Plan for Lidar Observations of the Polar Middle Atmosphere in the 26th Japanese Antarctic Research Expedition

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第26次南極地域観測隊におけるライダーを用いた極域中層大気観測計画

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要旨：昭和基地において第26次南極地域観測隊（1984-1986）で実施する，ライダーによる中層大気観測計画について記述する．この観測は，国際中層大気観測計画(MAP) の一環として計画されたものである．既に第24次観測隊（1984年）では，ルビーレーザーを用いて，成層圏下部のエアロゾル観測を実施した．今回は，新たに染素レーザーを用い，中間圏上部でのナトリウム層の時間・空間変動観測，および成層圏上部から中間圏までの領域の温度分布観測を実施する．

Abstract: A plan is described for lidar observations of the middle atmosphere which will be made by the 26th Japanese Antarctic Research Expedition, 1984–1986 (JARE-26) at Syowa Station (69°00′S, 39°35′E). This work has been planned as part of the Middle Atmosphere Program (MAP). The objectives of observation are to obtain the temporal and spatial variations of the sodium atomic layer in the upper mesosphere and those of temperature profile in the range from the upper stratosphere to the mesosphere by a tunable dye laser in addition to the aerosol observation in the lower stratosphere by a ruby laser which has been already started by the JARE-24 since 1983.

1. Introduction

A few years after the success of the first pulsed ruby laser oscillation by MAIMAN (1960), the observation of atmospheric parameters using laser radar (lidar) was started by FIOCCO and SMULLIN (1963). Then, according to the appearances of new types of high power laser, such as YAG and dye lasers, objects and ranges of the atmospheric observation have been largely extended. The ground-based lidar system, in particular, has become one of the powerful tools for observing the middle atmosphere. Measurements of aerosols in the lower stratosphere by Mie scattering, sodium and other alkali metals in the upper mesosphere by resonance scattering and temperature profiles in the range from the upper stratosphere to the mesosphere by Rayleigh scattering have been made at many lidar observatories in the world. The data accumulated by lidar

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observations have offered important information for analysis of the chemical processes and dynamics in the middle atmosphere.

In this paper we describe the significance and plan of observations of the sodium atomic layer and of the temperature profiles in the polar middle atmosphere, and the configuration of the lidar system. As for the aerosol observation, refer to paper by IWASAKA *et al.* (1981, 1983).

2. Significance and Objectives

2.1. Sodium atomic layer

In the late 1920's the sodium resonance line at 589.2 nm was discovered in the nightglow spectrum. Since 1950, according to the development of optical techniques, the temporal and spatial variations of the atmospheric sodium laser have been observed by means of twilight resonance scattering. Since the first application of lidar using a dye laser to the measurement of sodium (GIBSON and SANDFORD, 1971), the lidar technique has largely improved the resolution of height and time as well as the accuracy of measurement compared with those obtained by the twilight photometric method. Then, this technique has been employed by many workers in the world.

The observational results obtained were surveyed by HIRONO *et al.* (1979) and CLEMESHA (1984). Several features of the sodium layer are as follows:

(1) The abundance of sodium shows a winter maximum at all latitudes, but the amplitude of which depends on latitude.

(2) The vertical profile of sodium also shows a seasonal variation.

(3) As for the nocturnal variations, the abundance is enhanced at post-midnight and the profile shows a wave-like structure frequently.

On the basis of these results, various ideas have been proposed to explain the origin of the atmospheric sodium, photochemical processes and the dynamics in the upper atmosphere. However, the exact explanations for these problems have not yet been obtained because of the lack of data and accurate information about the interaction between sodium and other species. As listed in Table 1, the number of lidar observatories is not enough to obtain global data and most of them are placed at mid-latitudes of the Northern Hemisphere.

Therefore, it is very interesting to observe the atmospheric sodium in the high latitude region of the Southern Hemisphere. It is expected that the temporal and

Table 1. Observatories for the atmospheric sodium in the world.

