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MEASUREMENTS OF THE MESOSPHERE TEMPERATURE BY TWO MOLECULAR EMISSIONS IN YAKUTSK (62°N, 129,5°E)

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Abstract. The results of the hydroxyl and oxygen molecules rotational temperature measurements during two observational seasons 1999-2001 at Maymaga station (φ=63°N; λ=129.50°E) are presented. The rotational temperatures of OH(6,2) and O_2(0,1) bands have been measured with the infrared spectrograph equipped by the cooled CCD registration system. It is shown that the amplitude of seasonal change of hydroxyl rotational temperature is greater than the molecular oxygen variation. OH temperatures have been systematically higher the O_2 ones during winter. An abrupt decrease of the O_2 intensity connected with the springtime transition of the atmospheric circulation is found in both time series. For the first time a change of the temperature vertical gradient sign caused by mesopause height displacement to a higher (winter) level was shown in the data of August-September 2001.

Introduction

One of the methods widely used in investigation of the upper atmosphere is the ground-based optical measurements of intensity and rotational temperature variations of hydroxyl (OH) and molecular oxygen (O_2) emissions [Shefov, 1972, Noxon, 1978, Sivjee, 1992]. It is considered that the maximum of OH excitation is at~87 km and for the O_2(0-1) atmospheric band it is at ~94 km. So the simultaneous registration of OH and O_2 luminosity allows us to study the upper mesosphere conditions at the two height levels. In this paper we present the results of the nightglow measurements conducted during four observational periods from 1997 to 2001 in Yakutsk.

Experimental technique

In order to measure the temperature and register the wave propagation in the mesopause region, a spectrograph with a digital output which permits to register the molecular spectra in the near infrared nightglow has been created in IKFIA. The instrument consists of the spectrograph and the CCD-camera connected with a personal computer. The use of the CCD-detector with a thermoelectronic cooling system, which preserves the temperature by 50ºC lower than the ambient value, allows one to conduct measurements at the Yakutsk latitude from August to May, for the atmosphere around the mesopause is permanently sunlit in summer. The instrument characteristics permit to register simultaneously partly the OH(6,2) and atmosphere band O_2. Both the instrumentation and temperature calculation technique were previously reported in detail [Ammosov and Gavrilyeva, 2000].

Data

In this paper we analyze the mesosphere temperature data obtained with the infrared spectrometer for the period from 1997 to 2000. The device has been placed at the site of Maimaga (63ºN; 129,5º E) at the distance of 150 km to the north from Yakutsk. The observations were performed at night, under the cloudless conditions, at the elevation angle of the Sun > 9º. Also the data obtained during the moonless nights and in the absence of aurora were selected for analysis.

The hydroxyl band intensity and rotational temperature had been measured from August 1997. Registration of the O_2(0-1) began in the season of 1999-2000. In order to study changes in the mesosphere temperature at two heights during the year, we calculated their night average values. The rotational temperatures of the hydroxyl during 353 nights from August to April have been included in the analysis. Of them 53 date to 1997-98, 75 to 1998-99, 96 to 1999-2000, 129 to 2000-2001. The molecular oxygen measurements are scarcer: 85 of them date to 1999-2000 and 121 to 2000-2001. The data are distributed over months non-uniformly, the greatest amount of the data being collected from January to March. The duration of the time series is from 1,5 to 12 hours depending on the observation period, which on the average, was ~7,5 hours, changing from 2,5 hours in April and August to more than 10 hours in December - January. In most cases the observation time is centered near midnight.

Results

Though the location of the observation site does not permit to measure the upper mesosphere temperature during the whole year, seasonal variations in the atmospheric conditions are well traced. Figure 1 shows the night average temperature of OH (6,2) and O_2(0-1) obtained during two observational seasons. It is seen that the shorterterm temperature variations, which are quite similar at both heights, are superimposed on the seasonal variations. O_2 temperatures in both data sets are always smaller than the OH ones except for the autumn measurements. It is reasonable because according to numerous studies, in winter the mesopause height is approximately equal to 100 km, which is higher than both molecular band excitation levels [Lubken and von Zahn, 1991, von Zahn, et al., 1996, She and von Zahn, 1998]. In this case both emissive layers are located in the region of negative vertical gradient of the atmospheric temperature.

