INTERACTION OF THE EQUATORIAL MIDNIGHT PRESSURE BULGE AND THERMOSPHERIC ZONAL WINDS

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The zonal component of the thermospheric neutral wind in the equatorial region is found to flow eastward all night, having a minimum near midnight. The data, obtained by Spencer et al. (1981) on the Dynamics Explorer-2 (DE-2) satellite, and reported more recently by Wharton et al. (1984), indicate that the minimum feature is significant. The minimum is illustrated in Figure 1 which shows a 4th order Fourier series fit to the data points reported by Wharton et al. (1984). The table below the plot gives the amplitudes and phases of the four harmonic components used with the estimated errors for each amplitude. One asks whether this behavior is due to the local passage of the equatorial midnight pressure bulge associated with the midnight temperature anomaly. If so, it is to be exptected that other data characterizing the midnight temperature anomaly should show consistency with this observation, especially in view of the large changes observed in the zonal velocity in the midnight sector. Consistency in momentum conservation may be checked using available data from previous independent experiments. Such data, taken under similar conditions of solar activity, has been substituted into the momentum equation and found to be consistent using a priori estimates of the effect of viscosity.

The DE-2 data provide the zonal wind Ux, and its local time derivative $\partial U_x/\partial t$. The pressure gradient is obtained from the average equatorial nighttime neutral temperatures measured on AE-E (Herrero and Spencer, 1982) and the MSIS neutral density (Hedin, 1983), and this is shown in Figure 2. Specifying the ion-drag requires in addition the eastward ion-drift V_{ix} and the ion density n_i at the altitude of interest, 350 km in this case. The eastward ion-drift is well known near the equator from the Jicamarca measurements of 1970-71 (Woodman, 1972; Fejer et al., 1981; see Figure 3). Solar activity for that period was comparable to solar activity during the DE-2 measurements of 1981-82, essentially one solar cycle apart. The average ion density variation may be represented by Chiu's empirical model (Chiu, 1975), and this is plotted in Figure 4. Basically, zonal momentum is balanced as the pressure gradient dp/dx of the neutral gas is opposed by ion-drag and viscosity with the difference appearing as a local rate of change dUx/dt. That is,

$$\frac{\partial U_x}{\partial t} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{\mu}{\rho}\frac{\partial^2 U_x}{\partial z^2} - \nu_{in}(U_x - V_{ix})$$

where the ion-drag term is characterized by the ion frequency ν_{in} and the difference in velocities $U_x - V_{ix}$. μ is the coefficient of viscosity and ρ the neutral mass density (see, for example, Rishbeth and Garriott, 1971). The similarity between the nighttime zonal winds and the eastward ion-drift is worth noting as it is responsible for a drastic reduction in the ion-drag term. U_x and V_{ix} both reach their highest maxima togehter at 2100 hours LT, and pass through a minimum shortly after midnight and a secondary maximum between 0300 and 0400 hrs LT. This similarity makes it possible to approximate V_{ix} in terms of U_x. From Figures 1 and 2, $V_{ix} \sim 0.8U_x$. Thus, the ion-drag term may be written as U_x/τ_i where $\tau_i = 1/0.2\ \nu_{in}$, where ν_{in} is proportional to n_i. The viscosity term is the only component of the equation that cannot be characterized by actual data. Therefore, it can be determined in terms of the others, and its magnitude checked for consistency against estimated values. The table below gives the magnitudes of the terms entering the momentum equation for the four time regions shown in Figure 2. The values of U_x, $\partial U_x/\partial t$, Ni and $-1/\rho\ (\partial p/\partial x)$ used correspond to the times near the middle of each region. The viscosity is found from the net effect of the terms in the Table and compared to the a priori estimates. In regions I, II, and III the net effect gives a viscosity value varying between -.005 and +.005 m/s^2. This amounts to 30% or less of the dominant term in each case, and perhaps is not indicative of the average behavior. However, in the early morning hours (section IV) the viscosity term should account for .01 m/s^2, and the fact that it is positive here may be significant and consistent with the simultaneous reversal in the pressure gradient shown in Figure 2.

