THE DAILY AND SEASONAL VARİATION OF THE IONOSPHERIC E-LAYER DYNAMO CURRENT

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Introduction

- It is known that the small periodic variations in the earth's magentic field are caused by electric current, set up by the dynamo action resulting from the solar and lunar tidal motions in the ionosphere.

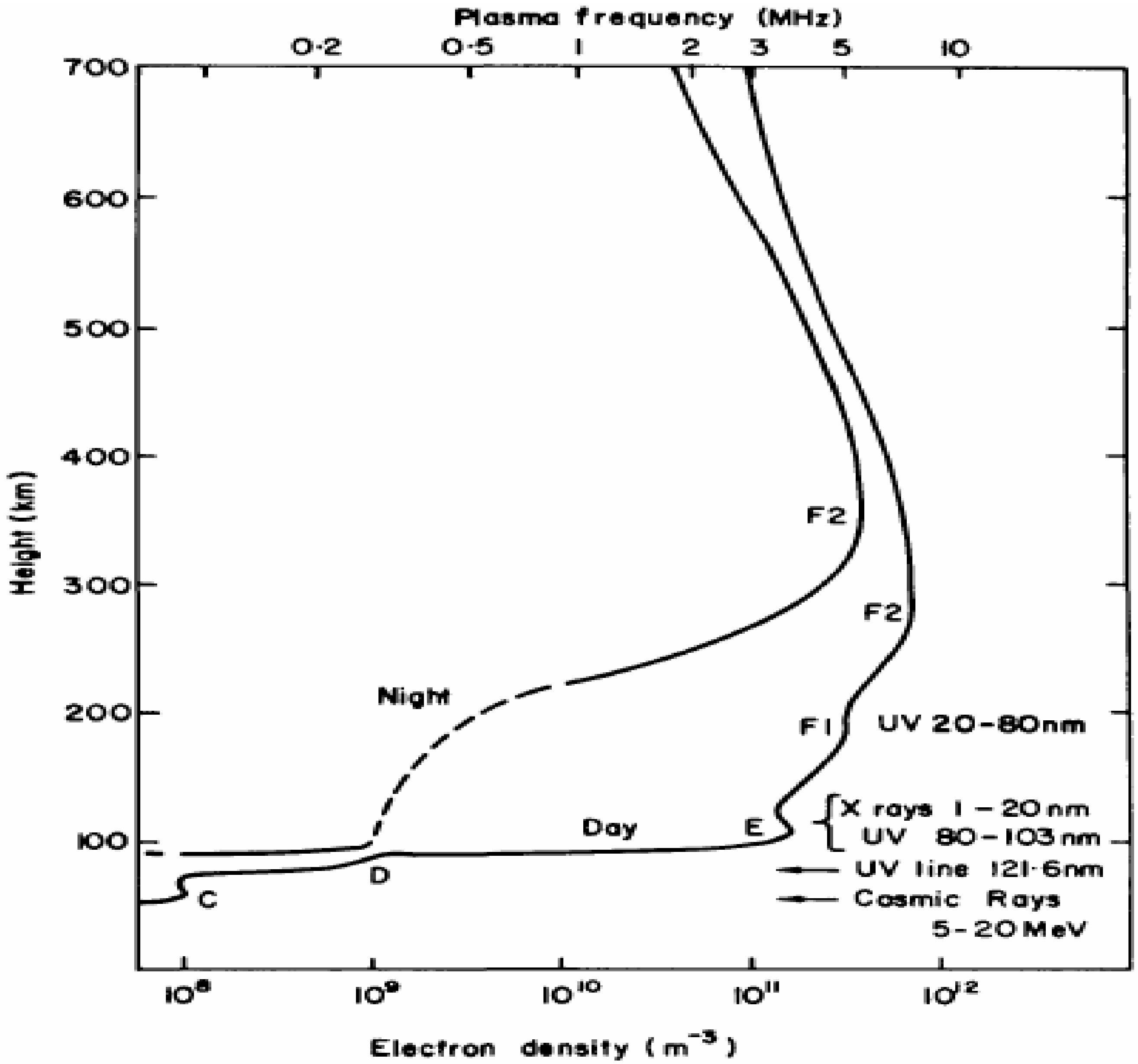
- The ionosphere carries electric currents, because winds and electric fields drive ions and electrons in different directions. By day, the most ionospheric current flows in the E-layer at 100-130 km height. At night, E-layer ionization almost disappears, (at least at middle and low latitudes. *Rishbeth, 1997*).

- Since the quite daily geomagnetic field variations are mainly due to the dynamo currents flowing in the ionospheric E-layer. It is important to know the daily and seasonally variations of the ionospheric E-layer dynamo current.

- In this study, we have obtained the general expression of the current density for the ionospheric plasma.

- The numerical values of the current density has been calculated by using the ionospheric parameters which obtained with the International Reference Ionosphere (IRI) model.

- Daily and seasonal variations of the current density have been examined separately for maximum and minimum sunspot number.



The ionospheric layer (according to the electron density variation)

The Current Generated in The Ionosphere

- The force acting on the charged particle in the ionospheric plasma is giveen by;

$$m_\alpha \frac{dv_\alpha}{dt} = q_\alpha(\mathrm{E} + v_\alpha \times B) - m_\alpha \nu_\alpha(v_\alpha - \mathrm{U}) \quad (1)$$

where ν is the collsion frequency, U is the horizontal neutral wind velocity, α denotes e, and i represents the electron and ion respectivelly.

- We assumed that the z-axis of the coordinate system with its origin located on the ground is vertically upwards. The x- and the y-axis are geograohically eastward and northward in the northern hemisphere.

