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Atmospheric tidal waves in the troposphere and lower stratosphere observed by Wuhan MST radar

Haiyin Qing
School of Physics and Electronic Engineering, Leshan Normal University, 614000, China

Abstract

In this paper, the observation data of the Wuhan MST radar in the whole 2012 are used making a statistical analysis on the low stratospheric and troposphere tidal waves. The results show that: (1) the diurnal tide is the strongest and most of the time at low levels of Sunday tide is stronger than the high tide of Sunday. (2) the amplitude of the tidal wave is not modulated by the fluctuation with a smaller time scale than their periods, and only these waves with a longer time scale than their periods can affect the variation of the amplitude of the tidal waves.

Keywords: MST radar; Atmospheric tidal waves; troposphere; stratosphere; planetary waves

1. Introduction

The atmosphere tides are mainly caused by the action of the sun or the moon. According to the difference of excitation souse can be divided into the lunar tides and the solar tides, according to the form of excitation can be divided into Thermal tides and Gravitational tides (Haurwitz, 1964). Among them, the lunar tides are excited by the effect of gravity, its cycle is a lunar day or an integral part of the lunar day; The solar tides are due to gravitational interaction and thermodynamic activity, and thermodynamic activity stronger than gravitational interaction, its cycle is a solar day or an integral part of the solar day. Here we will focus on the thermal tides of the atmospheric sun, and it is called atmospheric tides. atmospheric tides include diurnal tides, semi-diurnal tides, 8 hours tides, 6 hours tides, the main cause of it comes from troposphere water vapor phase change heating, stratospheric ozone absorption solar radiation heating, and sustained heating caused by deep currents in tropical regions. Tides are regarded as a common form of fluctuation in atmospheric activity, the scientists studied the law of it activities by various methods, and its interaction with the atmospheric background wind field and other forms of wave (Boy et al., 2006; Kohyama et al., 2016; Nguyen et al., 2016; Jacobi et al., 2017). Wuhan MST radar operated in September 2011, and accumulates a great deal of data of troposphere and stratosphere wind fields with a high time resolution, which is very helpful to study the activities of the atmospheric tidal waves and analyze the interaction between atmospheric tidal waves and other waves.

2. Data and Method

This paper mainly deals with the observation data of Wuhan MST radar in 2012. The months of 12, 1, 2 are divided into winter; the months of 3, 4, 5 are divided into spring; the months of 6, 7, 8 are divided into summer; and the months of 9,10,11 are divided into autumn. Then choose the most complete data in the strength of 50 days to carry out different tidal wave components in the four seasons. The time resolution of the data is 0.5 h, and the slip time length is 4 days. Fitting time series of wind field data in time window by least square method, the fitting model is as follows：

$$v(t) = v0 + \sum_{i=0}^{4} a_i\left(\frac{2\pi t}{T_i} + \varphi_i\right) \quad (1)$$

Where, a_i, T_i, φ_i are respectively the amplitude, period and phase of the 4h, 6h, 8h, 12h and 24h the tidal components. Statistical analysis shows that most of the four seasons all exist the tidal component, and there is not obvious seasonal difference. In a word, the amplitude of diurnal tidal wave is the strongest. The amplitude of 4 h tidal wave is the most weaker and most of the time is negligible. Generally speaking, the diurnal tides at all seasons and heights almost are dominant. By contrast, most of the time, the diurnal tidal waves at lower heights are stronger than that at higher heights which might be related to the background wind fields. Because it is stronger of the background wind fields in the troposphere, and the air density of the troposphere is relatively high. There is rarely energy to form a larger background disturbance to the region, but the stratosphere is different. Its air is relatively thin, then most of small scale movements may be broken here. At the same time, it is affected by the jets and wind shear in the tropospause region, which can seriously affect the stability of the background wind. Another obvious reason is the affection of tidal sources. In the lower atmosphere, the heat source is the absorption of water vapor and carbon dioxide near the infrared band of the solar radiation. The heat source in the middle atmosphere is the absorption of ozone against the ultraviolet radiation of the sun. As the ozone is decreasing, the absorption of ozone to the solar ultraviolet radiation is getting weaker and weaker, so it is difficult to provide the energy required to maintain the tidal fluctuation of the strong drift layer.

