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Aerosol Lidar Ratio Determination and Its Effect on Troposphere in Thailand

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Abstract

The empirical factor known as extinction-to-backscatter or lidar ratio (S) of Si Samrong district, Sukhothai province in Thailand were retrieved from radiosonde data for 5 consecutive days in April 2003 using Ackermann's numerical method. Daily mean aerosol lidar ratios (S_a) were obtained in the range from 50.268 ± 2.728 to 52.778 ± 2.383 which related to fine soil dust aerosols in troposphere. Since accurate lidar ratio is compulsory for estimating the aerosol optical properties and understanding transmission and reflection at the interested wavelength. Hence, this work was a preliminary attempt to retrieve the exact aerosol lidar ratio for Thailand in order to profoundly examine the roles of continental aerosol in regional climate corresponding to the available data at 532 nm wavelength from Mie scattering lidar measurement in the near future.

Keywords: Radiosonde; lidar ratio; mean aerosol lidar ratio; Mie scattering lidar; extinction-to-backscatter

1. Introduction

Tropospheric aerosols play a major role with both direct and indirect effects in our climate because of their relation to cloud formation and sunlight attenuation. Aerosols help to cool the lower atmosphere caused by the umbrella effect of scattering whereas absorption-type aerosols help to heat the atmosphere [1]. To understand the density and size distribution of aerosols as well as their optical

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properties, is essential and in the global interest. Takemura and Sasano [2] examined the extinction-to-backscatter or lidar ratio by determining from angular scattering measurements. The ratio, depending on wavelength and relative humidity, were calculated for four wavelengths. Results took the values of 66 ± 17, 60 ± 13, 52 ±13 and 42 ± 11 for the wavelengths 355 nm, 532 nm, 694 nm and 1064 nm, respectively. Tatarov [3] reported the systematic measurements of the particle optical properties especially the lidar ratio using a high-spectral resolution lidar over the period of August – December 2003 in Tsukuba, Japan. Mean values of aerosol lidar ratio by months over such period were in a range of 41 - 50 sr. Temporal and vertical cross-section of the lidar ratio, depolarization ratio, extinction and backscatter coefficients were obtained. Finally, the measured values of lidar ratio ranged mostly from 10 – 30 sr for ice cloud and 30 – 60 sr for aerosols.

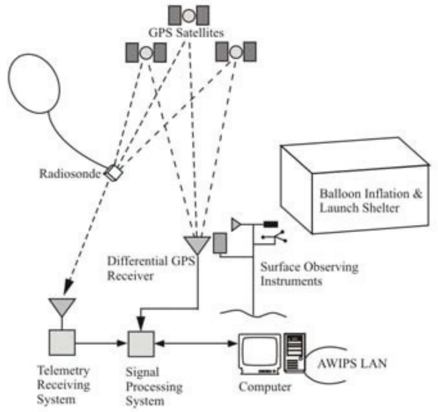
In real atmosphere, aerosol is a mixture of various components with different size distribution and refractive indices. As a matter of fact, some aerosol components change their size distribution and refractive indices due to variations of the relative humidity which often increases with altitude within the planetary boundary layer: PBL. Ackermann [4] proposed the numerical calculation of the extinction-to-backscatter ratio of tropospheric aerosol for the Nd: YAG wavelengths for continent, maritime and desert aerosols. For practical applications, the lidar ratio formula was in the form of a power series expansion with respect to the dependence of relative humidity whose data can be collected by radiosonde. Mitev et al. [5] performed the observation over Neuchatel, Switzerland during a case of winter Bise wind, using a ground-based backscatter lidar at a wavelength of 532 nm. They combined the lidar observed profiles with radiosonde measurements in order to show a coincidence of the altitudes of observed aerosol layers with the altitudes of the Bise wind layer. Besides, the lidar ratio of 50 sr was obtained by numerical study in Ackermann [4].

In this work, we intended to investigate a technique for lidar ratio calculation and also the values of aerosol lidar ratio for Si Samrong district in Sukhothai province whereas continental aerosol is mostly dominated. Because, the research site is typical rural area in the Midland of country without any industries, so the villagers have just their normal routine activities, yielding stable climate. This knowledge of lidar ratio could provide database of mean aerosol lidar ratio for rural area character in Thailand which is very useful for the further study of aerosol and cloud.

