Boundary layer height by Lidar aerosols measurements at Chung-Li ($25^{\circ}N, 121^{\circ}E$)

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ABSTRACT:

By using the fluctuation of Lidar aerosol backscattering signals, it is possible derive regions of boundary layer. We have used this technique to measure boundary layer aerosol and boundary layer heights. We found that the nocturnal boundary layer (NBL) height is about 570 m in Chung-Li, Taiwan with a larger value in the summer and lower in the winter. The height of boundary layer is also compared with wind shear and temperature inversion based on Radiosonde data. The disagreement between these methods are discussed.

1. INTRODUCTION:

The planetary boundary layer (PBL) defined as the part of the troposphere that is directly influenced by the presence of the earth's surface, and responds to surface forcing with a time scale of about an hour or less. The boundary layer from sunset to sunrise is called the nocturnal boundary layer (NBL). It is often characterized by a stable layer, which forms when the solar heating ends and the radiative cooling and surface friction stabilize the lowest part of the PBL. Waves, which are frequently observed in the nighttime boundary layer, transport litter heat, humidity, and other scalars such as pollutants. These waves can be generated locally by mean-wind shears and by mean flow over obstacles [4]. However, accurate measurements representative of NBL heights are complicated due to interferences of temperature, humidity, cloud cover, wind speed and different aerosols constituents. The description of the NBL structure obtained from Radiosonde made at synoptic hours can not contribute to a complete understanding of meteorology, therefore, in this paper our purpose is to identify a method [2-3] that can be used on a large set of Lidar data to understand the evolution of NBL.

2. METHOD AND ANALYSIS:

The aerosol content of the lower atmosphere fluctuates under the continuous influence of particle source and deposition mechanisms. These fluctuations in aerosol amount, particular in the atmospheric boundary layer, can easily be monitored by mean of a Lidar as the scattering from aerosol particles contributes strongly to the Lidar backscattered intensity in this region. Thus the inhomogeneities in aerosol content can be used as tracers of the structure and stratification of the NBL which can be attributed to the phenomena of convective activity and turbulence.

We define the range-squared signal (RSS) as Eq. (1).

$$RSS = P_R * z^2 \tag{1}$$

Where P_R is the Lidar return signal, z is the range between the laser source and the target. The standard deviation is calculated from the temporal fluctuation of RSS at each altitude, as Eq. (2).

$$\sigma_{RSS} = [\frac{1}{N} \sum_{i=1 \ldots N} (RSS_i - \overline{RSS})^2]^{1/2} \tag{2}$$

Where RSS_i is obtained from individual range-squared signal for every 0.56 minute, the N =5 corresponds to the number of profiles for the time interval of 2.8 minute. The $\overline{RSS}$ is the mean value of range-squared signal obtained from the 5 profiles of individual range-squared signal. The top of boundary layer is determined as the maximum value of the σ_{RSS} and some σ_{RSS} data are eliminated due to extreme fluctuation, which caused by lower clouds.

3. RESULT AND DISCUSSION:

3.1 The comparison between different definitions of the NBL measurements

Fig.1 shows the result of measurement carried out on Jan 16, 2003. The case was chosen for its stability in the boundary layer. Fig.1 shows the profile of the time variation of the top NBL height which determined from the fluctuation of aerosol backscattering signals calculated by using Eq.(2) described above. The height of NBL varied from 0.8 to 1.15 km during the whole night around 10 hours. The NBL height measured by Lidar is also compared with temperature inversion and wind shear data from Radiosonde. The Lidar NBL has a mean height 0.86 km during 20:00 to 21:00 (local time compare to the time of launch Radiosonde), whereas that determined by temperature inversion is 1.18 km and that by wind shear is 1.06 km. The difference can be attributed to several factors including the NBL definition, location of measurements, and poorer height resolution of Radiosonde compared with Lidar. From long-term observation of the NBL height, the Lidar measurements and Radiosonde data between March 2002 and August 2004 are shown in Fig.2. In Fig.2, we just show the mean height of temperature inversion due to its uncertainty is large and in fact, sometimes the NBL determined by temperature inversion is loosely. The average heights of NBL measured by Lidar and wind shear are 0.57 and 0.68 km, respectively. The heights of NBL show the periodic variation and the highest of NBL observed in June were relative to the summer strong convection. Comparing the height derived by Lidar, wind shear and temperature inversion (not show here), we found that it was shown better correlation between the height measured by Lidar and determined by wind shear, the correlation coefficient is R=0.59 shown as Fig. 3. This result suggests a relationship between wind shear, turbulence, and boundary layer height.

3.2Aerosol and NBL

From measurements of aerosol optical depth (AOD), height of NBL and relative humidity made in 2002-2004 as shown in Fig.4., we found that AOD in 0.5-1 km is the highest in the summer (Jun.-Aug.) with the mean value around 0.12 and lower mean value is 0.04 occurred in the fall (Sep.-Nov.). The variations of the NBL height and relative humidity (distributed over 925hPa) show the similar trend that appear maxima mean value in summer, and minima mean value in winter (Dec.-Feb.). Fig.5 show the variation of mean turbulence intensity (σ_{RSS}) with maxim mean value in summer during 2002-2004. Therefore, the higher mean height of NBL in summer may be caused by stronger turbulence (show in Fig.5) which carried more pollutant or large particle to higher altitude and produced more scattering or/and the increase of relative humidity in summer (Fig.4) causing hygroscopic aerosols to grow and the scattering cross section of the aerosols to increase. However, aerosol in 1-3 km has the highest optical depth in the spring. This is related with the long range transport of aerosol from remote sources [1]. It has been recognized that springtime dust and biomass burning aerosols are both dominant compared with other seasons. Such transportation causes a second layer of standard-deviation value of the RSS at 1-2.5 km sometimes. When compared with Radiosonde wind data, we found this layer is closely related with high wind speed produced by lower level jet. The wind speed at this level can reach 18 m/s sometimes.

