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U.S. DEPARTMENT OF COMMERCE
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Environmental Research Laboratories

The Correlation of the 10 to 30 MeV Proton Flux From the NOAA Satellites and the Thule 30 MHz Riometer

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THE CORRELATION OF THE 10 to 30 MeV PROTON FLUX FROM THE NOAA SATELLITES AND THE THULE 30 MHz RIOMETER

Larry J. Gardner*

There is a requirement for realtime specification of riometer absorption in the polar cap region using proton flux measured with satellite-borne detectors. The proton flux data from the NOAA series of satellites and the Thule 30 MHz riometer data satisfy this requirement. A study was done to correlate these two parameters within state-of-the-art theoretical reasoning. The results show that the correlation follows the theoretical square root relationship between the two.

1. INTRODUCTION

It is desirable to specify the state of the polar ionosphere during solar particle events, and much work has been done in correlating solar proton flux with polar riometer absorption (e.g., Van Allen et al., 1964, and Potemra, 1972).

The riometer is a device for monitoring cosmic noise. The absorption of this noise increases with increased ionization of the ionosphere (Little and Leinbach, 1959). Thus a riometer may be used to estimate the state of the ionosphere. If satellite proton data are available, then the state of the ionosphere can be estimated by their correlation with the riometer data. The purpose of this paper is, then, to establish such a correlation and determine the feasibility of specifying the state of the polar ionosphere from satellite-borne proton detectors and vice versa.

The riometer absorption A, expressed in decibels (dB), has been found to vary directly as the square root of the integral proton flux, J_o (Van Allen et al., 1964), i.e.,

$$A = m\, J_o^{\frac{1}{2}}, \tag{1}$$

where m is a proportionality constant.

However, as Adams and Masley (1966) point out, the 30 MHz riometer responds most effectively to the proton flux in the differential (rather than integral) energy range of 10 to 25 MeV. Also, the required data to establish the desired correlation in this energy range (actually 10 to 30 MeV) are readily available. So (1) must be modified for differential energy ranges.

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Potemra (1972) presents such an equation as

$$A = m' (dJ/dE)^{\frac{1}{2}}, \tag{2}$$

where dJ is the proton flux over the energy range, dE, and m' is a proportionality constant.

The major problem with using these equations is the evaluation of m and m'. These parameters vary with the spectral characteristic, γ, which is defined by

$$J/J_0 = (E/E_0)^{-\gamma}, \tag{3}$$

where J is the proton flux at energies greater than E, and J_0 is the proton flux for energies greater then E_0.

Potemra also shows the relationship between m and m' as

$$m' = m(\gamma E_0^{\gamma} E^{-\gamma-1})^{-\frac{1}{2}} \text{ in dB cm sec}^{\frac{1}{2}} \text{ MeV}^{\frac{1}{2}}. \tag{4}$$

He shows the relationship between m and γ as,

$$\begin{aligned} &\text{for } \gamma = 0.5,\ m = 0.052E_0^{0.25} \text{ in dB cm sec}^{\frac{1}{2}}, \\ &\text{for } \gamma = 1.0,\ m = 0.032E_0^{0.50} \text{ in dB cm sec}^{\frac{1}{2}}, \\ &\text{for } \gamma = 2.0,\ m = 0.012E_0 \text{ in dB cm sec}^{\frac{1}{2}}, \\ &\text{for } \gamma = 3.0,\ m = 0.0047E_0^{1.5} \text{ in dB cm sec}^{\frac{1}{2}}. \end{aligned} \tag{5}$$

Upon calculation of m and m', the riometer absorption can be predicted from the proton flux using (2).

2. THE DATA

The data corresponding to the energy ranges and riometer data mentioned in section 1, are readily available in near real time over the Air Force Astrogeophysical Teletype Network (ATN). These data consist of the NOAA satellites proton data (taken by 2π, omnidirectional sensors for greater than 10 MeV and greater than 30 MeV) and the Thule 30 MHz riometer. The 10 to 30 MeV flux can be obtained by subtracting the greater than 30 MeV flux from the greater than 10 MeV flux. See the Appendix for a description of the messages containing these data. It should be pointed out that the lower edge of this energy range is also close to the 7 MeV point where m is almost independent of γ (Potemra, 1972).

