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MODEL OF JOVIAN F REGION IONOSPHERE

by

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Introduction

To date, seven electron density profiles of the Jovian ionosphere have been furnished by the radio occultation experiments aboard the Pioneer and Voyager space probes (Strobel and Atreya, 1983). The data correspond to various localities (latitudes and longitudes) and times (dawn and dusk) and phases of sunspot cycle (high and low). This renders comparative studies difficult. Nevertheless, the possibility of existence of diurnal variation (Atreya, et al., 1979), equatorial anomaly (Mahajan, 1981) and auroral particle precipitation (Waite, et al., 1983) in the Jovian ionosphere have been put forth. The grand magnitude and depth of the equatorial anomaly, in particular, is a matter of great interest and speculation. Correct interpretations of the data and the physical processes in the complex Jovian atmospheric environment will remain a major task for the Aeronomer for decades to come.

Model studies of a Jovian ionosphere created by solar EUV radiation and subjected to model ExB drifts (Tan, 1986) showed that equatorial anomaly similar to that in the terrestrial ionosphere can indeed be produced in the Jovian ionosphere. However, owing to the differences in size and rotation period of the two planets and the ionic compositions, much larger drift velocities are required to produce a comparable anomaly in the Jovian ionosphere.

Objectives

The plan of this research project is to further develop the model of Tan (1986) to include larger ExB drift velocities and invoke other mechanisms which may contribute to the magnitude of the Jovian equatorial anomaly. Specific objectives include the following.

(1) Effect of increased drift velocity on the width of the anomaly. Run the existing program to accommodate larger drift velocities and observe the resulting ionization pattern, including the width of the anomaly.

(2) Incorporation of charged particle precipitation. To incorporate auroral and non-auroral charged particle precipitation from the study of Waite et al. (1983). The high electron densities at high latitudes are almost certainly due to the ionization effects of auroral charged particle precipitation.

(3) Magnetic field model. The Jovian magnetic field contains substantial quadrupole and octupole moments (Smith, et al., 1976; Acuna and Ness, 1976). How the departure from a purely dipole field will alter the morphology of the ionosphere is to be investigated. The effect of the tilt of the dipole axis (Tan and Wu, 1981) will also be studied.

(4) F Region Chemistry. The Jovian ionosphere chemistry may be complicated (cf. Shemansky, 1985). The effect of chemical reactions on the equatorial anomaly, if any, needs to be investigated if possible.

Effect of Increased Drift Velocity Amplitude

The formation of the equatorial anomaly in a solar EUV radiation induced Jovian ionosphere under the action of ExB drifts has been described by Tan (1986). Drift velocity amplitudes of up to 100 m/s were considered. We have since then increased the drift velocity amplitude to 200 m/s.

Figures 1 through 10 exhibit the results of the model computations with sinusoidal drift velocity models having amplitudes of 200 m/s. Figures 1 and 2 display the "planet-wide" contour plots of peak electron density in Models 1 and 2 of Tan (1986). The general features of these plots are similar to those for smaller drift velocity amplitudes. The width of the equatorial anomaly increased as expected with peak electron densities concentrated around 13.5 degrees latitude in either hemisphere.

Figures 3 through 10 are contour plots in meridional planes at selected hours in the two drift models. There appears to be the formation of a "bubble" of low electron density over the equatorial region in the early hours of the day in Model 2. The bubble seems to persist until midday before disappearing. Whether there is any physical basis for this needs to be looked into.

Estimation of Drift Velocity Amplitude from the "Width" of the Equatorial Anomaly

Model computations show that the amplitude of the sinusoidal drift velocity determines the latitude in either hemisphere where the peak electron density would be concentrated and hence the "width" of the equatorial anomaly. The converse problem of estimating the drift velocity amplitude from the width of the anomaly is examined from the geometry of drifting dipolar "tubes" of ionization. The range of the vertical drift at the equator can be calculated as a function of the drift velocity amplitude and the rotational period of the planet. The magnitude of this vertical range translates into a definite arc length at HmF2 heights from which the drift in latitude can be calculated. Twice this latitudinal drift gives the minimum width of the anomaly produced. The inverse relation would provide an estimate of the drift velocity amplitude required to produce an anomaly of a given width. The values of the drift velocity amplitudes thus obtained agree closely with those obtained by numerical computations for narrow anomalies of terrestrial and Jovian ionospheres, but the agreement breaks down for wider anomalies (Appendix I).

Jovian Magnetic Field Models

A Jovian F region model similar to the terrestrial F region model of Tan and Wu (1981) has been constructed to study the effect of the tilt of the Jovian dipole axis from the rotational. Preliminary runs indicate that the resulting ionization is symmetrically situated around the dipole equator thus reaffirming a strong magnetic control of the ionospheric plasma as in the terrestrial ionosphere.

Whereas the ionization is strongly controlled by the orientation of the dipole field lines, the field strengths are found to have negligible effect on the ionization pattern. For this, we used a simple dipole model but calculated the magnetic field strengths at each field point from the O_4 Model of Connerney (Courtesy of J. H. Waite, Jr.) and failed to detect any significant deviation in the electron densities.

The offset-tilted dipole model (Acuna and Ness, 1976) provides a better approximation of the Jovian magnetic field than the centered-tilted dipole model. But we have encountered difficulties in incorporating this in our time-dependent scheme.

Further, since the Jovian magnetic field contains substantial quadrupole and octupole moments, a more accurate description calls for the incorporation of quadrupole field components, particularly when the longitudinal variation in the Jovian F region is to be studied. Here also, we have encountered numerical difficulties. Attempts are being made to resolve these difficulties.

