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Tutorial Lecture

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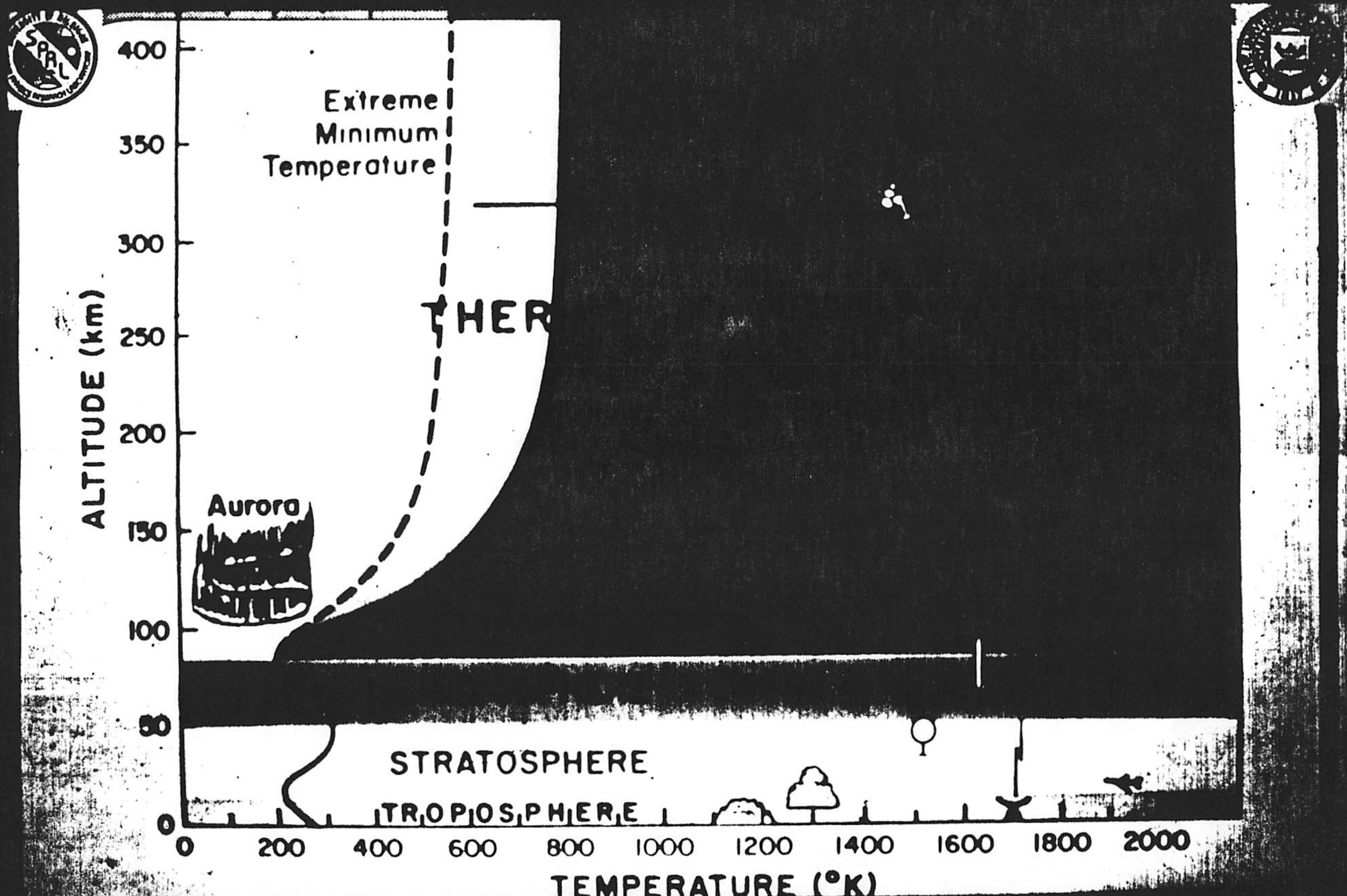
Overview of the Thermosphere/Ionosphere General Circulation Model (TIGCM)



Extreme
Minimum
Temperature
HER
Aurora
STRATOSPHERE
TROPOSPHERE
ALTITUDE (km)
400
350
300
250
200
150
100
50
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
TEMPERATURE (°K)
SPRL

NCAR THERMOSPHERE/~~IONOSPHERE~~ GENERAL CIRCULATION MODEL (~~TIGCM~~)

(TGCM)

- Primitive equations of dynamic meteorology adapted to thermospheric heights

- Horizontal grid 5° latitude x 5° longitude, geographic
- Vertical grid -- 25 constant pressure surfaces, 2 grid points per scale height, 95 to 500 km
- Time step 240 or 300 S

INPUT

- Solar EUV and UV radiation 5 to 250 nm
- Empirical ionospheric convection and auroral particle precipitation models

LONG RANGE MODEL DEVELOPMENT

1980	Ionosphere Dynamo MSIS Aurora Solar Tides	TGCM (100-500KM)	Atmosphere Explorer Dynamics Explorer Radar and Airglow
VTGCM (VENUS)			
1989	Dynamo Aurora Solar Tides	TIGCM (95-500KM)	Atmosphere Explorer Dynamics Explorer Air Force CEDAR
MTGCM MARS			
1991	Aurora Solar Tides	TIE-GCM (95-500)	Atmosphere Explorer Dynamics Explorer San Marcos CEDAR GEM
199~~3~~2	Aurora (GEM) Solar(RISE)	TIME-GCM (30-500KM)	UARS ISTP CEDAR GEM Air Force
1996	Aurora (GEM) Solar (RISE)	CCM/TIME-GCM (0-500KM)	UARS EOS Global Change Timed

$Z = -\ln P/P_0$

THERMODYNAMIC EQUATION

$P_0 = 5 \times 10^{-7}$ mb
~ 250 km..

$$\frac{\partial T}{\partial t} = \frac{g e^{z}}{P_0 C_p} \frac{\partial}{\partial z} \left\{ \frac{K_T}{H} \frac{\partial T}{\partial z} + \frac{K_E H^2 C_p \rho}{P_r} \left(\frac{g}{C_p} + \frac{1}{H} \frac{\partial T}{\partial z} \right) \right\}$$

Molecular thermal conduction

Eddy thermal conduction

$$- \underline{V} \cdot \nabla T - W \left(\frac{\partial T}{\partial z} + \frac{R T}{C_p m} \right) + \frac{(Q - L)}{C_p}$$

horizontal advection

vertical advection and adiabatic expansion

heat sources and radiative losses

<u>Upper Boundary Conditions</u>

No heat source or heat sink at upper boundary

$$\frac{\partial T}{\partial z} = 0$$

<u>Lower Boundary Conditions</u>

Temperature specified

$$T = T_s (z = -7)$$

THE EASTWARD MOMENTUM EQUATION

$$\frac{\partial u}{\partial t} = \frac{ge^{z}}{P_0}\frac{\partial}{\partial z}\left(\frac{\mu}{H}\frac{\partial u}{\partial z}\right) + \left(f + \frac{u}{r}\tan\phi - \lambda_{xy}\right)v$$

$$-\lambda_{xx} u - \mathbf{V}\cdot\nabla u - w\frac{\partial u}{\partial z} - \frac{1}{r\cos\phi}\frac{\partial \Phi'}{\partial \lambda} + (F_\lambda + \lambda_{xy} v_I + \lambda_{xx} u_I)$$

THE NORTHWARD MOMENTUM EQUATION

$$\frac{\partial v}{\partial t} = \frac{ge^{z}}{P_0}\frac{\partial}{\partial z}\left(\frac{\mu}{H}\frac{\partial v}{\partial z}\right) - \left(f + \frac{u}{r}\tan\phi - \lambda_{yx}\right)u$$

$$-\lambda_{yy} v - \mathbf{V}\cdot\nabla v - w\frac{\partial v}{\partial z} - \frac{1}{r}\frac{\partial \Phi'}{\partial \phi} + (F_\phi + \lambda_{yy} v_I - \lambda_{yx} u_I)$$

THE CONTINUITY EQUATION

$$\frac{1}{r\cos\phi}\frac{\partial}{\partial\phi}(v\cos\phi) + \frac{1}{r\cos\phi}\frac{\partial u}{\partial\lambda} + e^{z}\frac{\partial}{\partial z}(e^{-z}w) = 0$$

THE HYDROSTATIC EQUATION

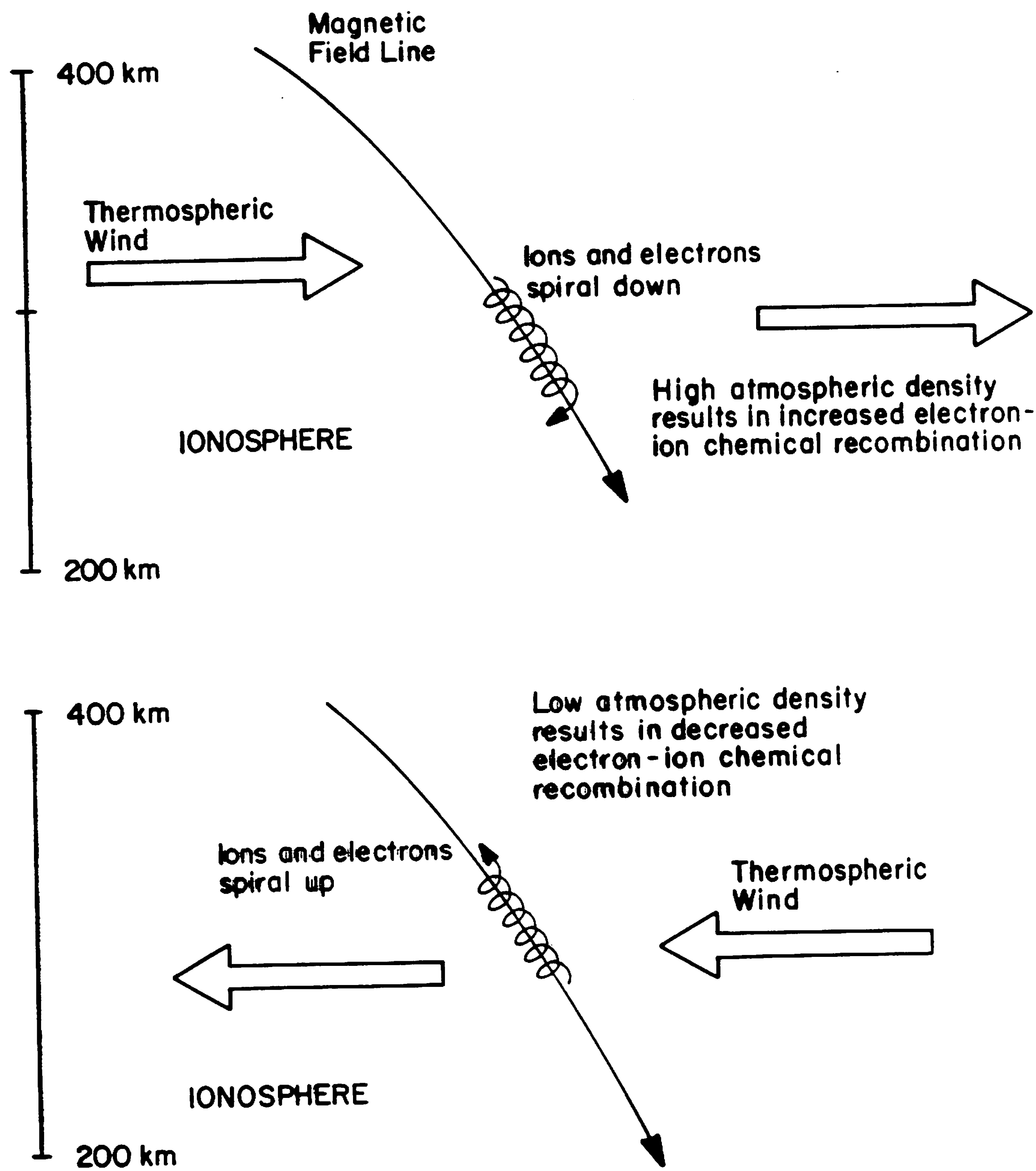
$$\frac{\partial \Phi}{\partial z} = \frac{RT}{m}$$

Upper Boundary Conditions

No sources of momemtum at upper boundary $\qquad \dfrac{\partial u}{\partial z} = \dfrac{\partial v}{\partial z} = \dfrac{\partial w}{\partial z} = 0$

Lower Boundary Conditions

Specified
$$U = U_s\,(z = -7)$$
$$V = V_s\,(z = -7)$$
$$\Phi = \Phi_s\,(z = -7)$$



Magnetic
Field Line
400 km
Thermospheric
Wind
Ions and electrons
spiral down
High atmospheric density
results in increased electron-
ion chemical recombination
IONOSPHERE
200 km
400 km
Low atmospheric density
results in decreased
electron-ion chemical
recombination
Ions and electrons
spiral up
Thermospheric
Wind
IONOSPHERE
200 km

ION DRAG PARAMETERS

$$\lambda_{xx} = \lambda_1 \,(1 - \sin^2 \delta \cos^2 I\,)$$

$$\lambda_{yy} = \lambda_1 \,(1 - \cos^2 \delta \cos^2 I\,)$$

$$\lambda_{xy} = + \, \lambda_1 \sin \delta \cos \delta \cos^2 I \, + \lambda_2 \sin I$$

$$\lambda_{yx} = + \, \lambda_1 \sin \delta \cos \delta \cos^2 I \, + \lambda_2 \sin I$$

where δ is the magnetic declination angle, I is the magnetic dip angle and

$$\lambda_1 = \frac{\sigma_P B^2}{\rho} \qquad\qquad \lambda_2 = \frac{\sigma_H B^2}{\rho}$$

where σ_P and σ_H are the Pedersen and Hall electrical conductivity, respectively. B is the strength of the magnetic field $= 0.282 \sqrt{1 + 3 \cdot \cos^2 \phi_m}$ Gauss, ϕ_M is the magnetic colatitude, and ρ is the TGCM density.

JOULE HEATING

The Joule heating for displaced poles is

$$Q_J = \underline{\lambda_{xx} \,(U_I - U_n\,)^2} + \underline{\lambda_{yy} \,(V_i - V_n\,)^2} + (\lambda_{xy} \; - \cancel{\lambda_{yx}\,)(U_i} - U_n\,)(V_i - V_n\,)$$

where U_i and V_i are the geographic zonal and meridional ion drift velocities defined by the Heelis *et al.* (1982) empirical model and U_n and V_n are the zonal and meridional neutral wind components determined at a given time step in the TGCM.

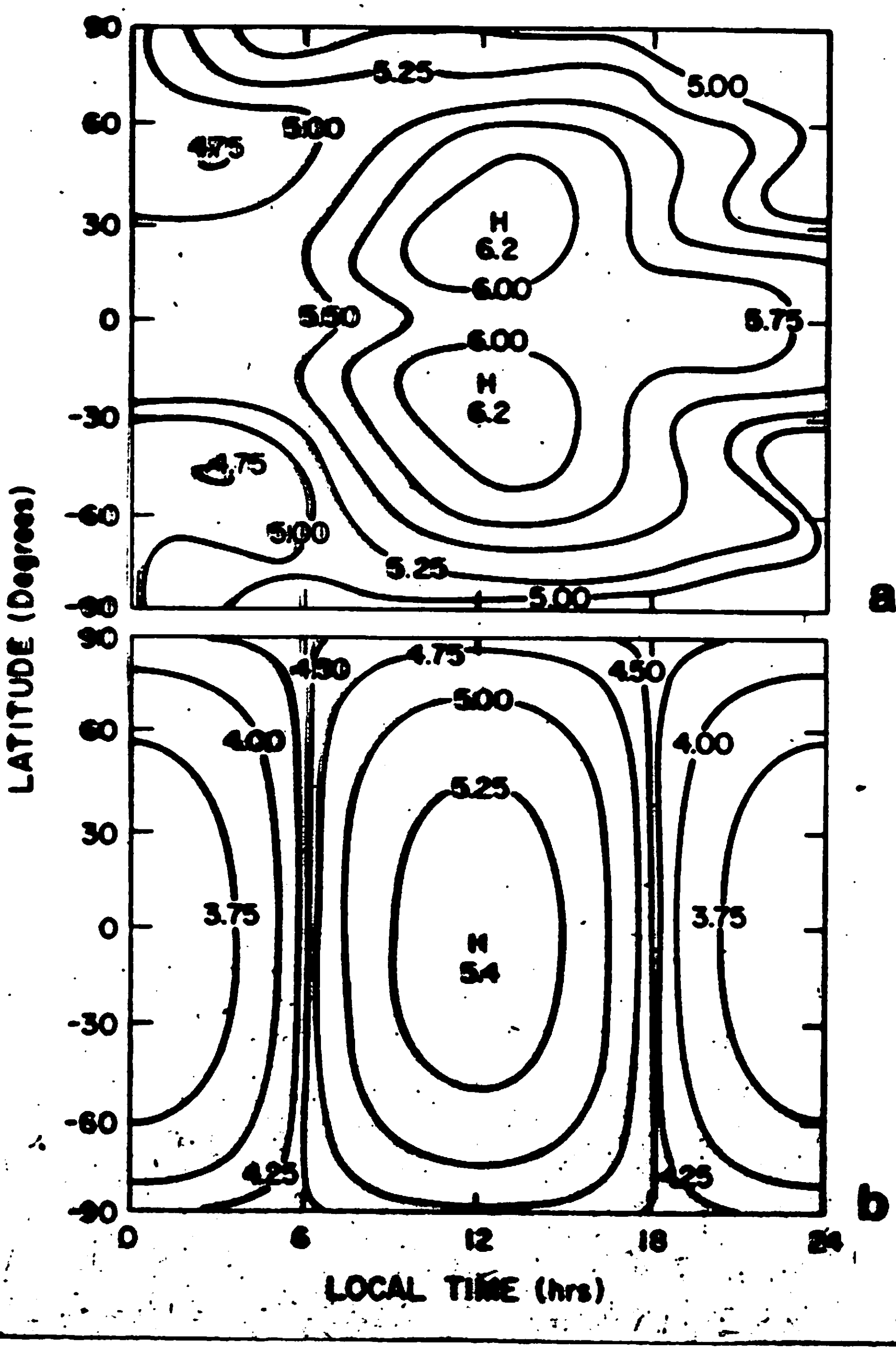
EMPIRICAL ELECTRON DENSITY MODEL (CHIU, 1975)

LOG_{10} (n_e, cm^{-3})

