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SPATIAL AND TEMPORAL DISTRIBUTION OF IONOSPERIC CURRENTS - 3: LATITUDE-LOCAL TIME AND LATITUDE - LONGITUDE CROSS SECTIONS OF EQUATORIAL ELECTROJET CURRENT DENSITY AND INTENSITY

C. AGODI ONWUMECHILI, P. O. EZEMA and S. O. OKO

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ABSTRACT

A comprehensive analysis of the POGO satellites data of 1967 –1969 has enabled us to present the daytime means, based on 09 hr to 15 hr, at each of 36 longitudes, and the all-longitude means at each of 7 local time hours, for each of 9 parameters of the equatorial electrojet (EEJ) necessary for the cross sections. The latitude-local time cross sections of EEJ current density and intensity each displays three contour cells. The forward current contour cell peaks at (12h, 0^0.) and the return current contour cells peak at (12h, 5.13^0N) and (12h, 5.13^0S). The latitude-longitude cross sections of EEJ current density and intensity each displays nine contour cells. The three forward current contour cells peat at (0^0, 100^0E), (0^0, 190^0E) and (0^0, 290^0E). The three return current contour cells to the north peak at (5.35^0N, 100^0E), ($5{,}05^0$N, 190^0E) and (5.30^0, 290^0E), while the three to peak at (5.35^0S, 100^0), (5.05^0S, 190^0E), while the three to the south peak at (5.35^0S, 100^0E), (5.05^0S, 190^0E) and ($5{,}30^0$S, 290E). The return current spreads thinly over an area of about four times the area of the forward current. Consequently, the ratio of the peak return current density or intensity to the peak forward current density or intensity is only about one quarter. On the average the percentage ratio is -23.25 ± 0.41. Arising from the decrease of EEJ with latitude while at the same time it increases everywhere as the peak current at the magnetic dip equator increases, the cross sections show that the contours extend farther in latitude when the peak current at the dip equator is larger.

Key words: latitude –local time, latitude. longitude cross sections, current density, and intensity inonospheric currents

INTRODUCTION

We are not aware of any publication of the latitude-local time and latitude-longitude cross sections of equatorial electrojet (EEJ) current density and intensity. Sing and Cole (1987), Untiedt (1967), Sugiura ad Poros (1969) and Davis et at (1967) worked on altitude-latitude cross sections but latitude-longitude and latitude-local time have not been worked upon. The purpose of this paper is to present and discuss such cross sections. We use the continuous distribution of current density model of Onwumechili (1965). We avoid the (r, ϕ,λ) coordinate system because r is used for the reduced distance later. We adopt the alternative coordinate system (x, y, z) often used for the model. In this system x is northward latitude and z is downward vertical distance, both measure from the current center, and y is eastward longitude.

The eastward current density j at the point (x, z) is given by

$$j = j_0 \frac{a^2\left(a^2 + \alpha x^2\right)b^2\left(b^2 + \beta z^2\right)}{\left(a^2 + x^2\right)^2\left(b^2 + x^2\right)^2}, \qquad \text{......} \quad 1$$

where j_0 is the peak current density at the current center x =0 =z, a is scale latitude, b is vertical scale length, and α and β are dimensionless constants controlling the distribution of current latitudinally and vertically respectively, Eq. (1) may be written as

$$j = C_0 \frac{a^2\left(a^2 + \alpha x^2\right)}{\left(a^2 + x^2\right)^2}, \qquad \text{......} \quad 2$$

$$where\ C_0 = j_0 \frac{b^2\left(b^2 + \beta z^2\right)}{\left(b^2 + z^2\right)^2} \qquad \text{......} \quad 3$$

C. AGODI ONWUMECHILI, 4813 Lackawanna St; College Park MD 20740, USA
P. O. EZEMA, Department of Physics and Astronomy, University of Nigeria, Nuskka, Nigeria
S. O. OKO, Department of Computer Science, University of Nigeria, Nsukka, Nigeria

When Eq. (1) is integrated with respect to z through the altitude extent of the current from $-L_2$ to L_2 we get the current intensity J as

$$J = J_0 \frac{a^2\left(a^2 + \alpha x^2\right)}{\left(a^2 + x^2\right)^2} \qquad \ldots\ldots \qquad 4$$

where J_0 is the peak current intensity at the current center.

CALCULATION OF THE CROSS –SECTIONS

The construction of latitude-local time and latitude-longitude cross-section of current density requires the calculation of the latitude at which a selected current density occurs at the given local time or given longitude. This calculation is simply achieved as follows. Re write equation (2) as follows;

$$p = \frac{1 + \alpha r^2}{\left(1 + r^2\right)^2} \qquad \ldots\ldots \qquad 5$$

where $p = j/C_0$, and $r = x/a$. The solution for r or x is

$$x^2 = a^2\left[(\alpha - 2p) \pm \sqrt{(\alpha - 2p)^2 - 4p(p-1)}\right]/2p. \qquad \ldots\ldots \qquad 6$$

In the case of current intensity of Eq. (4), putting $p– J/J_0$ and $r = x/a$ leads to the same Eq. (5). Thus the solution in Eq. (6) is used for the current intensity provided that p is correctly interpreted.

