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Mills tone Hill Thomson Scatter Results for 1974

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ABSTRACT

During 1973, the vertically-directed incoherent scatter radar at Millstone Hill (42.6°N, 71.5°W) was employed to measure electron density, electron and ion temperature and vertical ion velocity in the F-region over periods of 24 hours one or two times per month. The observations spanned the height interval 200-900 km approximately, and achieved a time resolution of about 30 minutes. This report presents the results of the measurements made using single long pulses in a set of contour diagrams. The behavior observed during these observations is discussed briefly in terms of the diurnal, seasonal, sunspot cycle, and magnetic disturbance variations reported previously and which now are believed to be largely understood.

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MILLSTONE HILL THOMSON SCATTER RESULTS FOR 1974

I. INTRODUCTION.

Since 1963, incoherent (Thomson) scatter radar measurements of F-region electron densities, and electron and ion temperatures have been conducted at Millstone Hill, Westford, Massachusetts (42.6°N, 71.5°W) (Refs. 1 to 11). This paper is the twelfth in a series of annual reports, and presents the results gathered in this program during the calendar year 1974. The observations reported were made for periods of 24 hours, approximately once a month. The results obtained in earlier years have been published and discussed in the articles listed in Table I, and have been transmitted to the World Data Center A, Boulder, Colorado.

The results reported in this paper are of F-region electron density N_e, electron and ion temperature T_e, T_i, and vertical velocity V_z and span the altitude interval 200-900 km, approximately. The measurements were made by transmitting single long pulses on each sweep of the radar time base and integrating the returns in a digital computer. Spectral information (from which T_e and T_i are determined) was obtained by examining the outputs from a bank of filters matched to the length of the pulse (0.5 or 1.0 msec)[21]. Additional measurements were made of the E- and F-regions by transmitting pairs of pulses, whose spacing could be varied allowing the echo autocorrelation function to be determined in the computer. This approach also allowed for the digital subtraction of unwanted returns from distant hills[22], and has been described in detail elsewhere[23]. Results gathered for E-region ion temperature using this pulse-pair method in 1974 have been employed in the study of tides in the lower thermosphere and reported in a number of papers (e.g., Ref. 24).

Other observations conducted in 1974 that are not reported here include short observing periods chosen to coincide with the overhead pass of the (Atmospheric Explorer) satellite or with the launch of a rocket from Wallops Island.

TABLE I

PUBLICATIONS CONCERNING THE MILLSTONE HILL UHF (68-cm Wavelength) THOMSON SCATTER RESULTS

Year	Months Covered	Publication
1963	February 1963 to January 1964 March, July, August, September April, July, November	Ref. 1 Ref. 12 Ref. 13
1964	January through December April, July, November	Ref. 2 Ref. 14
1965	January through December January, April, August June June, August, September	Ref. 3 Ref. 15 Ref. 16 Ref. 17
1966	January through December January, March, July, September	Ref. 4 Ref. 18
1967	January through December February, June, October, December	Ref. 5 Ref. 18
1968	January through December October	Ref. 6 Ref. 19
1969	January through December February, April, July September, October	Ref. 7 Ref. 20
1970	January through December	Ref. 8
1971	January through December	Ref. 9
1972	January through December	Ref. 10
1973	January through December	Ref. 11

Section II describes the equipment, data gathering and reduction procedures. During 1974, these were changed little from those employed the previous year and described in Ref. 9. Results for electron density, electron and ion temperature and vertical velocity are presented and discussed in Section III.

II. EQUIPMENT, OBSERVING AND DATA-ANALYSIS PROCEDURES.

A. Equipment.

The UHF (68 cm wavelength) incoherent scatter radar equipment has been described[1]. This system employs a fixed vertically-directed 220-foot diameter antenna and hence can measure only the vertical component of the ion drift. Extensive modifications to the data-taking procedures were made in 1968 (Ref. 6) which allowed the echo power spectra to be measured for many heights simultaneously. This scheme made use of banks of matched filters for each of the pulse lengths (0.5, 1.0 or 2.0 msec) employed, and has been described in detail in Ref. 21. Owing to an imperfect match between the filters and the spectra of the pulses (especially for the 0.5 msec pulses), some systemmatic errors were introduced in the measurements of T_e and T_i over some altitudes and empirical correction procedures were developed in an effort to remedy these[7,9]. In 1976, the filter bank system was replaced by a digital correlator which obviated this problem.

During 1974, some incoherent scatter observations were conducted using the smaller 84 ft. diameter steerable antenna and associated L-band (23 cm wavelength) radar. This system is described in Ref. 25. When used for incoherent scatter studies, control of the radar timing was assumed by the incoherent scatter timing unit (located in the Ionosphere Laboratory) and the 30 MHz IF output of the L-band receiver was connected to the 30 MHz IF input to the UHF receiver, so that the data taking and sampling procedure remained unchanged. (Actually, it was necessary to rearrange the elements of the filter bank to span a wider frequency range as described in Ref. 21.) These measurements were used to measure E-region winds and F-region electric fields[26] and have been reported in a number of papers [e.g., Ref. 27].

