

PAPER • OPEN ACCESS

Internal gravity and tidal waves in the mesopause region in Yakutia

To cite this article: V I Sivtseva *et al* 2019 *J. Phys.: Conf. Ser.* **1152** 012012

View the [article online](#) for updates and enhancements.

You may also like

- [Response of the High-latitude Upper Mesosphere to Energetic Electron Precipitation](#)
Zicheng Zou, Xianghui Xue, Wen Yi et al.
- [Climatological Gravity Waves in the Middle and Upper Atmosphere of Mars Based on ACS/TGO Observations](#)
Qianqian Ji, Xiaoqian Zhu, Zheng Sheng et al.
- [Reflection Characteristics of Layered Media in Polar Mesopause Related to Polar Mesosphere Summer Echoes](#)
Li Hailong, Wu Jian, Huang Jiying et al.





The
Electrochemical
Society

Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Internal gravity and tidal waves in the mesopause region in Yakutia

V I Sivtseva, P P Ammosov, G A Gavrilyeva, I I Koltovskoi, A M Ammosova

Yu G Shafer Institute of Cosmophysical Research and Aeronomy of SB RAS,
Yakutsk, Russia

E-mail: verasivtseva@gmail.com, ammosov@ikfia.ysn.ru, gagavrilyeva@mail.ru,
koltigor@mail.ru, ammosovaam@mail.ru

Abstract. The temperature of the mesopause region (87 km) is monitored at the Maimaga station (63.04 ° N, 129.51 ° E) using the Shamrock (Andor) spectrograph recording the hydroxyl (OH) band (3, 1). The temperature data obtained for the seasons from 2013 to 2017 are investigated. The standard deviations corresponding to the internal gravity σ_{gw} and tidal waves σ_{td} were obtained. The seasonal course of the tidal component σ_{td} varies from 2 to 5 K throughout all observation seasons. The seasonal variation of the gravitational component σ_{gw} observed at Maimaga station almost coincides for three observation seasons except for the 2014-2015 season. In this observation season, σ_{gw} has lower values in winter than in other seasons. Moreover, in this season average monthly temperatures exceed similar values in other seasons.

1. Introduction

Recently, the mesopause region has been of great interest to the study. This is due to the fact that this region actively interacts with the radiation particles coming from above, and with a wide spectrum of waves propagating upward from the lower layers of the atmosphere.

Wave activity makes a significant contribution to the temperature regime of mesopause. The tides cause adiabatic compression and expansion of the mesopause region, respectively, causing warming up or cooling of the environment [1, 2]. Internal gravity waves (IGW), propagating upward from the lower layers of the atmosphere, transfer the momentum and energy to the mesosphere and the thermosphere. At the height of the mesopause due to the wind shear, IGW undergo spectral filtering and are absorbed, causing warming up in this region [3] (thus, the seasonal course of the mesopause temperature correlates with the wave activity). The amplitude of IGW and tidal waves increases with altitude due to a decrease in atmospheric density, which makes it possible to detect them in the upper layers of the atmosphere.

A large number of studies of wave activity at the height of the mesopause were carried out at mid-latitudes [4, 5]. Therefore, the temperature behavior and the wave activity of high-latitude mesopause are of great interest. This paper presents studies of standard deviations of temperature σ from its mean values in the mesopause region (87 km) according to the measurements at the high-latitude station Maimaga (63.04 ° N, 129.51 ° E).



2. Spectrograph and data processing method

A photosensitive infrared spectrograph Shamrock SR-303i with a working wavelength range of 1490-1544 nm was used to record the OH (3, 1) hydroxyl band. The spectrograph makes it possible to measure the temperature of the mesopause with an accuracy of ~ 2 K. The software developed in this research allows the device to work completely in an autonomous mode.

