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Mishin, V.M., Nemtsova, E.I., Urbanovich, V.D. "Sezonnie izmeneniia sredneshirotnykh Sq-tokov po dannim MGG."
Akademiya Nauk SSSR, Sibirskoe otdelenie.Sibirskogo Instituta Zemnogo Magnetizma Ionosferi i Rasprostraneniya Radiovoln, Izvestiya, No.1, 90-101 (1966).

SEASONAL VARIATIONS OF MEDIUM-LATITUDE Sq CURRENTS ACCORDING TO MGG DATA (IGY)

N.L.

by: V.M. Mishin, E.I. Nemtsova, V.D. Urbanovich

Introduction

During the so-called "quiet days" free from the effects of sun activity, there are observed on the surface of the Earth certain changes in the magnetic field which accompany the 24 hour period, and which are called the quiet daily-sun variations and marked by the symbol Sq. The Sq variations reach their maxima during the hours of the day and the local summer season, in other words, they are connected with the conditions of lighting of the earth and its upper atmosphere by the Sun. These facts served as a basis for the modern dynamo-theory of Sq-variations, according to which Sq variations are created mainly by currents in the ionosphere; the electric conductivity of the latter is determined by the lighting conditions. In this manner, the regularities of seasonal chenges in the Sq-field relate to the number of the basic experimental facts which resulted in the creation of the dynamo-theory of Sq variations.

According to classical concepts /1/, the basic detail in seasonal changes of the Sq-field is as follows: the intensities of the northern and southern Sq-vortices (turbulences) change

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from winter to summer in the anti-phase in such a way that the intensity of each turbulence during the local summer exceeds by several times the intensity of the turbulence during the local winter; during the equinox $I_N \approx I_S$. In a series of subsequent articles /2 - 6/ the seasonal changes in the latitude of Sq-current focuses are noted, as well as the changes in location and intensity of the equatorial electric flux. However, a sufficiently complete picture of seasonal changes in Sq-currents has, apparently not yet been clarified. Thus, for instance, the relation I_{sum}/I_{wint} fluctuates according to the data from different authors /1, 3 - 5/ from 2 to 6; the annual progress of this relation has been investigated only with data obtained for three seasons; the seasonal variations of the Sq-field during different hours of the universal time have not been studied. For these reasons, as well as in connection with certain /7/ results obtained, the authors of the present article have undertaken an attempt to investigate the certain additional data on details in seasonal changes of the Sq-field.

A typical system of ionospheric currents responsible for the Sq-variations is presented in Figure 1. It shows that its basic parameters are the values of intensity of the northern and southern current vortices, the coordinates of the foci, the distribution of current density in the coordinates φ ,t. We analyze below the seasonal changes of these basic parameters of the Sq-currents, based on data for each of the 12 months of the year. Together with the mean daily systems of the Sq-currents

