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NUMERICAL MODELING
OF IONOSPHERIC PARAMETERS
FROM GLOBAL IMS MAGNETOMETER DATA
FOR THE CDAW-6 INTERVALS

November 1983
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Report UAG-88

NUMERICAL MODELING
OF IONOSPHERIC PARAMETERS
FROM GLOBAL IMS MAGNETOMETER DATA
FOR THE CDAW-6 INTERVALS

by

Y. Kamide, H.W. Kroehl, B.A. Hausman, R.L. McPherron,
S.-I. Akasofu, A.D. Richmond, P.H. Reiff and S. Matsushita

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service
Boulder, Colorado, USA 80303
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NUMERICAL MODELING OF IONOSPHERIC PARAMETERS
FROM GLOBAL IMS MAGNETOMETER DATA FOR THE CDW-6 INTERVALS


INTRODUCTION

The purpose of this technical report is to present the results of modeling efforts to estimate the distribution of ionospheric electric potential, ionospheric and field-aligned currents, and Joule heating rate from ground-based magnetic records for two intervals; (1) 0600-1800 UT on March 22, 1979, and (2) 1200 UT on April 1, 1979. This global modeling study constitutes one of the major contributions to the Coordinated Data Analysis Workshop (CDW-6) sponsored by the National Space Science Data Center, NASA.

The CDW series has been, and will continue to be, focused on large, cooperative analyses of multiple satellite and other platform data recorded during the International Magnetospheric Study (IMS, 1976-1979); see e.g., Roederer (1976) and Manka (1976) for the concept of the IMS. The purpose of the Analysis Phase of the IMS is to improve our understanding of the transport of energy, mass and charge through the solar terrestrial environment utilizing the most comprehensive and extensive bases obtained from space and ground-based instruments.

In this report, we briefly describe the algorithm of our numerical modeling and the characteristics of the two intervals. In Appendices I and II we show for intervals the results of applying this algorithm to the compiled data as plots of the global distribution of the equivalent current, the electric potential, the ionospheric current, the field-aligned current and Joule heating rate. We hope that these data products provide the scientific community with new insights into our understanding of magnetospheric and ionospheric processes associated with substorms.

THE PROCEDURE

Figure 1 outlines the steps required to prepare a motion picture of the derived parameters from the digital values of the magnetic variations. The practical procedures of each step are summarized as follows:

1) We started with digital values of the magnetic variations recorded every 5 minutes in magnetic coordinates (H and D) or geographic coordinates (X and Y). Approximately 70% of the data used were received directly from NSSDC as contributions to the CDW-6 data base while the remaining 30% were digitized from analog records to fill gaps in the spatial coverage. A typical quiet day's values were removed to eliminate Sq-type currents. In this case we used March 12, 1979, as the quiet day, since the 8 Kp values were 1-, 1-, 0+, 0+, 0+, 0+, 1 and 1 and xKp=5-. The resulting values were then transformed into the corrected geomagnetic coordinate system of Gustafsson (1969) and labeled XM and YM.

2) In view of the fact that this data base is one of the most extensive data sets ever assembled from ground-based magnetometers, we constructed the auroral electrojet indices, AE, AU and AL, from the XM values recorded at stations between 50° and 75° in corrected geomagnetic latitude. For the first interval, 57 stations met the latitude requirements and for the second interval 58 station data were used. Substorm activity described by these indices is presented later in this report.

3) The equivalent current function is calculated by fitting a magnetic potential function to the observed data estimating the portion of this potential which results from overhead currents.

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5. Geophysical Institute, University of Alaska, Fairbanks, AK 99701
6. Department of Space Physics and Astronomy, Rice University, Houston, TX 77251
7. High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO 80307 (sponsored by the National Science Foundation)
4) The ionospheric electrical potential is calculated for every 1° in latitude and 1 hour of local time. This process requires extensive computer computation to numerically solve a 2-dimensional, second-order, partial differential equation. A suitable model of the ionospheric conductivity, which is given as a function of the AE index, must be assumed.

5) Ionospheric current vectors are computed at each grid point from the electric field and the ionospheric conductivity.

6) The field-aligned current distribution is defined as the divergence of the ionospheric current.

7) The Joule heating rate is defined as the scalar product of the ionospheric current and electric field vectors.

