Lidar studies of specific manifestation features of stratospheric warming in winter of 2014-2015

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ABSTRACT

Studying the atmospheric thermal regime is one of important applications of lidar technologies. These studies in monitoring mode in Institute of Atmospheric Optics, Siberian Branch, Russian Academy of Sciences had been initiated since 1994 and continue until presently. A special attention is paid to studying the manifestations of sudden disturbances in the middle stratosphere, caused by wintertime stratospheric warmings (SWs). Reader can be acquainted with results on the subject in works [1-3]. In this paper, we present studies of SW during winter of 2014-2015.

RESULTS OF STUDYING SW DURING 2014-2015

A salient feature of stratospheric warming in winter of 2014-2015 was its quite long duration. Lidar observations indicated that it began on November 11, 2014 (see Fig. 1). The SW event developed maximally on November 27 and covered the altitude interval from 30 to 55 km, with maximal positive temperature deviation of 60 K from monthly average temperature being observed at height of 35 km. This same warming, but with somewhat smaller temperature deviations, was also recorded in Aura satellite observations.

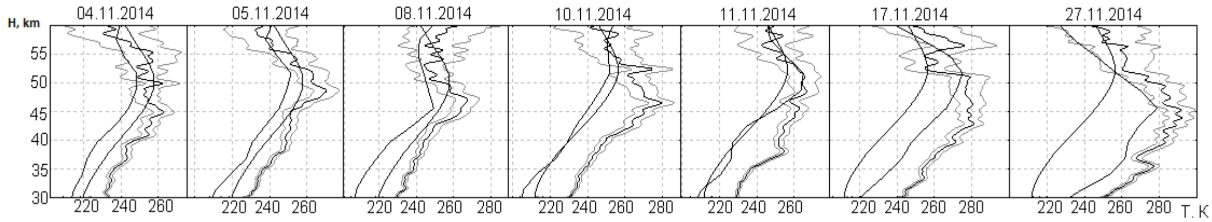

Figure 1. Vertical profiles of temperature, obtained over Tomsk from lidar measurements (thick solid line shows average values, and thin solid line shows standard deviation), Aura satellite measurements (dashed line), and monthly mean profile according to CIRA-86 model (dotted line).

In December, both lidar and satellite observations revealed stratospheric warmings at the beginning (December 3, 2014) and end (December 24, 2014) of the month in the same altitude interval of 30-55 km (Fig. 2).

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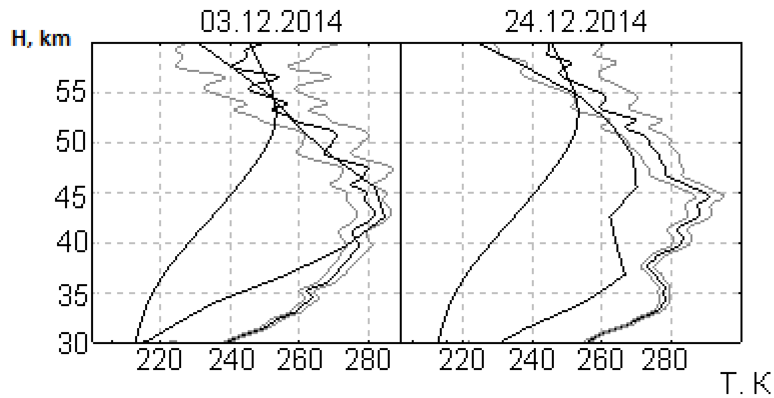

Figure 2. Lidar and satellite observations of stratospheric warming in December 2014

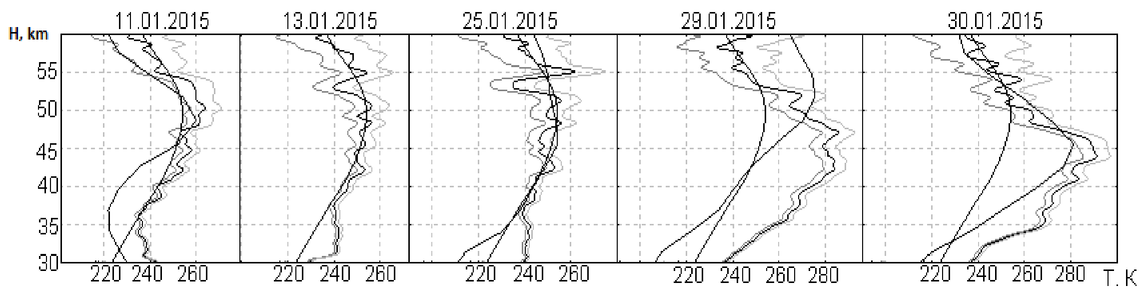

Figure 3. Vertical distribution of temperature in January 2015

The next SW began in late January 2015 and continued until the end of the second decade of February (see Fig. 3). This was one of the most long lasting (almost 1-month) SW events, recorded in lidar observations over Tomsk since 1996. The largest positive deviations of temperature were observed in altitude region of 40-45 km and could reach 60 K at height of 40 km (February 5, 2015).