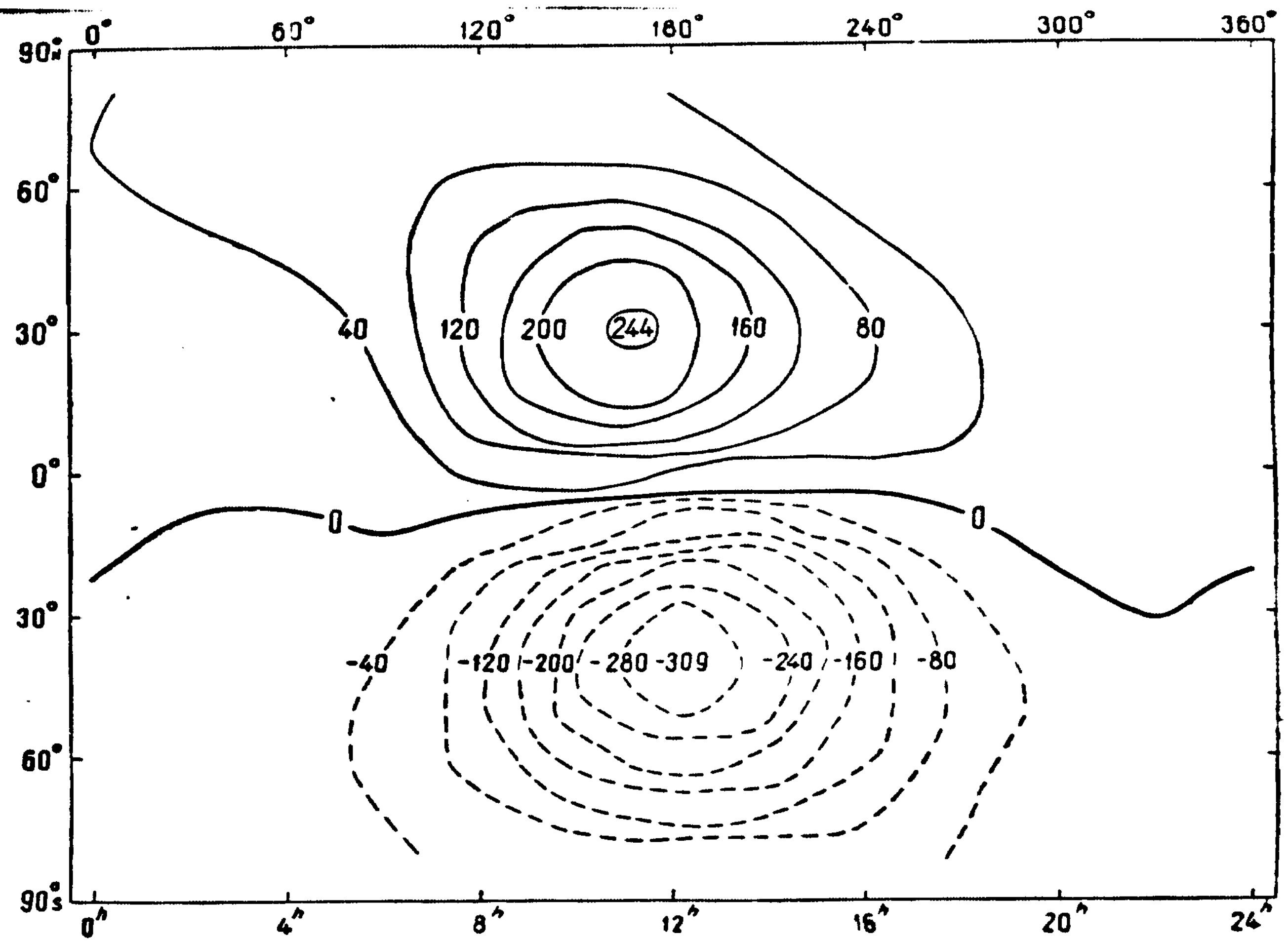

Fig. 1. External system of Sq-currents according to data of the American longitudinal sector. April 1958, local time. Units of current strength: 40,000A.

- Table 1

Observatory / Обсерватории	φ		λ		Observatory / Обсерватории	φ		λ	
Sitka 1. Ситка	57°04′	с. ш.	135°20′	з. д.	Palmyra 14. Пальмура	5°53′	с. ш.	162°05′	з. д.
Victoria 2. Виктория	48°31′	»	123°25′	»	Paramaribo 15. Парамарибо	5°50′	»	55°10′	»
Agincourt 3. Аженкорт	43°47′	»	79°16′	»	Foukene 16. Фукэне	5°28′	»	73°44′	»
Price 4. Прайс	39°36′	»	110°50′	»	Fanning 17. Фаннинг	3°54′	»	159°23′	»
Beloitte 5. Белойт	39°29′	»	98°08′	»	Jarvis 18. Джарвис	00°23′	ю. ш.	160°02′	»
Carrolton 6. Карролтон	39°22′	»	93°32′	»	Talara 19. Талара	4°36′	»	81°18′	»
Fredericksbourg 7. Фредериксбург	38°12′	»	77°22′	»	Chiklayo 20. Чиклайо	6°48′	»	79°48′	»
Espanola 8. Эспанола	35°59′	»	106°03′	»	Wankayo 21. Уанкайо	12°02′	»	75°19′	»
Tucson 9. Таксон	32°15′	»	110°50′	»	Appia 22. Апиа	13°48′	»	171°46′	»
Honolulu 10. Гонолулу	21°18′	»	158°06′	»	Yucca 23. Яука	15°32′	»	74°40′	»
Teoloucan 11. Теолоюкан	18°45′	»	99°11′	»	Moti Tahiti 24. Моти Тахити	17°33′	»	149°37′	»
San Juan 12. Сан Хуан	18°28′	»	66°07′	»	Trelieu 25. Трелью	43°15′	»	65°19′	»
Chimboat 13. Чимбот	9°06′	»	78°36′	»	Argentine Islds 26. Аргентинские о-ва	65°15′	»	64°16′	»

we have briefly investigated the seasonal changes in the parameters of the "instantaneous" current systems.

The average (mean) Sq-fields were investigated based on the data from the stations in the American section of logitudes ($\lambda = 190^\circ - 320^\circ$, see Table I). The "instantaneous" Sq-fields were calculated based on data of stations listed in /7/. The study has been completed following the materials received from observations during the IGY period within the latitude limits of $|\varphi| < 60^\circ$.

