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RE-ANALYSIS OF THE LONG-TERM HYDROXYL ROTATIONAL TEMPERATURE TREND ACCORDING TO MEASUREMENTS IN SPITSBERGEN

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Abstract. Reanalysis of the measurement data of the hydroxyl rotational temperature (band OH(6–2)) obtained at the auroral station in Adventdalen, Spitsbergen (78^{o}N,15^{o}E) during 1980-2001 is carried out. It has been revealed, that during this period the linear temperature trend during winter time near the beginning of January at the latitude of 78^{o}N is equal (–1.0 ± 0.2) K·year^{-1} for the period from 1983 up to 1993, but for the period from 1991 up to 2001 this temperature trend was close to zero.

Introduction

Within last decades on the basis of the measurement data of various characteristics of the middle atmosphere active studies of their temporal behavior have been carried out [Kokin and Lysenko, 1994; Golitsyn et al., 1996, 2000; Taubenheim et al., 1997; Ulich and Turunen, 1997; Bremer, 1998; Burns et al., 2001; Semenov et al., 2002, 2005; French et al., 2004]. It was revealed, that the temperature and density of the middle atmosphere at heights of 50-90 km had a long-term tendency to decreasing. The quantitative estimations of such long-term changes obtained by various authors, considerably differ from each other [Beig et al., 2003; Laštovička, 2005]. In many respects it can be caused by the duration of the temporal series of the measured parameters used for the analysis, by the influence of accompanying helio and geophysical conditions, and also by the conformity of temporal durations of the considered measured series of observation. Besides, the problem of revealing long-term changes of any characteristics of geophysical processes demands obligatory preliminary exceptions from the analyzed data of all types of periodic and casual variations. According to results of the analysis of materials concerning the temperature of hydroxyl emission on the basis of which the long-term trend was determined, the behavior of the trend had appreciable seasonal, latitudinal, high-altitude features, and the dependence on concrete temporal interval either. Non-compliance of these conditions is the reason of absence of unequivocal modern representation about the character of long-term change of condition of the atmosphere at the level of mesopause and lower thermosphere.

The undertaken efforts to revise both results of temperature measurements of the middle atmosphere and long-term trends determined on their basis, are in most cases directed to the achieving of conformity of the earlier calculated values of trends for previous time intervals to those values of trends which have been obtained in measurements during the recent years. In this connection rather an indicative example of evolution of conclusions about a long-term trend of temperature at the high latitudes was obtained at various times during the analysis of practically the same series of measurements of rotational temperature of hydroxyl in Spitsbergen, from –1 K·year^{-1} up to its absence.

Such approach obviously cannot be satisfactory as it is impossible to exclude long-term change of the trend during several dozens years. The reason of such process, apparently, is not only the influence of anthropogenous mechanisms on the terrestrial atmosphere, but also the influence of the centennial change of solar activity. Therefore in analyzing the accumulated data it is necessary to take into account the existing features of the trend's behavior.

Taking into account all above said, we decided to carry out our own reanalysis of the published measurement data of rotational temperature OH(6–2), obtained at the auroral station of Adventdalen (78^{o}N), Spitsbergen (Svalbard) during 1980–2001 with the purpose of revealing the true, in our opinion, long-term tendency of the temperature behavior at high latitudes.

The initial data

Seasonal values of the temperature trend during winter time according to measurements during about twenty years (1980–2001) in Spitsbergen were published in [Nielsen et al., 2002]. According to this paper the immediate value of the temperature trend was determined as – 0.6 K·year^{-1}. In the assumption of the influence of a trend of the wind speed at heights of stratosphere (30 hPa, i.e. ~ 24 km) this value of a temperature trend should be reduced up to – 0.3 K· year^{-1}. Further, these results were presented in paper [Sigernes et al., 2003 a,b]. In these papers the authors put all direct data of measurements in one long-term time sequence and drew already a conclusion, that the temperature trend can have values from (0.03 ± 0.002) K· year^{-1} up to – (0.4 ± 0.09) K· year^{-1}. All these conclusions, in turn, differ from those results, namely – 1 K· year^{-1} which had been submitted to the Second working group IAGA-ICMA-PSMOS «Long-term changes and trends in the atmosphere», which took place in Prague on July, 2–6, 2001.