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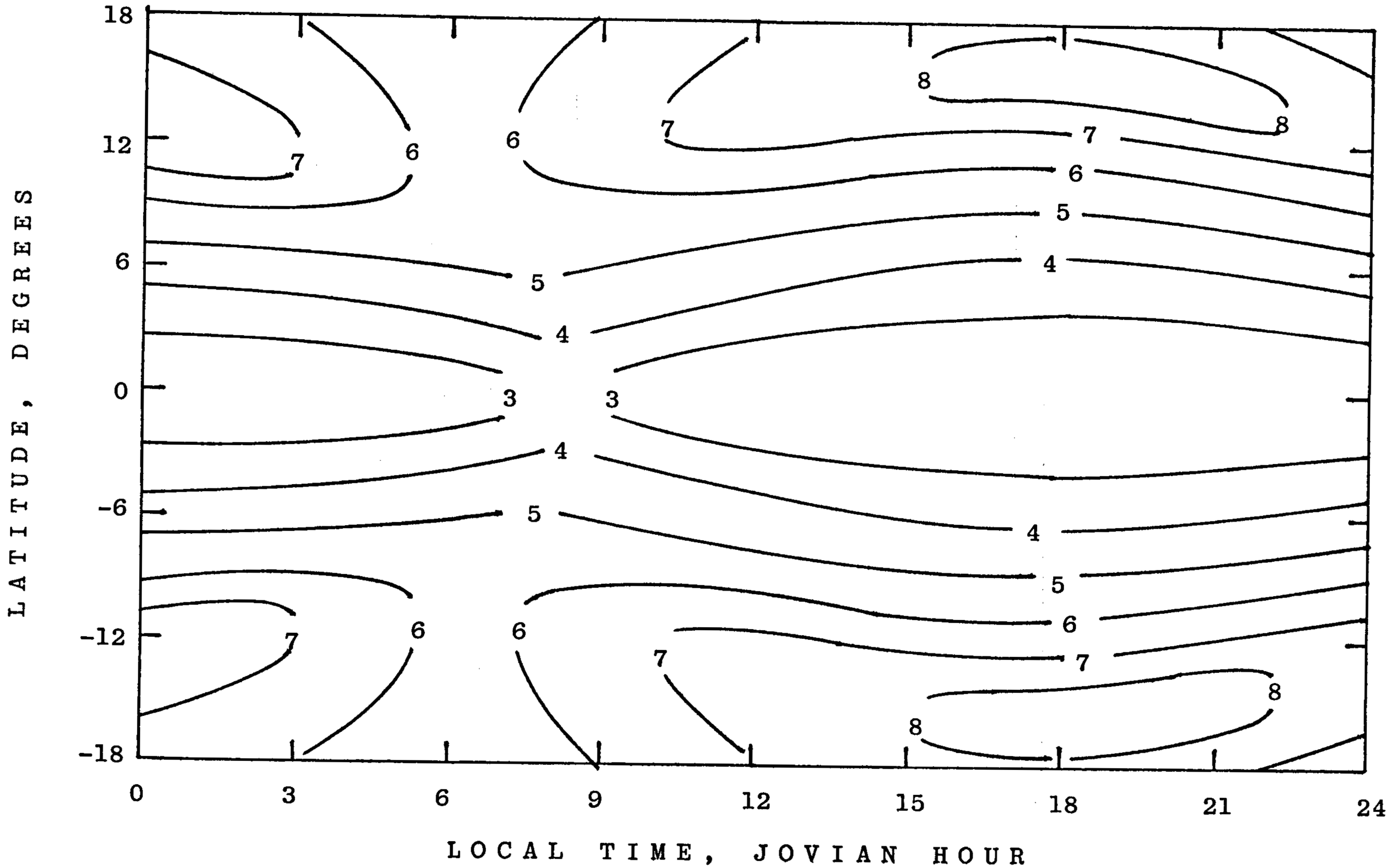

Fig.1. Contour plot of NmF2 in 10^5 electrons/cm^3 in Model 1 with Drift Velocity Amplitude of 200 m/s.

