OZONE DEPLETION OVER ANTARCTICA DURING OCTOBER 1989 EVENTS

I. V. Kuznetsov, A. F. Andriyanov, S. Yu. Dryagin, L. M. Kukin, A. B. Mazoor, O. S. Mocheneva, and P. L. Nikiforov

Institute of Applied Physics, Russian Academy of Sciences,
Ulyanov 46, 603600, Nizhny Novgorod, Russia

During the last 20 years, many investigations of ozone density variations in the polar atmosphere by the influence of solar proton events have been performed. So, in 1972 Heath et al. [1] have registered an 18% decrease of stratospheric ozone at altitudes 40-45 km on the eighth day from the beginning of the event. In 1982 Thomas et al. [2] have discovered depletion of the mesospheric ozone (up to 60% at altitudes 70-80 km) simultaneously with the proton events. Solomon et al. [3] and Rusch et al. [4] have developed some models and explained these phenomena by increasing of nitrogen and hydrogen species during the atmosphere ionization due to the influence of the proton flux. Lately (in spring 1989 and 1990) there were registered more then 8% depletion of the total ozone contents several days after the beginning of the event [5,6]. It is supposed that the ozone changing occurred at altitudes 15-25 km [5].

The very strong proton events took place in the second half of October 1989. Reid et al. [7] and Jackman et al. [8] have predicted 20-30% ozone depletion in the polar atmosphere at altitudes 40-45 km up to the middle of November. In addition there were predicted 8% and 18% ozone decreases during December 1989 above Southern and Northern Hemispheres, correspondingly. The results of experimental investigations were the following:

1% ozone depletion in the latitude band 60-80 S and 12% in the same band of Northern Hemisphere (December 1989 compared to December 1990/91, NOAA-11, SBUV/2) [8].

10-20% ozone decrease at altitudes 40-50 km on October 20 compared to October 23 (rocket measurements about 55 S and 50-60 E) [9].

5-25% total ozone contents depletion during proton events in Northern latitudes (optical ozonometer) [9].

30% decrease of ozone density at altitude 30 km in the latitude 34 N at the first half of November [10]. But two years later the same decrease was observed during the same period when strong proton events were absent [11] (simultaneous microwave and lidar ground-based measurements).

This short review demonstrates three occurrences to study: the depletion of the mesospheric ozone simultaneously with the phenomenon, the decrease of the stratospheric ozone at altitudes 40-45 km several days later, then the beginning of the phenomenon and the depletion of the ozone density at altitudes near the ozone layer maximum several days later also.

We have analyzed the data of our microwave ground-based observations of the ozone variations over the MIRNYY station (66.5 S, 93 E) [12]. The spectra of the atmospheric optical depth about the rotational transition frequency 142175 MHz (ozone lines) were measured by means of a heterodyne receiver with a noise temperature of 3000 K in the single side band. The filter bank spectrometer had 20 channels with a frequency resolution of 3 MHz and 16 channels with resolution 0.1 MHz at the ozone line centre. The total spectroscopy band was 110 MHz on one side of the rotational transition. The ozone altitude profiles approximately from 25 km to 65 km were calculated by Randegger's retrieval procedure [13] from the spectra averaged over 2-6 hours except for snow-fall moments.

As appears from the above we'll pay attention to the altitudes about 25, 45, and 65 km. But at first we would like to compare the variations of the line centre optical depth measured each 25 min. with frequency resolution 3 MHz and the variations of the solar proton flux [14]. This comparison from October 19 to 25 (local time, difference of UT is 7 hours) are shown in Fig. 1.