Method of Analysis

In order to calculate the mean daily Sq-fields we completed the usual spherical harmonic analysis described in /8/ as the "algorithm A". In order to approximate the Sq-fields the following series of spherical functions were utilized: $S_n^m(\theta, \lambda)$ with n = 1 - 4 and m = 1 - 4. Afterwards, based on the results of the analysis external and internal "equivalent systems of currents" were built and the values of the modulus of current density* in points located at a distance of 10° latitudinally and 15° longitudinally from each other. Near the focuses the values I (current function) and j(current density) was computed every

*) $j_e = \sqrt{\left(\frac{\partial I_e}{a \sin\theta \partial\lambda}\right)^2 + \left(\frac{\partial I_e}{a \partial\theta}\right)^2}$, where I is the current function.

3^o latitudinally and every 5^o longitudinally.

"Instantaneous" Sq-fields are calculated in the manner described in /8/ and /9/.

Seasonal Changes in Mean Daily Sq-currents

The basic parameters in the mean daily systems of Sq-currents are the focal values I which characterize the complete intensity of the Sq-vortices and their coordinates of the focuses are presented in Table 2. This table also shows the parameters of the points with maximal values of current densities. Seasonal changes of the basic parameters of Sq-currents are also shown in Figs. 2 and 3. Table 3 presents results of the harmonic analysis of the annual progress of the I_N and I_S magnitudes. The basic rules can be summed up as follows:

1. Fig. 2 illustrates the motion of the focuses of Sq-vortices during one year and the annual changes in the coordinates of the $j = j_{max}$ point. It is apparent that the changes in latitude in these three points are, in their main aspect, similar to those and may be connected with the annual changes in the geographic latitude of the subsolar point. Simultaneously, it is also apparent that the annual changes in the latitude of the focuses are not large (amplitude < 5^o) and are not regular. This fact evidently explains the disagreements apparent in the deductions of several authors /1 - 6/ who investigated the changes in latitude of the focuses during the changeover from winter to summer.

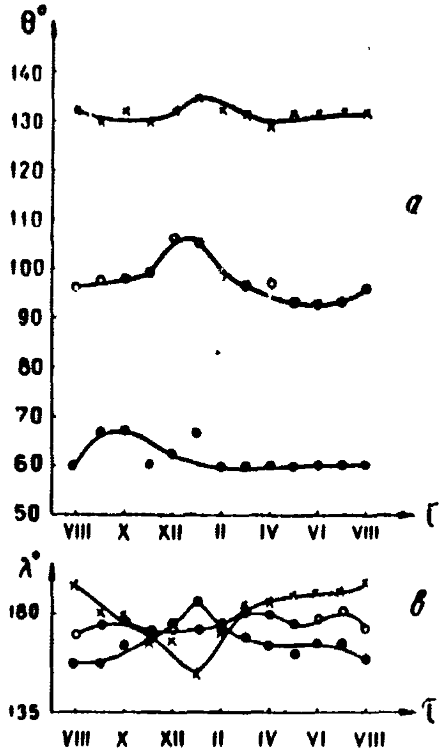

Fig. 2. Change in co-latitude (a) and (b) longitude of the foci of the external system of Sq-currents -- variations and points corresponding to the maximum intensity of current in the course of one year. American longitudinal sector:

Fig. 2

● position of northern foeus;
x position of southern focus;
0 position of point corresponding to maximum current.

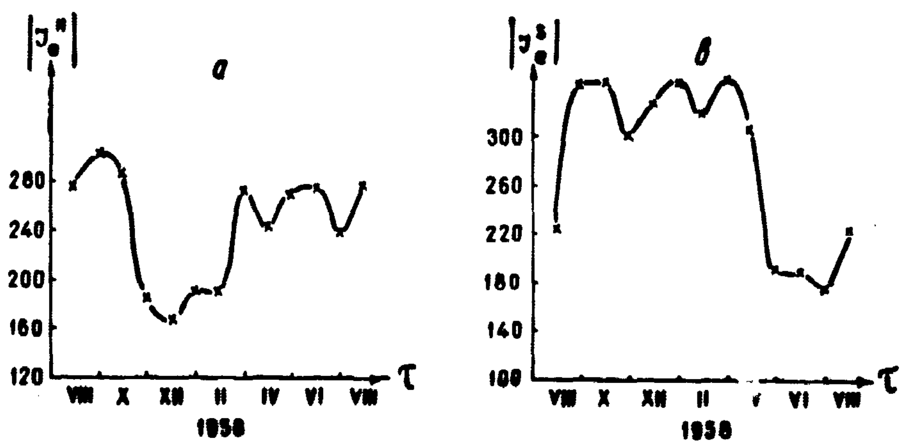

Fig. 3. Change in intensity of the (a) northern and (b) southern Sq-turbulences in the course of a year. Units of intensity: 1000A.

