# MILLSTONE HILL MEASUREMENTS AND TGCM SIMULATION FOR THE 30 MAY 1984 ANNULAR SOLAR ECLIPSE

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On 30 May 1984, the Millstone Hill incoherent scatter radar was operated to gather data on the effects of the annular solar eclipse on the structure and dynamics of the ionosphere and thermosphere. The eclipse path was about 3 deg. south of Millstone which experienced a maximum obscuration of 86% at about 1705 UT. Both the zenith and steerable antennas at Millstone were used in the experiment to collect data on the temporal evolution of the eclipse effects. This experiment represented the first opportunity at Millstone to collect data during an eclipse in the absence of a major magnetospheric disturbance which had previously made the unravelling of eclipse effects difficult. In addition, the configuration of the experiment and analysis of the data included a detailed examination of the effects on the neutral atmosphere. A major catalyst for this study was the opportunity to compare the results with the predictions made from the Thermospheric General Circulation Model (TGCM) at NCAR, as a calibration point for the model. The plans for the experiment were formulated at the February 1984 Incoherent Scatter Data Users Workshop; the Arecibo and Sondrestrom radars also participated as part of a radar chain experiment. The analysis of the data from these stations is in progress; this paper presents the initial results from Millstone Hill.

The observations, confirming the TGCM predictions, indicate a drop in electron density by 60% at the peak obscuration time in the altitude range 130 - 250 km. At higher altitudes, a smaller decrease (14%) is observed, in contrast to the model predictions and the difference is due to assumed flux boundary conditions. Although a difference in mean electron temperature exists between model and temperature, a good agreement is found in the relative drop ($\sim$25%) during the eclipse. Within somehwat large fluctuations it is possible to discern a 50° K drop in the exospheric temperature measurements as predicted from the TGCM.

From three dimensional ion drift measurements across the eclipse path a neutral wind velocity, governed primarily by the meridional component, of about 50 m/sec at eclipse time is observed. Within the uncertainties of the measurements, little change in the winds is observed prior to and following the eclipse, and the results are similar to previous summer day observations where a reversal occurs near 1400 EST. Electric fields derived from the data indicate magnitudes of the order of 1 mV/m or less, primarily north-westward except between 1530 and 1730 U.T. where the field is south-eastward. While the TGCM predicted similar overall wind magnitudes and directions as observed, it has been difficult to verify the convergence of wind perturbations onto the eclipse path as would be expected and as indicated by the model. This is because of geometric considerations of the ion drift vectors relative to the eclipse path, and because of the sensitivity of the radar measurements in the F-region to both the meridional and zonal components. It is nonetheless possible to state that the overall dynamic behavior predicted by the TGCM is consistent with the observations.

# ANNULAR SOLAR ECLIPSE OF 1984 MAY 30

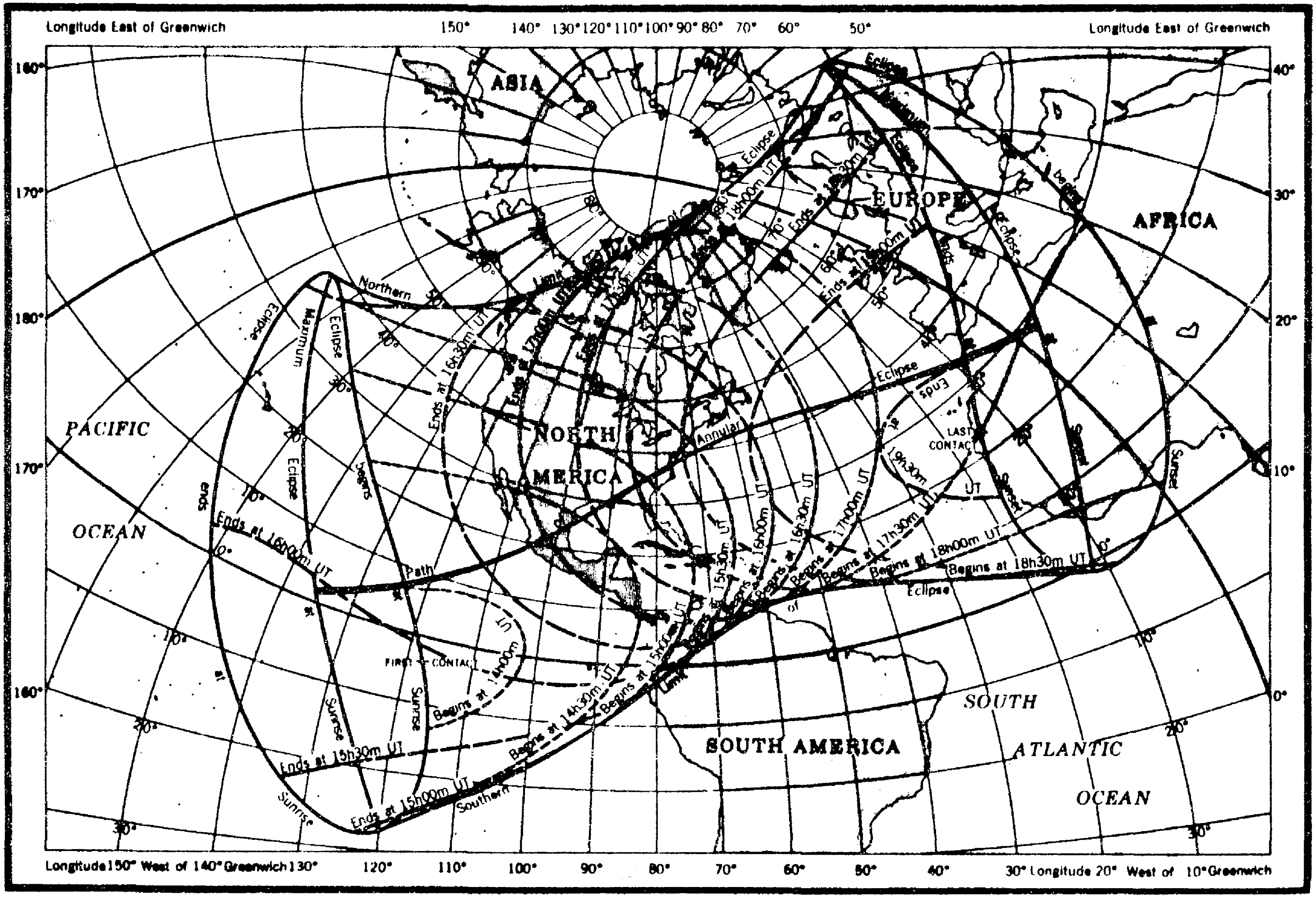



Figure 1.

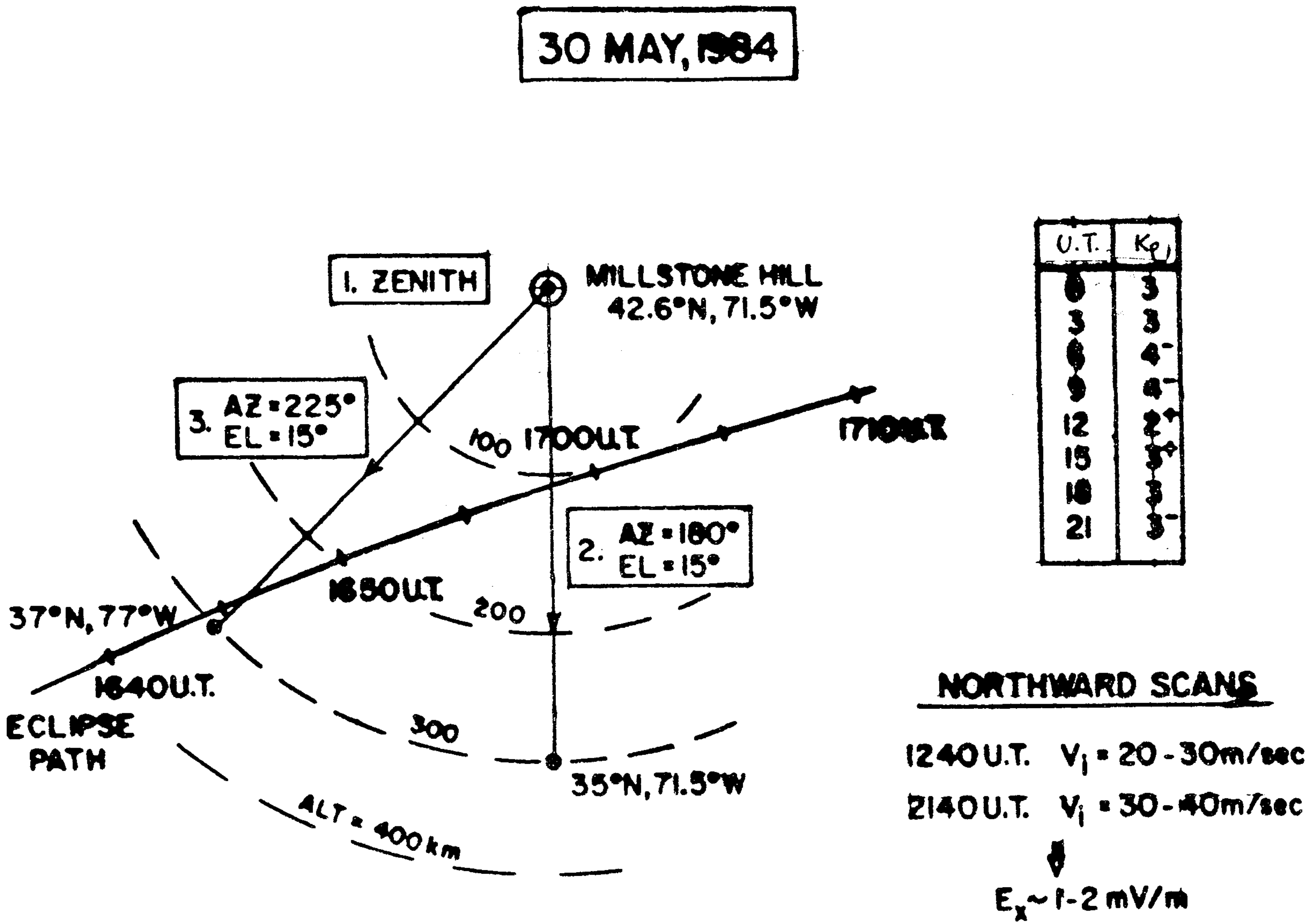

30 MAY, 1984
1. ZENITH
MILLSTONE HILL
42.6°N, 71.5°W
3. AZ = 225°
EL = 15°
2. AZ = 180°
EL = 15°
100
1700 U.T.
1650 U.T.
200
300
ALT = 400 km
37°N, 77°W
1640 U.T.
ECLIPSE
PATH
35°N, 71.5°W
U.T.
Kp
3
3
4-
4-
2+
3+
3
3-
12
15
21
NORTHWARD SCANS
1240 U.T. $V_l$ = 20-30 m/sec
2140 U.T. $V_l$ = 30-40 m/sec
$E_x$ ~ 1-2 mV/m

Figure 2.

