Proc. NIPR Symp. Polar Meteorol. Glaciol., 2, 1–7, 1989

# GRAVITY WAVE ACTIVITIES OVER SYOWA STATION, ANTARCTICA

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***Abstract:*** We observed gravity wave activities in the vertical profiles of the sodium layer in the upper mesosphere on 42 nights during the period from March to October, 1985. The data were obtained by lidar measurements at Syowa Station, Antarctica (69°00′S, 39°35′E). The wave parameters, such as vertical wavelength, vertical phase velocity, and period, were estimated from the vertical profiles of sodium density by means of a fast Fourier transform (FFT) technique. The seasonal and the nocturnal variations of gravity wave activities are reported and compared with the data obtained at other locations.

## 1. Introduction

Lidar measurements of the mesospheric sodium layer were made at Syowa Station, Antarctica (69°00′S, 39°35′E), during the period from the end of March to the middle of October, 1985, as a part of the Middle Atmosphere Program and the Antarctic Middle Atmosphere (MAP/AMA). The qualitative results were reported in previous papers (NOMURA *et al.*, 1987a, b, 1988), where we presented some interesting findings, that is, the seasonal variation of sodium abundance different from those obtained at mid-latitudes in the northern hemisphere, the oscillation of sodium abundance with a period of about 36 days, the presence of gravity waves, and the disturbance of the sodium layer by auroral activities.

In this paper, we quantitatively describe gravity wave activities in Antarctica. The vertical profiles of sodium density collected for 42 nights are analyzed by a fast Fourier transform (FFT) technique. The seasonal and the nocturnal variations of gravity wave activities are discussed compared with the results obtained at mid-latitudes in the northern hemisphere by GARDNER and VOELZ (1987).

## 2. Data Acquisition and Analysis

The mesospheric sodium layer was measured with the lidar system based on a dye laser tuned to the sodium $D_2$ resonance line (589.0 nm). The outline of the system was given in the previous papers (NOMURA *et al.*, 1985, 1987b). The vertical profiles of sodium density at intervals of 1 km were obtained about every 15 min by using 100 laser-beam shots. The data collected for 42 nights during the period from March to

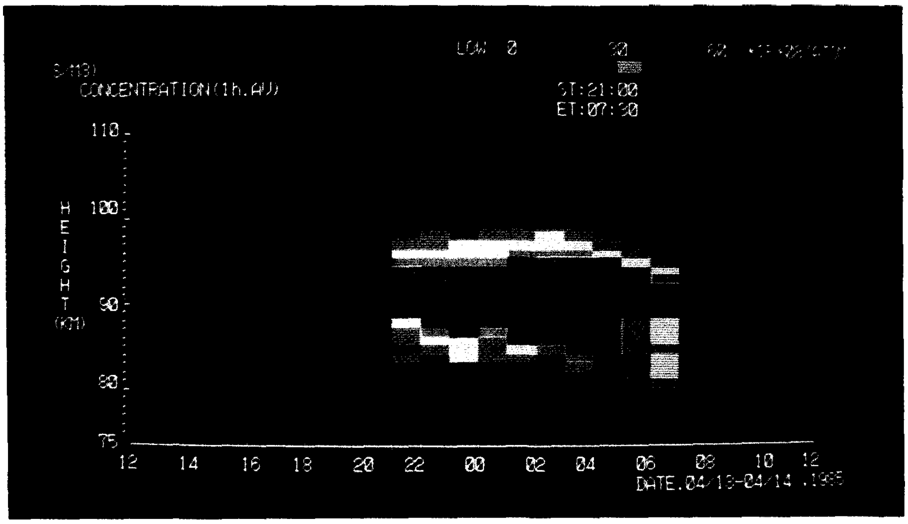


*Fig. 1. Nocturnal variation of hourly average vertical profile of sodium density in the form of contour plots measured on April 13–14, 1985.*