8) The above parameters are computed for every 5 minutes of data. A movie was made by interpolating 15 times between the computed values, and plotting the results on a 35-mm master microfilm which was used to create the 16-mm color film.

THE METHOD

Magnetic records from a total of 107 stations in the Northern Hemisphere (except for two which are in the Southern Hemisphere but close to the equator) are used in this project. Those stations are listed in Table 1, and their distribution in corrected geomagnetic coordinates are plotted on an orthogonic projection in Figure 2.

Details of the computations at each step outlined in Figure 1 are described in the following:

Current Function

The observed magnetic data from the stations were fitted to a magnetic potential function \( V \) which is represented by a spherical harmonic series with longitudinal wave numbers \( m \) from 0 to 6 and order \( n=m \) to 56, as expressed by the standard form:

\[
V(\theta, \lambda) = \sum_{m=0}^{6} \sum_{n=m}^{56} \left( a_n^m \cos m\lambda + b_n^m \sin m\lambda \right) P_n^m (\cos \theta)
\]

(1)

where \( \theta \) and \( \lambda \) are colatitude and east longitude (measured from midnight), respectively, in the corrected geomagnetic coordinate system. All terms involving associated Legendre polynomials \( P_n^m \) with even \( (n-m) \) are omitted from the series, except the \( n=m \) term, as the odd terms alone are basically sufficient to represent the Northern
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<tr>
<td>99. Honolulu</td>
<td>21.3</td>
<td>202.0</td>
</tr>
<tr>
<td>100. Victoria</td>
<td>48.5</td>
<td>236.6</td>
</tr>
<tr>
<td>101. Newport</td>
<td>48.3</td>
<td>242.9</td>
</tr>
<tr>
<td>102. Tucson¹</td>
<td>32.3</td>
<td>249.2</td>
</tr>
<tr>
<td>103. Boulder</td>
<td>40.1</td>
<td>254.8</td>
</tr>
<tr>
<td>104. Fort Severn</td>
<td>56.2</td>
<td>271.5</td>
</tr>
<tr>
<td>105. Fredericksburg</td>
<td>38.2</td>
<td>282.6</td>
</tr>
<tr>
<td>106. Great Whale River</td>
<td>55.3</td>
<td>282.2</td>
</tr>
<tr>
<td>107. Ottawa</td>
<td>45.4</td>
<td>284.4</td>
</tr>
</tbody>
</table>

¹ Denotes stations data was used for the first event only.
² Denotes stations data was used for the second event only.
Figure 2. A view of the northern hemisphere in corrected geomagnetic coordinates and plotted on an orthographic projection, i.e., the plotted distance between latitude circles varies as a sine function in colatitude.
Hemisphere potential. The choice of these maximum $m$ and $n$ values is based on trial and error tests with a variety of values. There are in total 358 coefficients, $a_{n}^{m}$ and $b_{n}^{m}$, to be determined in the harmonic series (1).

In seeking an appropriate potential function $V$, it is required here that the potential vary smoothly in space between stations. For details of the practical method of the calculation, see Kamide et al. (1982). The root-mean-square difference between computed and observed magnetic perturbations is typically 15%. However, at certain times the discrepancy rises above 20%.

It is then assumed that there is a relatively small internal contribution to the magnetic potential caused by a perfectly conducting layer 300 km below the Earth's surface. The remaining external potential $V(e)$ is extrapolated to 110 km altitude and converted to an equivalent ionospheric current function by the standard procedure:

$$\psi_{n} = \frac{1}{\mu_{0}} \sum_{n+1}^{\infty} \frac{a_{n}^{m} \psi(e)}{m}$$

where

$$a = R_{e} + 100\text{km}$$
$$\mu_{0} = 4\pi \times 10^{-7} \text{H/m}.$$  

Ionospheric Conductivity

At present there is no way to monitor continuously the global distribution of the ionospheric conductivity. Several conductivity models have been developed based on radar measurements of electron and ion density and temperature and satellite measurements of precipitating electrons and protons. In this report it is assumed that the conductance, that is, the height-integrated ionospheric conductivity, has two components: one is a background and is of solar ultraviolet origin and the other simulates an enhancement presumably due to substorm associated particle bombardment. We may call the former the quiet time conductance and the latter auroral enhancement conductance.