B. Observing Procedures.

During 1974, we attempted to make observations using the single long pulse method and the newer pulse pair scheme at least once per month for 24 hours. As the single long pulse observations had been undertaken for several prior years, the newer two-pulse measurements were accorded somewhat greater priority and in several months, no single pulse observations were made. Table II lists the operating modes employed for the single long pulse measurements and the altitudes over which these provided data. In normal or 'regular' operations, the cycle A, B, C was repeated every 30 minutes with 8 minutes of data being collected in each mode. Table III lists the dates and times when data were collected.

As described in Ref. 9, provision was made in 1971 to switch rapidly between the L-band and UHF radar transmitters and reload the computer with a new data-taking program which established automatically the proper condition for the interface equipment that transfers data from the radar to the computer[25]. During 1974, advantage was taken of this capability to switch rapidly between operation of the vertical and the L-band radars. Since the UHF radar measures only the vertical (V_z) component of the drift of the ions in the F-region, it is possible to recover from the measurements information only about the meridional winds in the thermosphere. To determine F-region electric fields and/or winds at E-region heights, it is necessary to measure the horizontal components of the ion drift. By employing the steerable L-band radar to measure the drift in the magnetic N-S and E-W directions, two additional components of the drift velocity could be measured. This allows for a solution for three orthogonal components. Measurements were conducted in 1974 that attempted to secure three drift components and were termed '3-D' (Table III). The L-band observations (D-mode) were conducted at 345° Az, 18° El, and 255° Az, 45° El. The sequence then was D-mode 8 mins., D-mode 8 mins., A-mode 4 mins., B-mode 4 mins., C-mode 8 mins., (Table II).

These L-band observations were undertaken primarily in an attempt to observe the E x B drift of the F-region brought about by electric fields of dynamo or magnetospheric origin. The drift component measured using the

TABLE II
THE NORMAL "ONE-PULSE" EXPERIMENT MODE SEQUENCE

Mode	Pulse Length (μsec)	Height Resolution (km)	Sample Spacing (km)	Altitude Coverage (km)	Measured Parameters	
					Direct	Deduced
A	100	15	7.5	100-1000	Power	Ne
B	500	75	30	150-1500	Power	N_e
			75	225- 675	Power spectrum	T_e, T_i, V_z
C	1000	150	30	300-2000	Power	N_e
			75	450-1125	Power spectrum	T_i, T_i, V_z
D_1	1000	60	30	105- 500	Power	–
			75	105- 425	Power spectrum	V_d
D_2	1000	110	30	215- 900	Power	–
			75	215- 780	Power spectrum	V_d

D_1 L-band observations at 18° elevation.
D_2 L-band observations at 45° elevation.
} Employed in 3-D experiments.

TABLE III
INCOHERENT SCATTER OBSERVATIONS – 1974

Begin			End			Mean Kp	Mean R_z	IMF	Obs[+]	Comment
Date	C*	EST	Date	C*	EST					
12 Feb	D	1330	14 Feb		0700	3+	35	A	3-D	
03 Apr	D	1300	04 Apr		1330	5-	21	T→ A	Reg.	Ionosonde failed at 03. Very disturbed.
16 Apr	QQ	0900	17 Apr	QQ	1030	1+	73	T	3-D	Ionosonde off 0230-0530.
13 May	QQ	1700	15 May	D	0730	3-	32	AT	3-D	TX off 05-08 on 14 May. Kp increase after 1300. No useful V_z data obtained.
10 Jun		0830	11 Jun	D	2130	4+	47	TA	Reg.	TX off 1330-2100 on 10 June. SC late in day on 10 June.
15 Jul		1700	16 Jul	Q	2300	2+	53	T	3-D	TX off 0300-0630. Poor data thereafter. Disturbed.
02 Oct		0830	03 Oct		0900	4-	50	T	Reg.	Poor data 00-04. Kp > 4+ 13-22.
26 Nov		0930	27 Nov		0900	3-	24	T	Reg.	
19 Dec	D	1630	20 Dec	D	1700	4-	41	T	Reg.	Disturbed.
26 Dec	Q	1700	27 Dec	D	1700	3+	8	T→ A	Reg.	Kp > 4+ 01-07.

* Condition

- QQ One of the five quietest days in the month.
- Q One of the ten quietest days in the month.
- D One of the five most disturbed days in the month.