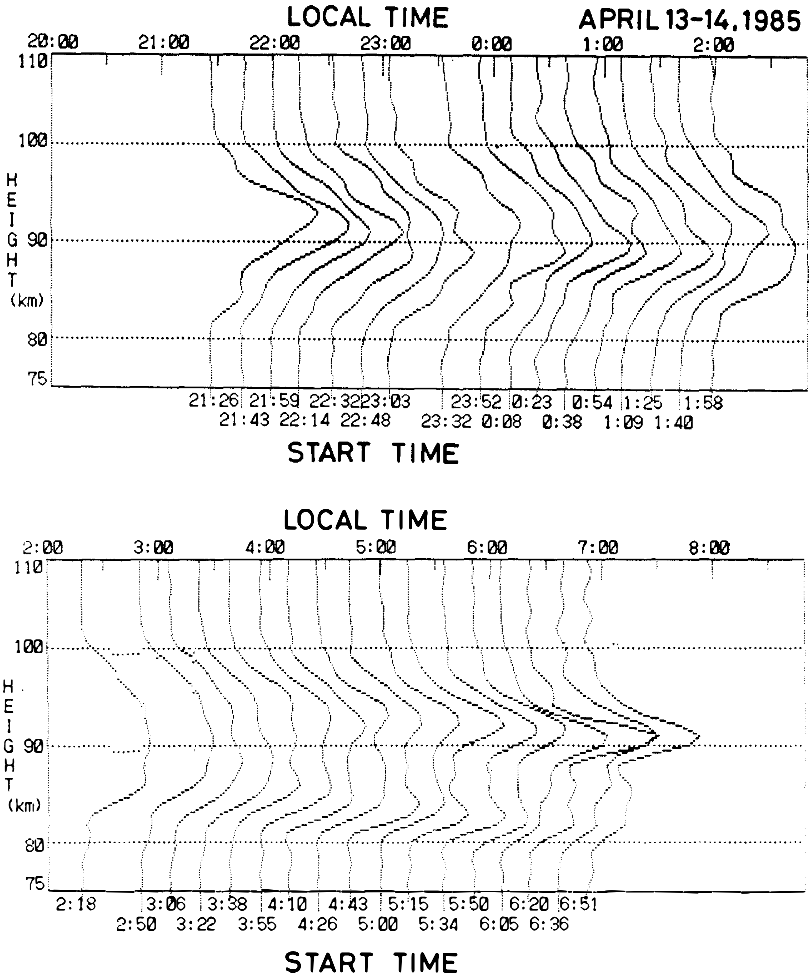


*Fig. 2. Nocturnal variation of normalized vertical profile of sodium density measured on April 13–14, 1985. Each profile is obtained by a lowpass filter with a cutoff frequency of 0.25 km$^{-1}$ (wavelength 4 km).*

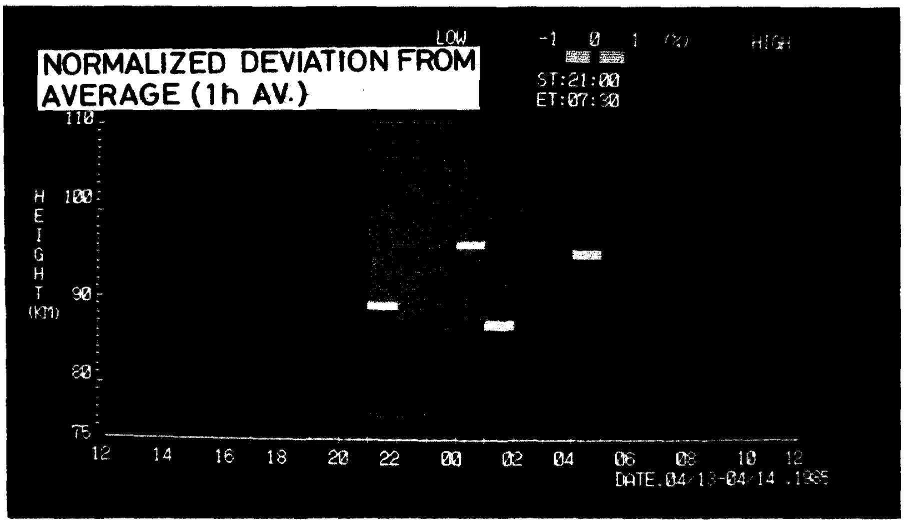


*Fig. 3.* *Nocturnal variation of the deviation of each normalized profile from the nocturnal average normalized profile in the form of contour plots on April 13–14, 1985.*

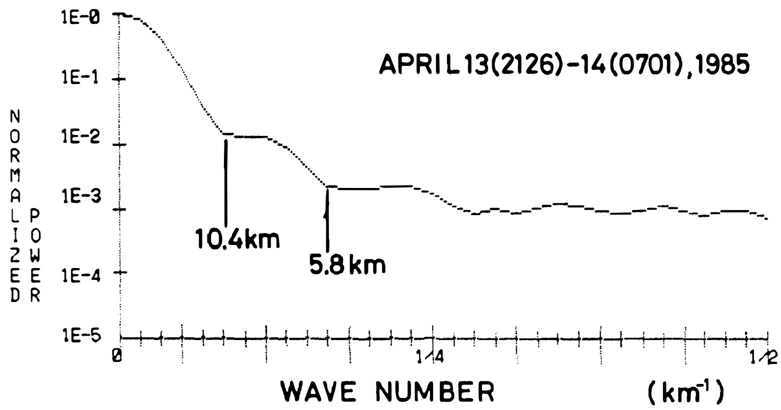


*Fig. 4.* *Nocturnal average spatial power spectrum obtained from a series of vertical profiles on April 13–14, 1985.*

October, 1985, are discussed in this paper.