It is clear that the calculation of the cross sections requires the values of j_0 - J_0, a and α for a given local time or a given longitude. These have been determined from the analysis of the POGO satellites data of 1967 –1969 (Onwumechili and Ezema 1992). Also required are the landmark parameters of the latitudinal profile of EEJ current density and intensity. These are w, j_m, J_m, x_m and L_1 which are calculated from j_0, J_0, a and α.

The focal latitude w degree is given by

$$w^2 = - a^2/\alpha. \qquad \ldots\ldots \qquad 7$$

The peak return current density J_m and the peak return current intensity J_m are calculated from

$$J_m = j_0\, \alpha^2/4\,(\alpha - 1) \qquad \ldots\ldots \qquad 8$$

$$J_m = J_0\, \alpha^2/4\,(\alpha - 1). \qquad \ldots\ldots \qquad 9$$

They occur at the latitude x_m degree of the peak return current, which is given by

$$x_m^2 = a^2(\alpha - 2)/\alpha \qquad \ldots\ldots \qquad 10$$

The return currents terminates at the latitudinal extent L_1 degree of the current system. This is obtained by solving the equation

$$\text{div } j = 0 \qquad \ldots\ldots \qquad 11$$

which leads to

$$(a/L_1 + L_1/a) \tan^{-1} a/L_1 = (\alpha - 1)/(\alpha + 1). \qquad \ldots\ldots \qquad 12$$

The comprehensive analysis of the POGO satellites data of 1967 –1969 yielded 894 values of each of the above parameters. For each parameter the 894 values are organized into a table of 36 longitude rows for $\lambda = 0^0, 10^0, 2^0, 30^0, \ldots 350^0$E, and 7 local time hour columns for t = 09, 10, 11, ... 15 hours. The data are limited to these hours.

LATITUDE-LOCAL TIME CROSS-SECTION OF EQUATORIAL ELECTROJET CURRENT DENSITY

The latitude-local time cross-section of equatorial electrojet (EEJ) current density j Akm^{-2} is set on a spherical surface. The latitude x is measured northwards and the local time t is measured eastwards. What is the radius of the sphere? From Eq. (2) and Eq. (3), it is seen that the radius of the sphere is R + z where R is the radius from the earth's center to the center of the current. Here we choose the case of z =0 and therefore we are concerned with the peak current density j_0. In this case the center of the EEJ is on the spherical surface.

But this peak current density j_0 depends on longitude. Here we are concerned with the all longitude mean j_0; the mean j_0 from all longitudes. Such values of all the necessary parameters are given in Table 1 for each local time hour t = 09, 10, 11, ...15 hour.

Table 1. Average values, from all longitudes, of certain parameters of equatorial electrojet current, derived from POGO satellites data of 1967 –1969, necessary for latitude –local time cross sections.

	Local	Time	Hours						
Parameter	09	10	11	12	13	14	15	MEAN	S. D
a degree	3.4758	3.4229	3.3394	3.3725	3.4174	3.5111	3.3762	3.4164	0.0606
α	-1.5446	-1.5265	-1.4826	-1.5274	-1.4798	-1.5423	-1.6298	-1.5333	0.0501
j_0 A/km^2	5.930	8.412	9.329	10.439	8.005	6.689	4.480	7.612	2.050
j_m A/km^2	-1.40	-1.94	-2.07	-2.41	-1.77	-1.57	-1.13	-1.76	0.43
J_0 A/km	123	185	197	220	172	144	92	162	45
J_m Akm	-28.94	-42.68	-43.67	-50.86	-38.01	-33.74	-23.29	-37.31	9.42
w degree	2.77	2.77	2.74	2.73	2.81	2.83	2.66	2.76	0.06
x_m degree	5.23	5.20	5.12	5.13	5.24	5.33	5.05	5.18	0.09
L_1 degree	11.90	11.79	12.28	11.63	12.60	11.82	10.25	11.75	0.74

The contour to be plotted is chosen, for example j =4 Akm^{-2}. For a selected local time hour t, the p =4/j_0 is found. Putting p, a and α for that hour t into Eq. (6) gives the latitudes ±x of the contour of 4 Akm^{-2} at that local time. This is repeated for all the local time hours. The latitudes for the contour of 4 Akm^{-2} so determined for all the hours are plotted and a smooth curve is drawn through them. In the same way all the other contours are calculated, plotted and drawn.

The resulting latitude-local time cross-section of EEJ peak current density is shown in Fig. 1. The continuous contours are for the eastward current densities return current densities of 10, 8, 6, 4, 3, 2, 1, 0.5 and 0.1 Akm^2. The broken contours are for the westward return current densities of –2, -1, -0.5 and –0.1 Akm^2. The cross-section shows that at any latitude the current density increases from morning to a peak around local noon and then decreases towards evening.

At a given local time the current density decreases from a maximum at the magnetic dip equator to zero at the current focus w^0. Thereafter, the current reverses into return current. Its density now begins to increase with latitude. It reaches a peak of j_m at the latitude x_m. Thereafter, its density decreases with latitude. The return current terminates at the latitude L_1 by which all the forward currents have returned. Therefore, all the contours need not close. The values of w, j_m, x_m and L_1 for each local time are given in Table 1. It is clear from the values of L_1 that the contour of –0.5 Akm^{-2} has been extrapolated beyond the latitudinal extent of the current.