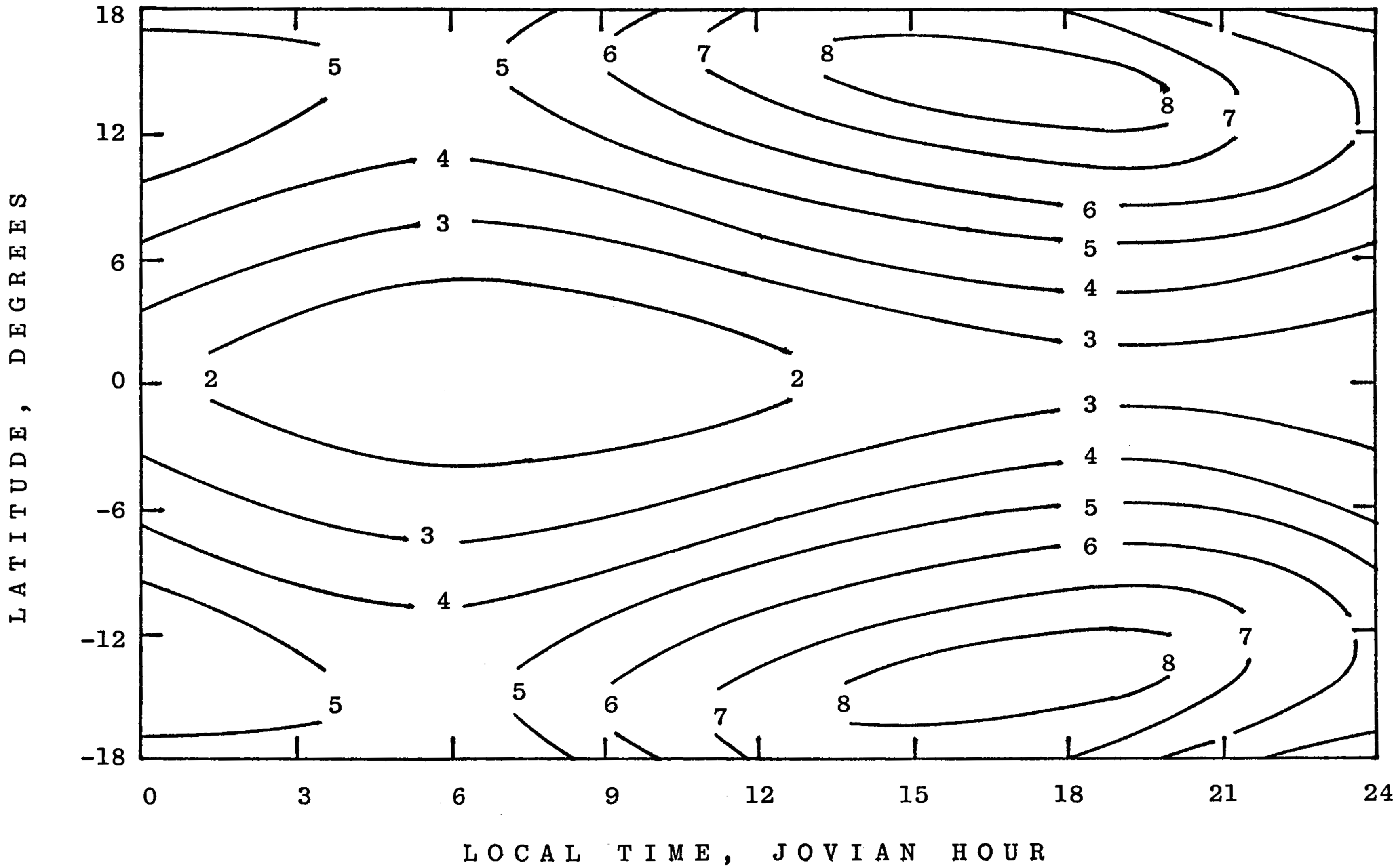

Fig.2. Contour plot of NmF2 in 10^5 electrons/cm^3 in Model 2 with Drift Velocity Amplitude of 200 m/s.

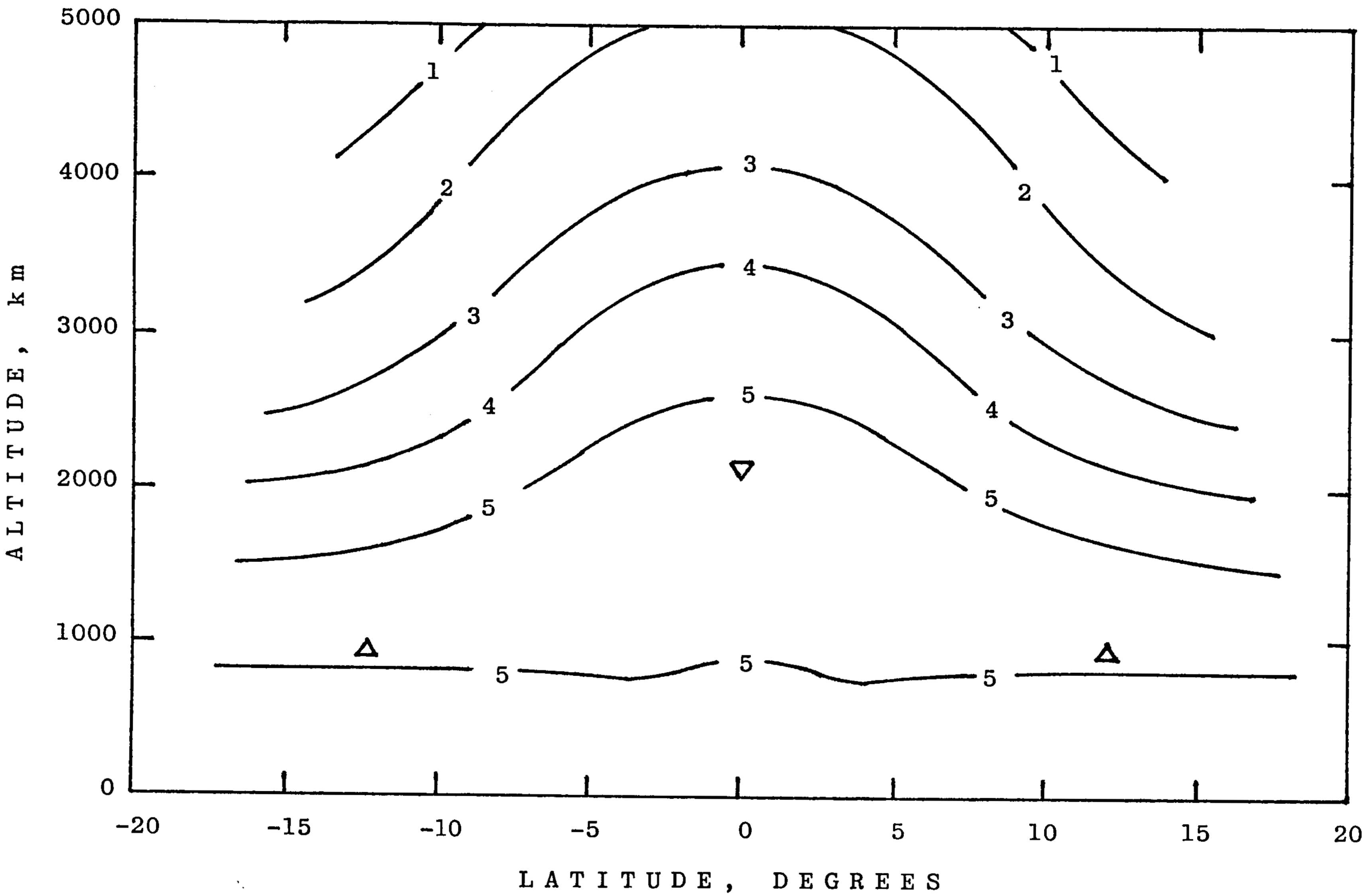

Fig.3. Meridional contour plot of electron density in 10^5 cm^{-3} in Model 1 at 0 hr LT. Pyramids indicate the locations of N_{max} at crests; inverted pyramid indicates the same at the equator.