At first a series of vertical profiles of sodium density is shown in Fig. 1 as colored contour plots. This figure shows the time variation of the sodium layer at sight, but does not make clear the gravity wave activities. Then we normalized each profile so as to have the same sodium abundance (Fig. 2); fluctuations due to shot noises (*i.e.*, with wavelength shorter than 4 km) were eliminated with a filter by an FFT technique described later. Moreover, the deviations of each normalized profile from the normalized nocturnal average profile are shown as contour plots in Fig. 3. This successfully identifies a downward phase propagation of gravity waves.

These vertical profiles are analyzed by an FFT technique. The nocturnal average spatial power spectrum on April 13–14 is shown in Fig. 4. It clearly shows activity of waves with a wavelength of about 8 km. Then, using a bandpass filter with the wavelength width between 5.8 and 10.7 km, successive vertical profiles are constructed with an inverse FFT (Fig. 5). These vertical profiles show significant wave structures of

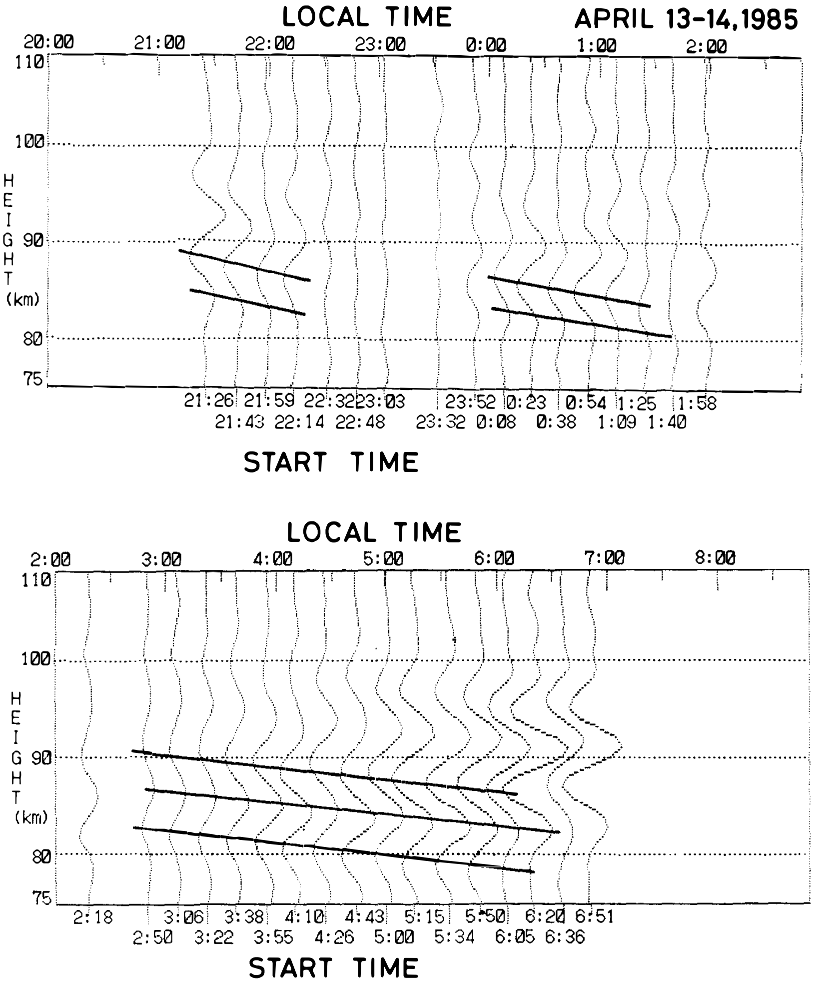


*Fig. 5. A series of vertical profiles of sodium density on April 13–14, 1985 through a bandpass filter with the wavelength width between 5.8 and 10.7 km.*

downward phase propagation. The FFT analysis determined important parameters of gravity wave, such as wavelength, phase velocity, and period.

