THE SEASONAL VARIATION OF THE MESOSPHERIC SODIUM LAYER AT OMUTA, JAPAN

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ABSTRACT

Measurements of the night-time atmospheric sodium layer have been intermittently performed since 2003, using a Nd: YAG laser pumped dye laser radar at Omuta(33.0°N, 130.48°E). It is observed that the seasonal variation of the column abundance of the sodium layer density at Omuta has no clear maximum. It is found that the sodium abundance at Omuta is smaller in fall than averaged data at Fukuoka (33.4°N, 130.2°E) and Tokyo (35.6°N, 139.4°E).

1. INTRODUCTION

It is well known that minor constituents such as alkaline metals, alkaline earths, iron and so on exist as free atoms in the mesosphere. It is easier to measure the mesospheric sodium than the other metals because the suitable lasers and detectors in the resonance wavelengths are easily obtained. The observation of the mesospheric sodium layer has been performed by many authors.[(1)-(2)] The research such as the seasonal variation of the sodium layer, the atmospheric tide and gravity wave were done based on the observational results. Since the mesospheric sodium does not influence a life side directly, general public seldom have interest in the sodium layer. There are not many sodium observation points. Unmanned observation becomes easier recently due to the diffusion of the internet technology. The advanced control of the thing such as laser tuning technology is necessary with sodium layer observation. Such a lidar is also in the stage which can be realized. If it is realized, it will be able to work for the expansion of the observation point drastically. We are trying to develop an unmanned sodium lidar system. Measurements of the night-time atmospheric sodium layer have been intermittently performed since 2003, using the lidar at Omuta.

2. EXPERIMENTAL SETUP

A Nd: YAG pumped dye laser, LAS INTEGRA 2010, was used for the lidar observation. The performance is shown in the table 1. A wavelength to use for the observation is the D_2 line of 589.995nm in air. The Kiten Red 620 is dissolved in ethanol as the laser medium whose concentration is 0. 133g/*l*. For the steady observation, Kiten Red 620 is used because it has the best performance in the wavelength region with the laser system.

Table 1 LIDAR parameters used in the experiment.

Receiver system		Emitter system	
laser	Nd: YAG pumped dye laser	Telescope	Nasmis-Coude
wavelength	588.995 nm	Diameter	50 cm
Output energy	20mJ	Focal length	5.25 m
Linewidth	11.5 pm	Detector	PMT R943-02
Repetition rate	10 Hz	Interference Filter	3nm
Tuning method	Wavemeter	Range resolution	200 m

The nominal value of the laser line width was 2 or 3 pm but the actual value is 11.5 pm owing to the degradation of the optical elements such as a grating. The laser wavelength is tuned to the D2 line of the sodium based on the OptoGalvanic spectroscopy using a Hollow cathode lamp and monitored and controlled by a wavelength meter with an accuracy of 0.1 pm during the observation. The detuning error in the data analysis is negligibly small because is laser line width is much larger that the bandwidth of the mesospheric sodium due to Doppler broadening. The laser wavelength measured by the wavemeter is monitored by an internet camera server with input and output ports. The wavelength is controlled through the internet from the observers.

The lidar station is 25 meters above sea level at Omuta city (33.0^{o}N, 130.48^{o}E) where is in the south of Fukuoka city (33.4^{o}N, 130.2^{o}E). The difference in characteristics of sodium layer between data of Omuta and that of