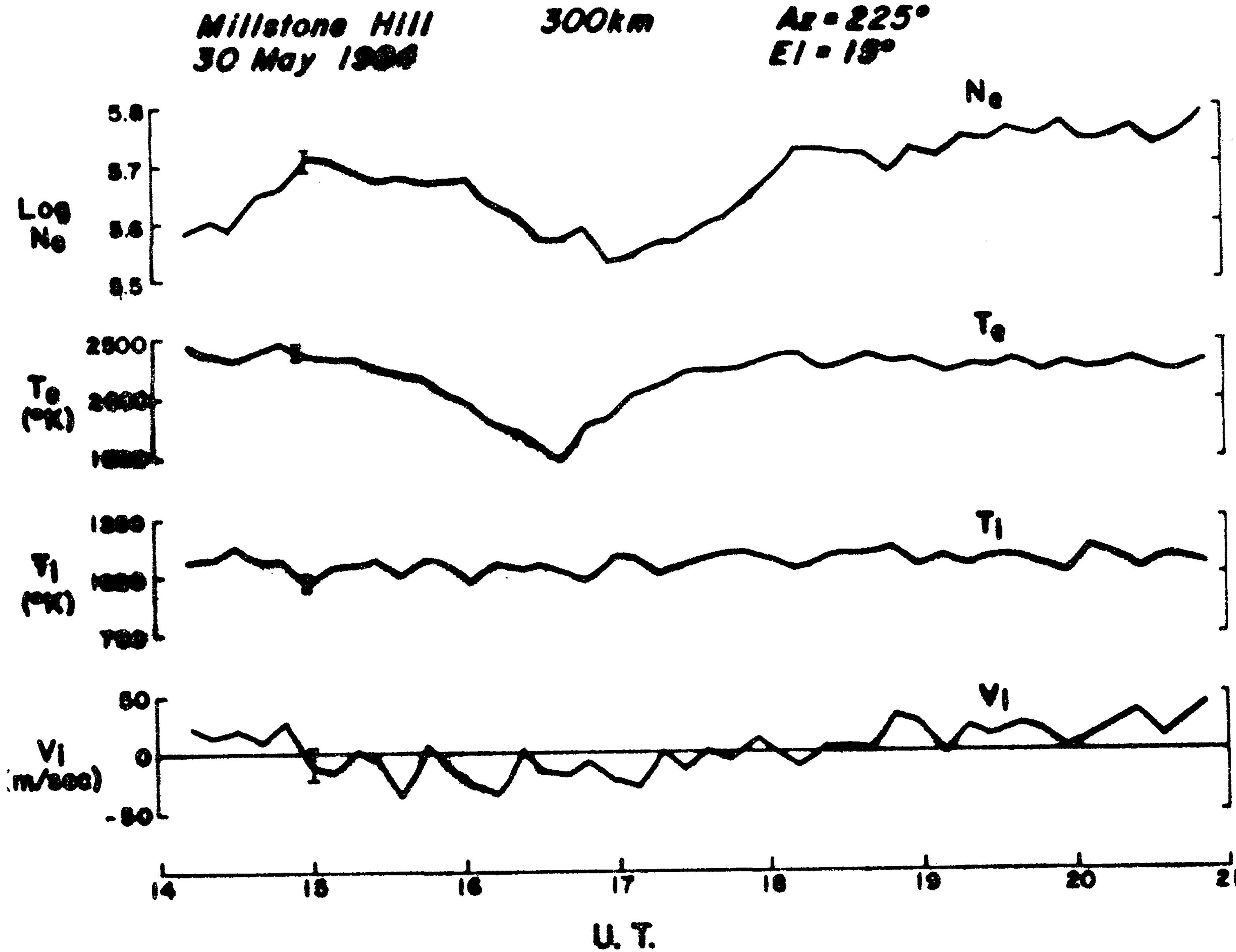

Millstone Hill
30 May
300km
Az = 225°
Ne
Log Ne
5.8
5.7
5.6
5.5
Te
2500
Te (°K)
Ti
Ti (°K)
Vi
50
0
-50
Vi (m/sec)
14
15
16
17
18
19
20
21
U. T.

Figure 3.

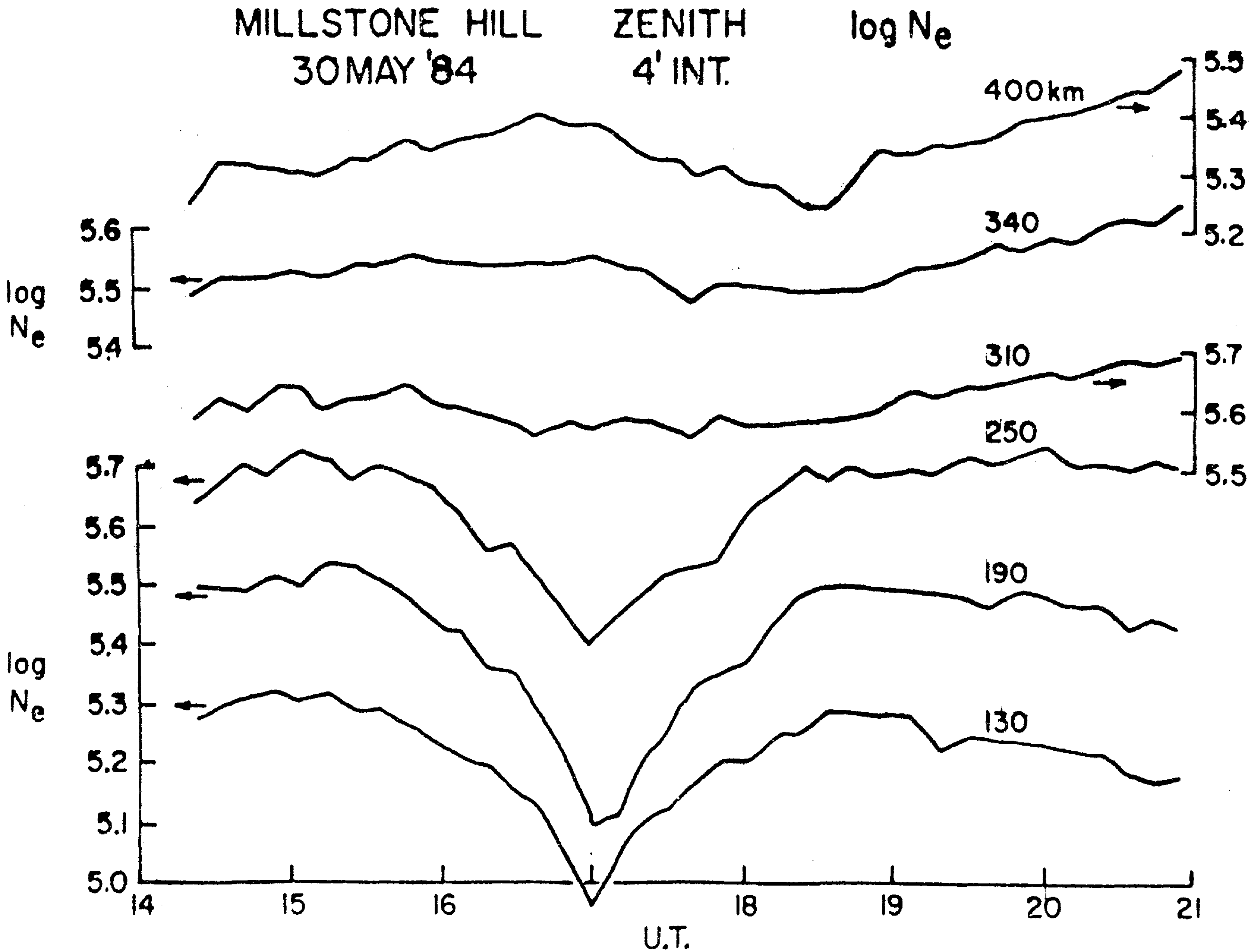
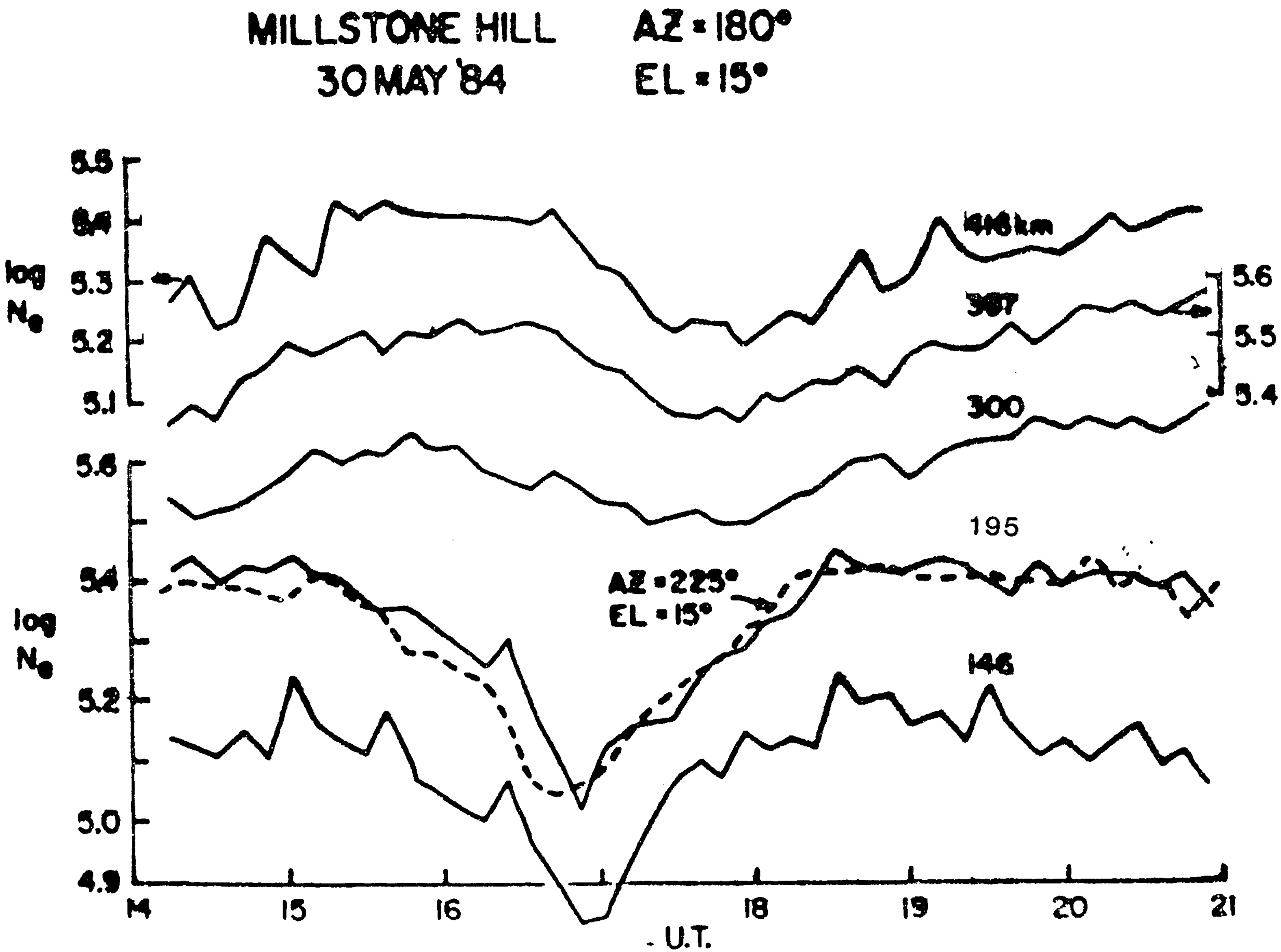