Latitude	Location	Institute
51°N	Winkfield (U.K.)	Appleton Lab.
44°N	Haute Province (France)	CNRS
40°N	Urbana (U.S.A.)	Univ. of Illinois
38°N	Mt. Zao (Japan)	Tohoku Univ.
33°N	Fukuoka (Japan)	Kyushu Univ.
23°S	São José Campos (Brazil)	Inst. Perquisas Espaciais
69°S	Ongul Island (Antarctica) (Syowa Station)	National Inst. of Polar Research

spatial variations of the sodium layer in the polar region are different from those at middle and low latitudes or those at high latitudes of the Northern Hemisphere because of differences in the geographic and geophysical situations. There are several factors peculiar to the polar region which have influence on the characteristics of the sodium layer, such as the dominant particle precipitation, the weak intensity of the solar ultra-violet radiation in winter, the active meteor ablation and the cooling of the atmosphere by the ice covering the Antarctic Continent.

2.2. Temperature

The vertical profile of temperature is one of the important factors which makes clear the dynamics in the middle atmosphere. Up to now, these data have been provided mainly by meteorological rockets. On the other hand, the lidar observation has been performed since 1978 (HAUCHECORNE and CHANIN, 1980). The principle of this technique is that, on the assumption of the ideal gas and the hydrostatic equilibrium, its profile is derived from the atmospheric density measured by Rayleigh scattering of laser beam. When the two methods are compared, lidar observation is superior in time resolution and continuity to the rocket-borne detection. But, the former has a demerit that the accuracy decreases with increasing altitude, whereas the latter is independent of altitude.

When the lidar is operating for observing aerosol or sodium, Rayleigh scattering signals from the atmospheric molecules are obtained at the same time. By utilizing these signals, neutral density and temperature can be obtained in the range from 30 to 70 km where the scattering from aerosols or sodium atoms is expected to be negligible.

3. Outline of the Observation Plan

The wintering period of the JARE-26 is from January 1985 to January 1986. The lidar observation is restricted at night in fine weather. Therefore, the effective period for observing at Syowa Station is shorter than that mentioned above. It may be expected that the lidar observation could be performed on 20–40 days during the period between April and October in 1985 according to the past meteorological data at this station. An attempt will be made to operate the lidar continuously for 24 hours in winter.

Fundamental data are obtained by accumulating 100 shots of laser pulse (about 5 min) which is emitted at a rate of 0.5 Hz. By averaging these data over any desired period, we obtain the temporal variation of the abundance and vertical profile. These results will be compared with the vertical profile of meteor trace and its horizontal velocity and direction obtained by the VHF doppler radar (50 and 112 MHz). By this comparison, the relation between the variation of the abundance of sodium and the influx of meteor, and that between the vertical profile of sodium and the horizontal wind of the middle atmosphere will be discussed. Temperature observation will be co-operated with that by meteorological rocket (MT-150JA1-11). Aerosol observation will be continuously performed and its results will be analyzed and be discussed in comparison with the past data since 1983. The lidar observation at Syowa Station is depicted in Fig. 1.

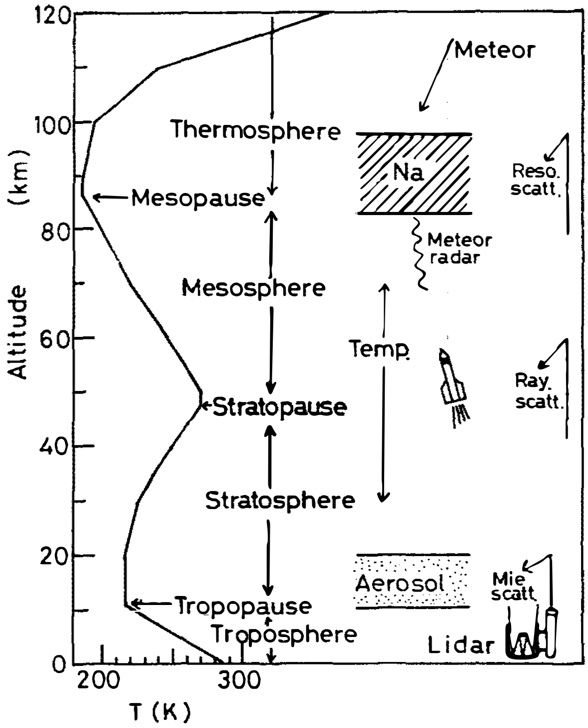

Fig. 1. Scheme of the observation for the polar middle atmosphere.