However, the most striking feature of the cross-section is the manifestation of three contour cells. The positive contour cell between the foci consists of eastward forward current. The two negative cells flanking it consist of westward return currents. The three contour cells peak at about (12 h, 5.13^{0}N), (12 h, 0^0) and (12 h, 5.13^{0}S) respectively.

Another striking feature of the cross-section is that a given contour tends to extend farther in latitude at a time when the peak current density at the dip equator is greater. This arises from the combination of the decreasing current density with latitude coupled with the increases of the density at all latitudes as the current density at the center increases towards local noon. This feature will be fully discussed later under the altitude-local time cross-section.

When z is not zero but z_1 in Eq. (3), we are on a spherical surface of radius R + z_1. Here the peak current density at the dip equator is $C_0 < j_0$. The cross-section on this surface has the same pattern as Fig. 1 but the current density is reduced everywhere on the surface relative to the density in Fig. 1 The current density relative to Fig. 1 depends on the particular longitude as is evident from Paper 2.

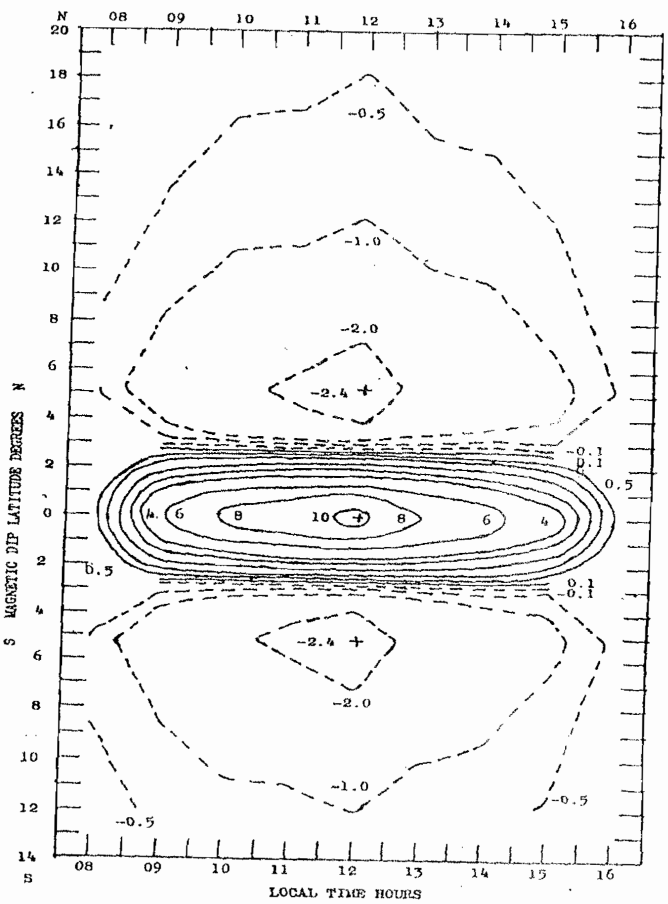

Fig. 1 Latitude –local time cross-section of the equatorial electroprojet (EEJ) current density on the spherical surface through the centre of the EEJ. Continuous contours are for the eastward forward current densities of 10, 8, 6, 4, 3, 2, 1, 0.5 and 1.0 Akm^{-2} and broken contours are for the westward return current densities of –2, -1, -0.5 and –0.1 Akm^{-2}. Contours outside 09 hr to 15 hr local time are extrapolations. Symmetry about the magnetic dip equator is assumed.

LATITUDE-LOCAL TIME CROSS SECTION OF EQUATORIAL ELECTORJET CURRENT INTENSITY

The latitude-local time cross section of the EEJ current intensity J Akm^{-1} is set on a spherical surface on which the latitude x is measured northwards and the local time is measured eastwards. Eq. (4) shows that the radius of the sphere can only be R, the geocentric radius to the center of EEJ. We are therefore concerned with the peak current intensity J_0 Akm^{-1}. But J_0 depends on longitude. To get around this we adopt the mean J_0 from all the longitudes.

The all longitude mean values of the necessary parameters: J_0, J_m, a, j_0 α, w, x_m and L_1 are given in Table 1 for each local time hour t =09, 10, 11,… 15 hour. Firstly, the contour to be plotted is chosen, for example J = -20 Akm^{-1}. For a chosen local time hour t, the values of p =-20/J_0, a and α for that hour are put in Eq. (6). For positive values of p only one of the values of x^2 is positive giving only two values of x. For negative values of p both values of x^2 are positive giving 4 values of x, two on either side of the equator. The solutions for x at all the local time hours are plotted. A smooth curve is drawn through them to get the contour of J = -20 Akm^{-1}. All the desired contours are similarly obtained.

The resulting latitude-local time cross-section of EEJ current intensity is shown in Fig. 2. The continuous contours are for the forward current intensities of 200, 150, 100, 50 and 20 Akm^{-1} and broken contours are for the return current intensities of –40, -30 and –20 Akm^{-1}. The cross-section is very similar to that of current density in Fig. 1. Therefore its explanations have to be abridged.

