COMPARISONS OF PBL-HEIGHT MEASUREMENTS BY CALIOP/CALIPSO, RADIOSONDE AND GROUND-BASED LIDAR

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ABSTRACT

In this talk, we demonstrate the potential retrieval of planetary boundary layer (PBL) height from the CALIOP/CALIPSO level-1B attenuated backscatter profiles. In particular, we find good quantitative agreement and correlation when compared to coincident observations from radiosonde and ground-based lidar. We further show the good consistency between the CALIOP-derived PBL height and the aerosol-layer-top of CALIPSO level-2 aerosol-layer products (5-km average). In addition, we demonstrate the value of PBL retrievals from CALIOP by exploring the spatial distribution of PBL heights and their seasonal over the US continent.

1. INTRODUCTION

The height of the planetary boundary layer (PBL) is an important parameter in air quality modeling and weather forecasting that affects the dispersion for air pollutants and turbulence [1]. Since lidar has been extensively demonstrated to observe the PBL height according to the sharp gradient of elastic scattering signal caused by the aerosol, the spaceborne lidar CALIOP/CALIPSO observations provide a good opportunity to derive the spatial distribution of PBL height over regional and global-scales [2-4]. In this study, we derive the PBL-height from the CALIPSO level-1B attenuated aerosol backscatter profile using the wavelet transform technique, and then evaluate the results by comparing with the radiosonde and ground-based CCNY-lidar observations, as well as CALIPSO level-2 aerosol-layer-top product in the low troposphere. We further provide preliminary results about the spatial distribution and variation of PBL heights over the continental US.

2. METHODOLOGY

The PBL height can be derived from the CALIPSO level-1 calibrated attenuated backscatter profile using the wavelet covariance transform (WCT) method that basically identifies sharp gradients of the range-corrected signal profile caused by aerosol distribution [5-6]. The covariance transform W_f (a, b) is a measure of the similarity of the range-corrected lidar backscatter signal and the Haar wavelet function. The selection of an appropriate value of the dilation 'a' is optimized which relates to the depth of the transition zone [7-8]. In addition, CALIPSO level-2 aerosol layer products provide aerosol-layer base and top, integrated attenuated backscatter, color ratio and depolarization ratio for different horizontal resolutions. Here, we focus on the potential of the 5 km resolution aerosol-layer-top within the low troposphere to identify and quantify the PBL top [9].

To match the CALIPSO and ground-based data in time and space, we choose the CALIPSO level-1B data with the distance of <90 km from the sites of CCNY-lidar and radiosonde. The level-1B signal profiles are firstly averaged over the 40-km horizontal range to improve the signal-to-noise ratio (SNR). Then, we screen out the low cloud data by checking the signal intensity, depolarization ratio and color ratio. The profiles blocked or totally attenuated by the mid to high clouds are also discarded by checking the near-surface return intensity. To see the correlation of aerosol-layer-top with the PBL-top, the data of level-2 aerosol-layer are selected with the following conditions: 1) single-layer (to avoid the influence of multiple-layers), 2) the layer must have a base lower than 0.3 km and top lower than 6 km (to avoid the aloft aerosol layer), and 3) the layer thickness must be greater than 100m (to avoid the random spike noise). In addition, to map the spatial distribution of PBL-height and aerosol-layer-top over the continental US, the level-1B data over the six-month long (June~August, 2006 and December 2006, Jan. ~ Feb. 2007) are analyzed to focus on differences between summer and winter as well as a more comprehensive two-year level-2 aerosol-layer data (June 2006-June 2008)

The ground-based CCNY-lidar site locates at the 40.821°N and 73.949°W in the east coast of US; the PBL height is calculated from the elastic scattering returns at 1064-nm channel with the wavelet transform technique [10]. Additionally, the radiosonde is routinely launched to measure atmospheric profiles (temperature, pressure, relative humidity and wind vector) twice per day at the Upton site, NY (OKX, 40.86N°/72.86°W). The observation time is at 7:00 am EST- eastern standard time in the morning and 7:00 pm EST in the night. According to the radiosonde data, the PBL height is commonly defined as the location with the sharp increase of potential temperature and sharp decrease of relative humidity [11]. The CALIOP overpass time near the radiosonde and lidar site is about 18:08 UTC (13:08 EST) in the day and 7:06 UTC (2:06 a.m. EST) in the night. The nearest distance of the CALIPSO ground track from the radiosonde site is ~7 km at night and ~40 km at noon while the distance of CALIPSO ground track from the CCNY-lidar site is about 40 km in the daytime.