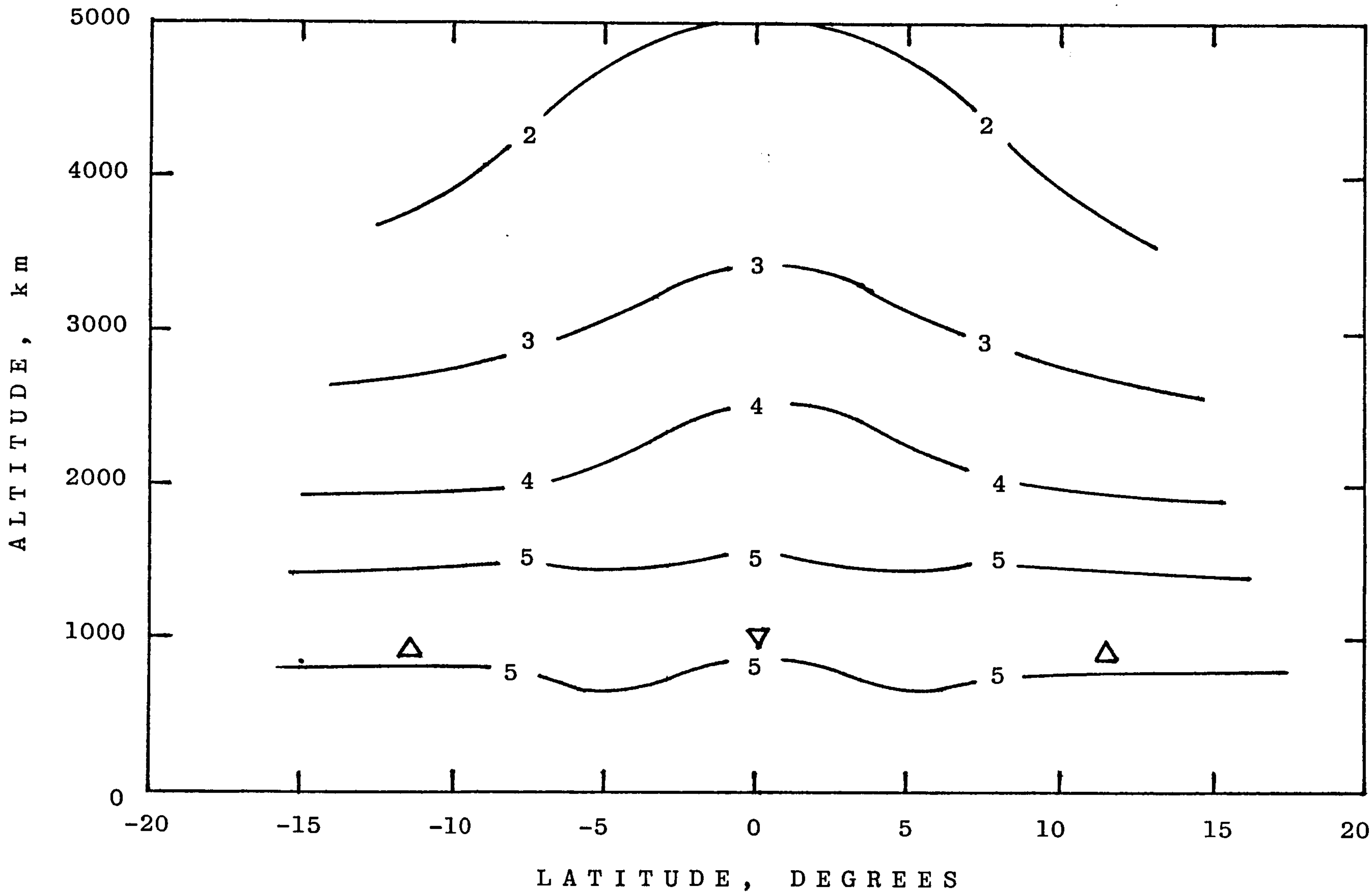

Fig.4. Meridional contour plot of electron density in 10^5 cm^{-3} in Model 1 at 6 hr LT. Pyramids indicate the locations of N_{max} at crests; inverted pyramid indicates the same at the equator.