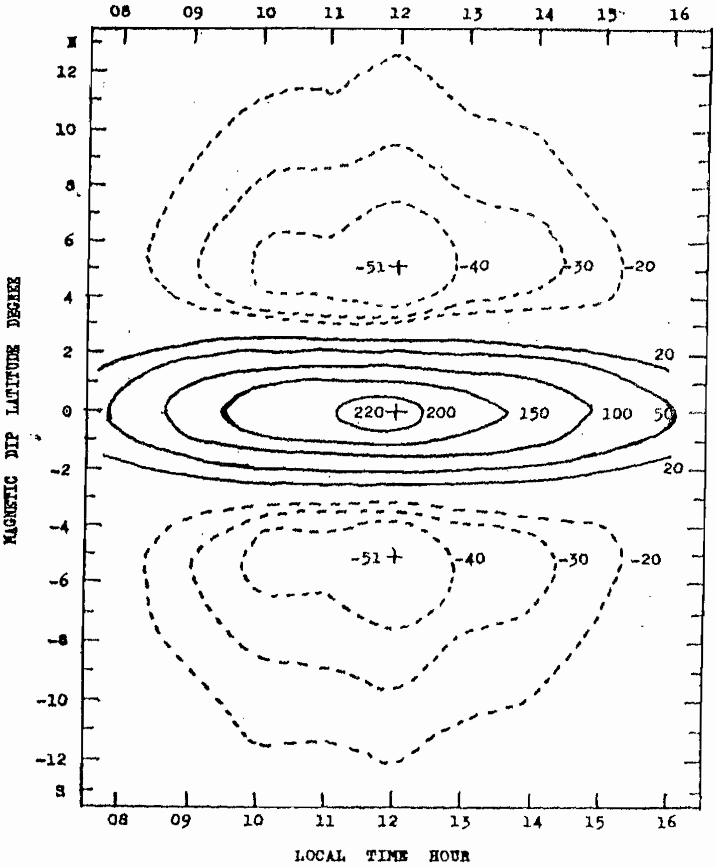

Fig. 2 Latitude-local time cross-section of the equatorial electrojet (EEJ) current intensity on the spherical surface through the centre of the EEJ. Continuous contours are for the eastward forward current intensities of 200, 150, 100, 50 and 20 Akm^{-1}, and broken contours are for the westward return current intensities of −40, -30 and −20 Akm^{-1}. Contours outside 09 hr to 15 hr local time are extrapolations. Symmetry about the magnetic dip equator is assumed.

At each latitude the current intensity increases with local time to a maximum at noontime and then declines towards evening. At a given local time the peak J_0 at the dip equator decreases with latitude to zero at the focal latitude w, beyond which the return current flows. The return current increases with latitude from zero at w to a peak J_m at latitude x_m and thereafter decreases to zero at the latitudinal extent L_1 degree. The values of w, J_m, x_m and L_1 are given in Table 1 for each local time hour.

The three contour cells are again evident and they peak at (12 h, 5.13°N), (12 h, 0°) and (12h, 5.13°S). Again the contours extend farther in latitude as the J_0 at the dip equator increases with local time. The cross-section for any selected longitude has the same pattern as in Fig, 2. However , the current intensity relative to Fig. 2 depends on the peak current intensity at the longitude relative to the all longitude peak current intensity.

LATITUDE-LONGITUDE CROSS SECTION OF EQUATORIAL ELECTROJET CURRENT DENSITY

In general the latitude-longitude cross section of EEJ current density j Akm^{-2} is set on a spherical surface of radius R + z, with the latitude x measured northwards and longitude λ measured eastwards. The C_0 needed for calculating the cross section is obtained from Eq. (3) by putting in the desired value of z and the values of b and β for the selected longitude. For convenience we start with the case of z =0, $C_0 = j_0$ on the spherical surface through the center of EEJ.

Even so, the peak current density j_0 at the centre of EEJ still depends on the local time t. For a start, we adopt the daytime mean j_0 from 09 hr to 15 hr local time. Correspondingly, the values of all the necessary parameters must be their daytime means. Accordingly, these parameters: the scale latitude a, the latitudinal current distribution parameter α, the peak forward current density j_0 at the current center, the peak return current density j_m, the focal latitude w, the latitude of peak return current x_m, and the latitudinal extent L_1 degree of the current system, are all given in Table 2 at 36 selected longitudes λ =0°, 10°, 20°, 30° … 350°E.

On electing to construct the contour for j = -1 Akm^{-2} for example, the fraction $p = -1/j_0$. The values of $-1/j_0$, a and α for a selected longitude λ are put into Eq. (6). For such a negative p, the x^2 has two positive values and therefore x has four values two on each side of the dip equator. With $p = -1/j_0$ the process is repeated for all the 36 selected longitudes in Table 2. all the solutions for x arising from $p = -1/j_0$ are plotted and a smooth curve is drawn through the points. Similarly, other desired contours are calculated, plotted and drawn.