3. RESULTS AND DISCUSSIONS

Figure 1 (a) shows a representative CALIOP attenuated backscatter coefficient profile (40-km or 120-shot average along the track) at wavelength 532-nm for the night of Aug.12, 2006. The multiple-layer structures of aerosol in this case are evident. The PBL height is found to be 1.81 km from the wavelet transform analysis and 1.75 km using the slope method. Figure 1 (b) gives the PBL heights (symbol '+') and level-1B image along the CALIPSO track. The PBL-heights generally match with the aerosol vertical structures, and also the low-cloud profiles are successfully screened out.

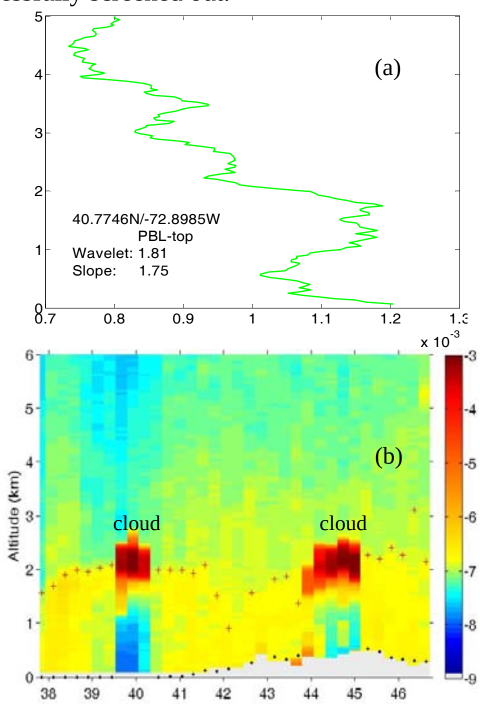

Figure 1. (a) CALIPSO level-1B attenuated backscatter profile (120-shot or 40-km average), (b) PBL heights (symbol '+') in the level-1B image along the track on Aug.12, 2006 (night).

We utilize 35days of coincident ground-based CCNY-lidar observations to assess performance. Over these days, we have 20 night cases when the PBL heights are derived from both CALIOP and radiosonde measurements after the cloud contaminated CALIOP profiles data were discarded. Figure 2 shows the day-by-day comparison and correlation between the CALIOP and radiosonde-derived PBL tops for night conditions. Good agreement is indicated with a correlation coefficient of 0.74 in Figure 2b. We note that the CALIPSO-derived PBL tops are a little lower than those by the radiosonde, which is probably caused by their differences on the observation time, location and range resolution.

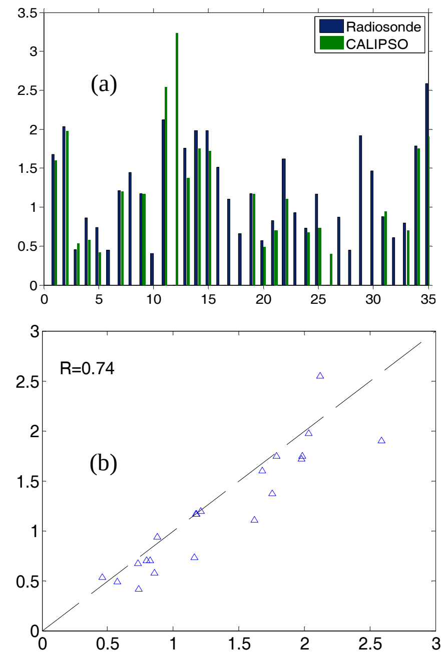

Figure 2. (a) Comparison between CALIOP/CALIPSO and radiosonde derived PBL-top nearby the OKX site in the night, and (b) correlation.

Figure 3 plots the comparison between the CALIOP- and CCNY-ground lidar derived PBL heights in the daytime. CCNY-lidar derived PBL-heights are averaged with the 1-hour centering at the CALIOP overpass time while the CALISPO-derived PBL-heights are averaged with the distance of 90 km from the CCNY-lidar site. Again, good quantitative agreement with high correlation are indicated.

Furthermore, in Figure 4, we extract the CALIPSO level-2 aerosol-layer-top and compare to the CALIPSO level-1B-derived PBL-top under the clear sky near the radiosonde site (OKX). The correlation coefficients are 0.96 for the only night time data and 0.877 for both day and night data.

