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ELECTRIC PROPERTIES OF THERMOSPHERE-PLASMASPHERE SYSTEM ESTIMATED FROM GROUND-BASED DATA

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SUMMARY: The current density in the dynamo region is estimated from thermospheric neutral wind pattern and plasmaspheric electric field. The diurnal variation of the meridional and the zonal component of the neutral wind velocity, is established from the altitudes of the descending sporadic E layer. The diurnal change of the westward electric field that maps from the dynamo region into the plasmasphere is deduced from the whistler data The vertical ionosonde data on sporadic E heights, h'Es, taken at Grocka observatory (44.6°N, 20.8°E), are used. The selected whistlers were recorded at Grocka station (L $\sim$ 1.9). All ground-base data used in this study were registered on quiet days.

1. INTRODUCTION

The solar heating of the stratosphere causes the motion of the neutral particles known as "tidal neutral wind". The energy of neutral particles undergoes wave propagation from the stratosphere, upwards to the thermosphere. The thermosphere is the part of the ionosphere, characterized by the steep increase of the electron temperature. At the same time the phase of the tidal wave propagates downwards, causing the redistribution of the electron density at lower thermosphere. As the result, the thin dense layer known as sporadic E, is formed. The diurnal variation of the neutral wind velocity vector can be determined following the altitudes of descending sporadic E layer. At the region from 80-200 km above the Earth, (dynamo region), the ion drag action of the neutral wind in the geomagnetic field generates the electric field $-\nabla V + \mathbf{u}x\mathbf{B}$. The electric field drives the ionospheric current with density: $\mathbf{j} = \sigma(-\nabla V + \mathbf{u}x\mathbf{B})$. Assuming the "thin shell" (2D) approximation of the polarization field ($\mathbf{E} = -\nabla V$), in the dynamo region and using the estimated wind velocity height profiles, the current density height profiles can be calculated. The values of electric field correspond to those in the plasmasphere. The term plasmasphere refers to a torus-like region in the magnetosphere, that extends above the ionosphere. There is a number of pieces of evidence presented in papers Richmond *et al.* (1976), Carpenter (1978), Richmond, (1979), Rash *et al.* (1986), and others, indicating that the plasmaspheric electric fields are ionospheric dynamo in origin. Namely, the geomagnetic field lines are equipotentials along their entire length between conjugate points, so the electric fields can be mapped between ionosphere and magnetosphere.

2. THEORETICAL BASIS

The first part of the study is based on so called corkscrew mechanism of the sporadic E formation. The theoretical formulation is given by Nygrèn *et al.* (1984). Whether the thin dense layer will be formed at some altitude or not, depends on the couple of conditions considering the local neutral wind pattern. One condition arises from the fact that the vertical ion velocity, v_{iz}, at the altitude of the layer formation, z_0, is zero:

$$v_{iz} = (\cos I/(1+\rho^2))(-\rho u_W - u_N \sin I) = 0 \ , \quad (1a)$$

$$\rho = -\mathrm{ctg}\alpha \sin I \ , \quad (1b)$$

where $\rho = \nu_{in}/\omega_i$ i.e. the ratio of ion-neutral collision frequency to ion gyrofrequency, I is the magnetic dip angle, u_W and u_N are the zonal (W-westward) and meridional (N- northward) component of the horizontal neutral wind velocity, respectively and (is the angle between North direction and the neutral wind velocity vector. From (1a), (1b) and (2), it follows that the layer can be formed only if the neutral wind velocity vector lies in the West-South quadrant or in the East-North quadrant. The illustration of the corkscrew mechanism is given in Figure 1.

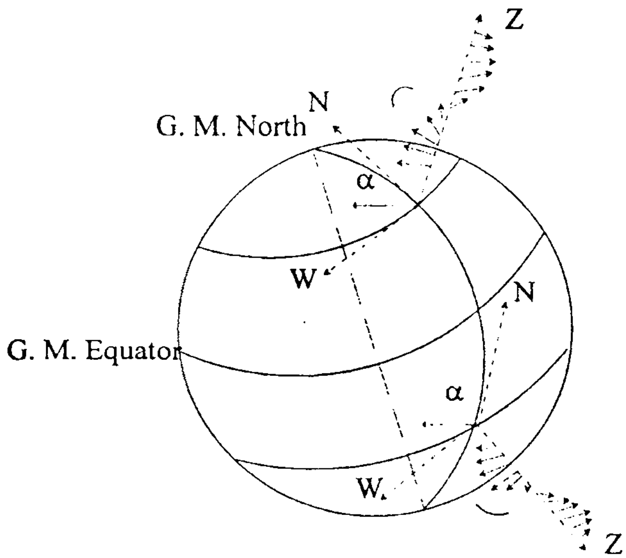

Fig. 1. Rotation of the neutral wind velocity vector.