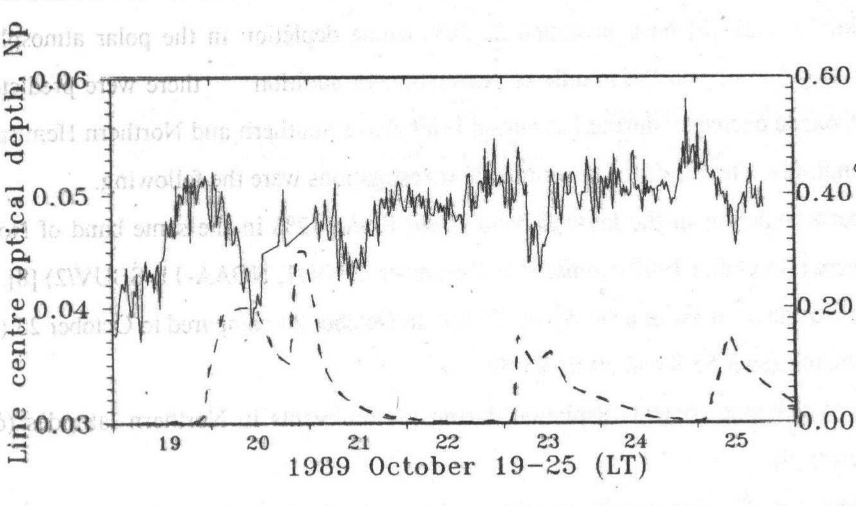

Fig. 1. Variations of the line centre optical depth measured with frequency resolution 3 MHz and the example of the proton flux increases with E=110-500 MeV

Fig. 2 demonstrates the correlation between optical depth variations on October 20 and 23 and the variations of the radio wave absorption in the ionosphere measured by means of the riometer at the frequency 32 MHz [15].

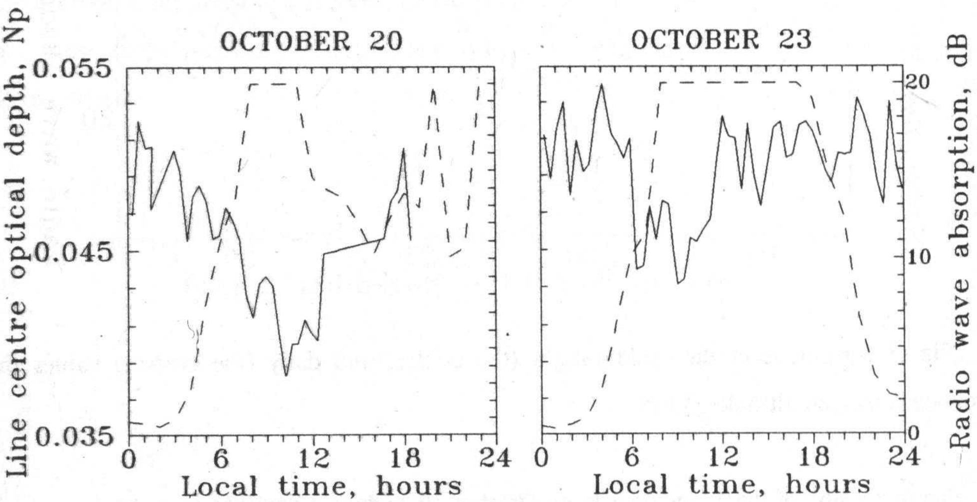

Fig.2.Examples of the correlation between decrease of line centre optical depth and the increase of the radio wave absorption at the frequency 32 MHz.

These figures show that there was the influence of the proton events to the ozone layer. Simultaneously or some later than the whole increases of the four proton particles it is seen the four decreases of the optical depth correlated with the increases of the radio wave absorption. When intensity of the proton flux was small (on October 22 and 24) the variations of the optical depth were small too. Fig. 1 also shows the considerable increasing of the optical depth before the beginning of the proton occurrence. The optical depth changing correlated with the large total ozone content increase and stratospheric temperature increase too [16]. In our opinion this occurrence (stratospheric warming) as well as diurnal variations of the mesospheric ozone density may veil the ozone variations due to the proton events.

Fig. 3 shows the ozone density variations from October 13 to November 2 at the altitude about 65 km, separately retrieved for measurements during daylight hours and night-time. Radio wave absorption variations are shown too .