FIGURES:

(1)

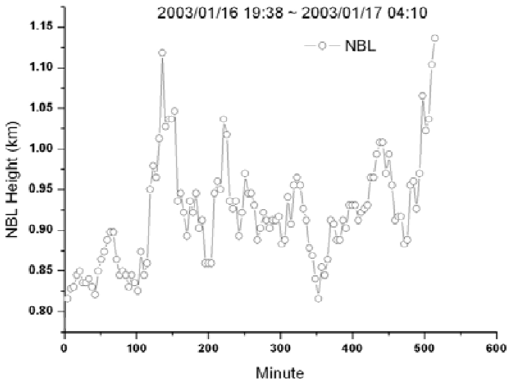

Fig. 1. The top variation of Nocturnal Boundary Layer (NBL) determined as the maximum standard-deviation value (σ_{RSS}) of the RSS with time.

(2)

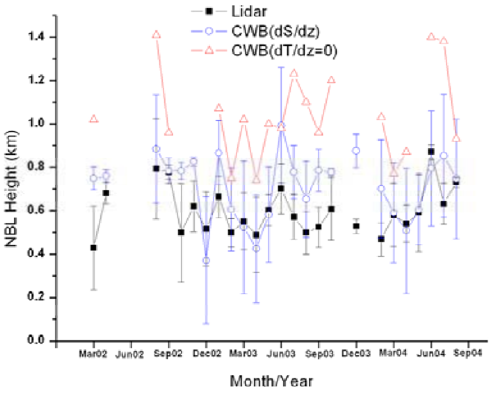

Fig. 2. The heights of NBL from the Lidar measurements (■) and Radiosonde data (CWB), including temperature inversion (△) and wind shear (○), between March 2002 and August 2004.

(3)

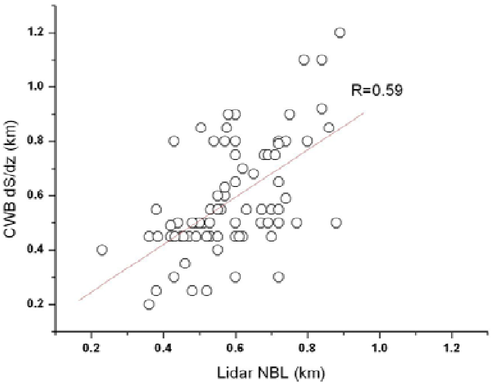

Fig. 3. The correlation coefficient is R=0.59 between the height measured by Lidar and determined by wind shear.

(4)

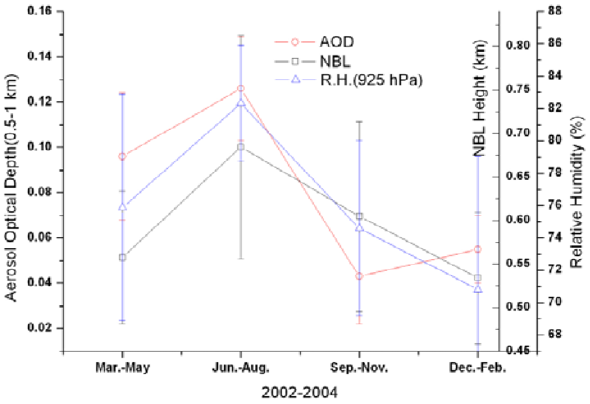

Fig. 4. The seasonal variation of the height of NBL (□), Aerosol Optical Depth (○) and Relative Humidity (△).

(5)

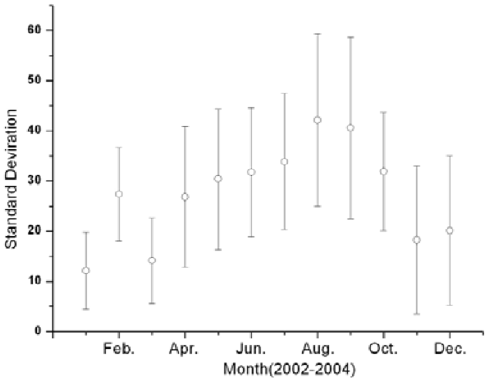

Fig. 5. The variation of mean turbulence intensity during 2002-2004.

REFERENCE:

1. Chiang, C.W., et al. Lidar measurements of spring dusts in 2002 at Chung-Li (25°N, 121°E), *TAO,* Vol. *15,* 813-824, 2004.

2. Flamant, C., et al. Lidar determination of the entrainment zone thickness at the top of the unstable marine atmospheric boundary-layer, *Boundary-Layer Meteorol.*, Vol. 83**,** 247–284, 1997.

3. Laurent, M., et al. Urban boundary-layer height determination from lidar measurements over the Paris area, *Appl. Opt.*, Vol. 38, 945-954, 1999.

4. Stull R.B., *An Introduction to Boundary Layer Meteorology*, Kluwer Academic Pulishers, Dordrecht, 1988.