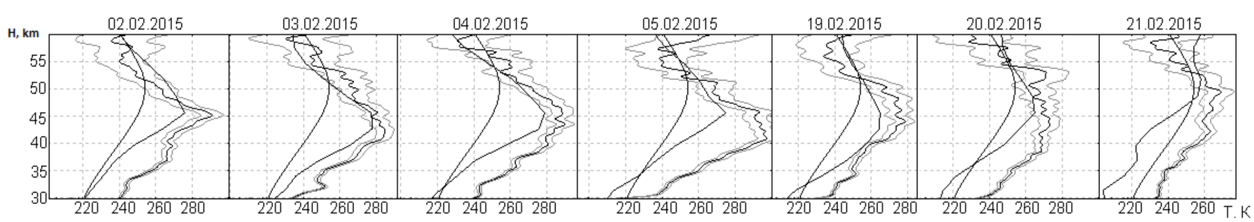

Figure 4. Vertical distribution of temperature in February 2015

SW observed in 2014-2015 was minor-type event, accompanied by no change from westerly to easterly air mass transport in the stratosphere, consistent with data taken from European Centre for Medium-Range Weather Forecasts (ECMWF) website [4] for all dates of lidar observations. As an example, Figure 5 presents the altitude distribution of zonal wind speeds and directions. As can be seen from the figure, wind over Tomsk is invariably westerly throughout the altitude interval from 0 to 50 km.

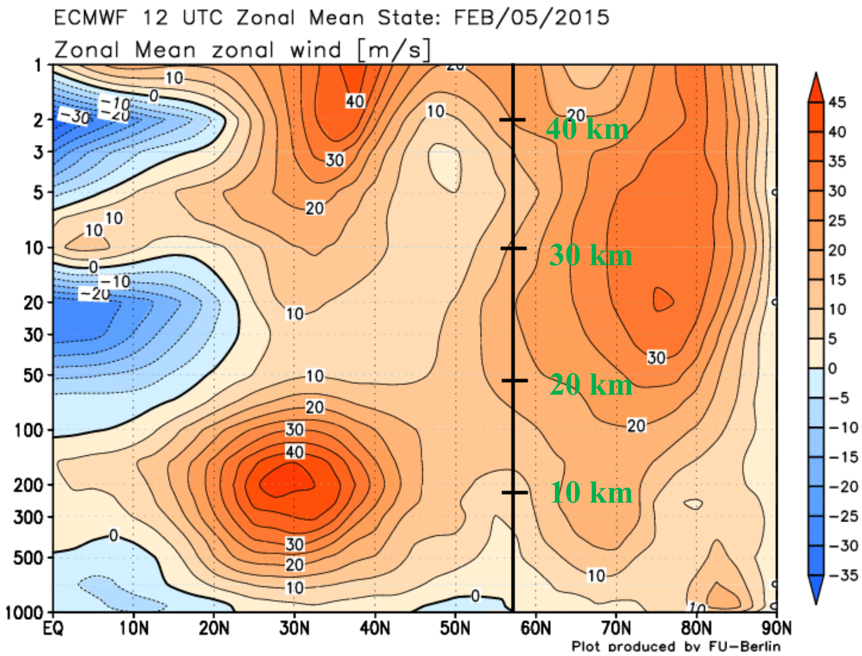

Figure 5. Altitude distribution of zonal wind speeds and directions in the Northern Hemisphere, recorded on February 5, 2015. Vertical thick line shows the altitude transect for the latitude of Tomsk.

Naturally, the disturbances of thermal regime of the stratosphere, caused by wintertime SWs, could not help influencing the occurrence of anomalies in vertical air density distribution. Studies in this direction were performed in our works [5,6]; it was shown that air density may decrease by as much as 30% at certain heights in the stratosphere during strong (major) SW periods. For separate dates of observations with most marked SW, Figure 6 presents the vertical profiles of deviations of temperature and density from their monthly average model-based values. From the figure we can see certain specific features in behavior of vertical profiles of density deviations as compared to vertical profiles of temperature deviations. As expected, positive (negative) temperature deviations are accompanied by density decreases (increases). There are characteristic inflection points, where deviations change their sign. In the plots, this occurs below the 30-km level (on November 27, January 29 and 30, and February 3) and below 25-km level (on December 3 and 27) for lower heights, and above the 50- and 45-km levels for upper heights for those same indicated dates. It can be seen that deviations in both temperature and density may reach 30%. The deviations had the largest amplitudes in observations performed on November 27 and December 24, 2014, and on January 30, 2015.