For the background conductance, we follow the quiet time distribution for equinoctial months, as described in equations (19) and (20) of Kamide and Matsushita (1979). For the auroral enhancement, we use an empirical model based on the work of Spilker et al. (1982) with updated improvements. In their work the height-integrated Hall and Pedersen conductivities ($\Sigma_{H}$ and $\Sigma_{P}$) are tabulated at every 1$^{\circ}$ (in latitude) and 1 hour (in MLT) for each level of auroral electrojet activity measured by the AE index. Data of precipitating particle energy flux and characteristic electron energy obtained from the Atmosphere Explorer satellites (AE-C and AE-D) were used along with the dependence of the conductivities on the characteristic energy of precipitating electrons obtained by Vickrey et al. (1981). It should be noted, however, that at two instants with the same value of the AE index, the auroral distribution and the conductivity distribution, as well as the current patterns in the polar region, may be significantly different. In our modeling the following adjustment is employed in the use of the conductivity model: by assuming that the latitude of the maximum equivalent current strength coincides with the latitude of the highest Hall conductivity, a latitudinal shift is made for the entire conductivity distribution when ever a difference between the two latitudes of the maxima is found.

Electric Potential

During the last several years, different techniques have been developed to analyze global magnetometer data in order to infer the three-dimensional distribution of electric currents around the Earth (e.g., Kishibe et al., 1979; Mishin et al., 1980; Kamide et al., 1981). These methods take the distribution of magnetic perturbation vectors observed on the Earth's surface as the input and try to estimate the distribution of ionospheric and field-aligned currents and other related quantities as outputs for a given model of ionospheric conductivities. In this report, we employ an improved version of the computer algorithm developed by Kamide et al. (1981).

The height-integrated ionospheric current can be considered to consist of two elements. The toroidal (solenoidal) current $J_{T}$ is related to the equivalent current function $\psi$ as

$$J_{T} = -\frac{a \psi}{\sin \theta \lambda}$$

The other part, the poloidal current $J_{P}$ can be considered as a closing current for field-aligned currents $J_{A}$. (Note that $J_{A} = \text{div} J_{P}$ and $\text{div} J_{T} = 0$ by definition and $J_{A}$ and $J_{P}$ together produce no ground magnetic variation under the assumption that magnetic field lines penetrate vertically into the horizontal ionosphere). The associated electric field $E$ is derivable from an electrostatic potential $\Phi$. A partial differential equation for $\Phi$ in terms of $\psi$ can then be written in the form

$$A \frac{\partial^{2} \psi}{\partial \theta^{2}} + B \frac{\partial \psi}{\partial \theta} + C \frac{\partial^{2} \psi}{\partial \lambda^{2}} + D \frac{\partial \psi}{\partial \lambda} = F(\psi, \theta, \lambda)$$

where coefficients $A$, $B$, $C$, $D$ and $F$ are given by the conductivities and their spatial gradients; see Kamide et al. (1982).
The above differential equation (4) is to be numerically solved with approximate boundary conditions:

\[ \phi(0, \lambda) = 0 \text{ at the pole} \]
\[ \frac{\partial \phi}{\partial \theta}(\pi/2, \lambda) = 0 \text{ at the equator} \]  

(5)

Once the electrostatic potential is obtained, the electric field \( \mathbf{E} \) is derivable from the potential \( \phi \) as

\[ \mathbf{E} = -\nabla \phi. \]

(6)

Practically, we solve (4) numerically by a finite difference scheme over a network of grid points spaced 1° in \( \theta \) and 15° in \( \lambda \). It was assumed in deriving (4) that the magnetic contributions of the magnetospheric ring currents and tail currents to \( \psi \) can be neglected and geomagnetic field lines are effectively radial. The breakdown of these assumptions at lower latitudes probably invalidates the calculated potential values at low latitudes.

