PROCEEDINGS OF SCIENCE

The influence of geomagnetic activity on the subauroral mesopause temperature over Yakutia

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Regular observations of the hydroxyl emission band (6-2) were carried out at the Maimaga station (63°N, 129,5°E) since 1999. Measurements were conducted with an infrared spectrograph. The monthly average residuals of OH(6-2) temperature after the subtraction of the mean seasonal variation were studied earlier. The residual temperature maximum follows peak of Ottawa 10.7 cm flux with 25 months delay was found. The effect of geomagnetic activity on the subauroral mesopause temperature was evaluated to find the possible reasons for the time lag. The rotational temperature data set comprises 2229 nightly averages which pass selection criteria. For the analysis was used Ap-index, which is indirectly dependent on the characteristics of the solar wind. The cross-correlation analyses showed connection between OH(6-2) rotational temperature with the geomagnetic activity. The correlation coefficient R = 0.44 with a value p=0.95. It can be concluded that the correlation between monthly average residuals of OH(6-2) temperature and monthly average of Ap-index is significant for period from 1999 to 2013.

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1. Introduction

Krassovsky V.I. was predicted that geomagnetic disturbances could affect the composition and temperature of the upper atmosphere [1]. Shefov N.N. in research was shown that the emission intensity and rotational temperature of the hydroxyl molecule react to variation of geomagnetic activity [2]. It is known that the total solar radiation fluctuates during the 11-year solar cycle by only 0.1%, while the radiation in the ultraviolet region changes to 5-8% [3]. At the maximum of solar activity, the enhanced ultraviolet is absorbed in the upper atmosphere by other atoms and molecules of oxygen, ozone, and heats up the environment through exothermic chemical reactions [4]. An additional channel of energy transfer from the Sun to the Earth can be geomagnetic disturbances, accompanied by direct penetration of energetic corpuscular particles, primarily protons and accelerated electrons in the magnetosphere, into the atmosphere [5]. In recent decades, numerous works have appeared, indicating the impact of 11-year activity of the Sun on the dynamics and temperatures of the thermosphere and even the troposphere [6]. In paper [7] the atmospheric temperature response at the hydroxyl (OH) emission height to the 11-year solar cycle reaches 7 K with a shift in the temperature range by 2 years relative to the solar cycle maximum are presented. As a measure of geomagnetic activity the Ap-index is used, which indirectly depends on the characteristics of the solar wind. Ap-index reaches a maximum about two years after the maximum of solar activity. The purpose of this research is to search for a possible mechanism for the response of the temperature of the subauroral mesopause to the solar cycle.

2. Equipment and database

Mesopause is a region of the atmosphere where the mesosphere borders on a thermosphere (80-100 km) and there is a temperature minimum. The OH radiation layer is approximately at an altitude of 87 km in mesopause region. The mesopause temperature data for the present paper were obtained with the infrared spectrograph made on the basis of a grating spectrograph SP-50. The device was installed at the optical station Maimaga (63°N, 129.5°E) which is at a distance of about 120 km to the north of Yakutsk. Observations were carried out in cloudless nights, with the sun at least 9° below the horizon. For the analysis, the data obtained during moonless time and in the absence of aurora were selected. To register the spectrum the CCD camera installed into the device and located after the spectrograph is used since 1999 [8]. It allows using the P-branch of spectrum for estimation the rotational temperature. The estimation method of rotational temperature of the molecular emission is based on the adjustment of modelling spectra constructed with the account of apparatus function of the device for various temperatures specified in advance, to the spectrum measured really using a standard least squares method. The modelling spectrum, whose deviation from the real one does not exceed a registration noise, is considered to be the most corresponding to the reality and its rotational temperature corresponds to the temperature at a height of mesopause. The exposure time is ~ 10 min. As the estimations show the errors of temperature measuring are in the range of 2–5 K. Calibration of the infrared spectrograph was performed twice a year by means of gas discharge lamp (Ne). The surveys of the nightglow spectrum are carried out from the middle of August to the middle of May, since the summer mesopause is constantly sunlit at the Yakutsk latitude. The longest night series of data are registered during winter months. The number of measuring per month varies from 10 to 25 nights [9]. 2229 nightly averages OH(6-2) temperature were measured by infrared digital spectrograph, satisfying the sampling criteria, for estimate the average monthly values of the hydroxyl temperature for the period August 1999 to May 2013 are presented in Figure 1.