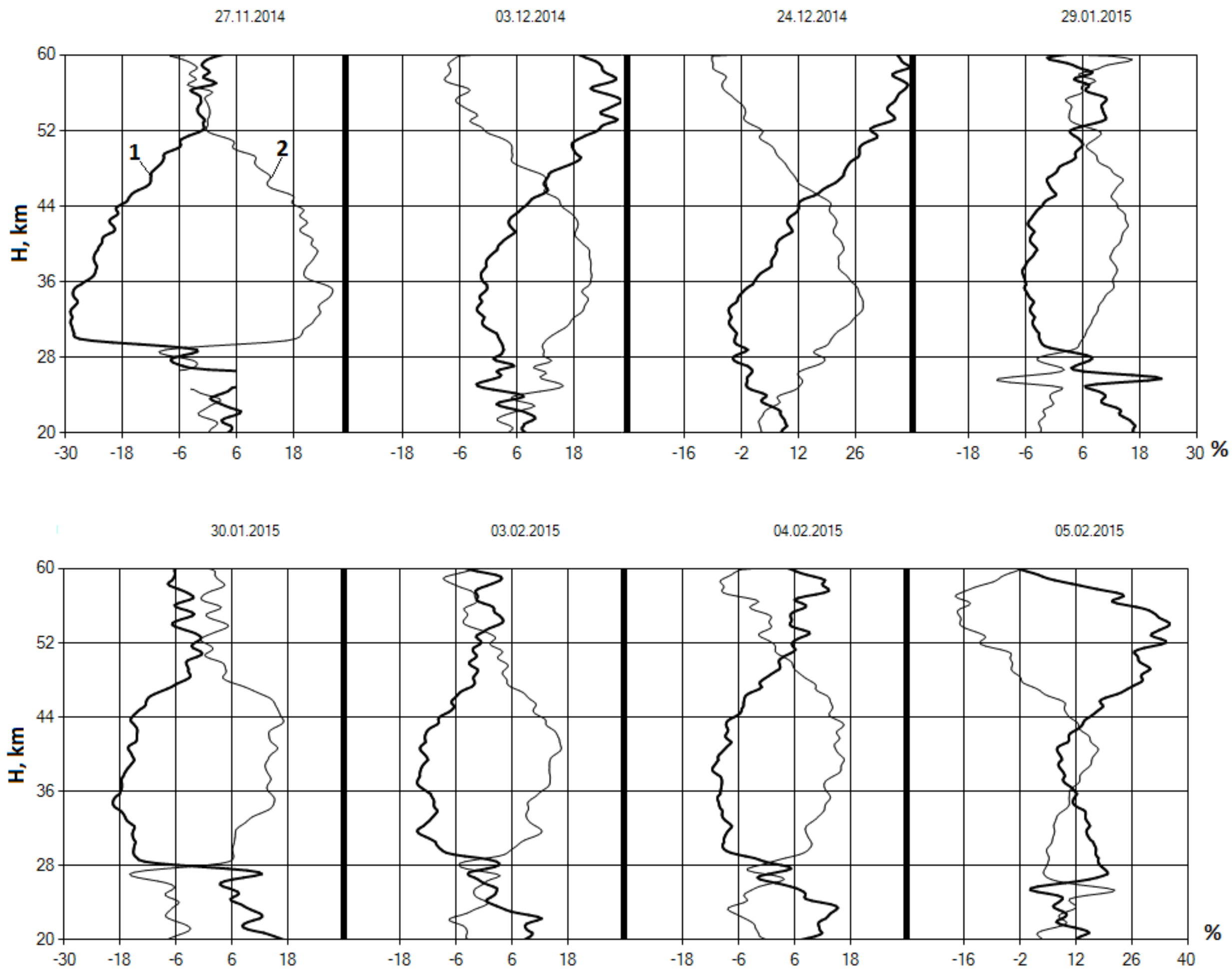

Figure 6. Vertical profiles of deviations of temperature and air density from their monthly average values according to data of lidar measurements over Tomsk: density (curve 1) and temperature (curve 2).

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REFERENCES

[1] Marichev V.N. Lidar investigations of stratospheric warming events over Tomsk in 2008-2010. // Atmospheric and Oceanic Optics. 2011. V. 24. No. 05. P. 386-391 [in Russian].

[2] Marichev V.N. Investigation into features of manifestation of winter stratospheric warming events over Tomsk from the data of lidar temperature measurements in 2010-2011. // Atmospheric and Oceanic Optics. 2011. V. 24. No. 12. P. 1041-1046 [in Russian].

[3] Marichev V.N. Studying the specific features of manifestation of wintertime stratospheric warmings over Tomsk according to lidar measurements of temperature. // XX International Symposium “Atmospheric and Ocean Optics. Atmospheric Physics”. Novosibirsk, resort-hotel “Sosnovka”, June 23-27, 2014. P. D67-D72.

[4] http://weather.uwyo.edu/upperair/sounding.html
[5] Marichev V.N. The analysis of the air density and temperature behavior in the stratosphere over Tomsk in periods of disturbed and quiet states performed according to the results of lidar measurements. // Atmospheric and Oceanic Optics. 2013. V. 26. No. 09. P. 783-792 [in Russian].
[6] Marichev V.N., Bochkovsky D.A. Lidar studies of specific features of vertical distribution of atmospheric temperature and density in periods of quiet and disturbed states of the stratosphere. // XX International Symposium "Atmospheric and Ocean Optics. Atmospheric Physics". Novosibirsk, resort-hotel "Sosnovka", June 23-27, 2014. P. D355-D360.