MILLSTONE HILL
30 MAY '84
ZENITH
4' INT.
log $N_e$
400km
340
310
250
190
130
5.5
5.4
5.3
5.2
5.7
5.6
5.5
5.6
5.5
5.4
log $N_e$
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5.0
log $N_e$
14
15
16
18
19
20
21
U.T.

Figure 4.



MILLSTONE HILL
30 MAY '84
AZ = 180°
EL = 15°
log Ne
416 km
387
300
195
146
AZ = 225°
EL = 15°
U.T.


Figure 5.

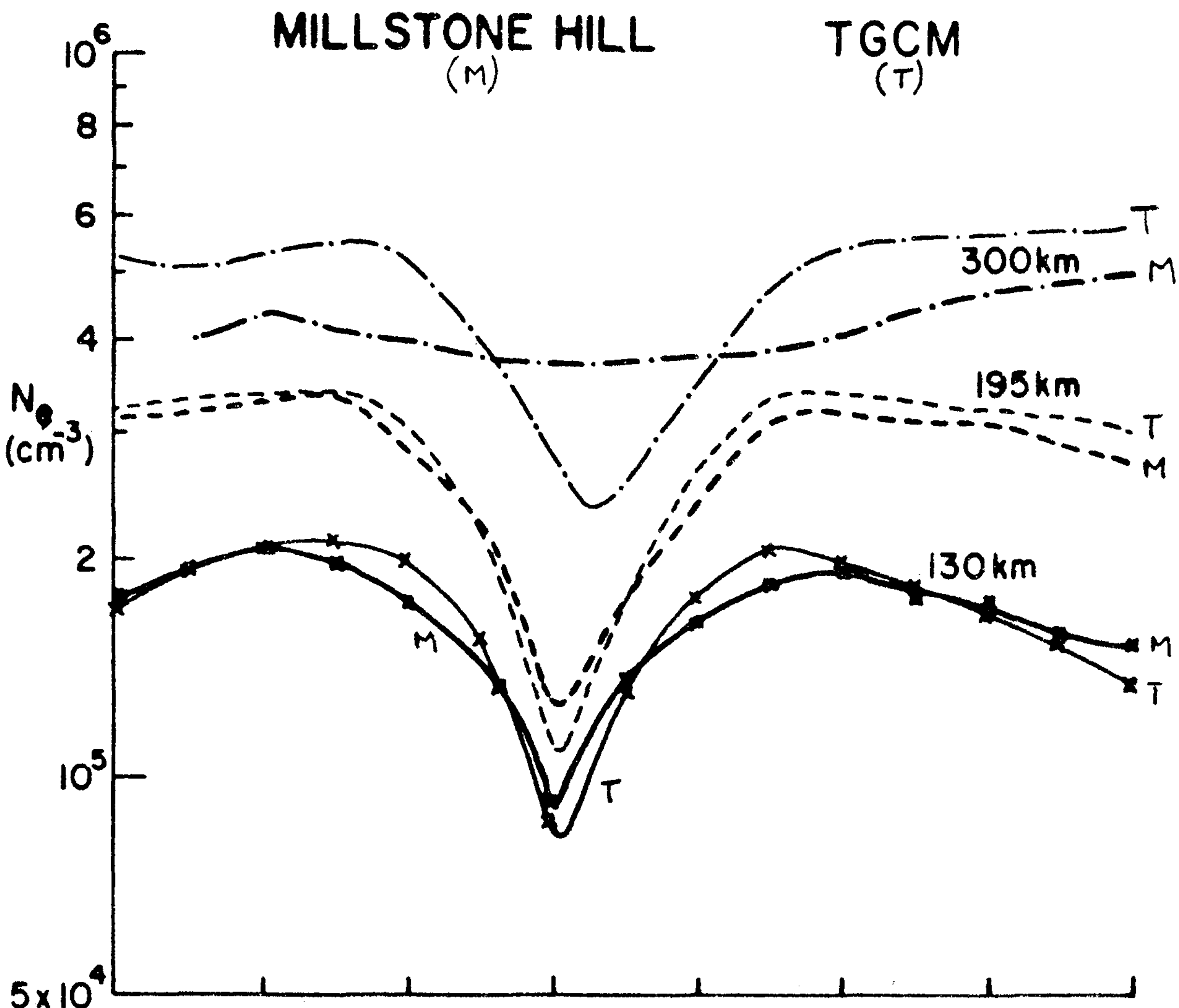

MILLSTONE HILL
(M)
TGCM
(T)
$10^6$
8
6
4
2
$10^5$
$5\times10^4$
$N_e$
$(cm^{-3})$
300km
195km
130km
T
M
14
15
16
17
18
19
20
21
U.T.

Figure 6.

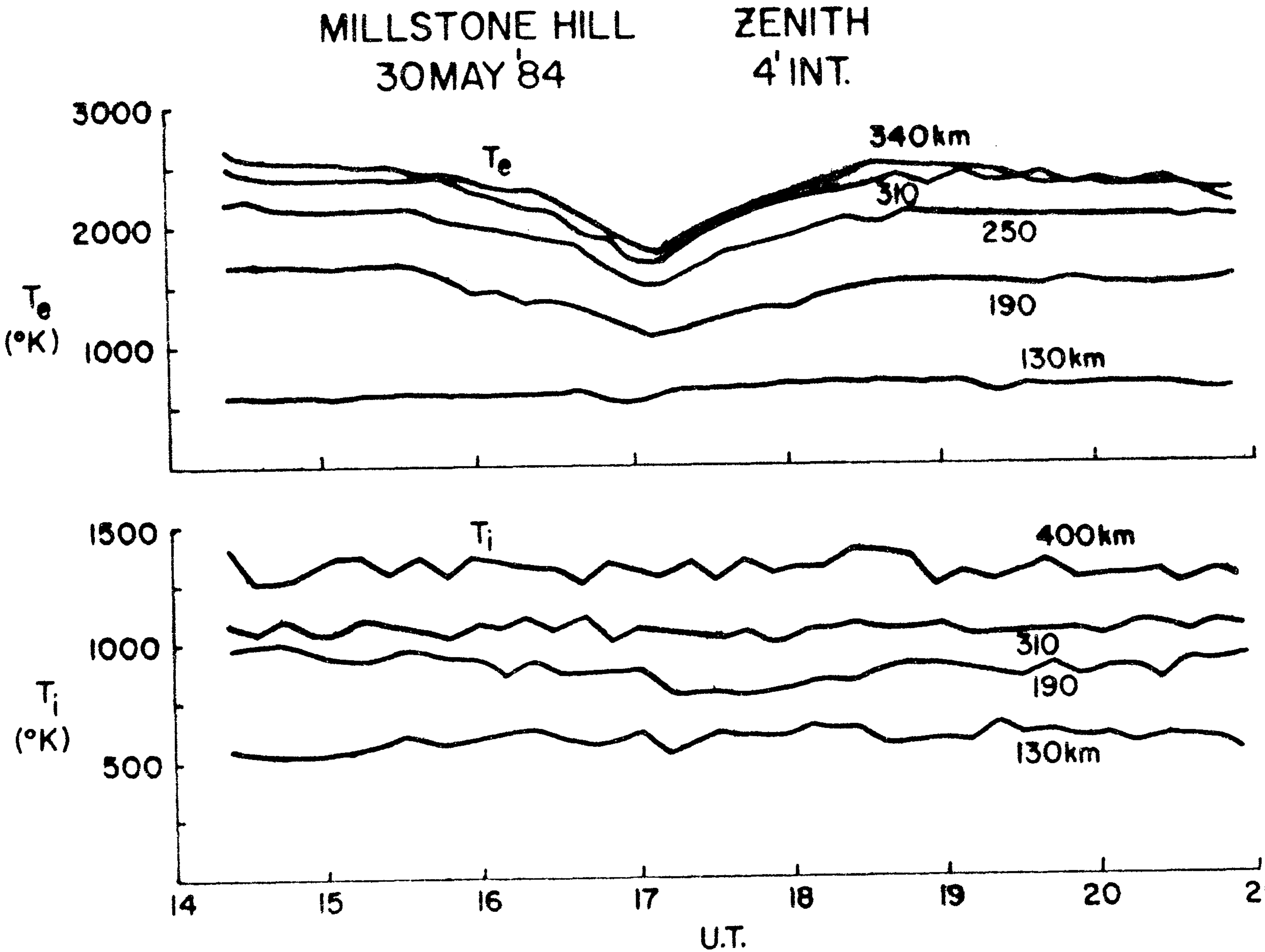
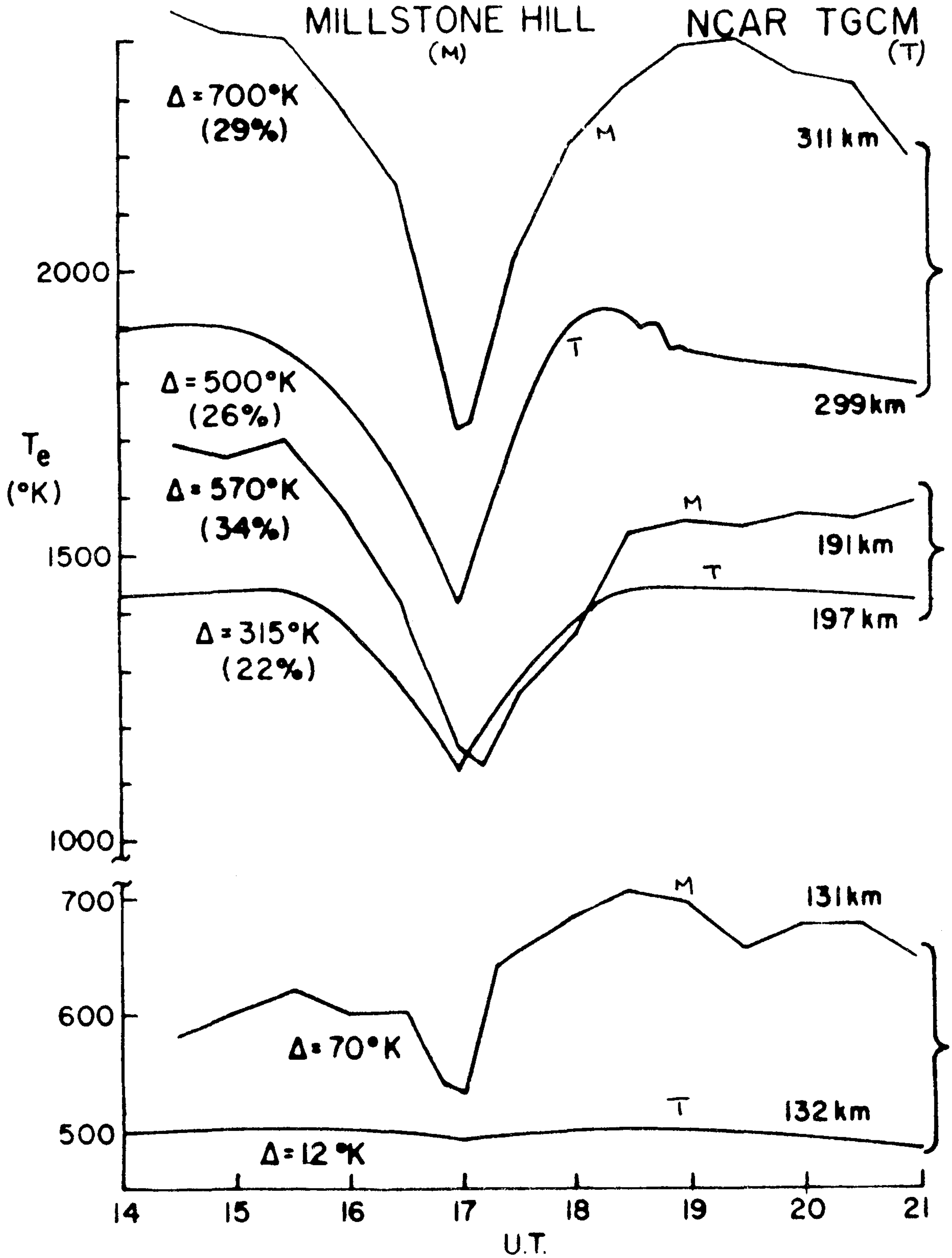

