AP-8 Trapped Proton Environment for Solar Maximum and Solar Minimum

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AP-8 Trapped Proton Environment for
Solar Maximum and Solar Minimum

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I. INTRODUCTION

The purpose of this report is to provide a new computer-accessible model of the stably trapped proton flux with energies between 0.1 and 400 MeV. This model will be called AP-8.

The need for a new model arises from two main factors. First, to cover this approximate energy range, it was previously necessary to use the four separate models designated AP-1, AP-5, AP-6, and AP-7. Each of these models was derived independently, and this resulted in significant discontinuities in the energy spectra (see Section V. Model Comparisons). Second, new data have become available that indicate a need for improvement in the previous models in certain regions of space. Particularly useful for this effort have been the OV3-35 and Azur677 data sets.

The basic approach in this effort has been empirical, with a reliance on theory in those regions of space where the data are uncertain or nonexistent. Comparison of the Azur data (beginning in November 1969) with data acquired prior to 1967 indicates that a reduction in the flux has occurred at low altitudes. This reduction is associated with the much discussed solar-cycle dependence. Sufficient Azur data are available to generate a solar maximum version of AP-8, which is designated AP8MAX, epoch 1970. This version should also serve for the coming solar maximum period around 1980. The reduction in solar maximum fluxes may be smaller than that for the epoch 1970, depending upon the general solar activity and the X-ray/EUV output.

Because most of the data used in generating AP-8 were acquired around the solar minimum period of 1964, this version is designated AP8MIN, epoch 1964. AP8MAX differs from AP8MIN only for altitudes less than about 1000 km and for L values less than 3.0 Earth radii (see Section V. Model Comparisons).

Sections II and III, respectively, present the analysis of the data and the generation of the model elements.

Section IV discusses the presentation of the models in the form of nomographs, B-L plots, R-L plots, and equatorial radial profiles. It also discusses nomographs of the orbit-integrated fluxes.

Section V discusses the comparison of the AP8MAX and AP8MIN models with each other, with the data, and with the previous AP models.

Section VI discusses the future needs to improve the models, such as more complete data coverage and periodic comparisons with newly available data sets.

The Appendix describes the machine-sensible format in which the models are available.
II. DATA ANALYSIS AND TIME VARIATIONS

Table I shows the data sets that have been considered in the construction of the models. Many of the old data sets and most of the new ones are unidirectional measurements. Therefore, we have converted all the omnidirectional measurements to unidirectional values. Where B field coverage was lacking, extrapolated points were generated by referring to similar data sets and the previous models. All further work was carried out using unidirectional values.

The next problem was to assess the effect of time variations on the intercomparability of the various data sets. Many authors have observed temporal variations of the trapped proton flux. In addition, time variations have been discussed in some detail in the documents for AP-5, AP-6, and AP-7. Particularly useful for observing long-term variations was the continual coverage of satellite 1963-038C for over 5 years. Results have been published for L values less than 3 Earth radii covering the period between October 1963 and December 1968. The following statements and observations describe the temporal variations for trapped protons.

As indicated in Figure 1, the inner zone is quite stable for protons with energies greater than 25 MeV. Above L = 2 Earth radii, some depletion occurs in response to major magnetic storms such as those of September 1963 and May 1967. The May 1967 storm had a maximum |Dst| value of about 370 gammas, and the 25- to 100-MeV proton flux at L = 2.2 Earth radii decreased by about a factor of four. The flux had nearly recovered to its prestorm value after 1 year 6 months, during which time there were no other large storms.

In the energy range between 8.2 and 25 MeV, there are no large, rapid changes in the flux except in response to major storms such as those of September 1963 and May 1967 at L values above 2.2 Earth radii. However, satellite 1963-038C data indicated a steady decrease with a decay time of approximately 7 years for L values in the range between 1.35 and 2.2 Earth radii. These data are shown in Figure 2.