A priori estimates of the viscosity term follow from approximating this term using a "viscosity" scale height H_v. This gives a viscosity decay time $\tau_v \approx \rho H^2/\mu$. Previous H_v estimates (Rishbeth, 1972) indicate values of the order of 100 km which are consistent with the numbers obtained here.

Table 1

	I (1930 LT)	II (2230 LT)	III (0130 LT)	IV (0430 LT)
τ_i (hrs)	0.81	2.1	6.2	7.2
U_x/τ_i (m/s^2)	0.035	0.014	0.004	0.002
$\partial U_x/\partial t$ (m/s^2)	0.020	-0.015	0.010	-0.025
$-1/\rho\ (\partial p/\partial x)$ (m/s^2)	0.050	0.004	0.015	-0.012

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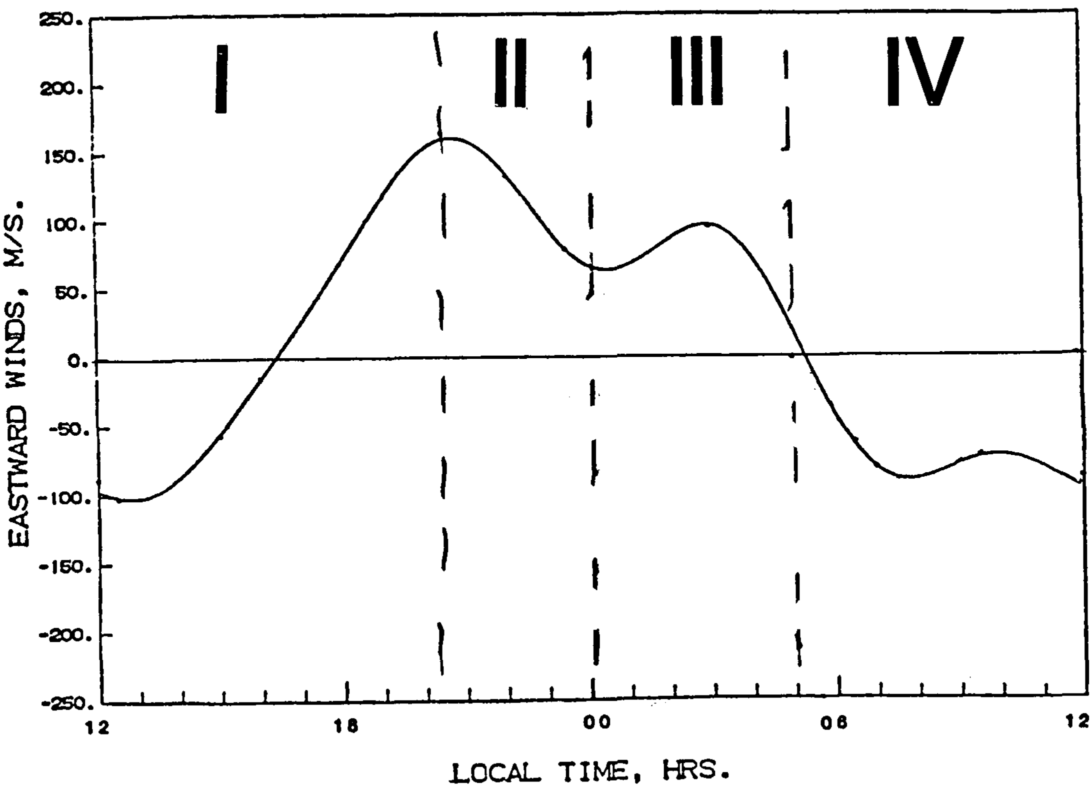
DE-2 ZONAL WINDS