The other condition comes from the requirement that the vertical motion of ions has to be convergent so that the layer can be formed. Therefore,

$$\mathrm{d}v_{iz}/\mathrm{d}z)_{z0} < 0 \ , \quad (2)$$

The determination of the wind pattern at the time of sporadic E formation is possible under some assumptions: a) the dependence $\rho(z)$ is known, (Grubor and Stupar, 1988), and b) the amplitude of the horizontal wind velocity (u), is determined. It is supposed to be u=100 m/s. The period of neutral wind wave can be deduced from the diurnal variation of the sporadic E layer height. In this study, the meridional and the zonal component of the horizontal wind velocity are expressed by equations:

$$u_N^n = u \sin 2\pi[(80 - z_0 + \lambda_N)/\lambda_N + nk\lambda_N/20] \quad (3a)$$

$$u_W^n = u \sin 2\pi[(80 - z_0 + \lambda_W)/\lambda_W + nk\lambda_W/20] \quad (3b)$$

where λ_N and λ_W are vertical wavelengths of meridional and zonal wind velocity component, respectively, $z_0 + \lambda_N$ (or $z_0 + \lambda_W$) is the height corresponding to $u_N = 0$ (or $u_W = 0$), closest to 80 km, k is the factor equalizing the step of moving upwards, n is the number of step ($n = 1 - 40$).

The second part of the study deals with the determination of the electric field in the plasmasphere, from whistler observations. Assuming the dipole geomagnetic field and electron distribution in the plasmasphere established by diffusive equilibrium, frequency of whistlers which propagate with minimum time delay - tn, the nose frequency - fn, along the path, can be estimated. The fn values of successfully recorded whistlers and their change with local time indicate the change of L value of the path along which a whistler propagates. L value corresponds to equatorial distance divided by Earth's radius, R_E. The rate of the change of L can be related to magnetospheric plasma drift caused by a large-scaled electric field

$$\mathbf{v} = (\mathbf{E} \times \mathbf{B}_{eq})/{\mathbf{B}_{eq}}^2 \quad (4)$$

where $\mathbf{B}_{eq}$ is the magnetic induction at the magnetospheric equator. In the plasmasphere the whistler nose frequency is given by $fn = 0.37 f B_{eq}$, where fB_{eq} is electron cyclotron frequency in the equatorial plane. Assuming that $\mathbf{E}$ is perpendicular to $\mathbf{B}_{eq}$ (Bernard, 1973), for a westward electric field component in the equatorial plane follows:

$$E_W = 2.1(10^{-2}\mathrm{d}(fn^{2/3})/\mathrm{d}t) \quad (5)$$

where fn is measured in Hz and E_W in V/m. If $\mathrm{d}(fn^{2/3})/\mathrm{d}t$ is positive, then the electric field is directed from East to West (Sazhin *et al.* 1992). On the basis of the recorded whistlers it is possible to define only equatorial east-west electric fields in the plasmasphere.

In the third part of the study the vertical profiles of the current density components in the dynamo region are calculated considering the determined neutral wind pattern and the polarization electric field:

$$j_N = (\sigma_p/\sin 2I)(E_N - u_W B \sin I) + (\sigma_H/\sin I)(E_W + u_N B \sin I) \quad (6a)$$

$$j_W = -(\sigma_H/\sin I)(E_N - u_W B \sin I) + \sigma_P(E_W + u_N B \sin I) \ , \quad (6b)$$

where σ_p and σ_H are Pedersen and Hall electrical conductivity, respectively.

The calculation assumes that the electric conductivity profiles are known (Richmond, 1979). As mentioned above, only E_W can be determined from the registered whistlers.

3. OBSERVATIONS

The height z_0, at which the sequential sporadic E layer is formed, scaled from ionograms taken at Grocka Ionospheric Observatory during the series of geomagnetically quiet days is plotted versus diurnal time, as shown in Fig. 2.

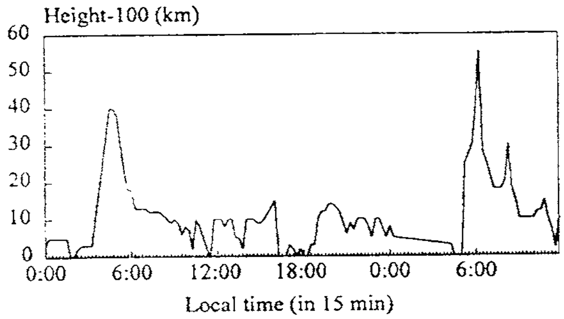

Fig. 2. The variation of sporadic E altitude from July 03, 0000 LT to July 04 1145 LT, 1988.

