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MONITORING OF VARIATIONS OF MIDDLE ATMOSPHERE OZONE IN POLAR LATITUDES OF ARCTIC DURING STRATOSPHERIC WARMING IN THE WINTER 2016

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Introduction

The study of response of the middle atmosphere (stratosphere and mesosphere) to any external impact (variations of sunlight, flux of cosmic ray particles, eruptions of volcanoes, and anthropogenesis factors) is an important physical problem. Ozone and temperature are basic atmospheric parameters. Ozone and temperature are important atmospheric parameters. The correlation of these parameters is of significant interest from the viewpoint of thermal balance of the middle atmosphere. The basic heating of the stratosphere (altitude range of 30-50 km) is caused by absorption of solar ultraviolet radiation by ozone molecules. Thermal changes influence the rate of ozone formation and destruction. Other types of wave processes can redistribute the structures of vertical profiles of ozone and temperature in the middle atmosphere. Sudden stratospheric warming (SSW) affects a lot of widely known atmospheric wave processes. Ground-based microwave radiometry allows investigation of ozone variations during large-scale wave disturbances in the middle atmosphere, such as, for example, stratospheric warming [1]. Last years there was an additional interest to SSW. In the winter of 2012-2013 there was a unique warming caused temperature increase a few tens of degrees at pressure level 10 hPa. In microwave and optical observations in Tomsk, there were noted visible variations of ozone and temperature in the middle atmosphere [2, 5]. The ozone concentration at altitudes from 25 to 60 km increased by 1.5 – 2 times. The maximum of positive deviation of temperature from its month average value reached 70 K at altitude of 30 km. Diurnal variations of ozone at altitude of 60 km associated with sunset and sunrise was about 30%. In addition, this warming according to [3] caused variations of the total electron content up to 100% in equatorial ionosphere. In middle and polar latitude variations of the electron concentration hypothetically are associated with variations of the neutral composition. In [4] it is discussed the possible role of the middle atmosphere ozone on the relationship between mesosphere and ionosphere.

In this paper we present some results of measurements of the ozone emission line in January-March 2016 by method of microwave radiometry. Measurements of spectra of middle atmosphere ozone were executed with the help of mobile radiometer (work frequency 110836.04 MHz). The device was installed in 2007 at physical faculty in Peterhof (60N, 30E) in 28 km from the centre of Saint Petersburg [1]. Fig. 1 shows the general view of the microwave equipment (mobile ozonemeter). On the measured spectra were appreciated of ozone vertical profiles in the layer of 22-60 km which were compared to satellite data MLS/Aura and SABER [6], and also with the data of ozonesonde at station Salekhard (67N, 67E), Sodankyla (67N, 27E) and Summit (73N, 38W). Significant variations in ozone number density, which were caused by sudden stratospheric warming in winter 2016, were observed in the atmosphere over Peterhof at altitudes of 40 to 60 km.

Microwave ground-based equipment used in the experiment

Method ground-based microwave radiometry is based on measurements of thermal atmospheric radiation in vicinity the ozone line in the range of millimeter and submillimeter waves. Microwave observations are weakly dependent on weather conditions and the presence of atmospheric aerosols, and this is an advantage compared with observations in the optical and infrared wavelength ranges. In addition, the microwave ozone observations can run around the clock. In recent years it is managed to make a significant step forward towards the creation of a new generation of mobile microwave spectrometers [7]. The device consists of an uncooled heterodyne receiver tuned to a fixed frequency 110836.04 MHz corresponding to a rotational transition of ozone molecules $6_{0,6}$– $6_{1,5}$, and multichannel spectrum analyzer. In front of receiver is a module that includes an antenna (scalar horn) and a switch to calibrate accepted intensity of atmospheric ozone line radiation. The beam width (by level -3 dB) of the horn antenna is 5.4°. The SSB noise temperature of the receiver is 2500 K. The SSB receive mode is provided by evanescent filter with direct losses of 0.5 dB and the suppression of the image channel of more than 20 dB. The spectrum analyzer consists of 31 filters with a variable bandwidth from 1 MHz to 10 MHz and a full analysis bandwidth of 240 MHz. The parameters of the device allow to measure a spectrum of the emission ozone line for time about 15 min with a precision of ~ 2%. Measurement of the spectra of thermal radiation is performed by a method of calibration for two "black body" loads that are at the boiling point of liquid nitrogen and at ambient temperature. Information about the content of the O_3 is contained in the measured radio emission spectrum of the middle atmosphere. Using the inversion of the obtained spectra it is possible to obtain data on the vertical distribution of ozone in the atmosphere. The criterion of the accuracy of inverse problem solution is the best fit ozone spectral lines calculated by the retrieved profile of the O_3 concentration to the original experimental spectrum. The error of estimating the vertical distribution of ozone on the measured spectra by above described device does not exceed 20%.

The results of observations and discussion

Fig. 2 displays the variation in the ozone content measured over Peterhof from 1 January to 31 March 2016. In the top part of Fig. 2 continuous line shows the data on total ozone content (TOC), which were obtained onboard device OMI/Aura. The average value of the TOC for the entire observation period amounted to (339±5) DU.

