SEASONAL AND INTER-ANNUAL VARIATIONS OF VERTICAL AEROSOL DISTRIBUTION OBSERVED IN THAILAND

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ABSTRACT

National Institute for Environmental Studies (NIES) had operated a dual wavelength Mie-scattering lidar with polarization detectability at Sri Samrong, Thailand (99.95E, 17.15N) for three and a half years in order to observe climatological aerosol structures in Southeast Asian region where the biomass burning is one of the dominant sources. From analysis of four dry seasons, seasonal increasings of optical thickness and depth of surface aerosol layer were confirmed every year. Also year to year variation was fairly large. Hot spot numbers detected from a satellite did not varied so much during these four years, and atmospheric stability (vertical gradient of the temperature) had corresponded with the interannual variation of aerosol concentration. It is suggested that the vertical structure of aerosols in this region is mainly determined by the vertical mixing from the surface to the free troposphere.

1. INTRODUCTION

In Southeast Asia, carbonaceous is one of significant sources of tropospheric aerosols during dry season[1]. The organic carbon and black carbon are considered to absorb the solar radiation effectively, and it causes substantial heating near the surface. This mechanism may affect the climate system in this region, and understandings of vertical structure of aerosols and its variations in various time scale are important to illustrate the whole climate system including radiation mechanism. Lidar is an ideal system to measure the vertical distribution of aerosols. In this paper we describe the aerosol distribution in the four dry seasons following the methodology of lidar observation and data analysis. Next, fire spot numbers derived from a satellite and atmospheric stability derived from routine upper air sounding data are compared with the variations of aerosol distributions.

2. LIDAR OBSERVATIONS AND ANALYSIS METHOD

NIES installed a dual-wavelength polarization lidar in Sri Samrong atmospheric observatory which is located in the northern part of Thailand on October 2001. Many radiation measurement equipment and aerosol detector/analyzers were also installed in this observatory. For the lidar, a Nd:YAG laser, a telescope with diameter of 20 cm, two photomultiplier tubes and an avalanche photo diode, and a digital oscilloscope were employed. The system was controlled by a Linux PC and operated automatically without human attendance. The specification of the lidar is similar to that of NIES dust network lidars[2; 3]. This system measures the vertical profiles of backscatter in both of 532 nm and 1064 nm four times per hour, regardless of weather conditions. In this paper the results of 1064 nm are not mentioned because of the difficulty of sensitivity corrections. For obtained data in fine conditions (cloud free or cloud were detected in the upper troposphere only), we introduced Fernald's method [4] to retrieve extinction coefficient of aerosols (α) at 532 nm from backscattering intensities. The maximum height of the analysis is fixed at 5 km and non-zero α is assigned there to avoid negative α between the surface and 5 km altitude. Backscattering coefficient of molecular is determined from air density profiles of U.S. Standard Atmosphere[5], and the extinction to backscatter ratio (S_1) is set to 50 sr. Details of this method is precisely described in a paper where same method was applied for a shipborne lidar observation results over western Pacific[6].

3. VARIATIONS OF MONTHLY MEAN PROFILES AND OPTICAL DEPTH

Figure 1 shows monthly mean profiles of α at 532 nm in the lower troposphere during November and April in the following year for four dry seasons (2001-02, 2002-03, 2003-04, 2004-05). At the beginning of dry seasons, aerosol concentration is generally small, and a boundary layer structure with top height around 2 km is clear. As the season proceeds, the concentration near the surface becomes larger, and the clear structure had disappear. Finally at the end of dry seasons, the top of the gentle slope of α reaches around 5 km.

Seasonal and inter-annual variations of optical depth (τ) at 532 nm, integrated α vertically, are shown in Fig. 2. In each year τ reaches its maximum between February and April in three seasons. However, the absolute value differs in different years. The highest value in 2001-02