In the energy range between 2.2 and 8.2 MeV, the flux at L = 3 Earth radii may either increase or decrease following a magnetic storm. The May 1967 storm resulted in an enhancement of more than a factor of 10, which was peaked at approximately L = 2.2 Earth radii. Depletion was observed at both higher and lower L values. In addition, there is evidence of a decrease in flux with a decay time of approximately 3 years 6 months for L values between 1.5 and 3 Earth radii. These data are shown in Figure 3.

Protons with energies between 0.1 and 1.0 MeV have been difficult to measure at L < 2.0 Earth radii because of background problems from high-energy protons and electrons. Results from the Azur satellite have indicated substantially less flux in this region than previously believed. The National Space Science Data Center (NSSDC) has received temporal plots of these data covering the time period between November 1966 and July 1970.
and including L values between 1.26 and 5.2 Earth radii. The energy response is composed of four contiguous channels covering the range between 0.25 and 13.5 MeV. The largest storm during this period occurred in March 1970 and had a maximum |Dst| value of 270 gammas. The first observable storm variation, which is an increase of less than a factor of two, occurs at L = 2 Earth radii in the 0.25- to 0.5- and 0.5- to 1.0-MeV channel.

At lower L values, no obvious storm effects are evident in any channel; the maximum long-term variation is less than a factor of two. A sample of these data is shown as Figure 4.

At altitudes less than about 1000 km, atmospheric variations have produced observable changes in the inner zone trapped proton flux, which are in reasonable agreement with theory. Heckman et al. have observed the 50- to 90-MeV proton flux at h minions 350 km decrease by 60 percent between 1966 and 1969. They have also presented evidence of a semiannual variation in the fluxes, which they relate to an observed semianual atmospheric density variation. Dragt has made extensive calculations predicting the solar-cycle dependence of the proton flux, based on the solar-cycle atmospheric density variation and a neutron decay source in a time-independent magnetic field. It is now known that the secular decrease of the Earth's magnetic field must be included in a complete theoretical description of the inner belt protons. In addition, the neutron spectrum between 10 and 100 MeV has been measured and found to be harder than that used by Dragt. Nevertheless, these calculations may still qualitatively represent the expected solar-cycle variations. Quantitatively, they are the best currently available. For example, at L = 1.6 Earth radii and h_{min} = 510 km the differential energy flux at 24 MeV is predicted to vary by a factor of 10 during the solar cycle while this flux at 760 MeV varies by a factor of three and lags the atmospheric density variation by about 1 year.

A temporal perturbation occurred within the inner zone as a result of the Starfish nuclear detonation on July 9, 1962. Filz and Holeman reported an abrupt increase of about a factor of seven in the 55-MeV trapped proton flux at an altitude of 350 ± 50 km. The flux decayed to a constant level within 1 year, as the solar-cycle increase offset the Starfish decay. However, Starfish protons contributed significantly to the measured flux for a period of about 4 years after the detonation.

McIlwain has observed the inward radial diffusion of a secondary peak of unknown origin in the 40- to 110-MeV equatorial proton flux. The peak was seen to move from L = 2.25 to L = 2.1 Earth radii between January 1963 and January 1965. At this rate, it should have merged with the primary peak by 1969 although we have no additional equatorial data at these energies to confirm this conclusion.

A new low-energy proton population in the inner zone has been found deep in the atmosphere at L = 1.0 to L = 1.1 Earth radii. This population appears to originate from the breakup of neutral particles that charge exchange produced in the outer zone ring current during storms.
The outer zone is considerably less stable than the inner zone, particularly on short time scales, because of the larger variations in the magnetic field during storms. The first short-term variation seen in the outer zone protons was reported by Davis and Williamson. A sudden commencement on September 30, 1961, followed by a storm with a maximum [Dst] value of 159 gammas, was associated with a factor-of-three decrease in the greater than 0.1-MeV proton fluxes at high latitudes in the L region between 3 and 4.5 Earth radii. Such decreases during storms have been reported by others. These decreases have recently been found to be adiabatic responses to the decreased magnetic field during storms.