Table 2

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
$I_n \cdot 10_a^{-3}$	191,9	190,1	276,3	243,0	269,9	276,0	236,0	277,6	303,7	287,3	186,0	166,3
θ_n°	66	60	60	60	60	60	60	60	66	66	60	63
λ_n°	165	170	170	165	160	165	165	155	155	165	165	170
$I_s \cdot 10_a^{-3}$	−344,2	−320,8	−347,9	−306,4	−191,1	−191,4	−175,6	−224,7	−343,0	−346,1	−300,0	−327,4
θ_s°	133	132	132	129	132	132	132	132	130	132	130	132
λ_s°	150	170	185	185	190	190	190	195	180	180	165	165
θ_j°	102	96	96	96	96	96	96	96	99	99	96	102
λ_j°	165	170	180	175	170	175	180	170	170	170	165	170

Note: I_N, I_S - the intensity of the northern (southern) ionospheric current vortex.

θ_n, λ_n (θ_s, λ_s) co-latitude and longitude of the N (S) focus

θ_j λ_j co-latitude and longitude of maximum current density.

Fig. 2 demonstrates also that there exist clearly-defined seasonal changes, heretofore not noticed in the logitude (local time) of focuses. These changes are described by a simple wave with extremes in the mid-winter period and the mid-summer period and an amplitude of about 30^{o}(2 hours). The longitudinal movement of the focuses in the two hemispheres occurs in the antiphase.

It is interesting to note that annual changes in the longitude of focuses of internal Sq-currents are analogous to those for external currents, however, the amplitude of these changes is greater than for the external systems. The latitude of the southern focus of the internal current system changes, within one year more than 15^{o}.

2. Fig. 3 and Table 3 show that the intensity of the northern and southern Sq-vortices (turbulences) are subjected to a clear-cut seasonal motion with maxima in mid-summer (local) and during the equinox season. The amplitudes of the two basic waves in the annual motion I_N and I_S, in other words, the amplitudes of waves with annual and semi-annual peiods are comparable, although the annual wave is predominant, especially in the southern hemisphere. We may note that the amplitudes of both harmonics in the southern hemisphere are larger than those in the northern hemisphere.

Data presented in Fig. 3 and Table 3 contain two additional basic characteristics when compared with those known previously.

First of all, the amplitude of the annual wave I_N and I_S according to data in Table 3 does not exceed 25% of the mean annual level. This magnitude is considerably smaller than the winter-summer half-difference according to data in /1/ and seems to be more acceptable from the position of the dynamo-theory of Sq-current generation. As a matter of fact, the amplitude of an annual motion of the electric conductivity of the atmosphere, when proceeding from the relation $\sigma \sim \sqrt{\cos \chi}$ does not exceed 20% of the mean annual level, while in the low latitudes, where the basic Sq-currents are found, this magnitude is < 10%.

Secondly, the amplitude of a semi-annual wave (about 15% of the mean annual level) is close to the amplitude of the anual wave and, in conformity with this fact, occurs simultaneously with the summer one, having equinox maxima I_N and I_S.

The phases of the semi-annual wave (see Table 3) differ from these equinox periods (22 March, 22 September) only by about 2 to 4 days.

Additional computations have shown that the semi-annual wave is present in the density of external Sq-currents on all latitudes. Its maximum phases are close everywhere to the equinox moments while the amplitudes change depending upon the latitude and the local time of day. The amplitudes reach thair maximum in the daylight hours and at the equator. At noon, at the equator the amplitude of a semi-annual wave of the current density reaches about 20 amp/km.

Table 3

Parameters	$R_1 \cdot 10^{-3}$	φ_1°	$R_2 \cdot 10^{-3}$	φ_2°	$A_0 \cdot 10^{-3}$	R_1/R_2
I_N	45	191,5	35	172	242	1,3
I_S	75,2	356	46,0	165	285	1,6

Note: $I_N(I_S)$ is the intensity of the northern (southern) ionospheric vortex.

$R_1(R_2)$ is the amplitude of the first (2nd) harmonic.

phase of the first (2nd) harmonic.

A_0 is the mean annual value I_N (I_S).

On latitudes $|\varphi| = 60^\circ$ the amplitude is about 10 amp/km. The relation of these magnitudes to the mean annual value of the current density is, in both cases, close to 0.2.

The existence of a semi-annual wave in the yearly progress of I_N, I_S and the Sq-current densities are difficult to understand when starting with the classical concepts of the nature of Sq-currents. The authors /10/ who obtained an analogous result independently, assume that the semi-annual wave in I_N and I_S is connected with the semi-annual changes in the densities of the upper atmosphere which have been found at a 200km altitude, according to data on the braking of satellites.