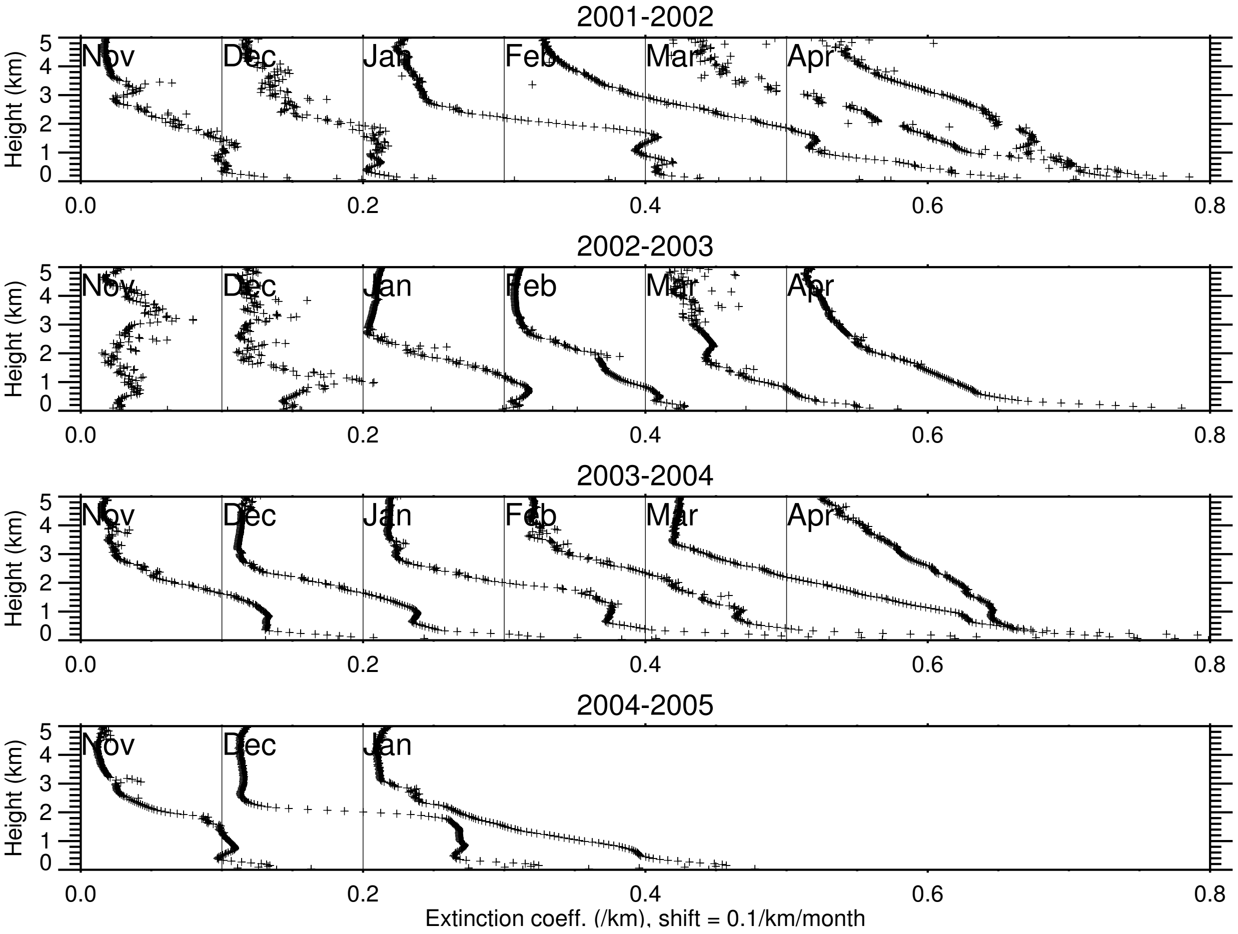

Fig 1. Monthly mean vertical distribution of aerosol extinction coefficient (α) at 532 nm during November and April for four dry seasons. α is derived from backscattering measurement utilizing Fernald's method. Profiles are shifted 0.1/km per month. Four panels corresponds to the dry seasons in 2001-02, 2002-03, 2003-04, and 2004-05 from the top to the bottom.

season was 0.75 and that in 2002-03 was 0.35. The value in 2002–03 was small throughout the dry season. The mechanisms for these seasonal variations and differences among years are considered in the following section.

4. NUMBER OF FIRE SPOTS AND ATMOSPHERIC STABILITY

At first the variations of the aerosol emission was investigated to explain the variations of the optical depth. In Southeast Asian region carbonaceous aerosols are considered to be emitted from biomass burnings. As in-house burning may not vary year-to-year so large, the wild fires may contribute for year-to-year variation of the aerosol concentration. In this study the number of fire spots detected by ERS-2 ATSR (—2001) [7] and ENVISAT AATSR (2002—) were employed to represent the wild fire activities. The fire spots are defined as areas where the surface temperature estimated by 3.7μm band exceeds 312K in the night time. Although observation of surface fires from satellite is affected by clouds, continuous lidar observation revealed that the clouds did not appeared so frequently. Figure 3 shows variations of fire spot numbers in Indochina peninsula for four dry seasons. Patterns of seasonal variation of fire spot numbers show some agreements with optical depth variations in Fig. 2. However, differences among four years are not well accounted by fire spot numbers. The tendency does not change greatly if we count the numbers only in smaller region (Chao Phraya River basin).

As another candidate to account for the year-to-year variation of aerosol concentration is the difference of transport of aerosols from the surface to the troposphere. Figure 4 indicates the time-height cross sections of atmospheric stability (vertical gradient of temperature) calculated from daily upper air soundings in Bangkok (98.98E, 17.78N). Although the distance between Bangkok and Sri Samrong is almost 300 km, both of them are located in the basin of Chao Phraya River and no mountains divide these two regions. In Fig. 4, very stable layer (positive dT/dz) appeared on November or December in 2001, 2003, and 2004. However, no stable layer appeared on November nor December in 2002. This difference im-

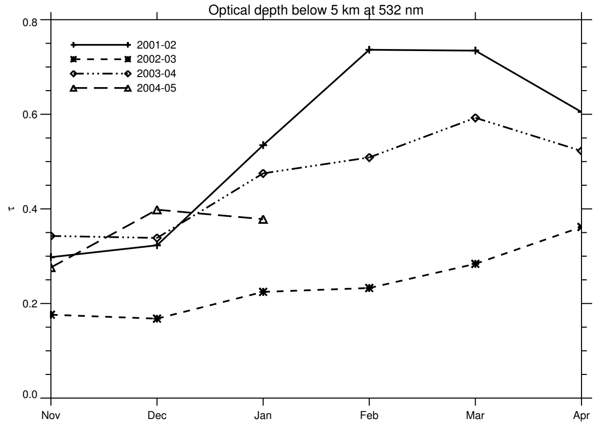

Fig 2. Monthly mean aerosol optical depth (τ) at 532 nm below 5 km, calculated from the extinction coefficient by the lidar (α). α, shown in Fig. 1, is derived from backscattering measurement and Fernald's method.