- The ambient magnetic field in the northern hemisphere is given by following equation (Rishbeth, 1972);

$$\mathbf{B} = (\mathrm{B}sinDcosI)\hat{x} + (BcosIcosD)\hat{y} - (\mathrm{BsinI})\hat{z} \quad (2)$$

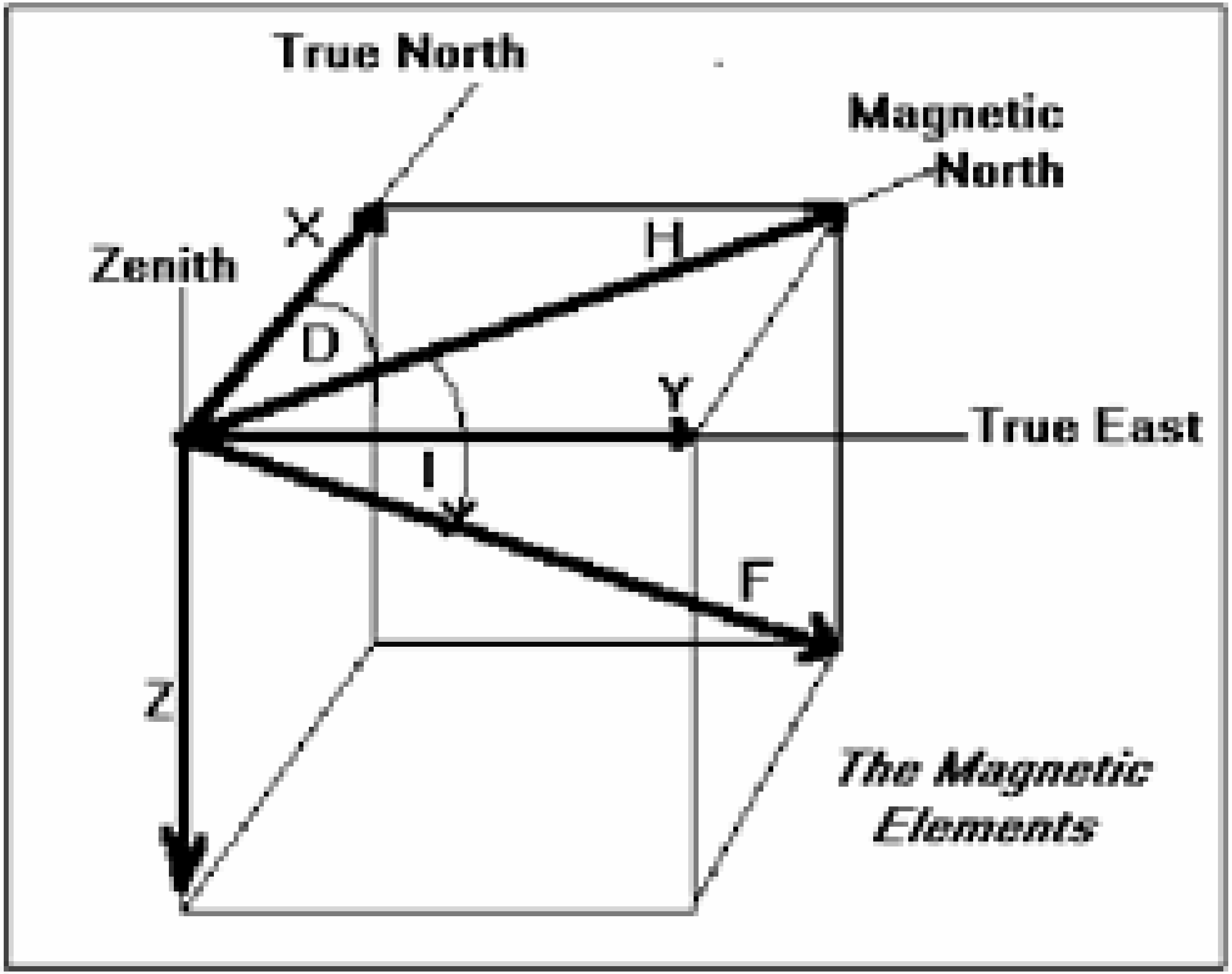
- Since the declination angle (D) of the of the geomagnetic field is small (≈ 3.5) for selected geographic coordinate (28^0 N, 39^0 E), it is neclegted. Than the geomagnetic field becomes;

$$\mathbf{B} = (BcosI)\hat{y} - (\mathrm{BsinI})\hat{z} \quad (3)$$

where I is the dip angle. For the steady-state condition, the current density can be obtained from Eq.1 as follow:

$$\mathrm{J} = \frac{dv_\alpha}{dt}\mathrm{E} + \frac{\omega_{c\alpha}}{\mathrm{V}_\alpha} J_\alpha \times \hat{a} + \mathrm{NeU} \qquad (4)$$

where N is the electron density, $\omega_{c\alpha} = |eB/m|$ is the gyro-frequency and $\hat{a} = (\cos I)\hat{x} - (\sin I)\hat{y}$ is the unite vector.



Magnetic field components

- The solution of Eq. 2 in cartesian coordinate system can be written in terms of of the componets of the current density as follow

$$J_x = \sigma_1 \left[\sum_{\alpha=e,i} \frac{m_\alpha \nu_\alpha}{e} U_x + E_x\right] - \sigma_2 \sin I \left[\sum_{\alpha=e,i} \frac{m_\alpha \nu_\alpha}{e} U_y - E_x\right] - (\sigma_2 \cos I) E_z \quad (5)$$

$$J_y = \sigma_2 \sin I \left[\sum_{\alpha=e,i} \frac{m_\alpha \nu_\alpha}{e} U_x + E_x\right] - [\sigma_0 - (\sigma_0 - \sigma_1) \sin^2 I] \left[\sum_{\alpha=e,i} \frac{m_\alpha \nu_\alpha}{e} U_y + E_y\right] + [(\sigma_0 - \sigma_1) \sin I \cos I] E_z \quad (6)$$

$$J_z = -\sigma_2 \cos I \left[\sum_{\alpha=e,i} \frac{m_\alpha \nu_\alpha}{e} U_x + E_x\right] + (\sigma_0 - \sigma_0) \sin I \cos I \times \left[\sum_{\alpha=e,i} \frac{m_\alpha \nu_\alpha}{e} U_y + E_y\right] \times [\sigma_0 - (\sigma_0 - \sigma_1) \cos^2 I] E_z \quad (7)$$

- Where σ_0, σ_1 and σ_2 are longitudinal (paralel), Pedersen (perpendicular) and Hall conductivities.

- The electron and ion collision frequencies are $\nu_e = \nu_{en} + \nu_{ei}$ and $\nu_i = \nu_{in} + \nu_{ie}$.