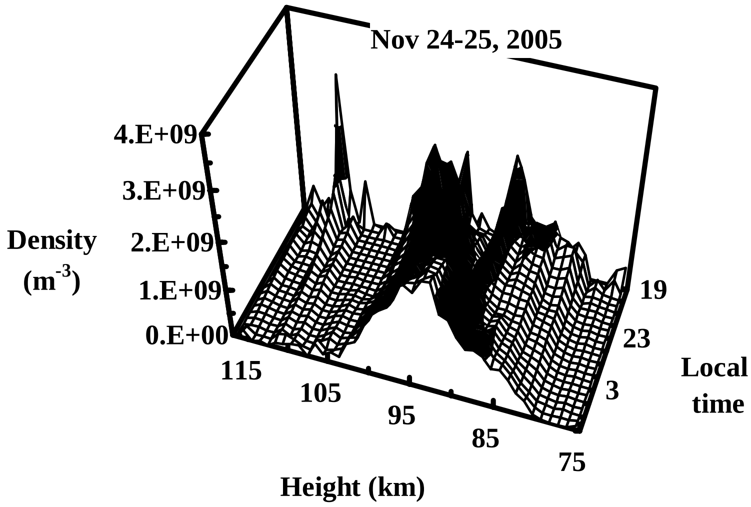

Fig. 1 Temporal variation of the density distribution of the mesospheric sodium layer over Omuta, Japan, on November 24-25, 2005.

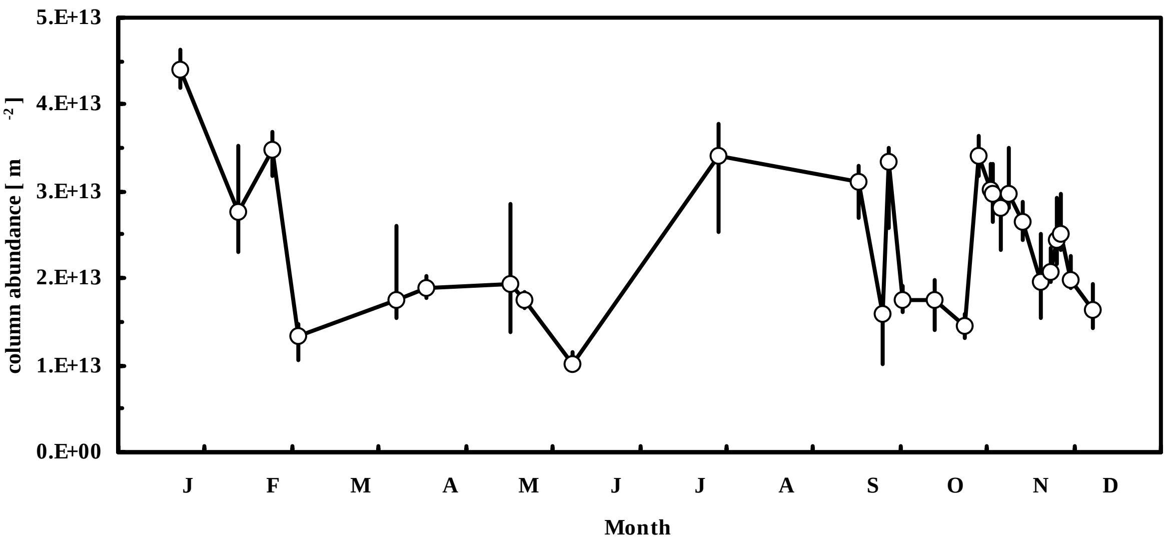

Fig. 2 Seasonal variation of the sodium column abundance nightly averaged over each night at Omuta (33.0^{o}N, 130.48^{o}E) in 2005. The bars in the figure do not indicate errors but the variation range of the abundance throughout the night from the twilight to the dawn.

