Cloud behavior in rainy season in Thailand observed by a lidar (Session 1: Radiation studies)

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Cloud behavior in rainy season in Thailand observed by a lidar

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1. Introduction

In GAME project, radiation is observed to monitor the radiative properties in Asia and support the other activities. Radiation monitoring at GAME is carried out at two sites in China and Thailand. In China, it was constructed in Shouxian (Anhui Province) and it was moved to Hefei (Anhui Province) from 1999. In Thailand, the radiation site was constructed at an agrometeorological station, Sri Samrong (17:09N, 99:57E), 500 km north of Bangkok. It was under Thai Meteorogical Department (TMD). There a lidar system was installed to monitor the cloud base height in addition to radiometers such as sky radiometer, pyranometer and pyrageometer. In this report, the lidar system is introduced with analysis method, and the data from July 1997 to January 1998 were analyzed to give the cloud behavior. This period corresponds to the rainy season to the beginning of the dry season.

2. MPL Lidar and Sri Samrong

The lidar system installed at Sri Samrong in Thailand is a micro-pulse lidar (MPL), which was developed by NASA and was manufactured by SESI Inc. It consists of a diode-pumped high-repetitive-pulse solid-state laser and a Cassegrain type telescope. The repetition frequency of MPL is 2500 Hz and the interval of the successive pulses corresponds to 60 km in light traveling distance. Each pulse has a small energy, which is completely eye safe after 20 cm expansion, even if it hits human eye directly. As the power is very small, the photon counting method is used for detection. The specification of MPL is shown in Table 1.

In order to obtain enough S/N, the signal is integrated over 20 or 30 sec to obtain one vertical profile. The data is stored in a hard disk and then transferred to a MO for further analysis. The FOV of the telescope is as narrow as 0.1 mrad for reducing the background noise.

The lidar was installed in an air conditioned cabin. Since the detector is fragile to the direct incidence of the solar radiation, the lidar attitude was tilted to the north by 19 deg. (The real altitude is obtained from the distance multiplied by 0.95 (cos 71deg).)

Usually the cloud and aerosol intensity was monitored from the time sequential profile of the range-square corrected lidar signal $X(R)$.

$$X(R) = (P(R) - P_B) \cdot R^2$$
$$P(R) = C\beta(R)T^2(R)/R^2 + P_B$$

Table 1 Specification of MPL

Laser	LD pumped Nd: YLF
Wavelength	523 nm
Output	5 μJ/pulse
PRF	2500 Hz
LD power	1 W (CW)
Telescope	20 cm ϕ Cassegrain-type
Detector	SPCU (Si APD)
Detection	Photon counting

where $P(R)$ is the receiving power, P_B is the background radiation, which works as the noise term. C is a system constant, $\beta(R)$ is the backscattering coefficient, and $T(R)$ is the transmission to the range R. The signal to noise ratio is obtained in terms of $n = P \cdot \tau\eta_Q / h\nu$ (τ: integration time, η_Q: quantum efficiency of the detector, h: Plank constant, ν: laser frequency) by

$$S/N = \frac{\sqrt{M}}{\sqrt{\mu}} \cdot \frac{n_S}{\sqrt{n_S + n_B}} \; .$$

In a usual analog detection, the excess noise factor μ is roughly 3, but in the single photon detection, μ =1. In the case of MPL, for the stratospheric cloud in the altitude over 10 km, S/N over 10 can be obtained. The aerosol in the troposphere can be obtained up to 10 km.

Some examples of lidar data (July 7, 1997) is shown in Fig. 1.

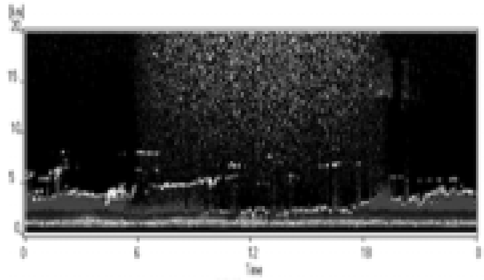

Fig.1 One day data (1997.07.07)

3. Cloud Detection

In the case of cloud detection, the cloud altitude is determined from the derivative signal of the lidar. When the S/N is enough large, the derivative of the lidar signal is taken and the point to become positive is taken as the cloud base, zero crossing point from positive to negative is the apparent cloud peak, and the point to approach zero is the cloud top (see Fig. 2). However, when the cloud altitude is higher than 8 km, the S/N is not enough for taking the derivative. So the altitude where the lidar signal is jumped by some amount (ex. 20 %), is determined as the cloud base.

In Fig. 3, the cloud base histogram of each month is shown.

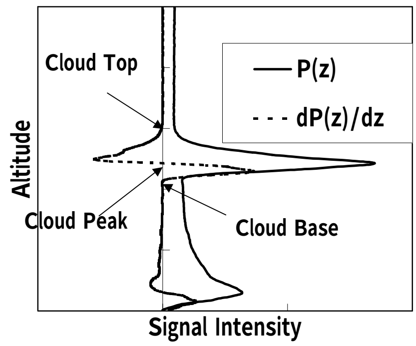

Fig.2 Cloud parameters

4. Analysis of Cloud Behavior

In Fig.4(a) and (b), monthly behavior of cloud is shown in July and August. Both data shows the cloud is ascending with time. It appears around 1.5 km above the ground and disappeared around 7 or 8 km. This is specific in monthly data and if we use the hourly data, the vertical movement of the cloud is not always upward dominant. The frequencies of the cloud of upward and downward were nearly equal. The upward dominant cloud movement was specific in the rainy season. In average, cloud were generated near the ground roughly every other day, and it ascends quickly with the speed of 3 – 5 km/day below 5 km in altitude, and above 5 km, the ascending speed of the cloud slows down to 1 to 3 km/day. Occasionally cloud appears in the high altitude (over 10 km) and descends down to the lower altitude with very fast speed (15 km/day). This is specific in rainy season and the cloud movement in October did not show this kind of features.

