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Ionosphere, Mesosphere and Lower Thermosphere

Mesopause temperature variations during strong sudden stratospheric warmings in 2008-2010

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ABSTRACT:

We carried out joint analysis of the stratosphere and mesopause temperature variations during strong sudden stratospheric warming (SSW) events in 2008-2010. The data about the variations of the mesopause temperature (~87 km) obtained from ground-based spectrographic measurements of the hydroxyl emission (834.0 nm, band (6,2)) at the ISTP Geophysical observatory (ISTP GPO) near Irkutsk (52°*N*, 103°*E*) and Zvenigorod station (56°*N*, 37°*E*) were used in this analysis. Satellite data on atmospheric temperature vertical profiles obtained by the EOS Aura Microwave Limb Sounder (MLS) were involved. We analyzed the strong SSWs which occurred in January–February 2008, January 2009 and January 2010 when stratospheric temperature disturbances of large spatial scales were observed. The satellite data on atmospheric temperature at the mesopause height showed a good agreement with those obtained from the ground-based measurements taken at both observatories. Temperature variations at the mesopause height were compared with those at stratospheric heights (31 and 46 km) during SSWs. We revealed that during all the analyzed SSWs the stratospheric temperature increase was accompanied by a temperature decrease in the mesopause. The time analysis of mesopause and stratospheric temperature variations revealed that the stratospheric temperature increased almost simultaneously – with a slight lead – with a mesopause temperature decrease. This study represents an experimental evidence of a dynamical coupling of the lower atmosphere and the mesopause after ground-based optical and satellite data..

Keywords: Temperature, Stratospheric Warming, Mesopause, Hydroxyl Emission.

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1. Introduction

Winter stratosphere is a region of pronounced meteorological activity. The most impressive events in the stratospheric circulation are winter sudden stratospheric warmings. During strong winter stratospheric warming variations in the dynamic and thermal regimes in the middle atmosphere are observed. Disturbances can cover large altitude range extending from tropospheric heights to the heights of the upper mesosphere and lower thermosphere [1]. Studying variations of the atmospheric parameters at different heights during the SSW events is very important to investigate dynamical coupling of the lower and upper atmosphere. First experimental results confirming the influence of stratospheric warming on the atmosphere temperature conditions were presented in [2,3]. In these works, the mesopause temperature variations were analyzed and the mesopause cooling by 30-40 K during SSW was found.

This work presents a comparison of temperature variations on the heights of the stratosphere and mesopause obtained at the ISTP GPO (52°N, 103°E, near Irkutsk) and Zvenigorod station (56°N, 37°E), during periods of strong winter stratospheric warming events in 2008-2010. In this study we used the data from spectrophotometric measurements of mesopause temperature (OH (6-2)) and satellite data on atmosphere temperature from Microwave Limb Sounder (MLS) aboard the EOS Aura spacecraft. The Aura was launched on 15 July 2004. MLS AURA temperature data are submitted as temperature altitude profiles from the Earth surface level up to ~130 km, the effective range is from 9–92 km. The accuracy in temperature measurements is 0.5-2K [4].

2. Results of measurements and analysis

In January-February 2008, January 2009 and January 2010, there were very intense, long time winter sudden stratospheric warmings, covering large part of the Northern Hemisphere.

Maximum temperatures near the North Pole in January 2008 and January 2009 exceeded historical maximum during the previous term of satellite observations [5]. At 10 hPa isobaric level (~31 km) the maximum temperature of the atmosphere reached very high values (see Table I) and exceeded the mean temperature of winter stratosphere at that altitude (~210 K) by 70 K. The characteristic feature of temperature disturbances in January-February 2008 was its oscillatory nature during period of about a month, sudden stratospheric warming of January 2009 was “major” SSW.

TABLE I

Maximum temperature of the stratosphere at 10 hPa isobaric level (~31 km) for each analyzed SSW event.

Year	T_{max}	Data	T_{max} site coordinates
2008	283 K	23.01.08	72.5°N, 90°E
2009	287 K	23.01.09	77.5°N, 40°W
2010	272 K	25.01.10	62.5°N, 122.5°E

The main objective of this research was to study atmosphere temperature variations at the mesopause height during SSW in 2008, 2009 and 2010 and compare the temperature data from satellite and ground-based measurements.