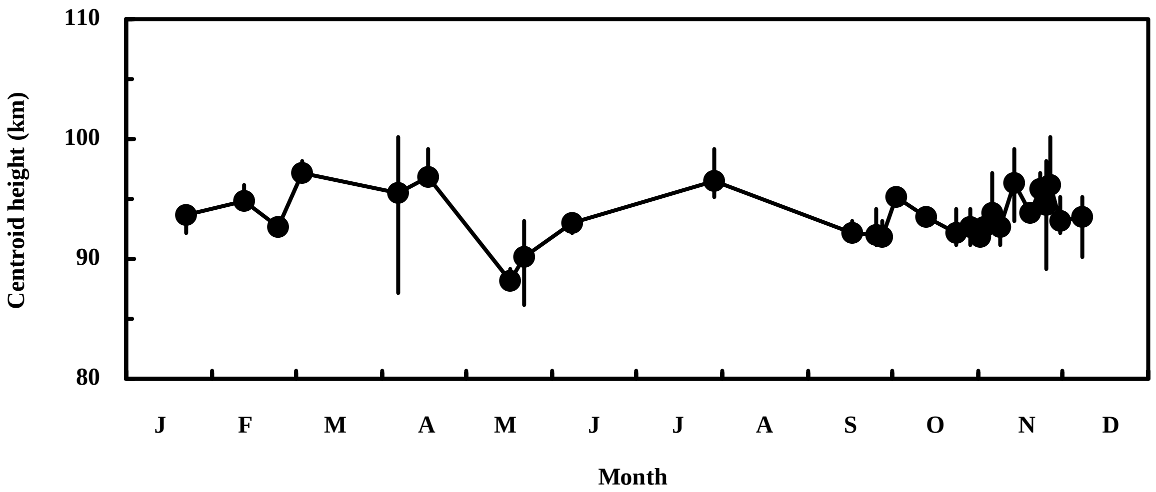

Fig. 3 Temporal variation of the height of the density peak of the nightly averaged vertical profile at Omuta, Japan in 2005. The bars in the figure indicate the variation range of the peak height throughout the night.

Fukuoka is not so large and is mainly due to the locations and the years observed.

3. OBSERVATIONAL RESULTS

For example, we observed a sharp incidence of the sodium persisting a few hours above the sodium layer. Figure 1 shows the contour plot of temporal and altitude variation of the sodium density during the entire nights of November 24th to 25th, 2005. The sodium data ware taken with a vertical resolution of 200m and a time resolution of 6 minutes but are smoothed by averaging with a vertical resolution of 1 km and a time resolution of 20 minutes. Figure 1 shows three-layered sodium layer became a single layer as the night progressed. It seems that the sodium layer was not quiet. Figure 2 shows a temporal variation of the sodium column abundance nightly averaged over each night at Omuta (33.0^{o}N, 130.48^{o}E) in 2005. The bars do not indicate error but the variation of the abundance throughout the night from the twilight to the dawn. The number of data points is dense in fall because the weather of fall was good at Omuta in 2005. Figure 3 also shows a temporal variation of the height of the density peak of the nightly averaged vertical profile at Omuta, Japan in 2005. The bars in the figure indicate the variation of the peak height throughout the night.

Figure 4 shows the seasonal variation of the column abundance of the sodium layer at Omuta (33.0^{o}N, 130.48^{o}E) in 2005 and monthly averaged column abundance at Fukuoka (33.4^{o}N, 130.2^{o}E) in 1981 and 1983 [(3)-(4)] at Hachioji, Tokyo (35.6^{o}N, 139.4^{o}E) from November in 1991 to October in 1999. It is observed that the abundance is generally smaller in spring. The winter abundance is apt to have larger value although the variation is large. This figure shows the abundance has no clear maximum like the high latitude variations. The difference between Omuta and Fukuoka is small in spring but large mainly in fall. Although the abundance at Fukuoka has a significant maximum in fall, the abundance at Omuta has no noticeable maximum. Figure 3 shows that the day-to-day variation is small in November and December in Omuta in 2005. Since the abundance on December in 2005 is less than that on December in 2004 in Omuta[(5)], it should be made clear the year-to-year variation.

Since the annually averaged abundance at Omuta is smaller than that at Hachioji, Tokyo, the calibration error should be studied. First, it should be considered that the yellow sand from China affects the result or not. Since the altitude of Rayleigh normalization for the calibration of the sodium absolute density is 35 km and enough high, the presence of Chinese yellow sand has small effect on the calibration. The assumed Rayleigh cross section at the normalization altitude and the laser linewidth can affect the absolute density calibration.

The density perturbation in the sodium layer can be obtained by subtracting the time-average of individual vertical profiles from its individual profiles. The sodium perturbations are attributed to atmospheric tide or gravity waves. We often observed semi-diurnal tides in the density perturbation in the sodium layer.