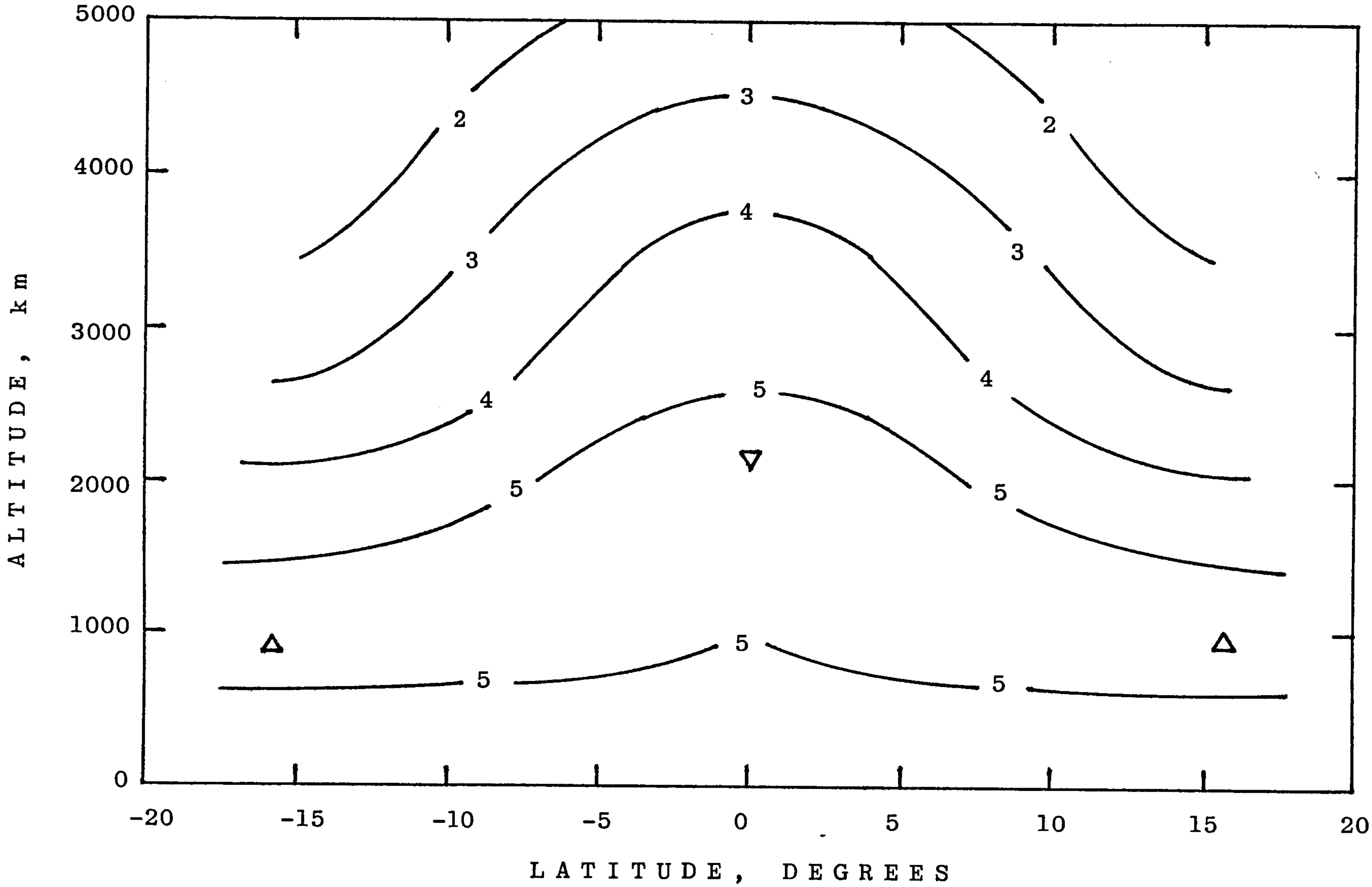

Fig.5. Meridional contour plot of electron density in 10^5 cm^{-3} in Model 1 at 12 hr LT. Pyramids indicate the locations of N_{max} at crests; inverted pyramid indicates the same at the equator.

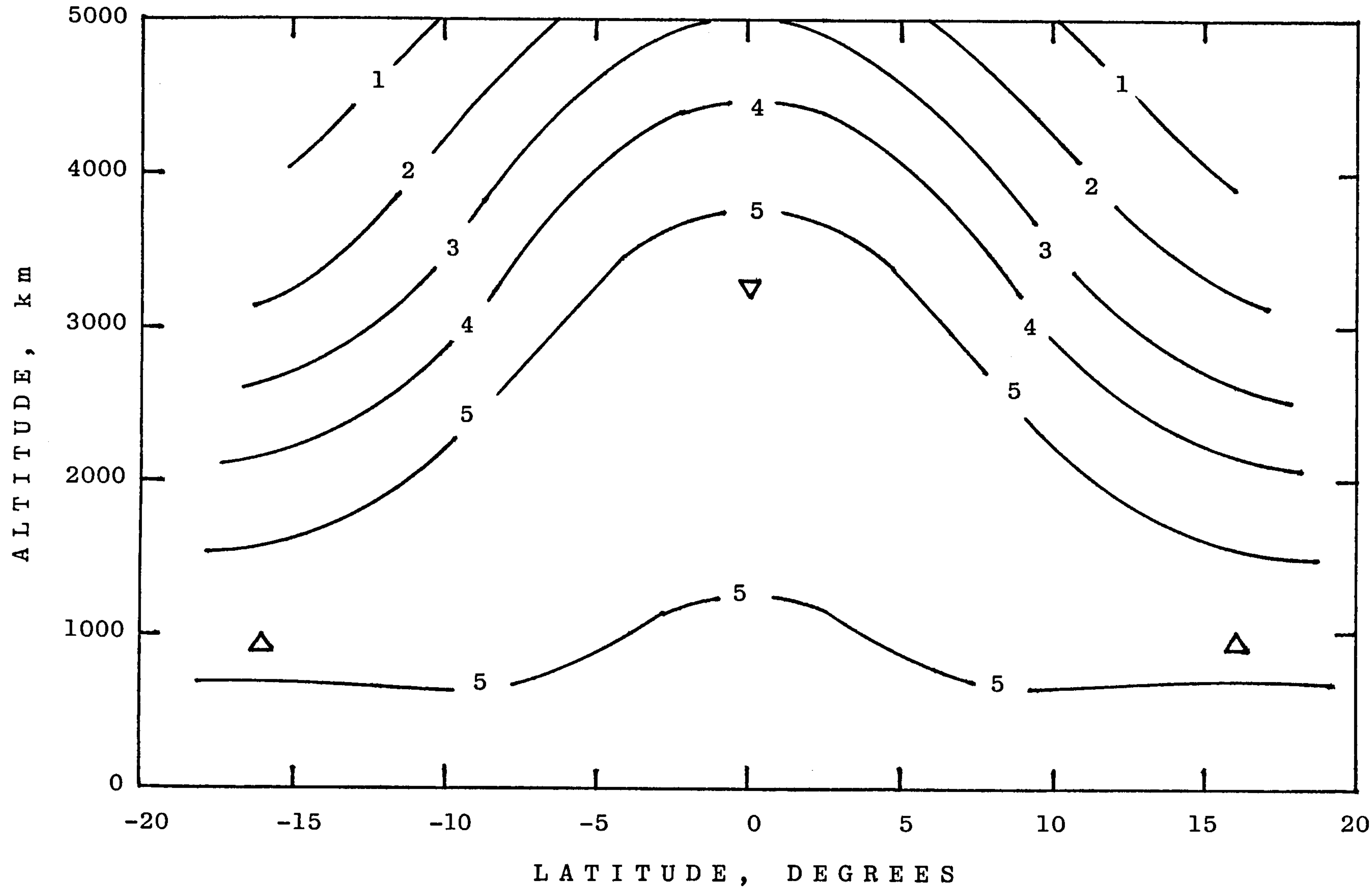

Fig.6. Meridional contour plot of electron density in 10^5 cm^{-3} in Model 1 at 18 hr LT. Pyramids indicate the locations of N_{max} at crests; inverted pyramid indicates the same at the equator.