4. Configuration of the Lidar System

In order to measure the atmospheric sodium and temperature, a new transmitter with a dye laser is added to the existing lidar system with a ruby laser which has been already set up at Syowa Station since 1983. Changes associated with this are mini-

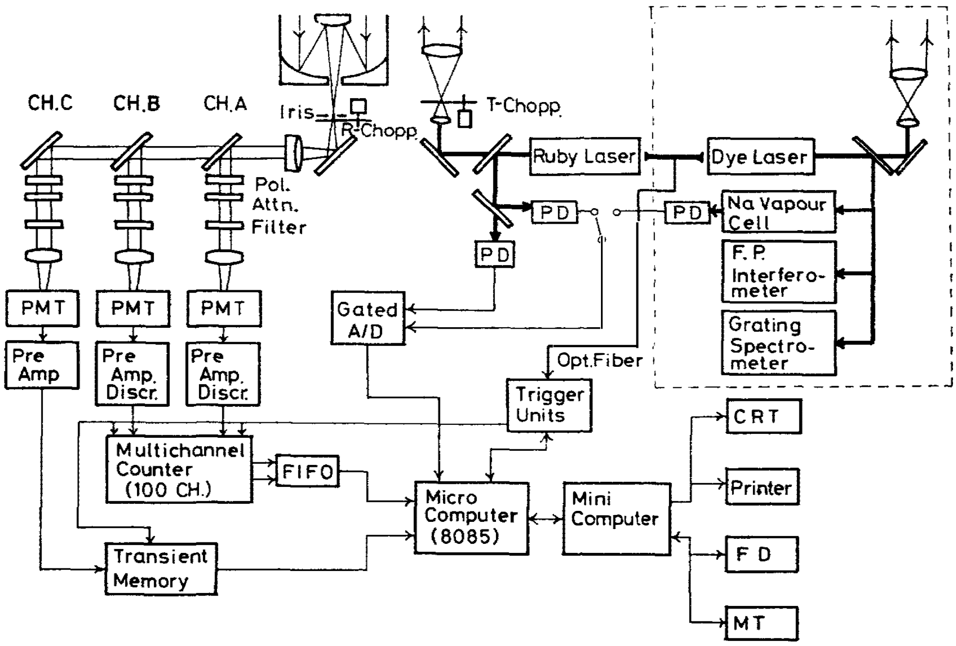

Fig. 2. Block diagram of the lidar system. The additional transmitter system based on a dye laser is indicated at the portion bounded by a broken line.

Table 2. Performances of transmitter and receiver.

Transmitter	Ruby laser	Dye laser
Wavelength	694.3 nm	589.0 nm
	347.1 nm	
Energy	0.8 J/pulse	0.2 J/pulse
	0.3 J/pulse	
Linewidth		0.003 nm
Pulse width	36 ns	500 ns
Repetition rate	0.5 Hz	0.5 Hz
Divergence	1.0 mrad	1.0 mrad
Receiver		
Telescope diameter	0.5 m	
Telescope area	0.17 m²	
Field of view	0.5–1.5 mrad	
Bandwidth	1.0 nm for 694.3 nm	
	2.5 nm for 347.1 nm	
	1.0 nm for 589.0 nm	
Detection	2 ch. for photon count.	
	1 ch. for analog	
Height resolution	0.1–10 km (P. C. mode)	
	7.5–750 m (Analog mode)	

mized by considering that the whole system could not be tested before leaving for Antarctica. The block diagram of the lidar system is shown in Fig. 2. Although it is impossible to operate two lasers in parallel at the same time, exchange of transmitter can be easily made in a short time. Almost all of the present systems of receiver, controller and data processing will be utilized except software.

A coaxial flashlamp pumped dye laser (UV-500, Candela) is used in transmitter. The dye solution is 4×10^{-5} M/l rhodamine 6G dissolved in methanol and pure water. The spectral narrowing and tuning to the sodiun D_2 resonance line (589.0 nm) are performed by placing three prisms and two temperature-controlled Fabry-Perot etalons inside the cavity. Tuning of output laser beam is checked by means of a cell of sodium vapor, a Fabry-Perot interferometer of 50 pm free spectral range and a 25 cm grating spectrometer.

As for the receiving system, photons received with a Casegrainian telescope are detected by three photomultiplier tubes (two for photon counting and one for analog) through each interference filter. Photon counting signals after amplification and discrimination are counted by multichannel counter (MCC) and then are transferred to a micro-computer. On the other hand, analog signal after amplification is stored in a transient memory and then to a micro-computer. After that, these signals are transferred to a host mini-computer (Melcom 70/10) by which various processings of data are performed, such as real time display, transfer to MT and analysis of accumulated data. Performances of transmitter and receiver are listed in Table 2.

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