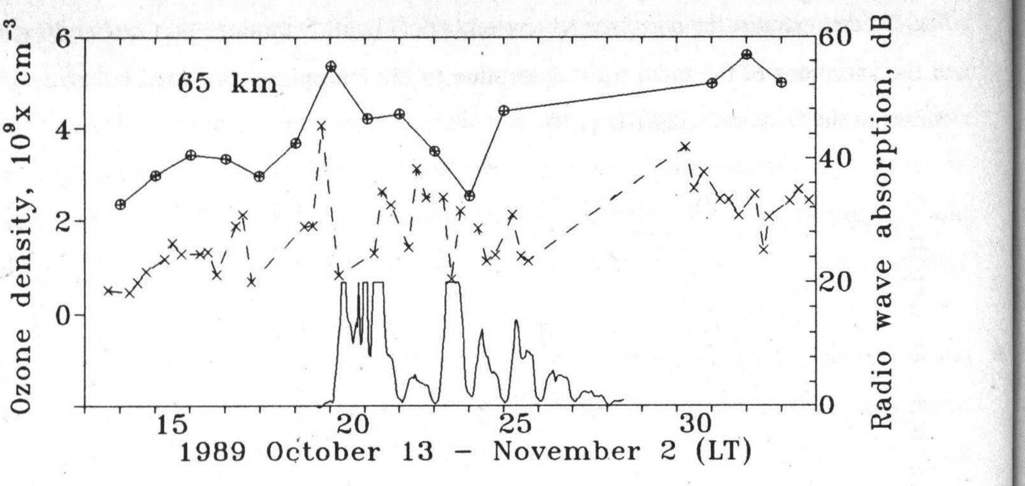

Fig. 3. Variations of the middle-night (the circles) and daily (the crosses) values the ozone density at altitude 65 km.

The increasing of the ozone density on October 19 as during daylight as night-time, may be explained by the stratospheric warming. Supposing the ozone density to remain invariable after this occurrence and taking into account the large radio wave absorption during the same period, i.e. there was the atmospheric ionization, the observed approximately 20-50% decrease of the ozone density from October 20 to 25 may attribute to the proton events.

Fig. 4 shows variations of ozone density at the altitude of about 45 km from October 13 to November 7. Points denote the values averaged over 6 hours.

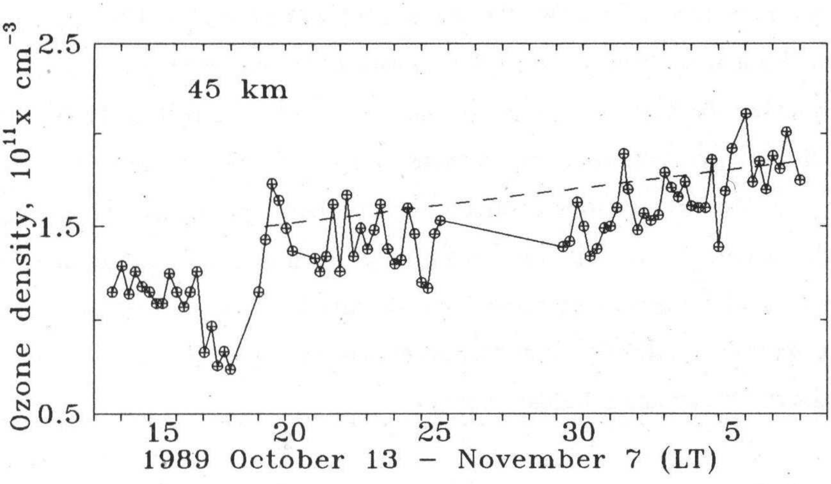

Fig. 4. Ozone density variations at altitude about 45 km from October 13 to November 7.

If ozone depletion took place at this altitude later then the stratospheric warming it was veiled by smooth increasing trend. Perhaps that this increasing was the linear trend (for example as shown by the dashed line). According to that the ozone depletion is approximately 15%, but we can't say about this supposition with certainty.

Fig. 5 presents the variations of the ozone density at the altitude about 25 km from October 13 to November 7.