\+ Observations

- Reg = Regular.
- 3-D = L-band and UHF radar measurements.

fixed 220-ft. diameter UHF antenna is at an elevation of 88° and in these reports has been labeled the 'vertical' drift (V_z). This component lies within 16° of the direction of the drift velocity along the magnetic field ($V_{||}$) and has been used in many analyses to compute the meridional horizontal wind speed at F-region altitudes (see, for example, Refs. 9, 11, 28-31). This interpretation neglects possible contributions to V_z brought about by E-W electric fields which cause drifts normal to the magnetic field (i.e., E x B drifts) in the N-S plane. At times of magnetic disturbance, these could be quite significant, especially at night. The L-band observations undertaken in the magnetic meridian plane (Az = 345°) at an elevation angle of 18° were intended to measure this E x B component, but suffered because the F-region appeared at a considerable range and the signal-to-noise ratio was poor. To compensate for this, at night the elevation was sometimes increased to 45°, but, as a rule, few good measurements were ever secured owing to the greatly inferior sensitivity of the L-band radar and the low electron densities then prevailing*. The E-W component of the horizontal drift was sampled by making observations at 45° elevation at 255° azimuth.

C. Data Reduction.

As described previously[21], no attempt was made to analyse the data in real time (i.e., as it is gathered) as this would be too time consuming. Instead, the samples of echo power collected as functions of range and frequency were stored on magnetic tape at the end of each integration period along with other pertinent information such as the mode type, start time and duration of the run. A profile of echo power vs. height (i.e., corrected for the R^{-2} dependence where R is the range) was computed and printed out by a high speed printer. Together with a printout of the signal-to-noise ratio at each point within each frequency spectrum, this allowed the quality of the data to be monitored while it was being gathered.

*Good estimates of horizontal drifts in the ionosphere at all times of day became possible with the installation of a fully-steerable 150-ft. antenna, for use with the UHF radar, in 1978.

The first step in analysing the data has been to construct a plot of the F-region critical frequency f_oF2 vs. time for the days of observation. For this, the values were scaled from the Millstone ionograms. Also included in the plots were values obtained at Ottawa (45°N) and Wallops Island (38°N), which are the two stations in routine operation closest to Millstone. Including values from these stations usually revealed any errors in scaling the local ionograms, and served to guide the interpolation that was necessary if any half-hourly values from Millstone were missing for any reason. Examples of these plots have been included in a number of previous reports[4,5].

Values for f_oF2 were scaled from the smooth curves drawn through the points on the plots at half-hour intervals and entered into the computer via punched cards. These were stored and used to obtain the value of f_oF2 at the mid-point of each A-mode run by linear interpolation*. The program combined measurements of echo power made with the all A-, B- and C-mode runs in each cycle of observation into a single "power profile". This was converted to an absolute profile of electron density vs. altitude by allowing for the effects on the backscatter power of altitude variations in the ratio T_e/T_i and normalising the resultant curve to have the correct value of electron density (N_{max})† at the peak of the layer.

Values for electron and ion temperature were recovered from the spectra assuming that O^+ was the only ion present. This assumption is a good one except at night near sunspot minimum when sufficient H^+ ions may be present at altitudes below 900 km to render the temperature estimates unreliable. More accurate values could have been obtained using a program due to J. L. Massa (private communication, 1976) which attempts to recover T_e, T_i and the H^+/N_e ratio at each altitude. Unfortunately this program consumed a considerable amount of computer time and hence was not run routinely. Results from such analyses have been presented previously[10,11,32].

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*Actually, the time chosen = start time + 4 minutes.
†$N_{max} = 1.24 \times 10^4 (f_oF_2)^2$ el/cm^3 when f_oF2 is expressed in MHz.

It has been found[21] that estimates of T_e/T_i obtained from the B- and C-mode data tend to differ at night in summer when $T_e/T_i \rightarrow 1.0$. This leads to differences in the etimates for T_i. It is believed that the discrepancy stems from the large amount of smearing of the frequency spectra of the signals introduced using 0.5 msec pulses (B-mode) particularly at night when the spectra are narrow. In principle, attempts are made to compensate for the smearing during the data analysis[21], but the measurement accuracy must suffer at such times. Since it also was evident that the filters employed in the receiver spectrum analyser in the B-mode were less perfectly matched to the transmitter pulse than those in the C-mode, it was believed that the systemmatic errors are primarily in the B-mode estimates. Assuming that C-mode was correct, J. E. Salah derived an empirical correction scheme by comparing the data in the two modes gathered at 525 km nominal height on four days[7], and this was employed to correct the B-mode temperatures gathered in 1969 and 1970[7,8]. Subsequently, B. A. Emery performed a more detailed comparison employing several heights, (to allow for differences in the effective center height of the pulse for the two modes) using two years' data[9]. Emery found that the corrections to be applied to the T_i and T_e/T_i values obtained in the B-mode depend not only on the prevailing value of T_e/T_i (taken to be that observed in the C-mode) but to a lesser extent also on T_i (again assumed to be the C-mode value). A smooth continuous correction scheme was derived from this comparison and employed to correct the results reported for 1971[9] and subsequently (including those presented here). Finally, the values for electron temperature were corrected for the effect of the changing Debye length with altitude[8].

