THULE RIOMETER OBSERVATIONS OF POLAR CAP ABSORPTION EVENTS (1962-1972)

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30 January 1973
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Polar Cap Absorption (PCA) events have been observed at Thule, Greenland, (geographic N 76° 33', W 68° 40') using a ground-based riometer for the past decade. The riometer was operated at a fixed frequency of 30 MHz, and utilized a two-element Yagi antenna directed toward the zenith. This report provides information for operational systems personnel and systems designers concerning the mean behavior of PCAs and other aspects of the phenomenon; for example, the extreme cases in duration and magnitude. In addition, included as an appendix are plots of db absorption and proton flux (obtained from satellites) versus time for each event. The total number of events is 29.
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<tr>
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<th>LINK C</th>
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<td>Solar proton events</td>
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Abstract

Polar Cap Absorption (PCA) events have been observed at Thule, Greenland, (geographic N 76° 33', W 68° 40') using a ground-based riometer for the past decade. The riometer was operated at a fixed frequency of 30 MHz, and utilized a two-element Yagi antenna directed toward the zenith. This report provides information for operational systems personnel and systems designers concerning the mean behavior of PCAs and other aspects of the phenomenon; for example, the extreme cases in duration and magnitude. In addition, included as an appendix are plots of dB absorption and proton flux (obtained from satellites) versus time for each event. The total number of events is 29.
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1. INTRODUCTION

For the past 10 years a 30-MHz riometer was operated on a continuous basis at Thule, Greenland. During that time, the riometer was used to observe polar cap absorption (PCA) events. These events were also observed by other experiments such as VLF propagation paths, HF propagation paths, and increases in fmin observed on an ionosonde located in Greenland.

The purpose of this report is to provide information to systems designers and operational systems personnel concerning the behavior of PCA events in such a way as to place this phenomenon in proper perspective with other ionospheric phenomena and geomagnetic disturbances. Provided for reference is a catalog of PCAs observed at Thule, from January 1962 through August 1972. It is important at this time to state that the events presented do not include all possible PCAs observed by other means during that period, nor certainly all the solar proton events observed on various satellites (Shea and Smart, private communication).

(Received for publication 30 January 1973)
The criteria used in selecting PCAs was that the observed vertical absorption
on the 30-\(\text{MHz}\) riometer must equal 0.5 dB above the diurnal and seasonal varia-
tion. This is important because the diurnal and seasonal variation in absorption
observed at Thule can be 0.8 dB (Cormier, 1970), which exceeds the PCA lower
limit of 0.5 dB.

2. MEAN BEHAVIOR OF PCAs AT THULE

During the observation period, a total of 53 PCA events was investigated. Of
this total, 11 did not produce events greater than 0.5 dB for two possible reasons:
first, the proton flux was of insufficient magnitude to produce an observable effect
on the riometer recording; and secondly, the seasonal effect (darkness during the
winter months) may have contributed to a reading of minimal absorption, the
mechanism of the nighttime recovery phenomenon (Reid, 1966; Leinbach, 1967).
Of the remaining, 13 were ambiguous for reasons such as equipment malfunction,
antenna problems, or data loss. However, the whole event period was not neces-
sarily lost. It is constructive to add at this time that the large PCA events greater
than 10 dB would certainly not be included in the questionable category, because
large PCA events are unambiguous on riometer recordings. The 29 remaining
events (see Table 1) illustrated in the Appendix are unambiguous events; they are
used to obtain the mean behavior of PCA events. In Table 1, the following informa-
tion is given: date of onset time; time in UT of the onset, max, and end time;
observed magnitude of dB absorption on the riometer; and proton flux observed by
satellites.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time (UT)</th>
<th>Riemeter</th>
<th>Protons/cm(^2) sec ster</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Begin</td>
<td>Max</td>
<td>End</td>
</tr>
<tr>
<td>1962</td>
<td>Feb 1</td>
<td>2000</td>
<td>1 Feb</td>
</tr>
<tr>
<td>1963</td>
<td>Feb 9</td>
<td>2200</td>
<td>9 Feb</td>
</tr>
<tr>
<td>1964</td>
<td></td>
<td></td>
<td>NONE REPORTED</td>
</tr>
<tr>
<td>1965</td>
<td></td>
<td></td>
<td>NONE GREATER THAN 0.5 dB</td>
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Table 1. List of PCA Events (Cont)