3. Analysis and Discussion

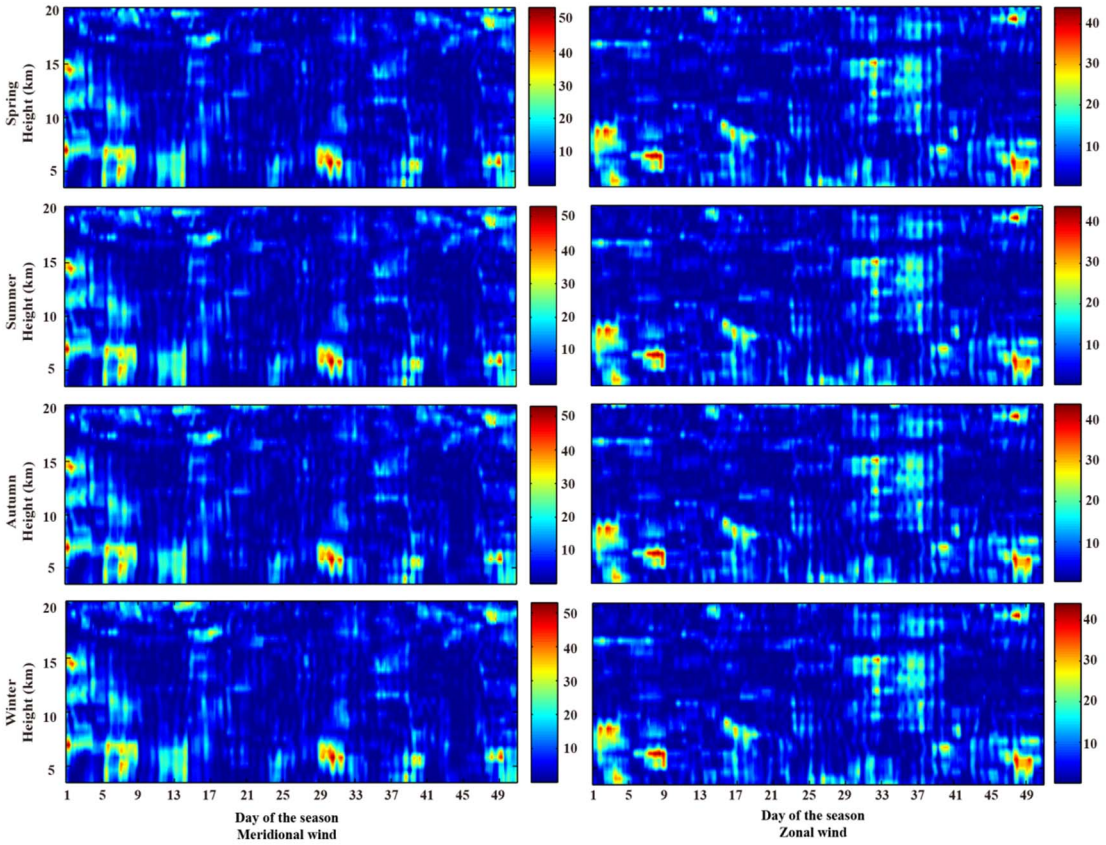

Figure 1. Spatiotemporal variation of the amplitude of the diurnal tides

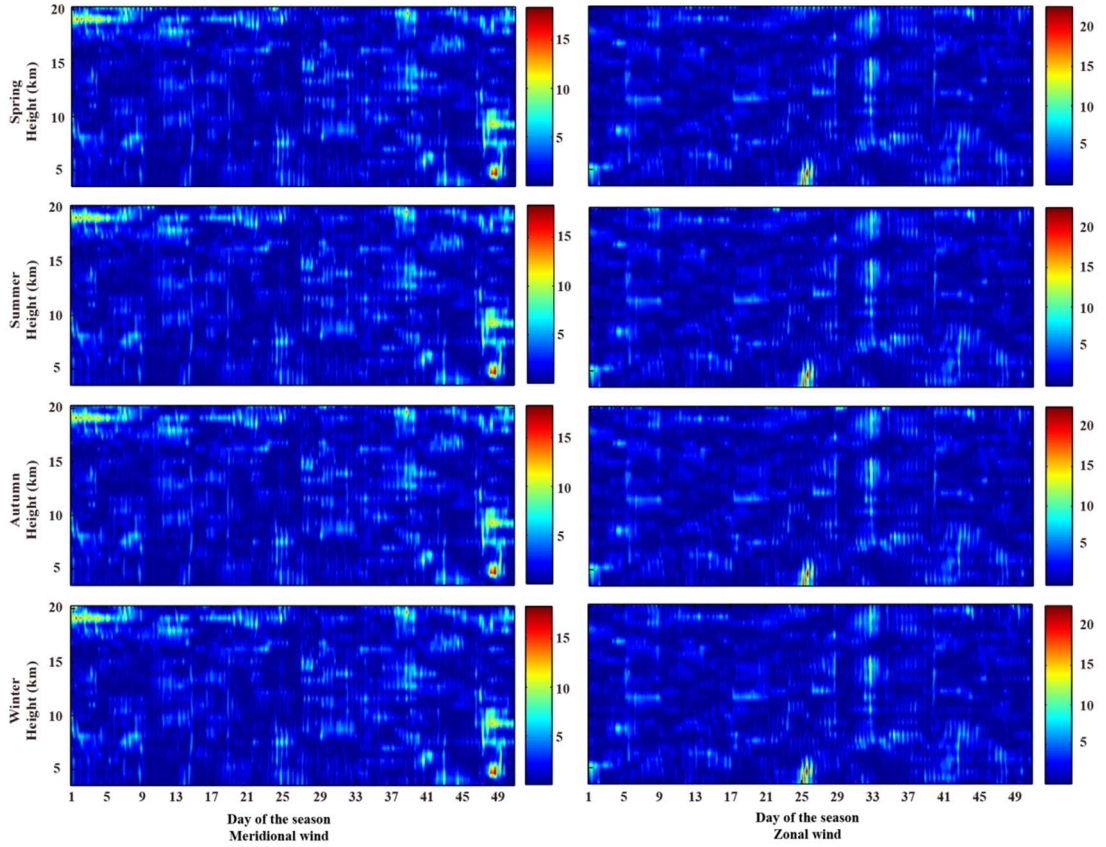

Figure 2. Spatiotemporal variation of the amplitude of the semi-diurnal tides

The amplitude variations of diurnal tides and semi-diurnal tides with the heights about 3~20 km are shown in Figure 1 and Figure 2. Though the amplitude variations of diurnal tides and semi-diurnal tides are not obvious space-time features, there's a prominent characteristic: At all heights, the amplitude of diurnal tides and semi-diurnal tides both appeared obvious periodic changes, and the disturbances are also very obvious. The fluctuate can appears at any time and any height, and exist in all the horizontal wind of the atmosphere. Thus, it can be seen it's not a modulation by accident, but a relatively stable modulation. The atmospheric wind field will be modulated by tidal waves, in that way the amplitude of atmospheric tidal waves how will it be modulation? And all the year round it's so obvious at all heights. At the same time, compared the variation between Figure 1 and Figure 2, it shows as if the amplitude fluctuation period of the diurnal tides is longer than that of the semi-diurnal tides. This paper uses the Lomb-Scargle spectrum to detect and analyze the disturbance components (Qing et al., 2014).

Figure 3 shows the average profile of Lomb-Scargle spectrum of the diurnal tides and the semi-diurnal tides with each height in different seasons. From Figure 3, we can see that the amplitude disturbance of the tidal waves in every season are almost the same, and the peak period is very closed in the zonal components and the meridional components. In the disturbance periods of the amplitude