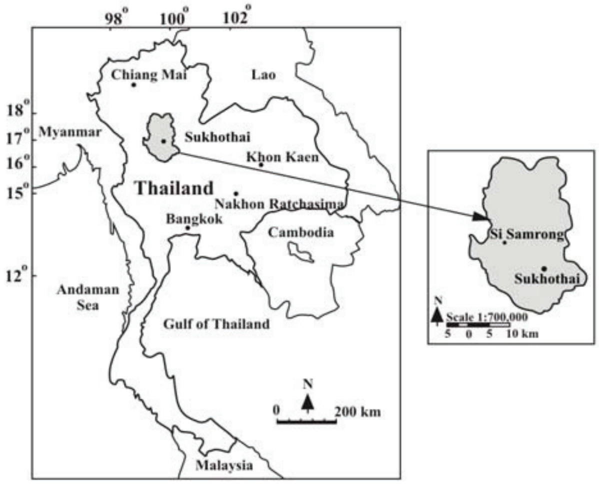
2. Measurements and Retrieval Algorithm

2.1 Radiosonde Instrument and Observation Site

Radiosonde [6] as shown in Fig. 1(a), is a balloon-borne instrument platform with radio transmitting capabilities. It contains instruments capable of making direct in-situ atmospheric measurements, such as air temperature, humidity and pressure with height, typically to altitudes of approximately 30 km. These observed data are transmitted immediately to the ground station by a radio transmitter located within the instrument package. The ascent of a radiosonde provides an indirect measure of the wind speed and direction at various levels throughout the troposphere. Radiosonde data were available only some clear sky days at every 3 hour interval from 00.00 – 21.00 LST, giving 8 period/day measurement. Data of 5 consecutive days from 22 – 26 April 2003 was analyzed in order to observe aerosol behavior in a representation of summertime.



(a)



(b)

Fig. 1. (a) Radiosonde diagram; (b) the research site at Si Samrong district, Sukhothai province

Sukhothai is located on the lower edge of the northern region, about 440 km far-away from Bangkok, roughly 1,200 m above sea level. Topography of Sukhothai typically features the basin of rolling plains with highlands and mountains stretching from the North to the West, Central plains and Southern highlands. Two main types of plains as, river and hillside plains are available for the agricultural cultivation. Nowadays, people do less crop cultivation due to the regular annual flood. Si Samrong district (17° 0′ 21″ N, 99° 49′ 35″ E) as shown in Fig. 1(b), was selected as the study area due to its landscape and location in the Middle of Chao Phraya basin, physically forming the heart of the Kingdom of Thailand.

2.2 Ackermann Algorithm

The empirical formula of lidar ratio, was introduced by Ackermann (Ackermann, 1998, [4]):

$$S(f) = \sum_{j=1}^{J} a_j f^{j-1} \quad (1)$$

obtained by radiosonde data, a_j is the polynomial coefficients and j is the total number of the coefficients. The relevant coefficients are listed in Table 1.

Table 1. Order coefficients for the power series expansion of the mean lidar ratio formula for continental aerosols at 532 nm wavelength

Order coefficient	Value of coefficient
a_1	4.531 x 10
a_2	2.628×10^{-1}
a_3	-3.085×10^{-3}
a_4	1.334×10^{-4}
a_5	-2.356×10^{-6}
a_6	1.412×10^{-8}

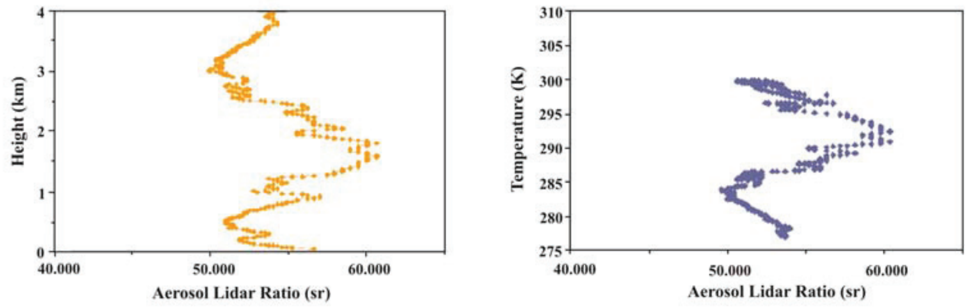
From the light scattering theory, the basic assumption of molecular density profile in the atmosphere is reasonably well known by the expression :

$$S(z) = S_a(z) + S_m(z) \tag{2}$$

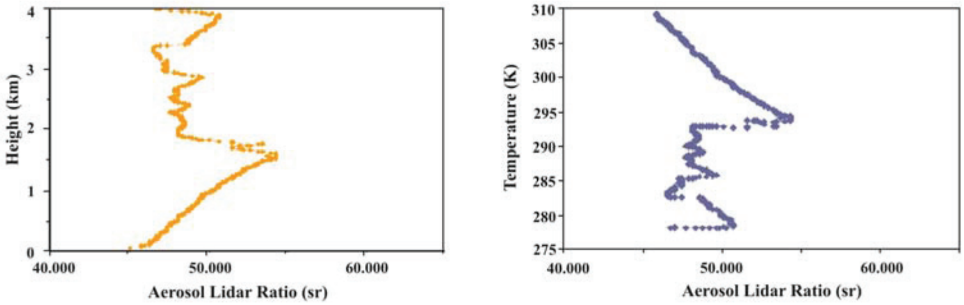
where both S parameters refer to lidar ratio, the subscripts a and m stand for aerosol and molecule, respectively. And z refers to the vertical height or distance in the atmosphere, generally, S_m is $\frac{8\pi}{3}$ sr. Depending on the aerosol type, S_a can be assumed in the range 10 sr < S_a < 100 sr. Cleaner atmosphere would be better explained by S_a closer to the lower limit while polluted atmosphere would reach the value of S_a greater than 40 sr [7].