The resulting latitude –longitude cross-section is shown in Fig. 3. There, the continuous contours are for EEJ forward current densities of 10, 8, 6, 4, 3, 2, 1, 0.5 and 0.1 Akm^{-2}. At any chosen latitude, the variation of current density with longitude has maxima at 100^{0}E, 190^{0}E and 290^{0}E and minima at 140^{0}E and 240^{0}E.

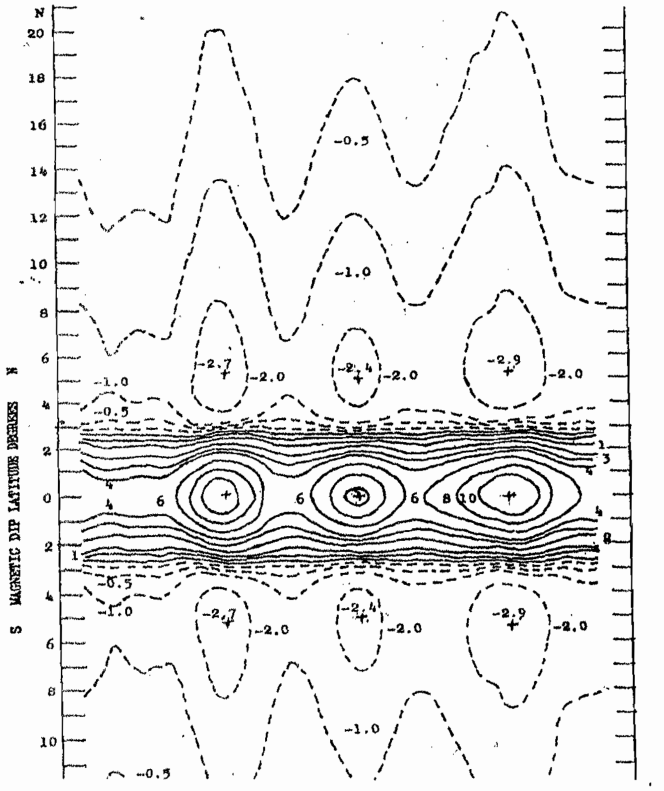

Fig. 3 Latitude-longitude cross section of equatorial electrojet (EEJ) current density on the spherical surface through the centre of the EEJ. Continuous contours are for the eastward forward current densities of 10, 8 ,6 ,4, 3, 2, 1, 0.5 and 0.1 Akm^{-2}, and broken contours are for the westward return current densities of –2, -1, -0.5 and –0.1 Akm^{-2}. Symmetry about the magnetic dip equator is assumed.

It is clear from Fig. 3 that along each longitude the current density is a maximum at the magnetic dip equator. From this maximum, it decreases to zero at the focus at w^0 dip latitude. From there return currents commence tenuously and increase to a peak j_m at a latitude of x_m^0. Thereafter, the return currents decrease and eventually terminate at L_1 degrees latitude by which all the forward currents have returned as a consequence of Eq. (11). All the above parameters are given in Table 2. The values of L_1 there show that the contour for –0.5 Akm^{-2} has been extrapolated beyond the latitudinal extent of the current system of the EEJ.

There are three striking features of the latitude-longitude cross-section of EEJ current density in Fig. 3. Firstly, there are nine contour cells: three of forward current density peaking at (0^0, 100^{0}E), (5.05°N, 190°E); three of return current density peaking at (5.35^{0}N, 100^{0}E), (0^0, 190^{0}E) and (0^0, 290^{0}E)' (5.30^{0}N, 290^0); and another three of return current density peaking at (5.35^{0}S, 100^{0}E), (5.05°N, 190°E) and (5.35^{0}S, 290^{0}E). The three maxima at the dip equator marked with crosses are 11.44 Akm^{-2} at 100^{0}E, 10.58 Akm^{-2} at 190^{0}E and 12. 42 Akm^{-2} at 290^{0}E; and the minima also marked with crosses are given in Fig. 3. This arises from the variation of current density with latitude having maximum at 0^0 latitude and minima at $\pm x_m^0$ latitude; and its variation with longitude having maxima at 100^{0}E, 190^{0}E and 290^0, and minima at 140^{0}E and 240^{0}E.

The second remarkable feature of Fig. 3 is that the current density contours extend farther in latitude when the peak current density at the dip equator is higher. This will be more naturally explained under the altitude-local time cross section later. The third remarkable feature is that the return current covers about four times the area of the forward current. The peak return current density j_m is therefore only about one quarter of the peak forward current density j_0. The all longitude average of the daytime means is $100j_m/j_0 = -23.25 \pm 0.41$.

Following Eq. 3 and Eq. (2), when the contour is set on the spherical surface of radius R + z where $z \neq 0$, the pattern is the same as Fig. 3 but the current density is reduced everywhere relative to Fig. 3.

When Table 2 is made for a selected local time and its parameters are used to construct the cross-section, the pattern will be the same as in Fig. 3. The current density will be higher or lower everywhere relative to Fig. 3 according as the peak current density for the selected local time is higher or lower than the peak current density used for constructing Fig. 3.

