Upper atmosphere planetary waves observed by airglow in the equatorial region

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Abstract

The upper mesospheric airglow emissions, OI 557.7 nm, NaD 589.3 nm, OH (6,2) and O2 Atmospheric (0,1) band, and the thermospheric OI 630.0 nm emission have been measured by using a ground-based multichannel airglow photometer in the equatorial region, São João do Cariri (7 S, 37 W), Brazil. It is found that there is an oscillation of around 3 day period in the mesospheric emissions and 5 to 7 day oscillation in some months for the thermospheric emission. The amplitudes of oscillation are larger in February and June. These long period oscillations are well known in the wind field as planetary waves. In case of the airglow, however, few observational evidence has been reported. Wave characteristics and source of the oscillation will be discussed.

INTRODUCTION

Planetary scale wave oscillation of the upper atmosphere have been subject of investigation of the atmospheric dynamical processes in the mesosphere and lower thermosphere (MLT) region. Migrating tidal waves (diurnal and semi-diurnal oscillations) have been studied extensively (for example, Forbes, 1982). Planetary waves with periods near 2 days, 5 days, 10 days and 16 days in the troposphere and stratosphere have also been identified (Salby, 1981, 1984, Walterscheid and Vincent, 1996).

The planetary waves manifest in the oscillation of a variety of atmospheric parameters, mainly horizontal wind velocity, density, temperature and airglow. However observation of the planetary waves have been limited to the wind measurements (Harris, 1994, Ward et al., 1996, Forbes et al., 1997). Amplitudes of the atmospheric density and temperature oscillation of the planetary waves are, therefore, not well known yet. Among the atmospheric remote sensing techniques airglow is one of the useful techniques to estimate variation of the atmospheric parameters. Only a few airglow observation results concerning the planetary wave, however, have been reported (Ward, et al., 1997). As far as we know, no observational evidence has been reported from the ground based measurements. Difficulty to get day to day continuous airglow observation would limit such investigation. In this present work, long term observations with more than 10 days of continuous data were obtained from the Brazilian equatorial region. Evidence of quasi-two days oscillation is pointed out and to be discussed.

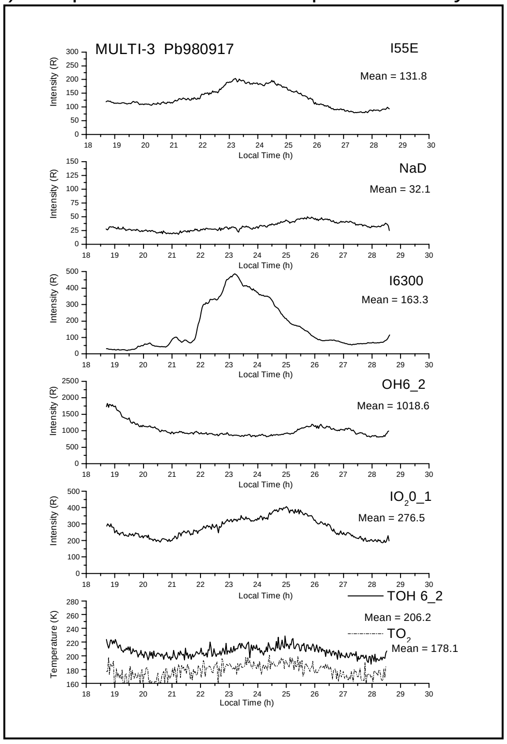

Fig. 1. Nocturnal variations of the emission intensities and the rotational temperatures at São João do Cariri, for the night of September 17, 1998.

INSTRUMENTATION

In order to measure several airglow emissions simultaneously, a multichannel tilting filter photometer, named as MULTI-4, was designed and constructed at INPE. Each emission line and the corresponding background continuum are measured separately by scanning the wavelength over 8.0 nm from the center wavelength via filter tilting. One sequence with five filters and the instrumental noise level check takes about 3 minutes, which is sufficient to observe airglow intensity nocturnal variation.

The photometer absolute sensitivities at different tilted positions are calibrated by using a laboratory standard light source (Eppley ES-8315) and MgO screen. A calibrated substandard light source, tungsten filament pilot lamp, was used for field observation. Estimated errors in the absolute intensity for OI 5577, NaD and OI 6300 are approximately 5 %, and for OH (6,2) and O2A the error is around 10 % owing to the increased systematic error in calibration. The instrumental error in determining the rotational temperature T(OH) in this study is ± 3 K.