Three cycles of the Es height variation per a day can be recognized. Knowing the value of $\rho(z_0)$, a is determined from (1b). The descending speed corresponds to the speed of $u(z)$ phase which propagates downward. Each cycle corresponds to the rotation of $\mathbf{u}$ for $\alpha = 360°$. During the period of the cycle the phase moves vertically by one wavelength. According to (1a) and taking in account the steep decrease of ρ with altitude, it is clear that the northward component of $\mathbf{u}$ is more efficient regarding the Es layer formation at upper dynamo region, while the westward component is more efficient at the lower heights. Each component propagates with its own wavelength. Considering these facts, values of λ_N and λ_W are calculated. The calculation of the vertical profiles $u_N(z)$ and $u_W(z)$ is carried out by expressions 3(a) and (3b).

The whistler data were recorded on a synoptic 3 min. every hour basis at Grocka station (Šulić, 1988). The broadband recordings (1- 10 kHz), stored on magnetic tape, were analyzed by PC486 based digital data acquisition system. The spectrograms with well-defined traces were scaled by the same PC486 system. Scaled frequency-time data were extrapolated by numerical program to determine fn and tn. At Grocka station whistlers are recorded in the frequency range that is below fn. By the same program other plasmaspheric parameters as: equatorial electron density, n_{eq}; L value of the path and total electron content N_T in the magnetic field tube with cross-section of 1 m^2 at the reference level of 1000 km height were defined. These parameters were used to study electric fields in the plasmasphere on July 03/04 1988. This summer day is characterized by quiet geomagnetic conditions as well as a day before. Whistlers were recorded in large number at Grocka station in the period from 1750 LT on July 03, 1988 to 0250 LT on July 04, 1988.

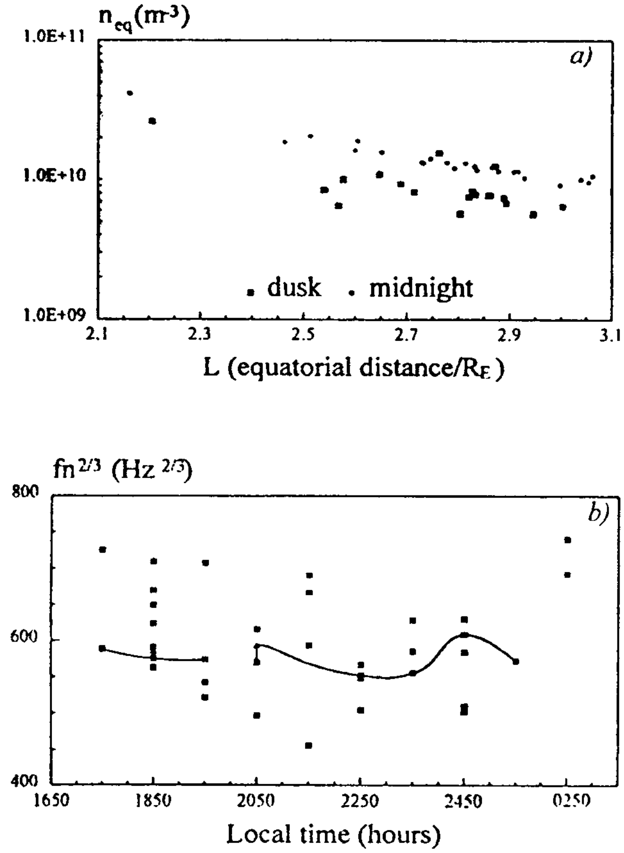

Fig. 3. a) The dependence of the equatorial electron density on the L value; b) The time variation of $fn^{2/3}$.

Fig. 3a shows equatorial electron density profiles versus L for dusk and midnight local time sectors. There are differences in electron density at the same L value for these two local time sectors. Fig 3b presents two-thirds power of whistler nose frequency against local time (points). Considering values of total electron content N_T for period 1750 LT and 1950 LT paths at $L \sim 2.8$ were used for defining electric fields. These paths are represented by light line. In the period from 2050 LT to 0150 LT total electron content N_T had lower values at similar L than for the period 1750 LT-1950 LT (heavy line).

The temporal variation of the westward component of magnetospheric equatorial electric field near $L \sim 2.85$ for quiet geomagnetic conditions is calculated using the relation (5).

4. RESULTS

The variation of E_W in the time interval between 1750 LT on July 03 and 0050 LT on July 04, is given in Fig. 4.