EQUINOX $F_{10.7} \sim 150$

300 KM

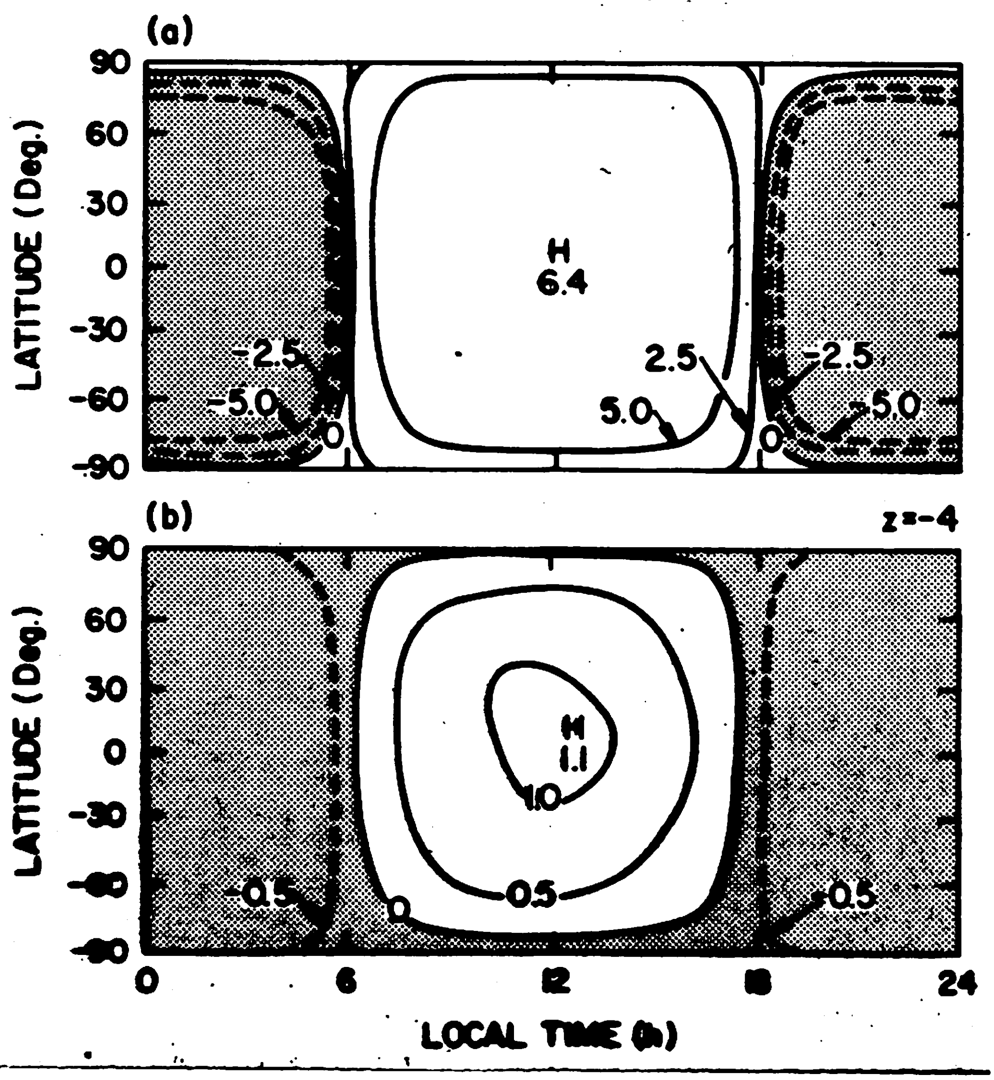
120 KM



PRESCRIBED SOLAR HEATING (

LOG_{10} (Q, ERGS $GM^{-1} S^{-1}$)

EQUINOX $F_{10.7} \sim 150$

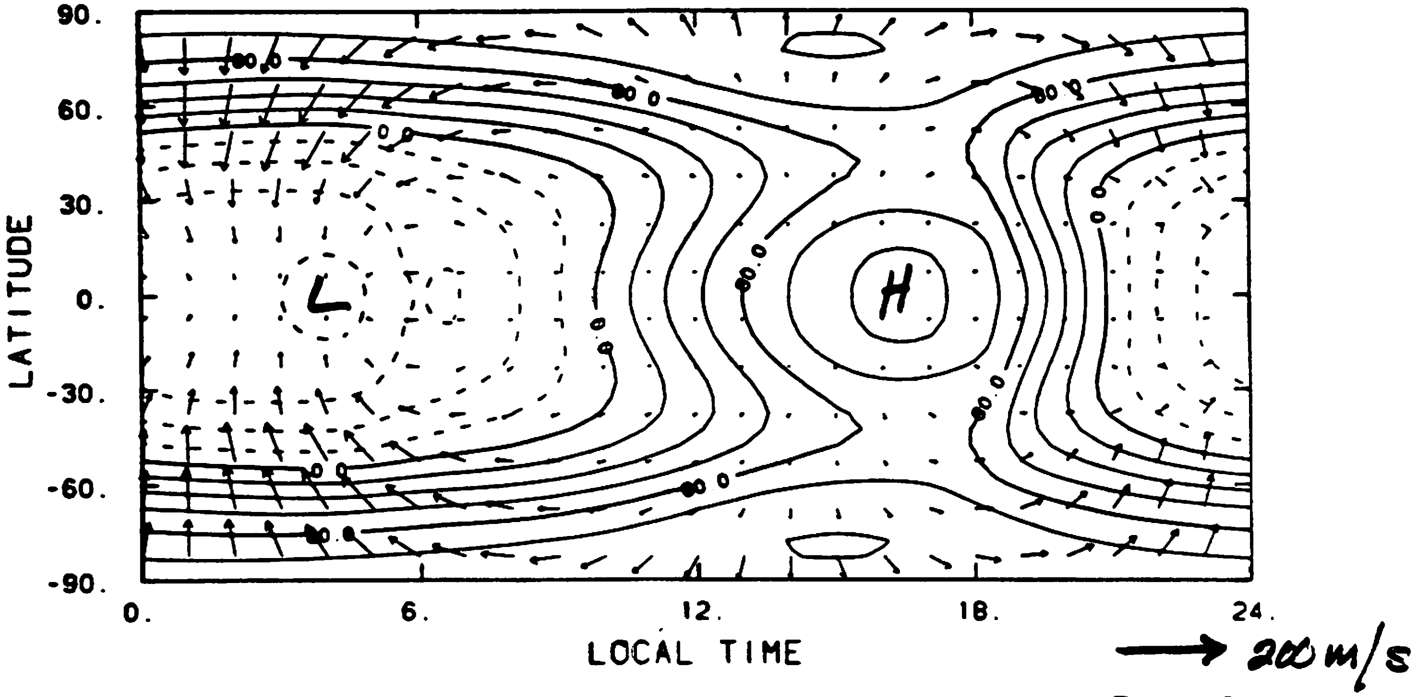


300 KM.

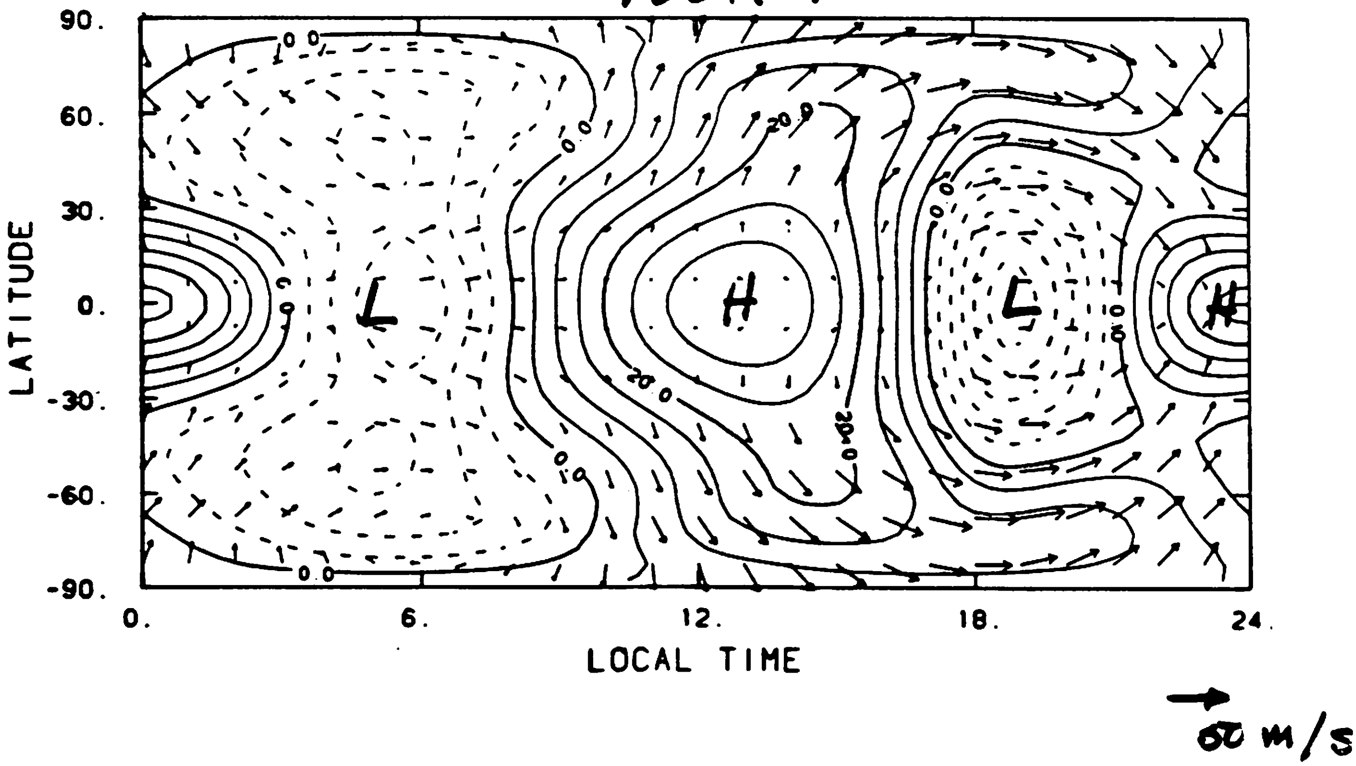
120 KM.

PERTURBATION TEMPERATURE (ΔT, K)
VECTORS OF NEUTRAL WIND (m/s)

300 KM   Z= 1 0



120KM   Z=-4.0

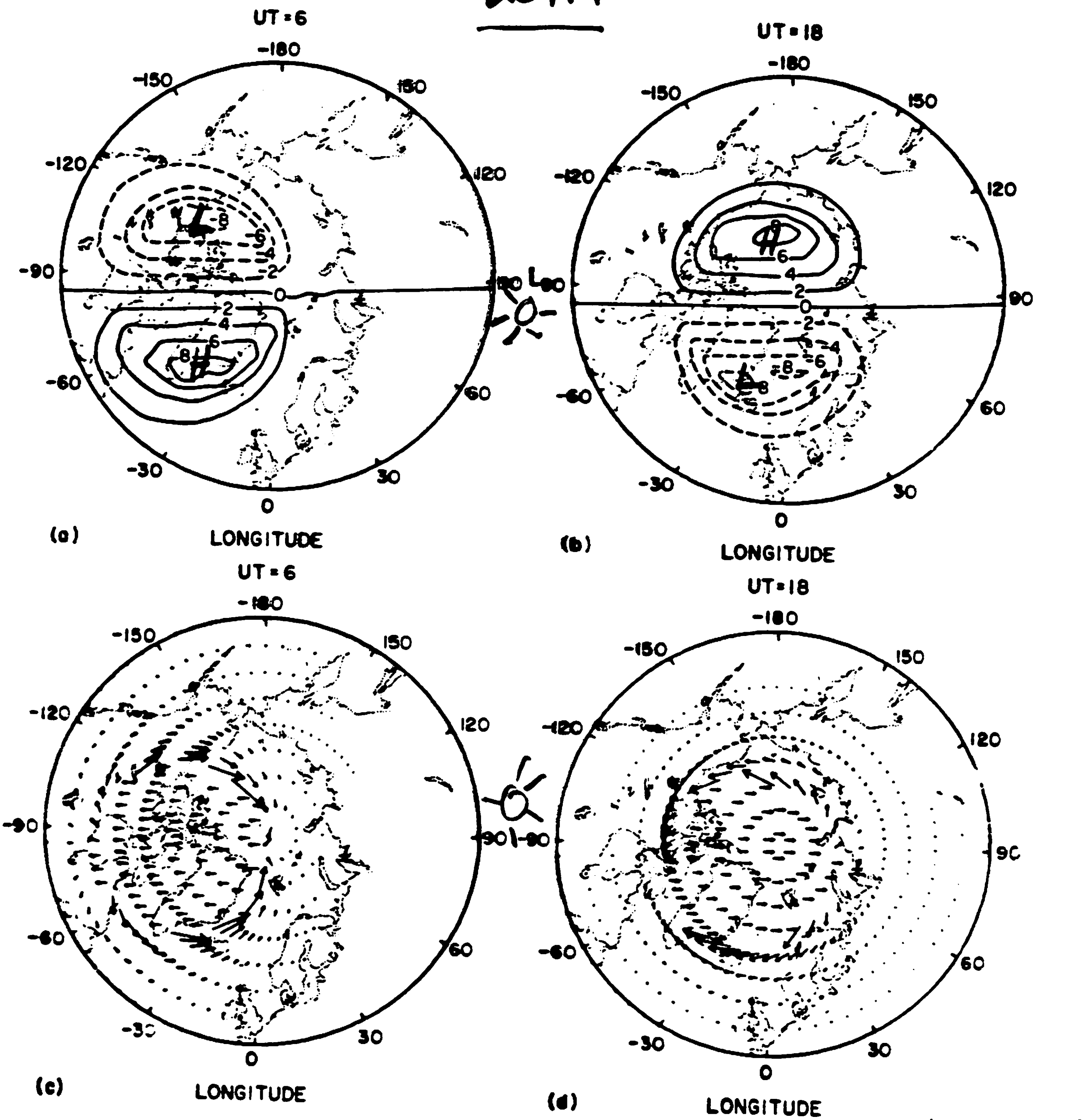


EQUINOX $F_{10.7} = 150$

SOLAR HEATING ONLY

IONOSPHERIC POTENTIAL (VOLTS)

20KV



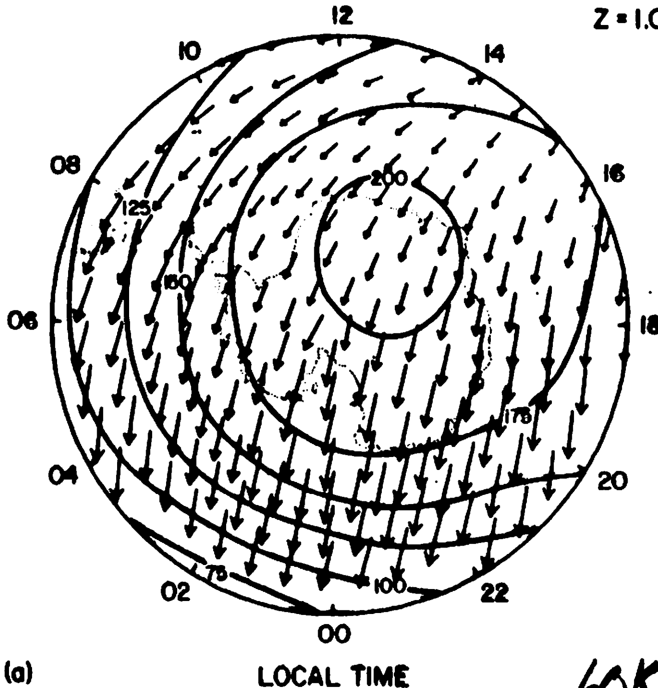
ION DRIFT $\longrightarrow$ M (MOMENTUM)

$\longrightarrow$ 500 m/s

Q_J (JOULE)