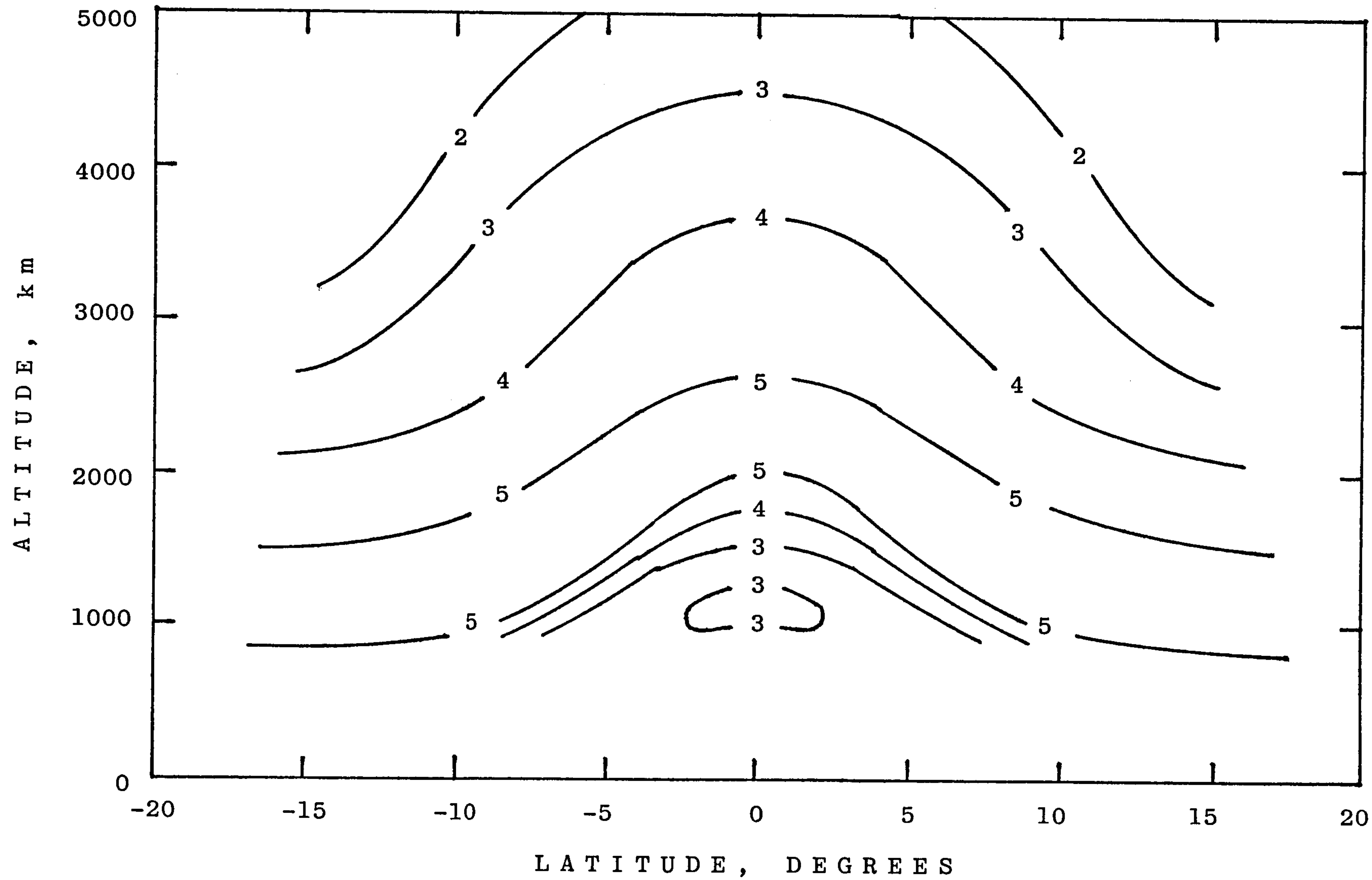

Fig.7. Meridional contour plot of electron density in 10^5 cm^{-3} in Model 2 at 0 hr LT. Pyramids indicate the locations of N_{max} at crests; inverted pyramid indicates the same at the equator.