**Ionospheric Currents and Field-Aligned Currents**

Once the electric field is determined, it is possible to derive the ionospheric current vector \( \mathbf{J} \) from

\[ \mathbf{J} = \mathbf{I}_p \mathbf{E} + \mathbf{I}_n \mathbf{E} \times \mathbf{n}_n \]

(7)

where \( \mathbf{n}_n \) is a unit radial vector. From the requirement that the three-dimensional current be divergence free, the field-aligned current density \( J_H \) (positive downwards) can be calculated as

\[ J_H = \text{div} \mathbf{J} = \text{div} J_p \]

(8)

**Joule Heating Rate**

The height-integrated Joule heating rate is defined by

\[ u_J = \mathbf{J} \cdot \mathbf{E} = \sum_p \mathbf{J}_p b^2 \]

(9)

The Joule heating rate in the entire Northern Hemisphere ionosphere \( u_J \) can then be obtained by integrating \( u_J \) as

\[ u_J = \int u_J a^2 \sin \theta \, d\theta d\lambda \]

**MAGNETIC ACTIVITY DURING THE CDAY-6 INTERVALS**

Figures 3a and b show auroral electrojet activity as described by the AE(57) and AE(68) indices for the first and second CDAY-6 intervals, respectively. The upper envelope, AU, depicts the maximum magnetic variation and the lower envelope, AL, describes the minimum magnetic variation. The distance between the two indices is another index, called AE.

**0600-1800UT on March 22, 1979**

Mid-latitude magnetic records indicate that this interval spanned a very quiet period, a storm sudden commencement at 0226 UT and the initial and main phases of a medium-size magnetic storm as Dst reached -74 nT during the 6th hour on March 22nd. From the auroral electrojet indices, we note two major substorms identified as relatively isolated enhancements in auroral electrojet activity. In the first sequence, an AE enhancement began at 1020 UT and was followed by the major expansion onset noted in the auroral zone as AL reached -1000 nT at mid-latitude by positive bays in the H-component and by Pi2 pulsations, all beginning at 1055 UT. This major onset was marked with a decrease in the strength of the east-west electrojet as the majority of the auroral zone is engulfed in westward current which reached its maximum intensity around 1130 UT.

Soon after the recovery of the first major substorm, both the AU and AL values intensified at 1325 UT. At 1435 UT another major expansion onset was recorded. This substorm reached its maximum intensity of about 2000 nT in AE at 1450 UT.

**1200 March 31-0600 April 1, 1979**

The interval is best characterized by continuous activity of the auroral electrojets. At mid-latitudes, the Dst index bounced between -22 and -35 nT and Kp was fairly stable at the level of 3. Unlike the previous interval, this interval shows almost continuous auroral activity from 0100 to 2000 UT which was followed by sharp substorm developments at 2130 and 0300 UT. The maximum phases of these latter substorms reach relatively large values of -1000 nT at 2320 UT and -740 nT at 0315 UT as recorded in the AL index.
Figure 3. Nonstandard AU and AL indices showing the maximum positive and negative excursions in the \( X_m \) component at 57(a) and 58 (b) stations between 50° and 75° corrected geomagnetic latitude.

EXAMPLES

In Figures 4a-j, we show some of the outputs from the extensive calculation for, as an example, 1125 UT on March 22, 1979, which was near the maximum epoch of the first intense substorm.

Figure 4a shows the distribution of the equivalent ionospheric current vectors which are essentially the observed magnetic perturbation vectors rotated clockwise by 90°. Data below 50° in corrected geomagnetic latitude are not shown in this diagram. One can notice that the intense westward electrojet flows in a wide local time span, from the noon sector to the premidnight sector, and maximizes in early morning hours. Unfortunately, there is a large gap in the distribution of magnetometers over eastern Siberia.
Figure 4d

Figure 4f

Figure 4g
In Figures 4b and 4c, we show the distribution of isointensity contours of calculated external current function (the so-called equivalent ionospheric current system) and of the associated equivalent current vectors, respectively. The current vectors are plotted at our grid points every 1° (in latitude) and 1 hour (in magnetic local time). Comparing Figures 4a and 4c, one must be cautious in interpreting the derived equivalent currents in regions where there is an absence of measurements. In particular, the large gap in the distribution of surface magnetometers over eastern Siberia can produce significant uncertainties. Our fitting algorithm generates a northward turning of the westward electrojet toward the polar cap through this data gap in 2000–2300 MLT sector. It is impossible to state definitively whether or not this pattern corresponds well with reality. These uncertainties must be kept in mind when interpreting the results of our subsequent outputs.