Beginning in 1976, the analog filter bank spectrum analyser was replaced by a digital correlator that is believed to be less likely to introduce systemmatic error. The data gathered with this device cannot be analysed with the ANALYSIS program and a new program (INSCAL) has been written which attempts to recover N_e, T_e, T_i as functions of height, allowing for the influence on the N_e profile of height variations of T_e/T_i and on the T_e profile of variations in N_e (via the Debye length correction), in a truly self-consistent fashion. That employed in ANALYSIS[21] represents only a first-order correction, but in view of the possible bias errors in the B-mode results at some times, a more elaborate approach seemed unwarranted.

The next part of the analysis involved smoothing the electron density, electron and ion temperature and vertical velocity estimates as functions of height and time. This operation was performed by fitting, in a least-mean-squares sense, a *two-dimensional polynomial surface* that best represents the data. The program that performs this is known as INSCON, and has been described in Ref. 8. The INSCON program could compensate for distortion in the profiles of T_e and T_i vs. altitude introduced by the fact that the effective center height for the pulse is not given simply by the time at which the echoes are sampled (i.e., the so-called "nominal" height), but is shifted owing to the variation of echo power with delay within the pulse. This effect automatically was taken into account in constructing the electron density profiles, but was not included routinely for the plots of T_e, T_i prior to 1970.

A subroutine of the INSCON program produced a plotting tape to drive a Calcomp plotter which was used to obtain contour diagrams of N_e, T_e, T_i and V_z. These are given in the next section. In addition, INSCON provided the coefficients of the polynomial fit from which the variation of any parameter as a function of height or time (within the period fitted) can be recovered. The sets of coefficients for each day were combined on a single tape which has been transmitted to the World Data Center (in Boulder). These, together with a simple FORTRAN *recovery program* (RCVR) allow numerical values to be obtained in machine-readable form by other users[8].

III. RESULTS FOR ELECTRON DENSITY, ELECTRON AND ION TEMPERATURES AND VERTICAL VELOCITY.

A. General.

Computer-drawn *contour plots* of N_e, T_e, T_i and V_z as functions of altitude and time have been generated in the manner outlined above (and described in detail in Ref. 8); these are presented for the days listed in Table III in Figures 1 through 10. Contours of N_e are labeled in units of $\log_{10} N_e$ (el/cm^3) and are drawn in steps of $\log_{10} N_e = 0.2$ wherever $\log_{10} N_e > 3.0$. Regions well above h_{max} F2 sometimes are encountered where, owing to experimental error, the density appears to be increasing with altitude. These usually have been edited from the plots, but in any case are not considered real. The accuracy of these plots is greatest in the vicinity of h_{max} F2 (shown as a broken line) where the experimental uncertainty is set chiefly by the uncertainty in determining f_oF2 (typically ±0.2 MHz). At higher altitudes, however, the uncertainty in the incoherent scatter measurements contributes to the overall uncertainty – especially at night when the echoes are weakest.

It is believed that the 30 minute time resolution provided by the 'regular' measurement scheme allows the normal diurnal variations to be followed adequately, but fluctuations caused, for example, by Traveling Ionospheric Disturbances (TIDs) with periods of less than about 2 hours, are effectively smoothed out.

The results for the electron and ion temperatures are presented as isotherms at 200°K and 100°K, respectively. The contours of vertical velocity V_z are plotted at intervals of 5 m/sec and have been corrected for the frequency 'chirp' introduced by the transmitter[7]. Since the beam is directed at an elevation of 88° due south, the drift component of the plasma that is measured is not precisely vertical, but for most purposes the distinction is unimportant.

The year 1974 was close to the sunspot mimimum of cycle 21 which occurred early in 1975. Zurich daily sunspot numbers R_z averaged over the days of observation are included in Table III and confirm this trend. The low value of the sunspot number is reflected in the low values of f_oF2 prevailing throughout 1974, which were typically in the range 5-7 MHz by day and ∿ 3 MHz by night. On some nights f_oF2 reached as low as 2 MHz, probably because Millstone then lay at the equatorward side of the midlatitude trough. At such times, the signal-to-noise ratio became very poor and useful results could be secured only for altitudes close to the peak of the F-layer.

Despite the decline in sunspot activity, the incidence of magnetically disturbed periods in our data set remained quite high as can be seen from the mean values of the Kp index listed in Table III. Indeed, only the data for 16-17 April was gathered on very quiet days (i.e., among the five quietest in the month) and that for 15-16 July fell on days which ranked as the ten quietest in the month.