Figure 1: Series of OH(6-2) rotational temperature obtained at the Maimaga station from 1999 to 2013

3. Results

The Maimaga rotational temperature data set comprises 2229 nightly averages which pass selection criteria. The seasonal change of temperature can be estimated as a sum of an annual, semiannual and terannual harmonics:

$$T = A_0 + A_1 \cdot cos(\frac{2 \cdot \pi}{365} \cdot (d - \varphi_1) + A_2 \cdot cos\left(\frac{4 \cdot \pi}{365} \cdot (d - \varphi_2)\right) + A_3 \cdot cos(\frac{6 \cdot \pi}{365} \cdot (d - \varphi_3)$$

где A_0 - average temperature for each year, A_1, A_2, A_3 - three components of the seasonal temperature change, and their phases φ1, φ2, φ, d - day number, for 1 day is taken on August 1st.

If their amplitude and phases are known the season variation can easily be removed from the time series. The fit of annual, semiannual and terannual terms to these data with amplitudes of 28.6 K (maximum on day 312), 10.6 K (maximum on day 350) and 3 K (maximum on day 361), respectively.

Earlier, we studied the residual rotational temperatures OH (6-2) measured at the Maimaga station from 1999 to 2013 after subtracting their seasonal component. It was found that the maximum in the series of residual temperatures is delayed by 25 months relative to the maximum flux of radio emission from the Sun with a wavelength of 10.7 cm (index F10.7). Index F10.7, which is emitted at a frequency of 2800 MHz (wavelength of 10.7 cm), characterizes the conditions in the solar corona and has a high correlation with the short-wave Sun ultraviolet radiation. However, it must be taken into account that measurements of the mesopause temperature were carried out at the subauroral station, where the influence of the sun on temperature is not limited only to light radiation, it is also necessary to take into account the contribution of geomagnetic activity. The increase in the response of the mesopause temperature when shifted by 25 months relative to the solar cycle is up to 7 K, indicates a possible connection with geomagnetic activity. It is known that geomagnetic activity reaches a maximum, approximately 2 years from the maximum of the solar cycle. Figure 2 shows the average monthly residual OH(6-2) temperature after subtracting the seasonal component and the Ap-index monthly averages.