LATITUDE-LONGITUDE CROSS-SECTION OF EQUATORIAL ELECTROJET CURRENT INTENSITY

It is clear from Eq. 4 that the latitude-longitude cross-section of equatorial electrojet current intensity can only be drawn on the spherical surface with radius R and therefore the surface passes through the

Table 2. Daytime average values, from 09 hr to 15hr, of certain parameters of equatorial electrojet current, derived from POGO satellites data of 1967 – 1969, necessary for latitude-longitude cross sections.

Long. Degree E	a degree	α	j_0 A/km^2	j_m A/km^2	J_0 A/km	J_m A/km	w degree	x_m degree	L_1 degree
0	3.3932	-1.5122	6.00	-1.37	128	-29.16	2.76	5.17	11.92
10	3.4131	-1.5148	4.90	-1.11	103	-23.34	2.78	5.21	12.14
20	3.4268	-1.5113	4.58	-1.04	97	-22.08	2.76	5.25	12.08
30	3.3934	-1.5158	4.95	-1.13	107	-24.45	2.76	5.17	11.89
40	3.4151	-1.5288	5.13	-1.19	111	-25.67	2.76	5.19	11.76
50	3.4883	-1.5339	4.86	-1.13	106	-24.65	2.82	5.30	11.98
60	3.3181	-1.5085	5.05	-1.15	100	-22.71	2.70	5.06	11.83
70	3.2599	-1.5160	6.92	-1.58	137	-31.33	2.65	4.97	11.57
80	3.1933	-1.5083	9.53	-2.16	191	-43.38	2.60	4.87	11.39
90	3.4368	-1.5389	10.96	-2.56	233	-54.41	2.72	5.12	11.48
100	3.5207	-1.5365	11.44	-2.66	252	-58.69	2.84	5.35	11.96
110	3.5027	-1.5353	9.75	-2.27	212	-49.33	2.83	5.32	11.96
120	3.6097	-1.5254	7.88	-1.82	170	-39.22	2.82	5.30	12.47
130	3.4375	-1.5216	5.13	-1.18	109	25.06	2.79	5.24	11.96
140	3.4498	-1.5206	4.80	-1.10	105	-24.12	2.80	5.25	12.06
150	3.4742	-1.5636	4.89	-1.17	104	-24.86	2.79	5.25	11.54
160	3.4153	-1.5601	6.43	-1.53	132	-31.46	2.74	5.16	11.45
170	3.3534	-1.5450	8.18	-1.92	167	-38.79	2.70	5.11	11.38
180	3.2935	-1.5217	10.04	-2.31	208	-47.88	2.67	5.04	11.53
190	3.2988	-1.5301	10.58	-2.46	222	-51.53	2.70	5.05	11.38
200	3.4143	-1.5583	9.02	-2.15	191	-45.50	2.74	5.17	11.31
210	3.4141	-1.5452	7.21	-1.70	153	-36.00	2.76	5.18	11.48
220	3.4243	-1.5337	5.94	-1.38	126	-29.33	2.77	5.21	11.79
230	3.3540	-1.5285	5.95	-1.38	123	-28.47	2.71	5.10	11.59
240	3.4066	-1.5132	6.39	-1.46	134	-30.59	2.77	5.19	12.01
250	3.5081	-1.5328	7.47	-1.74	161	-37.43	2.83	5.33	12.05
260	3.4777	-1.5437	8.48	-1.99	181	-42.52	2.80	5.27	11.76
270	3.4729	-1.5812	10.11	-2.46	219	-53.20	2.77	5.24	11.31
280	3.3792	-1.5571	11.20	-2.67	242	-57.60	2.72	5.13	11.35
290	3.4871	-1.5362	12.42	-2.90	269	-62.81	2.82	5.30	12.18
300	3.5359	-1.5142	11.71	-2.68	250	-57.18	2.87	5.39	12.55
310	3.5148	-1.5390	10.10	-2.36	214	-50.05	2.83	5.34	11.95
320	3.3866	-1.5582	7.80	-1.86	168	-39.98	2.72	5.13	11.28
330	3.3671	-1.552	6.21	-1.47	136	-32.27	2.71	5.12	11.25
340	3.3961	-1.5407	5.98	-1.40	134	-31.37	2.74	5.15	11.53
350	3.3564	-1.5099	6.04	-1.37	131	-29.82	2.73	5.12	11.70
Mean	3.4164	-1.5332	7.61	-1.77	162	-37.67	2.76	5.19	11.72
S.D.	0.0830	0.0083	0.40	0.57	52	12.24	0.06	0.11	0.34