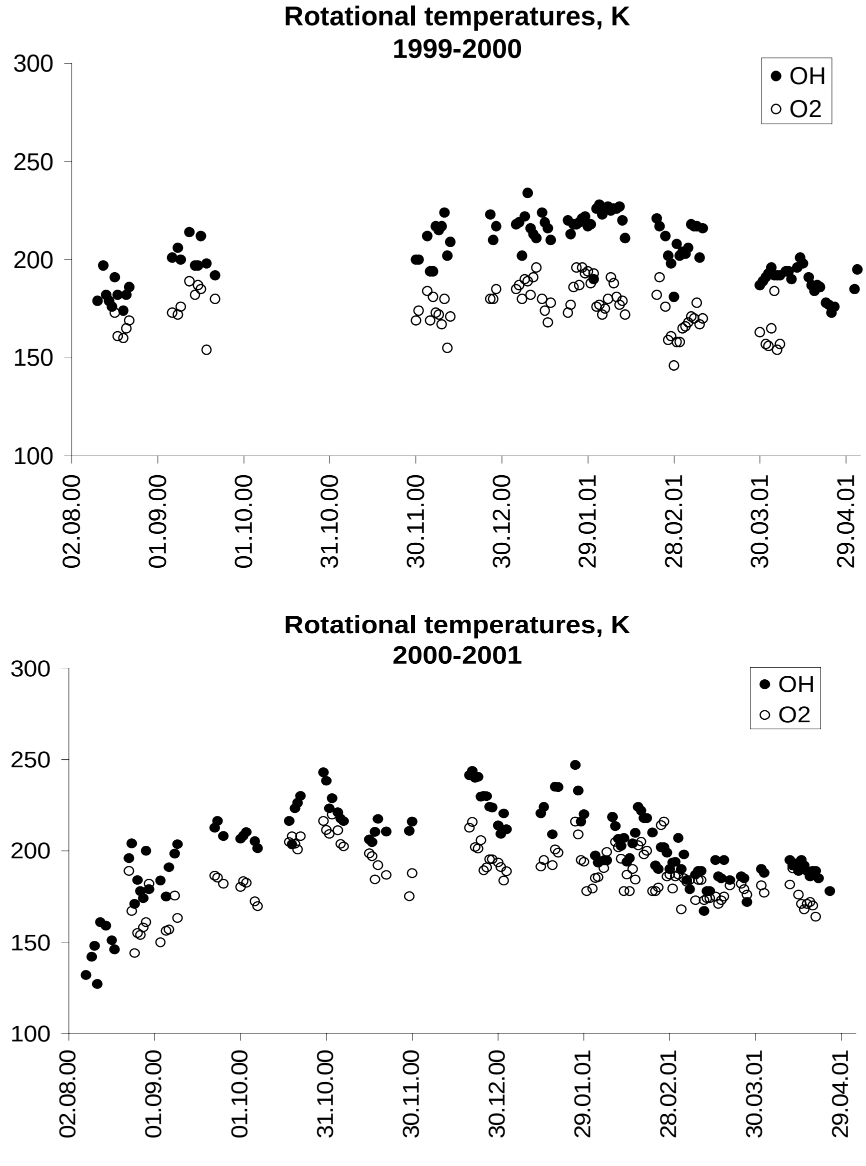
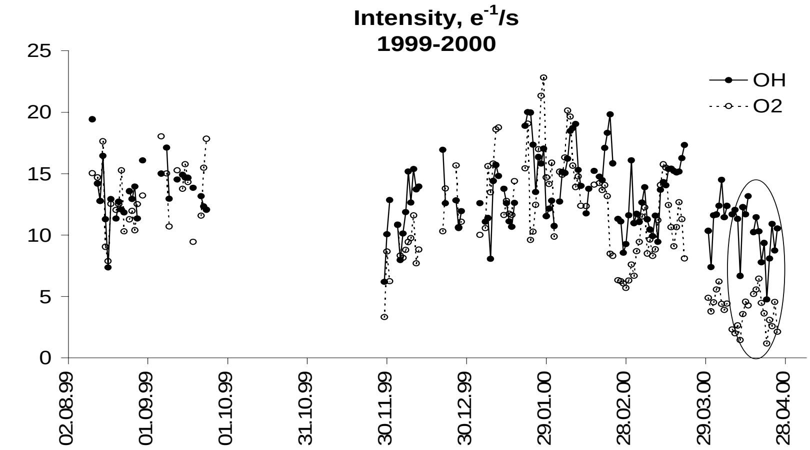