The following data were analyzed:

- Data on the variations of mesopause temperature (~87 km) obtained from ground-based spectrographic measurements of the OH emission (834.0 nm, band (6-2)) at the ISTP GPO (52N, 103E, near Irkutsk) and Zvenigorod station (56N, 37E). The accuracy of the temperature measurements is 2 K.
- Satellite data on vertical temperature distribution in the stratosphere-mesosphere from MLS (Microwave Limb Sounder) aboard the EOS Aura [4];
- Stratosphere temperature data from Stratospheric Research Group of FU Berlin [6];
- Annual NCEP data for the Northern Hemisphere [5].

Ground-based measurements of mesopause temperature (~87 km) have been carried out at the Zvenigorod station and ISTP GPO since 1955 and 2008 till present, respectively. Emission spectra of the upper atmosphere are registered using high aperture spectrometers. Cooled 1024×256 pixel CCD matrices are used as a radiation detector. The spectrometers' spectral range is 820-870 nm; field of view is 12 degrees. Fig. 1 presents an example of the emission spectrum of the night airglow in the area of 780-1030 nm obtained at these two observatories.

During strong SSW occurred in January–February 2008, January 2009 and January 2010, stratospheric temperature disturbances of large spatial scales were observed (Fig. 2).

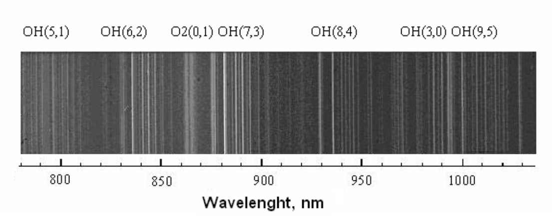

Fig. 1. The emission spectrum of the nightglow in the near infrared region. The emission bands of OH and O_2 molecules are indicated on the top.