Figure 1

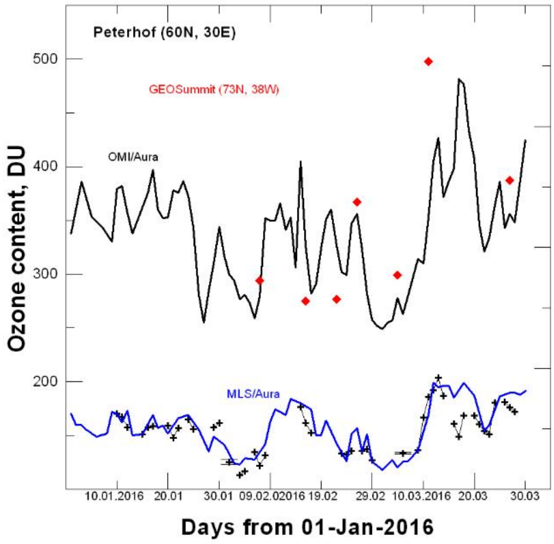

Figure 2

Maximum TOC 482 DU was marked on March 18. Rhombuses mark the values TOC which were measured at polar station Summit by ozonesonde. At the bottom of Fig. 2 gives the variations of the ozone content in the layer of 22 – 50 km according to the onboard device MLS/Aura $X_{O_3}^{MLS}(22-50)$ in DU (continuous line) and ozone content in the layer above 22 km, according to ground-based device $X_{O_3}^{MMW}(\geq 22)$in DU (crosses). The device MLS/Aura uses a limb method of measuring atmospheric parameters. We selected of ozone and temperature data, corresponding to the time span of the satellite over the Peterhof. For this purpose was chosen domain with coordinates (60±1.5)ºN and (30±5)ºE for Peterhof. Data $X_{O_3}^{MMW}$ correspond to the ozone profiles obtained from day and night ozone spectra. Systematic excess of ozone satellite data over ground-based data for the entire observation period amounted to the value of $X_{O_3}^{MLS} / X_{O_3}^{MMW}$ = (1.03±0.01). Well observed perturbations of ozone layer in the middle atmosphere, which began in the first decade of February and lasted until the end of March. The first maximum appeared on February 14, the second – on March 14, 2016. The ozone content values for these days were 184 DU and 203 DU, accordingly. The lowest ozone content 113 DU according to ground-based microwave sensing was observed on February 03.

Consider the character of the variability of ozone and temperature at selected heights middle atmosphere 25, 40 and 60 km above the Peterhof. In Fig. 3 shown the temporal variations of ozone concentration and temperature MLS/Aura data (thin continuous line) and SABER data (thick continuous line) at these altitudes in winter 2016. On the bottom of the figure shown the variations of ozone (filled circles) at a height of 25 km, according to ground-based microwave sensing and temperature according to the databases MLS/Aura and SABER. From satellite data minimum temperature (about 195 K) was obtained at the end of January which was observed during the first decade of February. Next it was steady increase of temperature on the altitude of 25 km from 195 to 220 K until the end of March. Such a change of the thermal structure of the middle atmosphere shows the development of minor stratospheric warming, which were mentioned by us earlier over Apatity (67°N, 33°E) [7]. The development of the stratospheric warming over the Peterhof occurred under the classical scheme [8] from top to bottom. Experimental confirmation of this scheme can be found in [8, 10]. This fact is confirmed by detected changes of ozone and temperature at the altitude of 40 km, which shifted in time relative to the data at an altitude 25 km (Fig. 3, mid panel). Noteworthy (Fig. 3) significant perturbation of ozone at levels of 40 km (mid panel) and 60 km (top panel), which began in middle of January 2016.

