Indian Journal of Radio & Space Physics
Vol. 6, March 1977, pp. 32-34

Effect of Solar X-Ray & Lyman-α Radiation on Ionospheric Absorption*

D N Madhusudhana Rao & K V V Ramana
Space Research Laboratories, Department of Physics, Andhra University, Waltair 530 003

Received 30 *April* 1975; *accepted* 15 *October* 1975

Results of a statistical analysis of A_1 absorption and solar X-ray and Lyman-α fluxes are presented. The observed small positive correlation coefficients between absorption and solar X-ray flux in the 1-8 Å and 8-20 Å bands show that the influence of solar X-rays on absorption is less during low sunspot activity period. Significant positive correlation between Lyman-α flux and absorption is obtained. Significant positive correlation between D region absorption (separated from total absorption) and Lyman-α flux shows that the influence of Lyman-α radiation on the D region is more than that of X-rays.

1. Introduction

The influence of different ionizing radiations in the lower ionosphere, E region and particularly the D region, is not well established. Generally, X-rays and Lyman-α radiation are considered as the sources of ionization in the ionosphere below 100 km. Vij and Hislop[1] observed that the 30-100 Å X-rays are the principal sources of ionization in the E-layer. There are contradictory ideas about the role of X-rays as ionizing source in the D region.[2-5] Thomas,[6] while reviewing the lower ionosphere, maintained that our ideas about the D region formation have to be constantly revised. Since the ionospheric absorption is entirely dependent on the ionization in the E and particularly the D region, it is of interest to study the influence of different ionizing radiations on absorption. Such a study will enable us to know the relative importance of these ionizing radiations. In the investigations reported here, ionospheric absorption data on 2·4 MHz measured at Waltair during 1971-73 are used. The X-ray flux data are obtained from the solar geophysical data bulletins.

2. Solar X-Ray Control on Absorption

As a first step to find out the dependence of absorption on solar X-ray activity, the data are superficially examined for any possible correlation. Fig. 1(A) shows day-to-day variation in absorption (in Feb. 1972) and changes in X-ray flux in both 1-8 Å and 8-20 Å bands together with values of sunspot number on the corresponding dates. A perusal of the figure indicates that there is some amount of correlation though not very prominent, between absorption and solar X-ray flux. A similar behaviour in the day-to-day variations of absorption and X-ray flux was observed at Colombo by Gnanalingam.[7] It is interesting to note from Fig. 1(B) enhancements in absorption even in the absence of X-ray flux enhancements. And there is a gradual increase in sunspot number coinciding with enhancements in absorption, indicating that the abnormal

