CIRRUS CLOUDS CLIMATOLOGY OVER THE EQUATORIAL REGION

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ABSTRACT

The lidar observation project of atmospheric structure over troposphere, stratosphere, mesosphere and low thermosphere above Kototabang (100.3E, 0.2S), Indonesia in the equatorial region has started from 2001. The lidar facility consists of the Mie and Raman lidars for tropospheric aerosol, water vapor and cirrus cloud measurements, the Rayleigh lidar for stratospheric and mesospheric temperature measurements and the Resonance lidar for metallic species and temperature measurements in the mesopause region. In this paper, we present the climatological characteristics of cirrus cloud obtained from the Mie lidar system.

1. INTRODUCTION

Cirrus clouds in the upper troposphere have attracted much attention because of their impact on the radiation budget [1]. They affect the earth's climate by reflecting incoming sunlight and regulating heat loss from the earth's surface. Due to the differences in their microphysical and optical properties, they cause a warming effect at tropics and a cooling effect at midlatitudes. Cirrus clouds are further thought to be the platform for the genesis of heterogeneous reactions that play an important role on the ozone budget in lower stratosphere/upper troposphere. Accordingly, a study on such clouds in tropics assumes significance, as vertical transport of air from troposphere to stratosphere is believed to occur mostly in the tropical region. The observations on cirrus clouds in the tropical region, however, are very few, so the fact that formation of cirrus in this region is more prevalent because of very cold environment [2].
Some experiments were conducted to investigate the importance of cirrus clouds using various techniques such as lidars on the Space Shuttle [3], the aircraft [4], and the ship [5]. Ground-based lidars have been used to study high temporal and spatial structure of cirrus at low latitudes such as at Nauru Island (1S) [6], Reunion Island (21S) [7], Mahe Seychelles (4S) [8] and Gadanki (14N) [9]. Based on the results from these observations, and using optical depth (tc) as a differentiator, the cirrus clouds can be classified into two categories, namely, optically thin (tc < 0.03) and thick (tc > 0.03). The thin cirrus has not only less optical depth but also less spatial thickness than the thick cirrus and it has been widely observed at different locations. Dowling and Radke [1] reviewed the existing observations on thin cirrus clouds and concluded that such clouds have the thickness of the order of 1.5 km and usually occur at an altitude of about 9 km. From the satellite measurements, such clouds are observed mostly in the tropics. Using SAGE II observations, Wang et al. [10] studied the climatological aspects of thin cirrus systems over the equator and showed that these clouds have optical depths less than 0.02, have 45% occurrence frequency and occur at an altitude of about 15 km.
Though the satellite observations provide valuable information on cirrus clouds, they have limitations on spectral, temporal and spatial sampling characteristics. The lidar technique has been successfully used to measure the scattering and depolarization characteristics of the high altitude clouds with good time and height resolutions. However, information on cirrus clouds in equatorial region for longtime observation is still scarce.
In this paper, the climatological characteristics of cirrus clouds using lidar observations at a Kototabang (0.2 S, 100.3 E), are presented. The study also includes the statistical variations of the above parameters based on observations made during April 2004–March 2006.

2. SYSTEM DESCRIPTION

We have constructed the lidar facility beside EAR (Equatorial Atmosphere Radar) at Kototabang (100.3E, 0.2S), Indonesia. The lidar system consists of the Mie and Raman lidars for tropospheric observations, the Rayleigh lidar for stratospheric and mesospheric temperature observations, and the resonance lidar for observations of metallic species and atmospheric temperature in the mesopause region. The laser system included in this lidar facility consists of four pulsed Nd:YAG lasers, two pulsed Ti:Sapphire laser and a dye laser. The receiving system consists of a Schmidt-Cassegrain telescope with 20cm diameter, a Schmidt-Cassegrain telescope with 35cm diameter and five Newtonian telescopes with 45cm diameter.
The most parts of this lidar system will be remotely controlled via the Internet from Tokyo Metropolitan University (TMU) in Japan. The lidar system is basically self-controlled and the remote control functions are limited the necessary control indication and grasping the situation. As an anti-blackout