3. Results and Discussions

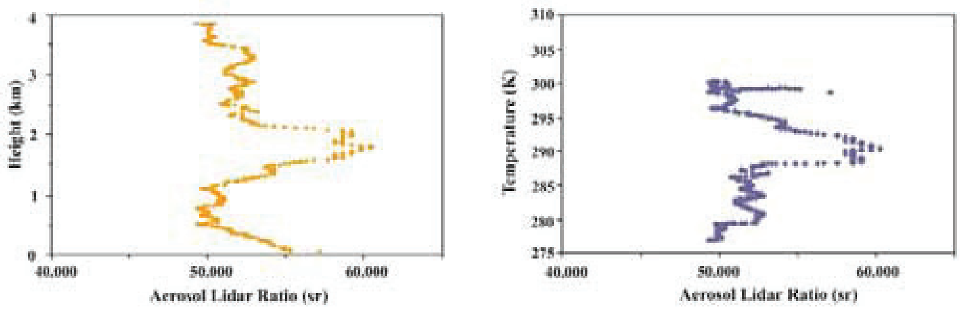
The measured data provided vertical H - T profiles of aerosol lidar ratio of April 2003 are shown in Fig. 2 for the height up to 4 km due to high concentration of aerosol in the first few kilometers above ground level [8]. Mean values of daily aerosol lidar ratios are reported in Table 2. In Fig. 3, the obtainable results show that the aerosol lidar ratios are in the range from 50.268 ± 2.728 to 52.778 ± 2.383, correlated to fine soil dust aerosols which come from anthropogenic source due to local routine behavior of the villagers. Besides, there is a good agreement between our result with ones obtained by the experimental method in the cited references [1, 3]. Thus the Ackerman algorithm are a practical tool for lidar ratio estimation at a Nd:YAG laser wavelength of 532 nm.



(a) 00.00



(b) 09.00



(c) 21.00

Fig. 2. H - T profiles of aerosol lidar ratio on 26 April 2003 at (a) 00.00; (b) 09.00 and (c) 21.00 LST

Table 2. Daily results of all corresponding parameters at Si Samrong district, Sukhothai province

Date in	**Mean values of**		
April 2003	**RH** (%)	**T** (K)	S_a (sr)
22nd	59.724	290.954	51.514 ± 4.332
23rd	67.011	290.921	52.778 ± 2.383
24th	56.689	290.492	50.268 ± 2.728
25th	59.336	291.054	50.807 ± 2.763
26th	62.000	290.940	51.507 ± 2.317

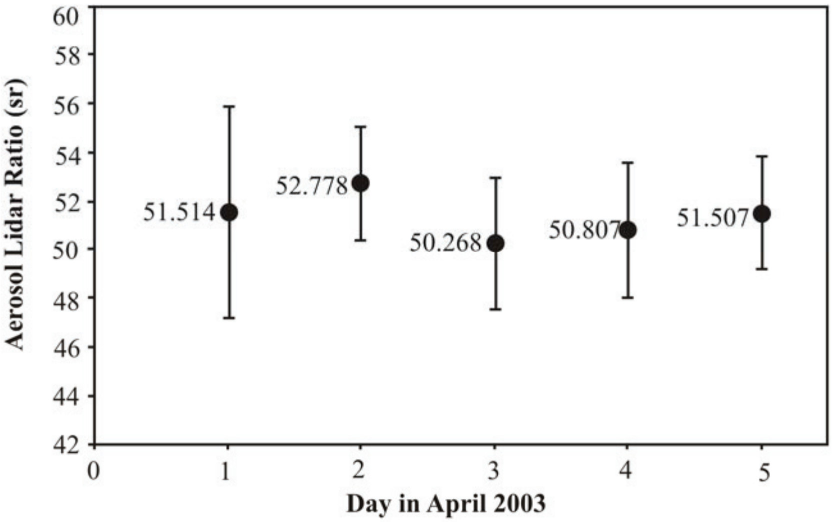


Fig. 3. Daily mean of aerosol lidar ratios of 5 consecutive day data from 22–26 April 2003, representing summertime of the year

4. Conclusion

In summary, the lidar ratios and their standard deviations for rural aerosol with the dependence on relative humidity are primarily observed. In fact, there exist a wide range of variability of aerosol in troposphere, giving us the remained interesting aspect to study aerosol in deep details such as size distribution, cloud trend and optical properties. Hence, the aerosol vertical profiles are required by additional considering Mie scattering data which could technically provide the implemented parameters. Since the mechanism of radiative distribution is still complicated and challenging, so the comprehension of the roles of tropospheric aerosol in regional climate should be pursued in order to benefit the knowledge of aerosol in Thailand.

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