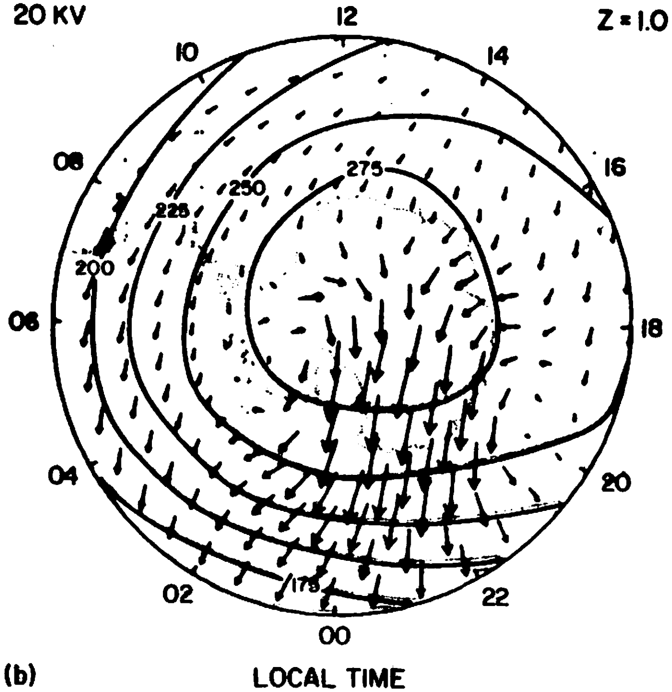
SOLAR ONLY

20KV



ΔT ~ 200K

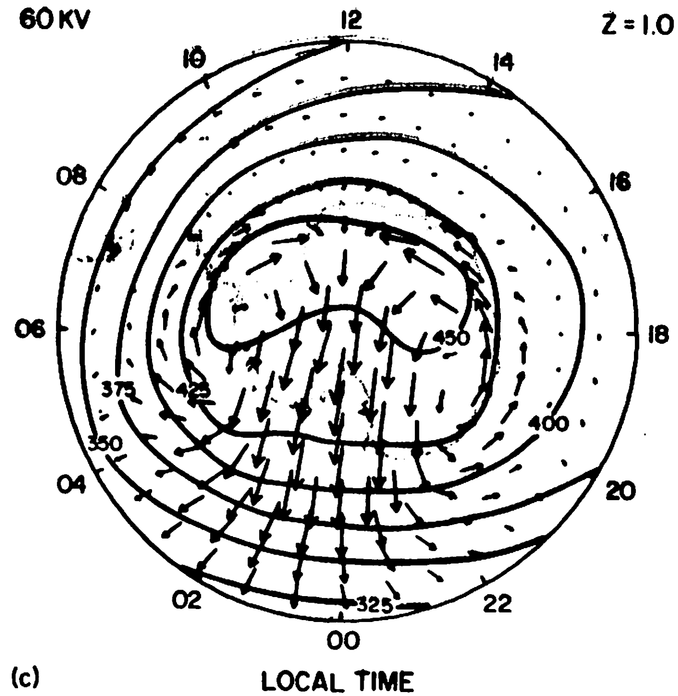
V ~ 100 m/s



ΔT ~ 275 K

V ~ 200 m/s

60KV



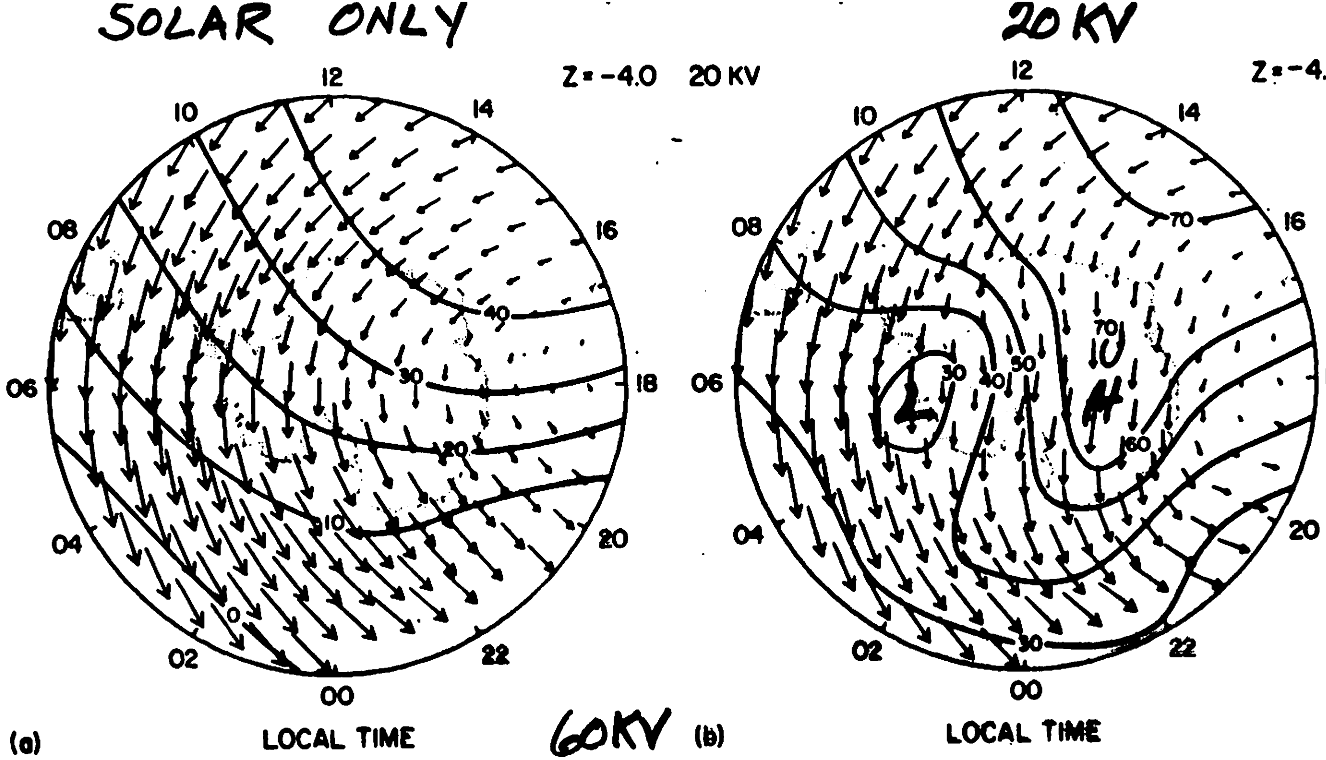
ΔT ~ 450 K

V ~ 400 m/s

EQUINOX

300KM

Figure 2

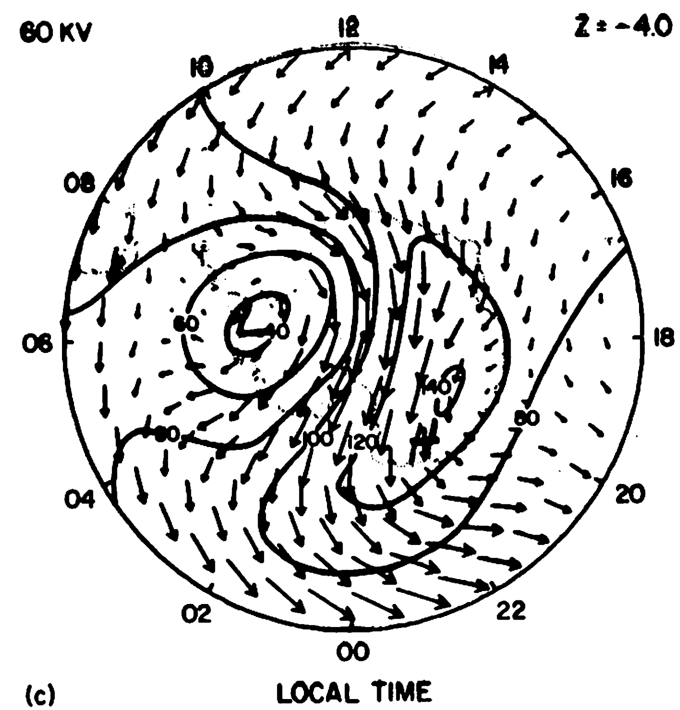


$V \sim 30 m/s$

$T_H \sim 70 K$

$T_L \sim 30 K$

$V \sim 60 m/s$



EQUINOX

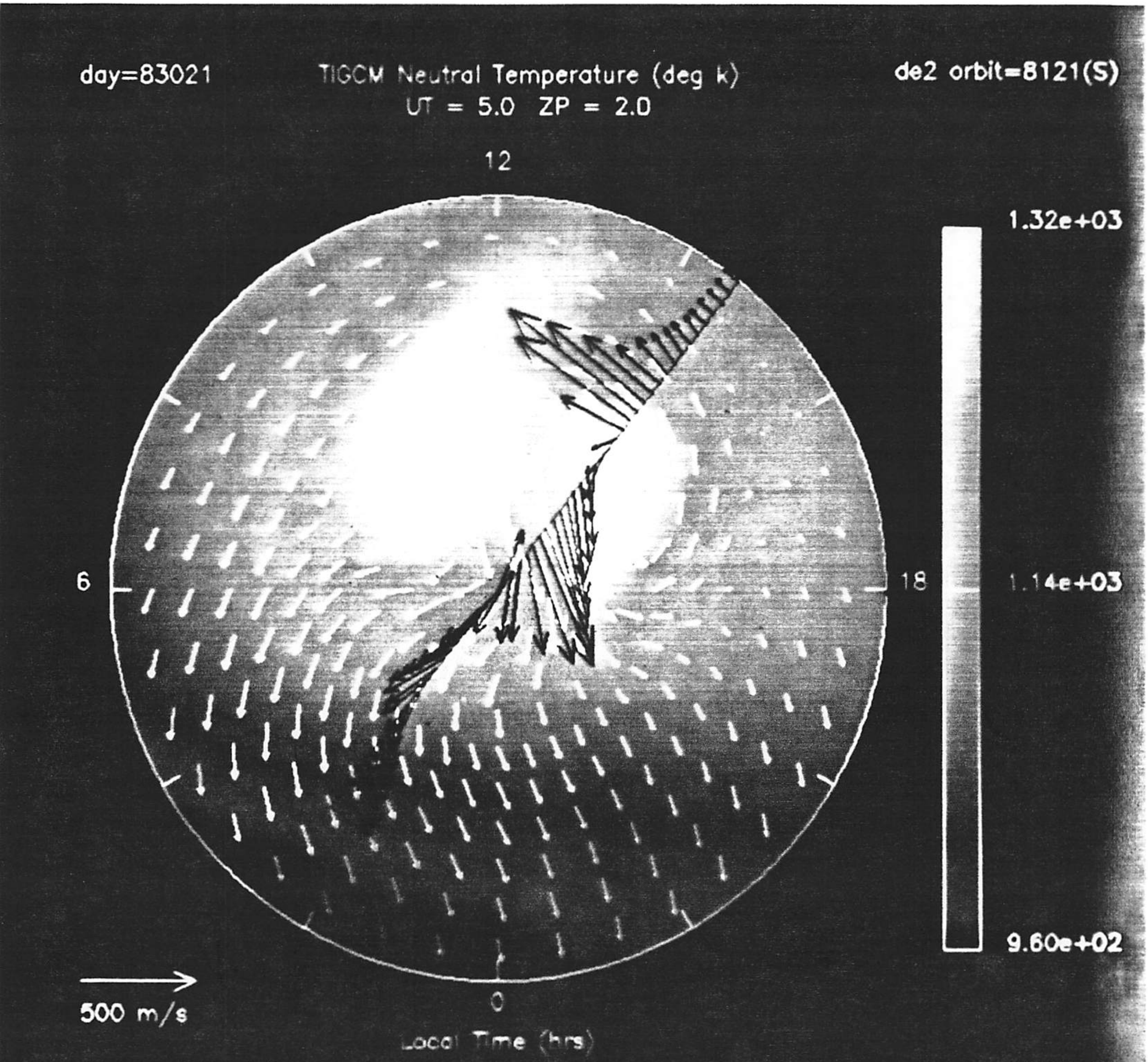
120 KM

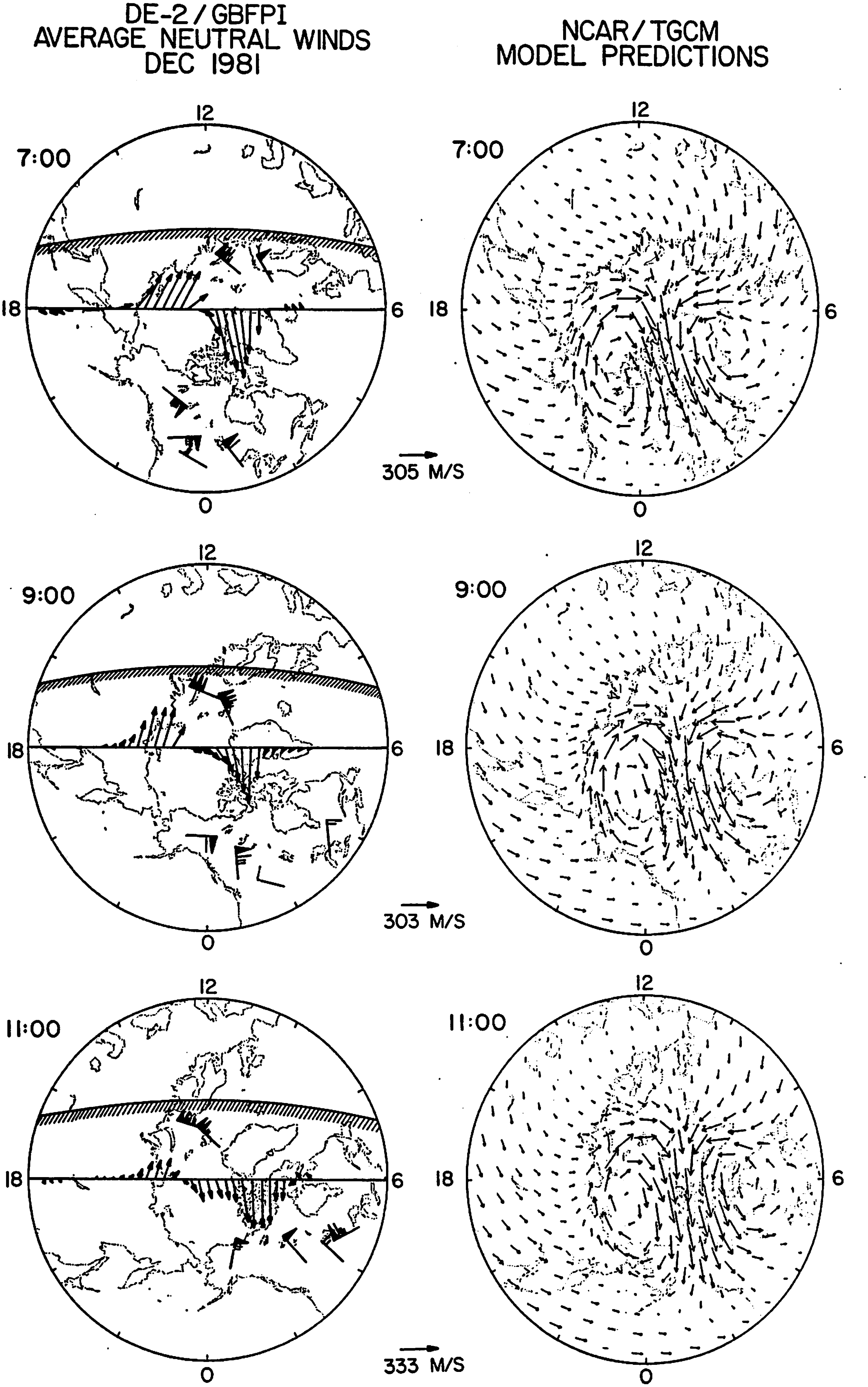
$T_H \sim 140 K$

$T_L \sim 30 K$

$V \sim 100 m/s$

Figure 3

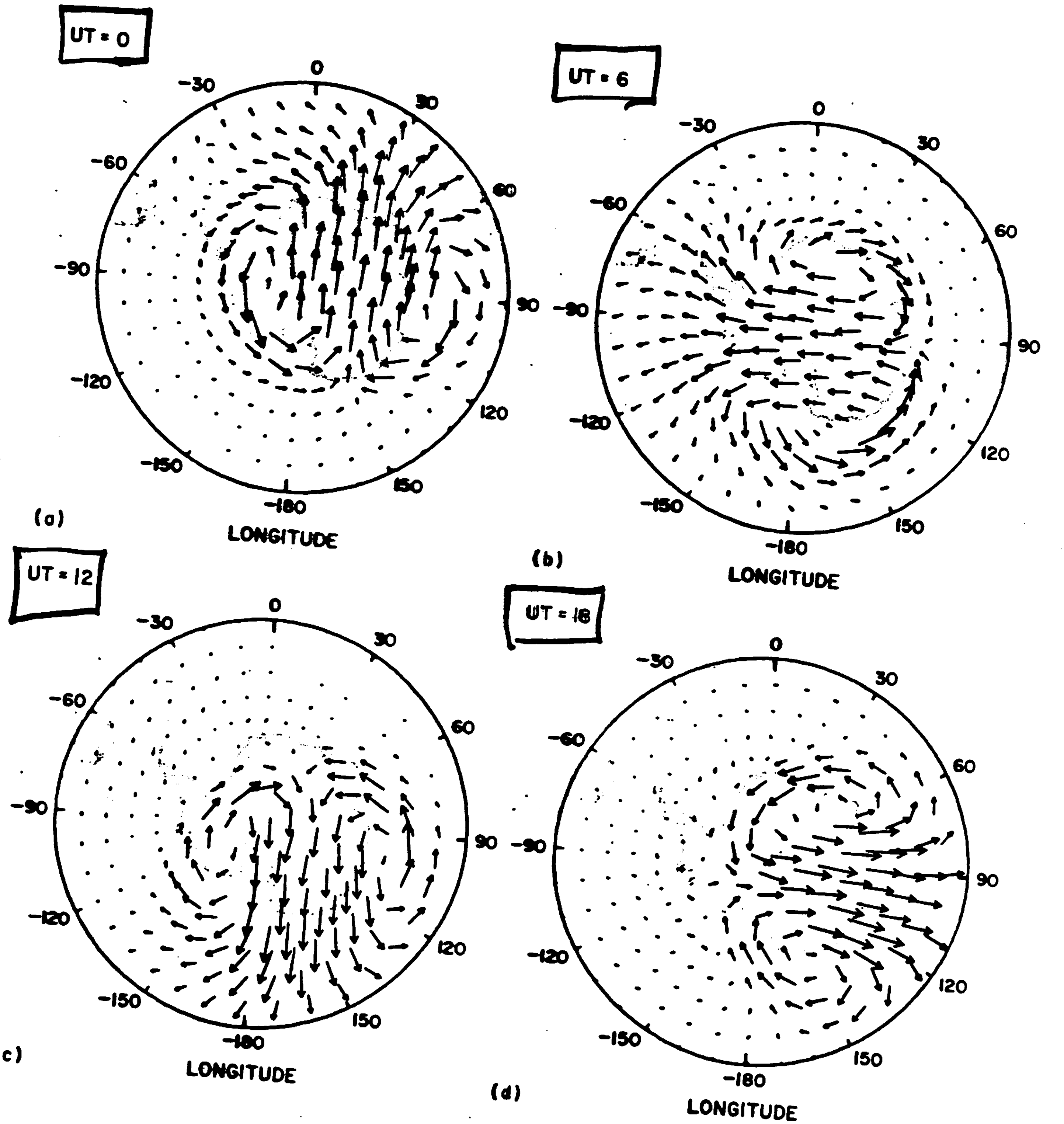

day=83021
TIGCM Neutral Temperature (deg k)
UT = 5.0 ZP = 2.0
de2 orbit=8121(S)
12
6
18
0
1.32e+03
1.14e+03
9.60e+02
500 m/s
Local Time (hrs)
History=ROBLE/RGR89/JADE09
Perimeter latitude=-37.5 deg


DE-2 / GBFPI
AVERAGE NEUTRAL WINDS
DEC 1981
NCAR/TGCM
MODEL PREDICTIONS
12
7:00
18
6
0
305 M/S
12
7:00
18
6
0
12
9:00
18
6
0
303 M/S
12
9:00
18
6
0
12
11:00
18
6
0
333 M/S
12
11:00
18
6
0

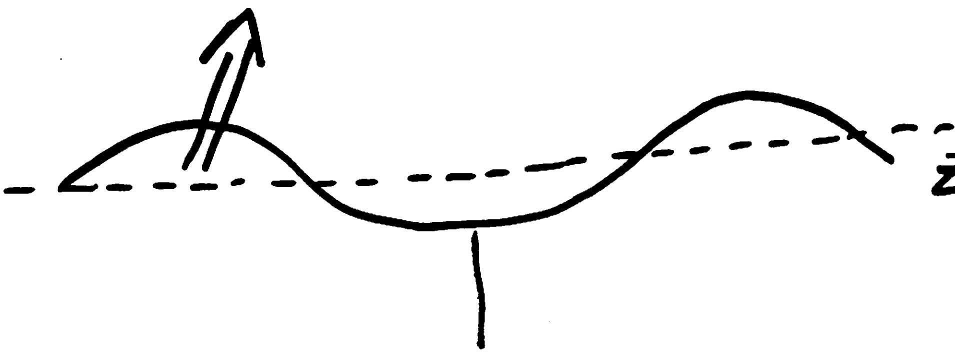
60 KV · EQUINOX

$V \sim 400\ m\,s^{-1}$

300 KM



TIDAL FORCINGS (FESEN et. al. 1986)



Z = -7 (95 KM)

H (HEIGHT OF CONSTANT PRESSURE SURFACE)

Φ_2 (97 km)

HOUGH FUNCTIONS (SEMI-DIURNAL)

2-2
2-3
2-4
2-5
2-6

SPECIFY AMPLITUDES AND PHASES

FORBES & VIAL (1991)

LTCS - STUDIES

RECENTLY ADDED DIURNAL TIDE

(FORBES ET. AL. 1992)

MAJOR CONSTITUENT TRANSPORT

The three major neutral constituents of the thermosphere - O_2 , O , and N_2 - are considered and used to define the mass maxing ratio of constituent i as

$$\psi_i = n_i \; m_i \left(\sum_{j=1}^{3} n_j \; m_j \right)^{-1},$$

where n_i is the number density of the ith species, with $i = 1$, 2 and 3 corresponding, respectively, to O_2, O , and N_2; m_i is the mass of the ith species. We furthermore define mixing ratios of O_2 and O as the vector

$$\underline{\psi} = \begin{pmatrix} \psi_{O_2} \\ \psi_O \end{pmatrix}$$

and therefore by definition the N_2 mixing ratio is obtained by $\psi_{N_2} = 1 - \psi_{O_2} - \psi_O$.

$$\frac{\partial}{\partial t} \underline{\psi} = - e^{z} \tau^{-1} \frac{\partial}{\partial z} \left[\frac{\overline{m}}{m_{N_2}} \left(\frac{T_\infty}{T} \right)^{0.25} \underline{\alpha}^{-1} L \underline{\psi} \right]$$

MOLECULAR DIFFUSION

$$+ e^{z} \frac{\partial}{\partial z} \left(K(z) e^{-z} \left(\frac{\partial}{\partial z} \underline{\psi} + \frac{1}{\overline{m}} \frac{\partial \overline{m}}{\partial z} \right) \right) - \left(\underline{V} \cdot \nabla \underline{\psi} + w \frac{\partial}{\partial z} \underline{\psi} \right) + \underline{S} - \underline{R} .$$

EDDY DIFFUSION [HOR. + VER.] ADV SOURCE + SINK

Upper Boundary Conditions

At the upper boundary condition, diffusive equilibrium is assumed so that $L \underline{\psi} = 0$.