Average altitude 350 km

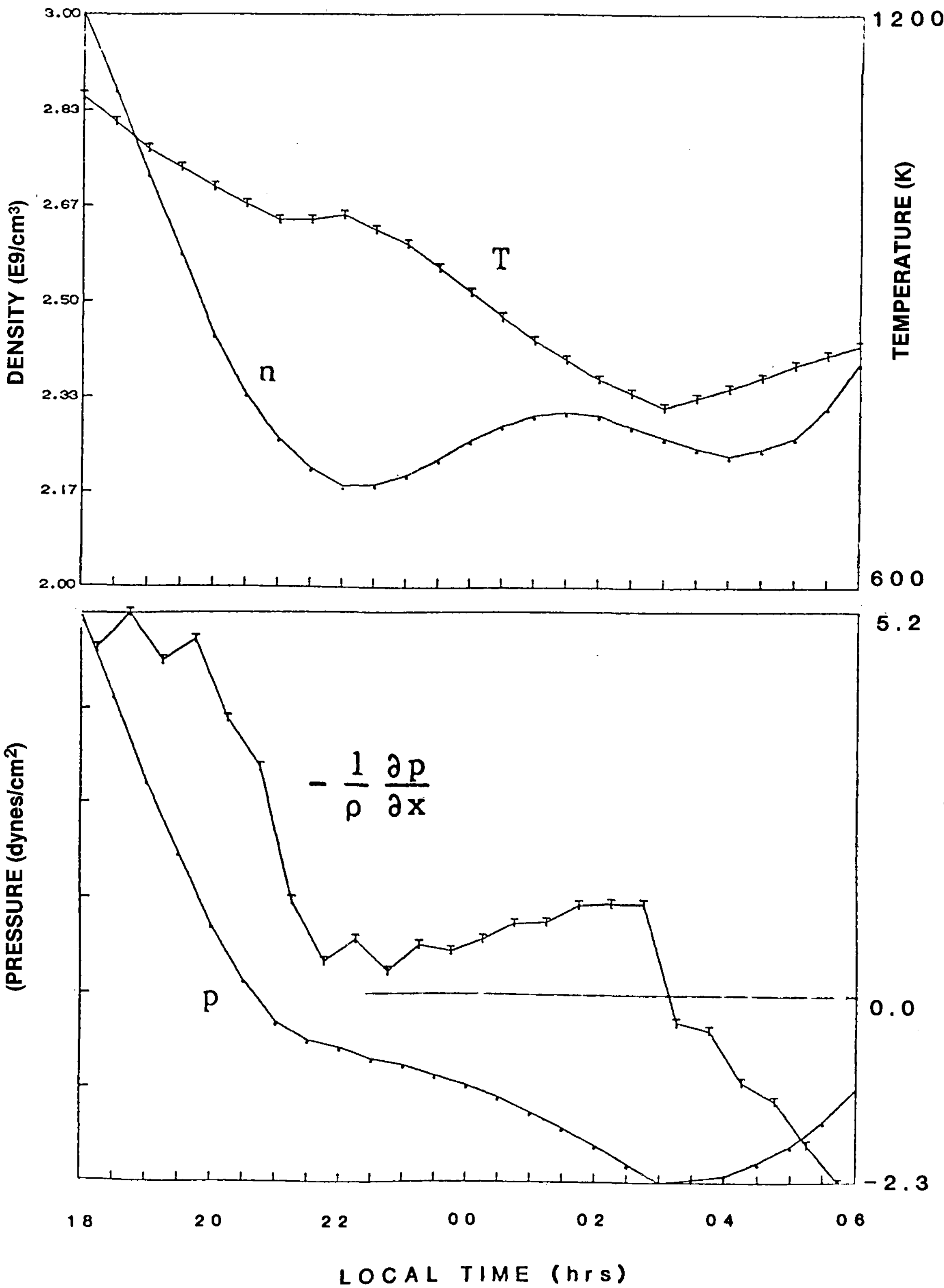
Latitude: -10 to 10 degrees



AMPLITUDES AND PHASES

ORDER	AMP(m/s)	PHASE(hrs)
1	117±7	-1.5
2	21±7	-9.9
3	34±7	10.3
4	19±7	-10.8

Figure 1



3.00
2.83
2.67
2.50
2.33
2.17
2.00
DENSITY (E9/cm³)
1200
600
TEMPERATURE (K)
T
n
5.2
0.0
-2.3
(PRESSURE (dynes/cm²)
DRIVING TERM (m/s²)
$-\frac{1}{\rho}\frac{\partial p}{\partial x}$
p
18
20
22
00
02
04
06
LOCAL TIME (hrs)