- The total current flowing in E-layer is approximatelly horizontal (Rishbeth, 1997). Hence, the vertical current density can be taken as zero. If we take the J_z current as zero, then from the solutions of Eq.(5-7) can be obtained the horizontal currents densities as;

- $$J_x = \left[\sigma_1 + \frac{\sigma_2{}^2 cos^2 I}{\sigma_0 sin^2 I + \sigma_1 cos^2 I}\right]\left[\frac{\nu_\alpha}{\omega_{c\alpha}} BU_x + E_x\right] - \left[\frac{\sigma_0 \sigma_2 sinI}{\sigma_0 sin^2 I + \sigma_1 cos^2 I}\right]\left[\frac{\nu_\alpha}{\omega_{c\alpha}} BU_y + E_y\right] \quad (8)$$

- $$J_y = \left[\frac{\sigma_0 \sigma_2 sinI}{\sigma_0 sin^2 I - \sigma_1 cos^2 I}\right]\left[\frac{\nu_\alpha}{\omega_{c\alpha}} BU_x + E_x\right] + \left[\frac{\sigma_0 \sigma_1}{\sigma_0 sin^2 I + \sigma_1 cos^2 I}\right]\left[\frac{\nu_\alpha}{\omega_{c\alpha}} BU_y + E_y\right] \quad (9)$$

- At middle latitude $\sigma_0 > \sigma_1 > \sigma_2$ and $\nu_i/\omega_{ci} \gg \nu_e/\omega_{ce}$ (Du and Stening, 1999a). If the divergence of the magnetic field line is neglected in E-layer, the height integrated east-west ($J_{\Sigma x}$) and south-north ($J_{\Sigma y}$) current densities can be written as;

- $$J_{\Sigma x} = B\Sigma_1 U_x - B\frac{\Sigma_1'}{sinI}U_y + \Sigma_1' E_x - \frac{\Sigma_2'}{sinI}E_y \qquad (10)$$

- $$J_{\Sigma y} = B\frac{\Sigma_2}{sinI}U_x + B\frac{\Sigma_1}{sin^2 I}U_y + \frac{\Sigma_2'}{sinI}E_x + \frac{\Sigma_1'}{sin^2 I}E_y \qquad (11)$$

where

$$\Sigma_1 = \int_{h_1}^{h_2}\frac{\nu_i}{\omega_{ci}}\sigma_1 dh, \qquad \Sigma_2 = \int_{h_1}^{h_2}\frac{\nu_i}{\omega_{ci}}\sigma_2 dh$$

$$\Sigma_1' = \int_{h_1}^{h_2}\sigma_1 dh\,, \qquad \Sigma_2' = \int_{h_1}^{h_2}\sigma_2 dh\,,$$

- The height-integrated current density can be expressed directly in terms of the magnetic field componets using Amper’s circuital relations.

- The eastward (B_x) and northward (B_y) componets of magnetic flux density B and the integrated layer current densities J_Σ are related by the following equations:

$$B_x \approx -f\mu_0 J_{\Sigma y} \qquad (12)$$

$$B_y \approx f\mu_0 J_{\Sigma y} \qquad (13)$$

- in which μ_0 is the magnetic permeability of free space. The value of f is about 0.5 (Rishbeth & Garriot)

- The eastward (H_x) and northward (H_y) horizontal componets of magnetic field

$$H_x \approx -f J_{\Sigma y}, \quad H_y \approx f J_{\Sigma y} \qquad (14)$$

Numerical Solutions

- The ionospheric E-layer current and magnetic field has been calculated at (38^0N, 39^0E) geographic coordinate for equinox and solstice days by using equations (10)-(13).

- The used ionospheric parameters for calculation have been obtained by using IRI-model.

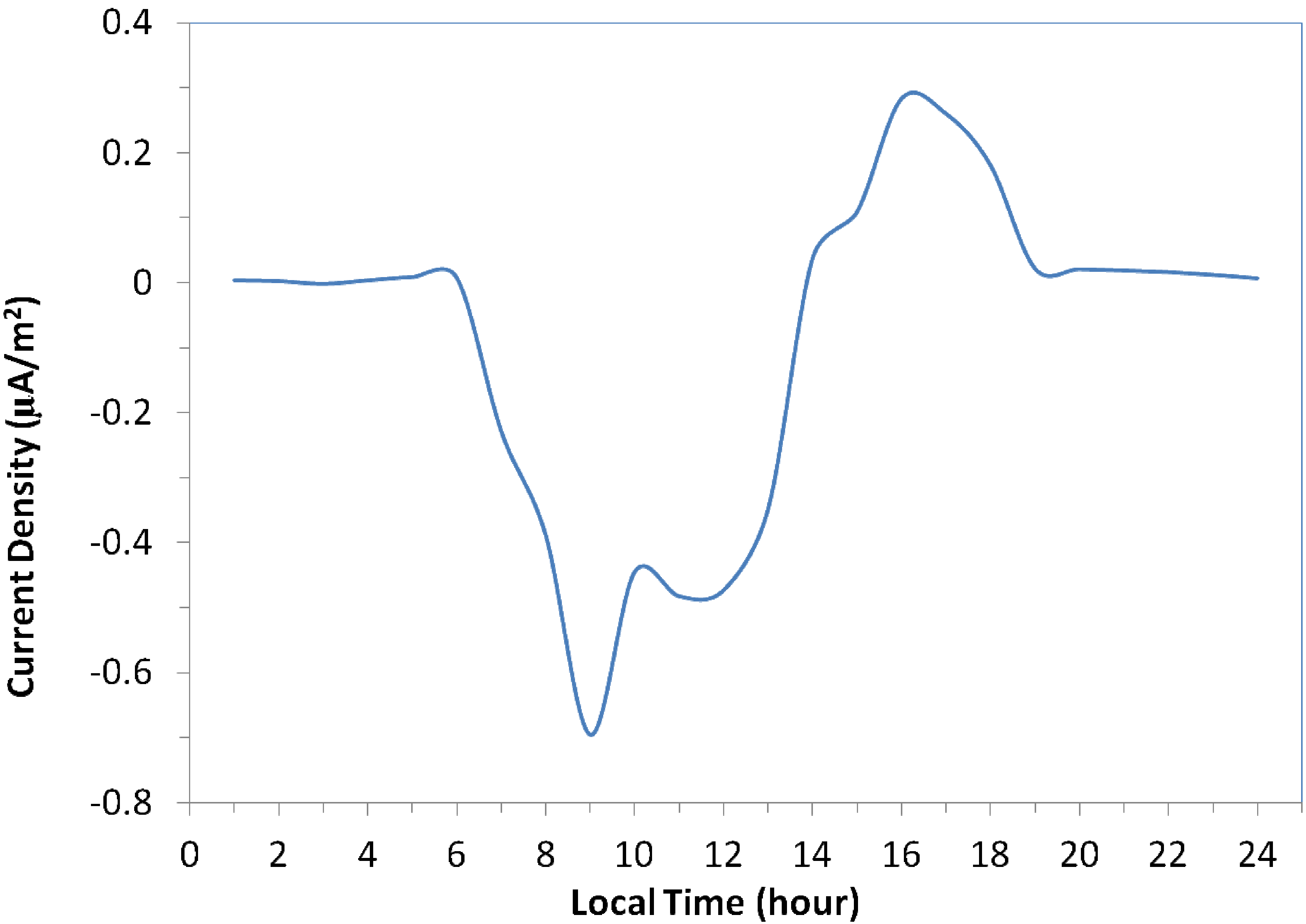
- Since in the ionospheric E-layer $\nu_{ei} \ll \nu_{en}$ and $\nu_{ie} \ll \nu_{in}$ the electron and ion collision frequencies were taken as;