Let us point out at present that the equinox maxima I_N and I_S have not been observed during the period of minimum sun activity in 1902 /1/. E.N. Nemtsova is preparing a publication with data which show that these maxima were not observed during the II IGY which was similarly a year of minimal sun activity.

3. We have noted above that seasonal changes in the parameters of the internal Sq-currents, in many cases, have a greater amplitude than the seasonal changes in external currents. This leads us to believe that seasonal changes in internal Sq-currents become stronger (in comparison with external ones) due to the existencem in the thin carrying layer inside of the Earth of sharp gradients of electric conductivity along the latitude and the longitude. In connection with this, Fig. 4 shows seasonal changes in the I_e/I_1 magnitude -- which is the relation of intensities of external and internal Sq-vortices. This relation characterizes the distribution in space of electric conductivity of that region of the Earth where induced Sq-currents are flowing. It is apparent that seasonal changes I_e/I_1 have a regular character and amplitude outside the limit of errors of the spherical analysis.

Inasmuch as the seasonal motions of the Sq-currents take place in the longitudinal direction, data in Fig. 4 may be interpreted to indicate that there exist considerable gradients in the electric conductivity of Earth along the longitude (in the American logitude section). This fact is another qualitative confirmation (independently obtained) of the deductions in /7/ and /11/.

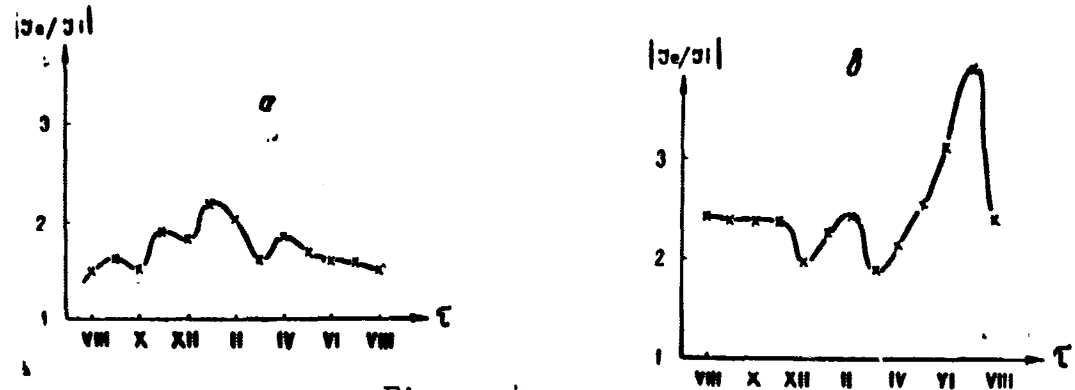

Figure 4
Changes in the relation of intensity between the external Sq-vortex and the internal Sq-vortex during a one-year period:

a. northern hemisphere

b. southern hemisphere

Table 4

	$I_N \cdot 10^{-3}$	θ°_N	λ°_N	$I_S \cdot 10^{-3}$	θ°_S	λ°_S
Summer.......	253	60	165	−114	114	210
Equinox......	225	57	180	−209	114	180
Winter.......	113	57	185	−220	117	170

Note: I_N(I_S) is the intensity of the northern (southern) ionosphere current vortex.

θ_N λ_N (θ_S λ_S) co-latitude and longitude of the northern (southern) focus.