Isocontours of the height-integrated Pedersen and Hall conductivities assumed for this particular time are displayed in Figure 4d. Note the different contour intervals used for the two conductivities. Figure 4e shows isocontours of the electric potential calculated for the combined set of the current function (Fig. 4b) and the conductivity model (Fig. 4d), and Figure 4f shows the corresponding electric field computed at our grid points. The potential pattern consists essentially of twin vortices in high latitudes with the highest and lowest potentials existing in the early morning and early afternoon sectors, respectively. However, there can exist many local deformations. It is important to point out that in many earlier works, the pattern of the electric potential has been assumed to be identical to that of the equivalent current system. By comparing Figures 4e and 4f, it is noticeable that the potential pattern is significantly different from the equivalent current system at and near auroral latitudes. Such a difference is caused simply by the nonuniform distribution of the ionospheric conductivity. It is also pointed out that because of vertical magnetic field lines in the potential calculation, the electric potential in subauroral latitudes, say below 60° is unrealistically large.

Figure 4g shows the distribution of the calculated ionospheric current vectors. One can notice by comparing the equivalent and 'true' ionospheric currents, that although the gross distributions of the two currents are similar, there are significant differences both in current direction and strength. The major portions of the equivalent currents flow nearly in an east-west direction, but the 'true' ionospheric currents have a considerable north-south component. For example, the westward electrojet in the morning sector has a significant southward component as well, and the eastward electrojet in the evening sector is actually flowing northeastward. In Figure 4h, we compare the Pedersen and Hall currents separately. It is evident that the Hall currents are remarkably similar to the equivalent currents. However, a significant difference can be found in the polar cap, where the Hall current is very small. This indicates that the main source of the polar cap magnetic perturbations are field-aligned currents, at least during substorms.

Figure 4i shows isocontours of the calculated field-aligned currents. There is a great variability in the field-aligned current distribution in comparison with the statistical pattern obtained by averaging a number of satellite measurements.

Finally, in Figure 4j, we show the distribution of the Joule heat production rate associated with the auroral electrojets. In the left-bottom corner, the total Joule heating integrated over the entire polar ionosphere (from the North Pole to 50° latitude) is indicated in the unit of watts.

ACKNOWLEDGEMENTS

The total CODAw-6 list of participants exceeds the scope of this report though we would like to express our appreciation to R.H. Manka, the organizer, and J.L. Vette, our most gracious host. This project represents a major effort of the magnetic fields subgroup. This report results from the cooperation of many people in numerous institutions in the world as the data were recorded at remote sites, processed at home institutes, sent to NSSDC, entered into the CODAw-6 data base, and sent directly to us. Special contributions were received from W. Haas, P. Fougere, E. Friis-Christensen, V. I. Mishin, G. Rostoker, W. F. Stuart, J. K. Walker and A. N. Zaitzev. We also wish to give a special note of thanks to the staff of Sigma Data supported by NASA/NSSDC, M. Teague, D. Sawyer and E. Teague. Parts of this study were supported by the following grants received from the Atmospheric Science Division of the National Science Foundation; ATN 80-17316, ATN 80-20376 and ATN 81-08994; from NASA; NGR-44-006137 and NSG-7-447; and from ONR; N00014-82-K-0031. The data plots and the 16-mm movie could not have been completed without the use of the computer resources made available to us by NCAR.
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APPENDIX I

Data Plots for 0600-1800 on March 22, 1979

Out of the various output plots shown in Figures 4a-j, we have chosen to show 5 polar plots (equivalent ionospheric current system, electrical potential, ionospheric current vectors, Joule heating rate and field-aligned current density) as well as the distribution of the observed magnetic perturbation noted as equivalent currents. The plots are reconstructed every 10 minutes for the 12-hour interval. The outermost circle is 50"R in corrected geomagnetic coordinates, with other circles spaced 10°. Date and UT are marked on each diagram. Note that all of the scales change at 1020 UT.
OBSERVED EQUIVALENT CURRENT VECTORS
MARCH 22, 1979
0840 UT