of the diurnal tides, the main period components are 24 hours, 29.2 hours and 35.6 hours. In the perturbation periods of the amplitude of the semi-diurnal tides, the main period components are 12.5 hours, 21.2 hours, 25.8 hours and 36.6 hours; The main period components are the mean values of the similar period in the meridional components and the zonal components. It can be seen from the periodic map that the amplitude of the tidal waves is not modulated by the fluctuations with a smaller time scale than their periods. So only these waves with a longer time scale than the periods of the tidal waves can affect the variation of the amplitude of the tidal waves.

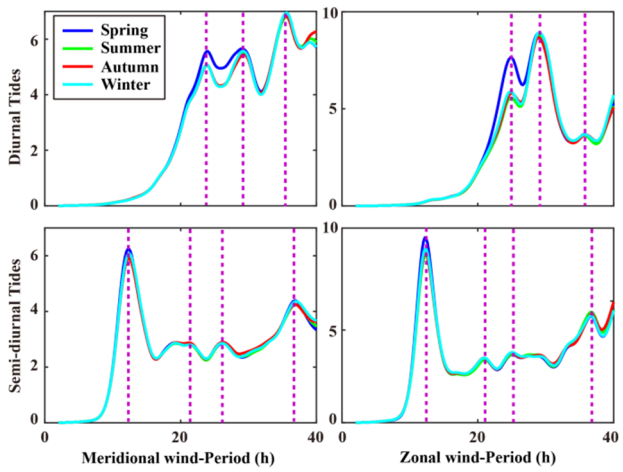

Figure 3. Mean perturbation period of the amplitude of the tides

4. Summary

In this paper, the observations from Wuhan MST radar with high temporal resolution are used to analyze the characteristics of the atmospheric tidal wave in troposphere and the low stratosphere. According to the statistics of data analysis in the whole 2012, we can see that the diurnal tides in the troposphere and low stratosphere in each season are almost strongest. The energy of the tidal waves in the troposphere is more powerful than that in the lower stratosphere. At the same time, according to the perturbation of amplitude of the diurnal tides and semi-diurnal tides, it can be found that the amplitude of the tidal wave is not modulated by the fluctuation with a smaller time scale than their periods, and only these waves with a longer time scale than the periods of the tidal waves can affect the variation of the amplitude of the tidal waves.

5. Acknowledgements

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6. References

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