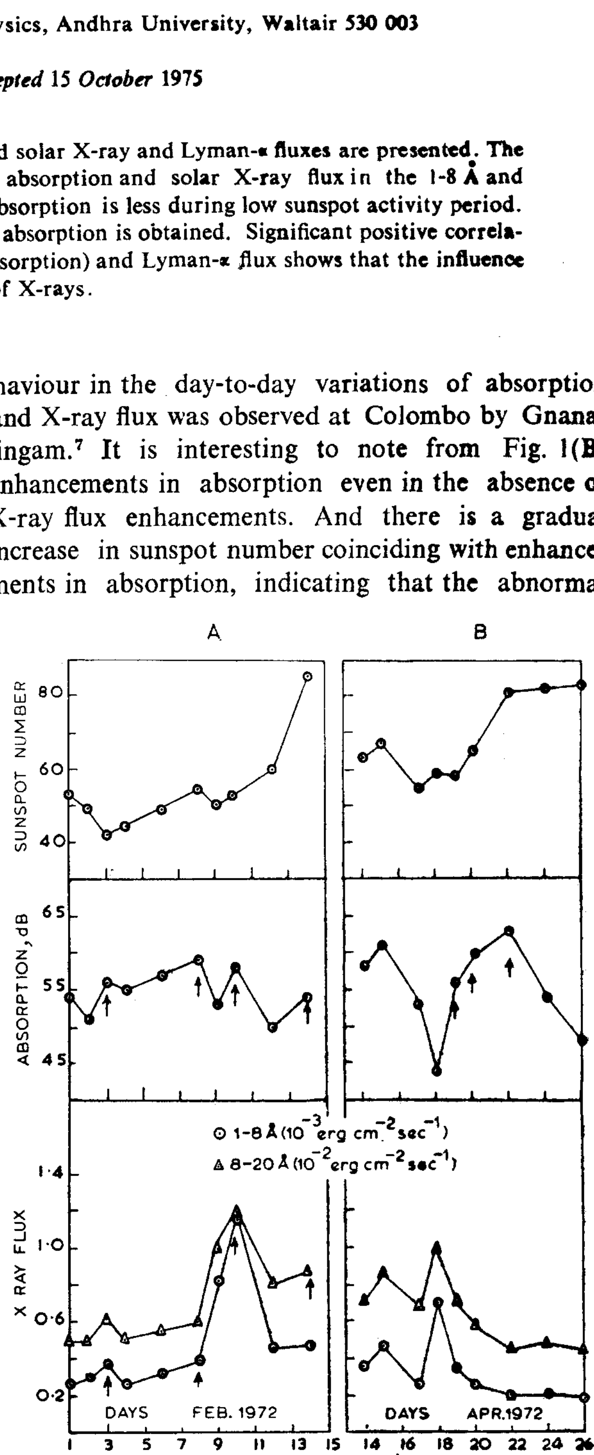

Fig. 1—Day-to-day variation of absorption, X-ray flux and sunspot number [A, day-to-day correlation of absorption with X-ray flux; and B, days of high absorption in the absence of X-ray activity]

* Paper presented at the Symposium on Earth's Near Space Environment, 18-21 February 1975, held at the National Physical Laboratory, New Delhi 110 012.

increase in absorption is caused by some solar ionizing source other than X-rays. The excessive absorption is normally due to increased ionization in the D region. Gnanalingam[7] while explaining similar enhancements in absorption in the absence of X-ray activity, attributed the same to unusual enhancements in the Lyman-α flux. There is every reason to believe that, as will be seen in the present case also, Lyman-α radiation is the possible ionizing source causing excessive absorption.

The total noon-time absorption data are studied statistically in order to draw somewhat more definite conclusions regarding the dependence of absorption on X-ray activity. Fig. 2 shows the scatter plot of total absorption versus X-ray flux. It is obvious that there is a large scatter of points. However, some amount of correlation between the parameters is discernible. The correlation coefficients between absorption and X-ray flux in the 1-8 Å and 8-20 Å wave length bands are found to be 0·2 and 0·22, respectively, which are significant at 0·05 level.[8] This shows that the effect of both the wavelengths is practically the same as regards absorption variations. The correlation coefficients obtained are very low when compared to those obtained by other workers. Gnanalingam[7] observed significant and high correlation coefficient, even higher than that between absorption and 10·7 cm flux. Ganguly[4] reported correlation coefficients of values 0·5 and 0·4 between absorption and 0-8 Å and 8-20 Å X-ray flux, respectively, at Calcutta. The low correlation coefficient obtained in the present case might be due to the fact that the influence of X-rays is less near sunspot minimum.[6] The results of Gnanalingam and Ganguly correspond to data taken during a period of higher solar activity whereas the present data correspond to low sunspot period. Lastovicka and Smilauer,[5] studying the influence of X-ray flux, pointed out that the role of X-rays under undisturbed conditions is less important in the lower ionosphere. Even in the

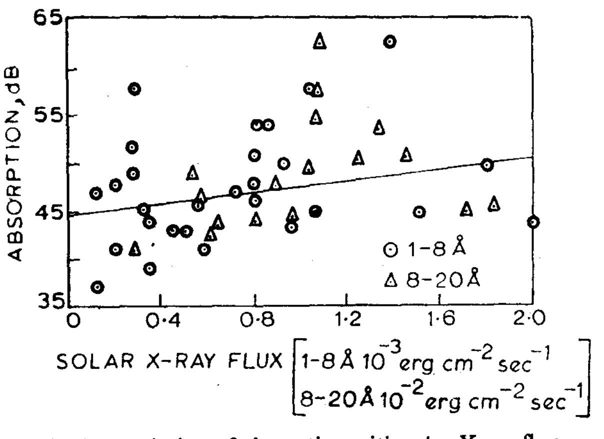

Fig. 2—Variation of absorption with solar X-ray flux

E-layer, the contribution of X-ray flux to the ionization is small except on a day of high solar activity near solar maximum.[9] Lastovicka[10] also observed that even in sunspot maximum period, X-rays do not control the normal day absorption.

3. Solar Lyman-α Control on Absorption

It has already been mentioned that Lyman-α radiation might be the possible cause for the abnormal increase in absorption in the absence of solar X-ray control. The availability of Lyman-α data[11] for a period of five months (Aug.-Dec. 1971) made it possible to study the dependence, if any, of absorption on Lyman-α intensity and to see whether it conforms to Lastovicka's observation. Fig. 3 is a plot of variation of absorption with Lyman-α flux. A cursory look at this plot is sufficient to arrive at the conclusion that there is a linear relationship between the variables. Here the scatter of points is not as much as in the case of X-ray flux (Fig. 2). Statistical analysis gave a value of 0·3 for the correlation coefficient. Lastovicka obtained a correlation coefficient of 0·52 between absorption and Lyman-α flux, which is higher than that (0·38) obtained for X-ray flux. Unfortunately, the Lyman-α data for the complete period of investigation are not available. However, the present result agrees well with the observation of Lastovicka.