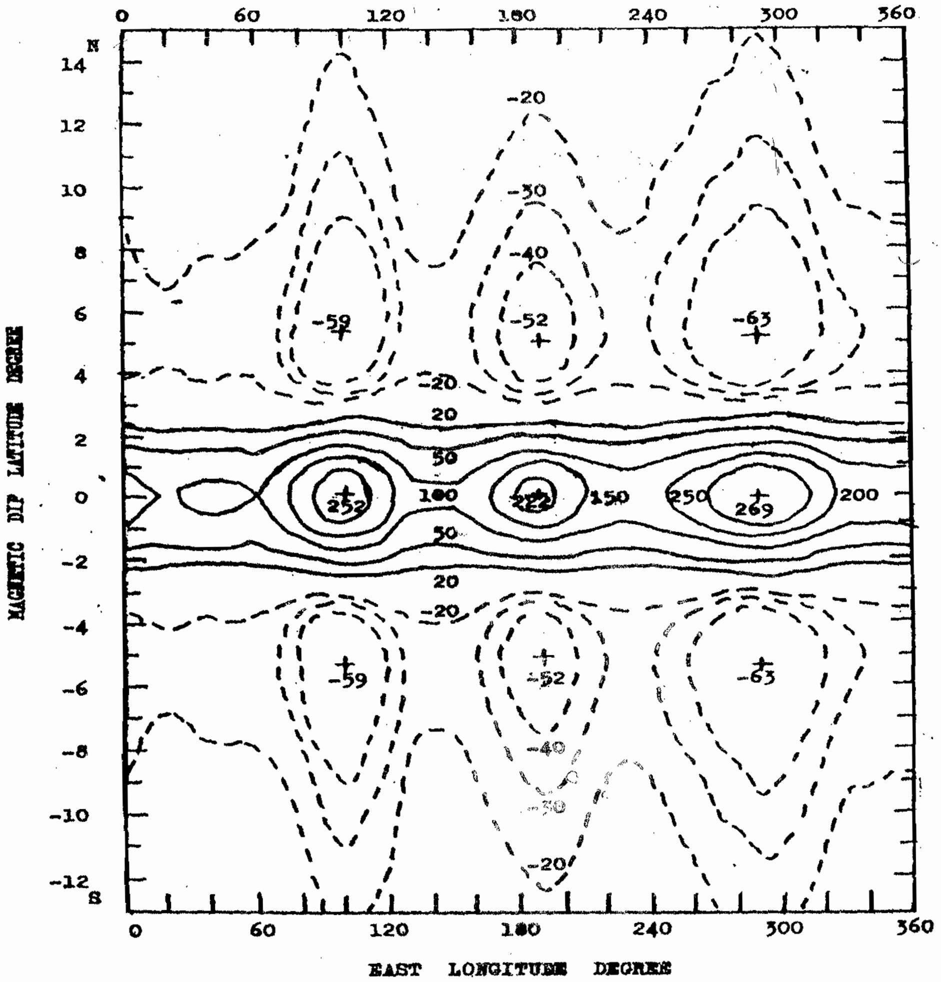

Fig. 4 Latitude-longitude cross-section of equatorial electrojet (EEJ) current intensity on the spherical surface through the centre of the EEJ. Continuous contours are for the eastward current intensities of 200, 150, 100, 50 and 20 Akm^{-1}, and broken contours are for the westward return current intensities of –40, -30, and –20 Akm^{-1}. Symmetry about the magnetic dip equator is assumed.

center of EEJ. Even then the peak current intensity J_0 at the current center depends on local time, In the circumstance, it is convenient to start with the daytime mean J_0 from 09 hr to 15 hr. Accordingly, the daytime mean of J_0, a, α, J_m, w, x_m and L_1 necessary for latitude-longitude cross-section of EEJ current intensity J_0 are given in Table 2 at 36 selected meridians of longitude $\lambda = 0^0, 10^0, 20^0, \ldots 350^0$E.

A meridian of longitude λ is chosen. Suppose it is decided to draw the contour for 50 Akm^{-2} for example. The values of $p = 50/J_0$, a and α from Table 2 for the chosen longitude are put into Eq. (6). For such a positive value of p, the solution for x^2 normally has only one positive value and therefore x has two equal and opposite values. Similarly, with the same $p = 50/J_0$ the values of x for all the36 longitudes are found. All the values of x are plotted and a smooth curve is drawn through them as the contour for J = 50 Akm^{-1}. The process is repeated for all the desired contours.

The resulting latitude-longitude cross-section of EEJ current intensity is given in Fig. 4. The continuous curves are contours of 250, 200, 150, 100, 50 and 20 Akm^{-1} of the forward current and the broken curves are contours of –40, -30, and –20 Akm^{-1} of the return current. Fig. 4 is similar to Fig. 3

The Fig.4 shows that at a given latitude the intensity J has maxima at 100^{0}E, 190^{0}E and 290^{0}E, and major minima at 150^{0}E and 230^{0}E with minor minima at 20^{0}E and 60^{0}E. Along a given longitude the EEJ current intensity J has a maximum at the dip equator, is zero at the focus at about $\pm$ 2.76^0, has a minimum at about $\pm$ 5.19^0 and the return current terminates at about 11.72^0 dip latitude.

As a consequence of the above variations of J with latitude and longitude, the latitude-longitude cross-section exhibits 9 contour cells. The three forward current cells peak at the dip equator at 100^{0}E, 190^{0}E and 290^{0}E. The three return current cells to the north peak at (5.35^{0}N, 100^{0}E, (5.05^{0}N, 190^{0}E) and

(5.30°N, 290°E) and the three return current cells to the south peak at (5.35°S, 100°E), (5.05°S, 290°E).

The three remarkable features of Fig. 4 are: (a) the nine contour cells; (b) that the contours extend farther in latitude where the peak current intensity at the dip equator is higher; and (c) that the return current covers an area of about four times the area of the forward current and is of much lower intensity than the forward current. On the whole, latitude-longitude cross sections display a beautiful pattern.