ELECTRIC POTENTIAL
00 MLT
250 nT

IONOSPHERIC CURRENT

JOULE HEAT RATE

FIELD-ALIGNED CURRENTS

TOTAL (W)
3.90E-10

CONTOUR INTERVAL 5 KV

CONTOUR INTERVAL 0.002 W/m²

CONTOUR INTERVAL 1 μA/m²
OBSERVED EQUIVALENT CURRENT VECTORS
MARCH 22, 1979
1030 UT

ELECTRIC POTENTIAL

IONOSPHERIC CURRENT

JOULE HEAT RATE

FIELD-ALIGNED CURRENTS

TOTAL (W)
9.98E+10

CONTOUR INTERVAL
0.006 W/m²

CONTOUR INTERVAL
5 μA/m²
OBSERVED EQUIVALENT CURRENT VECTORS

MARCH 22, 1979
1220 UT

DD MLT
ELECTRIC POTENTIAL

50°

CONTOUR INTERVAL 500 nT

IONOSPHERIC CURRENT

CONTOUR INTERVAL 80000 A

JOULE HEAT RATE

CONTOUR INTERVAL 15 KV

TOTAL (W)
3.15E+11

FIELD-ALIGNED CURRENTS

CONTOUR INTERVAL 3 A/m

0.006 W/m²
OBSERVED EQUIVALENT CURRENT VECTORS

MARCH 22, 1979
1530 UT

00 MLT

ELECTRIC POTENTIAL

00 MLT

50°

500 nT

IONOSPHERIC CURRENT

CONTOUR INTERVAL
80000 A

FIELD-ALIGNED CURRENTS

CONTOUR INTERVAL
3 A/m

JOULE HEAT RATE

CONTOUR INTERVAL
15 KV

TOTAL (M)
1.42E+12

CONTOUR INTERVAL
0.006 W/m²

73
OBSERVED EQUIVALENT CURRENT VECTORS

MARCH 22, 1979
1620 UT

00 MLIT
ELECTRIC POTENTIAL

500 nT

IONOSPHERIC CURRENT

CONTOUR INTERVAL
8000 A

TOTAL (W)
3.00E+11

JOULE HEAT RATE

CONTOUR INTERVAL
15 KV

FIELD-ALIGNED CURRENTS

CONTOUR INTERVAL
0.5 μA/m²
OBSERVED EQUIVALENT CURRENT VECTORS

MARCH 22, 1979
1710 UT

00 MLT
ELECTRIC POTENTIAL

50°

18

06

12

0

00 nT

CONTOUR INTERVAL
80000 A

EQUIVALENT CURRENT SYSTEM

00

12

81 1710

I ONOSPHERIC CURRENT

15 KV

81 1710

CONTOUR INTERVAL
1.38E+11

JOULE HEAT RATE

1.38E+11

TOTAL (W)

0.006 W/m²

CONTOUR INTERVAL

0

12

81 1710

FIELD-ALIGNED CURRENTS

5 A/m

CONTOUR INTERVAL

0.5 μA/m²
APPENDIX II

Data Plots for 1200 March 31-0600 April 1, 1979

Out of the various output plots shown in Figures 4a-j, we have chosen to show 5 polar plots (equivalent ionospheric current system, electrical potential, ionospheric current vectors, Joule heating rate and field-aligned current density) as well as the distribution of the observed magnetic perturbation noted as equivalent currents. The plots are reconstructed every 10 minutes for the 12-hour interval. The outermost circle is 50°N in corrected geomagnetic coordinates, with other circles spaced 10°. Date and UT are marked on each diagram.
OBSERVED EQUIVALENT CURRENT VECTORS