Between December 1962 and February 1965, Davis and Williamson observed a factor-of-two or more increase in the proton flux having energies greater than 0.5 MeV in the region between L = 2.5 and L = 5 Earth radii. At the same time, the 0.1- to 0.3-MeV flux decreased about a factor of three. White has reported similar observations at high B values.

The Azur data of Moritz show a large response to the March 1970 storm at high B values. At L = 3.04 Earth radii and B = 0.15 gauss, the 0.25- to 0.5-MeV flux increased by a factor of 20. After 4 months, which included three small storms, the flux was still a factor of four above the prestorm level. At the same time, the 1.65- to 13.5-MeV flux decreased by a factor of eight and then recovered in about 15 days. However, the net effect of the magnetic activity during the first 6 months of 1970 resulted in a factor-of-two decrease in the flux at L = 3.04 Earth radii as shown in Figure 5. At L = 4.85 Earth radii and B = 0.17 gauss, the 0.25- to 0.5- and 1.0- to 1.65-MeV fluxes showed order-of-magnitude fluctuations during the first 6 months of 1970. These data are shown in Figure 6.

Above L = 5 Earth radii, order-of-magnitude fluctuations were observed by Davis and Williamson on time scales as short as 10 minutes. The Azur data of Moritz also showed fluctuations up to factors of 50 at L = 5.2 Earth radii and B = 0.17 gauss.

At the synchronous orbit (L = 6.6 Earth radii), the particle population exhibits extremely dynamic behavior. At times, the solar wind momentum is sufficient to compress the boundary of the Earth's magnetic field on the sunward side to a position inside the synchronous orbit. As a result, the higher energy trapped particles disappear. In addition, solar protons have easy access to the synchronous region, especially during disturbed times. (For a quantitative estimate of the relative importance of solar and trapped fluxes for various spacecraft orbits, see the report by King and Stassinopoulos.) Stevens et al. have measured protons in the range between 0.06 and 3.3 MeV at L = 6.6 Earth radii. Quiet time fluxes showed a factor-of-four variation between noon and midnight because of the distortion of the magnetosphere. Magnetic storms resulted in an increase of the 2.6-MeV flux by more than a factor of 10 while the fluxes at intermediate energies dropped by a factor of 10. As the activity subsided, the fluxes rose to slightly above prestorm levels.
In summary, the inner zone is quite stable except at altitudes less than 1000 km where the solar-cycle variation becomes increasingly important. The long-term decrease seen in the lower energies is not understood, and therefore, its projection into the future is uncertain. Beyond $L = 2$ Earth radii, the effect of major storms becomes noticeable as nonadiabatic changes in the fluxes that recover with time constants varying from months to years. Beyond about $L = 5$ Earth radii, order-of-magnitude fluctuations occur on time scales as short as 10 minutes.

The results from the Azur spacecraft have provided sufficient data to observe the effects of the solar-cycle variation and to permit the generation of a solar maximum model. However, the absolute accuracy of the models at low altitudes is uncertain. The atmosphere below approximately 600 km causes a rapid drop in the fluxes with decreasing altitude. The resulting large spatial gradients are difficult to model accurately because small errors in the B and L coordinates can result in large flux changes. Nevertheless, the two models should provide a useful representation of the solar-cycle variation and also allow for updating as new data become available.

No attempt has been made to model the long-term decrease seen in the inner zone by satellite 1963-038C. A confirmation of this decrease by another satellite would be useful. Because the decay time varies from 3 to 7 years, a satellite with a comparable operating lifetime would be ideal.

No attempt has been made to model the temporal variations between $L = 2$ and 4.5 Earth radii with altitudes greater than 1000 km. These variations are produced by large storms in ways that depend on the details of each storm. It is expected that these storm effects will generally be less than a factor of two when averaged over a year.

