffter method and Marc Fischer's implementation of Heffter method at Southern Great Plains (SGP) for the month of April 2004. The results are categorized by regime types using Liu and Liang method.

The few cases with large outliers will be examined further.

Future Work

We plan to implement the Structure of the Atmosphere (STRAT) algorithm as part of the VAP to determine boundary layer height using Micropulse Lidar and Ceilometer data. Initial results for a day of data during MC3E from both instruments are shown.

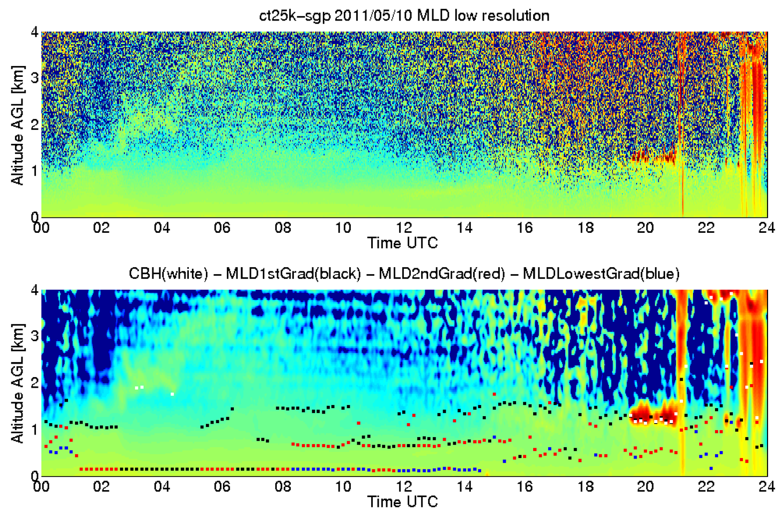

Figure 8: Boundary layer retrievals from STRAT algorithm applied to the Ceilometer data for May 10, 2010 at SGP. Top panel shows raw backscatter data, bottom panel shows smoothed data.

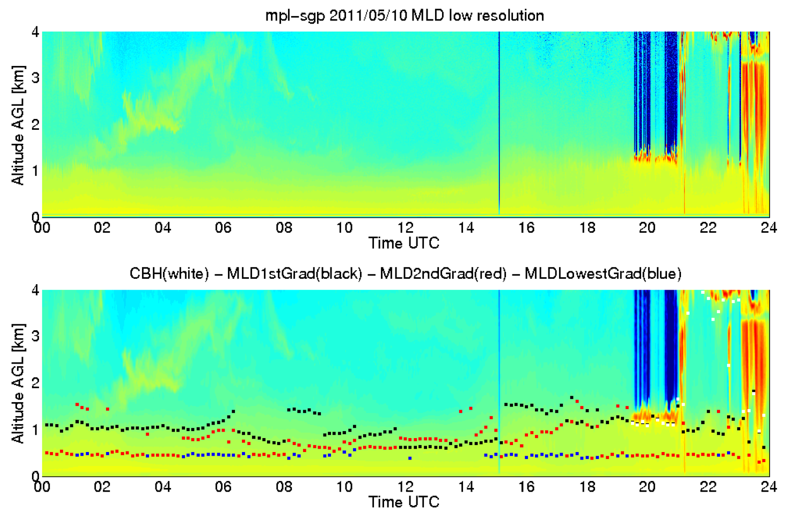

Figure 9: Boundary layer retrievals from STRAT algorithm applied to the Micropulse Lidar data for May 10, 2010 at SGP. Top panel shows raw backscatter data, bottom panel shows smoothed data.

Acknowledgements

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