OBSERVATIONS

Airglow observations were started on a routine basis at São João do Cariri (7.5° S, 35° W) January 1998. The observation site is a dry region in Brazil, permitting to get continuous observation from day to day. Up to the end of December 1998, 110 nights of observations were obtained with good sky condition, each with more than 6 hours of measurement. In Figure 1 an example of the nocturnal variations of the emission intensities and the rotational temperatures for the night of September 17 is shown. Mesospheric oxygen emissions, OI5577 and O2A(0,1), showed maxima around midnight, although the OI5577 peak leads to O2A for about one hour.

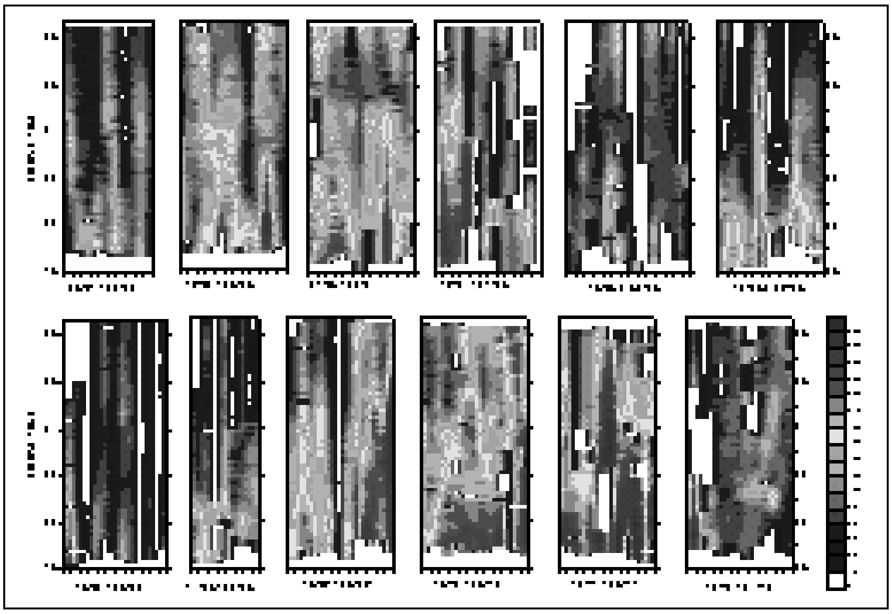

Fig. 2. Gray scale map of the OI 5577 emission intensity nocturnal variations, from January to December 1998.

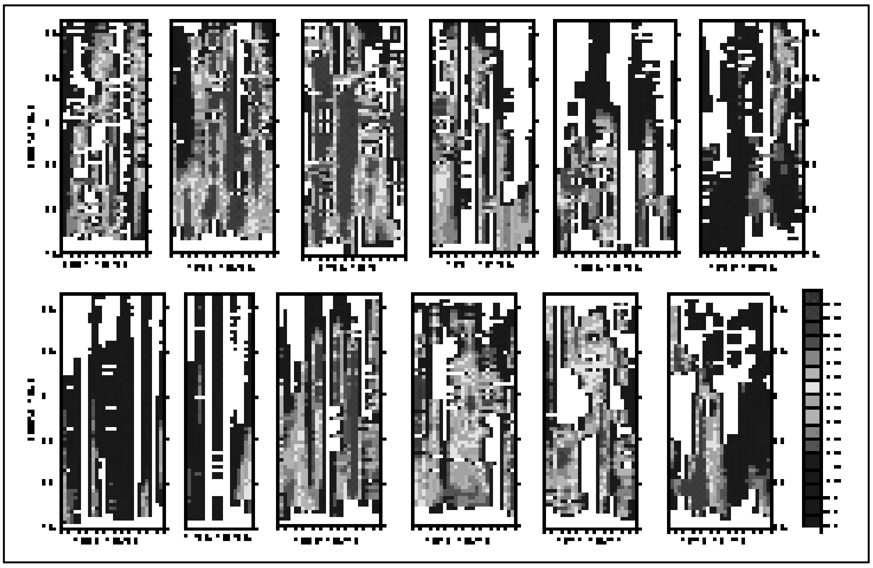

Fig. 3. Gray scale map of the OH (6,2) band intensity nocturnal variations, from January to December 1998.