MILLSTONE HILL
30 MAY '84
ZENITH
4' INT.
3000
2000
1000
Te
(°K)
340km
310
250
190
130km
1500
1000
500
Ti
(°K)
400km
310
190
130km
14
15
16
17
18
19
20
21
U.T.

Figure 7.



MILLSTONE HILL (M)
NCAR TGCM (T)
Δ = 700°K (29%)
Δ = 500°K (26%)
Δ = 570°K (34%)
Δ = 315°K (22%)
Δ = 70°K
Δ = 12°K
311 km
299 km
191 km
197 km
131 km
132 km
M
T
$T_e$ (°K)
2000
1500
1000
700
600
500
14
15
16
17
18
19
20
21
U.T.


Figure 8.

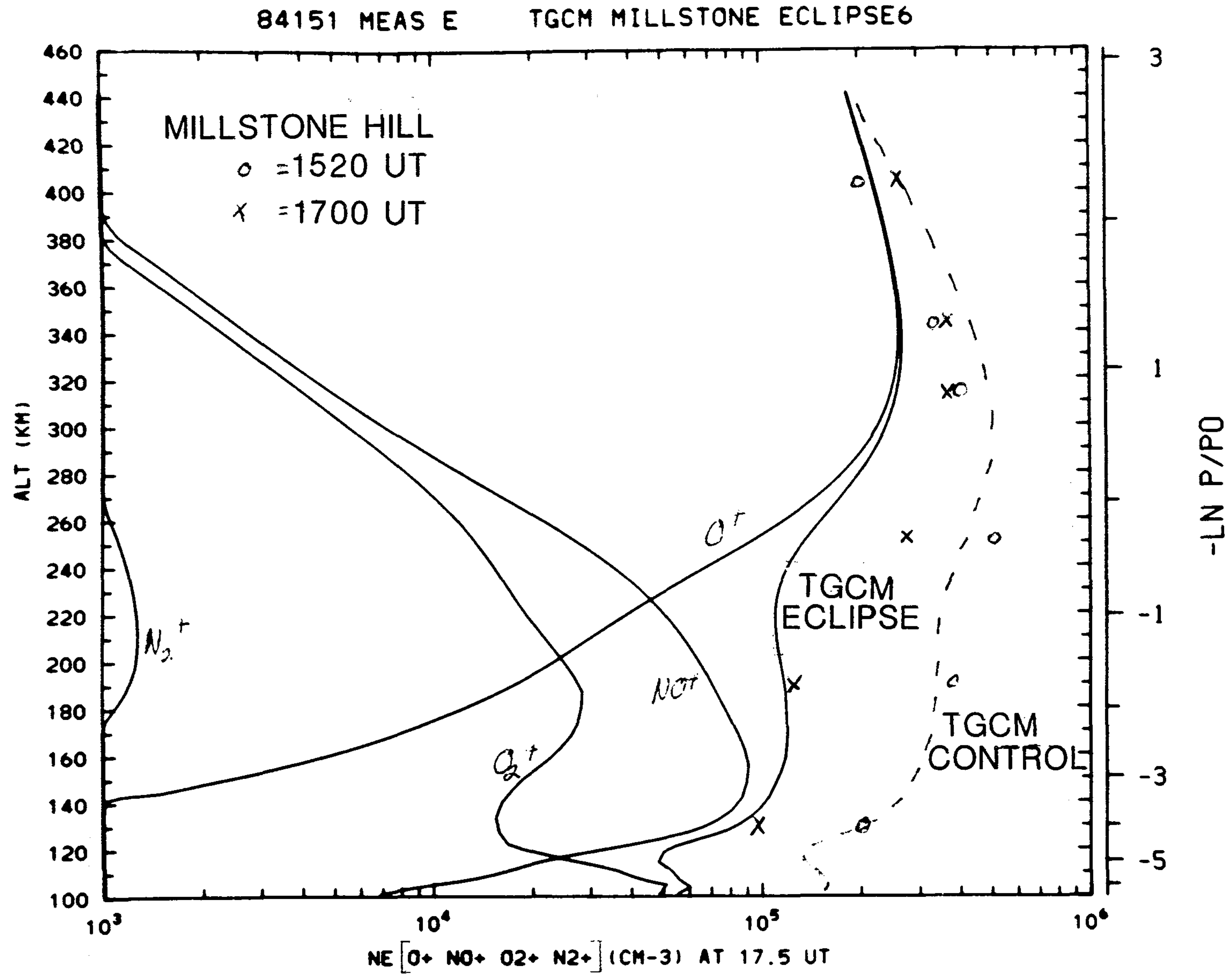



Figure 8a. NCAR TGCM update.

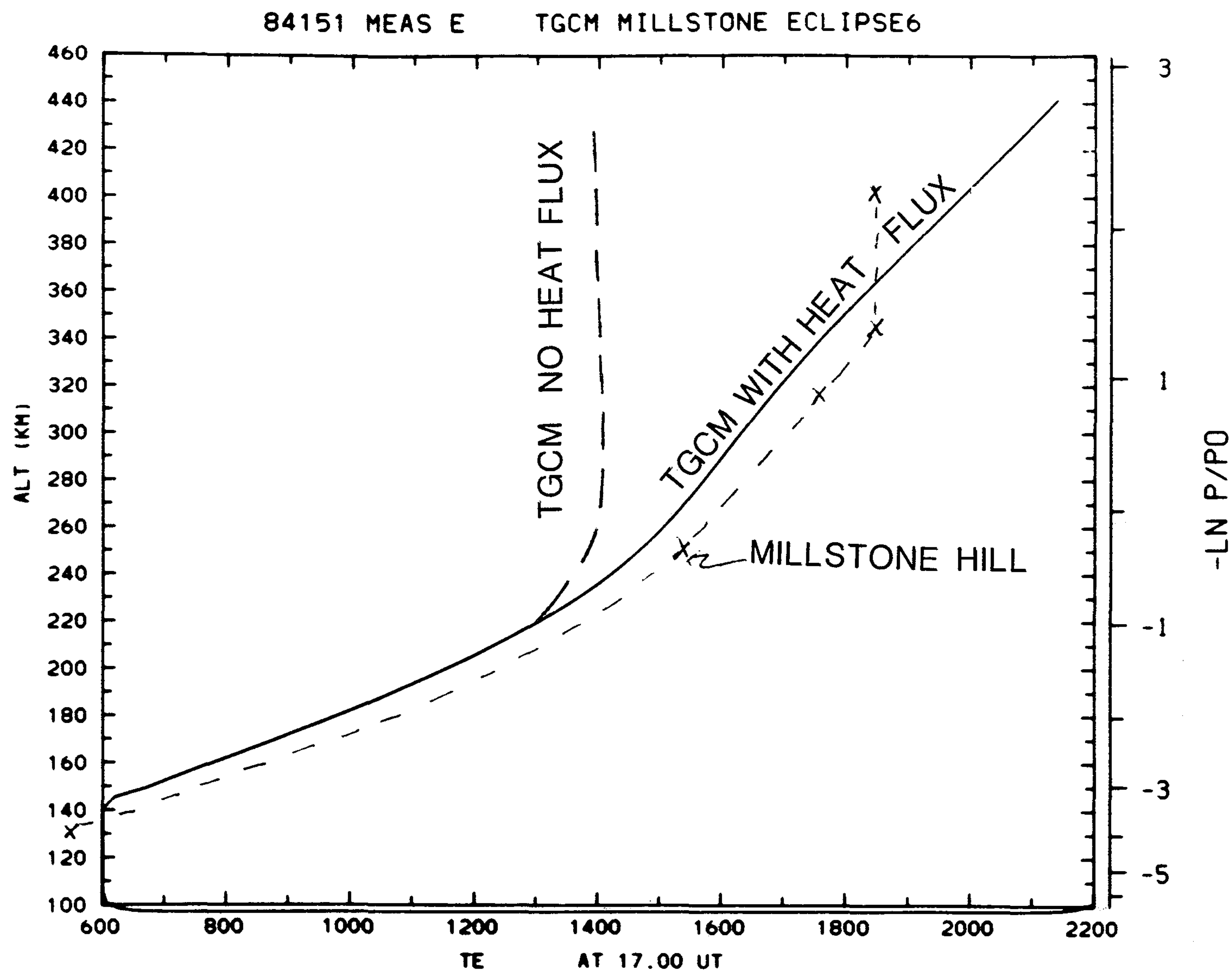



Figure 8b. NCAR TGCM update.