As more data are obtained in the region $L > 4.5$ Earth radii, a time statistical treatment may be feasible. The present modeling effort in that region has relied primarily on quiet time data, which may underestimate the average flux at some energies. In addition, the local time variation, which can amount to a factor of four at $L = 6.6$ Earth radii, has not been included explicitly. Instead, the model flux has been based on the higher flux observed at local noon.
III. MODEL GENERATION

The previous models used an analytic function in the form of either a power law or an exponential to fit the energy spectrum. However, the entire energy range between 0.1 and 400 MeV cannot be fit by such a simple function in the inner zone.\textsuperscript{4,52} Because the models are now being issued in tabular form, it was decided to use an analytic function only as an aid in the comparison of various data sets. The functional form chosen was the sum of two exponential-like terms having a total of six coefficients. This function was written as

\[ j = A_1 e^{A_2 E} + B_1 e^{B_2 E} \]

where \( A_1, A_2, A_3, B_1, B_2, \) and \( B_3 \) are the coefficients, \( E \) is the energy, and \( j \) is the differential flux. This function was then employed in a least squares program that simultaneously minimized the deviations for both energy interval and energy threshold points. The result was a single integral energy spectrum at a given B-L point. This technique was useful in the inner zone where there were more than six measurements available at each point. Typical spectra for various B values at \( L = 1.6 \) Earth radii are shown in Figure 7. A heavy line gives the resulting best-fit spectrum for each B (B/B_0) value. The energy interval data points were plotted at the minimum interval energy, and a line was drawn to the fitted spectrum at the maximum interval energy. Where sufficient data were unavailable for the least squares approach, spectra were drawn by hand. All spectra were then digitized and compared again with the data.

From the spectra, flux versus B value curves were generated and smoothed by slight adjustment of the B values. The flux versus B curves were then used to generate radial profiles that were also smoothed and digitized. These profiles were then used to generate new spectra. This completed one iteration. Two iterations were found to give smooth spectra and flux versus B curves, as well as reasonable radial profiles. The smoothed flux versus B curves were then converted to omnidirectional values for incorporation into the final model format. This format is discussed in the Appendix.
IV. MODEL PRESENTATION FORMATS

The models are displayed in several formats within this report. The most extensive presentation is in the form of nomographs that provide rapid interpolation of omnidirectional integral flux values as a function of B and L. A description of the use of these nomographs (also called carpet plots) is given in Appendix A of The Inner Zone Electron Model AE-5.

Figures 8 through 27 present the solar minimum model AP8MIN nomographs for L values between 1.2 and 3.2 Earth radii with energies between 0.1 and 400 MeV. Figures 28 through 38 contain the L values between 3 and 6.6 Earth radii. Because the solar maximum model AP8MAX does not differ from AP8MIN for L values above 2.9 Earth radii, nomographs for the solar maximum model are not shown for all L values. Figures 39 through 58 present the AP8MAX nomographs for L values between 1.2 and 3.2 Earth radii.

Plots of constant intensity contours are presented in both B-L and R-λ plots. Figures 59 through 64 show the B-L contours at six energies for the AP8MIN and AP8MAX models. Figures 65 through 70 show the corresponding R-λ plots for AP8MIN.

Equatorial radial profiles at several energies are shown in Figure 71 for the model AP8MIN. The AP8MAX equatorial radial profiles differ from AP8MIN only for L below 1.3 Earth radii and, therefore, are not shown.

The final set of model presentation figures shows orbit-integrated fluxes in the nomograph format. Figures 72 through 79 and Figures 80 through 87 give the AP8MIN orbit-integrated fluxes for energies less than or equal to 10 MeV and greater than or equal to 10 MeV, respectively. The AP8MAX model differs from the AP8MIN model only at low altitudes. Therefore, Figures 88 through 95 include only the AP8MAX orbit-integrated fluxes below 1000 nautical miles.

