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THE POSSIBLE MECHANIZM OF SEMIANNUAL VARIATIONS IN THE IONOSPHERE BY DATA OF TBILISI CITY

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ABSTRACT. The degree of ionization in the ionosphere, corresponding to a given zenith angle χ_0 is delayed by τ minute due to the sluggishness of ionosphere. Therefore the electrons concentration at a given χ_0 corresponds to $\chi_1 = |\chi_0| + \Delta\chi$ forenoon and $\chi_2 = -|\chi_0| + \Delta\chi$ afternoon. It follows that $\Delta\chi = 1/2(\chi_1 + \chi_2)$. It is possible to calculate χ_1 and χ_2 using well-known formula $\cos\chi = \sin\varphi \cdot \sin\delta + \cos\varphi \cdot \cos\delta \cdot \cos(T-12-\tau)$. First we calculate T_0, corresponding χ_0 in case of $\tau = 0$. Therefore, it is possible to calculate $\Delta\chi$ for fixed τ. On the other hand, if we calculate $V = |d\chi/dt|$ for χ_0 it becomes clear that $\Delta\chi = V \cdot \tau$. Consequently, forenoon the more $\Delta\chi$, the more χ_1 and so less the electrons concentration. Analogically, in the afternoon the more $\Delta\chi$ the less χ_2 and thus more the electrons concentration.

The data obtained at the ionospheric observatory of Tbilisi State University during 1964-1986 years have been analyzed. It is shown that $f_oE(\cos\chi = 0.2)$ has semiannual variations; at the same time the evening values of this parameter change in phase with seasonal variation of $\Delta\chi$ and morning values – in opposite phase. The correlation coefficients are 0.91 and - 0.85, respectively.

It is shown that semiannual variations are connected with Sun-Earth geometry (V) and sluggishness of ionosphere (τ). It is also shown, that the dependence between τ and solar activity (F10.7) is linear.

1. INTRODUCTION

Semiannual variations (SAV) are the variations for a six month period. If investigated quantity has equinox maximums, it's called direct SAV, but if it has minimums, than it's inverse variation.

The SAV is different from annual variations, among them seasonal variation is the most known. Seasonal variations are caused by inclination of the earth axis to the plane of ecliptic. That's why northern hemisphere takes the maximum heat from the sun during the time of summer solstice and minimum heat at time of winter solstice. In southern hemisphere seasonal-annual wave is changed in phase just with 180^0 relatively a northern hemisphere.

Consideration on the whole complex of existed facts that almost all geophysical phenomena, which proceed at a height more than ~ 90 km, experiences the SAV [1]. Thus, rhithm of SAV contains all thickness of the upper atmosphere. It is shown in [2,3], that the velocity of solar senith angle change is also subjected to SAV. An opinion on two basic sources of SAV: electromagnetic (equatorial region) and corpuscular (middle and high latitudes) has been forwed [1]. Yonezawa dedicated numerous works to SAV [4,5]. The authors of [6] suggest a new possible mechanizm of SAV at low latitudes: the semiannual variation of the amplitude of the diurnal tide in the lower thermosphere induces the semiannual variation of quatorial electrojet in the ionospheric E layer. It induces the semiannual variation of amplitude of ionospheric equatorial anomaly through the 'fountain effect'. This process causes the semiannual variation of the low latitude N_mF2.

Till today the researchers of this question haven't applied Sun-Earth geometry and sluggishness of ionosphere to explain SAV. It is shown in this work that SAV of E layer critical frequency (f_oE) is connected with Sun-Earth geometry and sluggisness of ionosphere.

2. **Theory**

It is established by different experiments that variation of N_mE will be described rather well by equation $N_mE \approx \sqrt{\cos\chi}$, where χ is the Sun's zenith angle. On the other hand, it is possible to make a good approximation to N(z)E by parabola. Critical frequency of E layer $f_oE \sim \sqrt{Nm}$ [7]. The investigation of tabulate critical frequency shows, that it is described well by the equation:

$$f_oE = (f_oE)_0 \cdot (\cos \chi)^{n}, \tag{1}$$

where $n = 0.25$ as it must be for equilibrium layer of Chapman [8].