For example, Rowlett et al reported that wavelike structures in the sodium layer had been observed with typical wavelength of 3 to 15 km and phase velocity of 1 to 3 m/s [(6)]. Since then, Clemesha et al reported the existence of strong semi-diurnal oscillation in total abundance and height [(7)]. The density response of atmospheric layer structures to gravity waves has been studied by Chiu and Ching[(8)]. Shelton et al [(9)] used Chiu and Ching’s approach to derive a linear model of the density response of the sodium layer to

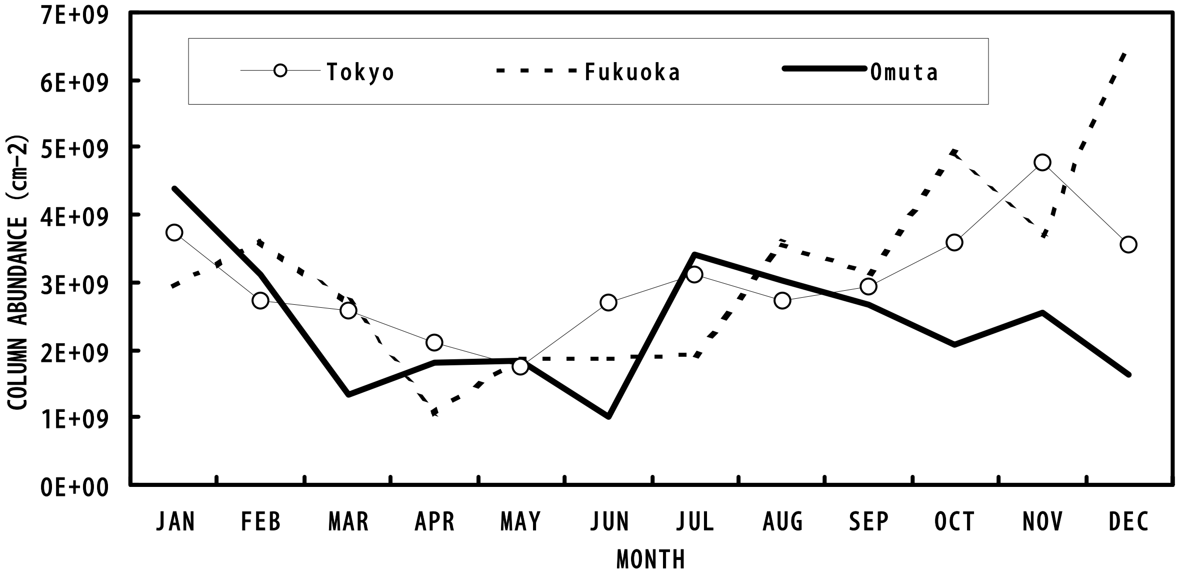

Fig. 4 Comparison of the seasonal variations of the monthly averaged column abundance between at Omuta, in 2005, this work, with Tokyo from November in 1991 to October in 1999 and Fukuoka in 1981and 1983.

gravity waves. Wavelike structures were also observed at Omuta. It is considered that the correlative analysis among the many lidar stations is a useful method for investigation on the atmospheric dynamics. So it is meaningful to increase the number of observation points.

4. CONCLUSION

Measurements of the night-time atmospheric sodium layer have been intermittently performed since 2003, using a Nd: YAG laser pumped dye laser radar at Omuta. As results, following conclusion is obtained.

1. It is observed that the seasonal variation of the column abundance of the sodium layer density at Omuta has no clear maximum. The abundance is small in spring and somewhat large in winter in 2005. It is considered that the clear winter maximum observed at middle and higher latitude is not observed at Omuta.
2. It is found that the sodium abundance at Omuta is smaller in fall than averaged data at Fukuoka and Tokyo. The reason of the difference may be attributed to the year-to-year variation.
3. It is observed that the vertical distribution of the sodium density abundance at Omuta has often semi-diurnal oscillations.

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