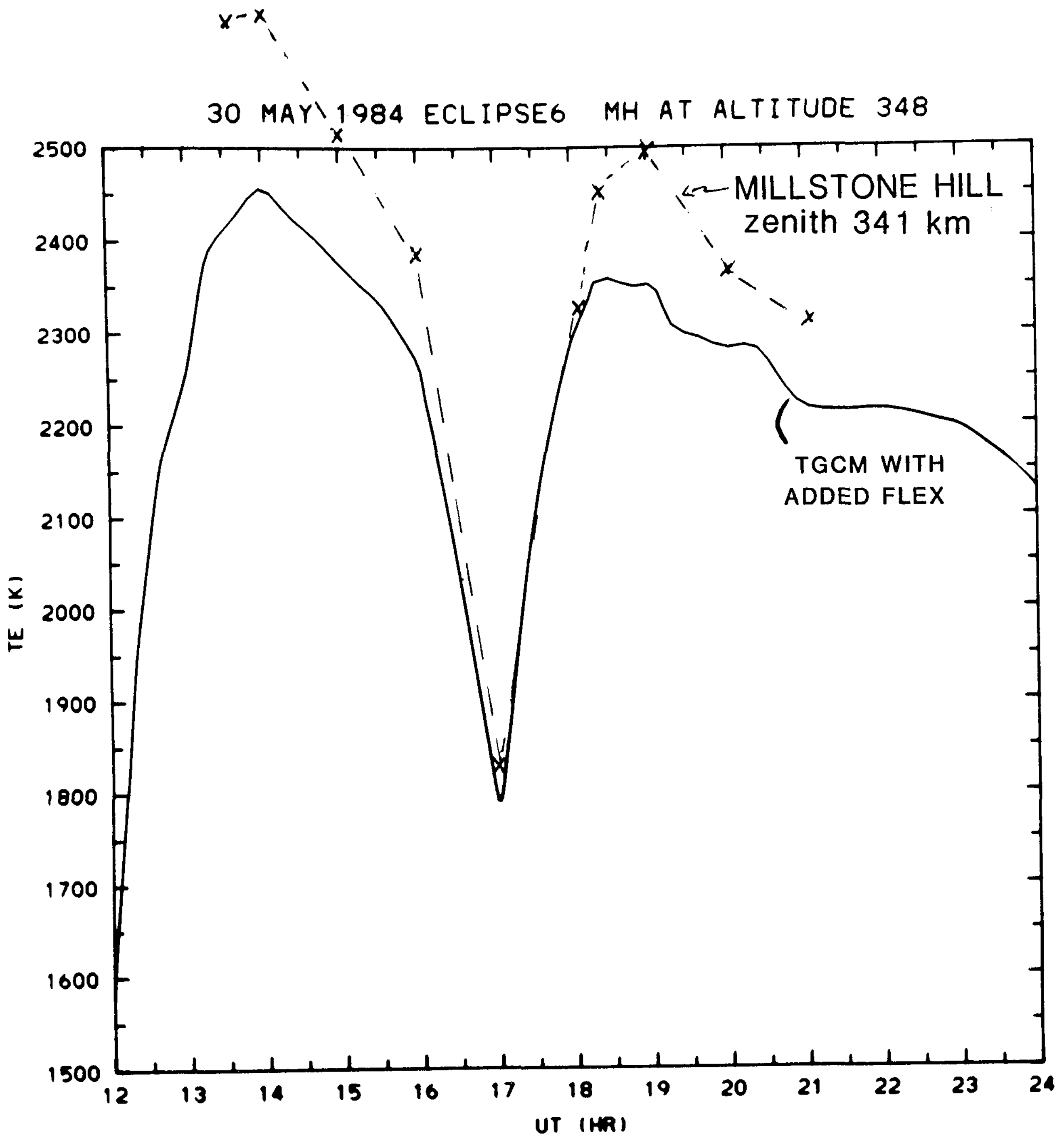
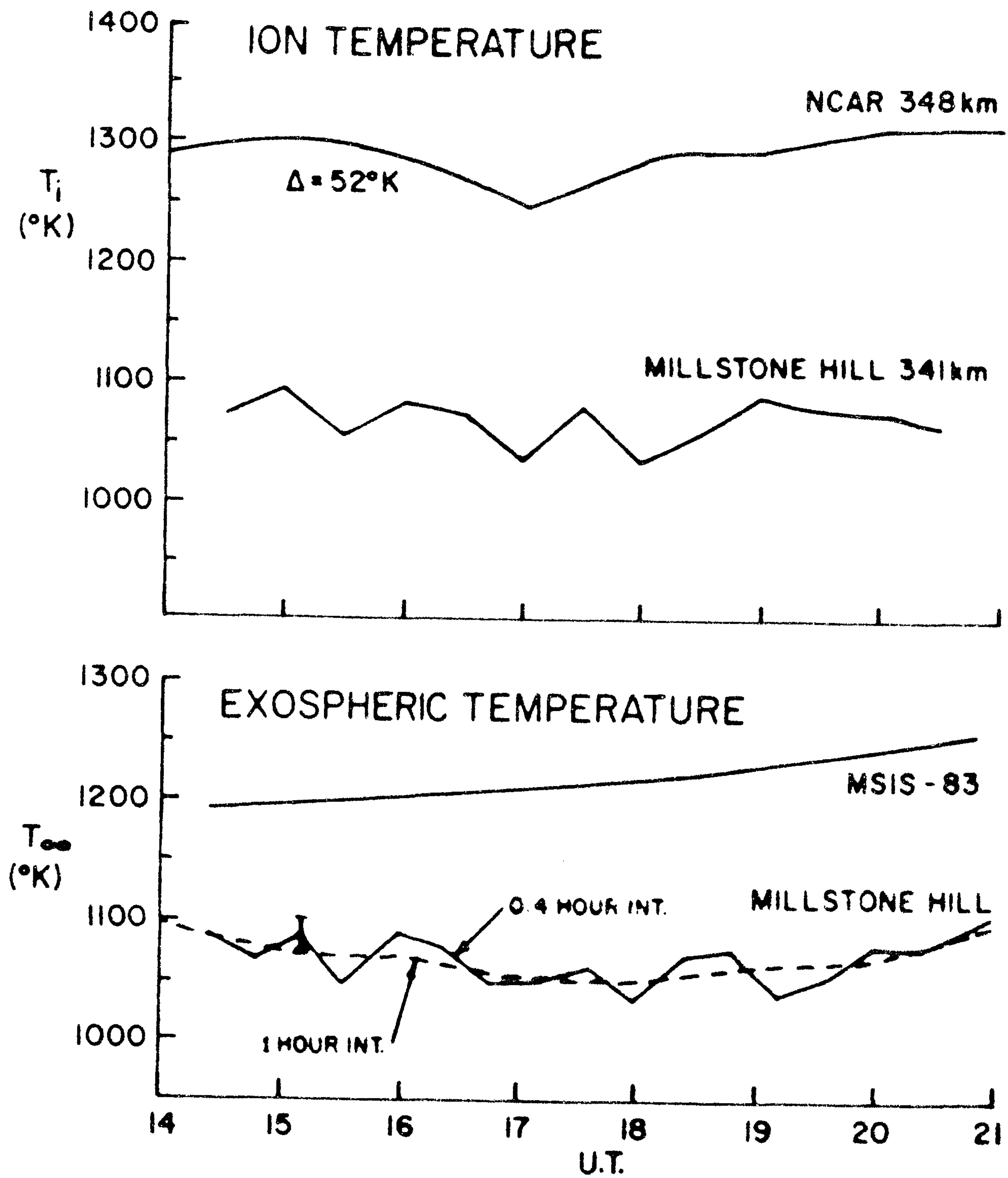



Figure 8c. NCAR TGCM update.



ION TEMPERATURE
NCAR 348km
Δ = 52°K
MILLSTONE HILL 341km
T_i (°K)
1400
1300
1200
1100
1000
EXOSPHERIC TEMPERATURE
MSIS - 83
MILLSTONE HILL
0.4 HOUR INT.
1 HOUR INT.
T_∞ (°K)
1300
1200
1100
1000
14
15
16
17
18
19
20
21
U.T.


Figure 9.