The first step in using Potemra's equations is to evaluate γ from (3), where E is 30 MeV and E_0 is 10 MeV; J and J_0 are the measured proton fluxes above energies E and E_0, respectively; m is then approximated from (5). We then calculate m' from (4) and the absorption can then be calculated from (2).

The best correlation between predicted and observed absorptions was obtained by using the average 10 to 30 MeV flux measured over the geomagnetic latitudes greater than 75° N for each satellite pass. This average is taken over about 8 min. The data are from the NOAA 2 satellite, but the proton sensors are the same for all the NOAA satellites.

This average flux was then used to calculate the 30 MHz riometer absorption from Potemra's work shown in section 1. The calculated absorption was then compared to the actual absorption observed when the satellite was closest to the geomagnetic latitude of the Thule riometer station, namely 88° N.

3. RESULTS

The NOAA satellite data were available from August 1972 through January 1975. Only four proton events were recorded during this period — 12 to 13 April 1973, 29 April through 1 May 1973, 4 through 8 July 1974, and 12 through 14 September 1974. These events represented an observed absorption from 0.0 to about 5.0 dB and allowed 110 comparisons between observed and calculated absorptions.

Figure 1 shows a scatter diagram for the 110 comparisons; 86 percent were within 0.5 dB; 93 percent were within 0.75 dB, and 97 percent were within 1.0 dB. The root-mean-square of the errors was 0.38 dB.

4. CONCLUSIONS

The results show that Potemra's equations work well for these events. Since there is a lack of data at present for the larger events and for events of other spectral characteristics, the results of this study should be used for "quick-look" estimates only.

Several aspects of this study should be pointed out:

The proton flux was assumed to be invariant for geomagnetic latitudes greater than 75°.

The contribution of alpha particles and electrons to the satellite proton sensor measurements was assumed to be negligible.

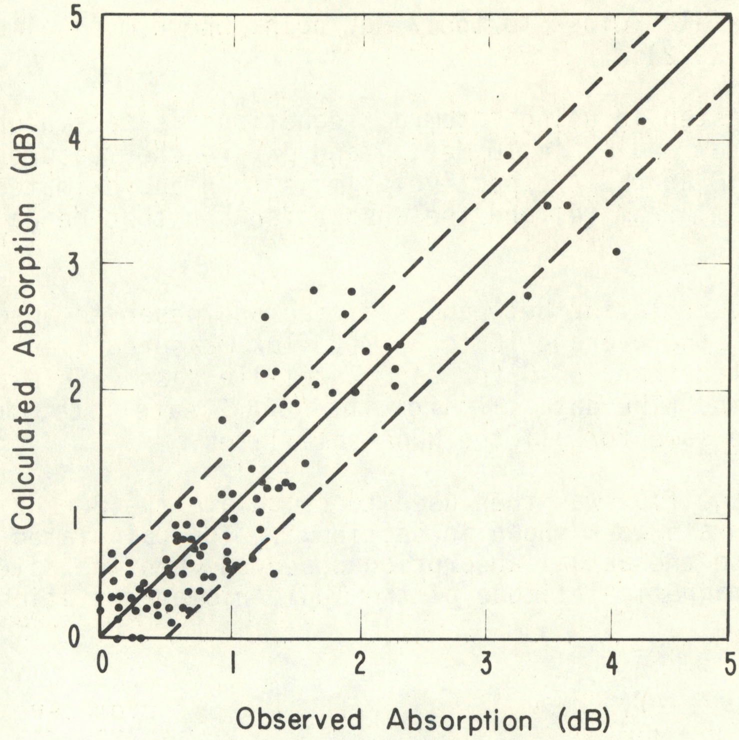

Figure 1. Scatter diagram of 30 MHz riometer absorption, as calculated from Potemra (1972), plotted against the observed 30 MHz Thule riometer absorption. The solid line indicates perfect agreement between the two absorptions and the dashed line indicates ± 0.5 dB.