measurement, we use a large UPS (Uninterrupted Power Supply) and all instruments can remotely restart. Parameters of the lasers can set remotely and monitor the situation by several cameras for safety. We connect to a LINUX server by SSH (Secure SHell) for network security, and use Windows 2000 based computers for interface with hardware. We also install SSH on Windows 2000, so we can update or start of a program.
For continuous cirrus cloud observation, we use small Mie lidar system with an Nd-YAG Laser operating at its second harmonic of 532 nm with energy of 20 mJ and a pulse repetition frequency of 10 Hz. The receiver employs a compact Schmidt-Cassegraine type telescope with an effective diameter of 20 cm. A beam splitter is employed for splitting the beam into Lo- and high-intensity components with two channels, using identical photo-multiplier tubes (PMTs) and amplifiers. The outputs of the amplifiers are connected to 12-bit AD-converters, which records 3000 laser-shot averaged profiles for both channels as one frame with a time resolution of 300 s and range resolution of 30 m.

3. OBSERVATIONS

Daily frequency distributions of effective data acquisition for each altitude observed by the Mie lidar at Kototabang are shown in Fig.1. Continuous observation is started from April 2004, but from March to June in 2005, data lack for a long time because of the laser trouble. We could get enough data for a period except it.

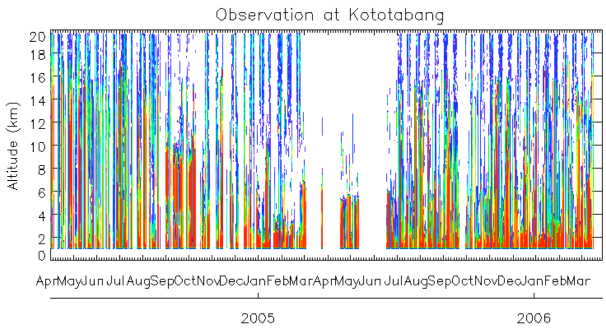

Fig. 1 Daily frequency distributions of effective data acquisition for each altitude.

We show an example of one day Mie lidar observation (Backscatter ratio at 532nm as a function of local time and altitude) in Fig.2. We closed a shutter of a window and stop observation from 11LT to 13LT to avoid direct injection of the sun light to the PMTs. The scattering ratio computation is accomplished by the normalization of the data with molecular density at a specified altitude (18km) taken from a model atmosphere (CIRA-86). When enough SNR can not be got by attenuation by clouds, we suppose that power of a laser, loss of optical system are unchangeable and convert the range corrected signal to the scattering ratio directly. In Fig.1, between 0-10LT, lower clouds of an altitude of 3km obstruct higher cloud, but after 10LT, cirrus clouds are observed at an altitude of 12-16km. In addition, a strong signal by the rain is observed at 03LT.

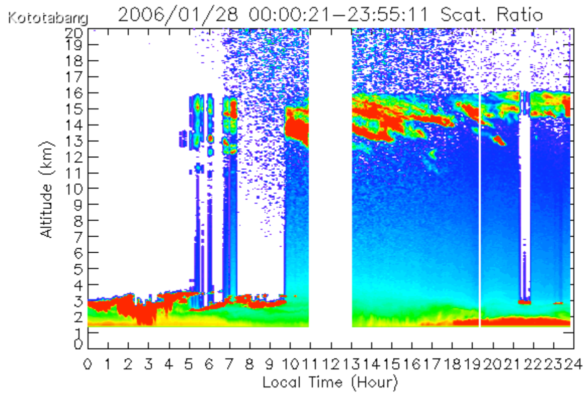

Fig.2 Example of Mie lidar observation. Backscatter ratio at 532nm as a function of local time and altitude.

4. RESULTS AND DISCUSSION

Using the data collected from April 2004 to March 2006, an attempt has been made to study the climatology of cirrus clouds over Kototabang (0.2 S; 100.3 E). From the scattering ratio data for each altitude, we count effective observation time and cloud observation time where the scattering ratio is greater than 3. We can get cloud occurrence frequency as cloud observation time / effective observation time. So-called subvisibul cirrus is not included in this count. In addition, we exclude less than an altitude of 5km because discrimination of scattering signal from a cloud to a raindrop or meaty aerosol are difficult. We show a seasonal variation of cloud occurrence frequency in Fig.3. We can see that cloud occurrence frequency is high at an altitude of 10-15km and from October to March (monsoon season). In addition, most of clouds do not occur in lower than an altitude of 10km in the dry season, but from November to December, even in lower than an altitude of 10km cloud occurs. We show local time dependences of cloud occurrence frequency in monsoon season (October-March) and in dry season (April-September) in Fig. 4 and Fig.5 respectively. We can see that cloud occurrence frequency is higher in nighttime than in daytime for both seasons. In addition, we can see that cloud occurrence frequency is higher in midnight at an altitude of 5-10km in monsoon season.