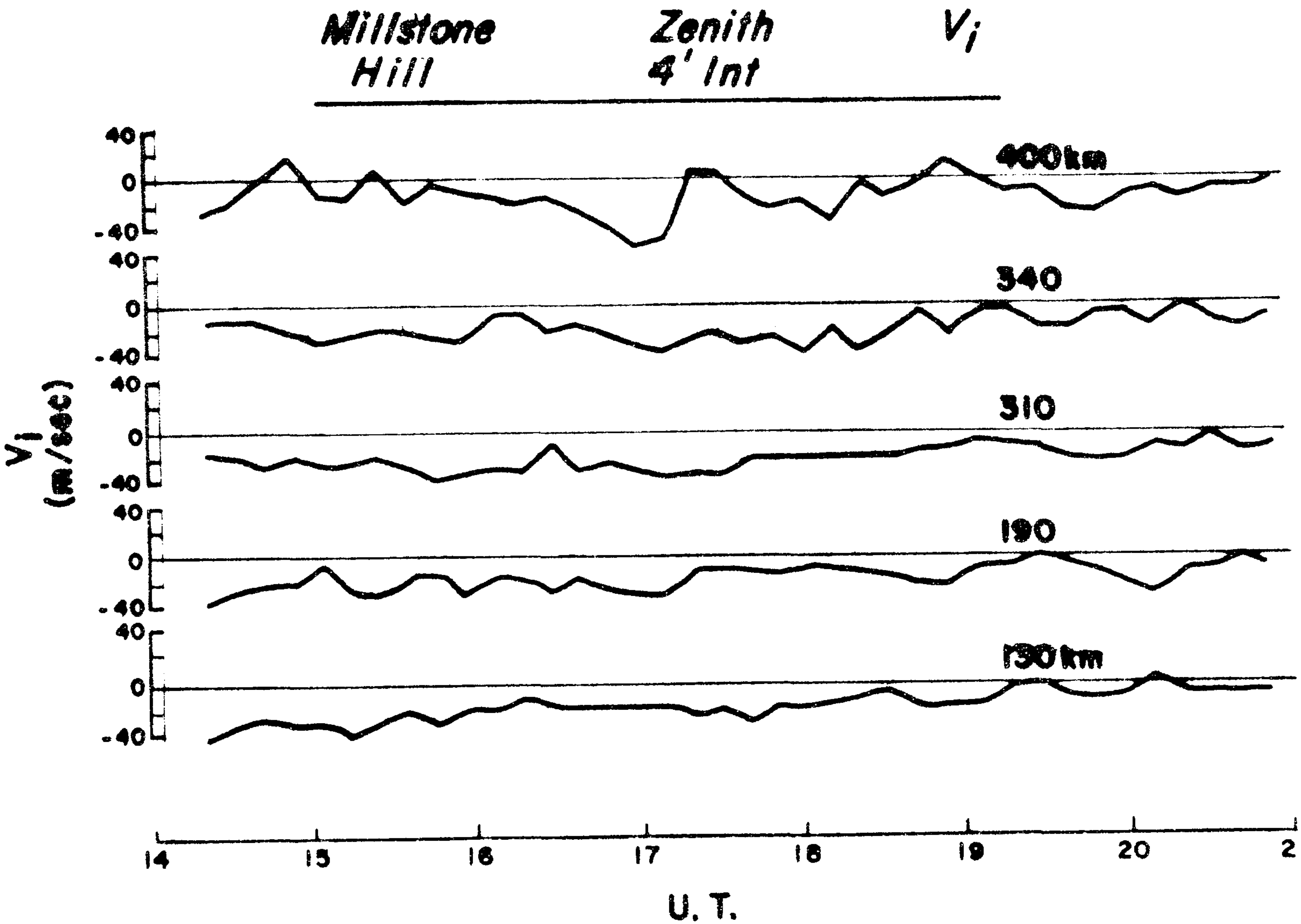

Millstone Hill
Zenith 4' Int
Vi
400km
340
310
190
130km
40
0
-40
Vi (m/sec)
14
15
16
17
18
19
20
21
U. T.

Figure 10.

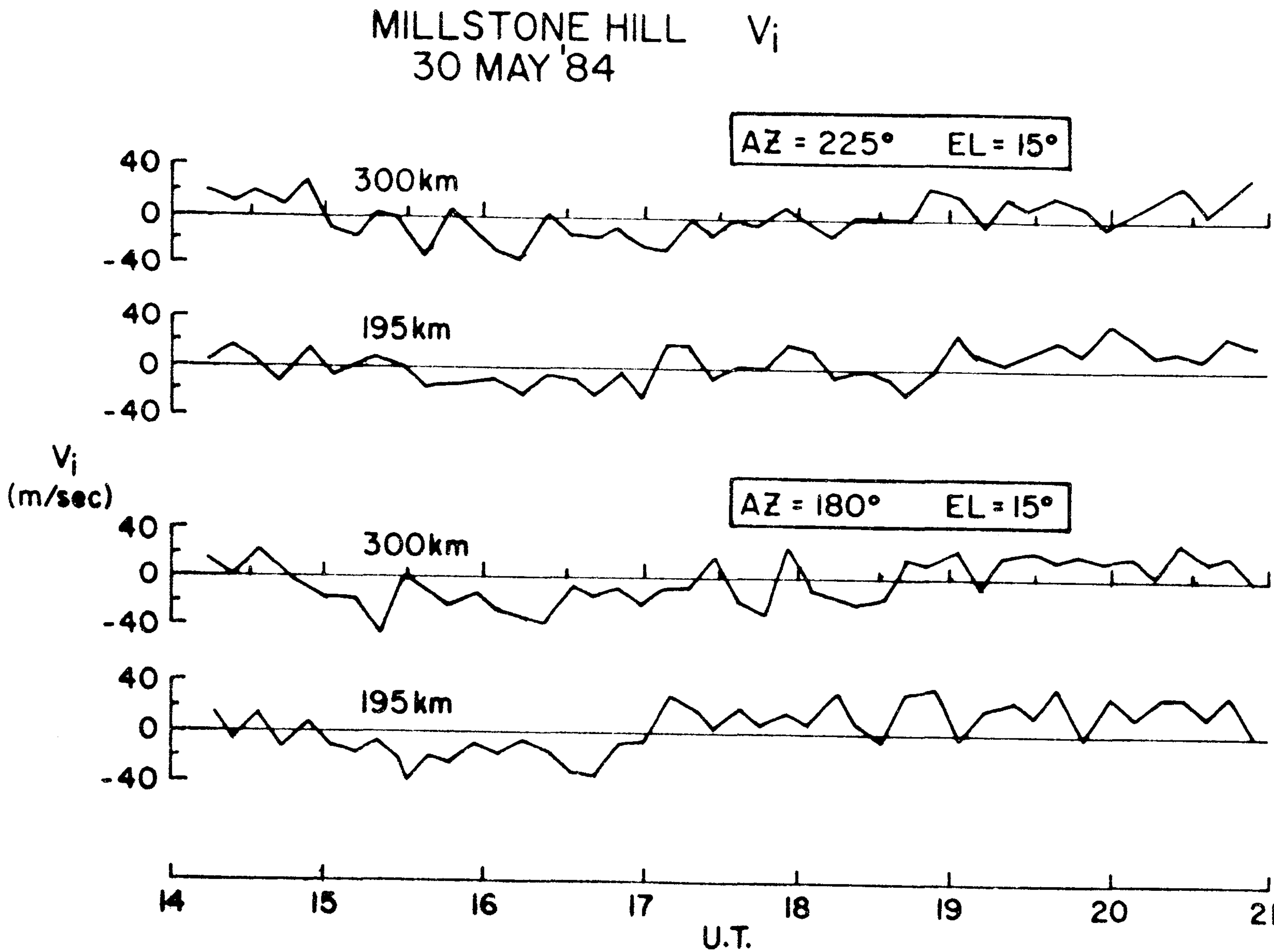

MILLSTONE HILL $V_i$
30 MAY '84
AZ = 225° EL = 15°
300km
195km
AZ = 180° EL = 15°
300km
195km
40
0
-40
$V_i$
(m/sec)
14
15
16
17
18
19
20
21
U.T.

Figure 11.

# DERIVATION OF NEUTRAL WINDS

$V_I$ (ZENITH) $-0.95\ V_{DIFF} = -0.29\ V'_N + 6\ E_X + 1.5\ E_Y$

$V_I$ (S, 15°E) $-0.54\ V_{DIFF} = -0.16\ V'_N - 17\ E_X + 0.8\ E_Y$

$V_I$ (SW, 15°E) $-0.4\ V_{DIFF} = -0.12\ V'_N - 12\ E_X + 15\ E_Y$

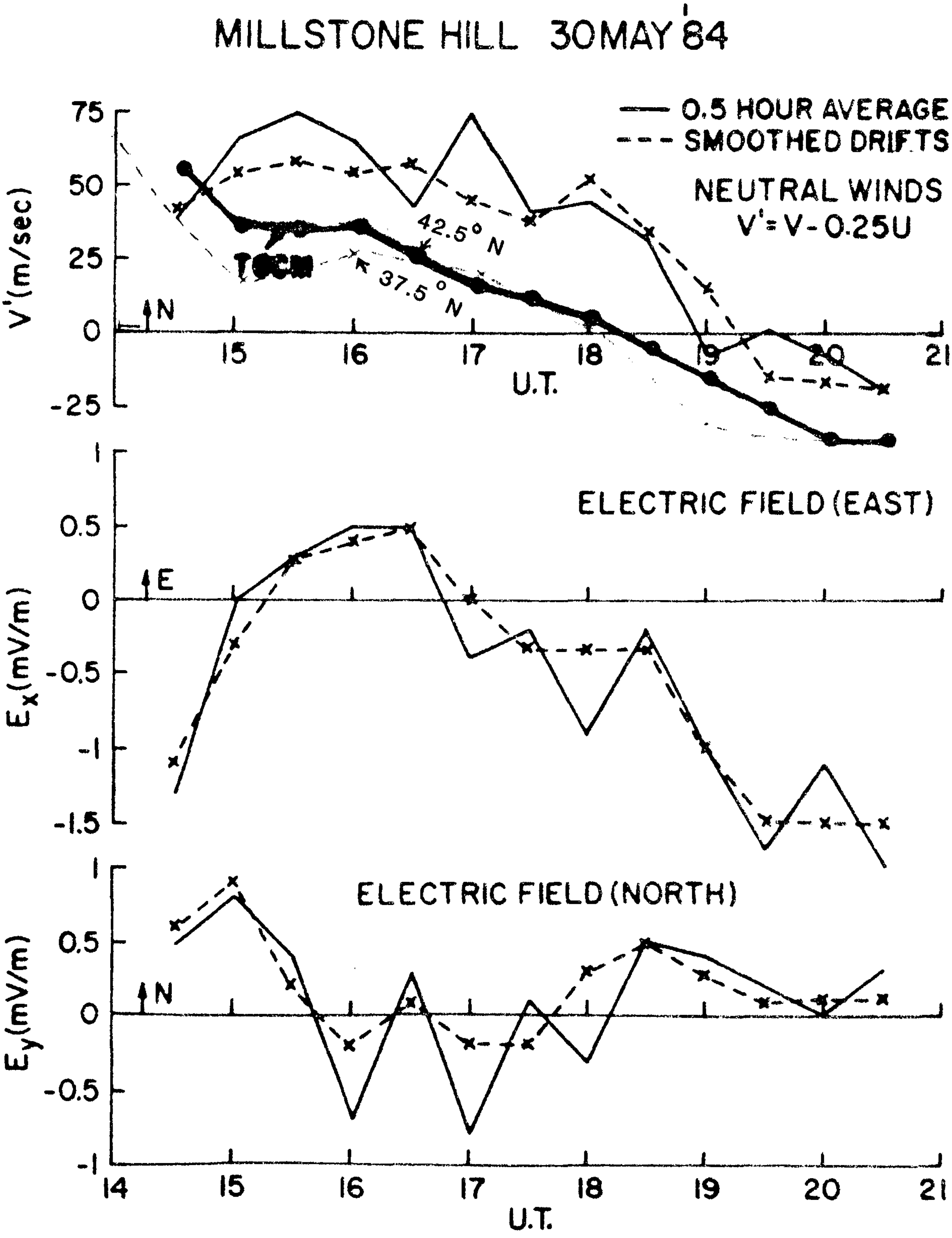
WHERE $V'_N = V_N - 0.25\ U_N$

$U_N$, Ex: EASTWARD POSITIVE

$V_N$, $E_Y$: NORTHWARD POSITIVE

U, V = M/SEC  E: MV/M

Figure 12.