## 3. Results and Discussion

The seasonal distributions of the wave parameters, that is, vertical wavelength, vertical phase velocity, and period, are shown in Fig. 6. The measured wavelengths, phase velocities, and periods range from 4 to 10 km, from 0.5 to 5 km/h, and from 1 to 8 h, respectively. The restriction of the wavelength range is due to the fact that vertically long wavelengths are limited by the thickness of the sodium layer and that the short wavelengths are limited by signal shot noises. The results suggest that there is no significant seasonal variation. This agrees with the result reported by GARDNER and VOELZ (1987).

Next, the histogram of the monthly average number of gravity wave events observed per hour is shown in Fig. 7. It is found that the frequency of events tends to descrease from autumn to spring although the frequency is slightly enhanced in July.

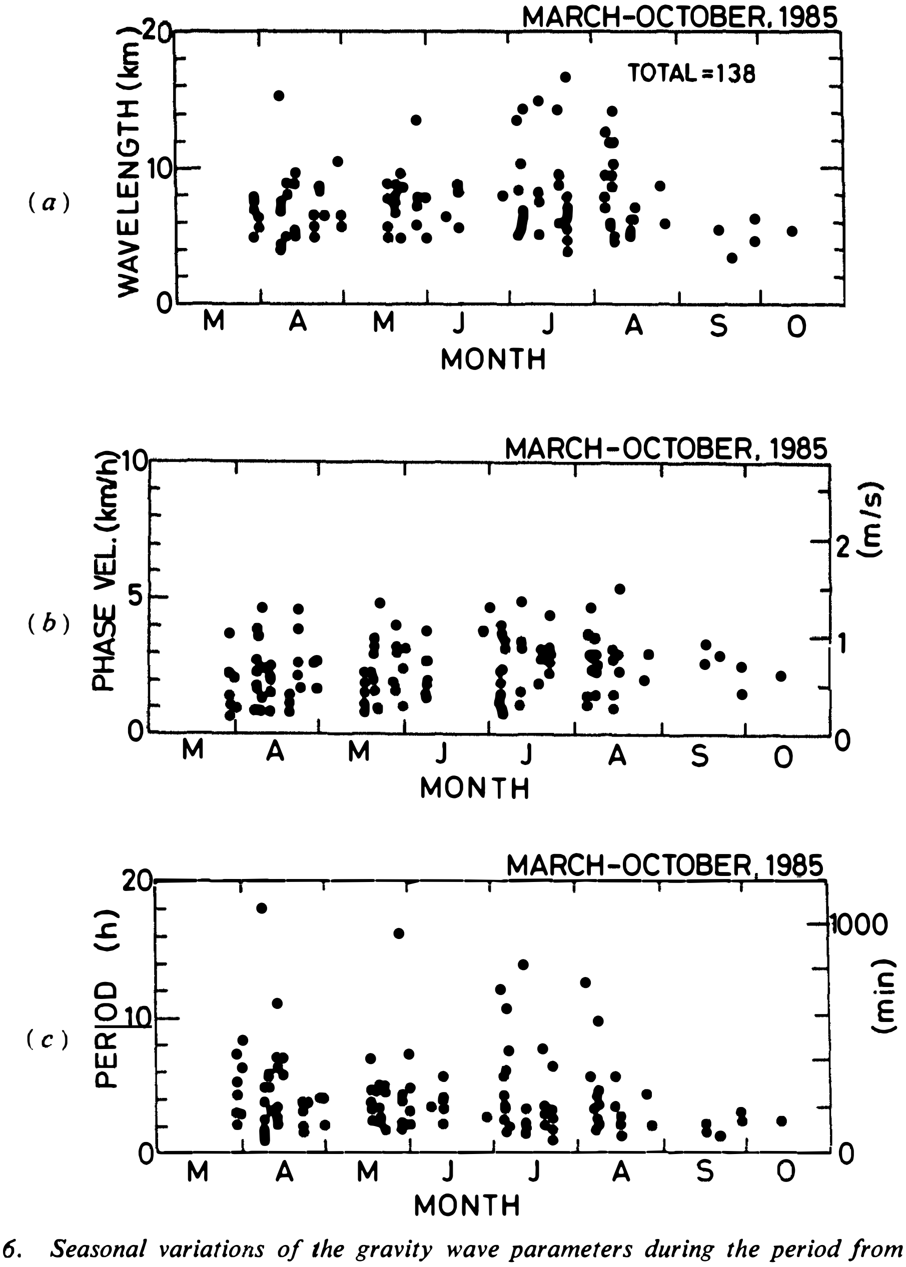


*Fig. 6. Seasonal variations of the gravity wave parameters during the period from March to October: (a) vertical wavelength, (b) vertical phase velocity, (c) period.*

It is of interest that this trend differs from that generally expected as there are many strong wave activities in winter.