In the interval 1750 LT-1950 LT the amplitude of the electric field variation is small, $|E_W| < 0.09$

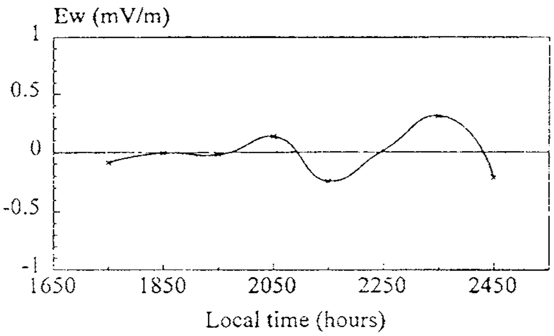

Fig. 4. The time variation of the westward electric field in the plasmasphere.

mV/m. From 1950 LT to 2250 the amplitude increases to about 0.25 mV/m. In the interval 2250 LT-0050LT, the amplitude increases up to 0.35 mV/m. It was reasonable to suppose that E_N varies in the same interval of values as E_W, while the vector of total electric field rotates in space and time. Knowing the amplitude of E_W at each variation cycle, the corresponding values of E_N is calculated. It is of interest to determine parameters of the neutral wind wave in three time intervals mentioned above and to calculate $u_N(z)$ and $u_W(z)$ as wel as $j_N(z)$ and $j_W(z)$ at characteristic times. The examples are given in Figures 5a and 5b.

Finally, the integration of current densities over the altitude interval 80-200 km was carried out:

$$J_N = \int_0^{200} j_N(z)\mathrm{d}z \ , \quad J_W = \int_0^{200} j_W(z)\mathrm{d}z \ .$$

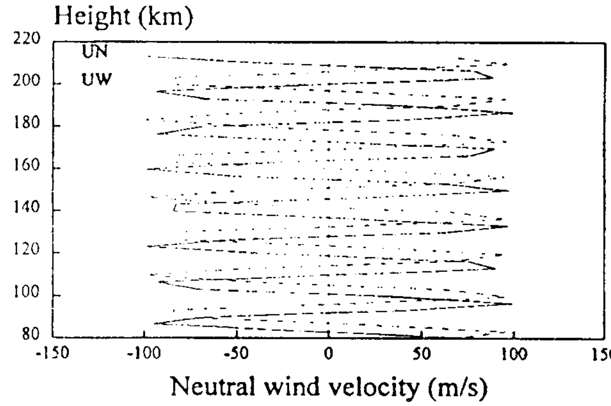

Fig. 5. a) The vertical profile of the neutral wind velocity.

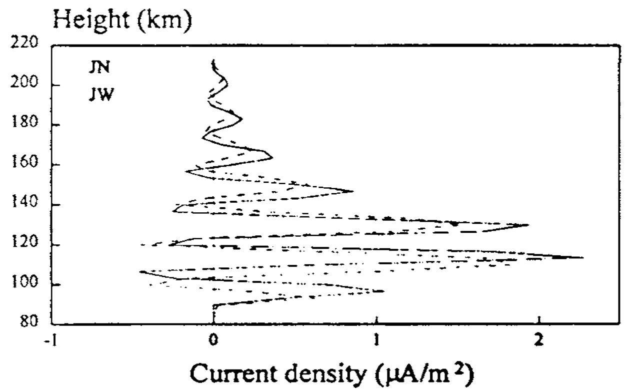

Fig. 5. b) The vertical profile of the current density.

These integrated currents are the origin of the geomagnetic field variation at the quiet days (so called Sq-variation). The results are summarized in the Table 1.

Table 1.

Time (LT)	λ_N (km)	λ_W (km)	E_N (mV/m) (deduced)	E_W (mV/m) (measured)	J_N (μA/m)	J_W (μA/m)
1845	13	19	0.071	-0.07	-62	-670
1945	18	18.3	0.095	-0.03	-190	8
2045	”	”	-0.22	0.12	200	-41
2145	”	”	-0.098	-0.23	105	-130
2245	”	”	-0.25	~0	15	-94
2345	”	”	0.14	0.32	310	31
2445	”	”	0.34	-0.08	330	-92

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ЕЛЕКТРИЧНЕ ОСОБИНЕ СИСТЕМА ТЕРМОСФЕРА–ПЛАЗМАСФЕРА ИЗВЕДЕНЕ НА ОСНОВУ ПОДАТАКА ПРИКУПЉЕНИХ НА ПОВРШИНИ ЗЕМЉЕ

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Оригинални научни рад

Густине струје у динамо региону су израчунате на основу шеме термосферског неутралног ветра и електричног поља у плазмасфери. Дневна варијација меридионалне и зоналне компоненте брзине неутралног ветра утврђена је помоћу опадајућих висина спорадичног слоја E. Дневна промена компоненте електричног поља усмерене ка западу, које се преноси из динамо региона у плазмасферу, изведена је из података о звиждућим атмосферицима (whistlers). Коришћени су подаци вертикалног сондирања о висинама спорадичног E слоја h'Es забележени на опсерваторији Гроцка (44.6°С, 20.8°И). Одабрани звиждући атмосферици забележени су у станици Гроцка (L $\sim$ 1.9). Све регистрације коришћене у овом раду прикупљене су у геомагнецки мирним данима.