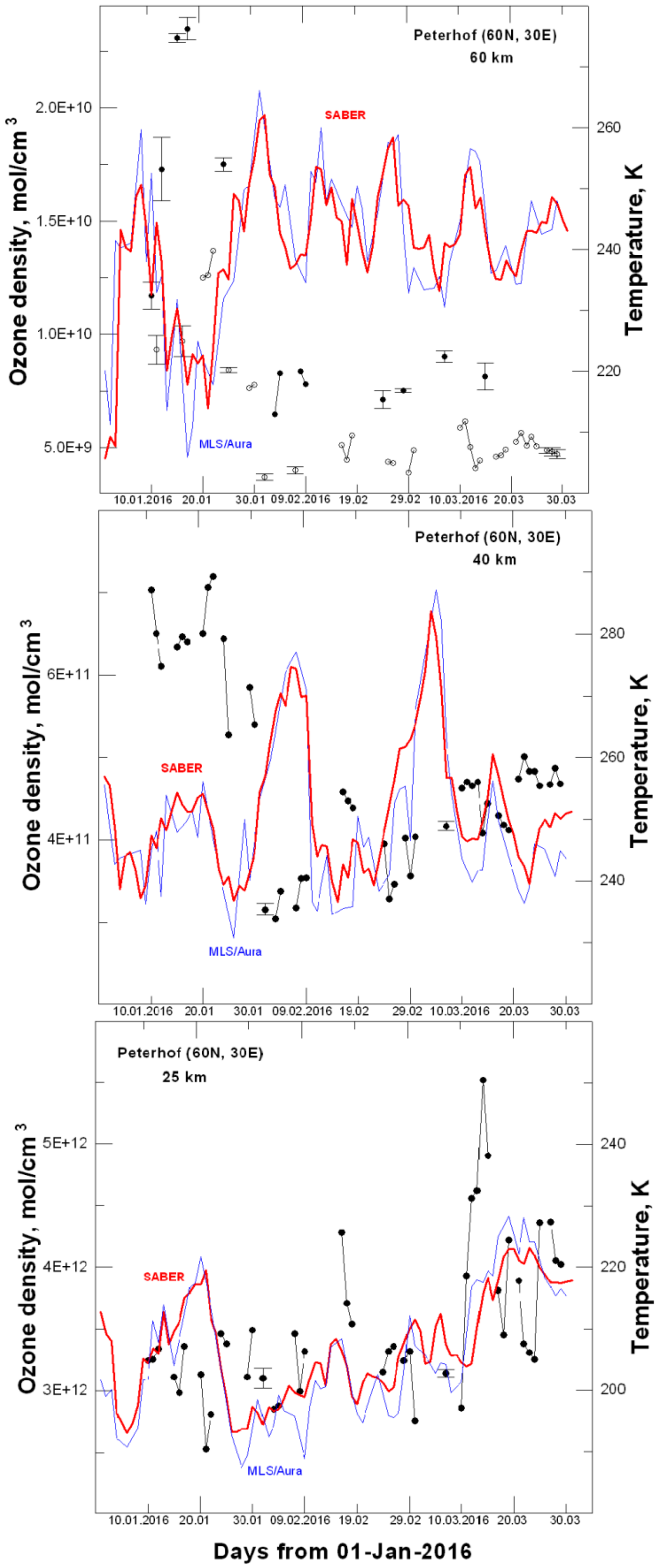
Peterhof (60N, 30E)
60 km
SABER
MLS/Aura
Ozone density, mol/cm 3
Temperature, K
2.0E+10
1.5E+10
1.0E+10
5.0E+9
260
240
220
10.01.2016 20.01 30.01 09.02.2016 19.02 29.02 10.03.2016 20.03 30.03
Peterhof (60N, 30E)
40 km
SABER
MLS/Aura
6E+11
4E+11
280
260
240
Peterhof (60N, 30E)
25 km
SABER
MLS/Aura
5E+12
4E+12
3E+12
240
220
200
Days from 01-Jan-2016

Figure 3

On the top panel of Fig. 3 shows night ozone density (filled circles) and day ozone density (open circles), that specifies exciting diurnal variations of ozone at altitude 60 km. The increase in ozone at 40 km and 60 km relative to the unperturbed period were in two and almost three times more at altitude 60 km.

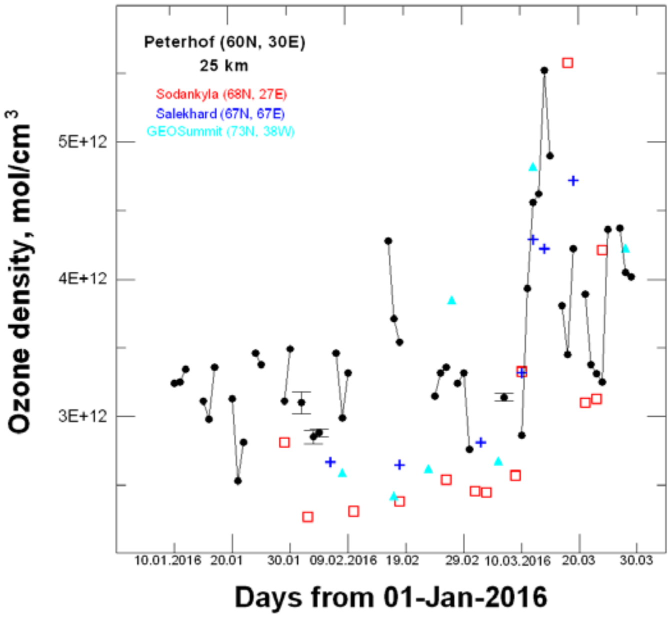

Figure 4

Conclusion

1. We show the new results of studying the dynamics of ozone content in the middle atmosphere over Peterhof (60N, 30E) during stratospheric warming in the winter 2016 by the microwave radiometry method.
2. Microwave results (vertical distribution of ozone) were compared with satellite data on the total ozone content (OMI/Aura), altitude profiles of ozone and temperature in the layer of 20-60 km (MLS/Aura and SABER/TIMED), and also with ozonesonde data at stations Sodankyla (68N, 27E), CEOSummit (73N, 38W) and Salekhard (67N, 67E).
3. Significant variations in ozone, which were caused by stratospheric warming of the minor type, were observed over Peterhof at altitudes of 40 to 60 km.

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