Figure 1. Comparison of the mesosphere temperatures measured at two heights ~ 84 km (OH) and 94 km (O2). Nightly averaged temperatures obtained during 1999-2000 are shown in the upper panel. The temperatures measured during 1999-2000 are plotted in the bottom panel.

Figure 2 illustrates the average night luminosity in both molecular emissions. As it is seen from Figure 2, the intensity of the molecular oxygen luminosity decreases from autumn to spring. The O_2 intensity drops to the noise level by the end of April. A springtime transition found by Shepherd et al. [1999] is clearly seen in both data sets. The ovals in Figure 2 correspond to the intensity enhancements due to springtime transitions in the spring 2000 and 2001.



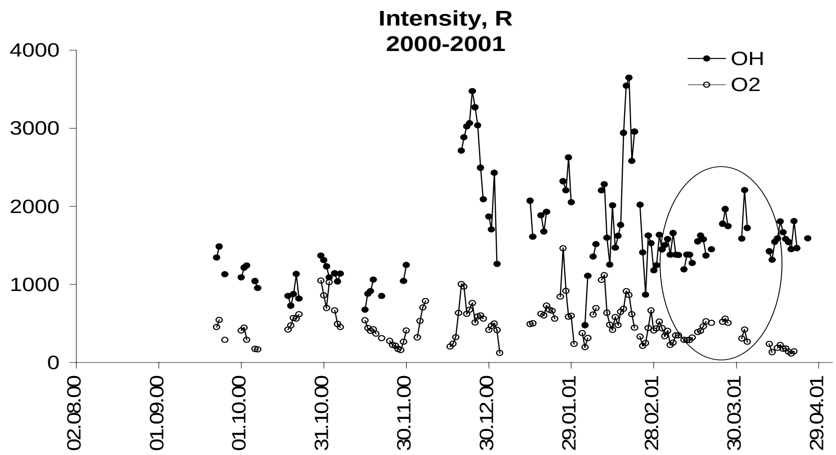


Figure 2. Comparison of the OH O2 intensities measured at two heights: ~ 84 km (OH) and 94 km (O2). Upper panel shows the nightly averaged intensities during 1999-2000. The measurement unit is e^{-1}/s. Nightly averaged intensities (R) obtained during 1999-2000 are plotted in the bottom panel. The ovals show the springtime transition periods in both data sets.

In this work nightly averaged values of the rotational temperatures obtained in August–September during 59 nights in 1999-2001 have been also studied. Unfortunately, we have the molecular oxygen temperature data for 2001 only. Based on a great number of measurements and the two-level model of the mesopause developed on the ground of these data, we conclude that the seasonal temperature variation at the hydroxyl emission luminosity height (87 km) is of maximum amplitude (She and von Zahn, 1998). The amplitude of the variations grows with latitude increasing.

Von Zahn et al. [1996] suggested that the altitude of the idealized mesopause at high and middle latitudes equals ~ 100 km in winter and ~ 86 km in summer. Owing to such annual variations the mesopause makes a sharp transition in spring from its winter state to the summer one and vise versa in autumn. The spring mesopause leap cannot be registered because of the very low level of O_2 intensity. In autumn the intensities of OH and O_2 are sufficient for temperature estimation. In 2001 simultaneous measurements of the OH and O_2 temperatures had been performed from the beginning of August. Nightly averaged values of TOH registered from August 9 to September 30 are presented in Figure3. It is seen that the temperature at the OH emission height (87 km) is lower than at the O_2 emission height (95 km) almost till the end of August. The vertical temperature gradient is positive. Starting from the second week of September, the O_2 temperature becomes lower than that of OH. The vertical temperature gradient turns negative. To determine the time when the vertical gradient changes its sign the regression lines by the data points were drawn. The time of the mesopause transition from summer to winter state can be estimated as an point of the intersection of the regression lines. The lines meet on August 28, i.e. at this time the temperature minimum is located about between 87 and 95 km.