In presented Figures [Sigernes et al., 2003 a,b] displaying the long-term change of temperature, the mean diurnal values are given for those winter periods on the basis of which conclusions about a long-term trend in the specified papers were made. However, these measurement data for each winter period, presented graphically in paper [Sigernes et al., 2003 a,b], allowed to reveal an incorrectness of the used procedure of determination of the trend. As noted in paper [Sigernes et al., 2003 b], at the initial stage of processing of observations materials when calculating the temperature the factors of intensity (line strengths) were used according to [Mies, 1974] and at the end of the considered period the authors used factors according to [Turnbull and Lowe, 1989]. However, in the last paper the authors, to process all the results of observation which had been accumulated at the station, again used the factors of intensity according to [Mies, 1974]. In paper [Shefov et al., 2006] the problem of application of different types of intensity factors was specially considered, and the occurrence of inevitable divergences of results of studies by different authors is shown. Unfortunately, the long-term discussion does not consider at all and does not take it into account. The results of papers [Sigernes et al., 2003 a, b] independently confirm such conclusion. In the given paper the results of revision of the conclusions made by the authors of papers [Nielsen et al., 2002; Sigernes et al., 2003 a,b] are presented.

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Results of the analysis and discussion

The first and necessary step was reduction of the Figures presented in [Sigernes et al., 2003 b] to unify the time scale. These figures contain the data for each winter period from 1980 up to 2001. In the paper they made various depending on the duration of the period of measurements in the concrete year. It is apparent that the data of measurements of temperature should be reduced to identical helio-geophysical conditions to exclude the influence of all regular and irregular variations. Only after that they can be used for revealing long-term changes. As can be seen from the description, in paper [Sigernes et al., 2003 a,b] data obtained during polar night, covering months from November up to February ($305 \le t_d \le 60$) were used. However, in the paper it is not indicated, to what local time the results of measurements within three hours of each day corresponded. For the winter period at the latitude of 78°N change of the solar zenith angle near the midnight from 18 up to midnight is ~ 10°. Therefore, possible average changes of temperature of a hydroxyl emission OH (6–2) within a day, apparently, are insignificant and do not exceed a few K. It is confirmed also with the data of papers [Myrabø et al., 1983, 1984]. However, during the entire winter period the seasonal variations are appreciably traced. In their background, naturally, there are various casual changes caused by the propagation of various wave disturbances. Therefore, the average seasonal variations of temperature have originally been obtained. For this purpose, the assumption that the character of average seasonal changes for all the considered winter periods remains constant has been made. The absolute value of temperature is determined only in view of the influences of the solar activity and the long-term trend.

It was originally necessary to exclude the influence of the solar activity. According to [Semenov and Shefov, 2005] the response of temperature of the hydroxyl emission to the solar activity depends on the month of the year. Therefore, on the basis of data presented in Figure of paper [Sigernes et al., 2003 b], the mean monthly values (for $F_{10.7} = 130$) for the specified years were originally obtained. Then they were used to obtain the empirical relationships on the basis of the mean monthly values for separate months of each year.

$$T(November) = 206 + 0.12 \cdot (F_{10.7} - 130) \qquad r = 0.48$$
$$T(December) = 210 + 0.09 \cdot (F_{10.7} - 130) \qquad r = 0.64$$
$$T(January) = 207 + 0.06 \cdot (F_{10.7} - 130) \qquad r = 0.65$$
$$T(February) = 201 + 0.03 \cdot (F_{10.7} - 130) \qquad r = 0.40$$

Unfortunately, because of the small number of the data used the presented dependencies not always possessed the sufficient reliability. In this case it was necessary to exclude in some cases a small amount of data owing to their significant deviation from the set of other values forming a closer group. Nonetheless, the calculated values of coefficients of regression (the response of temperature to the solar activity) satisfactorily agree with the results of studies of the response of the temperature to the solar activity, obtained from the analysis of rocket measurements at high latitudes in Heiss Island.

The same relationships enable one to obtain the estimation of the regularity of average seasonal variations of temperature during the winter period for the latitude of Spitsbergen station. It was known [Semenov and Shefov, 1996] that seasonal variations of temperature of the hydroxyl emission are well described practically by the first harmonic. On this basis the approximation for the considered case can also be presented as (the plot is located in the bottom left part of Fig. 1)