The degree of ionization in the ionosphere, corresponding a given zenith angle χ_0 is delayed by τ minutes due to the sluggishness of ionosphere [9]. Therefore the electrons concentration at a given χ_0 corresponds to $\chi_1 = |\chi_0| + \Delta\chi$ forenoon (morn.) and $\chi_2 = -|\chi_0| + \Delta\chi$ afternoon (even.); therefore $\Delta\chi = 1/2*(\chi_1 + \chi_2)$. It is possible to calculate χ_1 and χ_2 by well-known formula in astronomy

$$\cos\chi = \sin\varphi \cdot \sin\delta + \cos\varphi \cdot \cos\delta \cdot \cos(T\text{-}12\text{-}\tau) \tag{2}$$

first T_0 is calculated, corresponding χ_0 in case $\tau = 0$; i.e. it is possible to calculate $\Delta\chi$ for fixed τ. On the other hand, if we calculate $V = |d\chi/dt|$ [3] for χ_0, it becomes clear that $\Delta\chi = V*\tau$. Corresponding calculations are given in Table1. Consequently forenoon the more $\Delta\chi$ the more χ_1 and so less the electrons concentration . Analogically, afternoon the more $\Delta\chi$ the less χ_2 and so more the electrons concentration

The influence of sluggishness of ionosphere on the absorption radiowave is shown in [10]. Not only absorption is subjected to SAV, but other parameters of ionosphere, such as critical frequencies of E and F2 layers - f_oE and foF2.

If ionosphere hasn't sluggishness, i.e. $\tau = 0$ and following $\Delta\chi = 0$; resulting $f_oE(\cos\chi = \text{const.})$ must be just the same for every month.

If $\tau =$ const. ($\tau \neq 0$) in expession $\Delta\chi = V*\tau$, then variation of $\Delta\chi$ must be caused by variation of V; i.e. according to above given opinion, seasonal variation of morning values of $f_oE(\chi_0)$ must being in oposite phase with seasonal variation of V, and evening one – in phase. In the Fig.1 are showed seasonal variations of V and f_oE

Table 1.

Tbilisi

Values of Dc and Vt cos c = 0.2 t = 15min

φ =	42											
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
δ	**-21**	**-13**	**-2**	**10**	**19**	**23**	**22**	**14**	**3**	**-8**	**-18**	**-23**
Tm (0.2)morn	8.62	7.93	7.17	6.44	5.90	5.66	5.72	6.20	6.86	7.56	8.34	8.83
Te (0.2)even	15.38	16.07	16.83	17.56	18.10	18.34	18.28	17.80	17.14	16.44	15.66	15.17
P	-0.24	-0.15	-0.02	0.12	0.22	0.26	0.25	0.16	0.04	-0.09	-0.21	-0.26
Q	0.69	0.72	0.74	0.73	0.70	0.68	0.69	0.72	0.74	0.74	0.71	0.68
mor.cos(t-τ)	0.58	0.43	0.24	0.05	-0.09	-0.15	-0.14	-0.01	0.16	0.34	0.52	0.62
eve.cos(t-τ)	0.68	0.54	0.36	0.18	0.04	-0.02	-0.01	0.12	0.29	0.46	0.63	0.72
mcosχ	0.16	0.16	0.15	0.15	0.15	0.16	0.16	0.15	0.15	0.16	0.16	0.17
ecosχ	0.23	0.24	0.25	0.25	0.25	0.24	0.25	0.25	0.25	0.24	0.24	0.23
V(cosχ = 0.2)	0.548	0.647	0.723	0.742	0.717	0.695	0.701	0.735	0.738	0.689	0.590	0.515
χ_1	1.406	1.4123	1.417	1.418	1.416	1.415	1.415	1.417	1.4179	1.415	1.409	1.404
χ_2	-1.334	-1.328	-1.322	-1.321	-1.322	-1.324	-1.3232	-1.321	-1.321	-1.32	-1.332	-1.337
$\Delta\chi = 1/2(\chi_1+\chi_2)$	**0.0358**	**0.0423**	**0.0473**	**0.0486**	**0.0469**	**0.0455**	**0.0459**	**0.0481**	**0.0483**	**0.0451**	**0.0386**	**0.0337**
Vτ	**0.0358**	**0.0423**	**0.0473**	**0.0486**	**0.0469**	**0.0455**	**0.0459**	**0.0481**	**0.0483**	**0.0451**	**0.0386**	**0.0337**