$$\nu_e = \nu_{en} = 5.4 \text{ x } 10^{-16} N_n T_e^{1/2}, \ \nu_i = \nu_{in} = 5.4 \text{ x } 10^{-17} N_n (T_i + T_n)^{1/2}$$

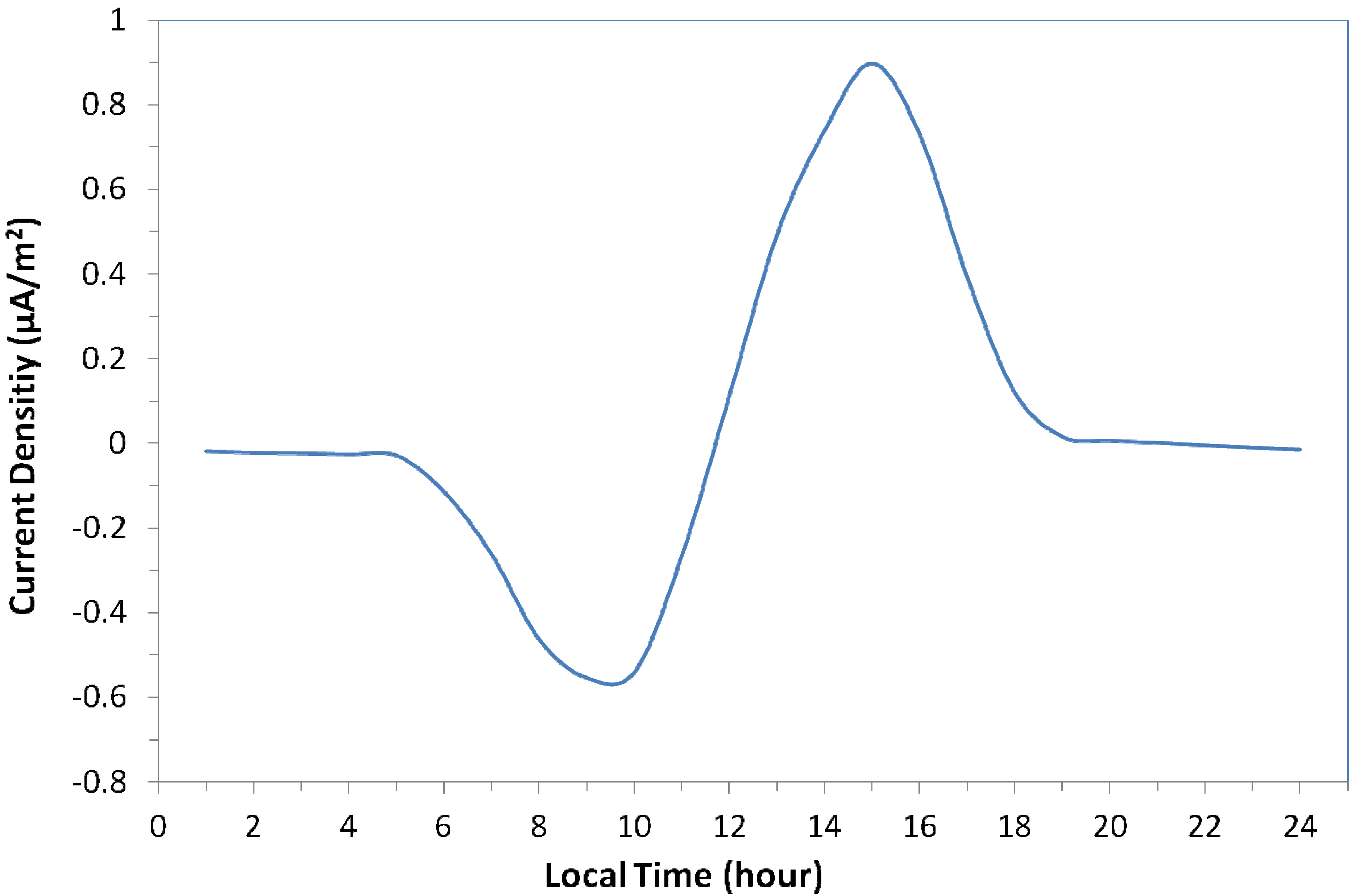
where N_n, T_e, T_n and T_i are the neutral density, electron, neutral and ion temperature respectively.

- The expressions of the σ_o, σ_1 and σ_2 conductivities of (Aydoğdu & Özcan, 1996) have been used in calculations.
- The eastward (E_x) and northward (E_y) electric field taken from (Du and Stening, 1999). The U_x and U_y componets of neutral winds have been calculated by using the euations of (Aydoğdu & Özcan, 1991)
- The height-integrated conductivities ((Σ_1, Σ_2, Σ_1' , Σ_2') have been calculated by integrating the conductivities (σ_1 and σ_2) with 1 m height interval from 90 to 150 km.