In two cases, 3-4 April (Figure 2) and 26-27 December (Figure 10), the magnetic disturbance appears to be associated with a sector boundary crossing in the interplanetary magnetic field (IMF in Table III). The disturbance on 10-11 June appears to have followed a storm sudden commencement that occurred during the early afternoon, but was missed as a consequence of transmitter problems (Table III). In the other cases, the disturbed behavior appears to have resulted from fluctuations in the IMF which gave rise to periods of southward B_z. On 13-15 May, it was quiet for the first 20 hours (i.e., until 13 hours on 14 May) and then very disturbed for the balance of the time (18 hours). In this and a few other cases, the mean Kp value ceases to be a reliable indication of conditions.

B. Winter Behavior.

The months of January, February, November and December together with parts of March and October usually exhibit a characteristic winter variation. In winter, the peak electron density exhibits a very large diurnal variation (10:1 near sunspot maximum) which diminishes as sunspot minimum is approached. The winter daytime values of N_{max} also exceed the summer daytime values, but this seasonal variation also decreases towards sunspot minimum.

The electron temperature exhibits a marked increase at sunrise and decrease at sunset. Following sunset, the temperature rises again (as the layer decays) because heat continues to be supplied via conduction from the plasma flux tube. This continues to be warmed by the escape of photo electrons from the conjugate point (which remains sunlit).

At night the density usually remains constant until a little before sunrise or may actually increase after midnight, reaching a peak near 03-04 hours. The maintenance of the winter night ionosphere has generally been attributed to the southward turning of the neutral thermospheric wind which serves to lift the layer to altitudes where the recombination rate is much reduced. We have elsewhere[11] argued that the increase is brought about by a downward flux of H^+ from the protonosphere which charge exchanges with O to produce O^+ via

$$H^+ + O \rightleftharpoons H + O^+ \tag{1}$$

The timing of the event can be explained as a consequence of the diurnal variation in the exospheric temperature. This reaches its diurnal minimum at about 0300 LT with the result that the abundance of O at altitudes ($300 < h < 1{,}000$ km) where charge-exchange is important is also at a mimimum. Conversely, the H abundance then maximizes. Both effects drive the chemical equilibrium balance to shift in a direction that requires reaction (1) to proceed to the right.

Marked nocturnal increases were seen on four of the five winter nights for which we have observations in 1974 (Figures 1a, 8a, 9a, 10a). It appears possible that the winter nocturnal behavior also is influenced by substorm activity as convection electric fields then appear capable of penetrating the plasamsphere to the latitude of Millstone[33-35]. It is anticipated that prior to midnight the layer would be lifted by an eastward magnetic field while after midnight, the layer would be lowered by a westward field. A further complication is the existence on disturbed nights of strong equatorwards winds (the so-called 'midnight surge') produced by auroral heating which also serve to lift the layer[11, 36-39]. Together with the fact that on very disturbed nights, the trough may move to the latitude of Millstone, it is clear that the 'normal' behavior can be greatly modified by magnetic disturbances. Of the five nights in our set, the only one that does not exhibit a clear increase is 13-14 February (Figure 1a) when Kp had a value of 2+ between 01 and 04 EST. The previous night did exhibit an increase and Kp was then higher (3+) and the two other nights which exhibit increases also were more disturbed. However, the night of 26-27 November exhibits an increase when Kp was only 2+, so it is difficult to draw any conclusions. The night of 19-20 December seems to have been anomalous as the nocturnal increase occurred much earlier than normal and this may be related to the level of magnetic activity (Kp reached 5- between 01 and 04 EST).

On three of the winter nights (Figures 8a, 9a, 10a), the contouring program had insufficient data to properly handle the region above 400 km for N_e, T_e and T_i, but has produced contours for V_2. However, it seems unlikely that this data can be very reliable. Judging from previous studies, it appears that nocturnal increases are associated with negative (i.e., downward) drifts at altitudes well above h_{max} F2 as would be anticipated.

C. Summer Behavior.

May, June, July, August, September, together with portions of April and October appear to exhibit a characteristic 'summer' behavior. This is exemplified by Figures 3-6. Typically, the electron density rises in the morning to a pre-noon peak. There is then a decrease and a pre-sunset increase. This behavior is thought to be caused by the thermospheric neutral wind which near midday is poleward and drives the layer downward into regions of increased recombination rate. In the afternoon, the meridional component of the wind reverses, lifting the layer and producing the sunset increase. The electron temperature rises rapidly at sunrise and decreases somewhat less rapidly, beginning in midafternoon when N_e starts to increase.

On disturbed days, the evening increase can be greatly enhanced by convection electric fields which penetrate to the latitude of Millstone and aid in lifting the layer. The second day of the storm the density usually is quite depressed. This anomalously large evening increase was observed on 14 May (Figure 4a) and 12 June (Figure 5a) when N_{max} F2 increased by almost a factor of three and h_{max} 2 was lifted by as much as one scale height (60 km). A more normal evening increase in N_{max} is of the order of 50%, and the layer may be lifted by less than half one scale height, as is evident from the quiet day results of 16-17 April (Figure 3a).