$$T_i^0(t_d) = T_i^{00} + \Delta T^0 \cdot \cos\frac{2\pi}{365} t_d ,$$

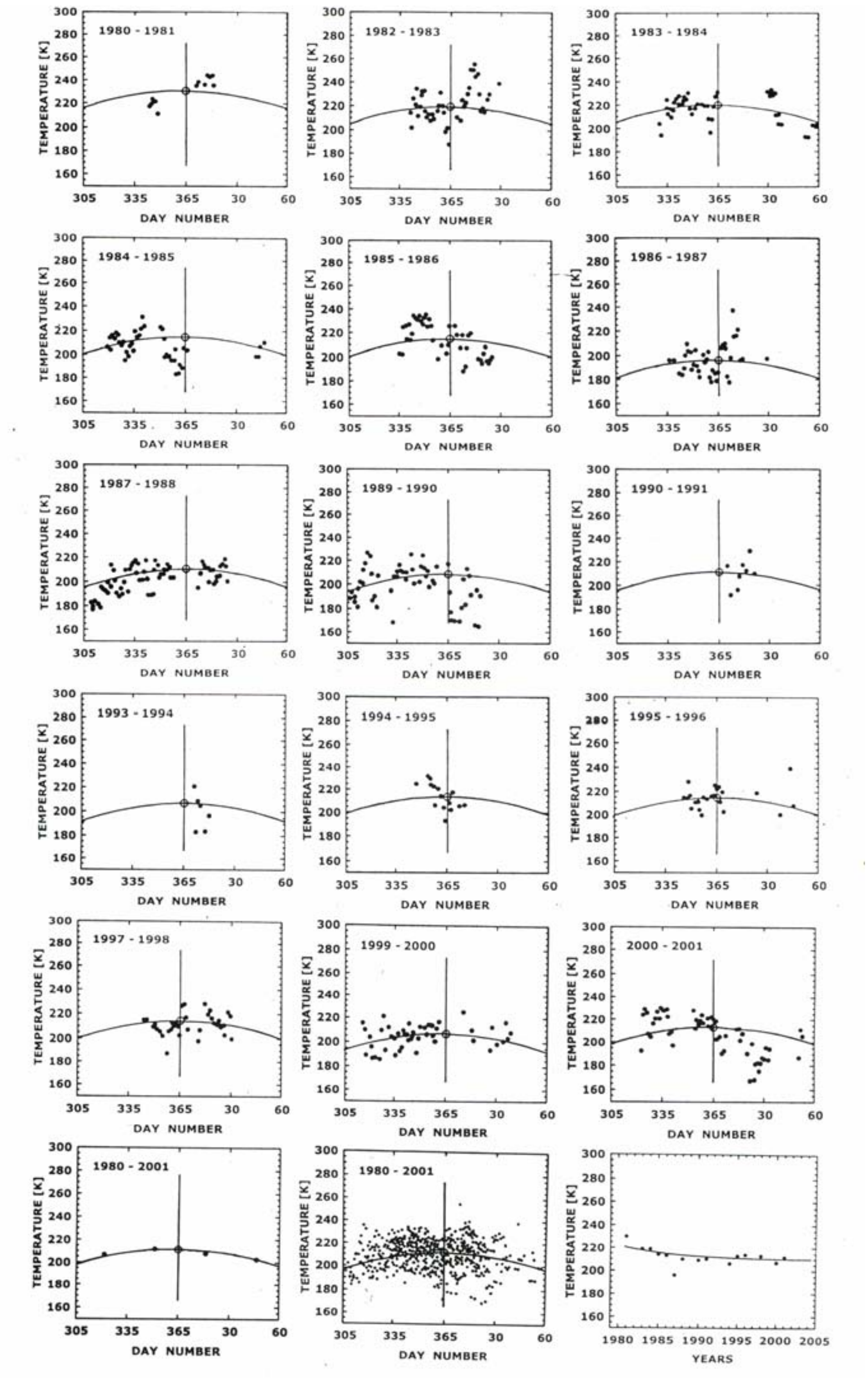

Fig. 1. Mean seasonal (monthly) variations of temperature after the elimination of solar activity variations and reduced to $F_{10.7}$ = 130. Panels below show from left to right: 1. the mean seasonal temperature variations; 2. The results of the performed systematization of all the above data. The dots are the data from the above mentioned pictures, the solid curve is the mean seasonal variations. This curve was applied in the picture of each winter season. The big circle shows the temperature for January 1; 3. The long-term variations of these values are presented in the bottom right part of the Figure. Solid line is an approximation.

where i is the number of year, t_d is the day of year, ΔT^0 is the amplitude of seasonal variations, T_i^{00} is the mean annual value of temperature of the given year (i). Numerical values of parameters are equal: T_i^{00} = 180 K, ΔT^0 = 30 K for $F_{10.7}$ = 130.

After introduction of a reduction on solar activity the given papers [Sigernes et al., 2003 b] for different years are shown in Fig.1.

