Mem. Natl Inst. Polar Res., Spec. Issue, 47, 62–66, 1987

LIDAR OBSERVATION OF THE MESOSPHERIC SODIUM LAYER IN ANTARCTICA: PRELIMINARY RESULT

Akio NOMURA[1], Yasunobu IWASAKA[2], Hiroshi FUKUNISHI[3], Takeo HIRASAWA[4], Sadao KAWAGUCHI[4] and Tetsuo KANO[1]

[1]*Faculty of Engineering, Shinshu University, Wakasato, Nagano 380*
[2]*Water Research Institute, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464*
[3]*Upper Atmosphere and Space Research Laboratory, Faculty of Science, Tohoku University, Aramaki Aoba, Sendai 980*
[4]*National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173*

Abstract: This report describes the lidar measurement of mesospheric sodium layer made at Syowa Station (69°00′S, 39°35′E) in 1985. Our result does not show any pronounced seasonal variation in sodium abundance. Auroral activity may have disturbed the sodium layer significantly.

1. Introduction

The existence of free sodium atoms (Na) in the upper atmosphere has been known since mid-1930's (*e.g.*, CHAMBERLAIN, 1961). For many years vertical distribution of sodium density has been measured by twilight airglow observation (*e.g.*, BLAMONT and DONAHUE, 1964). Recently lidar measurements of Na distribution have greatly increased our knowledge of the morphology of the Na layer. The global feature of the Na density due to atmospheric tides, the seasonal-latitudinal change, and the diurnal-latitudinal change have attracted the attention of many investigators (*e.g.*, SIMONICH *et al.*, 1979; JEGOU *et al.*, 1985; GRANIER *et al.*, 1985). However most of previous observations have been made at middle and low latitudes, and the measurement at high latitudes has been desired. JURAMY *et al.* (1981) performed laser sounding of the Na layer at Heyes Island (80°24′N) during polar winters of 1977–1978 and 1978–1979: one night in 1978, three nights in 1979. In their result the Na content variation with time scale of several hours was frequently observed, but the variations with longer time scales were not available owing to the lack of sufficient data.

A controversy exists concerning a possible enhancement of Na layer by auroral activity (*e.g.*, REES *et al.*, 1975). A precipitation of high energy particles effects on chemical reaction system controlling Na concentration. Additionally thermal structure of the lower thermosphere may be disturbed and directly and/or indirectly modify the Na distribution. Unfortunately there are still few measurements in high latitudes during auroral activity. If lidar measurements of Na layer are made during auroral activity, the data are useful to solve the problem.

A lidar observation of the Na layer was performed as a part of Middle Atmosphere Program/Antarctic Middle Atmosphere (MAP/AMA) at Syowa Station (69°00′S, 39° 35′E) in 1985. Here we describe preliminary results of the Na layer observed at 42 nights during the period from March to October in 1985. These observations showed very interesting results, which may be useful to understand the nature of the Na layer in high latitudes.

2. Lidar Measurements

The detail of the lidar system used here was already described elsewhere (NOMURA *et al.*, 1985). The main characteristics are given in Table 1.

To determine Na concentration we used the procedure given by MEGIE and BLAMONT (1977), and a signal calibration was made by comparison of the signal intensity of Rayleigh scattering from the stratosphere with the estimation from atmospheric

Table 1. Characteristics of lidar.

Transmitter	Ruby laser	Dye laser
Wavelength	694.3 nm 347.1 nm	589.0 nm
Energy	0.8 J/pulse 0.3 J/pulse	0.2 J/pulse
Line width		0.003 nm
Pulse length	36 ns	500 ns
Repetition rate	0.5 Hz	0.5 Hz
Divergence	1.0 mrad	1.0 mrad
Receiver		
Telescope	0.5 m diameter	
Field of view	0.5–1.5 mrad	
Filter bandwidth	1.0 nm for 694.3 nm 2.5 nm for 347.1 nm 1.0 nm for 589.0 nm	
Detection	2 channels for photon counting 1 channel for analog	
Height resolution	0.1–10 km for photon counting mode 7.5–750 m for analog mode	

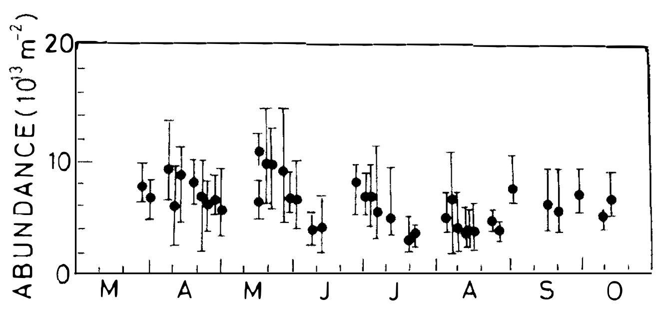

Fig. 1. Total abundance of sodium atom measured at Syowa Station (69°00′S, 39°35′E) in 1985.