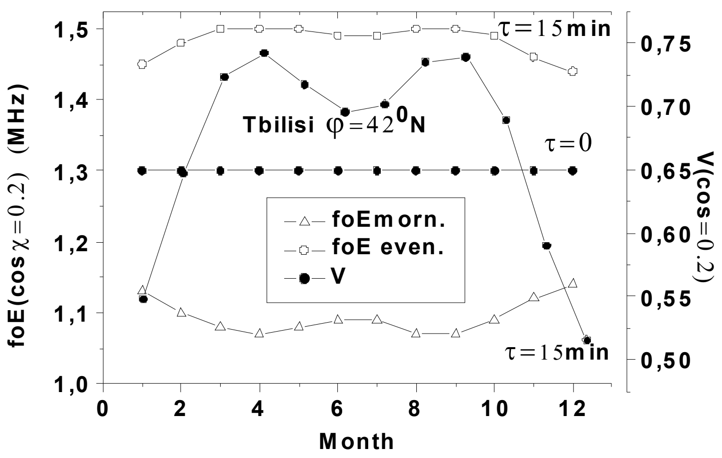

Fig.1. Seasonal variations of foE(cosχ = 0.2) and sun's angular rate V(cosχ = 0.2) (theoretical values)

(calculated by formula (3)) for the data: $\varphi = 42^0$, $(f_oE)_o = 4$MHz; n = 0.70; τ =15 min; cos $\cos\chi_0 = 0.2$

$$f_oE(\chi_0) = (f_oE)_o\cdot[(P + Q\cdot\cos(T_o\text{-}12\text{-}\tau))]^n , \qquad (3)$$

where $P = \sin\varphi\cdot\sin\delta$, $Q = \cos\varphi\cdot\cos\delta$. This confirms the above opinion.

3. EXSPERIMENTAL RESULTS

The data obtained at the ionosphere observatory of Tbilisi State University ($\varphi = 42^0$) during 1964-1986 years have been analyzed. Polynom of second power was applied for approximation of diurnal variation of f_oE instead of (3) formula. Polynom describes experimental data very good: coefficient correlation R>0.98. $\mathbf{f_oE = \mathit{a}t^2+bt+c}$ formula is much more simple (where **t** local time and f_oE- corresponding critical frequency) than (3). The shift of parabola's peak from 12 o'clock (τ) can be calculated comparatively easy by ***a*** and **b** coefficients.

It is necessary to exclude Sun's activity for investigated seasonal variation of f_oE. f_oE is a function of solar activity as well as of Sun's zenith angle - $f_oE(\chi$, F10.7). To study a dependence of f_oE on the F10.7 it is necessary to fix χ. It was done as for f_oF2 in [11]. Dependence between f_oE and F10.7 is linear, as for f_oF2, but coefficient correlation is smaller than in case of f_oF2. Here it should be noted that more below, in the D region correlation between absorption of radiowave and F10.7 is very bad as it turned out when studing this question.

In Fig.2 seasonal variations of $f_oE(\cos\chi = 0.2)$ and $\Delta\chi = V\cdot\tau$ are given for F10.7 = 150. Correlation coefficients between f_oE and $V\cdot\tau$ are 0.85 (morn.) and 0.91 (even.).

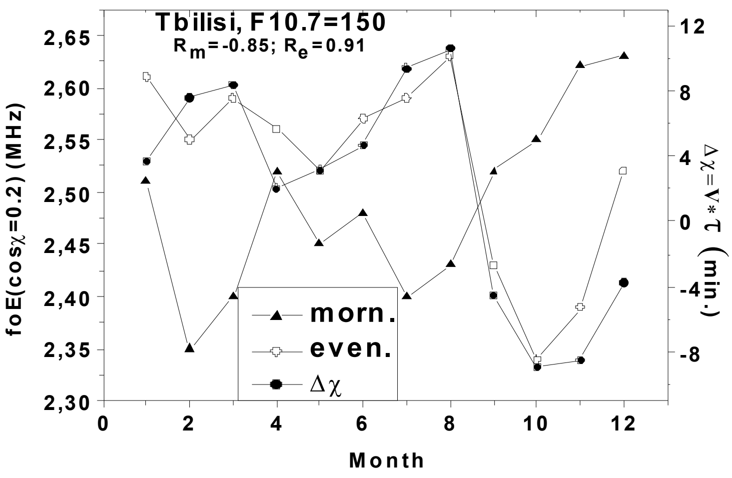

Fig.2. Seasonal variations of $f_oE(\cos\chi = 0.2)$ and $\Delta\chi$ (experimental values)