Following an anomalous evening increase, the nighttime density often falls to a very low value as the trough moves into position over Millstone. The F-layer critical frequency may then drop to less than 2 MHz and become quite difficult to measure. This appears to have occurred during the night of 14-15 May (Figure 4a) and the electron temperature became quite large (Figure 4b).

One of the days of observation clearly shows the depressed density behavior characteristic of the second day of the storm. This is 3-4 April (Figure 2a), but this is better classified as an equinoctial day.

D. Equinox Behavior.

There is a period of a few weeks around March/April and September/October each year that follows neither the winter nor the summer behavior described above (and in many earlier reports). On these days, the diurnal variation is more regular, exhibiting neither evening nor post-midnight increases in electron density. We do not have good samples of this behavior in the current data set. The results for 2-3 October (Figure 7), while they appear to conform to this pattern, are marred by the absence of data from midnight to 4 a.m. Those for 3-4 April exhibit the depressed density state that typically occurs in summer on the second day of a magnetic storm.

IV. CONCLUDING REMARKS.

The vertical-incidence, incoherent-scatter studies described in this and previous reports[1-20] were undertaken to examine the F-region of the ionosphere at midlatitudes and the physical causes for the high degree of variability in its behavior from day to day, season to season and with sunspot number. The first systematic series of measurements was conducted in 1963 using the then newly-completed 220-ft. vertically-pointing antenna[1,12,13] near the start of sunspot cycle 21. The measurements reported here for 1974 were gathered at the end of that cycle.

We believe we have collected good examples of most types of behavior seen at our location in North America; further that the concomitant increase in our understanding resulting from satellite observations, theoretical studies as well as our own measurements provides a basis for explaining (at least in general terms) most, if not all, of these variations. In particular, during this decade, the very important role that neutral winds play in controlling the F-layer became clear. It is now recognized that these winds are responsible for modifying the height (and hence the peak density of the layer) as well as redistributing the principal neutral constituent (atomic oxygen) from which it is formed.

Disturbed behavior, to a large degree, is thus associated with anomalous thermospheric winds brought about by heating at high-latitudes caused by the auroral electrojet and energetic particle precipitation. A consequence of this recognition has been the effort to improve the capabilities of Millstone by adding a large steerable antenna to the UHF radar; this was accomplished during 1977. Since 1978, our incoherent radar scatter studies have exploited the scanning capability of this antenna to study the auroral region to the north of Millstone. For the future, the thrust will be increasingly toward observations co-ordinated with other radars and satellites in an effort to gain a global picture of the dynamical behavior of the thermosphere in place of independent localised observations that have characterized much of the effort heretofore.

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TR-608 (1a)