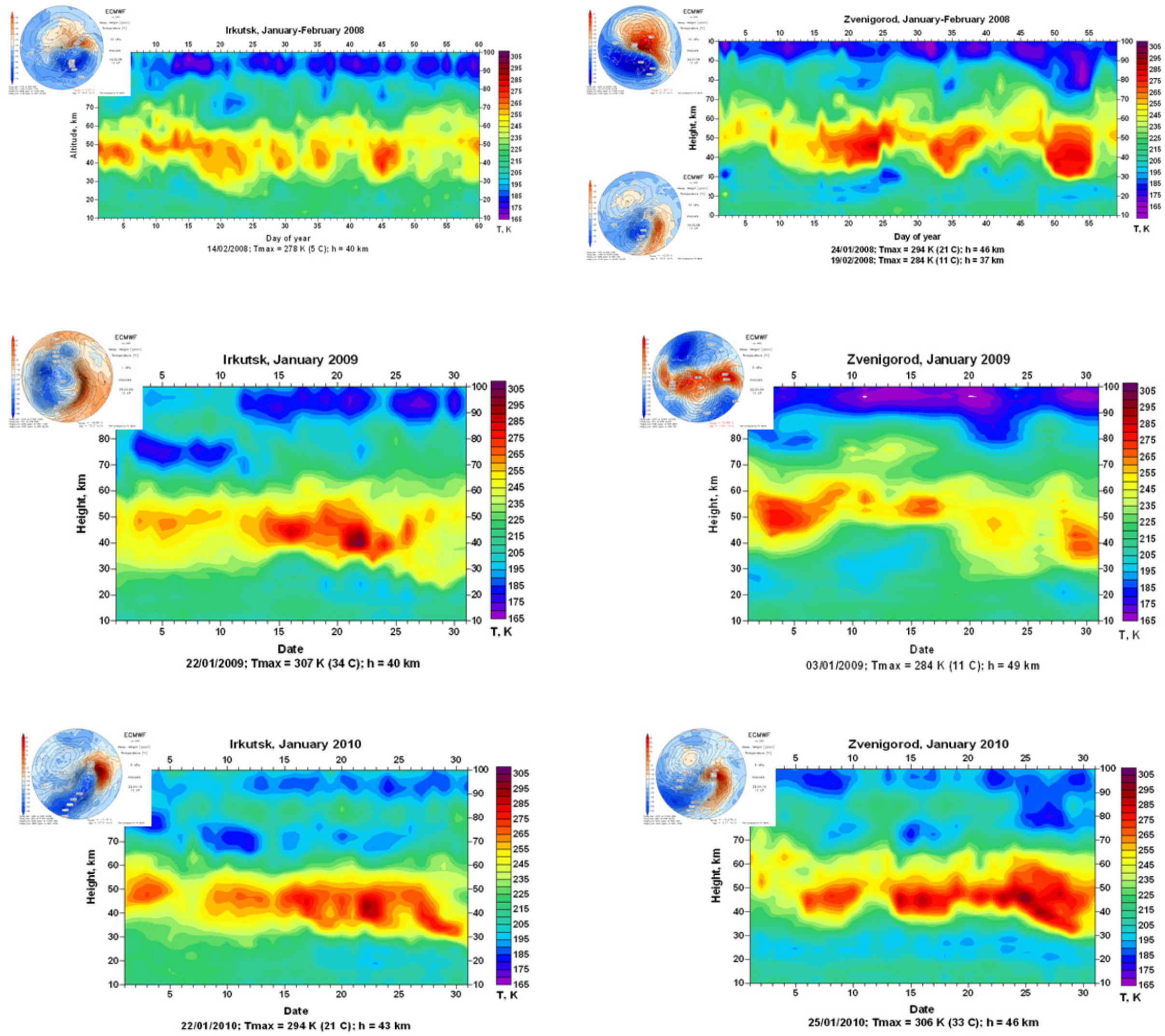

Fig. 2: Altitude-temporal maps of the atmospheric temperature distribution according to the MLS AURA [5] for the region of Irkutsk and Zvenigorod (search radius is 900 km). In the left corners of the panels there are maps of the stratospheric temperature distributions in the Northern Hemisphere at altitude levels where the stratosphere temperature reached maximum values for the days of maximum stratospheric warming in these regions [6].