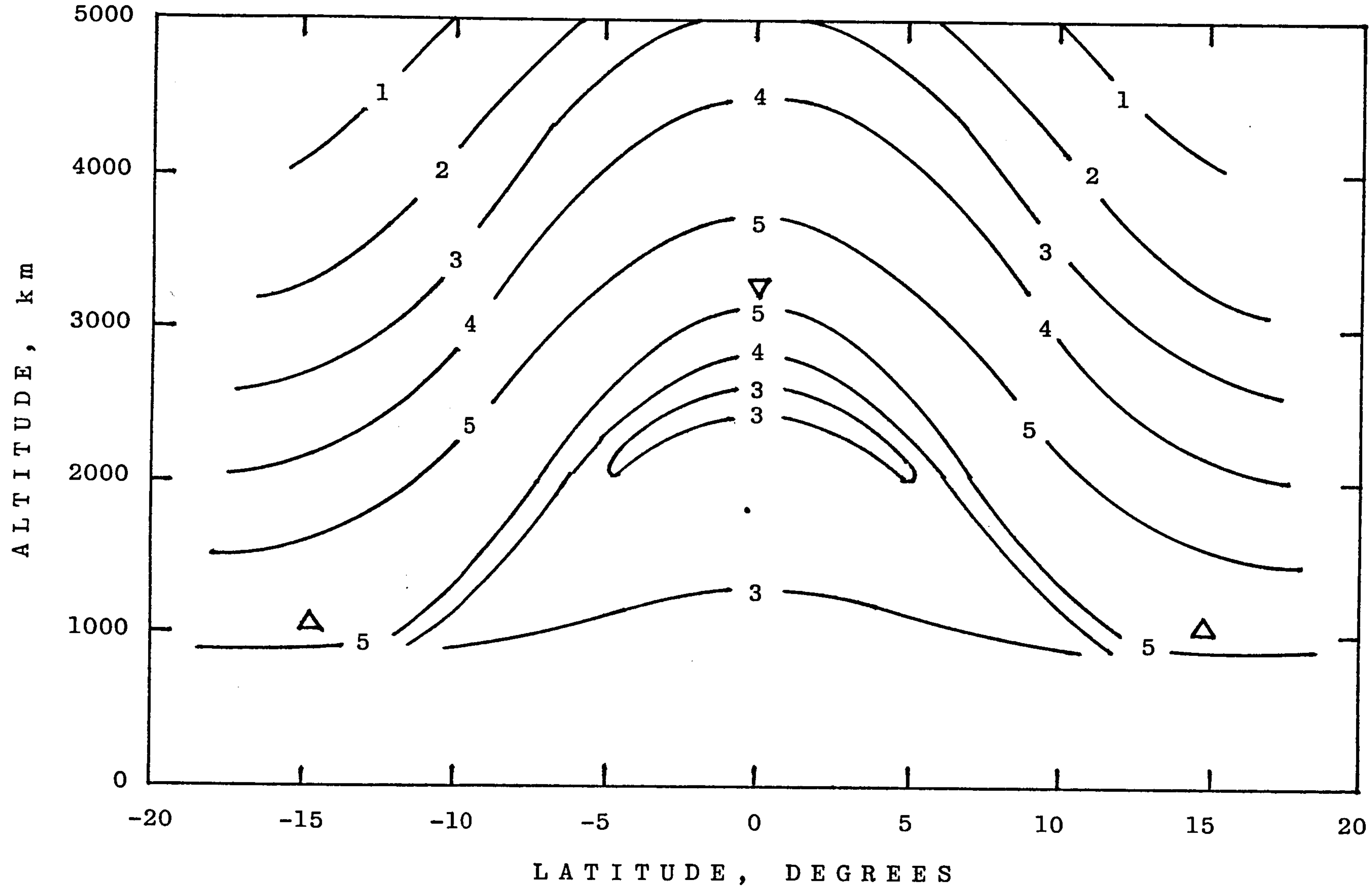

Fig.8. Meridional contour plot of electron density in 10^5 cm^{-3} in Model 2 at 6 hr LT. Pyramids indicate the locations of N_{max} at crests; inverted pyramid indicates the same at the equator.

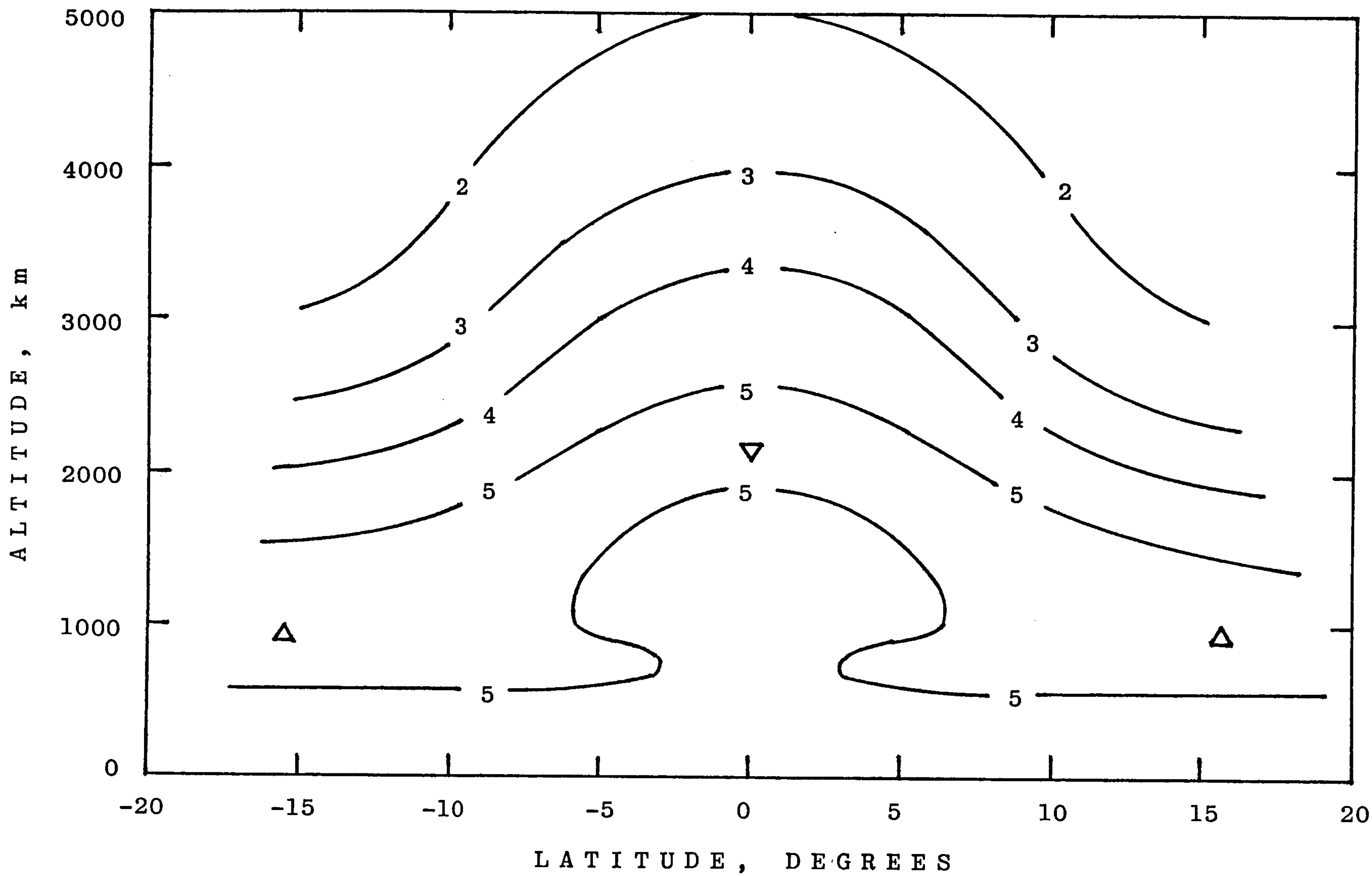

Fig.9. Meridional contour plot of electron density in 10^5 cm^{-3} in Model 2 at 12 hr LT. Pyramids indicate the locations of N_{max} at crests; inverted pyramid indicates the same at the equator.