The histogram of the number of gravity wave events versus nighttime is shown in Fig. 8. It is obtained by averaging all of the data from March to October. The result shows two significant peaks from 2100 to 2200 LT and from 0500 to 0600 LT (note: LT=UT+3 h). It is of interest to compare this result with that obtained at Urbana, Illinois (40°10′N) by GARDNER and VOELZ (1987). Their result indicated only one large peak appearing from 2100 to 2200 LT; they thus suggested that there was a diurnal variation in gravity wave activities. We think that their peak corresponds to the first small peak of ours. However, another increment of gravity wave

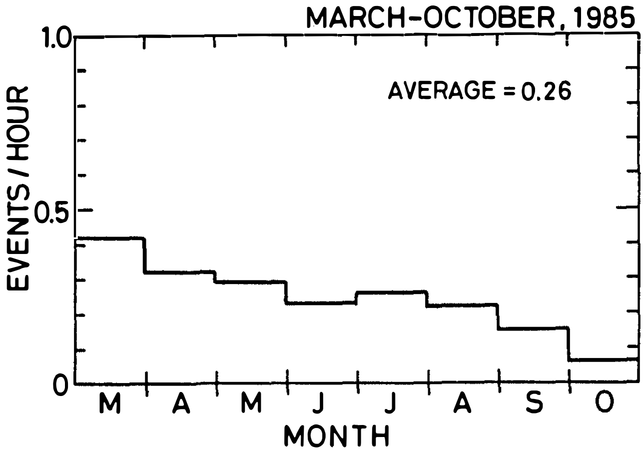


*Fig. 7. Histogram of the monthly average of the number of gravity wave events per hour during the period from March to October.*

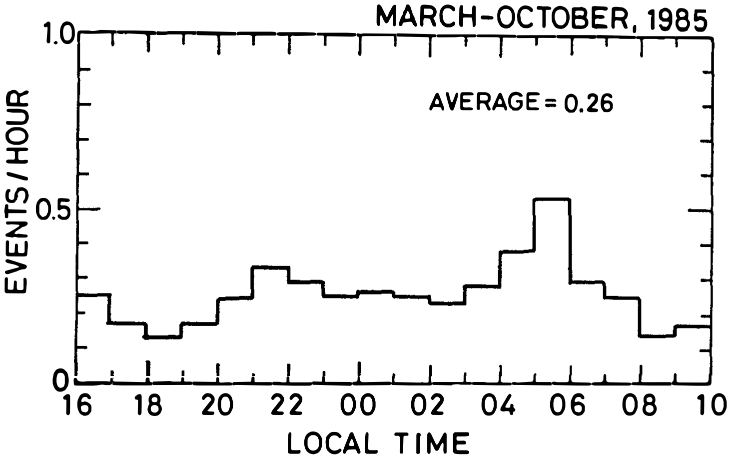


*Fig. 8. Histogram of the hourly bverage of the number of gravity wave events per hour versus nighttime. This is obtained by averaging all data from March to October.*

events in the early morning in Antarctica is not observed in their result. Moreover, note that the average number of wave events in Antarctica (0.26 events/h) is much less than that at Urbana (0.86 events/h). This suggests that polar gravity wave activities are weaker.

## 4. Summary

Gravity wave activities in Antarctica are discussed using the vertical profiles of the mesospheric sodium layer observed on 42 nights by the lidar measurements at Syowa Station during the period from March to October, 1985. The gravity wave parameters, such as vertical wavelength, vertical phase velocity, and period, are determined analyzing sodium density profiles with an FFT technique. This paper reported the seasonal variation of the measured wave parameters, and the seasonal and the nocturnal variations of the number of gravity wave events per hour.

The seasonal variation of gravity wave events indicates that there is a trend where in the frequency decreases from autumn to spring although there is a slight rise in frequency in winter. However, we do not detect any significant seasonal variations in vertical wavelength, vertical phase velocity, and period. The nocturnal variation of the number of gravity wave events per hour shows two peaks from 2100 to 2200 LT and from 0500 to 0600 LT, which differs from that obtained at mid-latitudes in the northern hemisphere. Our data show the strong activity in the early morning in Antarctica. It is suggested that gravity wave activities in Antarctica are weaker than at mid-latitudes in the northern hemisphere.

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*(Received February 25, 1988; Revised manuscript received August 31, 1988)*