Figure 2

Fejer et al., J. Geophys. Res. 86, 215-218, 1981

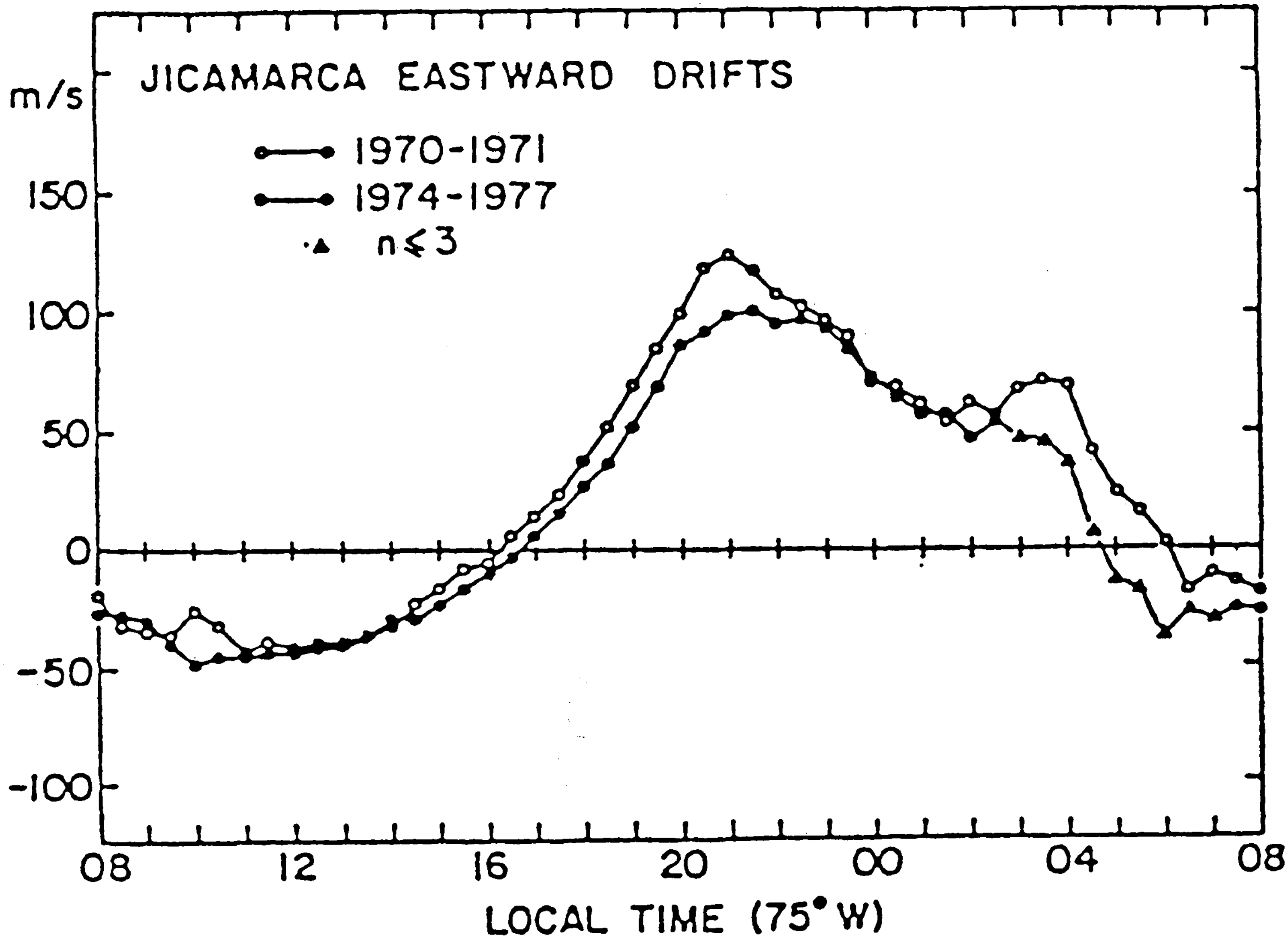
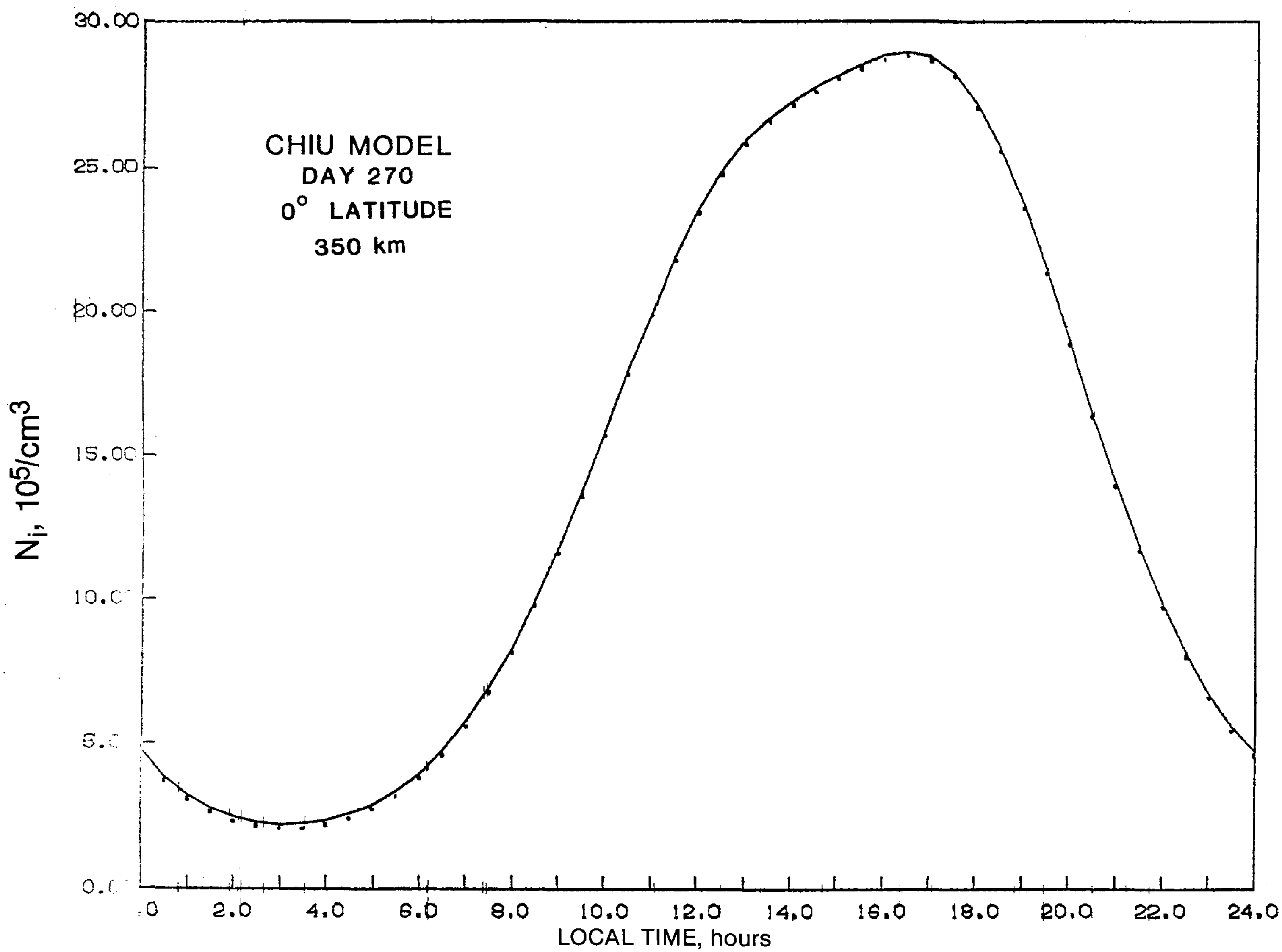


Figure 3



CHIU MODEL
DAY 270
0° LATITUDE
350 km
Ni, 10^5/cm^3
30.00
25.00
20.00
15.00
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
LOCAL TIME, hours

Figure 4