It should be noted that high-altitude orbits can pass through regions of space with significant fluxes where the L values are greater than 6.6 Earth radii. Although the models are only valid up to L = 6.6 Earth radii, the models will give flux values at higher L values based on an extrapolation to zero flux at L = 11 Earth radii. The maximum orbit altitude presented here is 18,000 nautical miles, which corresponds to an L value of about 6.3 Earth radii. The maximum contribution to an orbit-integrated flux value from regions L > 6.6 Earth radii is less than 15 percent.
V. MODEL COMPARISONS

Figures 96 through 151 show comparisons of the AP8MIN and AP8MAX models with the data, with themselves, and with the earlier models designated AP-1, AP-5, AP-6, and AP-7. The models are displayed as flux versus B field curves and as flux versus energy curves at a given L value for each type of comparison. The data set codes are listed in each figure when data are presented. Table 1 describes the data set associated with each code. The plotting symbol corresponding to a given code is also shown. For a few of the figures, the large number of data sets required the association of a plotting symbol with more than one code. The ambiguity can be removed by noting the data set energy range and then referring to Table 1.

The flux versus B (B/B₀) field curves are plotted against log-log or log linear scales for selected integral energies. B₀ is the equatorial B value as given in the upper right-hand corner of each figure. This B₀ value is computed from

\[ B₀ = 0.311653/L^3 \text{ (gauss)} \]

where L is the L value in Earth radii. Each model curve is labeled with the corresponding integral energy value.

The flux versus energy curves are plotted against log-log scales. The model curves are labeled with the corresponding B/B₀ values. Data points associated with a given curve have their symbols followed by a numerical subscript. Number one refers to the spectral curve with the smallest B/B₀ value, and the higher numbers are matched with the larger B/B₀ values in a monotonically ascending order. Some data points represent fluxes measured within an energy interval. An interval flux is added to the model flux obtained at the upper interval energy, and the resulting flux is plotted with the appropriate symbol at the lower interval energy. A dashed line is drawn from the model curve at the upper interval energy to the plotted symbol.

Figures 96 through 115 present flux versus B/B₀ and flux versus energy curves from the AP8MIN model and compare them with selected data sets for 10 different L values.

Figures 116 through 125 present the corresponding curves from the AP8MAX model and compare them with the Azur data sets for five different L values.

The AP8MIN and AP8MAX models are compared directly in Figures 126 through 135.

The final set of figures from 136 through 151 shows the comparison between the AP8MIN model and the earlier models designated AP-1, AP-5,
AP-6,³ and AP-7.⁴ A major difference is apparent in the inner zone low-energy flux at L = 1.5 Earth radii as shown in Figure 145. The new model (AP8MIN) has less flux at the equator for energies below about 1.0 MeV in accordance with the Azur results.⁷ At the higher L values, such as L = 6.6 Earth radii shown in Figure 143, the AP8MIN flux versus B/B₀ curves are cut off at lower B/B₀ values. This is also in accordance with the Azur results.⁷

VI. FUTURE IMPROVEMENTS

Despite the large number of data sets available for this modeling effort, there are some regions of space, time, and energy that are not well covered.

The spectrum in the inner zone for energies above 150 MeV is not well supported by data in these models. Results from the OVI-19 satellite should improve this situation.

There are few equatorial measurements for energies above 10 MeV at L values between 2.0 and 3.5 Earth radii. This is the region in which McIlwain observed a secondary radial peak in the 40- to 110-MeV flux that was seen to diffuse inward.⁴

A long-term monitor should be initiated for proton fluxes out to L = 3 Earth radii with energies less than 25 MeV. Satellite 1963-038C instruments have measured decay times of 3 to 7 years in this region.¹³ Such a monitor could be expected to yield considerable information on the sources and losses of these particles.

Additional observations of the low-energy fluxes above L = 5 Earth radii should eventually allow a statistical treatment of these rapidly varying fluxes.

The solar-cycle dependence of the low-altitude fluxes is very difficult to model accurately. It is hoped that sufficient data will be obtained through the coming solar maximum period to improve the model considerably in this area.