Exposure time for obtaining one measurement of the hydroxyl spectrum in the OH (3, 1) band is 60 sec. Short exposure not only allows to significantly expand the range of periods of internal gravity waves under investigation, but also includes acoustic waves (3-5 min periods) in the spectrum. The data were averaged in 3 min increments to exclude acoustic waves from consideration.

The method for estimating the rotational temperature of molecular emissions is based on fitting the model spectra constructed with allowance for the spectrograph's instrument function for various predetermined temperatures, to the actually measured spectrum [6, 7]. The rotational temperature, determined from the intensity distribution in the hydroxyl (OH) band, is close to the kinetic temperature of the neutral gas at the emission height [8]. The transition probabilities calculated by Mies [9] were used to estimate the rotational temperature along the hydroxyl band.

In order to exclude data with a high level of noise interference, a sampling of the spectra satisfying the signal-to-noise ratio > 20 was performed, then the temperature was averaged in steps of 3 min. The standard deviation of temperature σ from its mean value is assumed as a characteristic of the night wave activity. It is a superposition of various active waves at night and the noise of the detector dark current. According to [10], the superposition of waves can be represented as:

$$\sigma = \sqrt{\sigma_{td}^2 + \sigma_{gw}^2 + \sigma_{noise}^2} \quad (1)$$

Where σ_{td} is the standard deviation of temperature due to tidal waves, σ_{gw} is the standard deviation of temperature due to internal gravitational waves, σ_{noise} is the component of the standard deviation of temperature caused by the noise of the dark current of the detector. σ_{noise} was calculated as the arithmetic average of the errors of each individual measurement per night. The planetary waves were not taken into consideration, since their time scale is much longer than one night.

The value of σ_{td} was determined by separating the harmonics corresponding to the 24-, 12-, and 8-hour components of the daily tide from the night temperature series by the method of least squares.

$$f_{td} = \bar{T} + A_1 \cos\left(\frac{2\pi}{1440}(t - \varphi_1)\right) + A_2 \cos\left(\frac{2\pi}{720}(t - \varphi_2)\right) + A_3 \cos\left(\frac{2\pi}{480}(t - \varphi_3)\right) \quad (2)$$

f_{td} is the sum of the harmonics of the daily tide, periods are indicated in minutes.

The result of subtracting the sum of the daily tide harmonics from the nighttime temperature range corresponds to the contribution of the dark current noise and the spread of IGW to the temperature. Hence, the standard deviation σ_{gw} is calculated.

3. The results of observations and their analysis

The tidal components of the standard deviations of temperature are shown in figure 1.

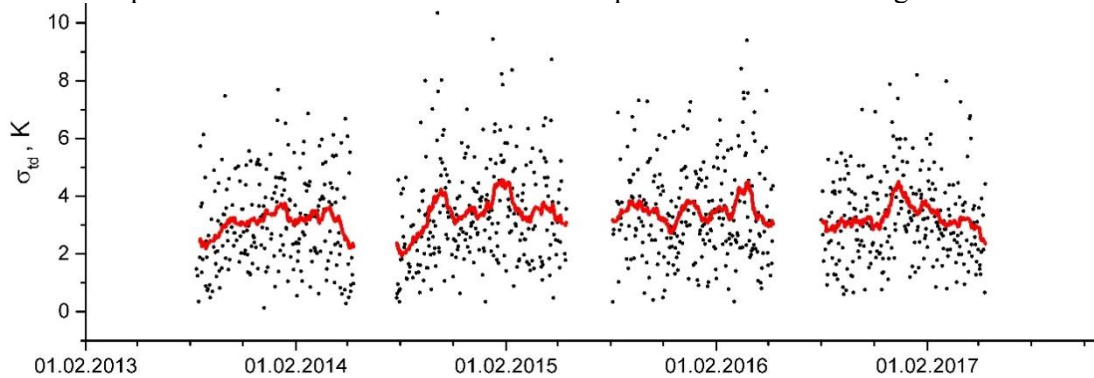


Figure 1. Seasonal variations of the tidal component of standard deviations of temperature

The red line is a moving average line with a transmission window of 30 days and represents the seasonal course of the tidal component σ_{td} . The seasonal course of the tidal component of standard deviations of temperature σ_{td} varies from 2 to 5 K throughout all observation seasons.