MILLSTONE HILL 30MAY'84
0.5 HOUR AVERAGE
SMOOTHED DRIFTS
NEUTRAL WINDS
V'=V-0.25U
42.5° N
37.5° N
TGCM
V'(m/sec)
75
50
25
0
-25
N
15
16
17
18
19
20
21
U.T.
ELECTRIC FIELD (EAST)
Ex(mV/m)
1
0.5
0
-0.5
-1
-1.5
E
ELECTRIC FIELD (NORTH)
Ey(mV/m)
1
0.5
0
-0.5
-1
N
14
15
16
17
18
19
20
21
U.T.


Figure 13.

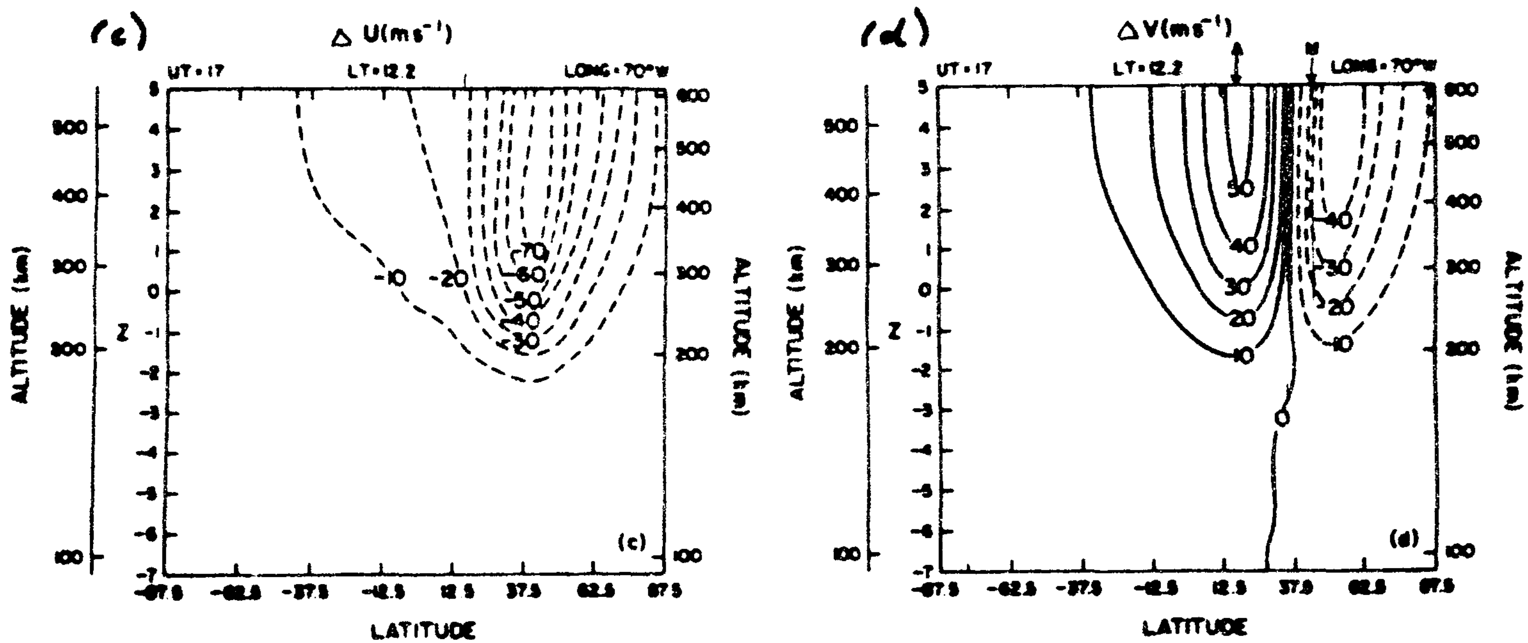
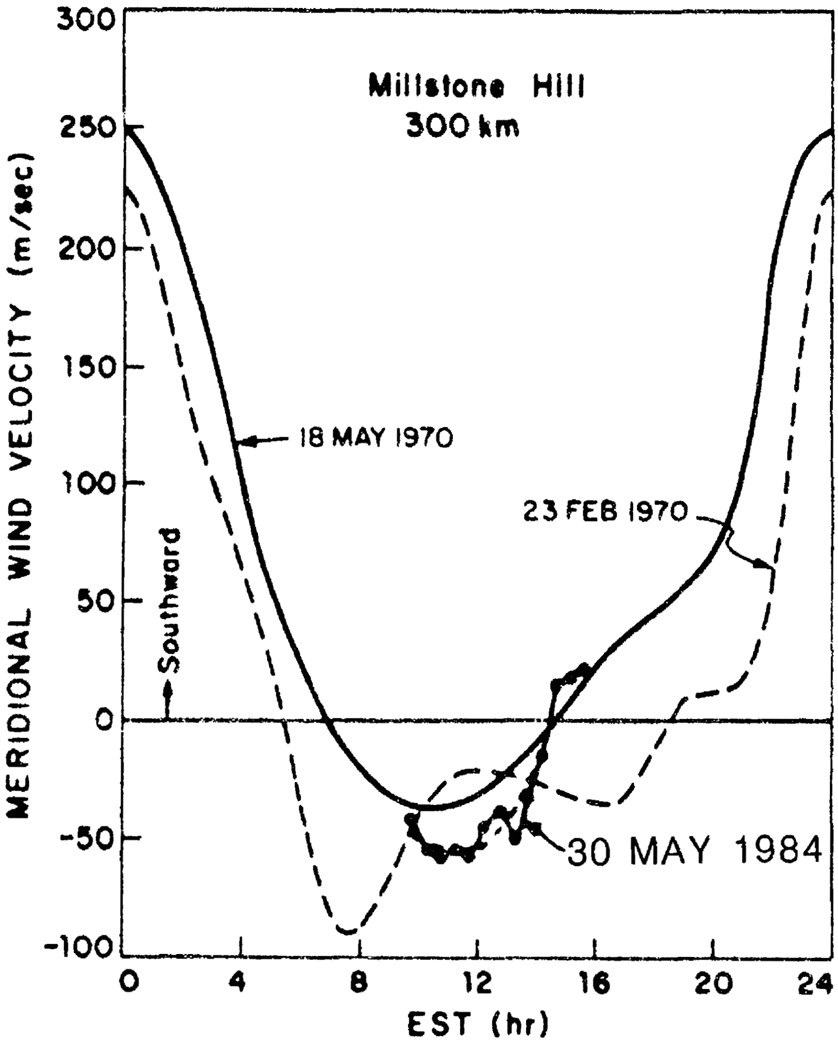



Figure 14. NCAR TGCM predictions of Neutral Wind Perturbations for Eclipse - 17 U.T.



Millstone Hill
300 km
MERIDIONAL WIND VELOCITY (m/sec)
300
250
200
150
100
50
0
-50
-100
Southward
18 MAY 1970
23 FEB 1970
30 MAY 1984
0
4
8
12
16
20
24
EST (hr)


Figure 15.

Wand and Evans: Millstone Hill Electric Fields

JGR 86, 103 (1981)

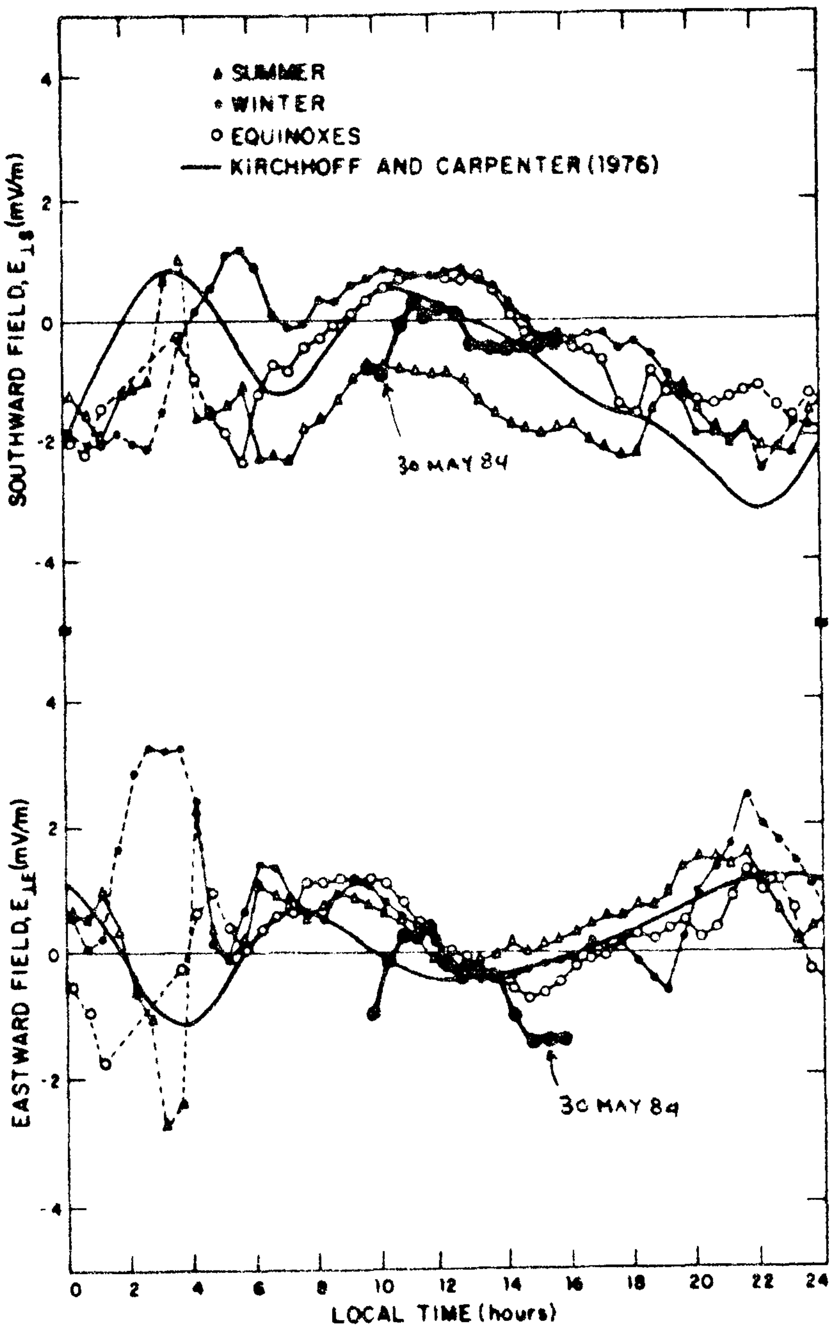



Figure 16.