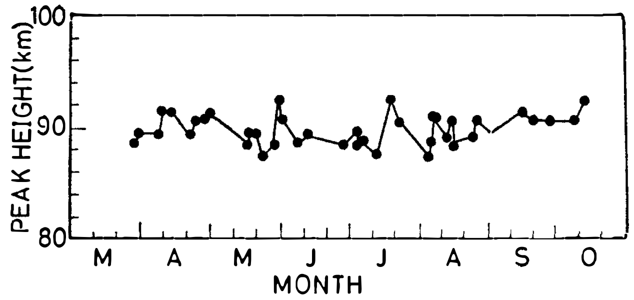

Fig. 2. Height of the sodium layer peak at Syowa Station in 1985.

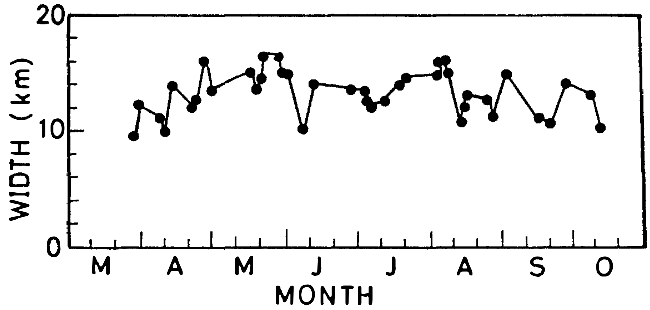

Fig. 3. Thickness of the sodium layer at Syowa Station in 1985.

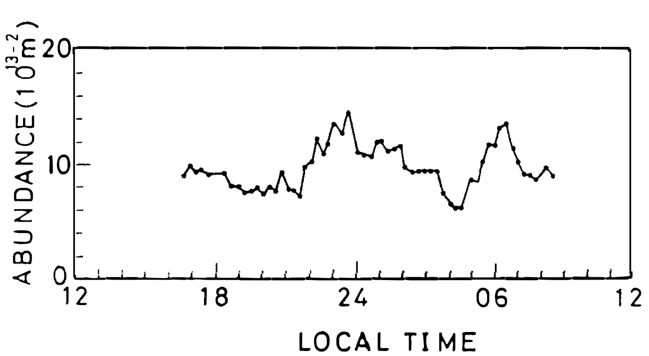

Fig. 4. Nocturnal variation of sodium total abundance at Syowa Station during the night of May 20–21, 1985.

density profile obtained by the radiosonde measurement at Syowa Station.

Figure 1 shows daily averaged total abundance of Na measured in 1985, and Fig. 2 the height of the layer peak. The observed temporal variation of the layer thickness is shown in Fig. 3. An example of observed nocturnal variation of Na total abundance is illustrated in Fig. 4. Fortunately we could observe the Na layer during auroral activity. Figure 5 shows the Na layer observed when a very active aurora appeared over Syowa Station.

3. Discussion and Summary

According to SIMONICH *et al.* (1979), lidar measurement at São José dos Campos (23°S, 46°W) clearly shows a winter maximum and a summer minimum of Na total

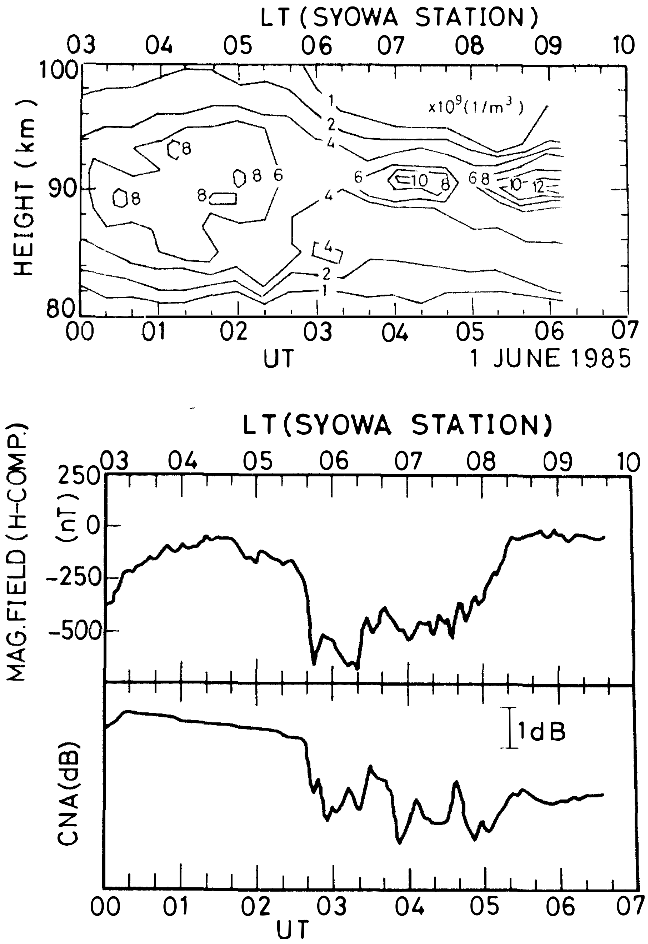

Fig. 5. Changes of sodium layer structure, magnetic H component and CNA during an active auroral event at Syowa Station on June 1, 1985.

abundance. The lidar measurements of GIBSON and SANDFORD (1971) and MEGIE and BLAMONT (1977) also show a winter maximum. However there appears to be no significant seasonal change in the total Na abundance at Syowa Station.