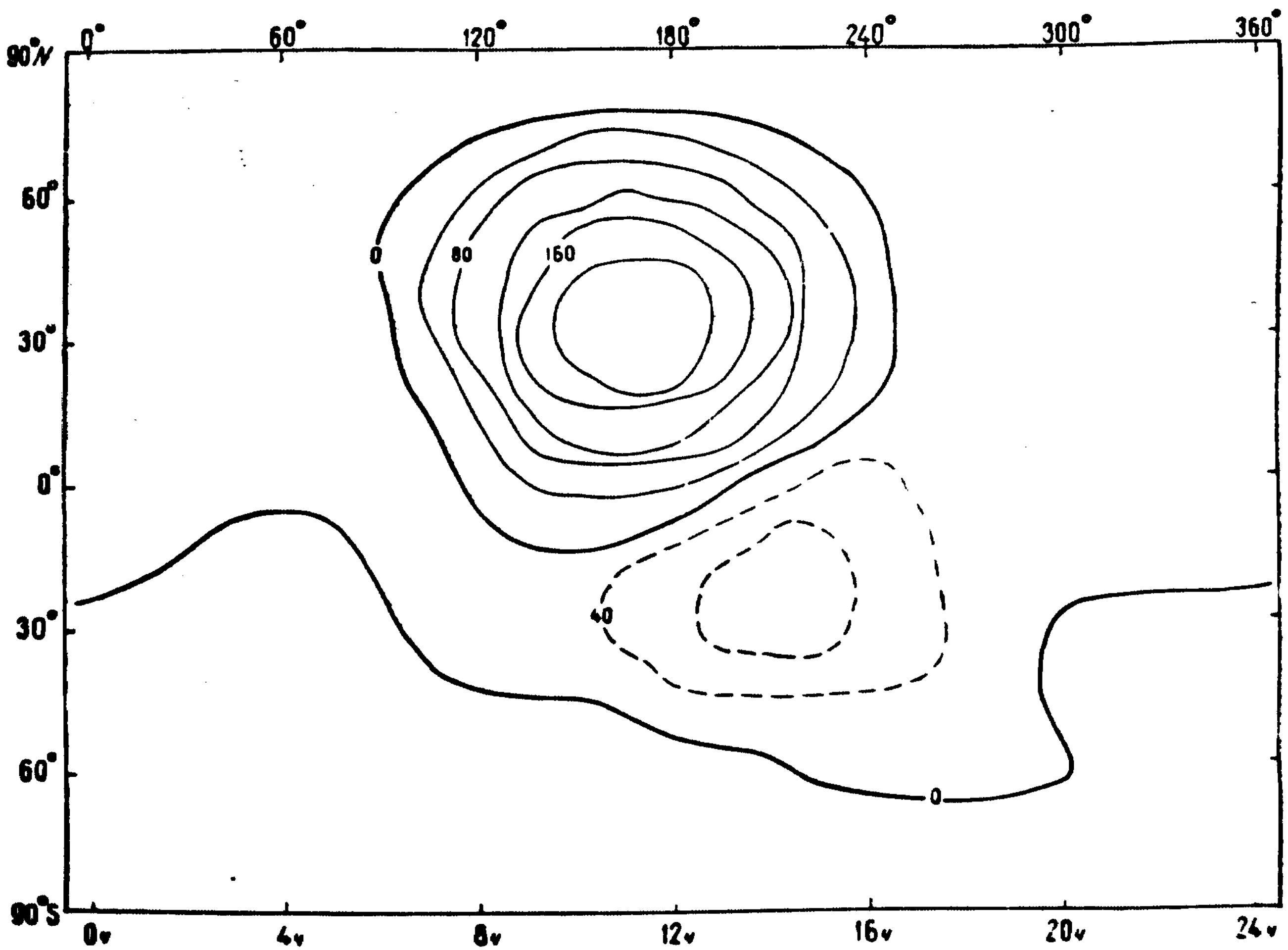

Fig. 5

External "instantaneous" system of currents at 3.5 o'clock universal time. Summer 1958. Local time. Unit of current measure, 40,000 A.

On Seasonal Variations in "Instantaneous" Systems of Sq-Currents

In this chapter the problem is to compare the seasonal changes in the mean daily and "instantaneous" systems of the Sq-currents. In order to achieve this aim and using the method described in /8, 9/ we performed a spherical harmonic analysis of Sq-fields with given values δX, δY, δZ * at a station network listed in /7/, at 3.5 o'clock universal time. The analysis was conducted according to data averaged for each season: V - VII, XI - II and equinox.

The "instantaneous" equivalent systems of currents at 3.5 o'clock universal time and the three seasons of the year are shown in Figs. 5, 6, and 7. Table 4 brings the basic parameters of ionospheric current systems. It is apparent that seasonal changes in the parameters of "instantaneous" Sq-currents are similar to those which have been described above for mean daily current systems. In the annual progress I_N and I_S we see local summer maxima and during the equinox season. We can also perceive seasonal changes in the focus logitude which occur in opposite directions in the northern and southern hemispheres. Seasonal changes in the focus longitude are very small.

Simultaneously, seasonal changes of "instantaneous" Sq-currents reveal, in comparison with the mean daily (24 hour) currents

* here, as in the previous chapters, δX, δY, δZ are the deflections of X, Y, Z from their values duering the night hours, averaged by international quiet days.