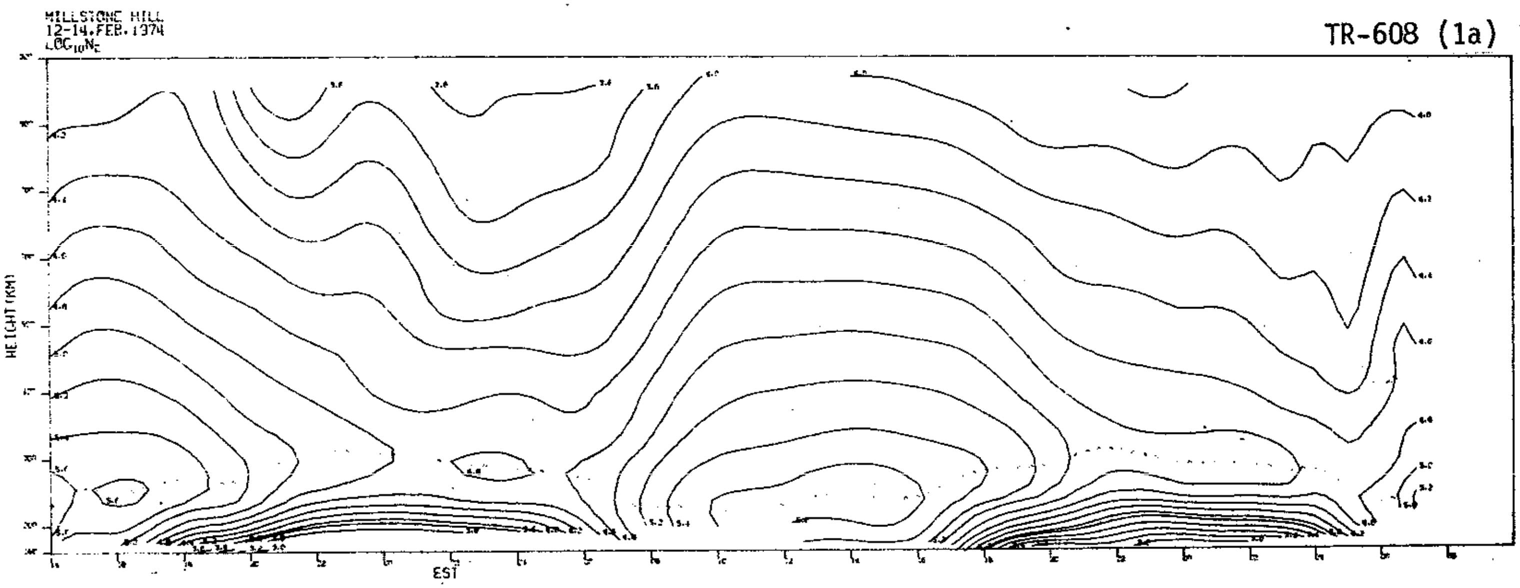


Figure 1a. Contours of $\text{Log}_{10}\ N_e$ vs. height and time for 12-14 February 1974.

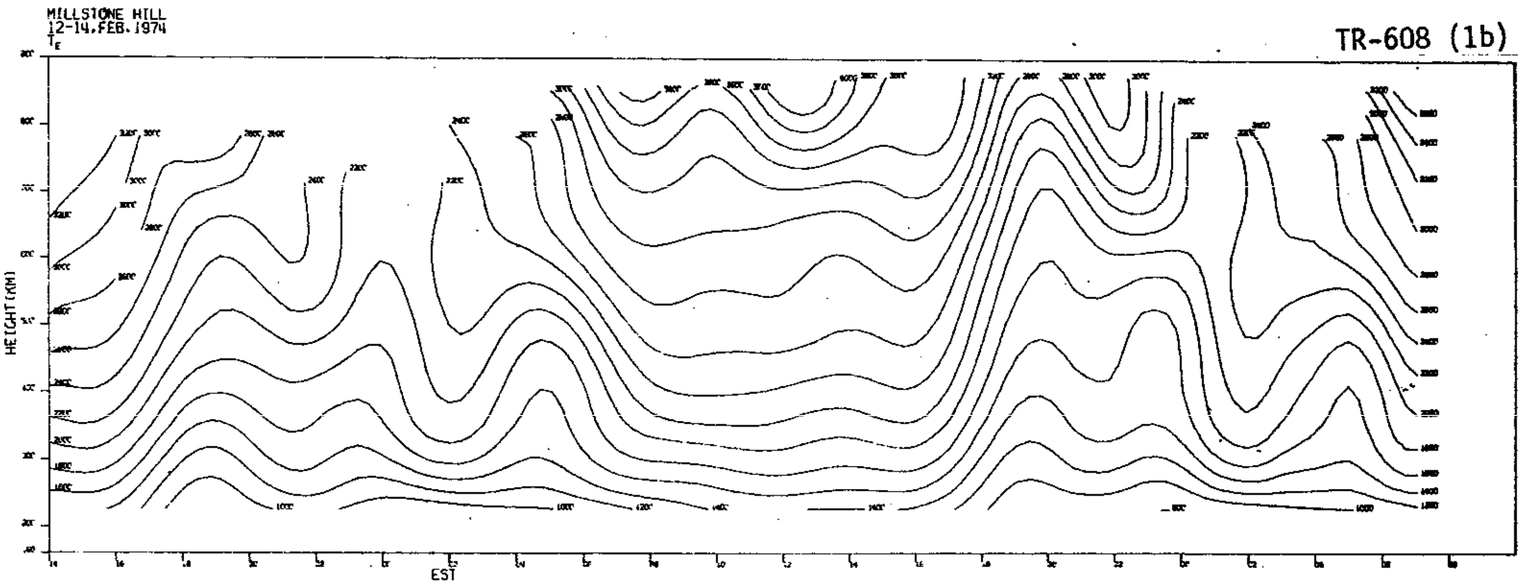


Figure 1b. Contours of electron temperature T_e vs. height and time for 12-14 February 1974.