Results and Discussions



Daily variation of the J_x (east-west) current



Daily variation of the J_y (north-south) current

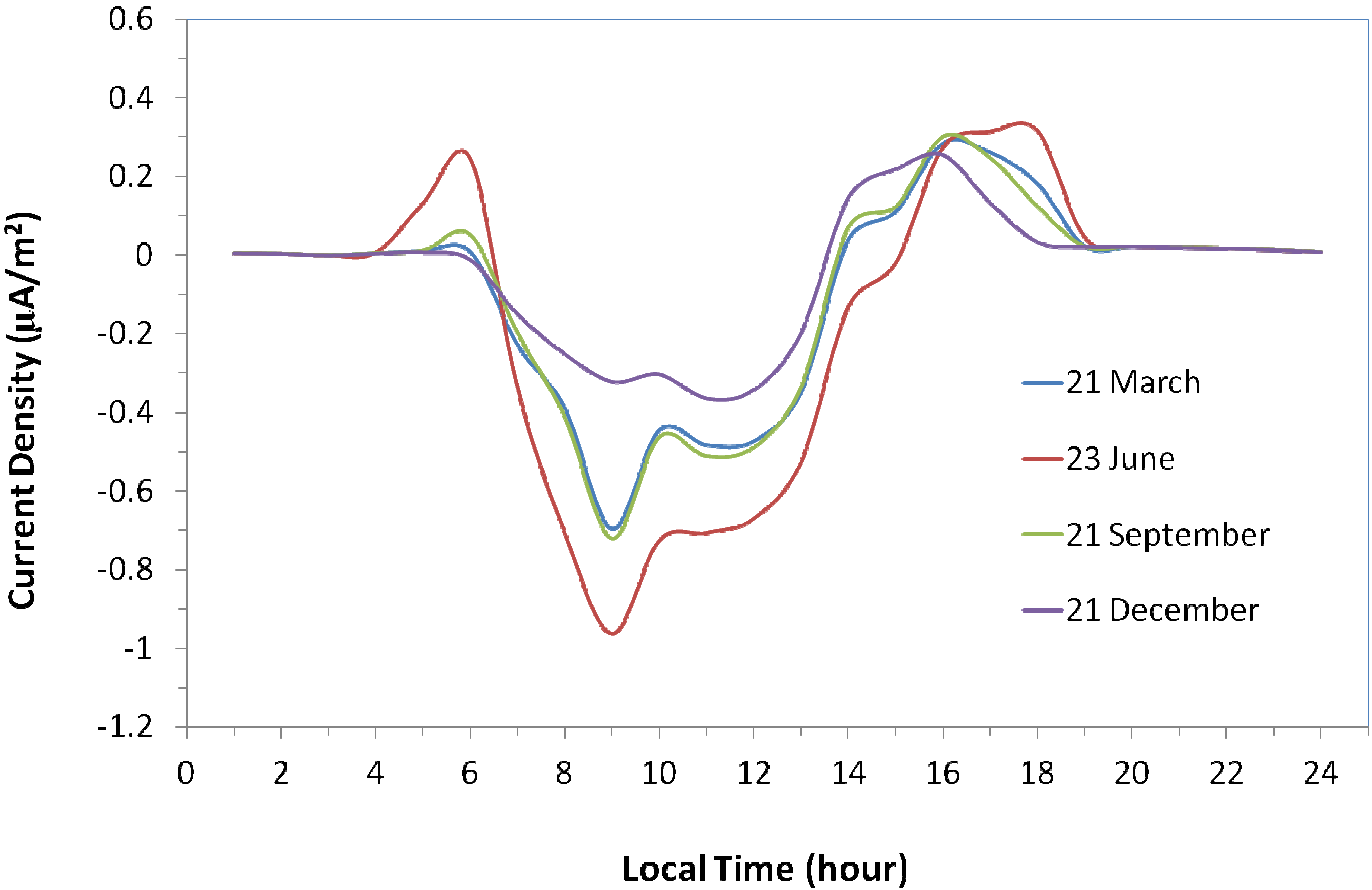
1. East-west and north-south currents are almost zero at night times (Sunrise time ≈ 06 , Sunset time ≈19.00)