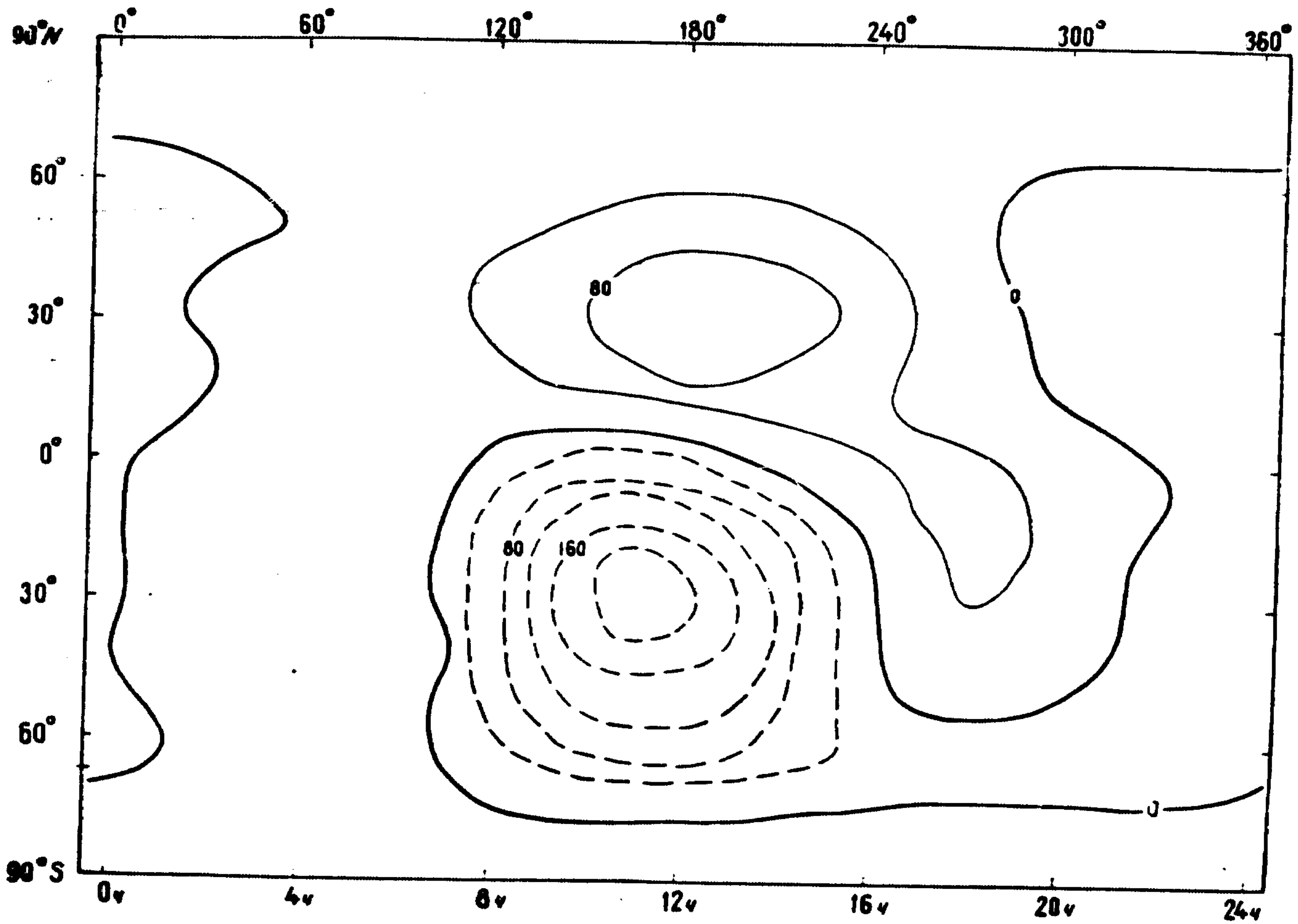

Fig. 6. External "instantaneous" system of currents at 3.5 o'clock universal time. Winter 1958. Local time. Unit of current measure, 40,000 A.