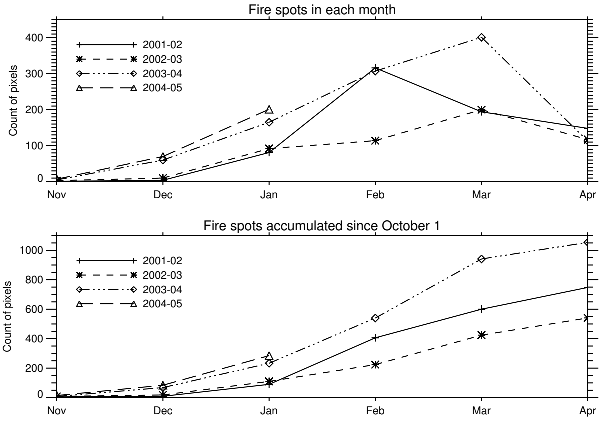

Fig 3. Numbers of fire spots in each month (top) and numbers accumulated since November (bottom).

plies that the stable layer capped the top of the surface boundary layer and confined aerosols emitted from the surface. This mechanism explains the clear structure of boundary layer, and the increment of aerosols in this layer. Even in 2002-03 season, on January a stable layer appeared and the aerosol profile in Fig. 2 shows a boundary layer structure. In the latter half of the dry seasons the stable layer disappeared. Then the vertical mixing became active and the aerosols near the surface were transported to the middle troposphere. The smooth slopes of α up to 5 km in the end of dry seasons shows the vertical diffusion with the source near the surface. The cause of the differences in the atmospheric stability is not obvious, however in 2002-03 El Niño occurred. Some larger structures of atmosphere or climate system may affect the atmospheric stability in Southeast Asia, and control the vertical distribution of aerosols in the troposphere.

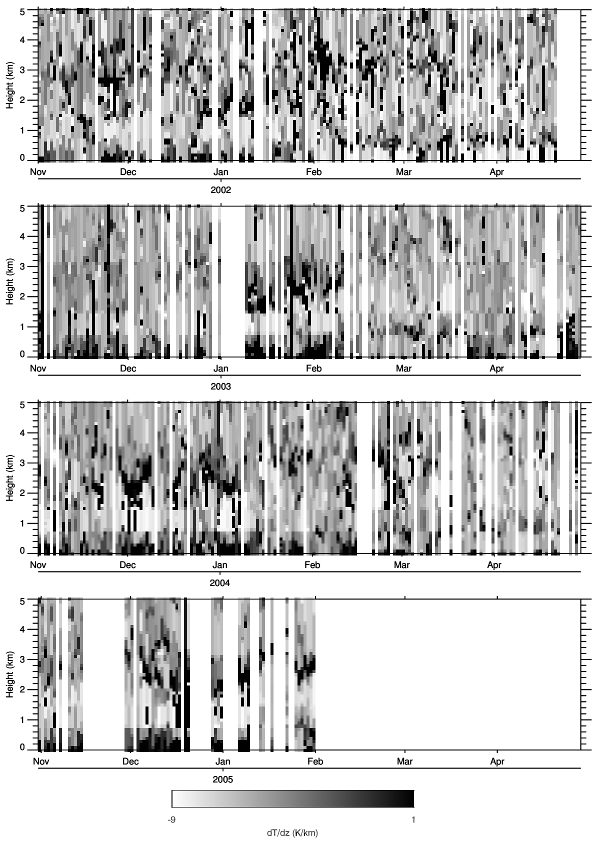

Fig 4. Time-height cross sections of the atmospheric stability (vertical gradient of the temperature), calculated from routine upper air soundings at Bangkok.

5. CONCLUDING REMARKS

Continuous lidar observation during four dry seasons in Thailand revealed seasonal and inter-annual variation of vertical distributions of aerosols. In ordinary years a clear structure of the boundary layer appeared at the beginning of the dry seasons, and it disappears as the season proceeds. Finally the smooth gradient of aerosol concentration reached up to 5 km. However, in one season the variation showed large differences from other years. It was not explained by the variations of sources, and the vertical transport controlled by the atmospheric stability may account for these differences. The effects of larger climate systems like El Niño have to be considered as the reason of the stability.

The observation in Sri Samrong finished on January 2005, and the lidar moved to Phimai (102.56E, 12.18E) with other radiation equipments. Continued observation in the center of Indochina peninsula may contribute the understandings of aerosol behavior and climate in this region.

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