<table>
<thead>
<tr>
<th>Date</th>
<th>Begin</th>
<th>Max</th>
<th>End</th>
<th>Time (UT)</th>
<th>Riometer</th>
<th>Max Proton Flux</th>
</tr>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>dB</td>
<td>Protons/cm² sec ster</td>
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<tr>
<td></td>
<td>0100 7 Jul</td>
<td>1200 7 Jul</td>
<td>2100 8 Jul</td>
<td>0100 7 Jul</td>
<td>2.4</td>
<td>16E &gt; 20 MeV</td>
</tr>
<tr>
<td></td>
<td>0800 2 Sep</td>
<td>1300 3 Sep</td>
<td>2000 6 Sep</td>
<td>0800 2 Sep</td>
<td>14.0</td>
<td>1,300E &gt; 15 MeV</td>
</tr>
<tr>
<td>1967</td>
<td>1500 28 Jan</td>
<td>1800 29 Jan</td>
<td>0300 31 Jan</td>
<td>1500 28 Jan</td>
<td>2.7</td>
<td>0.6E &gt; 15 MeV</td>
</tr>
<tr>
<td></td>
<td>1900 11 Mar</td>
<td>1900 12 Mar</td>
<td>2000 12 Mar</td>
<td>1900 11 Mar</td>
<td>1.0</td>
<td>9E &gt; 10 MeV</td>
</tr>
<tr>
<td></td>
<td>0600 28 May</td>
<td>0900 28 May</td>
<td>1700 30 May</td>
<td>0600 28 May</td>
<td>4.1</td>
<td>115E &gt; 10 MeV</td>
</tr>
<tr>
<td></td>
<td>0900 6 Jun</td>
<td>0200 7 Jun</td>
<td>2200 8 Jun</td>
<td>0900 6 Jun</td>
<td>1.8</td>
<td>20E &gt; 10 MeV</td>
</tr>
<tr>
<td>1968</td>
<td>1000 9 Jun</td>
<td>0800 10 Jun</td>
<td>0100 12 Jun</td>
<td>1000 9 Jun</td>
<td>6.5</td>
<td>354E &gt; 10 MeV</td>
</tr>
<tr>
<td></td>
<td>1200 31 Oct</td>
<td>1900 2 Nov</td>
<td>0600 3 Nov</td>
<td>1200 31 Oct</td>
<td>2.5</td>
<td>133E &gt; 10 MeV</td>
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<tr>
<td></td>
<td>1400 18 Nov</td>
<td>1600 19 Nov</td>
<td>1900 20 Nov</td>
<td>1400 18 Nov</td>
<td>1.7</td>
<td>849E &gt; 10 MeV</td>
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<td>1969</td>
<td>1400 24 Jan</td>
<td>1700 24 Jan</td>
<td>0900 25 Jan</td>
<td>1400 24 Jan</td>
<td>1.2</td>
<td>3E &gt; 10 MeV</td>
</tr>
<tr>
<td></td>
<td>1200 25 Feb</td>
<td>1500 25 Feb</td>
<td>0100 26 Feb</td>
<td>1200 25 Feb</td>
<td>2.1</td>
<td>8E &gt; 10 MeV</td>
</tr>
<tr>
<td></td>
<td>1100 30 Mar</td>
<td>1900 30 Mar</td>
<td>0800 31 Mar</td>
<td>1100 30 Mar</td>
<td>1.3</td>
<td>2E &gt; 10 MeV</td>
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<td></td>
<td>1300 11 Apr</td>
<td>13 Apr</td>
<td>0900 21 Apr</td>
<td>1300 11 Apr</td>
<td>&gt; 10</td>
<td>1,348E &gt; 10 MeV</td>
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<tr>
<td></td>
<td>1200 2 Nov</td>
<td>1600 2 Nov</td>
<td>0200 5 Nov</td>
<td>1200 2 Nov</td>
<td>1,317E &gt; 10 MeV</td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td>1200 7 Mar</td>
<td>1500 28 Mar</td>
<td>2100 8 Mar</td>
<td>1500 28 Mar</td>
<td>5.1</td>
<td>9E &gt; 10 MeV</td>
</tr>
<tr>
<td>1971</td>
<td>0300 25 Jan</td>
<td>1600 26 Jan</td>
<td>2000 27 Jan</td>
<td>0300 25 Jan</td>
<td>2.3</td>
<td>1,170E &gt; 10 MeV</td>
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<tr>
<td></td>
<td>1200 6 Apr</td>
<td>1800 6 Apr</td>
<td>0200 8 Apr</td>
<td>1200 6 Apr</td>
<td>2.2</td>
<td>51E &gt; 10 MeV</td>
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<tr>
<td></td>
<td>0800 21 Apr</td>
<td>1000 21 Apr</td>
<td>0400 5 May</td>
<td>0800 21 Apr</td>
<td>0.9</td>
<td>3E &gt; 10 MeV</td>
</tr>
<tr>
<td></td>
<td>2200 1 Sep</td>
<td>1000 2 Sep</td>
<td>0400 5 Sep</td>
<td>2200 1 Sep</td>
<td>5.2</td>
<td>245E &gt; 10 MeV</td>
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<td></td>
<td>0100 17 Dec</td>
<td>0800 17 Dec</td>
<td>1600 17 Dec</td>
<td>0100 17 Dec</td>
<td>1.9</td>
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</tr>
<tr>
<td>1972</td>
<td>1500 20 Jan</td>
<td>1100 21 Jan</td>
<td>0500 22 Jan</td>
<td>1500 20 Jan</td>
<td>1.8</td>
<td>30E &gt; 10 MeV</td>
</tr>
<tr>
<td></td>
<td>2300 29 May</td>
<td>2300 29 May</td>
<td>0300 1 Jun</td>
<td>2300 29 May</td>
<td>2.2</td>
<td>39E &gt; 10 MeV</td>
</tr>
<tr>
<td></td>
<td>1000 3 Aug</td>
<td>4 Aug</td>
<td>&gt; 16</td>
<td>1000 3 Aug</td>
<td>&gt; 16</td>
<td>10E &gt; 10 MeV</td>
</tr>
</tbody>
</table>