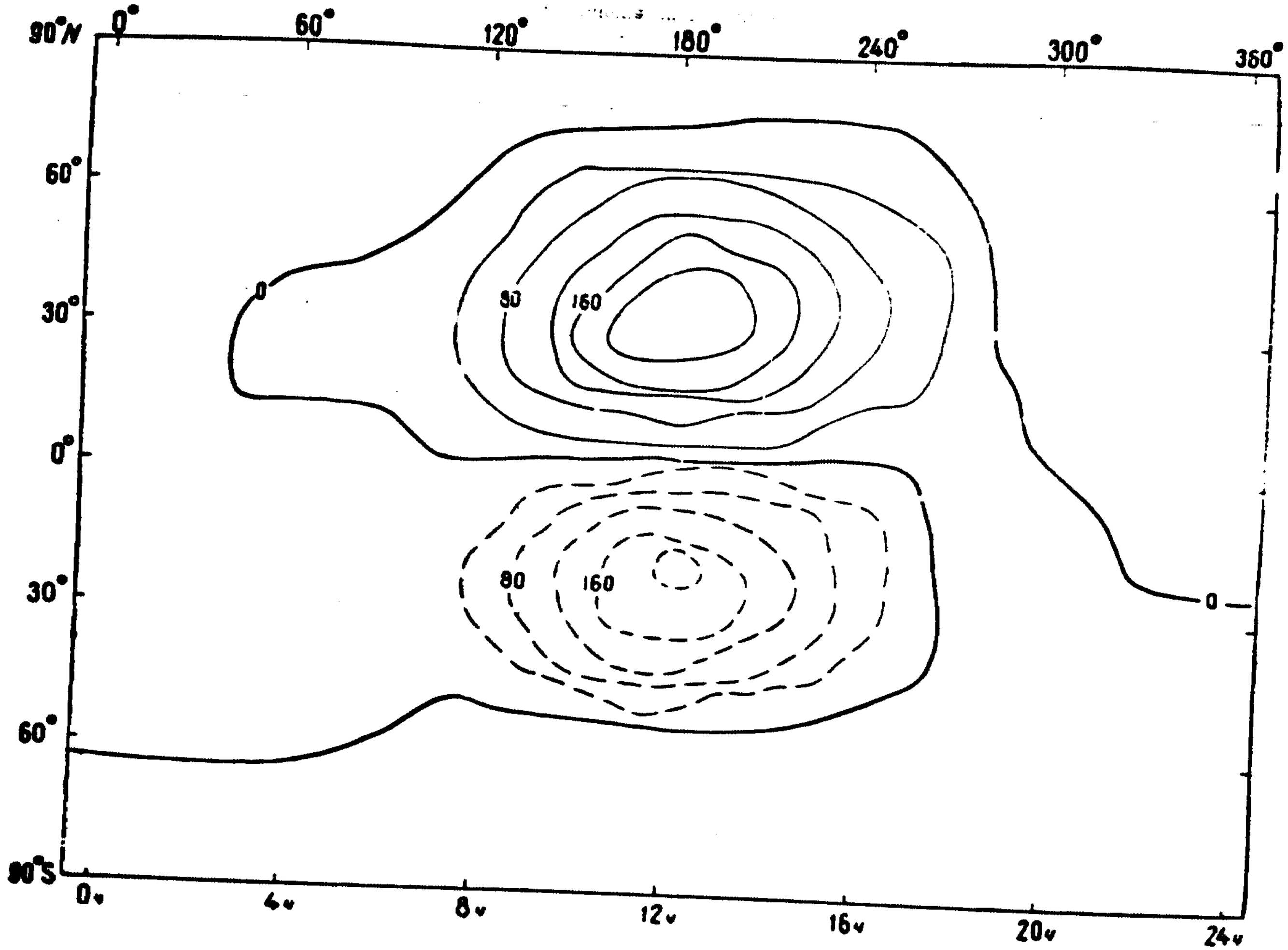

Fig. 7. External "instantaneous" system of currents at 3.5 o'clock universal time. Equinox 1958. Local time. Current measured in units of 40,000 A.

some important peculiarities; their analysis will be presented in the next article.

The authors extend their thanks to N.G. Khmelevskaya for her help in the preparation of initial data.

BIBLIOGRAPHY

1. S. Chapman, J Bartels. Geomagnetism. Oxford, 1940.
2. M. Hasegawa, J. Geophys. Res., 65, N 5, 1437, 1960.
3. A. T. Price, G. A. Wilkins. Phil. Frans. Roy. Soc. A, 256, 1066, 31, 1963.
4. A. T. Price, D. J. Stone. Annals of the IGY, XXXV, part III, p 69, 1964.
5. S. Matsushita. J. Geophys. Research, 65, N 11, 3835, 1960.
6. M. Fatkulin, Ya. Fel'dshtein. Geomagnetizm i Aeronomiya, No. 5, p. 858, 1965.
7. A.D.Bazarzhapov, V.M. Mishin, E.I. Nemtsova, M.E. Sholno. This collection
8. A.D.Bazarzhapov, V.M. Mishin, E.I. Nemtsova, M.L. Platonov, collection "Geomagnitnye issledovaniya" (Geomagnetical research) No. 8, 1966.
9. V.M. Mishin, A.D. Bazarzhapov, coll. "Geomagnitnye issledovaniya", No. 8, 1960.
10. S. Matsushita, M. Haeda, J. Geophys. Res., 70, N 11, p.2535, 1965.
11. V.M. Mishin, Geomagnetizm i Aeronomia, 1966 (at printer's)

article submitted

21 April, 1966

Translated by
Translation and Interpretation Div.
INSTITUTE OF MODERN LANGUAGES
WASHINGTON, D.C.

Under contract with the NASA Goddard Space Flight Center, Greenbelt, Md., 1968.