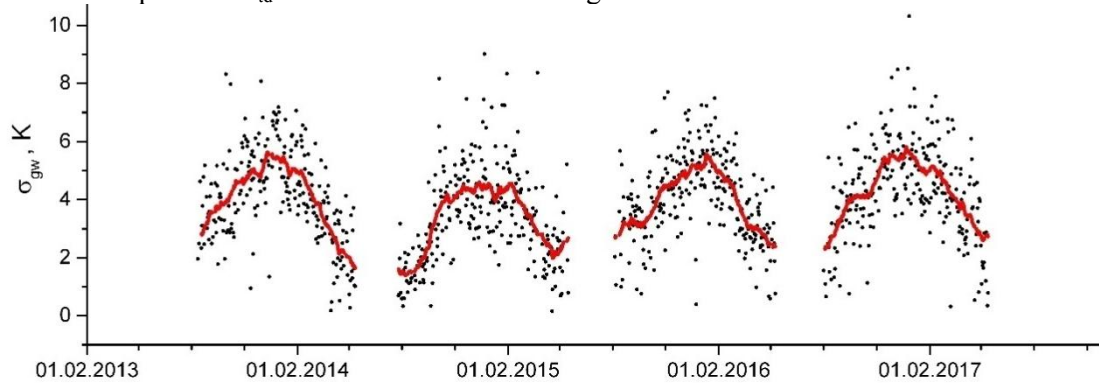


Figure 2. Standard temperature deviations caused by internal gravity waves

The standard temperature deviations corresponding to IGW are shown in figure 2, where the red line denotes a moving average with a transmission window of 30 days, representing the seasonal variation of the gravitational component σ_{gw} . The values of the gravitational component of standard deviations of temperature σ_{gw} observed at Maimaga station and their seasonal variations almost coincide for three observation seasons except one. In the observation season 2014-2015, the gravitational component of standard deviations of temperature σ_{gw} has lower values in the winter period than in the other observation seasons. In addition, during this season the average monthly temperatures of the winter mesopause, on the contrary, exceed the values in other seasons by an average of 8.3 K (figure 3). The seasonal variation of the gravitational component varies from 2 to 6 K, and in the 2014-2015 season from 1.5 to 5 K.