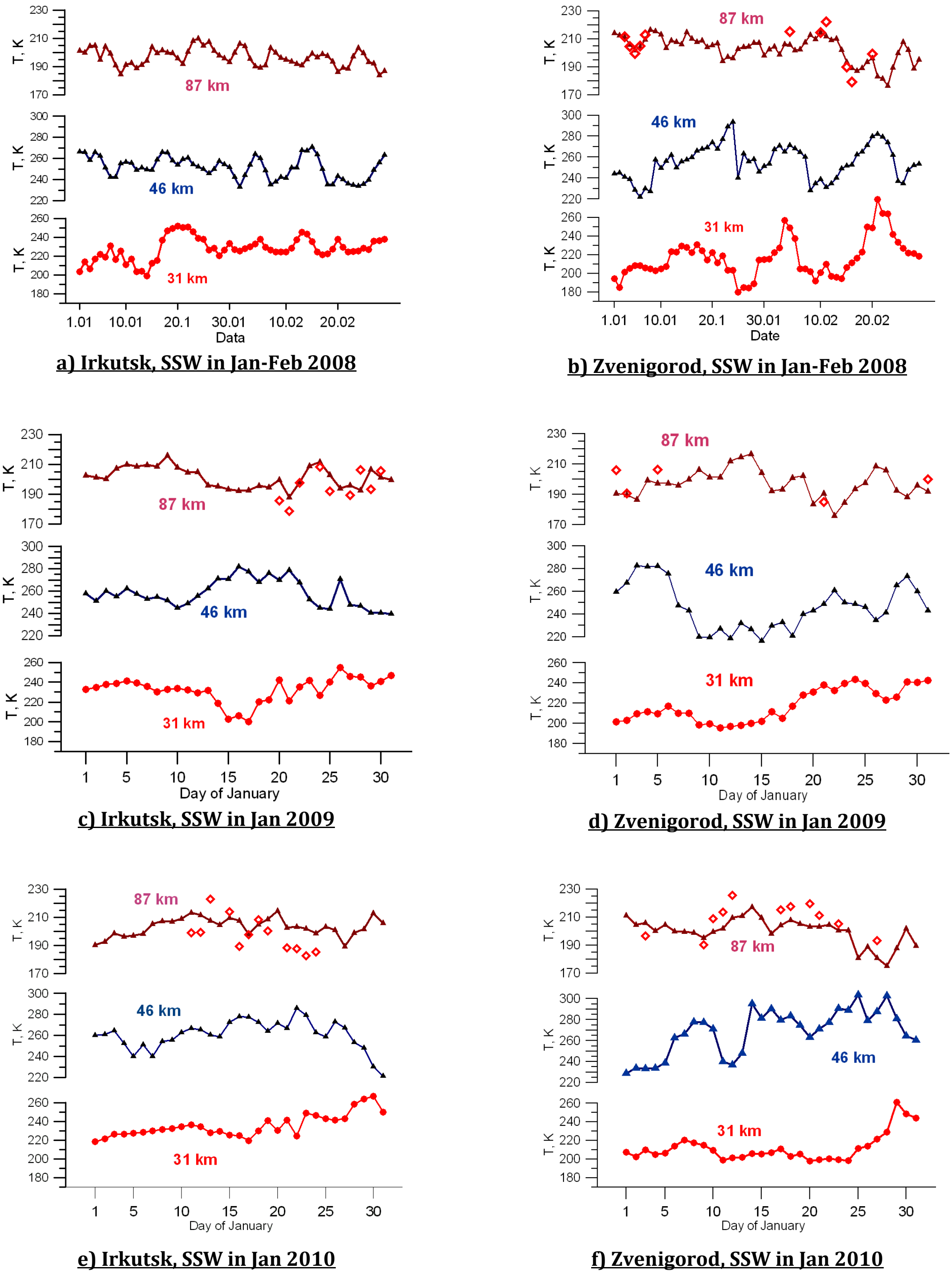

Fig. 3: Temperature of atmosphere according to satellite (solid line) and ground-based (red squares) data.

Figure 3 presents graphs of the temperature distribution according to the MLS AURA data at the stratosphere (31 and 46 km) and the mesopause (87 km). Also, the figure shows the data from ground-based measurements of mesopause temperature in Irkutsk for SSW in 2009 and 2010 and Zvenigorod for SSW in 2008-2010 (red squares). It can be noted that the satellite data on atmospheric temperature at the mesopause height showed a good agreement with those from the ground-based measurements taken at both observatories.

Temperature variations at the mesopause height (87 km) were compared with those at stratospheric heights (31 and 46 km) during SSWs. We revealed that, during all the analyzed SSWs, the stratospheric temperature increase was accompanied by almost simultaneous – with a slight lead - a temperature decrease in the mesopause. The character and magnitude of the mesopause temperature decrease depend on SSW intensity. In all the analyzed SSWs when the temperature at the stratospheric height increased by 20-35 K, the mesopause temperature considerably decreased by 20-30 K. Thus, during the SSW in January 2010 (Fig. 3e,f) the maximum temperature was 306 K in the stratosphere (~46 km) near Zvenigorod on January 25 and 294 K near Irkutsk on January 22, whereas the mesopause temperature decreased to 170 and 180 K, respectively. For the undisturbed conditions the mean temperature of winter mesopause is about 210 K.

The key mechanism of stratospheric warming, initially proposed by Matsuno [7] and now widely accepted, is the growth of upward propagating planetary waves from the troposphere and the interaction between the transient wave and the mean flow. The interaction decelerates and/or reverses the eastward winter stratospheric jet and also induces a downward circulation in the stratosphere causing adiabatic heating and an upward circulation in the mesosphere causing adiabatic cooling. Obtained experimental results of mesopause cooling agree with this model. Mesospheric cooling for SSW in January 2009 was revealed also in [8].

3. Conclusions

The following conclusions can be derived from the previous analysis. The analysis of the atmospheric temperature variations during the stratospheric warming events in 2008-2010 according to ground-based and satellite measurements revealed temperature disturbances in the wide range of the middle atmosphere, from the stratosphere to the mesopause.

It is revealed, that the increase of the stratosphere temperature was accompanied by significant mesopause cooling (up to 30 K).

During the analyzed SSW events, the stratospheric temperature increased almost simultaneously – with a slight lead – with a mesopause temperature decrease.

The comparison of satellite and ground-based data on mesopause temperature showed a good agreement.

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