THE INFLUENCES OF THE GALACTIC COSMIC RAY ON THE ATMOSPHERIC OZONE

Ye Zonghai Xue Shunsheng
(Institute of Space Physics, Academia Sinica,
P.O.Box 5112, Beijing, China)
Wang Lianying
(Institute of Atmospheric Physics, Academia Sinica,
P.O.Box 2718, Beijing, China)

I. Introduction. Warneck [1] and Nicolet et al. [2] first put forward that cosmic ray is a sourice of NO production in the atmosphere. The Nicolet et al.[3,4,5] proved that each ion pair producted by cosmic ray forms about 1-1.5 NO moleculees because of the ionization and the dissociation processes. Because of the reaction between NO and O in the atmosphere NO will dispapear in part, so the change of [NO] will directlly influence [O_3] in the atmosphere. The observational results proved that the solar cosmic ray events will cause the large decrease of[O_3] in the polar stratosphere [6] . Ruderman et al.[7] proved that[O_3] has the law of 11 years variation.

This paper has analysed the relationship between yearly variation of cosmic ray intensity and [O_3], and[O_3] disturbance initiated by Forbush decrease for 1965-1976. The data of cosmic ray intensity were selected from the records of the superneutron monitor at Deep River station and the ionization chamber at Beijing station;[O_3] data were selected from Resolute (74.4°N, 94.6°W), Canada, Bismarck (46.4°N, 100.5°W), America, Kagoshima (31.4°N, 130.4°E), Japan, Kodaikanal (10.1° N, 77.3°E), India. The statistical results show that [O_3] prominently is modulated and disturbed by 11 years variation and Forbush decrease of the galactic cosmic ray.

II. The modulation of 11 years variation of cosmic ray intensity on the ozone. Fig. 1c is the curves of yearly variation of cosmic ray intensity. The solid line is the data of the superneutron monitor at Deep River. The dashed line indicats μ meson component recorded by the ionization chamber at Beijing. It can be seen that there is the maximum of cosmic ray intensity during the solar activity minimum (1964-1965), there is the minimum of cosmic ray intensity during the solar activity maximum (1969-1970). Fig. 1a,b are the corresponding content of O_3 at four variant latitudes. Used [O_3]data is selected from "Ozone data for the world" published by Canada[8] . The analysis results show that except Resolute Station at high latitude 11 years variation of [O_3] is very evident. The ozone content decreases when cosmic ray intensity increases, The ozone content increases whe cosmic ray intensity decreases. This means the relationship between the ozone variation and cosmic ray intensity variation is the nagetive correlation.

It is seen from fig. 1 that 11 years variation of [O_3]has evident latitude effect. From maximum year of cosmic ray in-

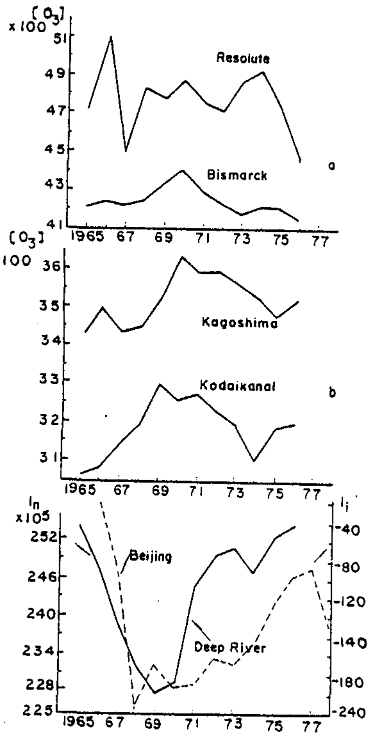

Fig.1 The modulation of 11 years variation of cosmic ray intensity on the ozone

tensity to minimum year $[O_3]$ increased by 7.8% and 5.8% at Kodaikanal and Kagoshima respectively. The increase of $[O_3]$ decreased with the increase of the latitudes, $[O_3]$ only increased by 4.8% at Bismarck. But 11 years variation of $[O_3]$ become indistinct at Resolute in the polar region.