Lower Boundary Conditions

At the lower boundary, we utilize the observation that the atomic oxygen concentration $n(O)$ peaks near 97 km and assume that $\partial n(O)/\partial z = 0$. This assumption and conservation of total oxygen atoms implies

$$\frac{\partial}{\partial z} \psi_2 = \psi_2 \qquad \psi_1 + \psi_2 = \text{constant}$$

S - PHOTODISSOCIATION (EUV + SRC)

R - O + O + M $\longrightarrow$ O_2 + M

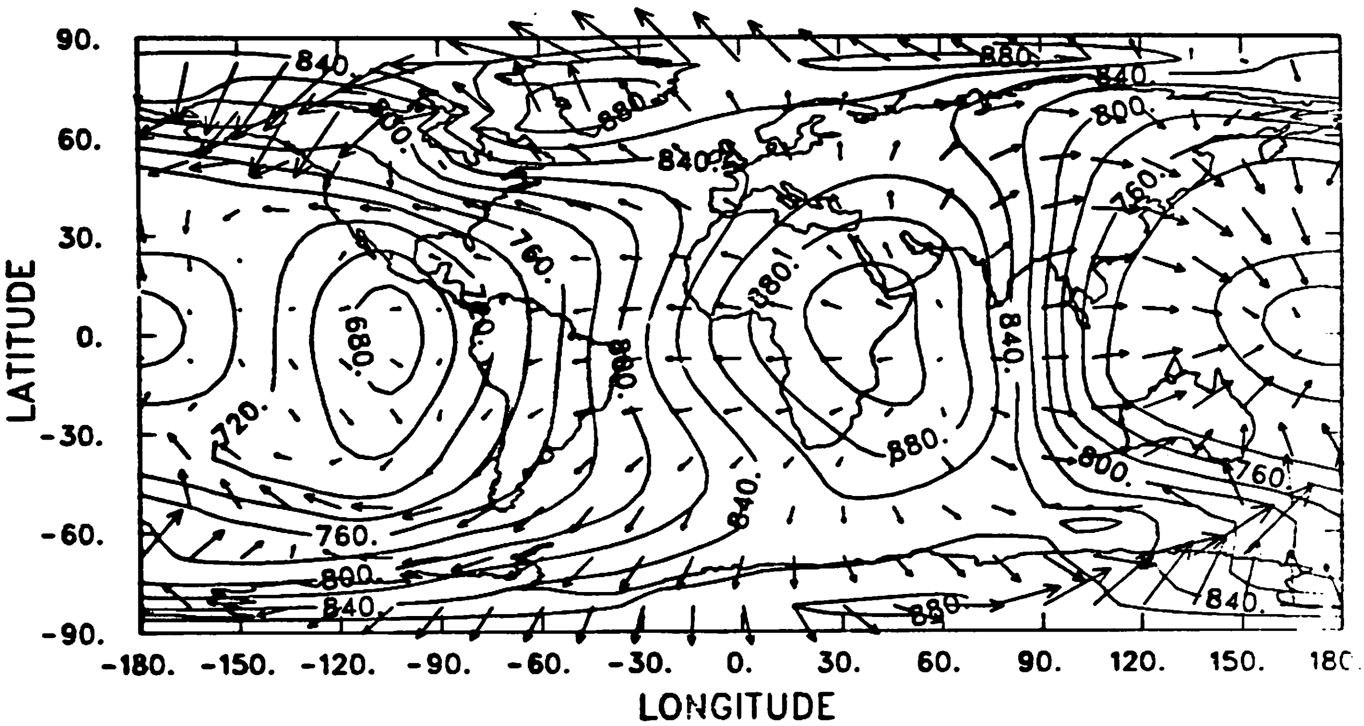
EQUINOX – SOLAR MINIMUM

EARTH

300 KM

UT = 12.00

Z = 2.0



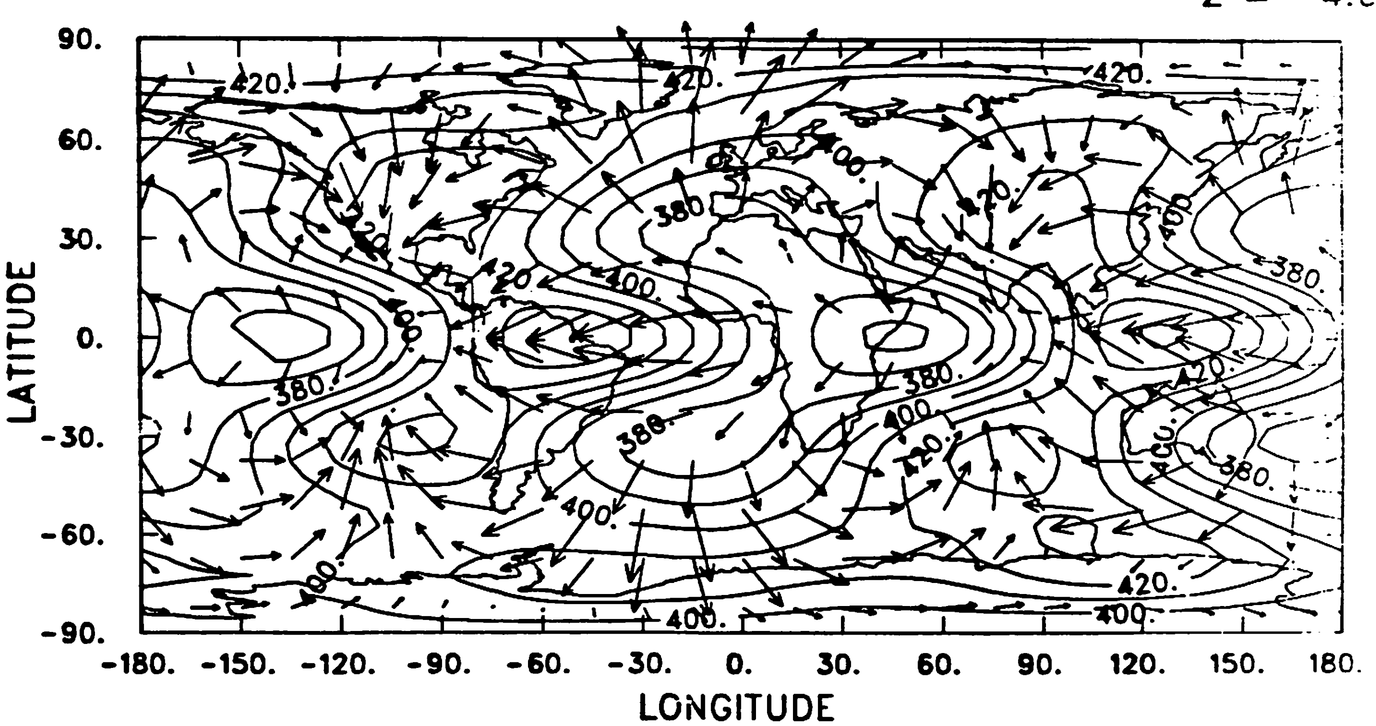
M/S

400 M/S

120 KM

UT = 12.00

Z = -4.0

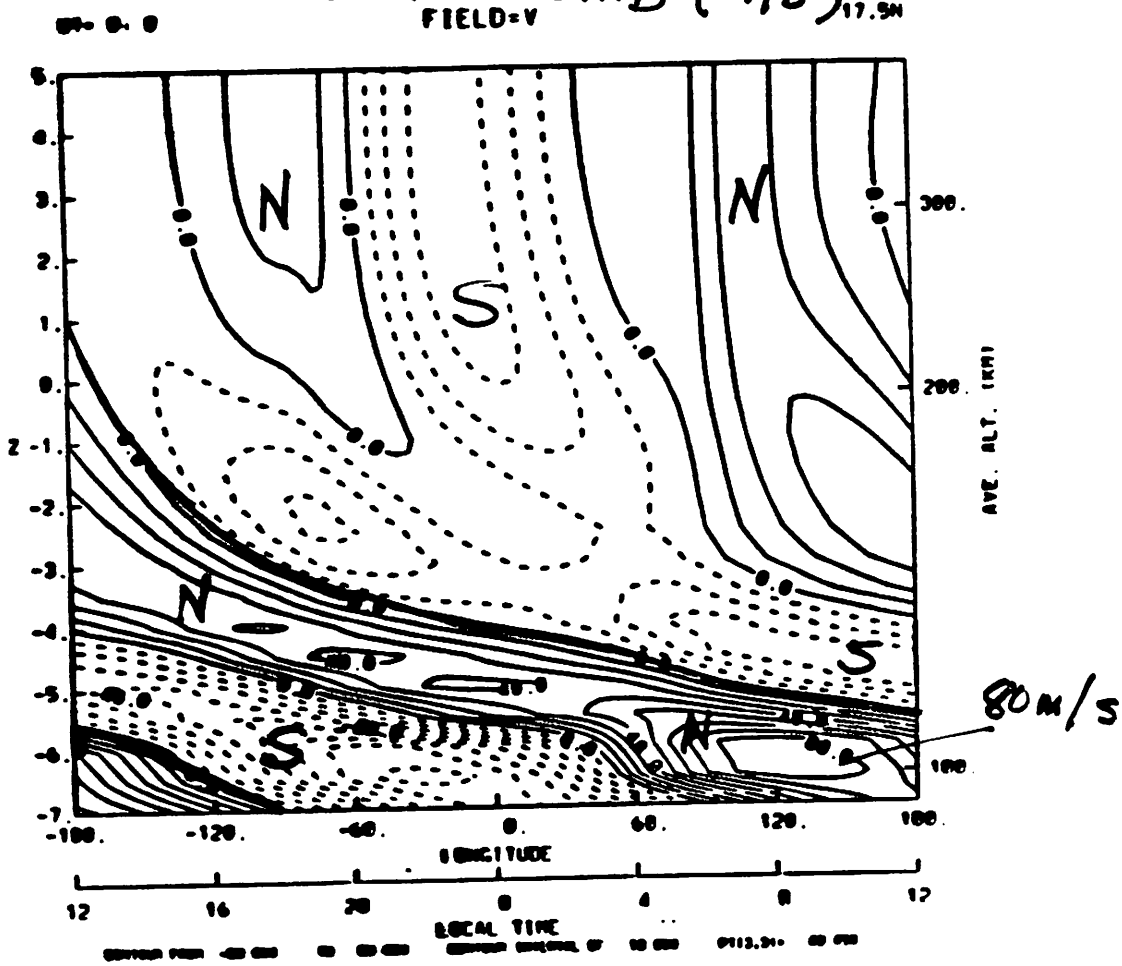


100 M/S

M/S

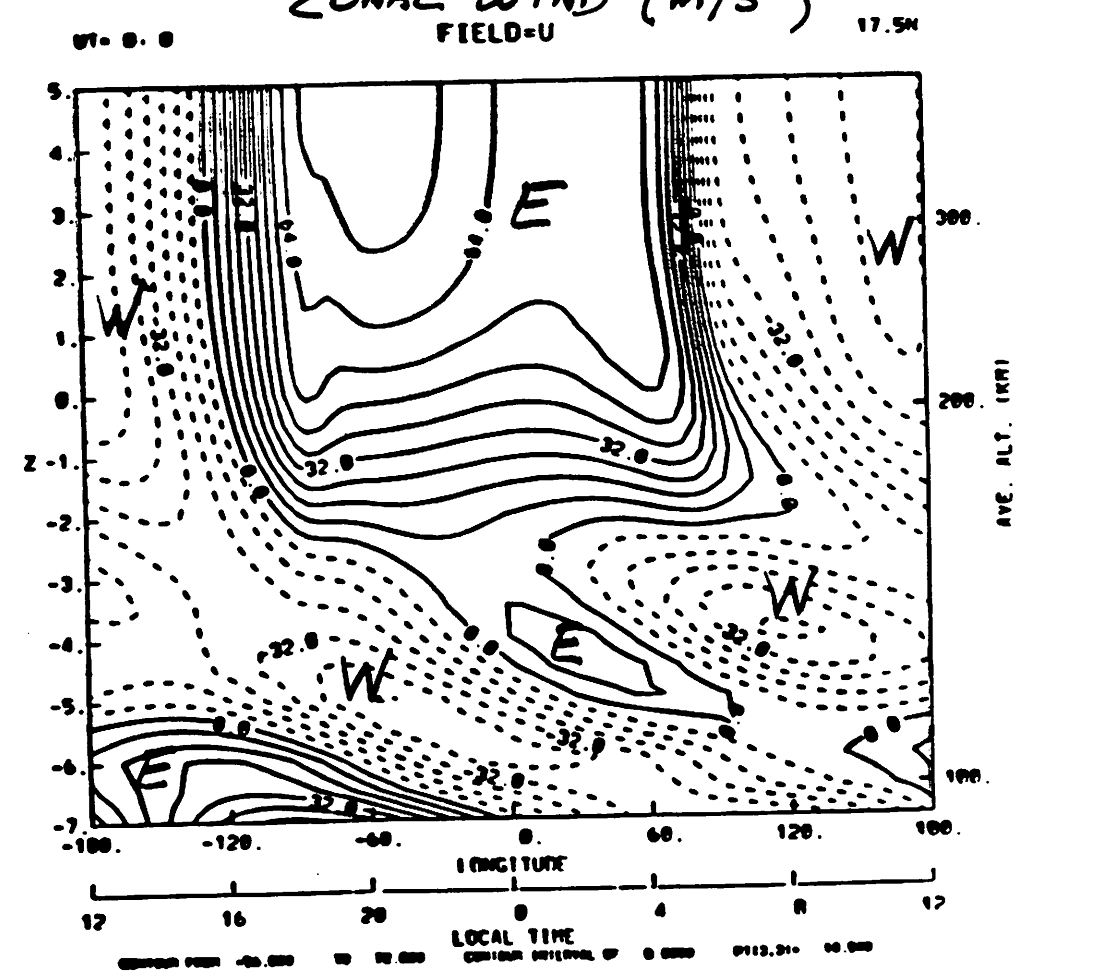
MERIDIONAL WIND (M/S)

Δ ~ 10 m/s

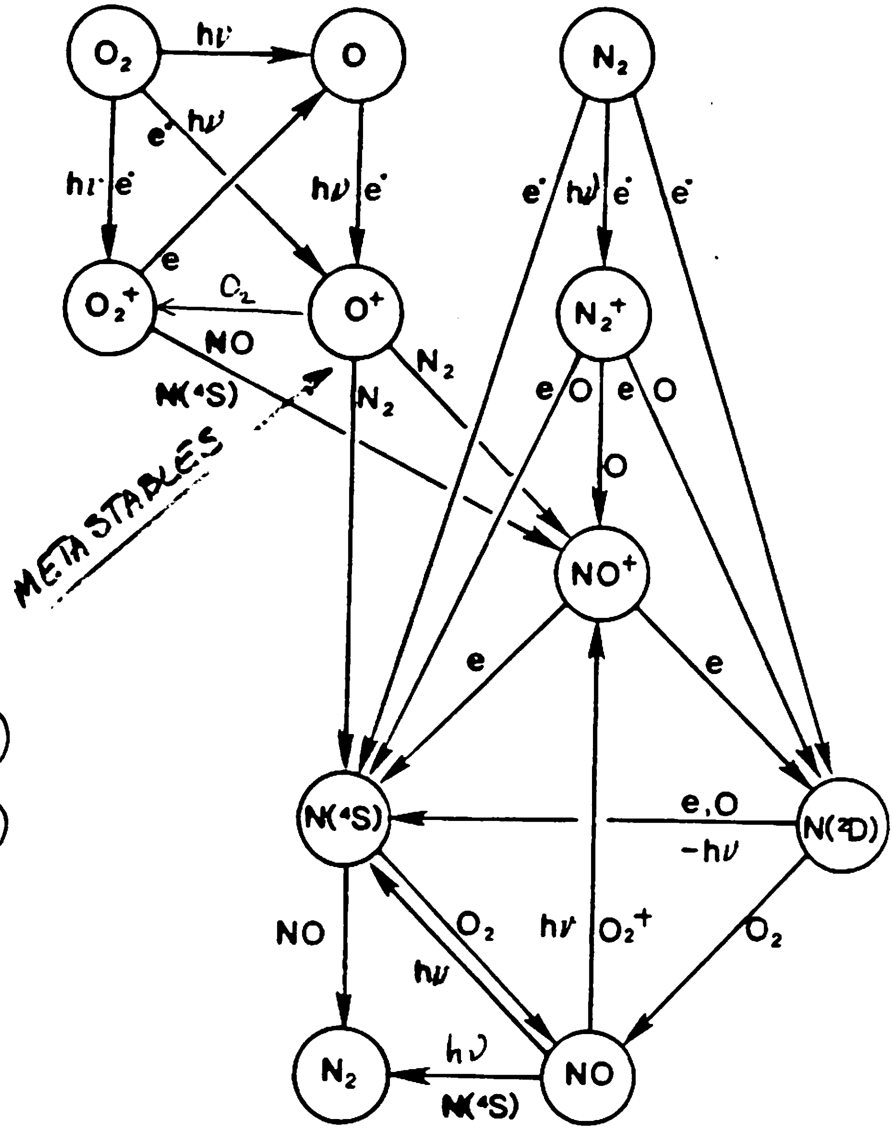


ZONAL WIND (M/S)

Δ ~ 8 m/s



TIGCM CHEMISTRY



$O^+(^2P)$

$O^+(^2D)$

$O^+(^4S)$

TIGCM

Neutral-Neutral Constituent Reactions and Rates used in the Model.

