Atmospheric ozone layer over Yakutia

A.A. Mikhailov, P.P. Ammosov, G.A. Gavril'eva, and S.V. Nikolashkin

Institute for Space-Physical Investigations and Aeronomy, Siberian Branch of the Russian Academy of Sciences, Yakutsk

Received November 12, 2004

The state of the atmospheric ozone layer over Yakutia is considered. Isolated local reductions of the ozone layer thickness (hole) have been detected. The dynamics of holes motion in the ozone layer is followed. The problem of holes formation in the atmospheric ozone layer is discussed.

The state of the stratospheric ozone layer is of great importance for all living beings. Biological organisms are defenseless because of the action of the solar ultraviolet radiation at a wavelength less than 3200 Å (UV-B) – in the cells the mutations may occur, which destruct the cells. The ultraviolet radiation causes larger variations than the hard radiation (X-rays and gamma-radiation). This action may cause some diseases of skin (cancer), as well as blindness (cataract, burns of retina), and so on.

The stratospheric ozone layer (up to 90% of the atmospheric ozone is contained in the stratosphere) is the main factor attenuating the ultraviolet radiation. The UV radiation is absorbed in the reaction

$$O_3 + h\nu \rightarrow O_2 + O, \qquad (1)$$

where O_3 is the ozone molecule, $h\nu$ is the ultraviolet radiation, O_2 is the oxygen molecule, O is the oxygen atom.

As is shown in Ref. 1, the decrease of the total ozone content by 1% can increase the number of people, getting the skin cancer, by 10–20%. In Yakutsk in the past two decades, based on data of the republic eye-hospital, the number of people getting cataract increased by several times.

The state of the ozone layer reproduced from data of the Central Aerological Observatory (CAO, Dolgoprudnyi, Moscow Region) and Yakutsk Territorial Management of Hydrometeorology and Monitoring of the Environment (YTMHME) during 1990s rose the anxiety – the process of ozone accumulation over Yakutia during spring months was interrupted for reasons unknown to us, Refs. 2 and 3. As noted in Ref. 2: "In none of inhabited earth's territories the ozone holes do not occur so often and reach such a size as in Yakutia." The state of total ozone content in the atmospheric column of unit cross section (we denote this value as $N(O_3)$) over Yakutsk during the period from 1974 until 1984 is shown in Fig. 1. An averaged value of the total ozone content, $N(O_3)$, over the above-mentioned period of time is shown by solid curve. The values of $N(O_3)$ spaced from the mean value of $N(O_3)$ by $\pm 2\sigma$, where $\sigma = \sqrt{N(O_3)}$, are shown by dashed line.

The total ozone content is shown graphically as triangles in Fig. 1 based on data of the National Climate Center of the USA[4] during 2002. These data are given for the 10th, 20th, 30th days of the month averaged over one day. Figure 1 shows that the ozone state, $N(O_3)$, is close to normal value. But on the 20th of February and on the 30th of August the total ozone content was below the mean value by more than 2σ. The observed ozone deficit on the 20th of February is determined by a global decrease of the total ozone content throughout the entire northern hemisphere, its value over Yakutsk is 367 Dobson units. The observed ozone deficit over Yakutsk on the 30th of August depends upon the arrival of the "hole" in the ozone atmospheric layer from the Arctic. The ozone hole size was about (1000×1000) km^2. This ozone hole was generated over the East Siberian Sea on July 30 and gradually moved along a curved path over the West Yakutia to the south of Yakutia. The speed of motion was equal on the average to about 100 km a day.

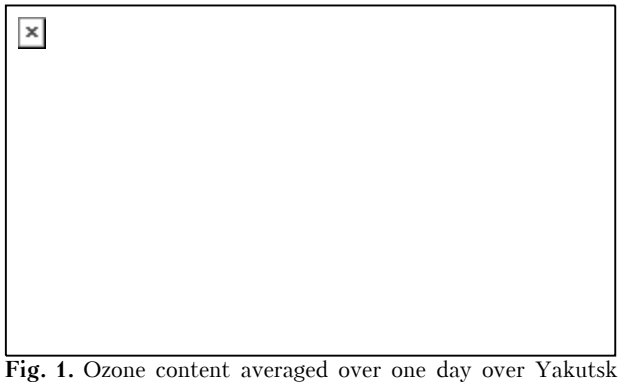

Fig. 1. Ozone content averaged over one day over Yakutsk during 1974–1984 (solid curve); $N(O_3)$ deviations by $\pm 2\sigma$ (dashed line); 2002 (∫ connected by line); 2003 (©); 2004 (+).

During summer time, when because of seasonal variation the total ozone content reaches its minimum, the occurrence of the hole can decrease the level of the ozone content to a hazardous magnitude. We demonstrated in Ref. 5 that the intensity of solar ultraviolet radiation grew exponentially with the decrease in the ozone thickness by the formula:

$$I(N) = I(N_0)e^{k\Delta N}, \qquad (2)$$

0235-6880/05/01–02 155-02 $02.00

where $I(N)$ and $I(N_0)$ are the ultraviolet radiation intensities at the ozone content N and N_0, k is constant, $\Delta N = N_0 - N$.