2. The J_x current is westward between 6 and 15 hours and eastward between 15 and 19 hours .

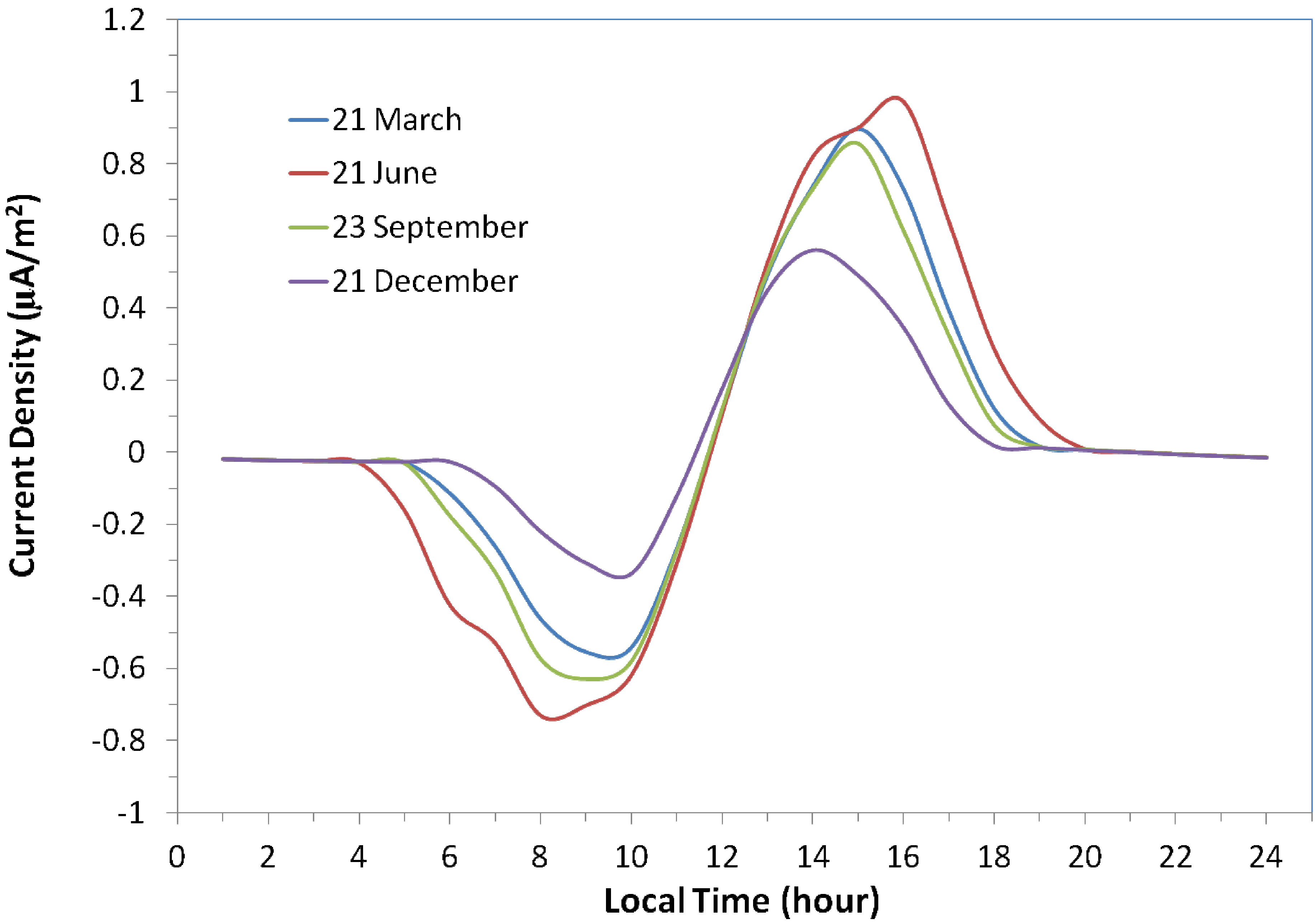
3. The maximum value of the J_x current is about 0.7 μ A/ m^2