## SUMMARY

| | | NCAR TGCM | MILLSTONE HILL |
|---|---|---|---|
| $\frac{\Delta N_E}{N_E}$ | 130 KM | 61% | 55% |
| | 200 KM | 68% | 62% |
| | 300 KM | 56% | 14% |
| $\frac{\Delta T_E}{T_E}$ | 130 KM | 2% | 12% |
| | 200 KM | 22% | 34% |
| | 300 KM | 26% | 29% |
| $\frac{\Delta T_\infty}{T_\infty}$ | | ~5% | ~4% |
| V-0.25U | 300 KM<br>17 UT | + 20 M/SEC (N)<br>(42.6°N) | +45 M/SEC (N)<br>(42.6-35°N) |
| | E-FIELD | | < 1MV/M<br>EASTWARD 15-17 UT<br>SOUTHWARD 16-18 UT |

Figure 17.

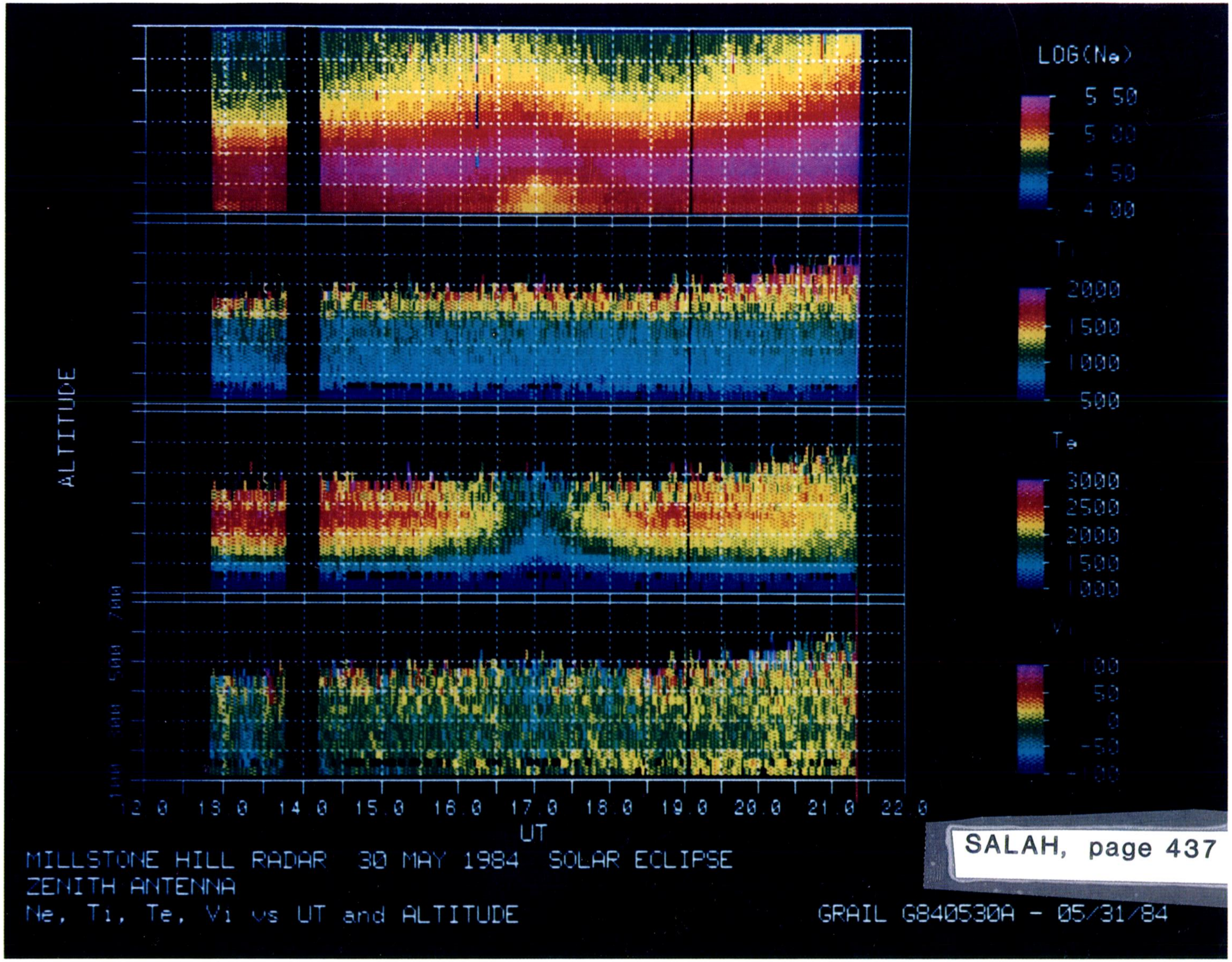

LOG(Ne)
5.50
5.00
4.50
4.00
Ti
2000
1500
1000
500
Te
3000
2500
2000
1500
1000
ALTITUDE
12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0
UT
MILLSTONE HILL RADAR 30 MAY 1984 SOLAR ECLIPSE
ZENITH ANTENNA
Ne, Ti, Te, Vi vs UT and ALTITUDE
GRAIL G840530A - 05/31/84
SALAH, page 437

Figure 18.

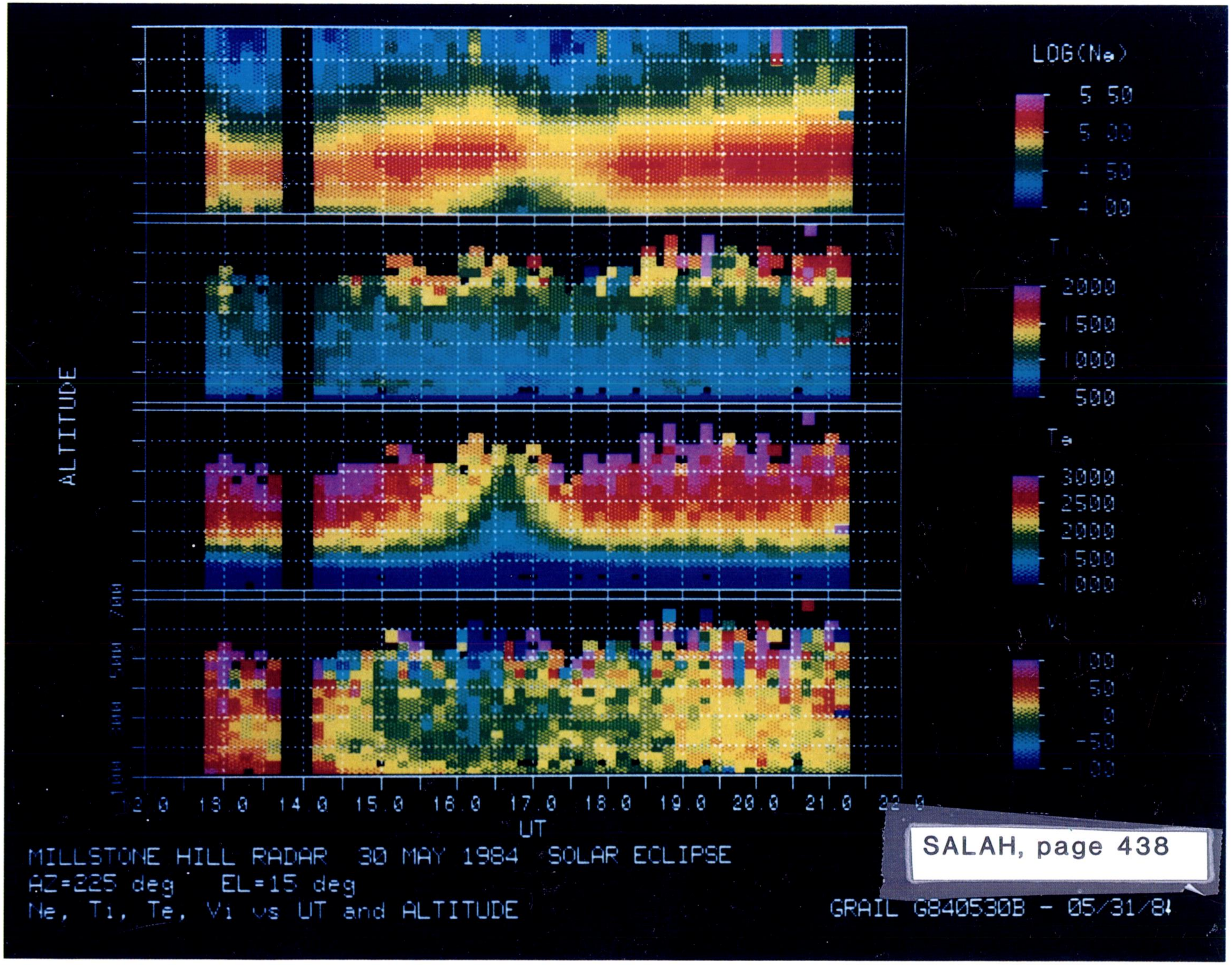

LOG(Ne)
5.50
5.00
4.50
4.00
2000
1500
1000
500
Te
3000
2500
2000
1500
1000
50
0
-50
ALTITUDE
12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0
UT
MILLSTONE HILL RADAR 30 MAY 1984 SOLAR ECLIPSE
AZ=225 deg EL=15 deg
Ne, Ti, Te, Vi vs UT and ALTITUDE
GRAIL G840530B - 05/31/84
SALAH, page 438

Figure 19.