TROPICAL CIRRUS CLOUDS NEAR COLD POINT TROPOPAUSE OBSERVED UNDER SUPERSATURATED CONDITION: SIMULTANEOUS OBSERVATIONS BY LIDAR AND CRYOGENIC FROST POINT HYGROMETER

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ABSTRACT

Simultaneous vertical profiles of cirrus cloud backscattering and frost point temperature were obtained for the first time in the tropopause region over Bandung, Indonesia, (6.9°S, 107.6°E). These profiles were measured by ground-based lidar and by balloon-borne Cryogenic Frost point Hygrometer (CFH) sondes. Supersaturation up to several ten percent was observed by the CFH just below the cold point tropopause at the altitude where a cirrus cloud was observed by lidar. The water vapor mixing ratio decreased slightly at the altitude of the cirrus cloud, suggesting that this decrease was caused by uptake in the cirrus cloud, and that the water vapor reduction corresponds to the lower limit of the cloud water content of the observed cirrus cloud. Theoretical calculations of the scattering parameters for the observed cirrus cloud particles, and estimations of the time constant for sedimentation and condensational growth indicate that particles size range is between 4 μm and 30 μm.

1. INTRODUCTION

Optically thin cirrus clouds near the tropopause, ubiquitous throughout the tropical region [1], are often referred to as subvisual cirrus clouds (SVC) because they are visually undetectable [2]. The appearance of these clouds is closely related to the transport of water from the troposphere to the stratosphere and the dehydration processes in the tropical tropopause region where the temperature is very low. Since these thin cirrus clouds cover a wide area of the tropical tropopause, they influence the global climate through radiative processes.

There are several observations by airborne hygrometers of supersaturation over ice in cirrus clouds. In spite of many studies of tropical thin cirrus clouds, the dynamical and microphysical processes within cirrus clouds are still not clear. Although supersaturation in cirrus clouds has been reported, the detailed vertical profiles of cirrus clouds by lidar and water vapor by balloon borne hygrometer have not yet been simultaneously obtained. Thus, continuous observations of cirrus clouds by ground based lidar combined with accurate humidity observations by balloon borne hygrometers will enhance the understanding of cirrus cloud processes near the tropical tropopause. We conducted observations of cirrus clouds using a Mie lidar system at Bandung, Indonesia, to understand their properties as function of altitude. The lidar is tuned for cirrus cloud observations in the tropical tropopause region. We also used the recently developed balloon-borne cryogenic frost point hygrometer (CFH) to accurately measure humidity in the upper troposphere and lower stratosphere. The CFH is a new development based on the well-established NOAA/CMDL frost point hygrometer. The first simultaneous lidar and balloon borne CFH observations were conducted to study the relation between cirrus clouds and humidity around the tropical tropopause over Indonesia.

2. INSTRUMENTS

The lidar is a Nd:YAG laser-based Mie scattering depolarization lidar. Only the second harmonic wavelength (532 nm) of the laser is used for the observations. The lidar detects two polarization components of the backscatter signal, which are parallel and perpendicular to the polarization plane of the linearly polarized transmitted laser pulse. The diameter of the

receiving telescope is 20 cm. The bandwidth of the interference filter is 0.3 nm (FWHM). The field of view of the telescope is 0.5 mrad. The signals from the detectors (photomultiplier tubes) are processed by 12-bit transient recorders. The vertical resolution of the lidar data is 15 m and the integration time of the data is 30 s.

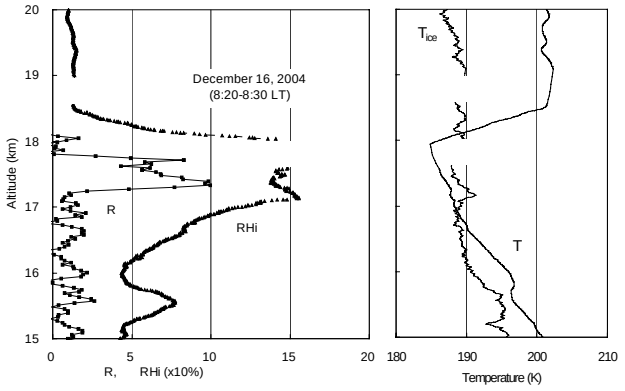
The CFH measures the temperature of a small frost layer that is kept in equilibrium with the atmospheric water vapor, which is by definition the frost point temperature. The frost point measurement is not affected by cloud particles while the CFH is in cirrus clouds. A detailed description of the CFH can be found in the paper by Vömel et al. [3].

3. RESULTS

In December 2004, four CFH water vapor / ECC ozone payloads were launched at Banudng. During this period the lidar was operating almost continuously. Although lidar observations in the tropopause region were often interrupted by dense lower level clouds, which are common during the rainy season, lidar profiles in the tropopause region were obtained during the CFH soundings on 15 and 16 December, 2004.

Fig. 1 shows the profiles of the scattering ratio R, relative humidity over ice RHi, ambient temperature T, and frost point temperature T_{ice} observed on Dec. 16, 2004. In Fig. 1a, cirrus clouds are clearly seen between 17.2 and 17.8. These clouds were just below the cold point tropopause (CPT) at 17.9 km. Throughout this altitude range the depolarization ratio of the cirrus clouds is around 30-40%.

RHi profile were taken during the balloon ascent. The profile shows supersaturation between 16.8 km and 18.1 km.



(a) (b)

Fig. 1

4. SUMMARY

A few to several tens percent of supersaturation were observed by the Cryogenic Frost point Hygrometer (CFH) just below the tropopause in the same altitude range where the lidar observed thin cirrus clouds. Although the degree of supersaturation was similar to former studies [4, 5, 6], a detailed relation between the vertical distributions of humidity and cirrus cloud was obtained for the first time using CFH and lidar observations. The vertical range of cirrus clouds and supersaturation did not coincide precisely. Supersaturation was observed over a vertical range larger than that of cirrus clouds. The humidity profile also showed fine structure within cirrus clouds existed, with a pronounced decreased in the altitude of the cirrus clouds while still remaining above saturation.

Assuming that this water vapor decrease was due to uptake by cloud particles, the lidar observed backscattering coefficient, theoretical calculations of the scattering parameters for the cirrus cloud particles, and estimations of the time constant for sedimentation and condensational growth indicate that the particle size range is between 4 μm and 30 μm. Direct observations of cloud particles will improve the understanding of the nature of the tropical tropopause cirrus clouds.

5. REFERENCES

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