4. The J_y current is southward between 6 and 12 hours and northward between 12 and 19 hours.

5. The maximum value of the J_y current is about 0.9 μ A/ m^2

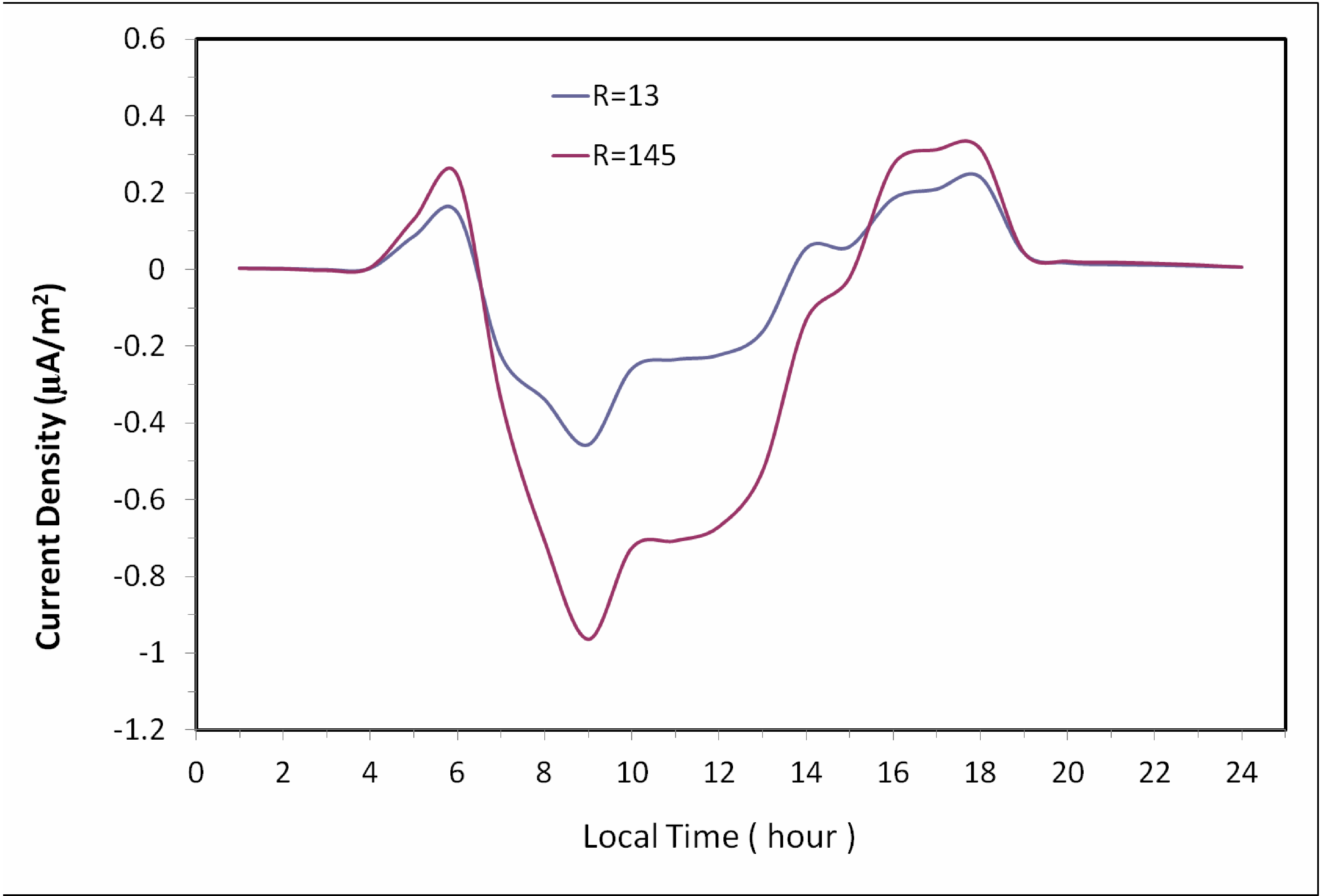


Seasonal variation of the J_x (east-west) current

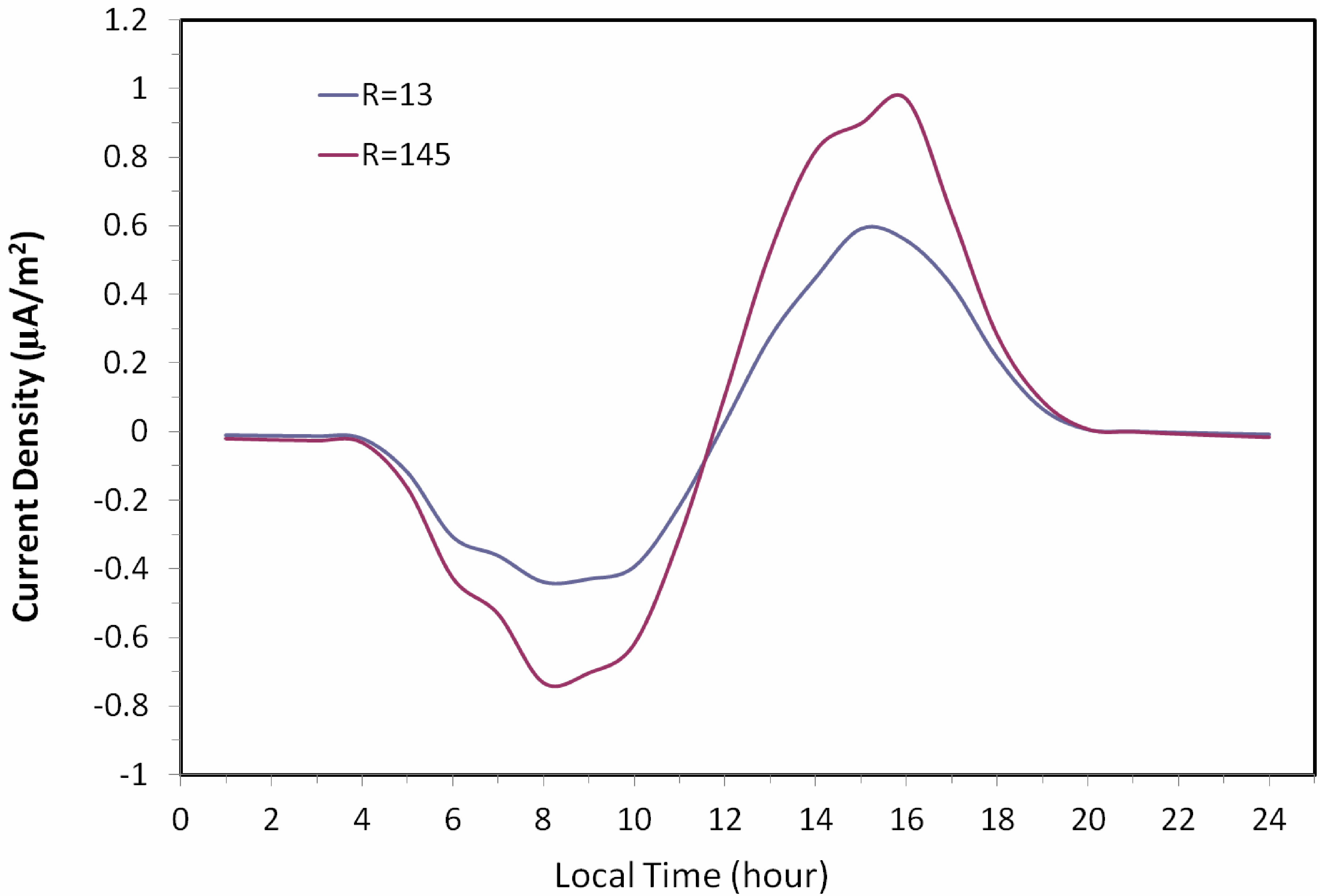


Seasonal variation of the J_y (north-south) current

1. Both J_x and J_y currents change seasonally.
2. The values of both J_x and J_y currents on the 21 June are bigger than the other seasons values.
3. The currents on 21 March and 23 September are aproxmatelly equal.
4. The values of currents on the December are smaller than the other seasons values.