It is possible to construct latitude- longitude cross-section at a selected local time. In that case a Table 2 is made with values of the parameters at that local time. The pattern is the same as in Fig. 4. However, the current intensity everywhere is higher or lower than as in Fig. 4 according as the peak current intensity J_0 at the selected local time is higher or lower than the J_0 used for Fig. 4

CONCLUSION

A comprehensive analysis of POGO satellites data of 1967 –1969 produced 894 values of each parameter of the equatorial electrojet (EEJ). This makes possible a table for each parameter consisting of 36 longitude rows for 0^0, 10^0, 20^0, ... 350^0E and 7 local time hour columns for 09, 10, 11, ... 15 hour. Because of space consideration, only the daytime means based on 09 hr to 15 hr, for each of the 36 longitudes; and the all-longitude means for each of the 7 local time hours are presented, for only the 9 parameters necessary for the cross sections.

The necessary parameters are: the scale latitude a, the latitudinal current distribution parameter α, the peak forward current density j_0 Akm^{-2} and intensity J_0 Akm^{-1} at the latitude x_m where the return current is greatest, the focal latitude w where the current is zero, and the latitudinal extent L_1 degree where the return current terminates.

The latitude-local time and latitude-longitude cross sections are set on the spherical surface through the center of EEJ on which latitude is measured northwards while local time and longitude are eastwards. The cross sections are calculated and constructed with the all-longitude and daytime means on the basis of the continuous distribution of current density model. The implications of other cross sections based on other spherical surfaces or on the parameters at a selected local time, or on the parameters of a selected longitude are indicated.

Essentially the cross sections demonstrate that In the case of latitude-local time cross section: (i) Along a circle of latitude, the current increases from morning to a maximum around local noon and then decreases towards evening. (ii) At a local time in daytime, the forward current is maximum at the magnetic dip equator, the current is zero at w^0 dip latitude, the return current is maximum at $x_m{}^0$ dip latitude and terminates at $L^0{}_1$ dip latitude. (2) In the case of latitude-longitude cross-section: (i) Along a circle of latitude, the current has maxima at about 100°E, 190°E, and 290°E, major minima at about 140°E and 230°E, and subsidiary minima at about 20°E and 60°E. (ii) Along a meridian of longitude, the current varies with latitude as in 1 (ii) above.

Because of the variation of the current with local time and latitude as in (1) above, the latitude-local time cross-section displays three contour cells. The contour cell of the forward current peaks at (12 h, 0^0). The contour cells of the return current peak at (12 h, 5.13°N) in the northern hemisphere and at (12 h, 5.13°S) in the southern hemisphere.

Because of the variation of the EEJ current with latitude and longitude as in (2) above, the latitude-longitude cross-section displays 9 contour cells. The 3 contour cells of the forward current peak at (0^0, 100°E), (0^0, 190^0) and (0^0, 290°E). The six contour cells of the return current peak at (5.35°N, 100°E), (5.05°N, 190°E) (5.300N, 290°E) in the northern hemisphere; and at (5.35°S, 100°E), (5.05°S, 190°E) and (5.30°S, 290°E) in the southern hemisphere. On the whole, they constitute a beautiful pattern.

The latitude-local time and latitude-longitude cross sections show that the return current spreads thinly over an area of about four times the area of the forward current. As a result of this, the peak return current intensity J_m is only about one quarter of the peak forward current intensity J_0. On the average their percentage ratio is $100_m/J_0$ = -23.25 ±0.41.

These first latitude-local time and latitude-longitude cross sections of EEJ current density and intensity show that the contours extend farther in latitude when the peak current at the dip equator is larger. This arises from a combination of two factors: (1) in general, the current decreases with latitude, and at the same time, (ii) the current is larger everywhere when the peak current at the magnetic dip equator is larger.

We find no precedents to compare with the cross sections.

REFERENCE

Davis T.N, Burrows K., and J.D. Stolarik, 1967 A latitude survey of the equatorial electrojet with rocket-borne Mangnetometers, J. Geophys. Res., 72: 1845 -1861

Onwumechili C.A., 1965 A three dimensional model of density distribution in ionospheric current causing part of quiet day geomagnetic variations, proc. Second International Symposium on Equatorial astronomy, ed. F. de Mendoncs, , Brazilian Space Commission, Sac Paulo, pp. 384 – 386.

Onwumechili C. A. and P. O. Ezema, 1992, Latitudinal and vertical parameters of equatorial electrojet from an autonomous data set J. Atoms. Terr. Phys., 54: 1535 –1544.

Singh A and K.D. Cole, 1987 A numerical model of the ionospheric dynamo – II. Electric current at equatorial and low latitudes, J.Atmos. Terr. Phys.; 54: 1535 –1544.

Sugiura M. and d. J. Poros, 1969 An improved model equatorial electrojet with a meridional current system, J. Geophys. Res., 74: 4025 -4034

Untiedt J., 1967 A model of the equatorial eleectrojet involving meridional currents. J. Geophys. Res., 72: 7599 -5810