As significant new data sets become available, it is expected that brief reports will be issued comparing the data with the AP8MAX and AP8MIN models.
APPENDIX

AP8MAX and AP8MIN Data Card Deck Formats

The models AP8MAX and AP8MIN are available as separate data card decks. This is in contrast to the recent electron models, such as AE-5,53 which are available as BLOCK DATA decks.54 The only difference between these two forms is in the method of input to the programs. The BLOCK DATA deck is a FORTRAN subprogram that inputs the data before execution. The current AP-8 decks may be input with FORTRAN read statements. The BLOCK DATA deck format was impractical for the AP-8 models because AP8MIN requires 16,591 storage locations and AP8MAX requires 16,394 storage locations. Because this amount of storage will be prohibitive to some users, compressed versions of approximately 7000 words each are available in BLOCK DATA statement form. These versions are designated AP8MINC and AP8MAXC and are compatible with programs MODEL and ORP54 issued previously.

The data deck cards have the following two formats:

<table>
<thead>
<tr>
<th>Card Number</th>
<th>Variable Name</th>
<th>Columns</th>
<th>Format</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DESCR(1)</td>
<td>1-4</td>
<td>1A4</td>
<td>Model name</td>
</tr>
<tr>
<td></td>
<td>DESCR(2)</td>
<td>5-8</td>
<td>1A4</td>
<td>Model name (concluded)</td>
</tr>
<tr>
<td></td>
<td>DESCR(3)</td>
<td>11-20</td>
<td>F10.3</td>
<td>Epoch year</td>
</tr>
<tr>
<td></td>
<td>DESCR(4)</td>
<td>21-30</td>
<td>F10.3</td>
<td>Energy scaling factor</td>
</tr>
<tr>
<td></td>
<td>DESCR(5)</td>
<td>31-40</td>
<td>F10.3</td>
<td>L value scaling factor</td>
</tr>
<tr>
<td></td>
<td>DESCR(6)</td>
<td>41-50</td>
<td>F10.3</td>
<td>B/Bq value scaling factor</td>
</tr>
<tr>
<td></td>
<td>DESCR(7)</td>
<td>51-60</td>
<td>F10.3</td>
<td>Flux scaling factor</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>LB</td>
<td>71-74</td>
<td>A4</td>
<td>Card sequence identifier</td>
</tr>
<tr>
<td></td>
<td>IC</td>
<td>75-78</td>
<td>I4</td>
<td>Card sequence number</td>
</tr>
</tbody>
</table>

where N is 2370 and 2329 for AP8MIN and AP8MAX, respectively.

It is recommended that the model data be read into common block arrays of the form

COMMON/AP8MIN/D8MIN(8),L8MIN(16583)
COMMON/AP8MAX/D8MAX(8),L8MAX(16296)

for the AP8MIN and AP8MAX models, respectively. A subroutine that will
read in and print the model data is as follows:

```fortran
SUBROUTINE MODINT(JUNIT, DESCR, LIST)
  DIMENSION DESCR(8), LIST(1)
  EQUIVALENCE (LENGTH, DUMD)
  READ(JUNIT,1000,END=30) (DESCR(I), I=1,7), LENGTH, LB, IC
  DESCR(8)=DUMD
  WRITE(6,1002) (DESCR(I), I=1,7), LENGTH, LB, IC
  LNT=LENGTH+1
  LP=LNT/7
  LPP=LP*7
  IF (LPP .NE. LNT) LP=LP + 1
  KL=1
  DO 20 IC=2,LP
    K2=KL+6
    READ(JUNIT,1001,END=30) (LIST(K), K=KL,K2), LB, IC
    WRITE(6,1003) (LIST(K), K=KL,K2), LB, IC
  20 KL=K2+1
  RETURN
  WRITE(6,1004)
  RETURN
1000 FORMAT(2A4,2X,5F10.3,110,A4,I4)
1001 FORMAT(7I10,A4,I4)
1002 FORMAT(2X,2A4,2X,5F10.3,110,2X,A4,I4)
1003 FORMAT(2X,7I10,2X,A4,I4)
1004 FORMAT(5X,**READ EOF ON JUNIT***)
END
```

The AP8MIN model would be read in from data cards with the following call:

```fortran
CALL MODINT(JUNIT, D8MIN, L8MIN)
```

where JUNIT is the card reader unit number.