Change of J_x (east-west)current with solar activity

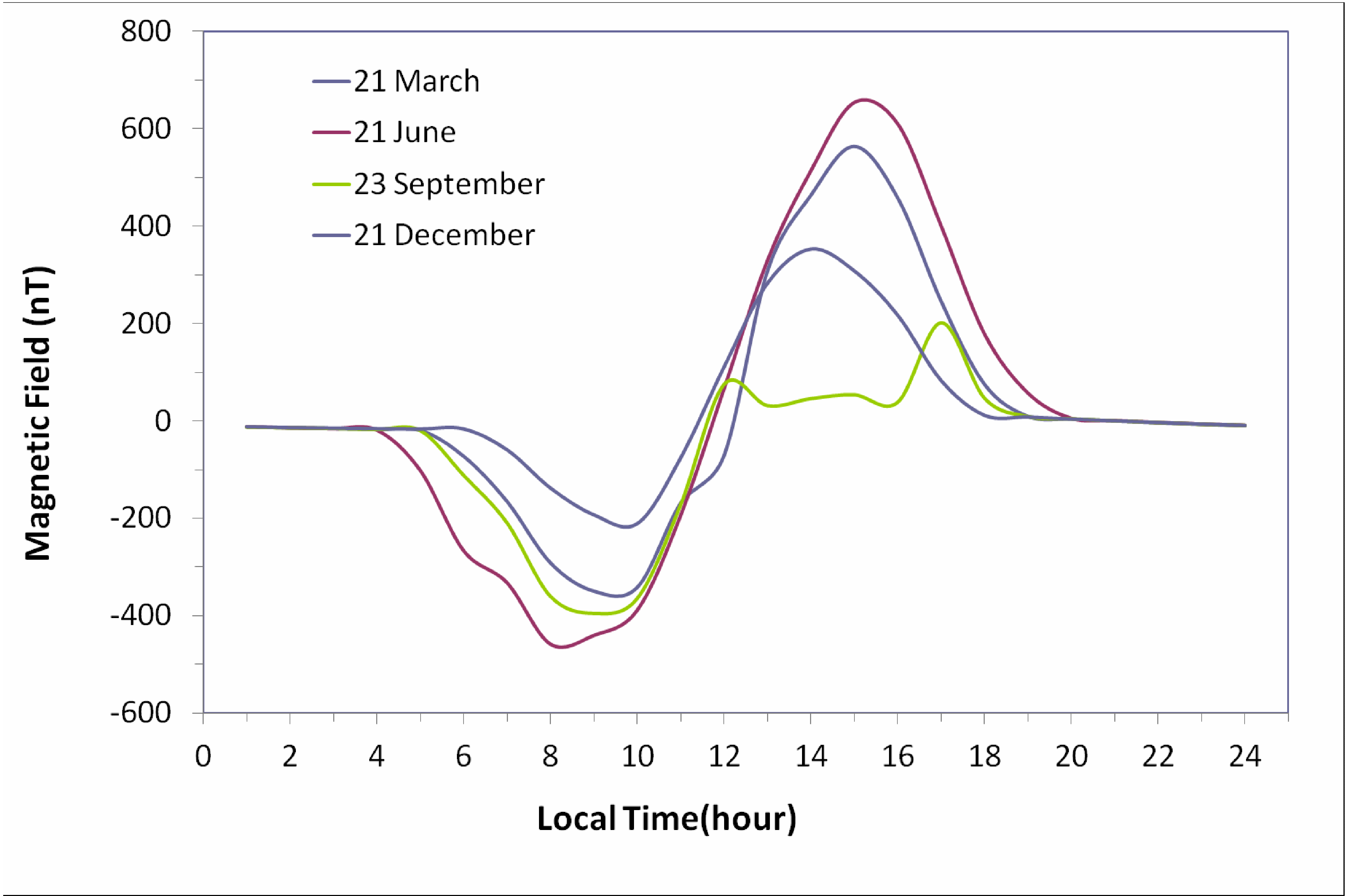


Change of J_y (orth-south) current with solar activity

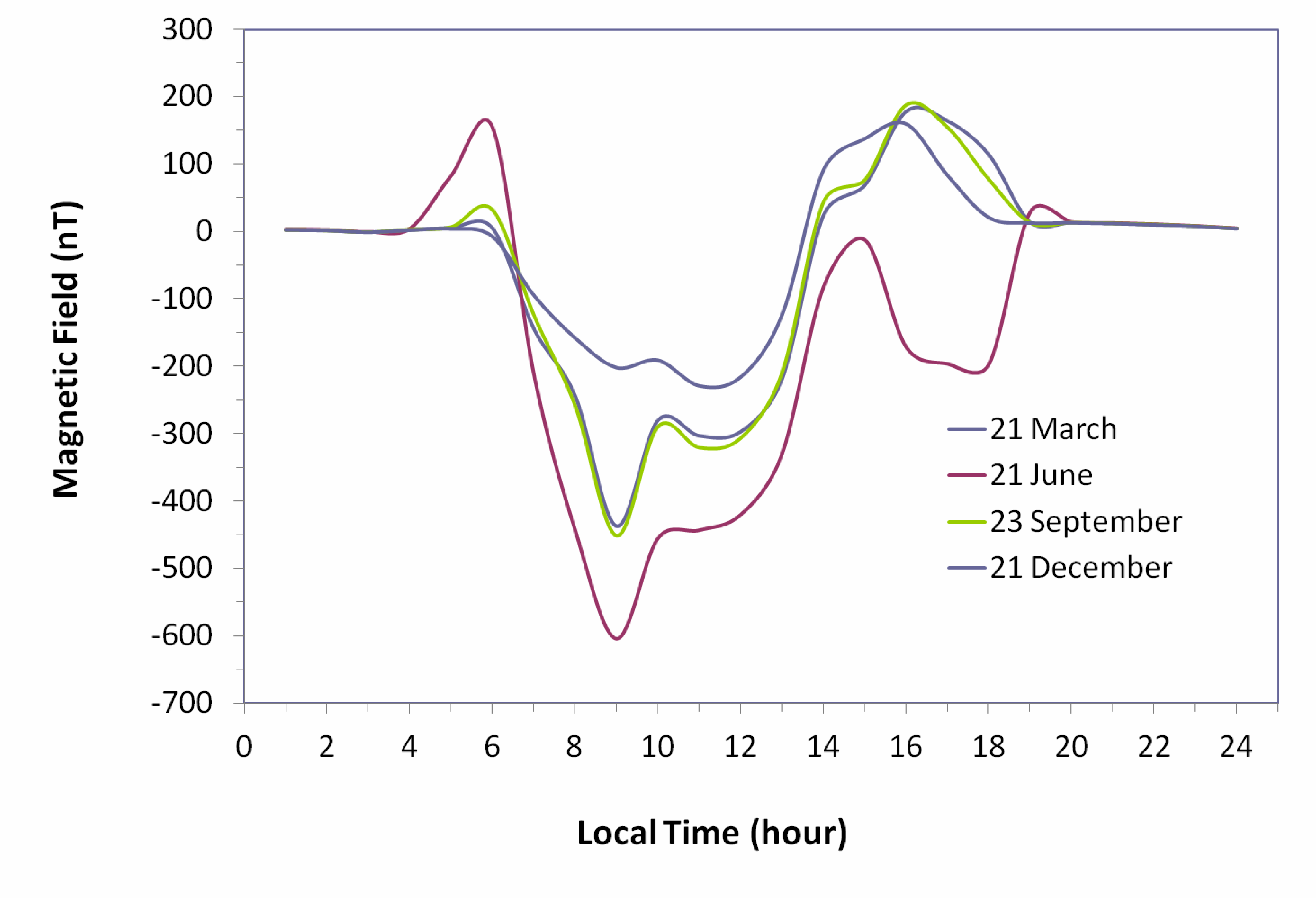
1. The current density is increasing with increasing solar activity

2. For quiet days (R=13), the maximum value of the J_x current is aproximatelly 0.45 $\mu A/m^2$, while for the active days (R=145) this value is 0.96 $\mu A/m^2$.

3. Similarly, the value of J_y on active days is about 50 percent larger than the value on quiet days.



Daily and seasonal variation of H_x (east-west) magnetic field



Daily and seasonal variation of H_y (north-south) magnetic field

İlginiz için teşekkür ederim

Thank you for your attention