The measurement suggests that the sodium layer was stable, that is, the height of the maximum density is 90 ± 3 km and the thickness of the layer 13 ± 3 km, as shown in Figs. 2 and 3, respectively.

Oscillations with a period of several hours were frequently found in the nocturnal variation of the total abundance (one example is shown in Fig. 4). Such as oscillation was frequently observed, especially in winter. MEGIE and BLAMONT (1977) found that the Na total abundance is stable during the same night unless there is a meteoric shower. We speculate that the oscillatory variations have been caused by dynamical processes rather than by photochemical ones because the solar radiation is very weak in polar winter.

The observations during auroral activity shows that the disturbance of the Na layer structure seems to be associated with an active aurora accompanied by a large cosmic noise absorption (CNA). However for the cases of weak auroras the disturbance of the layer was not found. Figure 5 shows the results on June 1, 1985. A break-up of aurora occurred at 0530 LT, and CNA changed rapidly at 0540 LT. The total abundance of Na suddenly began to decrease at 0540 LT and thickness of the layer also decreased. The topside of the layer seems to be especially modified. A good coincidence of Na layer disturbance and an active aurora seems to suggest a possible effect of aurora on the Na layer.

The atmospheric heating associated with the polar magnetic disturbance will cause air convections and waves in the upper atmosphere (*e.g.*, DICKINSON *et al.*, 1977; PROLSS, 1980). These dynamical motions may disturb the sodium layer. A high energy particle precipitation can also disturb the chemical reactions controlling Na production and loss. At present, we cannot give a definite conclusion on the auroral effect on the mesospheric Na layer in high latitudes owing to a lack of sufficient information about Na chemistry and air motions when auroral activity is high.

Acknowledgments

Authors would like to acknowledge the great help received from the members of the 26th Japanese Antarctic Research Expedition.

References

BLAMONT, J. E. and DONAHUE, T. M. (1964): Sodium dayglow: Observation and interpretation of a large diurnal variation. J. Geophys. Res., **69**, 4093–4127.

CHAMBERLAIN, J. W. (1961): Physics of the Aurora and Airglow. New York, Academic Press, 704 p. (Int. Geophys. Ser. Vol. 2).

DICKINSON, R. E., RIDLEY, E. C. and ROBLE, R. G. (1977): Meridional circulation in the thermosphere. II. Solstice conditions. J. Atmos. Sci., **34**, 178–192.

GIBSON, A. J. and SANDFORD, M. C. W. (1971): The seasonal variation of the nighttime sodium layer. J. Atmos. Terr. Phys., **33**, 1675–1684.

GRANIER, C., JEGOU, J. P., CHANIN, M. L. and MEGIE, G. (1985): General theory of the alkali metals present in the earth's upper atmosphere. III. Diurnal variations. Ann. Geophys., **3**, 445–450.

JEGOU, J. P., GRANIER, C., CHANIN, M. L. and MEGIE, G. (1985): General theory of the alkali metals present in the earth's upper atmosphere. II. Seasonal and meridional variations. Ann. Geophys., **3**, 299–312.

JURAMY, P., CHANIN, M. L., MEGIE, G., TOULINOV, G. F. and DOUDOLADOV, Y. P. (1981): Lidar sounding of the mesospheric sodium layer at high latitude. J. Atmos. Terr. Phys., **43**, 209–215.

MEGIE, G. and BLAMONT, J. E. (1977): Laser sounding of atmospheric sodium; Interpretation in terms of global atmospheric parameters. Planet. Space Sci., **25**, 1093–1109.

NOMURA, A., IWASAKA, Y., FUKUNISHI, H., KANO, T., HIRASAWA, T. and KAWAGUCHI, S. (1985): Plan for lidar observations of the polar middle atmosphere in the 26th Japanese Antarctic Research Expedition. Nankyoku Shiryô (Antarct. Rec.), **85**, 62–67.

PROLSS, G. W. (1980): Magnetic storm associated perturbations of the upper atmosphere. Recent results obtained by satellite-borne gas analyzer. Rev. Geophys. Space Phys., **18**, 183–203.

REES, M. H., ROMICK, G. J. and BELON, A. E. (1975): The intensity of the sodium D-lines in the auroral zone. Ann. Geophys., **31**, 311–320.

SIMONICH, D. M., CLEMESHA, B. R. and KIRCHHOFF, V. W. J. H. (1979): The mesospheric sodium layer at 23°S; Nocturnal and seasonal variations. J. Geophys. Res., **84**, 1543–1550.

(*Received July 9, 1986; Revised manuscript received December 24, 1986*)