NOTE: The dimension of LIST is determined in the calling routine.
REFERENCES


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Table 1. Data Used in Making AP8MAX and AP8MIN Models (continued)

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Table 1. Data Used in Making APBMAX and APBMIN Models (continued)
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Figure 1. Ten-Day Average Counting Rates for Proton Energies 25 to 100 MeV as Seen by Satellite 1963-038C. (The decrease in the L = 1.27 R_p curve during 1965 is a decay of Starfish electrons which contaminated the measurement.)
Figure 2. Ten-day Average Counting Rates for Proton Energies 8.2 to 25 MeV as Seen by Satellite 1963-053E.
Figure 4. Counting Rates for Protons in the Range of 0.25 to 13.5 MeV at $L = 2.0$ $R_E$ as Seen by Satellite Aur$^{44}$
Figure 5. Counting Rates for Protons in the Range of 0.25 to 15.5 MeV at \( L = 3.04 \) Re as Seen by Satellite Azur.
Figure 6. Counting Rates for Protons in the Range of 0.25 to 1.65 MeV at L = 4.85 R_E as Seen by Satellite Azur.*5
Figure 7. Integral Spectra Obtained by a Generalized Least Squares Curve-Fitting Procedure (Data points are also shown.)
MODEL AP8 MIN FLUX DISTRIBUTIONS
ENERGY = 0.4 MEV
SOLAR MINIMUM FIG. 10

OMNIDIRECTIONAL FLUX (PROTONS/SQCM-SEC)
MODEL AP8 MIN FLUX DISTRIBUTIONS
ENERGY = 1.0 MEV
SOLAR MINIMUM FIG. 13
OMNIDIRECTIONAL FLUX (PROTONS/SQCM-SEC)
MODEL AP8 MIN FLUX DISTRIBUTIONS
ENERGY = 2.0 MEV
SOLAR MINIMUM FIG. 14

OMNIDIRECTIONAL FLUX (PROTONS/SQCM-SEC)
MODEL AP8 MIN FLUX DISTRIBUTIONS
ENERGY = 4.0 MEV
SOLAR MINIMUM FIG. 15

OMNIDIRECTIONAL FLUX (PROTIONS/SQCM-SEC)
MODEL AP8 MIN FLUX DISTRIBUTIONS
ENERGY = 20. MEV
SOLAR MINIMUM FIG. 20

OMNIDIRECTIONAL FLUX (PROTONS/SQCM-SEC)
MODEL APB MIN FLUX DISTRIBUTIONS
ENERGY = 0.2 MEV
SOLAR MINIMUM

OMNIDIRECTIONAL FLUX (PROTONS/SECVM-SEC)
MODEL APB MIN FLUX DISTRIBUTIONS
ENERGY = 1.0 MEV
SOLAR MINIMUM FIG. 33

ONWARD DIRECTIONAL FLUX (PROTONS/SQCM-SEC)
MODEL AP8 MIN FLUX DISTRIBUTIONS
ENERGY = 6.0 MEV
SOLAR MINIMUM FIG. 36

OMNIDIRECTIONAL FLUX (PROTONS/SQCM-SEC)
MODEL AP8 MIN FLUX DISTRIBUTIONS
ENERGY = 10. MEV
SOLAR MINIMUM FIG. 38

OMNIDIRECTIONAL FLUX (PROTONS/SQCM-SEC)

L VALUES (NE)