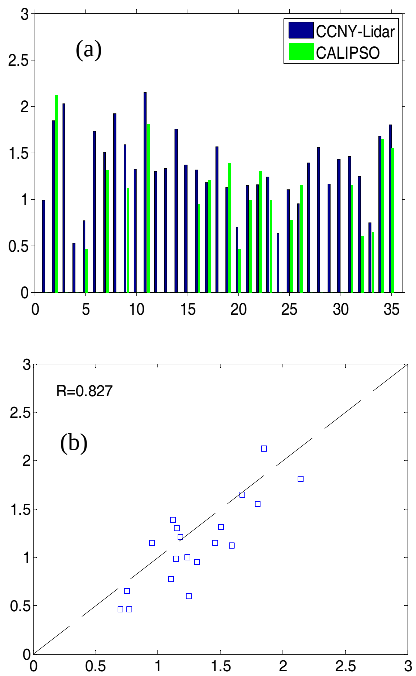

Figure 3. (a) PBL-height comparison of CALIOP/CALIPSO and ground-based CCNY-lidar measurements in the daytime, (b) correlation.

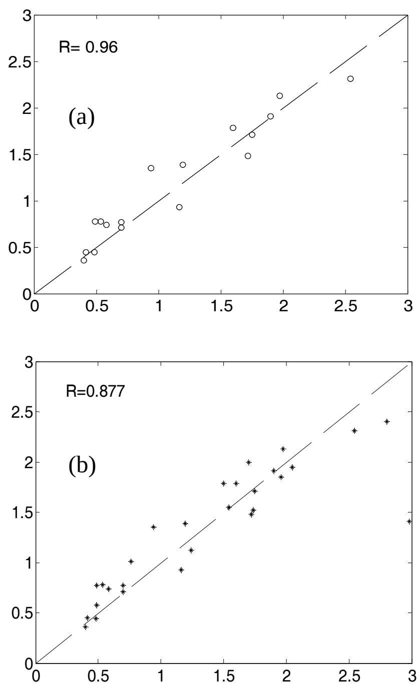

Figure 4. Correlation between the CALIPSO-derived PBL-top and aerosol-layer-top near the OKX site, (a) night data, (b) day and night data.

Finally, the spatial distribution of PBL heights is initially derived over the continental US with the 6-month level-1B data (June~August, 2006 and December 2006, Jan. ~ Feb. 2007, day+night data) and 2-year level-2 aerosol-layer products (June 2006-June 2008). The spatial grid resolution is taken with 1-by-1 degree in latitude and longitude. The PBL-heights are subtracted from the surface elevation which is provided in the CALIPSO product. The statistical histograms of PBL-top and aerosol-layer-top over the US continent are shown in Figure 5. Both show the similar distribution in summer and winter, respectively. But, the PBL-height shows the higher peak position than the aerosol-layer-top in summer, which may relate to the deep entrainment zone or transient layer, and further analysis is needed. The significant geographic difference of PBL-height is indicated with the low values over the coasts areas and these differences will be further enumerated in our presentation. In addition, we explore statistical differences between daytime and nighttime PBL height development. Further analysis and investigation with the current multiyear data will be presented and regional comparisons to models such as WRF will be presented.

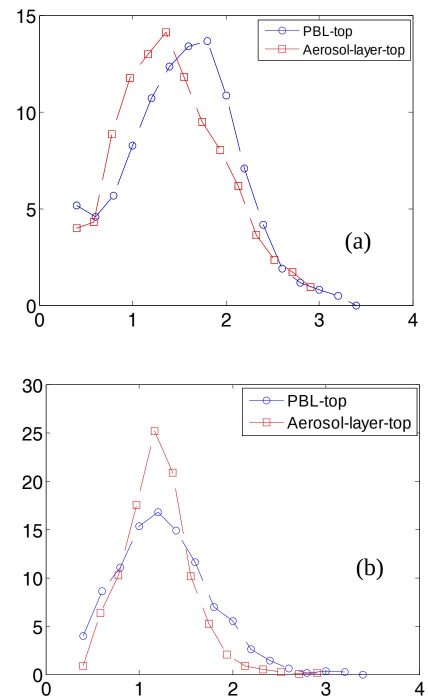

Figure 5. Histogram distribution of PBL-top and aerosol-layer-top from the CALIOP/CALIPSO data in the US continent. (a) Summer, (b) Winter.

4. SUMMARY

In summary, in this study we estimated the PBL height from the CALIOP level-1B attenuated backscatter profiles with the wavelet transform analysis. The comparisons with radiosonde and ground-based lidar measurement show good quantitative agreement and correlation with minimal bias detected. We also show the consistency between the CALIPSO-derived PBL-top and the particularly selected level-2 aerosol-layer-top in the lower troposphere. Preliminary statistics illustrate the spatial distribution of PBL-heights and aerosol-layer tops over the continental USA, together with seasonal, diurnal and geographic differences which are clearly illustrated. Further long-term statistical analysis on the PBL-top spatial distribution and variations due to geography, season and diurnal cycle will be further investigated and assessed against climate model forecasts such as WRF..

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