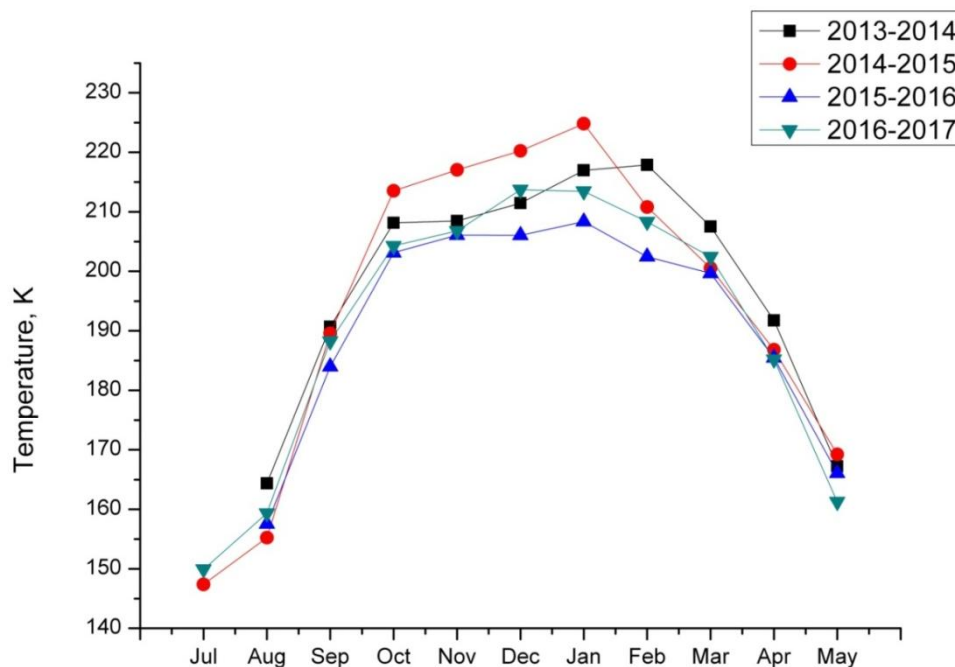


Figure 3. Mean monthly rotational temperatures of hydroxyl

The lower IGW activity in the winter period of the 2014-2015 season can be explained by the fact that it is possible that during this season a significant part of the IGW energy was absorbed at a height

close to the height of the emission layer, which is confirmed by the observed elevated mean monthly temperature during this period.

4. Conclusions

The standard deviations of temperature σ from its mean values in the mesopause region were investigated according to measurements at the Maimaga station (63.04 ° N, 129.51 ° E). The spectra are recorded using a Shamrock (Andor) photosensitive infrared spectrograph recording the OH band (3, 1) in the far infrared region (about 1.5 μm). The data for the seasons from 2013 to 2017 were studied.

The standard deviations corresponding to the internal gravity σ_{gw} and tidal waves σ_{id} were obtained. The seasonal course of the tidal component σ_{id} varies from 2 to 5 K throughout all observation seasons. The seasonal variation of the gravitational component σ_{gw} observed at Maimaga station almost coincides for three observation seasons except for the 2014-2015 season. In this observation season, the gravitational component σ_{gw} has lower values in the winter period than in the other observation seasons. In addition, during this season, the average monthly temperatures of winter mesopause exceed similar values in other seasons.

Acknowledgments

The research was supported by “Scientific and Educational Foundation for Young Scientists of Republic of Sakha (Yakutia) within the Project №17-2-009477 “Scientific and Educational Foundation as an instrument for young scientists to develop their professional competence and science popularization” 20171201005-2, RFBR No. 17-05-00855 A and grant of the Head of the Republic of Sakha (Yakutia) for young scientists, specialists and students.

References

- [1] Chapman S and Lindzen R 1972 *Atmospheric tides* (Moscow: Mir Publishers) p 295
- [2] Brasseur G and Solomon S 1987 *Aeronomy of the middle atmosphere* (Leningrad: Gidrometeoizdat Publishers) p 413
- [3] Hines C O 1974 *The upper atmosphere in motion* (Washington D C: AGU) p 1027
- [4] Offermann D, Wintel J, Kalicinsky C, Knieling P, Koppmann R, Steinbrecht W 2011 *J. Geophys. Res.* **116** D00P07
- [5] Perminov V I, Semenov A I, Medvedeva I V, Pertsev N N 2014 *Geomagn. Aeron.* **2** **54** 230–9
- [6] Ammosov P P and Gavril'yeva G A 2000 *Prib. Tekh. Eksp.* **6** **43** 792–7
- [7] Gavril'yeva G A and Ammosov P P 2002 *Geomagn. Aeron.* **2** **42** 267–71
- [8] Shefov N N, Semenov A I, Khomich V Yu 2006 *Studying the Upper Atmosphere as an Indicator of Its Structure and Dynamics* ed M A Yatsenko (Moscow: GEOS) p 741
- [9] Mies F H 1974 *J. Mol. Spectrosc.* **2** **53** 150–80
- [10] Offermann D, Gusev O, Donner M, Forbes J M, Hagan M, Mlynyczak M G, Oberheide J, Preusse P, Schmidt H, Russell J M III 2009 *J. Geophys. Res.* **114** D06110