Reactions

$$N(^4S) + O_2 \xrightarrow{\beta_1} NO + O + 1.4eV$$

$$N(^2D) + O_2 \xrightarrow{\beta_2} NO + O(^1D) + 1.84eV$$

$$N(^4S) + NO \xrightarrow{\beta_3} N_2 + O + 2.68eV$$

$$N(^2D) + O \xrightarrow{\beta_4} N(^4S) + O + 2.38eV$$

$$N(^2D) + e \xrightarrow{\beta_5} N(^4S) + e + 2.38eV$$

$$N(^2D) + NO \xrightarrow{\beta_6} N_2 + O + 5.63eV$$

$$N(^2D) \xrightarrow{\beta_7} N(^4S) + h\nu$$

$$NO + h\nu \xrightarrow{\beta_8} N(^4S) + O$$

$$NO + h\nu|_{Ly-\alpha} \xrightarrow{\beta_9} NO^+ + e$$

NO_x

$$O + O + M \xrightarrow{\gamma_1} O_2 + O$$

$$O + O_2 + M \xrightarrow{\gamma_2} O_3 + M$$

C_x

MINOR CONSTITUENT TRANSPORT

$$\frac{\partial \psi_m}{\partial t} = e^{-z} \frac{\partial}{\partial z} D_m \left(\frac{\partial}{\partial z} - E_m \right) \psi_m$$

Molecular and Thermal Diffusion

$$- \left[\underline{V} \cdot \nabla + \omega \frac{\partial}{\partial z} \right] \psi_m + S_m + e^{z} \frac{\partial}{\partial z} e^{-z} K_E \left(\frac{\partial}{\partial z} + \frac{1}{\overline{m}} \frac{\partial \overline{m}}{\partial z} \right) \psi_m$$

Transport — Source & Sink — Eddy Diffusion

where

E_m = gravitational forces + thermal diffusion + frictional interaction with major species

Upper Boundary Conditions

Diffusive Equilibrium:

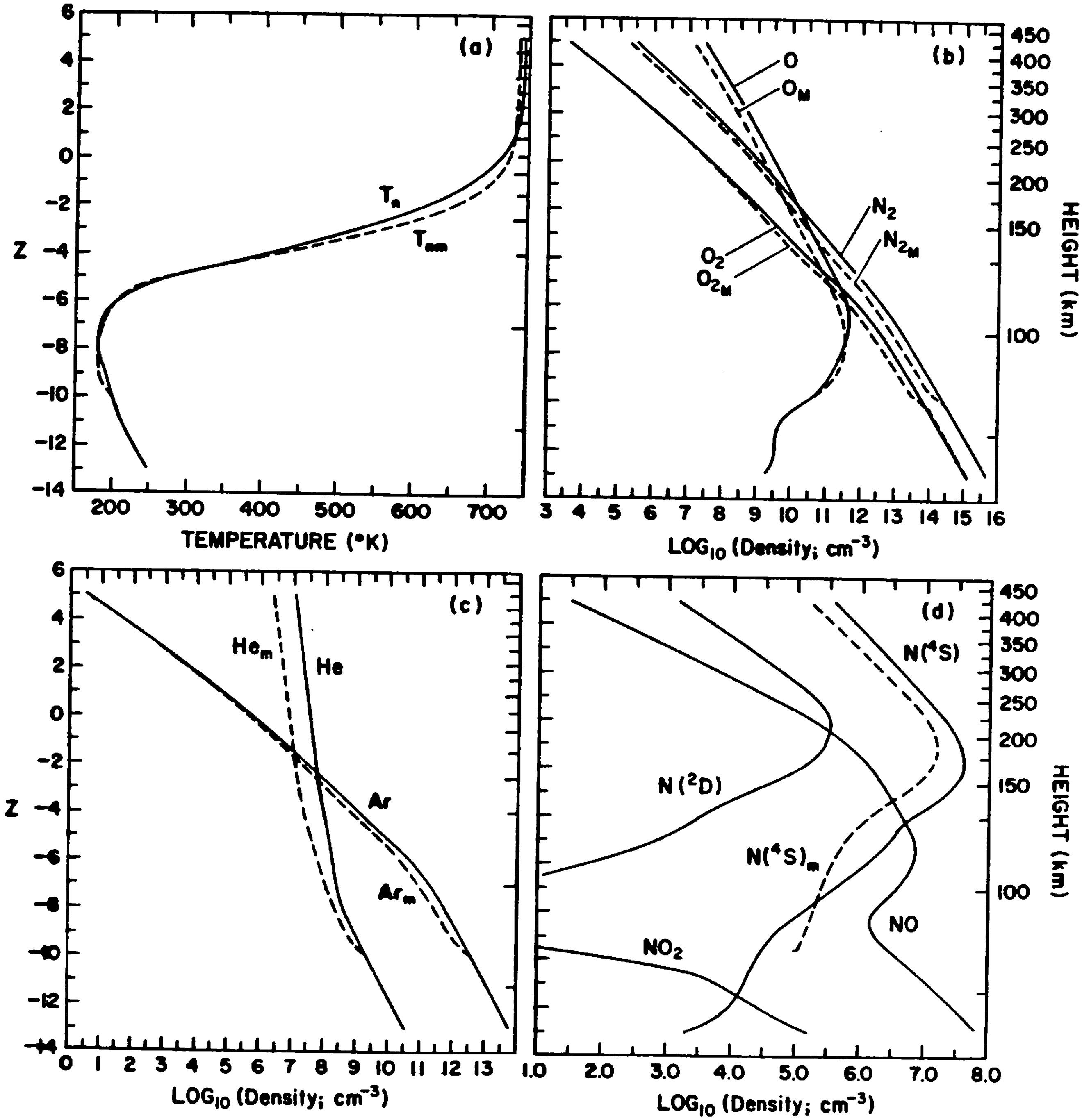
$$\left(\frac{\partial}{\partial z} - E_m \right) \psi_m = 0$$

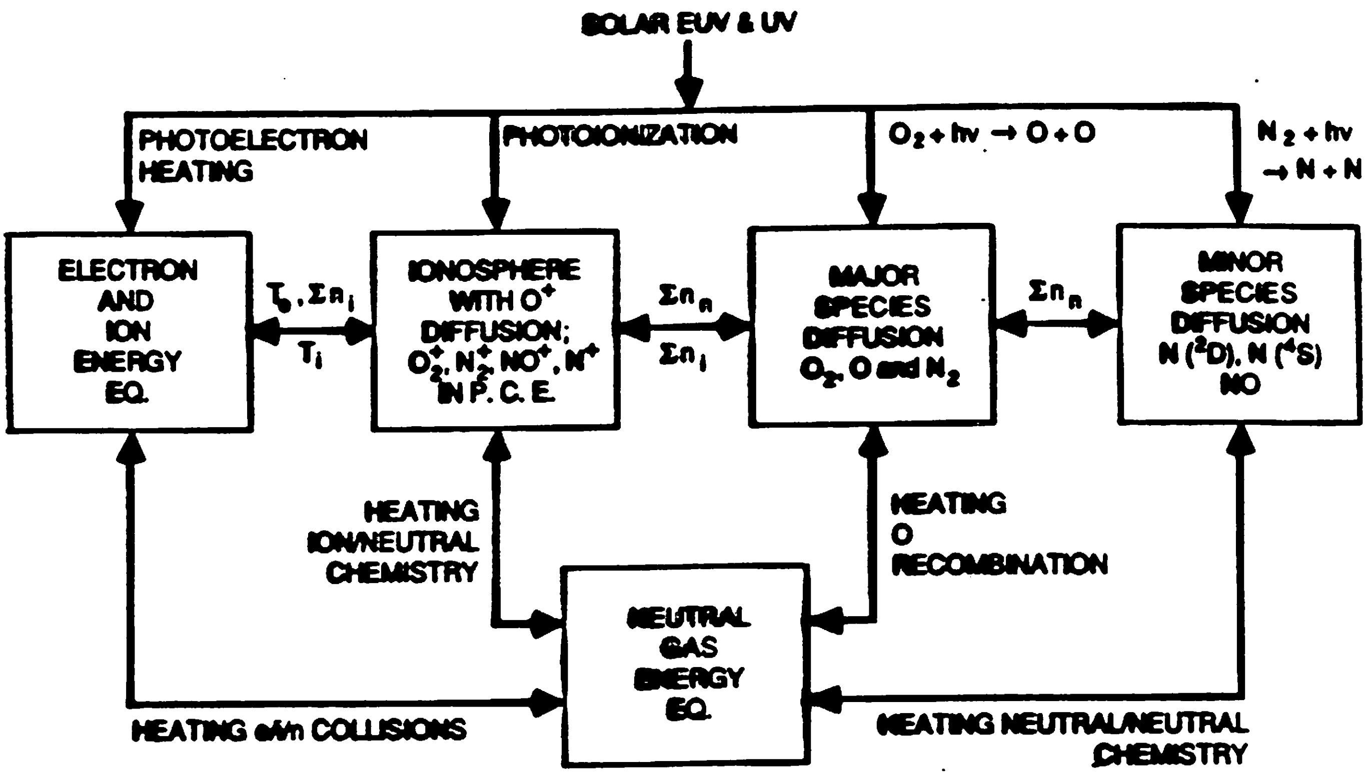
Lower Boundary Conditions

$N(^4S)$ Photochemical Equilibrium

NO Specified Mass Mixing Ratio

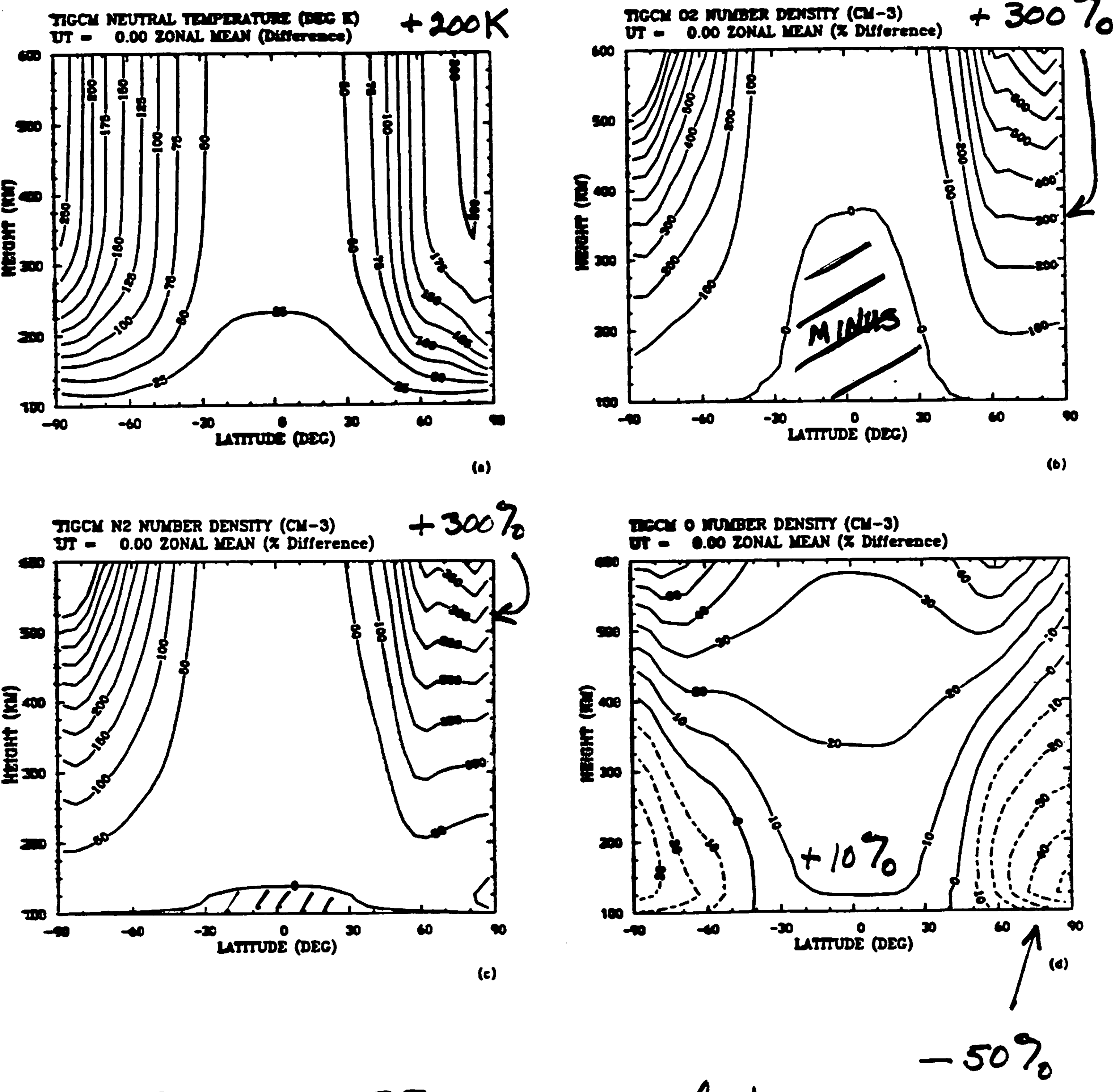
1-D GLOBAL AVERAGE MODEL




SOLAR EUV & UV
PHOTOELECTRON HEATING
PHOTOIONIZATION
$O_2 + h\nu \rightarrow O + O$
$N_2 + h\nu \rightarrow N + N$
ELECTRON AND ION ENERGY EQ.
$T_e, \Sigma n_i$
T_i
IONOSPHERE WITH O^+ DIFFUSION; O_2^+, N_2^+, NO^+, N^+ IN P. C. E.
Σn_n
Σn_i
MAJOR SPECIES DIFFUSION O_2, O and N_2
Σn_n
MINOR SPECIES DIFFUSION N (^{2}D), N (^{4}S) NO
HEATING ION/NEUTRAL CHEMISTRY
HEATING O RECOMBINATION
NEUTRAL GAS ENERGY EQ.
HEATING e/i/n COLLISIONS
HEATING NEUTRAL/NEUTRAL CHEMISTRY

EQUINOX (STORM − QUIET)

ΔT (K) 70KV − 20KV



TEMPERATURE, O, O_2 and N_2 changes.

FIGURE 6

EULERIAN IONOSPHERE

O^+ EQUATION WITH HORIZONTAL AND VERTICAL TRANSPORT

β = ALONG $\vec{B}$

$\perp$ = PERPENDICULAR TO $\vec{B}$

$$\frac{\partial n}{\partial t} - Q + Ln = -\nabla \cdot n\underline{V}$$

where $\underline{V} = \underline{V}_\beta + \underline{V}_\perp$

$$\underline{V}_\beta = \left[\underline{b} \cdot \frac{1}{\nu}\left(g - \frac{1}{\rho_i}\nabla p_i\right) + \underline{b} \cdot \underline{u}\right] \cdot \underline{b}$$

$$\underline{V}_\perp = \frac{1}{|B|}\underline{E} \times \underline{b}$$

now, $$-\nabla \cdot n\underline{V}_\beta = b_z^2 \left(\frac{\partial}{\partial z} + \frac{\nabla \cdot b}{b_z}\right) D \left(\frac{\partial}{\partial z} T_p + \frac{g m_i}{k}\right) n$$

$$-(\underline{b} \cdot \underline{u})\, n\, \nabla b - \underline{b} \cdot \nabla (\underline{b} \cdot \underline{u}\, n)$$

$$-\nabla \cdot \underline{v}_\perp = \underline{B} \times \underline{E} \cdot \nabla (n / B^2)$$

Upper Boundary Conditions

Mixed boundary condition

$$-b_z^2 D \left(\frac{\partial}{\partial z} T_p + \frac{g m_i}{k}\right) n + n\, (\underline{b} \cdot \underline{u}) b_z + \frac{n\,(\underline{E} \times \underline{B})_z}{B^2} = \Phi_z$$

Lower Boundary Conditions

Photochemical equilibrium

$$n = Q / L$$

O_2^+, N_2^+, N^+ and NO^+

Once the O^+ distribution is determined the O_2^+, N_2^+, N^+ and NO^+ equations are solved simultaneously assuming photochemical equilibrium with the O^+ distribution. From the chemistry specified, the production and loss terms are equated and a fourth order equation for n_e can be derived:

$$\boxed{a_4 n_e^4 + a_3 n_e^3 + a_2 n_e^2 + a_1 n_e + a_0 = 0}$$

where

$$n_e = n(O^+) + n(O_2^+) + n(N_2^+) + n(N^+) + n(NO^+)$$

$$a_3 = \alpha_1 (\alpha_2 E + \alpha_3 C) - \alpha_1 \alpha_2 \alpha_3 (F + G)$$

$$a_2 = \alpha_1 EC - \alpha_1 (\alpha_2 E + \alpha_3 C)(F + G) - \alpha_1 \alpha_2 D - \alpha_1 \alpha_3 B - \alpha_2 \alpha_3 A$$

$$a_1 = -\alpha_1 [EC(F + G) + DC + BE] - \alpha_2 E(A + D) - \alpha_3 C(A + B)$$

$$a_0 = -EC\ (A + B + D)$$

$$A = k_2 n\ (O^+) n\ (N_2) + k_7 n\ (N^+) n\ (O_2) + \beta_9 n\ (NO)$$

$$B = \eta (O_2^+) + k_1 n\ (O^+) n\ (O_2) + k_6 n\ (N^+) n\ (O_2)$$

$$C = k_4 n\ (N\ (^4S)) + k_5 n\ (NO)$$

$$D = \eta (N_2^+)$$

$$E = k_3 n\ (O)$$

$$F = n\ (O^+)$$

$$G = n\ (N^+).$$

The quartic equation can be solved exactly yielding four roots. Three of the roots are imaginary or not physical leaving one real and physical root, for the electron density, n_e. Once n_e is known, the ion number densities can be determined from