For the obtaining of the average variations by other method, the data of measurements of temperature of the winter periods of each year have been combined on one graph by consecutive their the shift along the axis of ordinates concerning the measurement data for chosen in our case of the winter period of 1983–1984 . Such procedure has allowed to provide the minimal dispersion between the data of various years. Results of the made systematization are shown in the bottom middle part of Fig.1. Average distribution of probability of a deviation of the measured values of temperature from the mean winter variations is well represented by Gaussian distribution with a dispersion 21 K. By this is meant that the other essential regular variations are excluded, and deviations are caused by the casual reasons.

It is necessary to note, that absolutely similar character of winter variations of temperature is obtained on the basis of measurement data of temperature of the hydroxyl emission in the Southern hemisphere at Davis station, 68.6°S, 78.0° E [Burns et al., 2001; French et al., 2004]. The average regularity of temperature change revealed in such a way is presented in the Figure as a solid line. This regularity further was applied to the concrete data of each year for providing their minimal deviation from it. Then with its help the values of temperature for the moment of the beginning of the year (the vertical line corresponds t_d = 1), indicated by the big circle in Figures for each year are obtained. Thus, possible various fluctuations of temperature

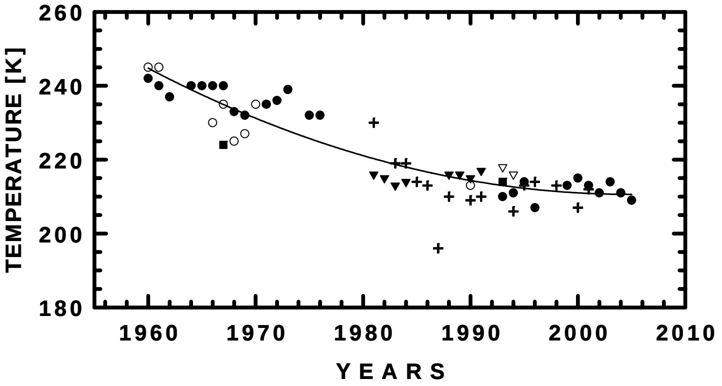

Fig. 2. Long-term temperature variations for winter periods according to various data. The circles are Zvenigorod, squares are Wuppertal, triangles are Yakutsk, inverted triangles are Maynooth, diamonds are Quebec and Delaware. The Spitsbergen data are shown with crosses. The solid line is an approximation.

during each winter period, caused by casual processes, were smoothed. Therefore, the mentioned above values of temperature for the beginning of January contain practically only long-term changes.

The presented data enable one to estimate long-term variations of temperature. As it is seen, an almost linear diminution of temperature with the trend ~ – (1.0 ± 0.2) K·year^{-1} was distinctly observed during the period of 1983-1990. The same value was obtained on the basis of data of initial paper [Sigernes et al., 2003 a]. It is important to emphasize, that it corresponds well with the conclusions of paper [French and Burns, 2004], obtained for winter conditions of the Southern hemisphere (– (0.5÷1.5) K·year^{-1}). Such value confirms the earlier made conclusion of the authors of the presentation at a symposium in Prague in 2001. It correlates well with the results for winter conditions, presented in [Golitsyn, et al.., 2000; Semenov, et al., 2002]. However, the data from the beginning of 1990 testify about the deceleration of the rate of temperature decrease. In this period the temperature trend approaches the zero value (Fig. 1, the right bottom figure). Such a result is in a good agreement with data of long-term measurements at middle latitudes [Semenov and Shefov, 2006]. The comparison of these data is shown in Fig. 2. Long-term variations of temperature during all the interval of years are satisfactorily described by the expression

$$T(t) = 214 - 0.50 \cdot (t - 1990) + 0.017 \cdot (t - 1990)^2, K$$

where t is the number of year. This approximating dependence is presented also separately for the data of Spitsbergen (Fig. 1, the right bottom Figure). From it one can see that temperatures in the beginning of the period of measurements at Longyearbyen station exceeded the subsequent values not casually and they are the consequence of the previous long-term variations. The comparison of all available data of the hydroxyl emission temperature measurements showed a satisfactory agreement between them. The approximation shown above allows one to obtain the average regularity of variations within the limits of the considered interval of years.

Conclusion

The considered reassessment of the published before values of the temperature trends of the mesopause [Nielsen et al., 2002; Sigernes et al., 2003 b] is caused by the results of discussion of this problem, which took place in Sozopol, Bulgaria, in 2004. The results of discussion in this Working Group are briefly presented in [Laštovička, 2005]. In this review it is indicated, that the data of observation in Spitsbergen [Laštovička, 2005] testify to the value of the trend close to zero for winter conditions. Apparently, this conclusion corresponds only to the 1990, and not only for the entire time interval from 1980 till present.

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