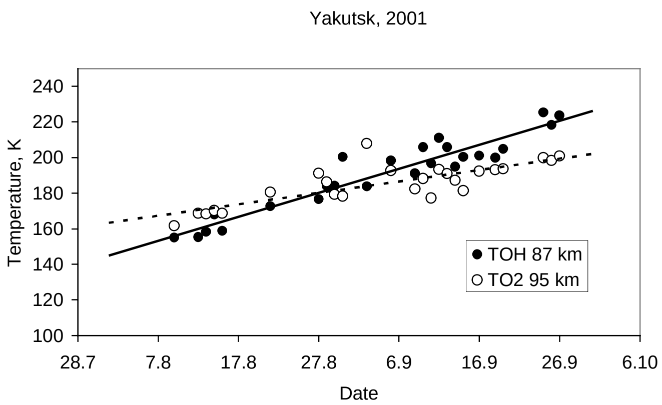


Figure 3. The rotational temperatures measured over Yakutsk from 09 August to 26 September 2001. Solid circles represent OH temperatures; open circles correspond to O_2 temperatures. The solid line is the regression line through OH data; the dashed line is that through O_2 data.

Conclusions

From analyzing the measurements of intensity and rotational temperatures of OH and O_2 molecular emissions over Yakutsk from 1997 to 2001 it is shown that:

1) Seasonal change of the atmospheric temperature at the luminosity heights of OH(6,2) (87 km) and O_2(O-1) (94 km) is consistent with the results obtained earlier at other high-latitude stations. The amplitudes of the annual and semiannual components for hydroxyl are ~34K and ~11K, for molecular oxygen they are ~26K, and ~8K, respectively.
2) Intensity of the molecular oxygen atmosphere band decreases from autumn to spring for both observational periods, whereas no clear seasonal dependence in the OH luminosity behavior has been found. A springtime transition of the atmosphere is well pronounced in the temporal series of OH and O_2 nightly averaged intensities. After factor 2-3 intensity increase at the end of March/beginning of April, the OH intensity relaxes to the initial level. The O_2 intensity remains at the noise level at the end of April.
3) Simultaneous measurements of the emissions excited at different heights permit to determine the transition time of the mesopause from the summer to winter level.

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References

Ammosov P.P., Gavrilyeva G.A. Infrared Digital Spectrograph for Hydroxyl Rotational Temperature Measurements, Instruments and Experimental Techniques. 2000, V.43. P.792-797, Translated from Pribory i tekhnika eksperimenta.

Lubken F.-J., von Zahn U. Thermal structure of the mesopause region at polar latitudes. J. Geophys. Res. 1991. V. 96, P. 20841-20857.

Lübken F.-J. Thermal structure of the Arctic summer mesosphere. J. Geophys. Res. 1999. V. 104. P. 9135-9150.

Noxon J.F. Effect of internal gravity waves upon night airglow temperatures. 1978. J. Geophys. Res. V. 5. P. 25-27.

She C. Y., von Zahn U. Concept of two-level mesopause: support through new lidar observations. J. Geophys. Res. 1998. V. 103. P. 5855-5863.

Shefov N.N. Hydroxyl emission. Ann. Geophys. 1972. V. 28. P. 137-143.

Shepherd G.G., Stegman J., Espy P., Mclandress C., Thuillier G., and Wiens R.H. Springtime transition in lower thermospheric atomic oxygen. J. Geophys. Res. 1999. V. 104. P. 213-223.

Sivjee G.G. Airglow hydroxyl emissions. Planet. Space Sci. 1992. V. 40. P. 235-242.

von Zahn U., Hoffner J., Eska V., and Alpers M. The mesopause altitude: Only two distinctive levels worldwide? 1996. Geophys. Res. Lett., V. 23. P. 3231-3234.