III. <u>The disturbance of Forbush decrease on $[O_3]$</u>. 1. <u>Data analysis</u>. In order to study the disturbance stage of Forbush decrease for variant amplitudes on $[O_3]$, Forbush decrease events are divided >1%, >2%, >3% and >5% four importances based on their amplitudes. The disturbance analysis of the solar flare and Forbush decrease on vorticity arear index (VAI) showed that the disturbances of VAI have evident seasonal property [9]. So the time occurred Forbush decrease is also divided the winter (10-3 months) and the summer (4-9 months). According to the seasons and importances occurred Forbush decrease, their variant combination is analysed. There were 234 Forbush decrease events during 1965-1976. The distribution of various Forbush decrease events as table 1 shown.

Table 1 The distribution of Forbush decrease events

importance / season	>1%	>2%	>3%	>5%
winter	119	49	22	4
summer	115	48	28	4
total	234	97	50	8

The method of the statistical study has used the superposed epoch method. The day of the minimum of Forbush decrease is considered as the zero day. The abscissa denotes the time in days for all of the figures in this section. The ordinate represents the ozone content. The horizontal line refers to the average value of the total absembly of $[O_3]$. The dashed line represents confidence level with probability 0.05 or the degree of confidence 95%. n is the number of Forbush decrease events.

2. <u>Analysis results</u>. The statistical study for all Forbush decrease events shows that the disturbance of Forbush decrease on $[O_3]$ is of statistical significance, and the amplitude of $[O_3]$ disturbance increases with the increase of Forbush decrease amplitude. The disturbance of Forbush decrease on $[O_3]$ increases with the increase of the latitudes. But at

high latitudes, the effect of the solar cosmic ray and precipitating particles on $[O_3]$ will be over Forbush decrease, so that the ozone disturbance produced by Forbush decrease all is covered.

The disturbance of Forbush decrease occurred in the winter on $[O_3]$ is larger and more evident. Usually on the day started Forbush decrease, i.e. about at -1 day, $[O_3]$ begins increase, and there is a larger increase after the fourth day. The amplitudes of $[O_3]$ disturbance increase with the increase of the latitudes of the observational stations. Fig. 2 shows the disturbance of $[O_3]$ for variant latitude regions in the winter. Because the data of $[O_3]$ observed in the winter at Resolute is a few numbers, the change of $[O_3]$ can not be given.

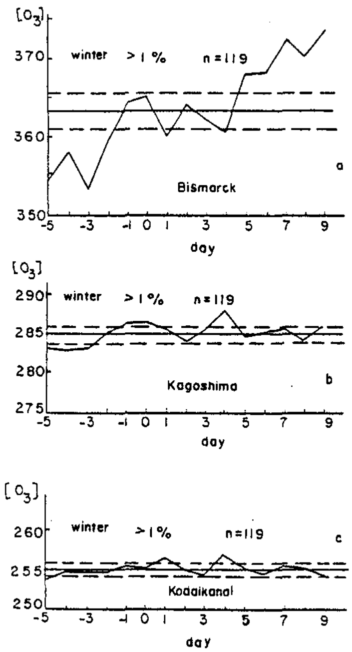

Fig.2 The disturbance of Forbush decrease in the winter on $[O_3]$

The disturbance Forbush decrease occurred in the witner on $[O_3]$ at same latitude increases with the increase of Forbush decrease amplitudes. If the average value of $[O_3]$ from the third day to the fifth day before the zero day is considered as the undisturbance value of $[O_3]$, that the largest disturbance of >1% Forbush decrease on 0 was about 5.3%. The largest disturbance of >2%, >3% and >5% Forbush decrease events were 5.9%, 6.2% and 10.3% respectively.