MARCH 31, 1979
1420 UT

00 MLT
ELECTRIC POTENTIAL

250 nT

IONOSPHERIC CURRENT

CONTOUR INTERVAL
50000 A

JOULE HEAT RATE

CONTOUR INTERVAL
10 KV

FIELD-ALIGNED CURRENTS

CONTOUR INTERVAL
0.3 μA/m²

TOTAL (W)
9.42E+10

CONTOUR INTERVAL
0.005 W/m²
OBSERVED EQUIVALENT CURRENT VECTORS
MARCH 31, 1979
1510 UT

EQUVALENT CURRENT SYSTEM

00 MLT → 250 nT

ELECTRIC POTENTIAL

IONOSPHERIC CURRENT

CONTOUR INTERVAL 50000 A

JOULE HEAT RATE

FIELD-ALIGNED CURRENTS

CONTOUR INTERVAL 10 KV

TOTAL (W)
1.34E+11

CONTOUR INTERVAL 0.005 W/m²

CONTOUR INTERVAL .3 μA/m²
OBSERVED EQUIVALENT CURRENT VECTORS
MARCH 31, 1979
1520 UT
18 06
00 MLT
250 nT
ELECTRIC POTENTIAL
90 1520
12 00
CONTOUR INTERVAL
10 KV
JOULE HEAT RATE
90 1520
12 00
TOTAL (W)
1.44E+11
18 06
00
CONTOUR INTERVAL
0.005 W/m²
EQUIVALENT CURRENT SYSTEM
90 1520
12 00
CONTOUR INTERVAL
50000 A
IONOSPHERIC CURRENT
90 1520
12 00
FIELD-ALIGNED CURRENTS
90 1520
12 00
CONTOUR INTERVAL
.3 μA/m²
OBSERVED EQUIVALENT CURRENT VECTORS

MARCH 31, 1979
1820 UT

00 MLT

ELECTRIC POTENTIAL

00

CONTOUR INTERVAL 10 KV

JOULE HEAT RATE

TOTAL (W)
1.82E+11

CONTOUR INTERVAL 0.005 W/m²

FIELD-ALIGNED CURRENTS

00

CONTOUR INTERVAL .3 μA/m²

EQUIVALENT CURRENT SYSTEM

CONTOUR INTERVAL 500000 A

IONOSPHERIC CURRENT

00
OBSERVED EQUIVALENT CURRENT VECTORS
MARCH 31, 1979
2040 UT

00 MLT
ELECTRIC POTENTIAL
250 nT

IODOSPERIC CURRENT
90 2040
12

TOTAL (W)
1.392 x 10^11

FIELD-ALIGNED CURRENTS
90 2040
12

CONTOUR INTERVAL
50,000 A

CONTOUR INTERVAL
10 KV

CONTOUR INTERVAL
0.005 W/m²

CONTOUR INTERVAL
-3 μA/m²

142
OBSERVED EQUIVALENT CURRENT VECTORS

APRIL 1, 1979
0000 UT

00 MLT → 250 nT

ELECTRIC POTENTIAL

IONOSPHERIC CURRENT

CONTOUR INTERVAL 50000 A

JOULE HEAT RATE

FIELD-ALIGNED CURRENTS

CONTOUR INTERVAL 10 KV

CONTOUR INTERVAL 2 A/m

TOTAL (W) 1.69E+11

CONTOUR INTERVAL 0.005 W/m²

162
OBSERVED EQUIVALENT CURRENT VECTORS

APRIL 1, 1979
0210 UT

00 MLT

ELECTRIC POTENTIAL

12

50°

250 nT

06

18

IONOSPHERIC CURRENT

12

CONTOUR INTERVAL 50000 A

00

18

06

12

18

06

JOULE HEAT RATE

CONTOUR INTERVAL 10 KV

FIELD-ALIGNED CURRENTS

CONTOUR INTERVAL 2 A/m

TOTAL (W)

8.08E10

00

CONTOUR INTERVAL 0.006 W/m²

175
OBSERVED EQUIVALENT CURRENT VECTORS
APRIL 1, 1979 0500 UT
00 MLT 250 nT

ELECTRIC POTENTIAL

IONOSPHERIC CURRENT

JOULE HEAT RATE

FIELD-ALIGNED CURRENTS

TOTAL (W) 3.06E+10
CONTOUR INTERVAL 0.005 W/m²

CONTOUR INTERVAL 50,000 A

CONTOUR INTERVAL 3 μA/m²
OBSERVED EQUIVALENT CURRENT VECTORS

APRIL 1, 1979
0520 UT

00 MLT

ELECTRIC POTENTIAL

OO MLT

250 nT

IONOSPHERIC CURRENT

CONTOUR INTERVAL
50000 A

CONTOUR INTERVAL
10 KV

JOULE HEAT RATE

TOTAL (W)
2.98E+10

FIELD-ALIGNED CURRENTS

CONTOUR INTERVAL
0.005 W/m²

CONTOUR INTERVAL
0.3 μA/m²
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