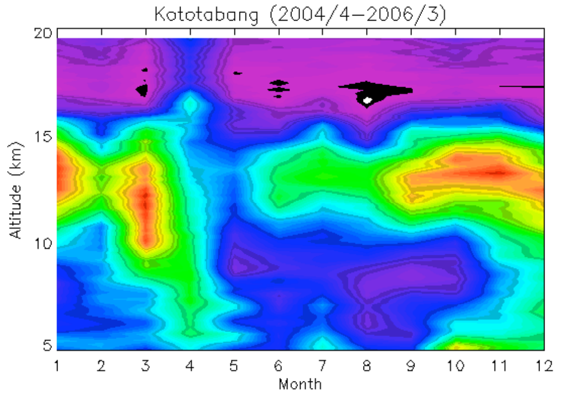

Fig.3 Seasonal variation of cloud occurrence frequency.

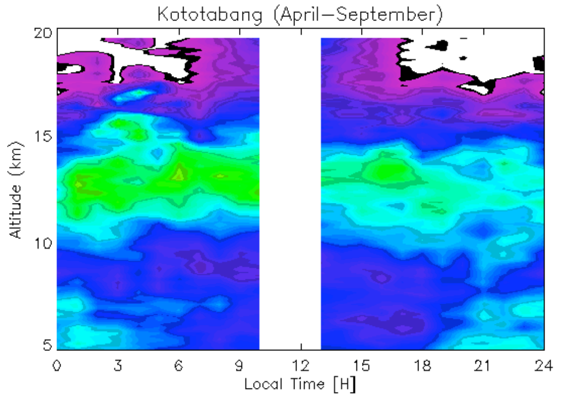

Fig.4 Local time dependence of cloud occurrence frequency (Monsoon season).

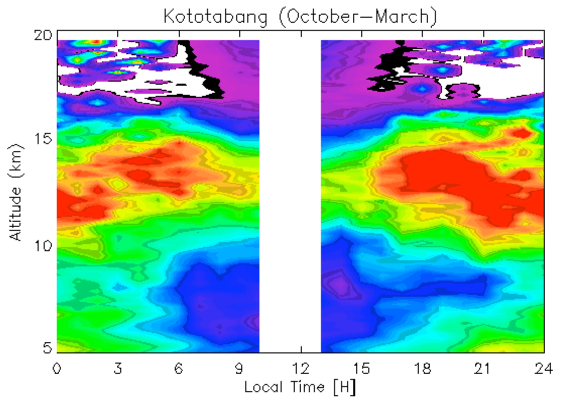

Fig.5 Local time dependence of cloud occurrence frequency (Rainy season).

We show the power spectrum for time series of cloud occurrence frequency. The lacked data are interpolated. In a range of an altitude of 6-15km, a period of 20 days component is dominant. This period accords with a period of convective activity in the tropics, which is conventionally reported.

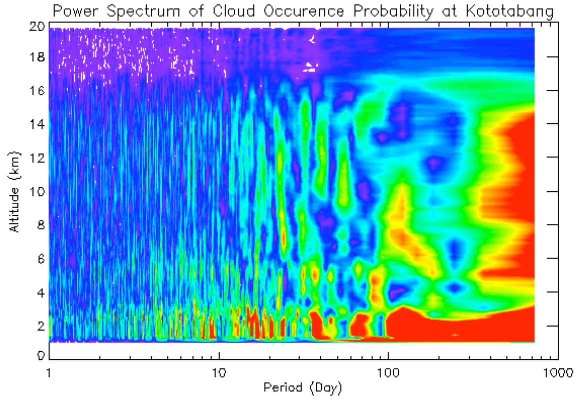

Fig.6 Power spectrum of cloud occurrence frequency.

5. CONCLUSIONS

The lidar data collected over Kototabang (0.2 S; 100.3 E) were used to characterize the tropical cirrus climatology.

A polarization lidar with a photon count mode operates at the nighttime of fine weather from August 2005. This lidar can observe polarization characteristics of subvisibul cirrus that observation was difficult with a small lidar. Microphysical study of cirrus cloud is expected in future using this data.

ACKNOWLEDGMENTS

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