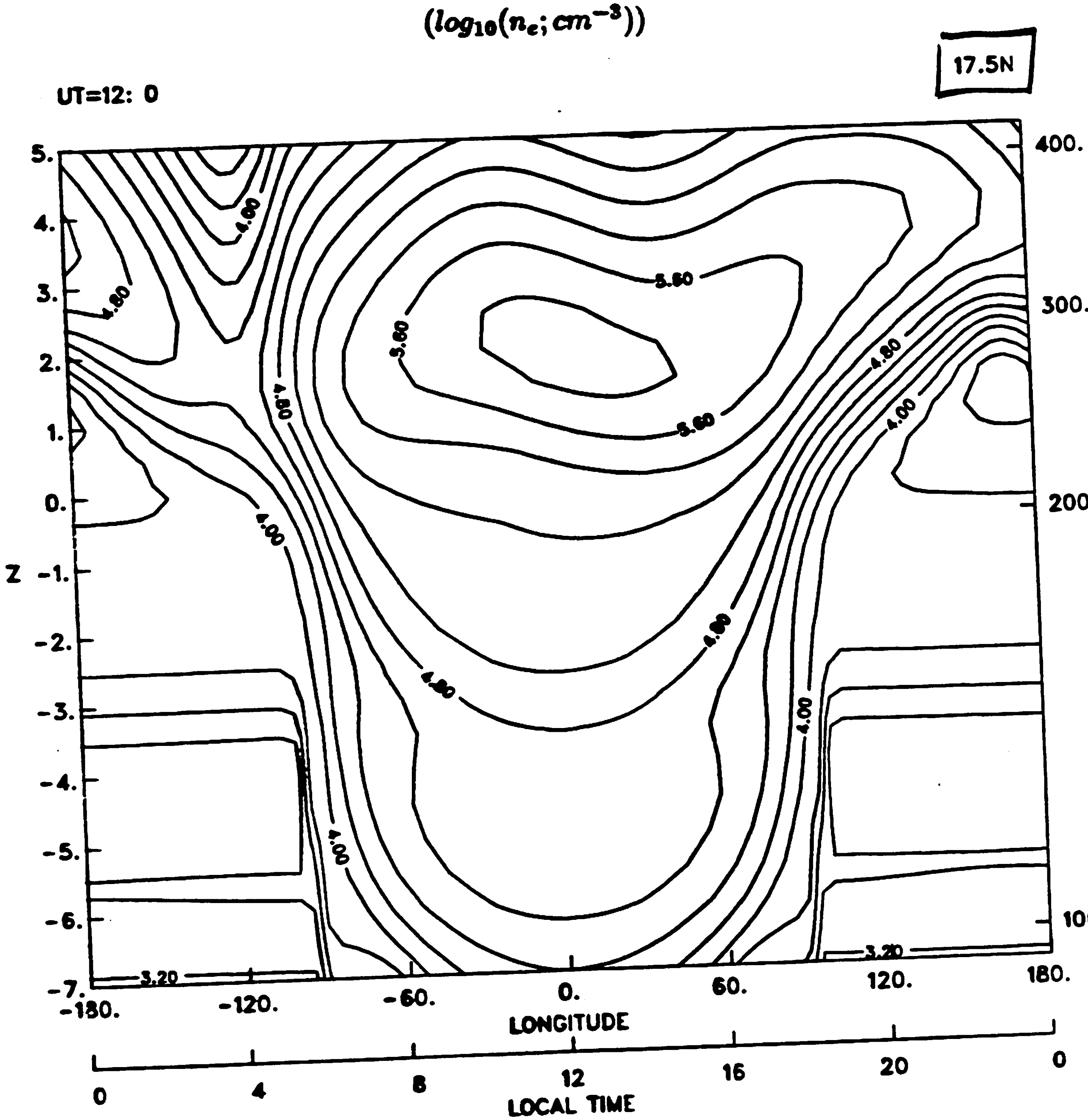
$$n\ (N_2^+) = D/(E + \alpha_3 n_e)$$

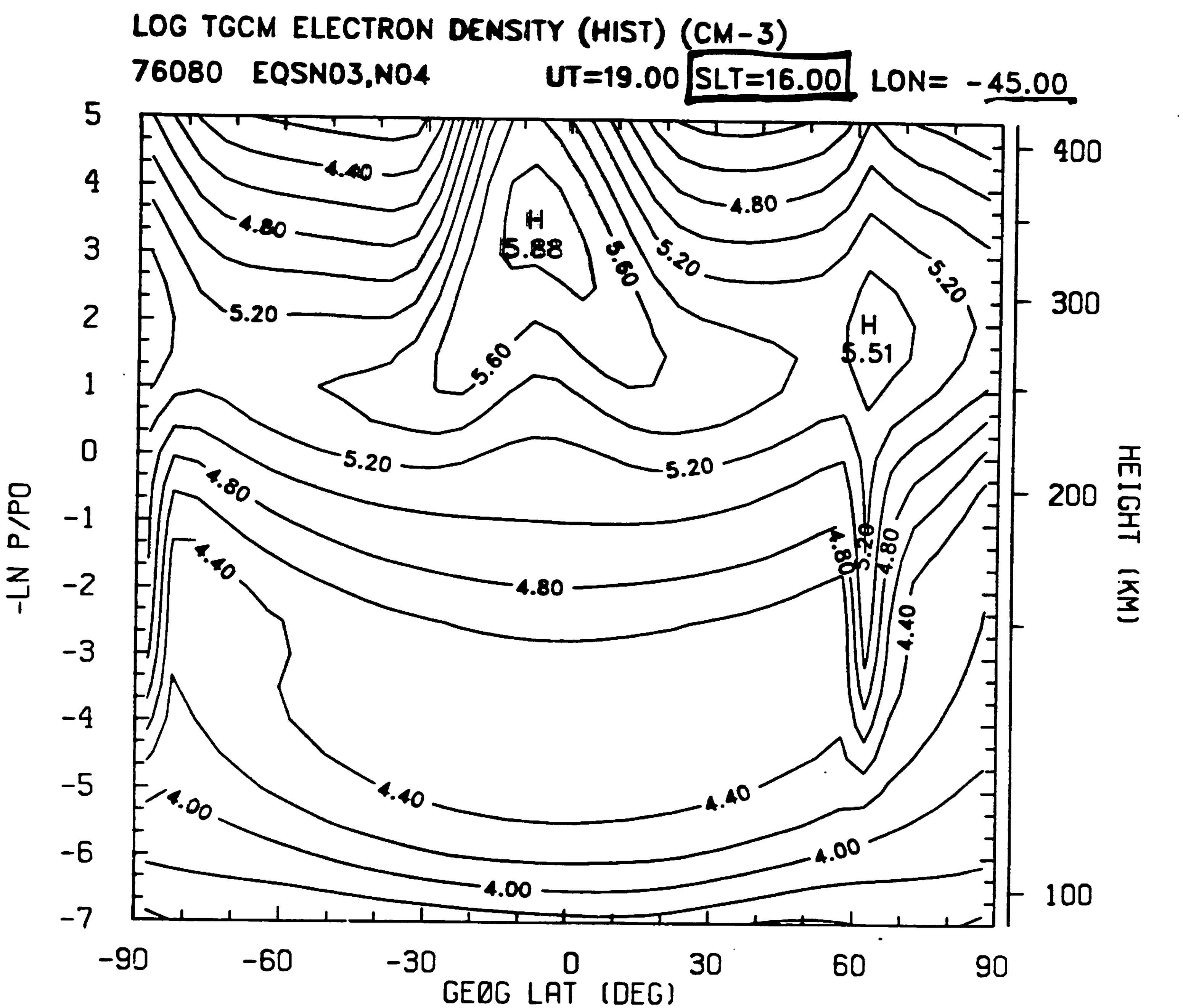
$$n\ (O_2^+) = B/(C + \alpha_2 n_e)$$

$$n\ (NO^+) = (A + ED/(E + \alpha_3 n_e) + CB/(C + \alpha_2 n_e))/(\alpha_1 n_e)$$

$$n\ (N^+) = \eta (N^+)/((k_6 + k_7) n\ (O_2) + k_8 n\ (O)).$$

ARECIBO


(log10(n_e; cm^-3))
17.5N
UT=12: 0
5.
4.
3.
2.
1.
0.
Z -1.
-2.
-3.
-4.
-5.
-6.
-7.
400.
300.
200.
100.
AVE. ALT. (KM)
4.00
4.80
5.60
3.20
-180.
-120.
-60.
0.
60.
120.
180.
LONGITUDE
0
4
8
12
16
20
0
LOCAL TIME


LOG TGCM ELECTRON DENSITY (HIST) (CM-3)
76080 EQSN03,N04 UT=19.00 SLT=16.00 LON= -45.00
4.40
4.80
5.20
5.60
H
5.88
5.51
4.00
-LN P/PO
HEIGHT (KM)
GEØG LAT (DEG)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
400
300
200
100
-90
-60
-30
0
30
60
90

TIGCM OUTPUT

- Neutral gas temperature, T_n
- Neutral winds, U, V, W
- Height of constant pressure surface, h
- Neutral composition and density

  Major – O, O_2, and N_2

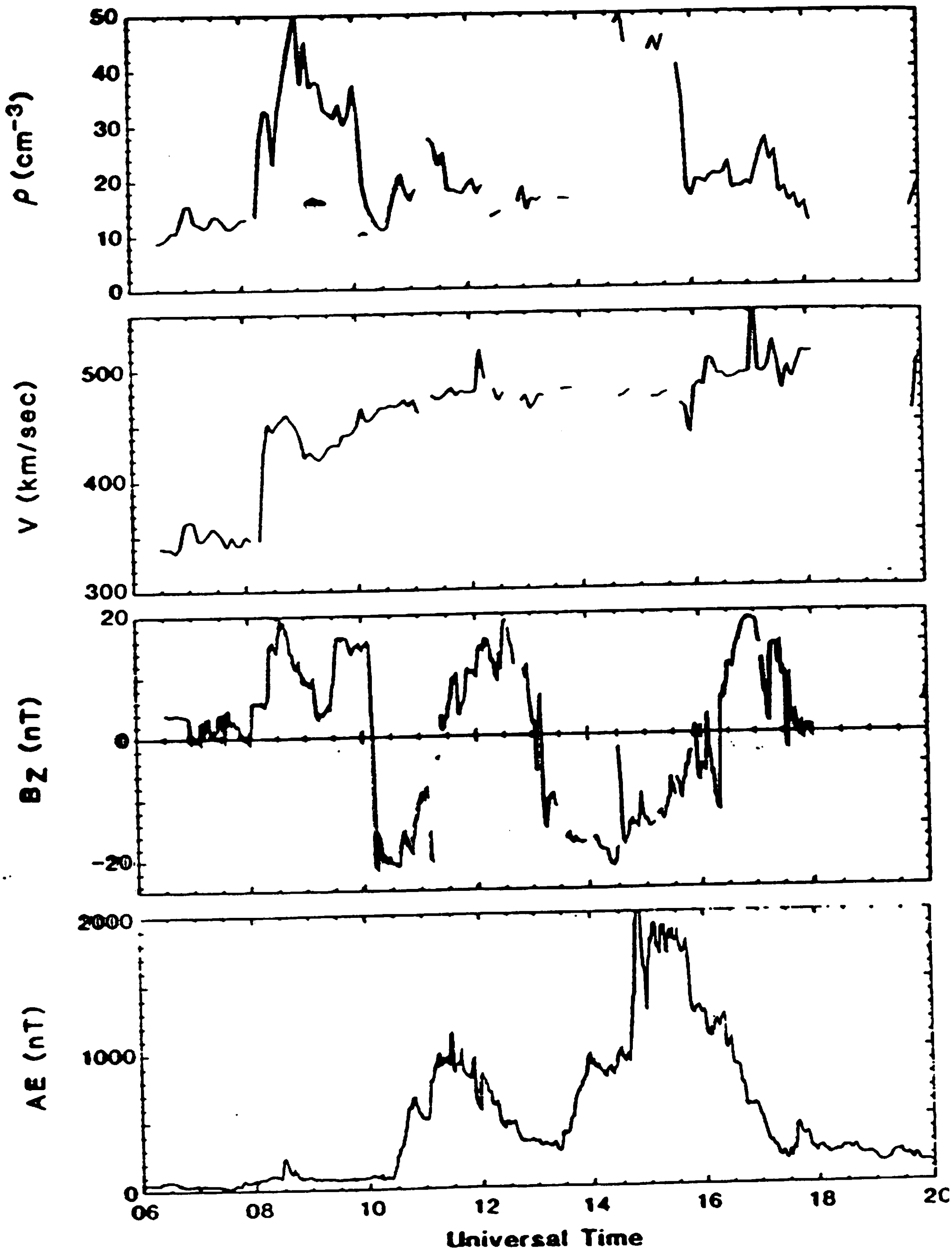
  Minor – $N(^2D)$, $N(^4S)$, NO, He, and Ar
- Ion composition