Day to day variations: In order to see day to day variation of the nocturnal variations, color shaded nocturnal intensity variations are plotted as a function of day number from January to December. The day to day variation of the OI 5577 is shown in Figure 2. As can be seen, the intensity level is increasing from gray to black. Each new moon period is grouped in a block. The blank columns appeared in the blocks means lack of data point due to bad sky condition. During the first

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three months, from January to March, almost of all the nights the airglow data were collected successfully. From the figure there are two things coming out, (1) the OI 5577 emission has peak intensity during the equinox months, March/April and September/October. The peak intensity shifts from month to month, showing a seasonal dependency of the phase, (2) there seems to have a 2 to 3 day oscillation superposed on the long term trends.
Figure 3 shows the case of OH (6,2) band emission. It is also shown seasonal dependency with equinox maxima. It is interesting to note that the phase of the peak intensity is around midnight, which is different to the case of OI 5577. The phase shift intensity maxima between the OI 5577 and OH is most probably due to tidal diurnal oscillation. Further investigation will be necessary comparing to the dynamical model. In this picture it is also possible to see tendency of 2 to 3 days oscillation.

DATA ANALYSIS AND DISCUSSION

Nocturnal and day to day variations of the airglow emission intensities showed in the Figures 2 and 3, reveal that these emission rates are mainly controlled by dynamical process in the mesopause region. Semiannual oscillation (SAO) with the equinox maxima is generated by interaction between solar diurnal tides and gravity waves in the mesosphere (Lieberman et al., 1993)
It is interesting to point out that the quasi-two day period oscillations could be seen for all of the mesospheric emissions. In order to see the periodicity with more detail, the Maximum Enthropy Spectral Analysis (MESA) was applied for variation of the nocturnal mean values for each emission. Figure 4 shows the period and amplitude from the MESA analysis for OI 5577, O2 atmospheric band, OH(6,2) band and OH rotational temperature. The results of the NaD and OI 6300 emissions are not included in the figure.
From the figure it is clear that there is a strong tendency to have a quasi-three days oscillation for all of the emissions. It was not the quasi two-day oscillation as predicted from the previous works. In February, the OH and rotational temperature show around 2.5 day period. In April, however, the two parameters show 5.5 and 7 day periods, respectively. Month to month variation of the amplitude shown in Figure 4 reveal that in general the amplitude is larger in February and May/June and lower in March/April and September. It seems to indicate that the 3 day oscillation is strong in the month after the solstices. Harris and Vincent (1993) have presented large amplitude quasi-2 day wave oscillation of the wind system in the equatorial region just after the solstices. Our present results show similar results for the airglow emissions.

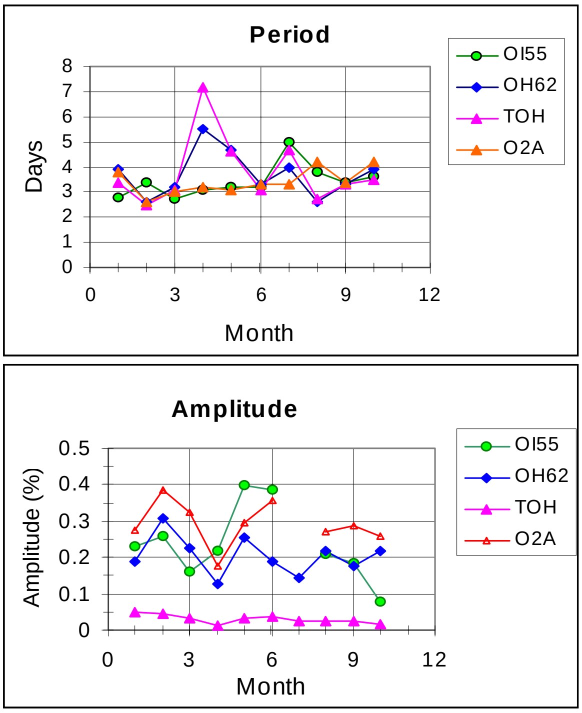

Fig. 4. Period (in days) and Amplitude (%) of the day to day variations of the OI 5577, O2 atmospheric (0,1) band, OH (6,2) band, and OH rotational temperature, observed at Cariri in 1998.

CONCLUSIONS

Mesospheric airglow emissions, OI 5577, NaD, OH(6,2) and O2A (0,1) bands and atmospheric temperature at around 87 km and 94 km were monitored by a multi-channel photometer at São João do Cariri (7.5° S, 35° W) in 1998. Good local weather condition permitted to carry out continuous observation during 14 days around the new moon period. All of the mesospheric emissions demonstrate nearly three-day-oscillation. This is longer than the two-day period observed from the wind measurement (Harris and Vincent, 1993). Planetary wave activities are known to be significant at middle latitudes, but not well known in the equatorial region. Our present results strongly suggest that the planetary wave with quasi-two to three-day period is also evident at the equator. Further investigation is necessary in order to clarify the source of oscillation.

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