\( \Delta B = 0.12 \)
\( \Delta L = 0.02 \)
MODEL AP8 MAX FLUX DISTRIBUTIONS
ENERGY = 4.0 MEV
SOLAR MAXIMUM FIG. 46

OMNIDIRECTIONAL FLUX (PROTONS/SQCM-SEC)
MODEL AP8 MAX FLUX DISTRIBUTIONS
ENERGY = 20. MEV
SOLAR MAXIMUM FIG. 51
Figure 61. APSMIN and APSMAX S-L Plot of Constant Intensity Flux Contours with an Energy of ≥ 10 MeV
Figure 6.2. APMIN and APMAX. B-L Plot of Constant Intensity Flux Contours with an Energy of 50–500 MeV.
Figure 43. AP8MIN and AP8MAX 3-1. Plot of Constant intensity Flux Contours with an Energy of 100 MeV.
Figure 64. *AP8MIN* and *AP8MAX* B-L Plot of Constant Intensity Flux Contours with an Energy of ≥ 400 MeV
Figure 65. AP8MIN R-\Theta Plot of Constant Intensity Flux Contours with an Energy of \geq 0.1 MeV
Figure 67: AP8MIN R-λ Plot of Constant Intensity Flux Contours with an Energy of > 10 MeV
Figure 69. ANP8MIN R-A Plot of Constant Intensity Flux Contours with an Energy of ≥ 100 MeV
ORBITAL INTEGRATION MAP 150 TO 4000 N.M. CIRCULAR ORBIT 60 DEGREE INCLINATION MIN SOLAR PROTONS ENERGY LESS 10 MEV FIG. 74
ORBITAL INTEGRATION MAP 4000 TO 18000 N.M.
CIRCULAR ORBIT 30 DEGREE INCLINATION
AP8 MIN SOLAR MINIMUM PROTONS ENERGY LE 10 MEV FIG. 77
ORBITAL INTEGRATION MAP 300 TO 1500 N M.
CIRCULAR ORBIT 0 DEGREE INCLINATION
AP8 MIN SOLAR MINIMUM PROTONS ENERGY GE 10 MEV
FIG. 80

PROTONS/SQCM-DAY
ORBITAL INTEGRATION MAP 150 TO 1500 N.M.
CIRCULAR ORBIT 60 DEGREE INCLINATION
AP 8 MIN SOLAR MINIMUM PROTONS ENERGY GE 10 MEV
FIG. 82

104
ORBITAL INTEGRATION MAP 1500 TO 9000 N.M.
CIRCULAR ORBIT 90 DEGREE INCLINATION
AP8 MIN SOLAR MINIMUM PROTONS ENERGY GE 10 MEV FIG. 87
ORBITAL INTEGRATION MAP 450 TO 1000 N.M.
CIRCULAR ORBIT 0 DEGREE INCLINATION
APR MAX SOLAR MAXIMUM PROTONS ENERGY LE 10 MEV FIG. 89

\[ \Delta E = 1.0 \]

\[ \Delta \text{ALT} = 150 \text{ DEG} \]
ORBITAL INTEGRATION MAP 150 TO 1000 N.M.
CIRCULAR ORBIT 90 DEGREE INCLINATION
AP8 MAX SOLAR MAXIMUM PROTONS ENERGY LE 10 MEV FIG. 91
ORBITAL INTEGRATION MAP 450 TO 1000 N.M.
CIRCULAR ORBIT 0 DEGREE INCLINATION
AP8 MAX SOLAR MAXIMUM PROTONS ENERGY GE 10 MEV FIG. 92
ORBITAL INTEGRATION MAP 150 TO 1000 M.E.
CIRCULAR ORBIT 60 DEGREE INCLINATION
AP8 MAX SOLAR MAXIMUM PROTONS ENERGY GE 10 MEV
FIG. 94
PROTONS/SQCM-DAY
LATITUDE 50-00
EQUATOR 00-00
60-00
Figure 96. AP8MIN and Data Flux vs B/B₀ Comparison Plot for L = 1.15 RE
Figure 97. AP8MIN and Data Flux vs B/B_0 Comparison Plot for L = 1.17 RE
Figure 98. AP8MIN and Data Flux vs B/B₀ Comparison Plot for L = 1.20 RE
Figure 99. AP8MIN and Data Flux vs B/B₀ Comparison Plot for L = 1.50 Rₑ
Figure 100. AP8MIN and Data Flux vs B/B₀ Comparison Plot for L = 2.00 RE
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