The disturbance of Forbush decrease occurred in the summer on $[O_3]$ in low latitudes can also be seen, but its disturbance is very less than in the winter. The disturbance of Forbush decrease on $[O_3]$ all is covered at high latitudes. It always is the decrease tendency after the solar flare, and it lasts several days (see Fig.3).

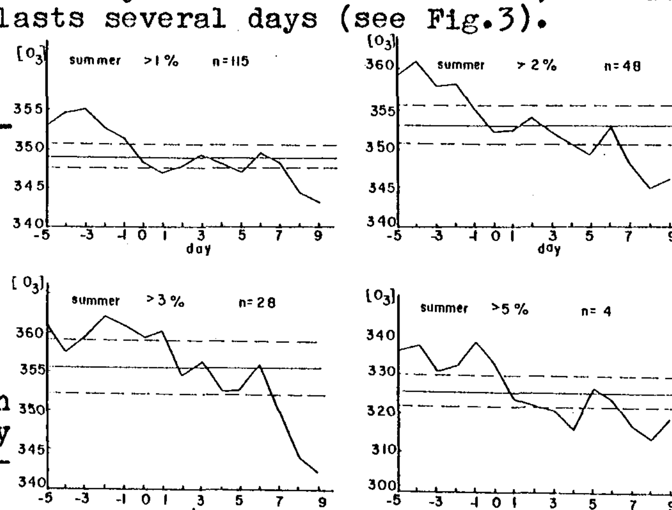

Fig.3 The change of $[O_3]$ during Forbush decrease in the summer at Bismarck.

IV. <u>Conclusions and discussion.</u> According to the results discribed above, we obtain the following conclusions:

$[O_3]$ is modulated by 11 years variation of cosmic ray intensity. The relationship between the ozone variation and cosmic ray intensity variation is the negative correlation. The 11 years vibration of $[O_3]$ is most evident at the middle and the low latitudes. The law of this variation is more indistinct at the high latitudes. Because the influences of the solar cosmic ray and precipitating particles on $[O_3]$ are so large that the effect caused by the long period variation of cosmic ray intensity is covered.

The disturbance of Forbush decrease occurred in the winter on $[O_3]$ is very remarkable. The disturbance of $[O_3]$ evidently increases with the rising of the latitudes. Usually $[O_3]$ increases after Forbush decrease started, and lasts several days. The disturbance occurs the maximum after the fourth or the fifth day. The amplitude of $[O_3]$ disturbance also increases with the increase of Forbush decrease amplitude.

The disturbance of Forbush decrease occurred in the summer on $[O_3]$ is very interesting. The effect of Forbush decrease on $[O_3]$ is also evident at the low latitudes, but the disturbance of $[O_3]$ is just opposite to the effect caused by Forbush decrease at the high latitudes. Evidently, this is not produced by Forbush decrease. It is produced by the solar cosmic ray and precipitating particle events. As was shown by Shah [10], the disturbance of the solar cosmic ray events occurred in the summer on VAI is the most remarkable. We discover that the larger solar cosmic ray events occur in the summer. So the disturbance of the solar cosmic ray events occurred in the summer on $[O_3]$ can also be the most remarkable.

References.
1. Warneck, P. (1972), J. Geophys. Res., Vol. 77, 6589
2. Nicolet, M. et al. (1972), Annals Geophys., Vol. 28, 751
3. Brasseur, G. et al. (1973, Planet. Space sci., vol. 21 939
4. Nicolet, M. (1975), Planet, Space Sci,. Vol. 23, 637
5. Reagan, J. B. (1981), J. Geophys. Res., Vol. 86, 1473
6. Donald, F. H. et al. (1977), Science, Vol. 197, 866
7. Ruderman, M. A. et al. (1975), Planet. Space Sci., Vol. 23, 247
8. Ozone data for the world, environment Canada, atmospheric environment Service 1965-1976
9. Ye Zonghai et al. (1984), Chinese Journal of Space Science, Vol. 4, 198
10. Shah, G. N. (1981), J. Atmos. Terres. Phys, Vol. 43, 147