The dependence of τ on the F10.7 has been studied. It was found that τ increases linearly with increasing of F10.7 (Fig.3). It can be explained in this way: Stream of ionising quantum which incidences on the ionosphere, increases with increasing the Sun's activity. At the same time there takes place a

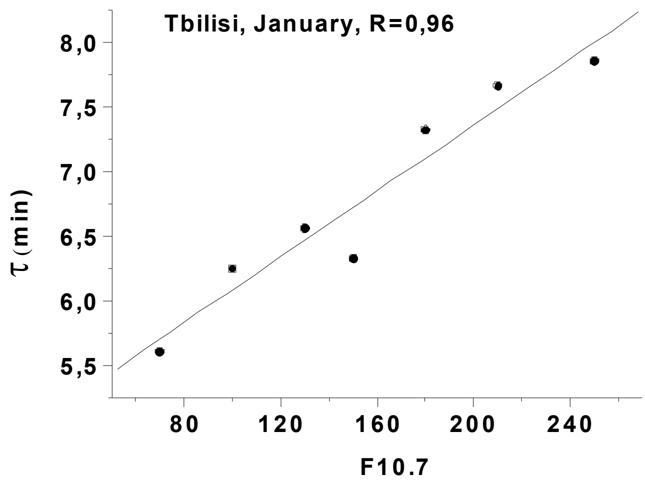

Fig.3. Dependence between time of relaxation and sun's activity.

recombination and the establishment of equilibrium needs more time. As is seen from Fig.2 $V\cdot\tau$ has negative values in some months. As $V > 0$, it is clear that $\tau < 0$ and this has no physical sense. It may be connected with the following fact: as the Earth's orbit is ellipse, in one focus of which the Sun is placed, the Earth performs not uniform motion, or Sun moves on celestial equator faster or slower in different months. Therefore the measure of time in possible – a clock works evenly. In order to have the solar time measured the astronomers had to introduce a certain fictive point refered to as the "average solar body", that actually shifts the "apparent solar body". The "average solar body" moves evenly on celestial equator performing the entire annual detour and is considered by the scientists as an index for average solar time. Daily corrections of time, so-called time equation (η), are given in Astronomic Calendar. Average solar time t_m and appeared solar time t_0 are connected by equation: $t = t_0 + \eta$ [12]. Seasonal variation of monthly mean values of η and τ (for different activity) are given in Fig.4. It is clear that seasonal trends τ and η are similar. Actual measured τ is sum of appear τ (τ_0) and η: $\tau = \tau_0 + \eta$. Therefore, if τ_0 is small τ will become negative.

Table 2.

Correlation coefficient R between t and F10.7

1	2	3	4	5	6	7	8	9	10	11	12
0.96	-0.98	0.98	-0.76	0.99	0.96	1.00	1.00	0.99	0.91	-0.95	0.90

As was noted above, the dependence between τ and F10.7 is linear (Fig.3). The values of correlation coefficient of this dependence are given in Table 2. As is seen for February, April and November correlation coeficients are negative – the increase of activity causes decrease of τ, that cannot be explained the approach by given above.

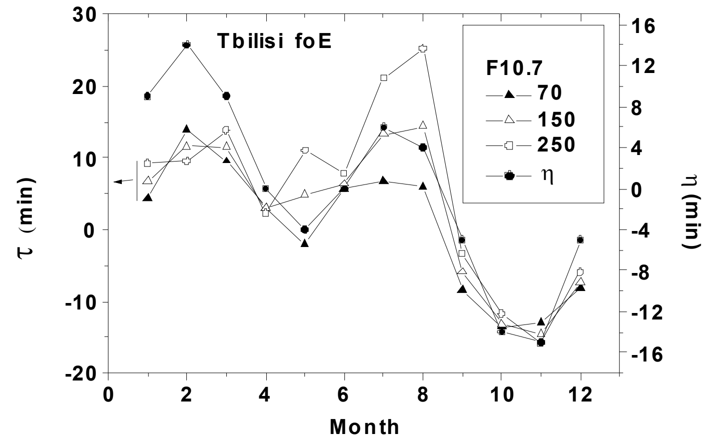

Fig.4. Seasonal variations of relaxation time (experimental values for different activity of sun by f_oE) and time equation

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