4. Solar Lyman-α Control of D-Region Absorption

As was mentioned earlier, the sources of ionization in the daytime D region are still a matter under investigation. Nicolet and Aikin[12] suggested that under normal conditions, ionization at heights of about 88 km is produced by Lyman-α (1216 Å) and below 70 km by cosmic rays. Poppoff and Whitten[13] observed that hard X-rays of wavelengths less than 10 Å are responsible for effects associated with flares. Hunten and McElroy[14] proposed that solar radiation in the range 1027-1118 Å also is a source of ionization of the metastable molecules $O_2(^1\Delta_g)$. But, Lyman-α radiation is still considered as the dominant source of ionization in the D region.

It has already been shown that the dependence of absorption is more on Lyman-α than on X-ray

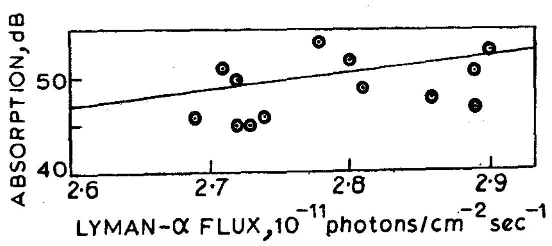

Fig. 3—Variation of absorption with solar Lyman-α flux

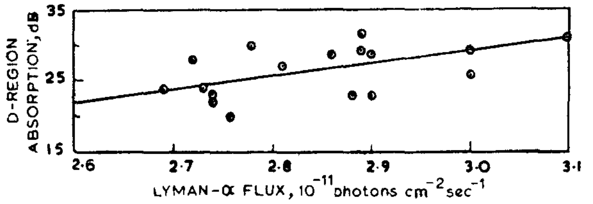

Fig. 4 – Variation of D-region absorption with Lyman-α flux

flux. The above analysis was done for total absorption values. It has been established that more than 60 percent of this total absorption comes from D region. As the Lyman-α flux has little influence in the ionization of the E region, it would be better to remove the E region contribution from the total absorption and study whether the correlation between the Lyman-α flux and D-region contribution to the total absorption shows any improvement. The E-region contribution from the total absorption is separated using Jaeger's method.

Fig. 4 shows a plot of L_D (D-region contributions to the total noon absorption) versus Lyman-α flux. There is an obvious linear relationship between the two variables, and infact the picture is better than in the case of total absorption versus Lyman-α flux variation. The correlation coefficient between L_D and Lyman-α flux is 0·46 (significant at 0·02 level), which is evidently higher and significant than that obtained between total absorption and Lyman-α flux. It is also interesting to note that no significant correlation is obtained between D region absorption and X-ray flux.

This observation, though made with limited data, confirms the proposition that in the daytime D region at solar minimum, Lyman-α radiation is a principal source of ionization and the influence of X-rays is less.

5. Conclusions

The absorption is found to have positive correlation with solar X-ray flux in the 1-20 Å band. The observed small correlation coefficient when compared with that obtained at other equatorial and low latitude stations, indicates that the influence of X-rays on absorption decreases with decrease of solar activity.

One of the important findings is the existence of positive correlation between absorption and solar Lyman-α flux.

The observed high and significant correlation between Lyman-α flux and D-region absorption shows the Lyman-α radiation is still the major ionizing source in the D region.

Acknowledgement

One of the authors (DNMR) acknowledges with thanks the financial support given by the CSIR, New Delhi. Thanks are due to Prof. B R Rao, for his interest in this work.

References

1. Vij K K & Hislop R, *J. geophys. Res.*, **76** (1971), 8441.
2. Kane J A, *Planet. Space Sci.*, **17** (1969), 609.
3. Nestorov G, *Geomag. Aeronomy*, **10** (1970), 844.
4. Ganguly S, *J. atmos. terr. Phys.*, **34** (1972), 2009.
5. Lastovicka J & Smilauer J, *Pure appl. Phys.*, **98** (1972), 178.
6. Thomas L, *J. atmos terr. Phys.*, **33** (1971), 157.
7. Gnanalingam S, *G F S C Rep. No.* X-625-72-726.
8. Fisher R A, *Statistical Methods for Research Workers* (Oliver & Boyd), 1958.
9. Sengupta P R, *J. atmos. terr. Phys.*, **32** (1970), 1273.
10. Lastovicka J, *J. atmos. terr. Phys.*, **35** (1973), 815.
11. VidalMadjar, Private Communication, 1973.
12. Nicolet N & Aikin A C, *J. geophys. Res.*, **65** (1960), 1469.
13. Poppoff I G & Whitten R C, *J. geophys. Res.*, **67** (1962), 2986.
14. Hunten D M & McElroy M B, *J. geophys. Res.*, **73** (1968), 2421.