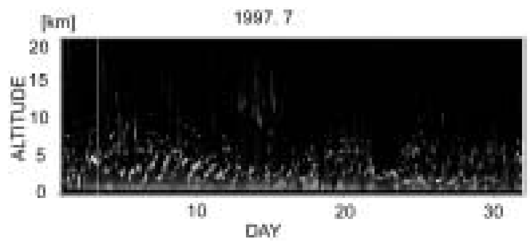

Fig. 4(a) Cloud behavior in July, 1997.

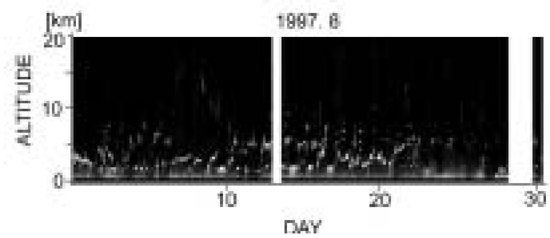

Fig. 4(b) Cloud behavior in August, 1997.

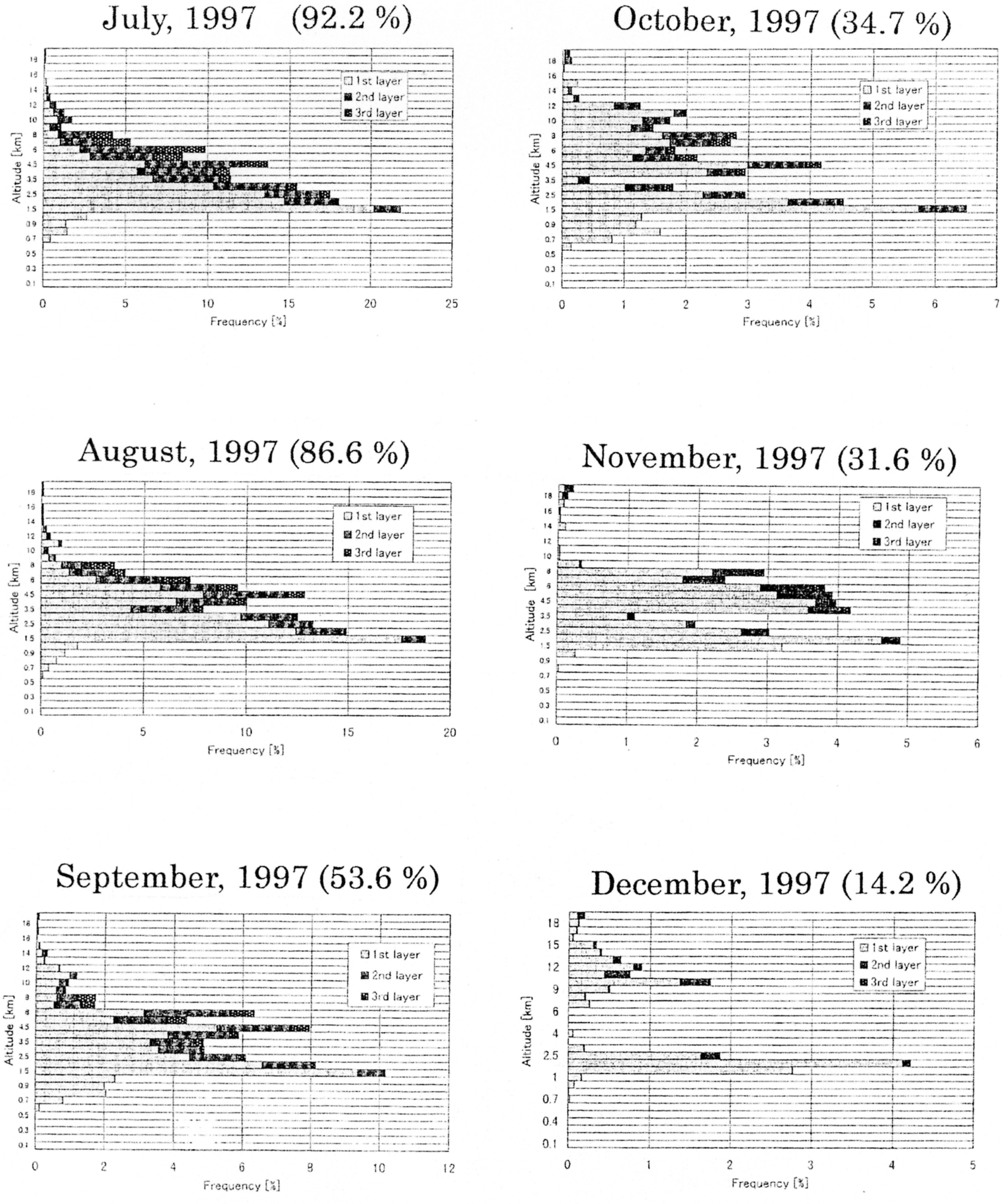

Fig. 3 Statistics of cloud base height at Sri Samrong. Each multiple layer is counted independently. So the total of the occurrence becomes more than 100 % in July and August.

5. Summary

In this paper, we report the cloud behavior which was observed by an automatic lidar system. The lidar shows often the trouble, but it has the potential to monitor the cloud movement and also aerosol behavior. It will help the actual vertical profile of atmosphere in real time and will give the fruitful result in future.