The mean behavior was obtained to help answer questions asked by many investigators, for example: How many PCAs can one expect a year? How long does a PCA last? How often can severe PCAs be expected to occur? During what percentage of time can one expect to have appreciable HF absorption phenomena?
The mean duration of a PCA event is 63.6 hours. The mean magnitude is 4.0 dB. The mean duration of the proton flux is 84.3 hours. The proton flux was cut off when the flux reached 1 proton/cm$^2$ sec ster for energies of $E \geq 10$ MeV. The longest event occurred on 11 April 1969, which lasted 203 hours. The shortest event was 9 hours observed on 24 March 1966.

Another parameter of interest to system designers is the amount of time a particular absorption level is exceeded, which leads to the amount of power required to account for the expected absorption. The levels chosen in this report are $\geq 10$ dB, $\geq 5$ dB, $\geq 3$ dB, $\geq 2$ dB, and $\geq 1$ dB. The total number of hours of PCA events observed during the 29 events is 1853 hours or 76.8 days. The percentages of the total time of occurrence for each level are as follows:

- $\geq 10$ dB - 3.6%
- $\geq 5$ dB - 11.3%
- $\geq 3$ dB - 17.9%
- $\geq 2$ dB - 29.0%
- $\geq 1$ dB - 57.3%

When considering the foregoing percentages, one must note that the hours of absorption are not evenly distributed over the report period. To illustrate this, representative levels are shown in the Figure 1 histogram. The most striking feature of this figure is the lack of any events during the years 1964 and 1965. During 1964, no reference to any appreciable solar proton event was reported; during 1965, no absorption event which exceeded 0.5 dB was detected on the riometer. Large events greater than 10 dB were observed only in three distinct years; namely, 1966, 1969, and 1972.

The relationship between the proton flux curve observed on satellites and the riometer absorption as reported by Judy and Adams (1969), namely, $J = KA^2$ where $J$ = proton flux, $A$ = riometer absorption and $K$ is 8/2 was investigated so as to verify its reliability. The relationship was shown to be very good for the months of March through September. The months of April and October do not behave systematically; that is, some follow the relationship and some do not. The winter months show no consistent behavior. Of course, the data sample is too small to draw definite conclusions concerning the relationship.
Acknowledgments

The author thanks Dr. S. Silverman and his staff for the operation and maintenance of the riometer equipment at the AFCRL Geopole Observatory at Thule AFB, Greenland. Thanks also to Dr. K. Toman of AFCRL for the critical reading and the suggestions for the improvement of this paper.

References


Appendix

Twenty-nine PCA Events Used to Obtain Mean Behavior

Included are plots for the 29 PCA events listed in Table 1 and used in the histogram of Figure 1. The graphs show plots of dB absorption versus universal time for the 30-MHz Thule riometer. Some graphs contain plots of the square root of the proton flux of energies ≥ 10 MeV as observed from various satellites.* The events prior to 24 May 1967 do not have proton flux data readily available in the ESSA data pamphlets. The August 1972 events do not have proton flux data available as yet in the ESSA data pamphlets of the comprehensive series.

Included on the plots is the calculated value of expected absorption (represented by the letter x) using the Judy and Adams relationship of \( J = KA^2 \). In these cases, the value for \( K \) is 8.

The mean behavior as discussed in the foregoing is presented as a guide to operational personnel and, in particular, systems designers. For instance, if one needs real-time information, a system or systems must be designed to operate in the extreme cases, adding to the cost of the system. If the information could be delayed a number of hours until the severe disturbance was terminated, then one could design the system for the mean-behavior magnitude, that is, about 4 dB.

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*The proton flux data were obtained from the Solar Geophysical Data, IER-FB-Part II, 282, 292, 298, and 300; Comprehensive Reports 301, 303, 309, 313, 328, 336, 338, and 339, U.S. Department of Commerce, Environmental Sciences Services Administration.
Plot 1  Feb. 1, 1962

Plot 2  Feb. 9, 1962
Plot 3  Mar. 24, 1966

Plot 4  July 7, 1966
Plot 5  Aug. 28, 1966
Plot 7  Jan. 28, 1967

Plot 8  Mar. 11, 1967
Plot 12  Oct. 31, 1968

Plot 13  Nov. 18, 1968
Plot 14  Jan. 24, 1969
Plot 18  Nov. 2, 1969

Plot 19  Mar. 7, 1970
Plot 22  April 21, 1971
Plot 24 Dec. 17, 1971

Plot 25 Jan. 20, 1972
30 MHz

√PROTON FLUX

CALCULATED dB

dB ABSORPTION

PROTONS/cm² sec ster

MAY 28 1972
MAY 29 1972
MAY 30 1972
MAY 31 1972

TIME-UT

Plot 26  May 28, 1972