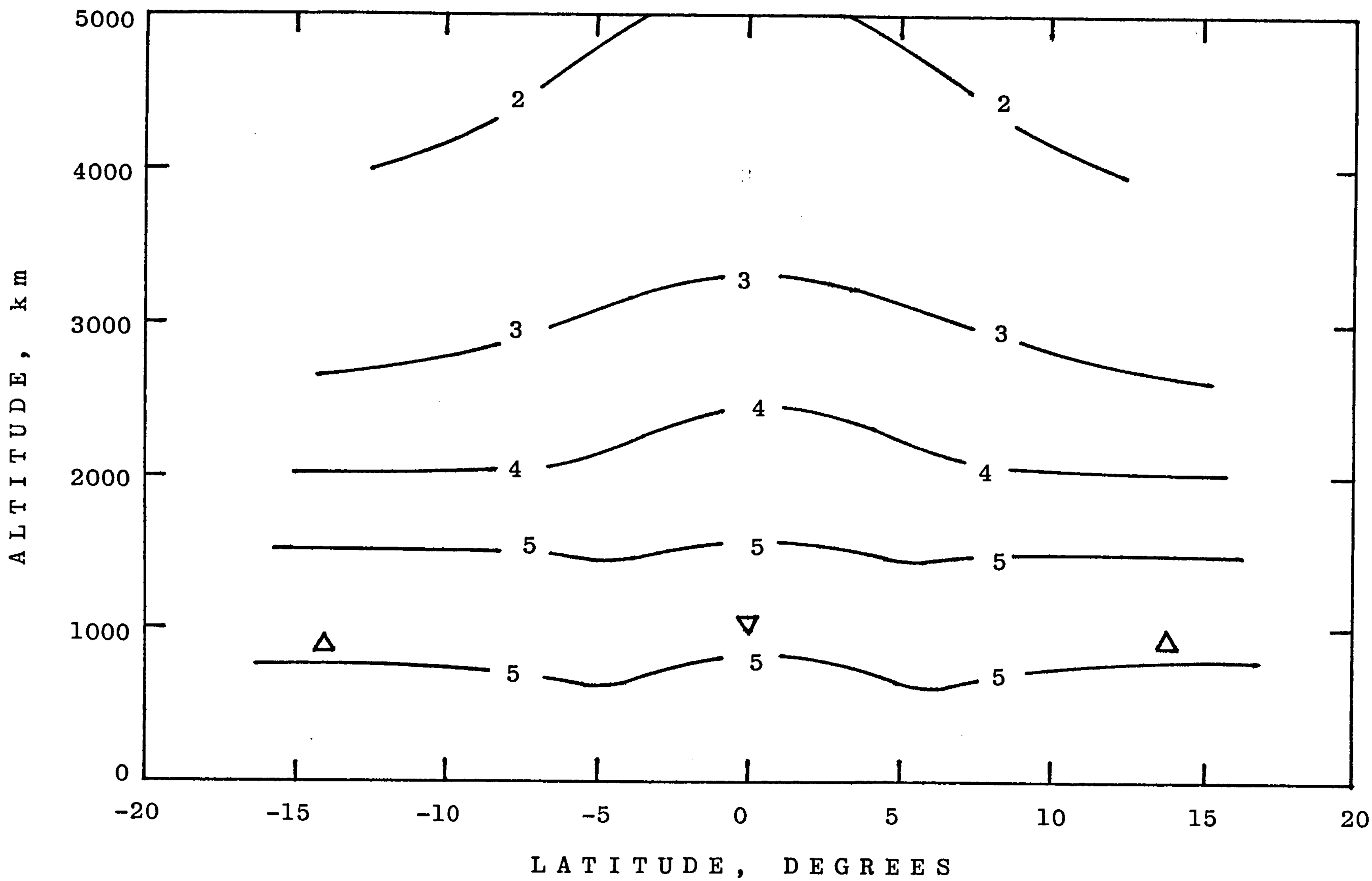

Fig.10. Meridional contour plot of electron density in 10^5 cm^{-3} in Model 2 at 18 hr LT. Pyramids indicate the locations of N_{max} at crests; inverted pyramid indicates the same at the equator.

APPENDIX I. Abstract submitted to American Geophysical Union Spring 1988 Meeting.

1. 1988 Spring Meeting

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Estimation of Electrodynamic Drift Velocity Amplitude from the Width of the Equatorial Anomaly of a Planetary Ionosphere

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The equatorial anomaly in the terrestrial ionosphere is known to be caused by a diurnal east-west electric field through the "fountain effect". Detailed numerical modelling shows that the amplitude of the drift velocity determines the latitude in either hemisphere where the maximum electron density would be concentrated and therefore the "width" of the anomaly. The converse problem of estimating the drift velocity amplitude from the width of the anomaly is examined. A semi-empirical expression of the drift velocity amplitude is obtained as functions of the latitude of the crest of ionization, the rotational period of the planet, the equatorial radius of the planet and the altitude of the peak electron density. The results obtained from this expression agree closely with those obtained by numerical modelling for narrow anomalies of terrestrial and Jovian ionospheres, but for wider anomalies, the introduction of an adjustable parameter is called for. Results for the Saturnian ionosphere show that peak ionizations around 5, 10 and 15 degrees latitudes would require drift velocity amplitudes of 41m/s, 134m/s and 246m/s respectively.

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