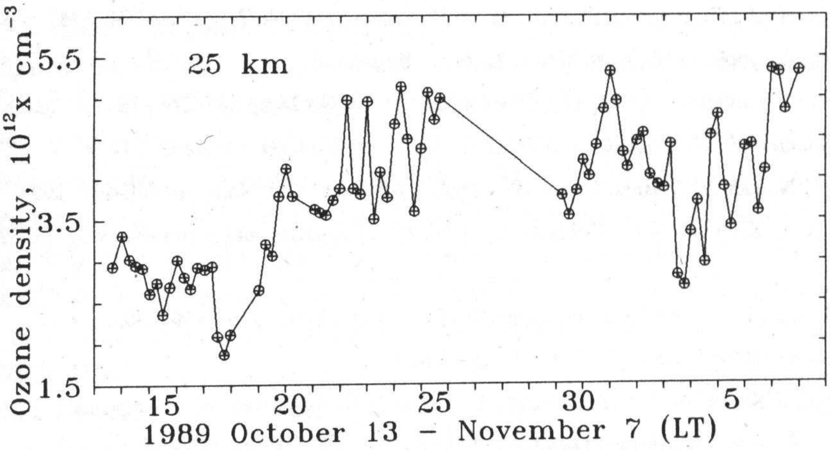

Fig. 5.The variations of the ozone density at the altitude about 25 km from October 13 to November 7.

It is seen the considerable increasing of the ozone variations amplitude from October 30 to November 6. Minimum of the ozone density (about 50%) noncorrelated with the variation of the radio wave absorption was observed on November 3-4. The decrease of ozone content above 25 km during this occurrence was about 25 Du (20%). The simultaneous decrease of total ozone content was about 60 Du (17%)[16]. In our opinion this occurrence may attribute as to the dynamic ozone variations as to the same proton events.

In conclusion we would like to pay attention that registered ozone depletion at altitude about 65 km is in accordance with measurements [2] and “hydrogen” model [4]. The “nitrogen” model decrease at altitude about 45 km [3,8] isn't corroborated by the results of our October measurements. Minimum at altitude about 25 km (if it was due to the proton events) can not be explained by these models.

Perhaps we can expand our notion of ozone density response to solar activity after the analysis of the ozone spectra measured on 1989 August when the considerable proton event occurred too.

REFERENCE

1. Heath D.F.,Krueger O.J.,and Crutzen P.J., Science, v.197, p.886, 1977.
2. Thomas R.J., Barth C.A., Rottman G.J., et al., Geophys.Res.Lett.,v.10,N 4, pp. 253-255, 1983.
3. Solomøn S., Reid G.C., Rusch D.W., Thomas R.J., Geophys.Res.Lett.,v.10, No4, pp. 257-260, 1983.
4. Rusch D.W., Gerard J.C., Solomon S.,et al., Planet.Space Sci., v.29,No 7, pp. 767-774, 1981.
5. Shumilov O.I., Raspopov O.M., Kasatkina E.A., et al., Reports of
6. Stephenson A.E., Scourfield M.W.J., Geophys.Res.Lett., v.12, No.24,pp.257- 260, 1992.
7. Reid G.C., Solomon S., Garsia R.R., Geophys.Res.Lett., v.18, No.6,pp. 1019-1022, 1991.
8. Jackman C.H., Nielsen J.E., Allen D.J., et al., Geophys.Res.Lett.,v.20, No.6, pp. 459-462, 1993.
9. Zadorozhny A.N., Kihtenko V.N., Kokin G.A., et al., Geomagnetizm and aeronomy, v.32, pp.32-40, 1992.
10. Parish A., Connor B.J., Tsou J.J, et al., J.Geophys.Res., 97(D2),pp. 2541-2546, 1992.
11. Parrish A., Microwave Journal, v. 35, No. 12, pp. 24-34.
12. Kulikov Yu.,Yu, Kuznetsov I.V., Andriyanov A.F., et al., J.Geophys.Res., 1994, in press.
13. Randegger A.K., Pure and Applied Geophys., 118, pp. 1052-1065, 1980.
14. Solar-Geophysical Data, Prompt Reports, No. 543, Part 1, pp.13-16.
15. Kopejchuk A., private communication.
16. Sakunov G.G., Blum E.M., Information Bulletin of the Russian Antarctic Expedition, 117, pp.5-10, Gidrometeoizdat, 1993.