  O^+, NO^+, O_2^+, N_2^+, and N^+ $\Sigma n_i = n_e$

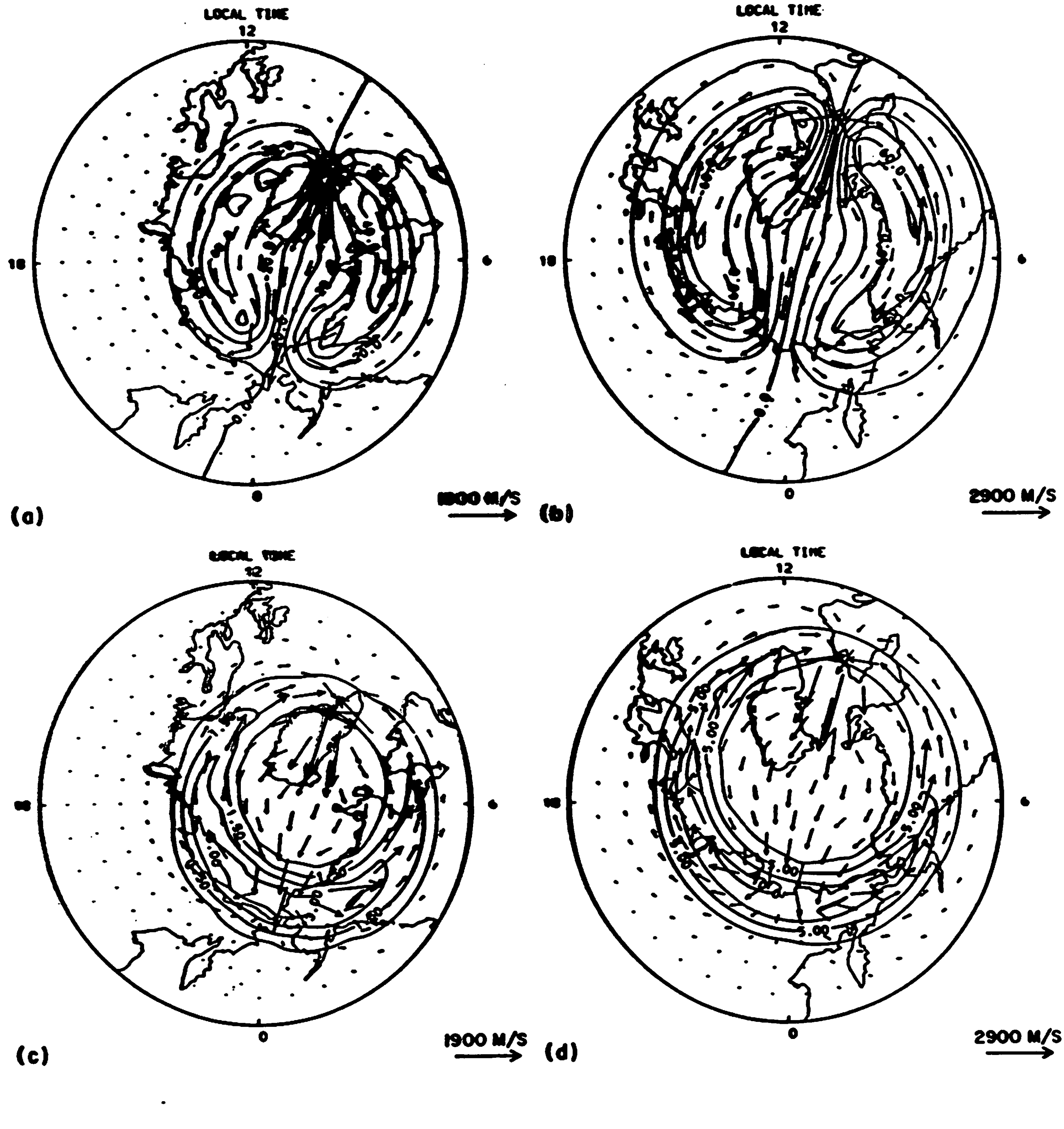
  Ion temperature, T_i

  Electron temperature, T_e
- Global dynamo —— TIE-GCM

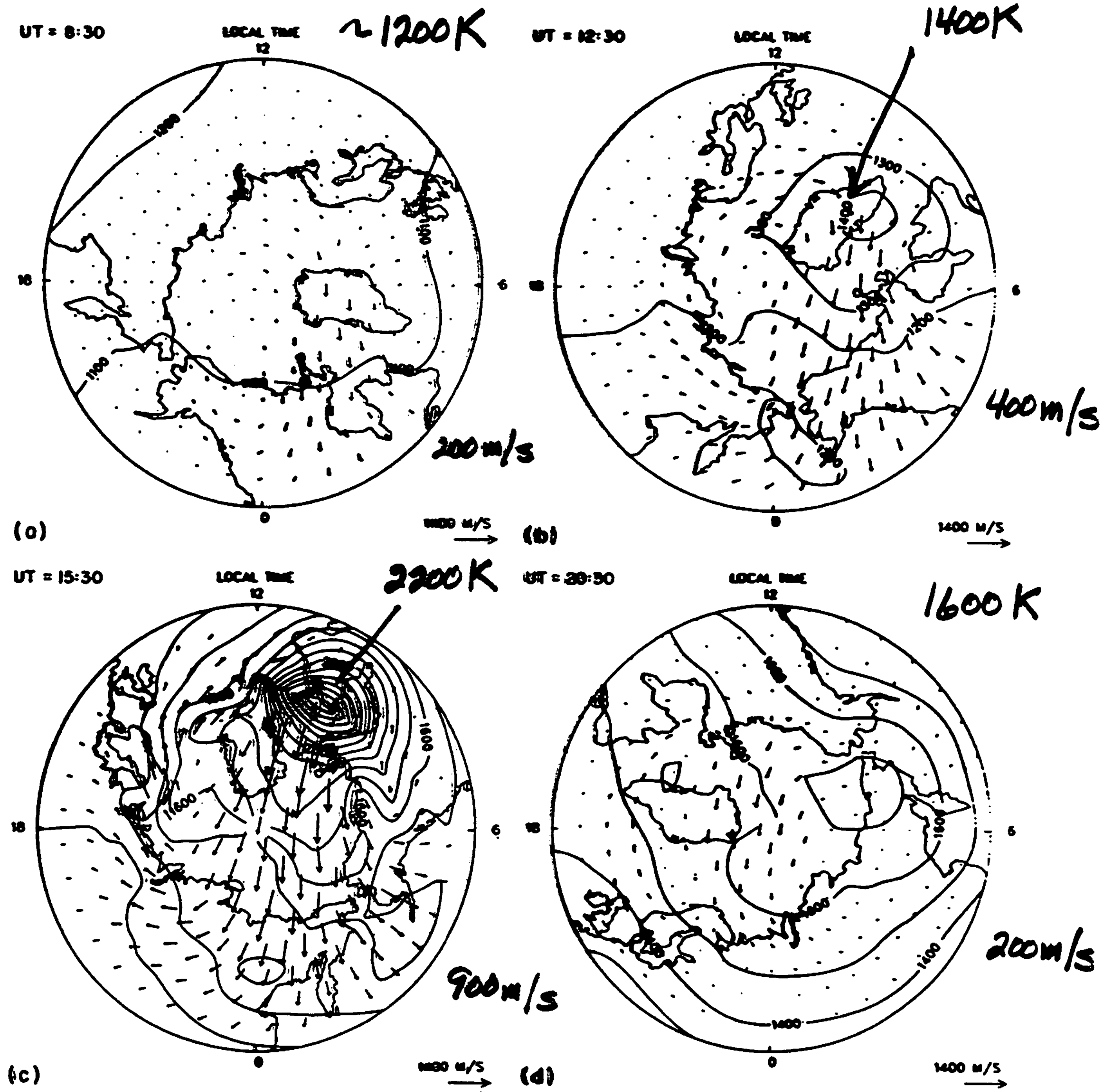
  $\vec{E}$, $\vec{J}$

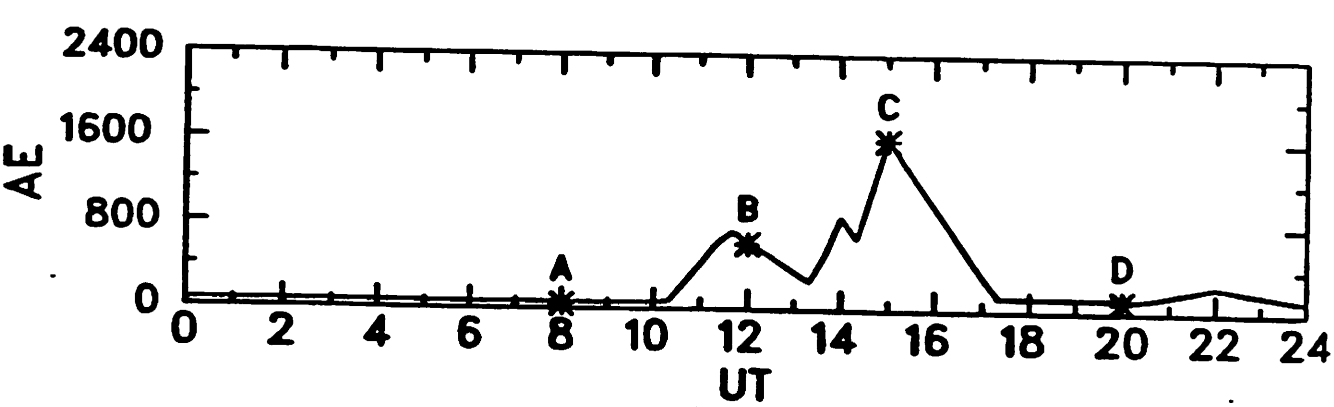


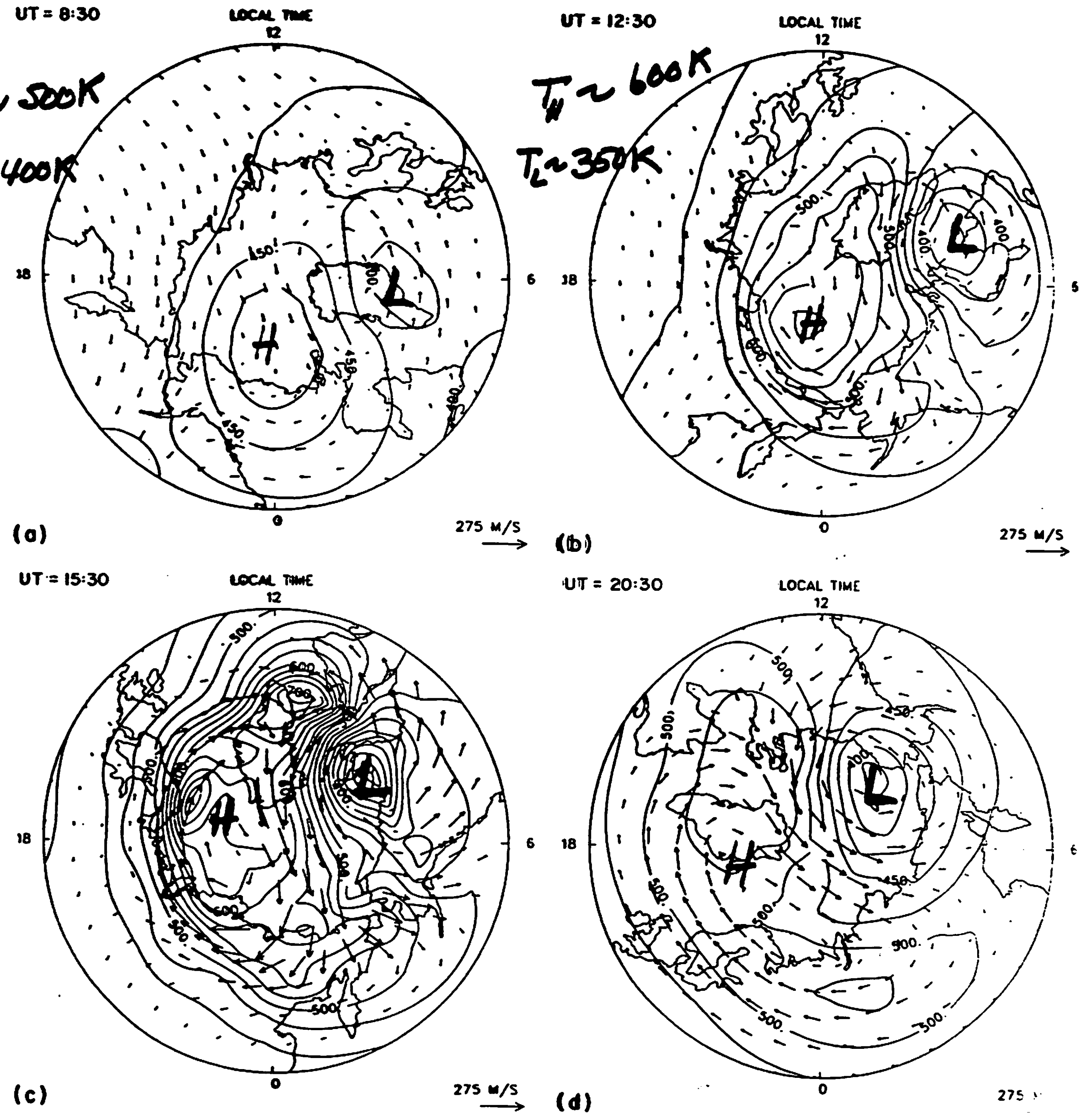
ρ (cm^{-3})
V (km/sec)
B$_Z$ (nT)
AE (nT)
Universal Time
06
08
10
12
14
16
18
20



LOCAL TIME
12
18
6
0
(a)
2900 M/S
(b)
1900 M/S
(c)
2900 M/S
(d)


UT = 8:30
LOCAL TIME
~1200K
200m/s
(a)
UT = 12:30
LOCAL TIME
1400K
400m/s
1400 M/S
(b)
UT = 15:30
LOCAL TIME
2200K
1600
900m/s
(c)
UT = 20:30
LOCAL TIME
1600K
1400
200m/s
1400 M/S
(d)