This dependence is shown in Fig. 2. On August 30, 2002 the ozone content over Yakutsk was 260 Dobson units. Figure 2 shows that the ultraviolet radiation intensity on August 30 increased by a factor of 100 as compared with its level on August 20. This increase can affect the human health. In the future it would be desirable to inform people on the appearance of "the hole" in the stratospheric ozone layer.

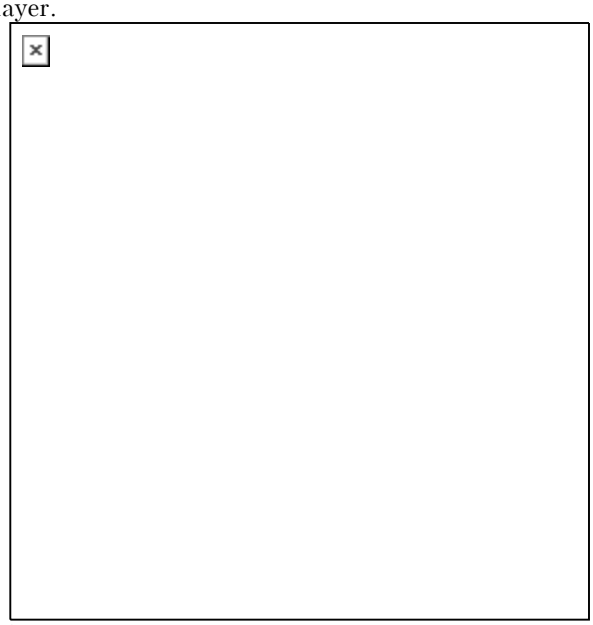

Fig. 2. The ultraviolet radiation intensity at $\lambda = 2500$ Å depending on the ozone layer thickness.

Figure 1 also shows the ozone content during 2003 by squares according to Ref. 4. The ozone deficit was observed in late March, in July, and early in December. The ozone deficit in March is determined by a global decrease of the ozone content in the northern hemisphere. The second ozone deficit in July is determined by the air mass invasion with the reduced ozone content on July 13 from equator to the Western Siberia. The area with the reduced ozone content was equal to 1500×1500 km^2. On July 16 this area moved toward West Yakutia, and on July 18 the area reached the city of Yakutsk. At this point the ozone content over the city was equal to 280 Dobson units. Then the area with the decreased ozone content moved to the northeast. On the background of this decrease of the ozone content in late July the "hole" in the atmospheric ozone layer of 500×500 km^2 size appeared over Yakutsk. As a result the ozone content was equal to 250 Dobson units. Only in early August the "hole" disappeared. As in late July 2002 the ultraviolet radiation intensity increased by more than one hundred times. In early December the decrease of the ozone content was also observed. This decrease was caused by the air mass invasion also from the Western Siberia and on December 10 it reached Yakutsk. The ozone thickness was equal to 255 Dobson units. In this case the sun rose above Yakutsk not higher than 20° above the horizon and for solar rays the ozone thickness increased as $1/\cos(90° - 20°)$, i.e., by about three times. Thus the solar ultraviolet radiation in December, when the ozone content $N(O_3)$ was equal to 255 Dobson units, was harmless. Then the air mass moved toward Kamchatka.

In 2004 the ozone content over Yakutsk was within 2σ as compared with the long-term mean value. The observations made over a 3-year period demonstrate that the occurrence of the hole in the ozone layer over Yakutia is caused by its arrival from the Arctic and from the side of equator. We have revealed no connections between the falling second stages of rockets launched from Baikonur and Plesetsk and the occurrence of the "holes" in the ozone layer over Yakutia. But at the same time it should be noted that the holes in the ozone layer arrived in Yakutia on August 30, 2002 and July 13, 2003 moved close to the area of the fall of the second stages of rockets (Altai and Verkhoyanskii Region of Yakutia, respectively). It is hard to tell whether the above factor played a part in the supplementary decrease of the ozone content over Yakutia. Unfortunately, for definite conclusions there is little statistics. This problem calls for further investigation.

Acknowledgments

The work was supported by the Russian Foundation for Basic Research (Grant No. 03-02-96011).

References

1. Sh. Rown, *Ozone Crisis. Fifteen-year Evolution of Unexpected Global Danger* [Russian translation] (Mir, Moscow, 1993) 320 pp.
2. A.A. Chernikov and G.M. Kruchenitskii, *Reports of the Central Aerological Observatory* (Government of the Republic of Sakha, Yakutsk, 1997), 25 pp.
3. A.A. Mikhailov, P.P. Ammosov, G.A. Gavril'eva, N.N. Efremov, and S.V. Nikolashkin, *State of Ozone Layer over Yakutia*, Nauka i Tekhnika v Yakutii, No. 2, 49–50 (2003).
4. http://www.cpc.ncep.noaa,gov/products/stratosphere/tovsto/archive/np/.
5. A.A. Mikhailov, Nauka i Obrazovanie (Yakutsk), No. 4, 51–55 (1997).