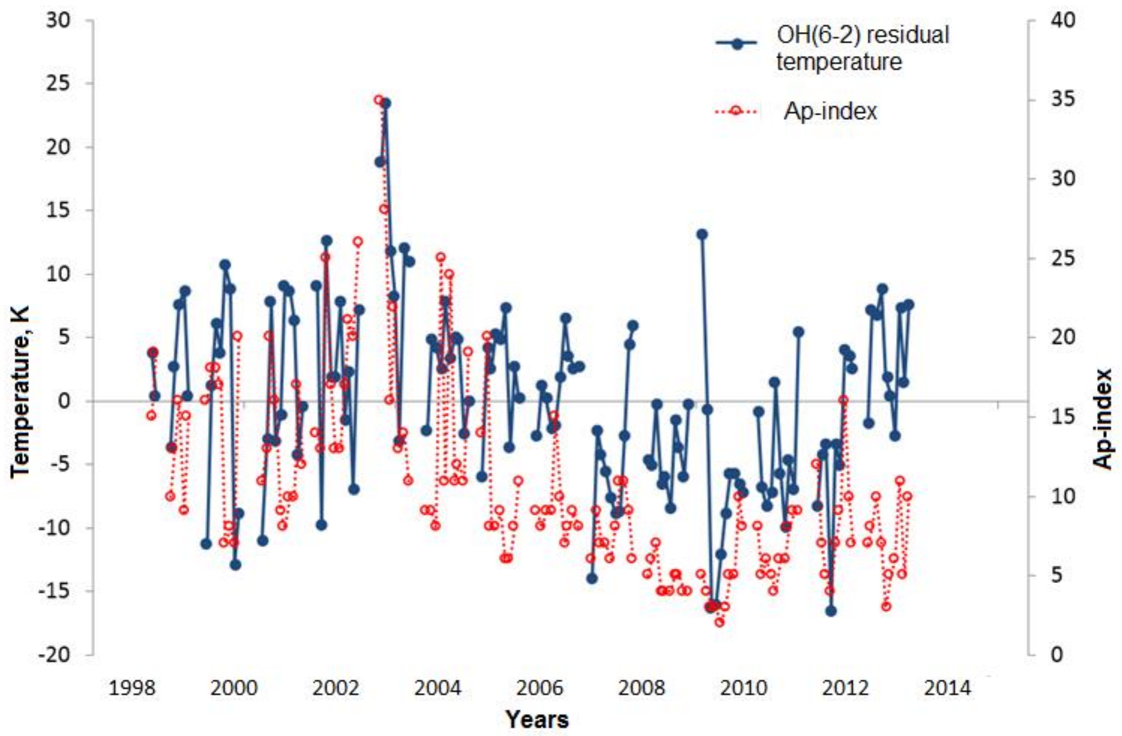

Figure 2: Residual OH(6-2) temperatures and the Ap-index from 1999 to 2013.

To determine the correlation between the geomagnetic activity and the OH(6-2) rotational temperature, the mean monthly values of the residual hydroxyl temperatures and the monthly averages of the Ap-index were used. The Ap-index is the average planetary index of geomagnetic activity, obtained as the arithmetic mean of the eight Kp-indices characterizing the oscillations of the horizontal component of the Earth's magnetic field, measured every 3 hours by magnetometers at several points of the globe over the past day. It should be clarified that in order to find the average monthly values of the Ap-index, a sample was taken of the average daily values, in which only those days occurred during which observations of the emission of hydroxyl emission were carried out.

To evaluate the dependence between the OH(6-2) rotational temperature and geomagnetic activity, a correlation analysis was performed. Figure 3 shows the cross-correlation function of the average monthly residual OH(6-2) temperature with an average monthly value of the Ap-index. The correlation coefficient is R = 0.44, with a level of 95% confidence interval. The correlation found is statistically significant.

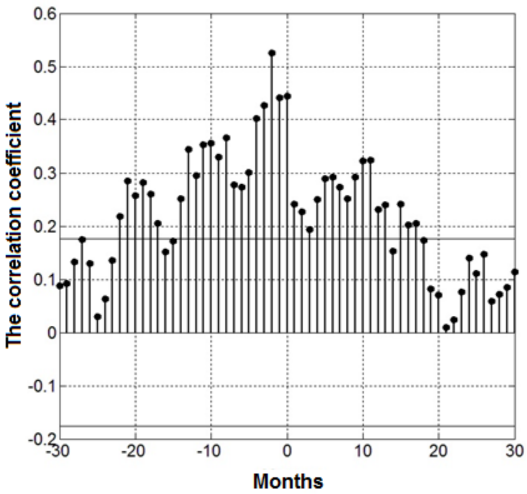

Figure 3: Cross-correlation function for the residual temperature with the Ap-index average monthly value.

4. Conclusions

According to observations of the emission of hydroxyl emission 2229 mean values of the rotational temperature of hydroxyl were found at Maimaga station from 1999 to 2013. Based on the results of cross-correlation analysis the influence of geomagnetic activity on the temperature of the subauroral mesopause was revealed between the mean monthly residual OH(6-2) temperatures after subtracting the seasonal components and the average monthly values of the Ap-index. The correlation coefficient R = 0.44 with a value p=0.95. The correlation found is statistically significant.

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