The results are valid only for daytime riometer measurements. When the sun was below the horizon for part of the 12 to 14 September 1974 event, the absorption appeared to be suppressed by a factor of five or six. These data were not considered in the results. The other three events occurred during daytime hours at Thule, Greenland.

Spot checks of the proton data from August 1972 through January 1975 showed when a proton enhancement occurred, a riometer absorption should be expected. The converse is not true, however. Several significant (as high as 10 dB) absorptions were observed during this period without corresponding proton enhancements. These absorptions are thought to be caused either by equipment malfunctions or rare auroral absorption over the polar cap.

5. ACKNOWLEDGMENTS

I wish to thank Dr. H. Sauer for the NOAA satellite data and many helpful discussions on their interpretation. I also thank Mr. G. Heckman for many helpful discussions. I thank Mr. J. Schroeder for the Thule riometer data reduction and explanations for decoding the teletype reports. I thank Dr. H. Leinbach for many helpful discussions and a critical review of this paper.

6. REFERENCES

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APPENDIX: USER'S GUIDE FOR THE DATA USED IN THIS STUDY

A. NOAA SATELLITE DATA

The NOAA satellite data format is shown below as transmitted over the ATN.

HSAK KSOC DAHHMM

QL/SPM/NH/RXXXXX/ELXXX.XX/PXXXXX/MO/DA/YR/HH/MM/SS/

MNSEJKKLBBTCCFDDJKKLBBTCCFDDJKKLBBTCCFDDJKKLBBTCCFDDJKKLBBTCCFDD

MNSEJKKLBBTCCDFDD etc.

HSAK KSOC	Station identifier
DAHHMM	Day, hour, and minute of time of transmission of the message
QL/SPM	Identifier
NH	Hemisphere (N=North, S=South)
RXXXXX	Orbit number
ELXXX.XX	East longitude of equatorial crossing
PXXXXX	Pass number
MO/DA/YR	Month, day, and year of begin time of data
HH/MM/SS	Hour, minute, and second (to the nearest 0.1 sec) of the beginning of the data
MN/SE	Elapsed time in minutes and seconds from the begin time from line 2 of the code
J,L,T and F	Power to which 4 must be raised to obtain the count rate
KK	Counts per sec for electrons greater than 140 KeV
BB	Counts per sec for protons greater than 60 MeV
CC	Counts per sec for protons greater than 30 MeV
DD	Counts per sec for protons greater than 10 MeV

KK, BB, CC, and DD must be multiplied by 4 to the corresponding J,L,T, or F power.

Each data group consists of 12 digits and each group is separated in time by 50 sec. Note: The location of the satellite is not given in this message. The user must obtain the orbital elements from the National Environmental Satellite Service, Suitland, Md., and then compute the geomagnetic coordinates for each data point from them. To convert from counts per second to flux (in units of particles per second per square centimeter per steradian) the greater than 10 MeV counts must be divided by 0.791 and the greater than 30 MeV counts by 6.28.

B. THULE 30 MHz RIOMETER DATA

The Thule 30 MHz riometer data are in the format shown below as transmitted over the Air Force ATN.

HXAK PANC DAHHMM

DATBB 256Ø1 YMMDD ØHHMM

11111 Øxxxx 1xxxx 2xxxx 3xxxx 4xxxx 5xxxx 6xxxx 7xxxx
33333 etc.

HXAK PANC	Identifier
DAHHMM	Day, hour, and minute of time of transmission of message
DATBB	Identifier
256Ø1	Station number
YMMDD ØHHMM	Year (last digit of calendar year), month, and day of data

The group beginning with the number 5 in the line beginning with 11111 gives the Thule 30 MHz riometer absorption in millivolts. The user must establish a quiet day curve from these readings and compute the absorption in dB relative to this curve.