AE
2400
1600
800
0
A
B
C
D
0
2
4
6
8
10
12
14
16
18
20
22
24
UT



$T_H \sim 500K$

$T_L \sim 400K$

$T_H \sim 600K$

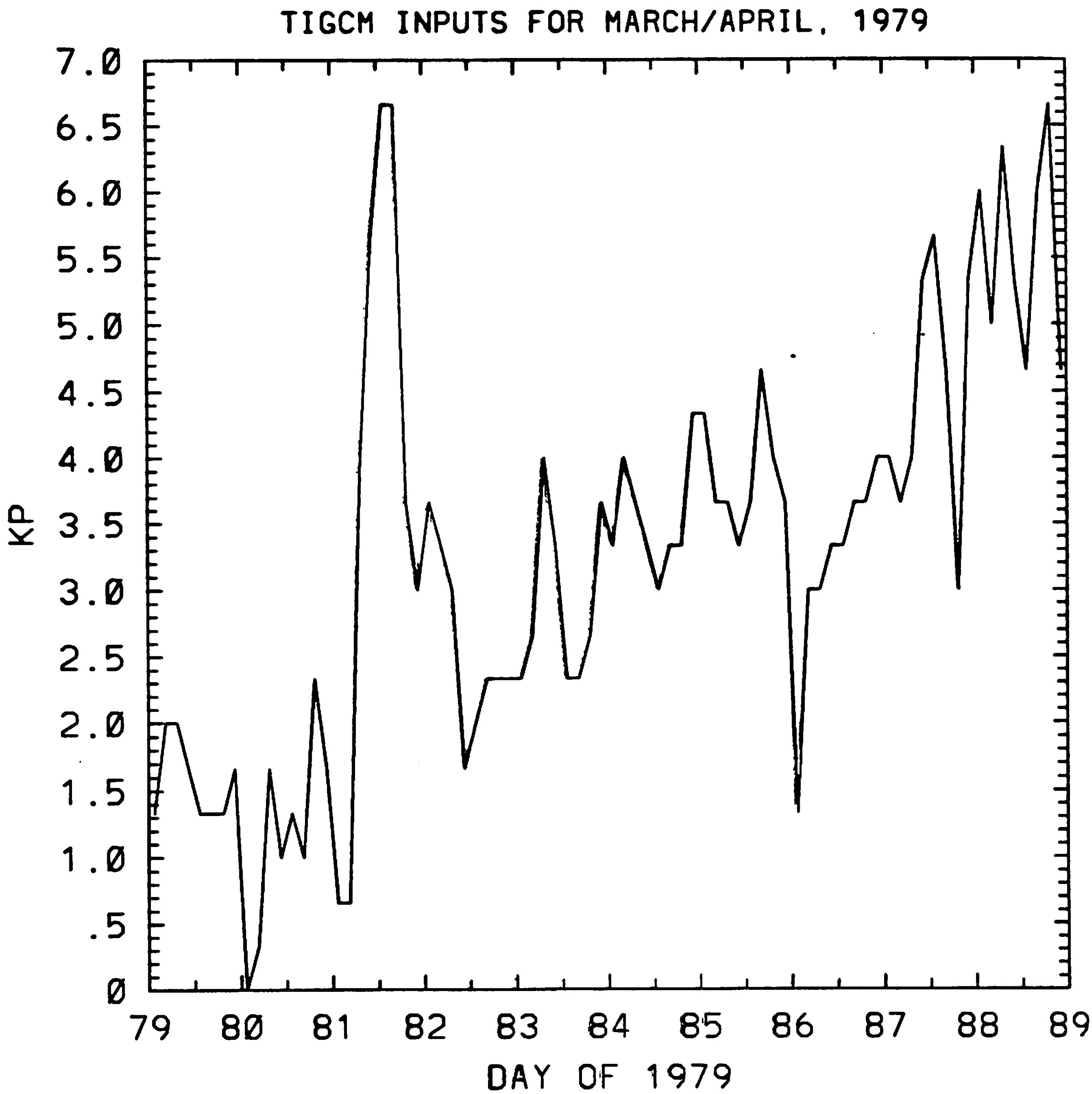
$T_L \sim 350K$

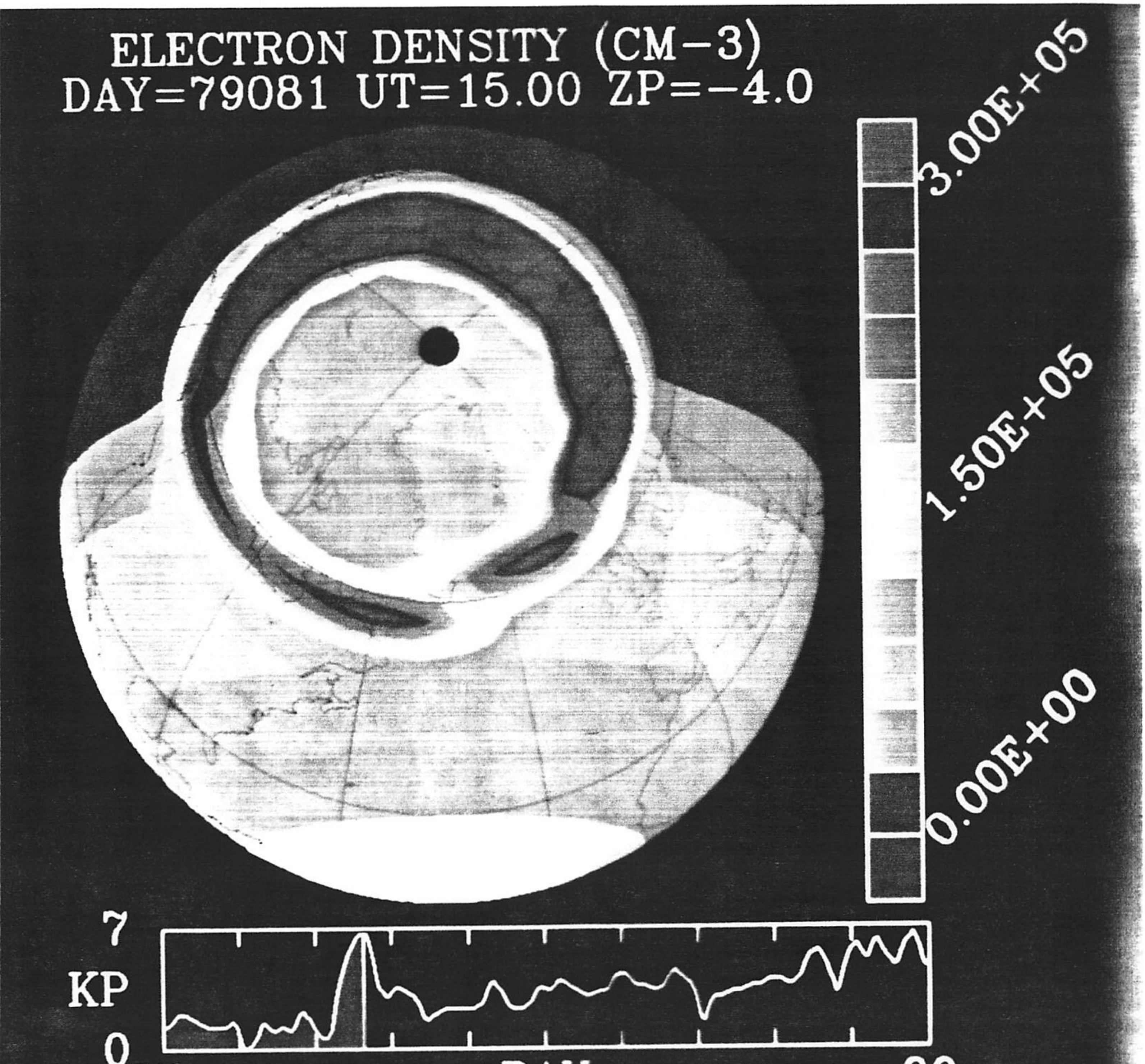
$T_H \sim 650K$

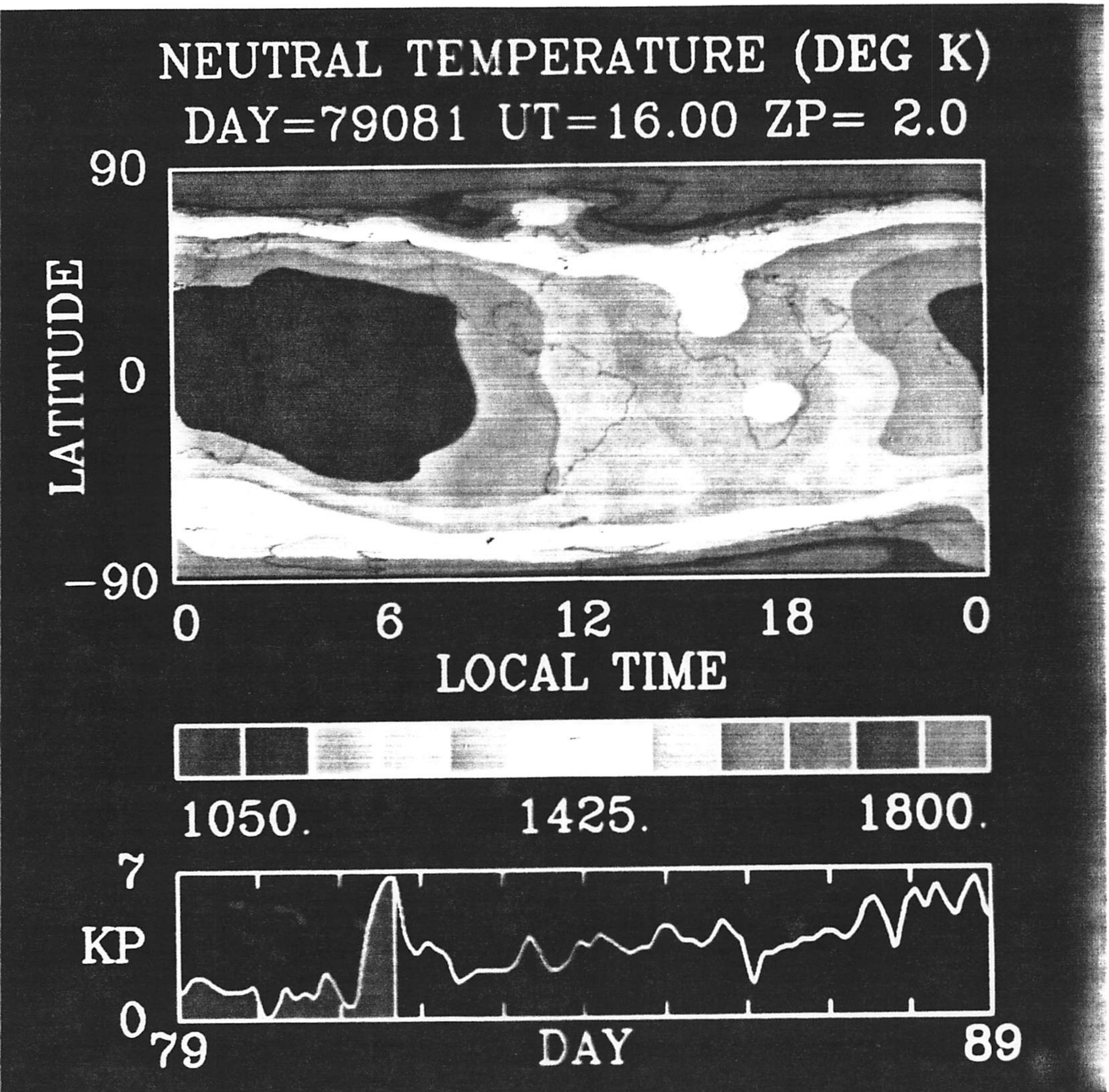
$T_L \sim 300K$

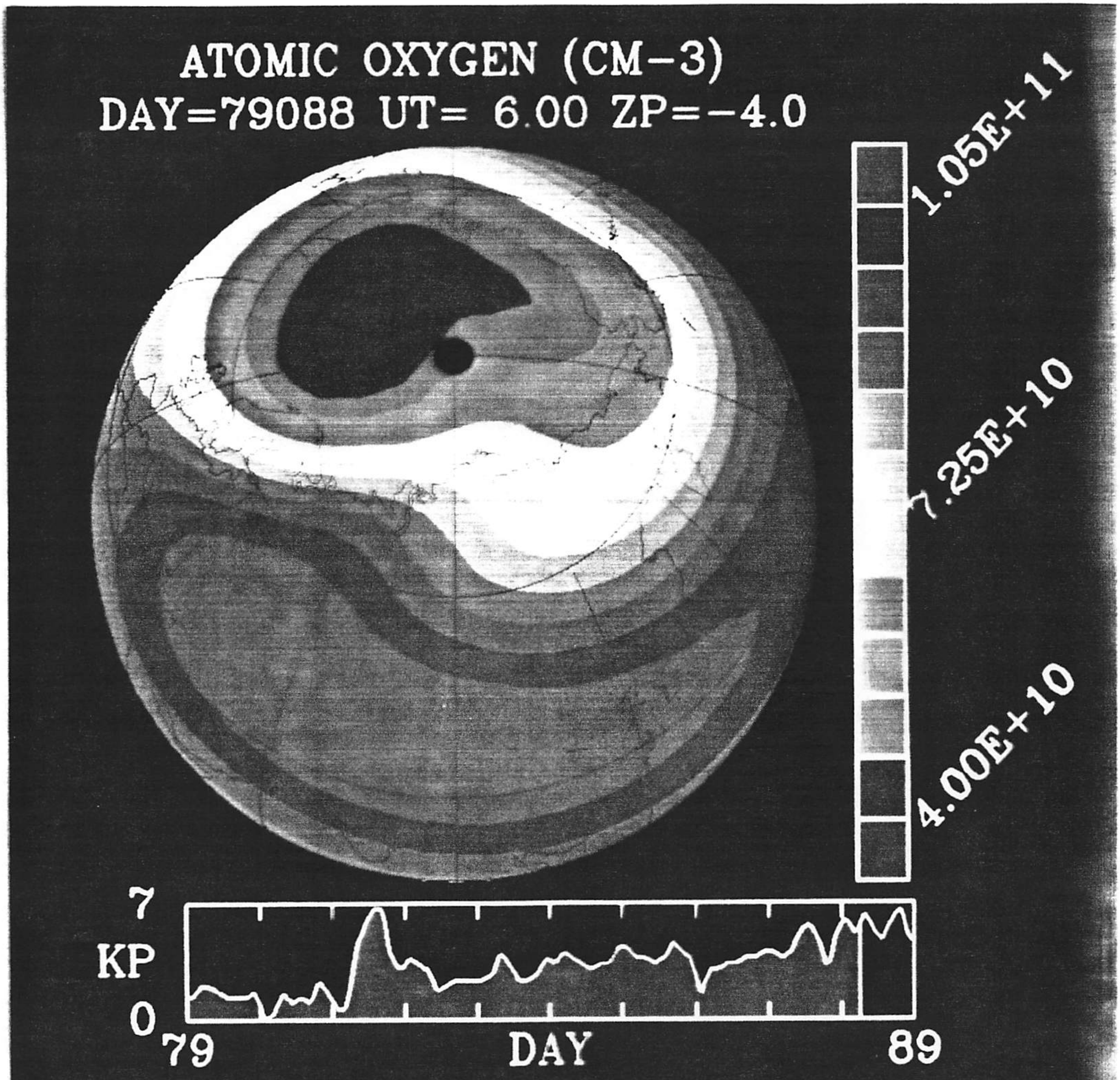
$T_H \sim 500K$

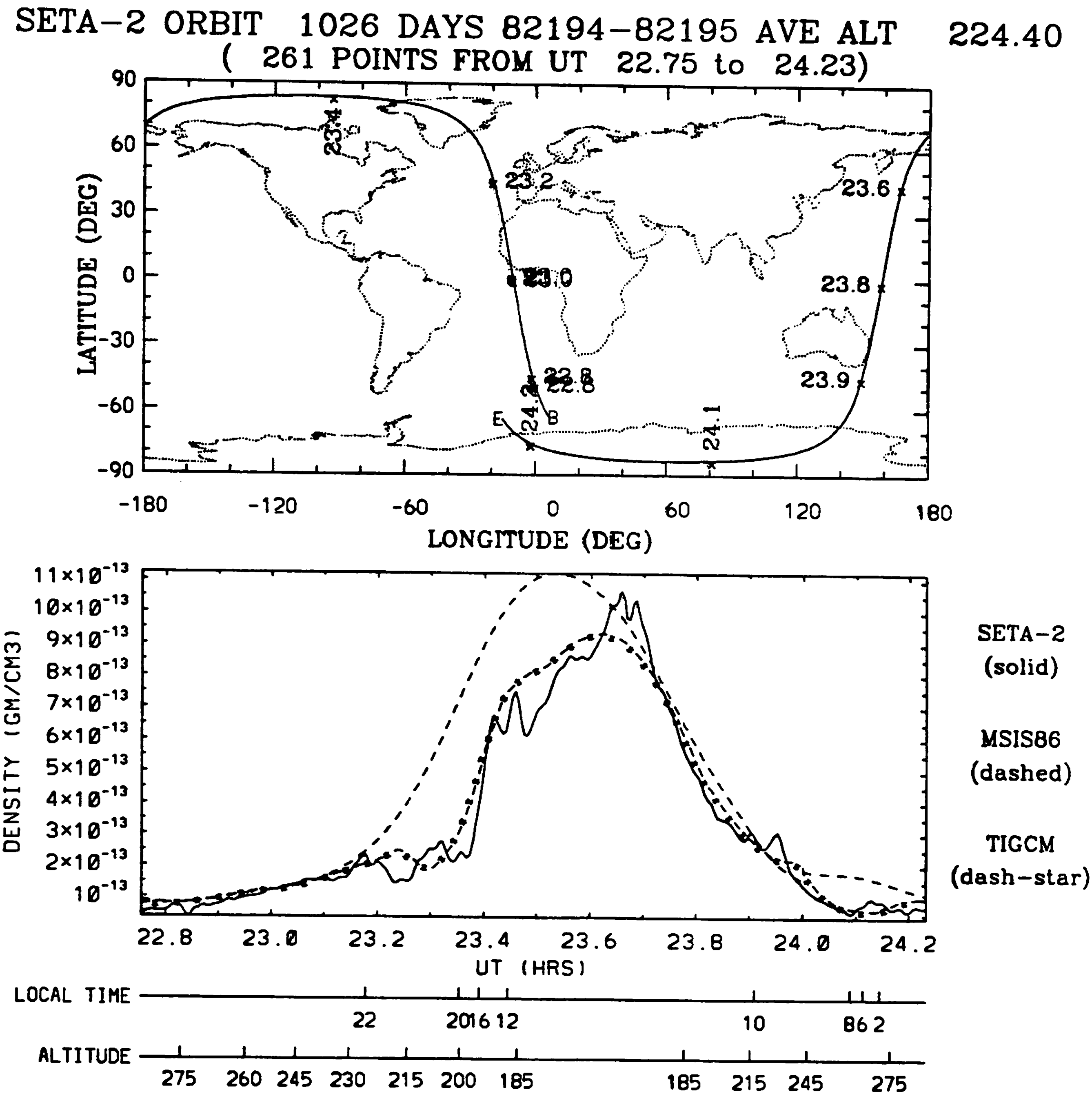
$T_L \sim 350K$


TIGCM INPUTS FOR MARCH/APRIL, 1979
KP
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
79
80
81
82
83
84
85
86
87
88
89
DAY OF 1979

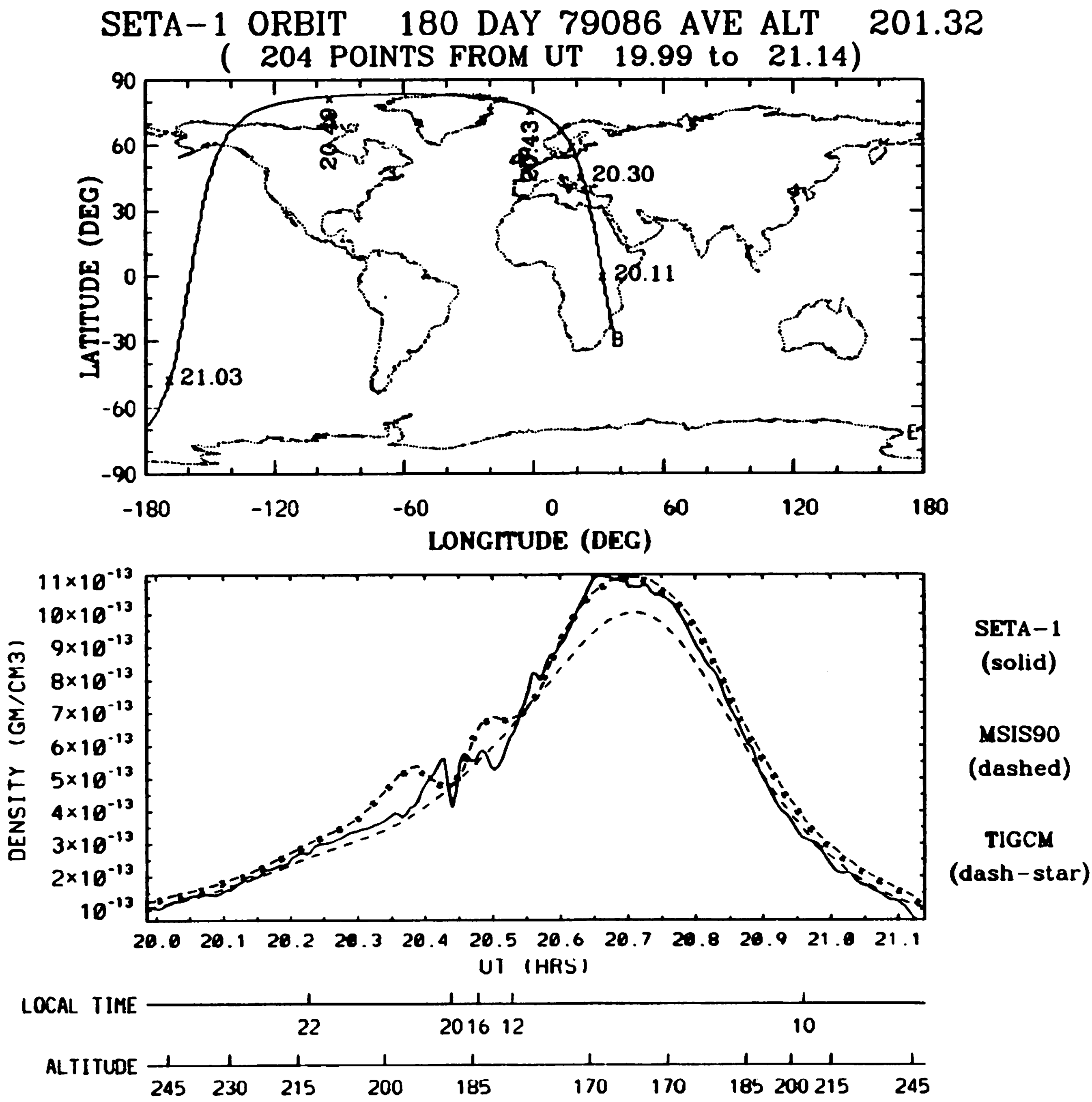

ELECTRON DENSITY (CM-3)
DAY=79081 UT=15.00 ZP=-4.0
3.00E+05
1.50E+05
0.00E+00
7
KP
0
79
DAY
89

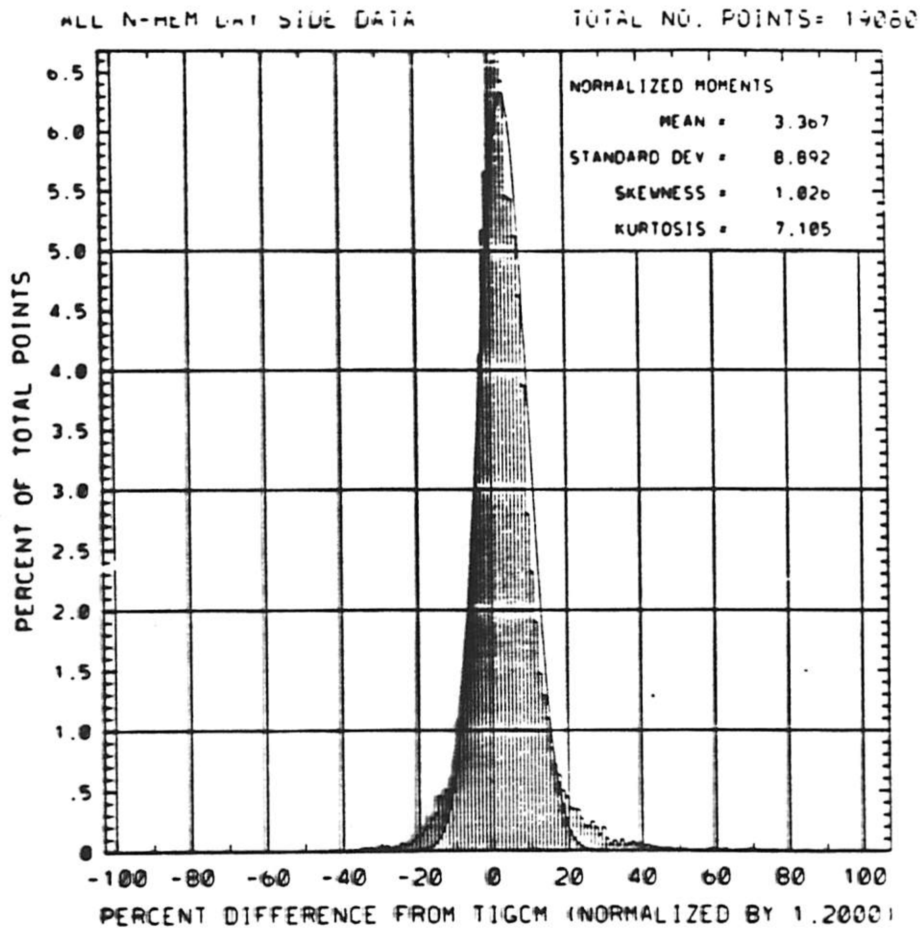

NEUTRAL TEMPERATURE (DEG K)
DAY=79081 UT=16.00 ZP= 2.0
90
LATITUDE
0
−90
0
6
12
18
0
LOCAL TIME
1050.
1425.
1800.
7
KP
0
79
DAY
89

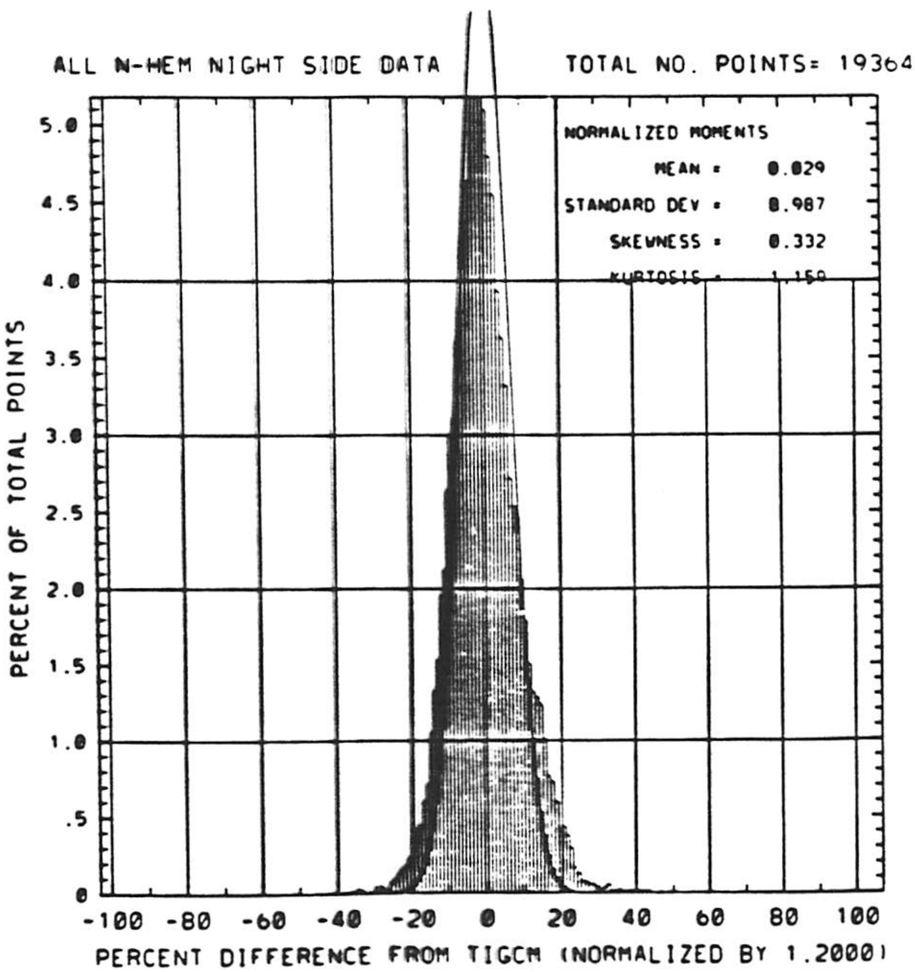

ATOMIC OXYGEN (CM-3)
DAY=79088 UT= 6.00 ZP=-4.0
1.05E+11
7.25E+10
4.00E+10
7
KP
0
79
DAY
89



SETA-2 ORBIT 1026 DAYS 82194-82195 AVE ALT 224.40
(261 POINTS FROM UT 22.75 to 24.23)
LATITUDE (DEG)
LONGITUDE (DEG)
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180
23.2
23.6
23.8
23.9
24.1
23.0
22.8
E
B
DENSITY (GM/CM3)
11x10^-13
10x10^-13
9x10^-13
8x10^-13
7x10^-13
6x10^-13
5x10^-13
4x10^-13
3x10^-13
2x10^-13
10^-13
22.8
23.0
23.2
23.4
23.6
23.8
24.0
24.2
UT (HRS)
SETA-2
(solid)
MSIS86
(dashed)
TIGCM
(dash-star)
LOCAL TIME
22
20
16
12
10
8
6
2
ALTITUDE
275
260
245
230
215
200
185
185
215
245
275


SETA-1 ORBIT 180 DAY 79086 AVE ALT 201.32
(204 POINTS FROM UT 19.99 to 21.14)
LATITUDE (DEG)
LONGITUDE (DEG)
20.30
20.11
21.03
B
E
DENSITY (GM/CM3)
SETA-1
(solid)
MSIS90
(dashed)
TIGCM
(dash-star)
UT (HRS)
LOCAL TIME
22
20
16
12
10
ALTITUDE
245
230
215
200
185
170
170
185
200
215
245


ALL N-HEM DAY SIDE DATA
TOTAL NO. POINTS= 19060
NORMALIZED MOMENTS
MEAN = 3.367
STANDARD DEV = 8.892
SKEWNESS = 1.026
KURTOSIS = 7.105
PERCENT OF TOTAL POINTS
PERCENT DIFFERENCE FROM TIGCM (NORMALIZED BY 1.2000)


ALL N-HEM NIGHT SIDE DATA
TOTAL NO. POINTS= 19364
NORMALIZED MOMENTS
MEAN = 0.029
STANDARD DEV = 8.987
SKEWNESS = 0.332
PERCENT OF TOTAL POINTS
PERCENT DIFFERENCE FROM TIGCM (NORMALIZED BY 1.2000)

SUMMARY

What have we learned

- Thermosphere is stable, no internal instabilities diurnally reproducible
- Variability caused by variations in solar and auroral forcing.
- Lower thermosphere appears highly variable because of disturbances from lower atmosphere
  - + Tides
  - + Gravity Waves and mixing
  - + 2 day .... 16 day wave.
  - + TIME-GCM suggest large variability in lower thermosphere.
- Global composition – O/N_2, O/O_2 ratio
- Ionospheric variability
  - + winds
  - + composition
  - + ion drag.
- Processes — station, satellite track etc
- Diagnostic Processes, Physical & chemical processes.