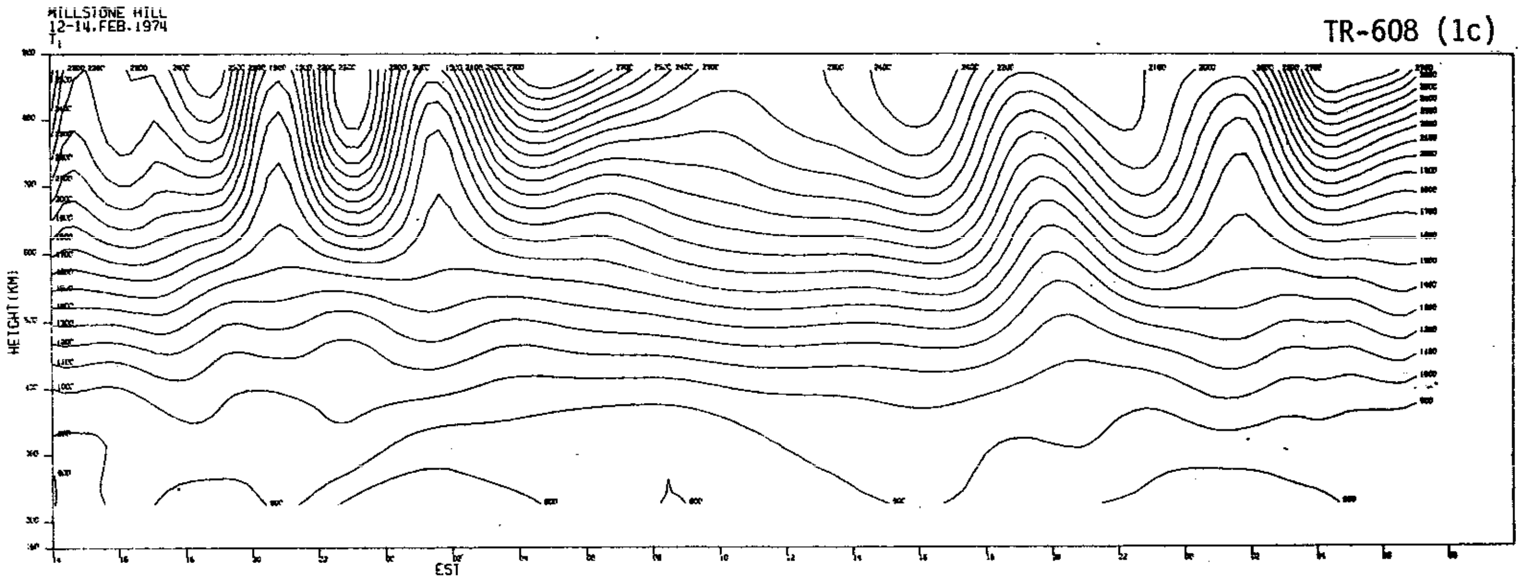


Figure 1c. Contours of ion temperature T_i vs. height and time for 12-14 February 1974.

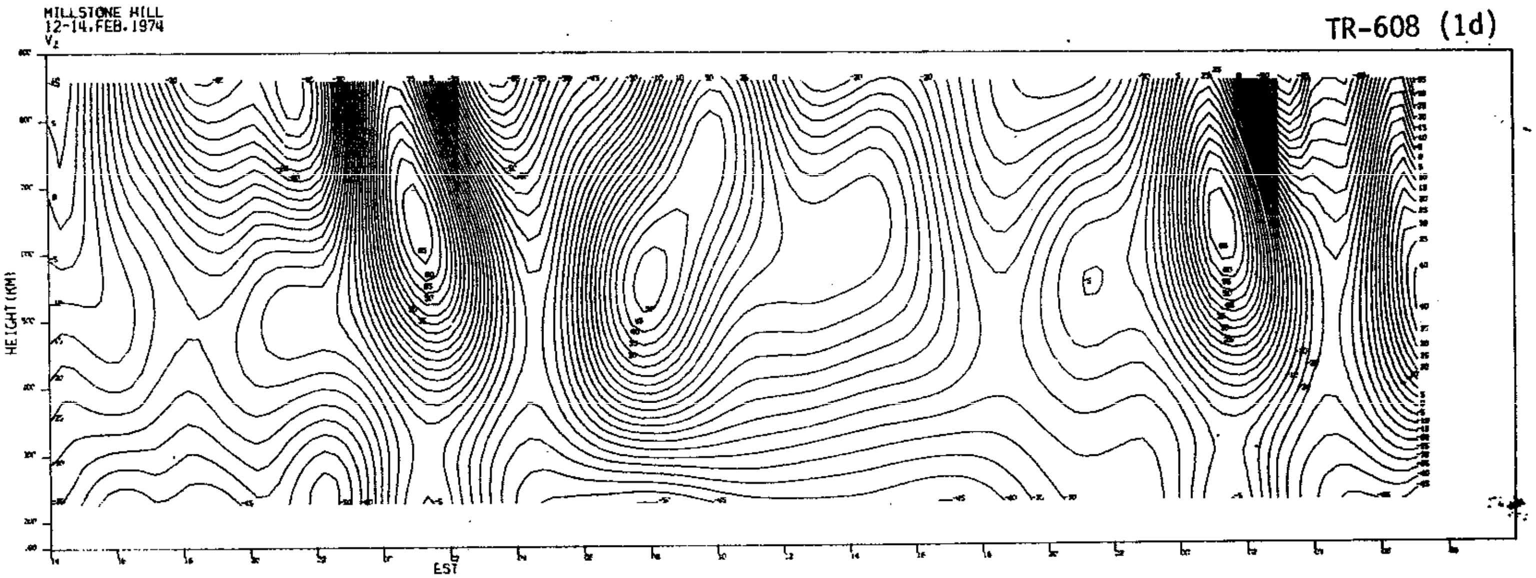


Figure 1d. Contours of vertical velocity V_z vs. height and time for 12-14 February 1974.

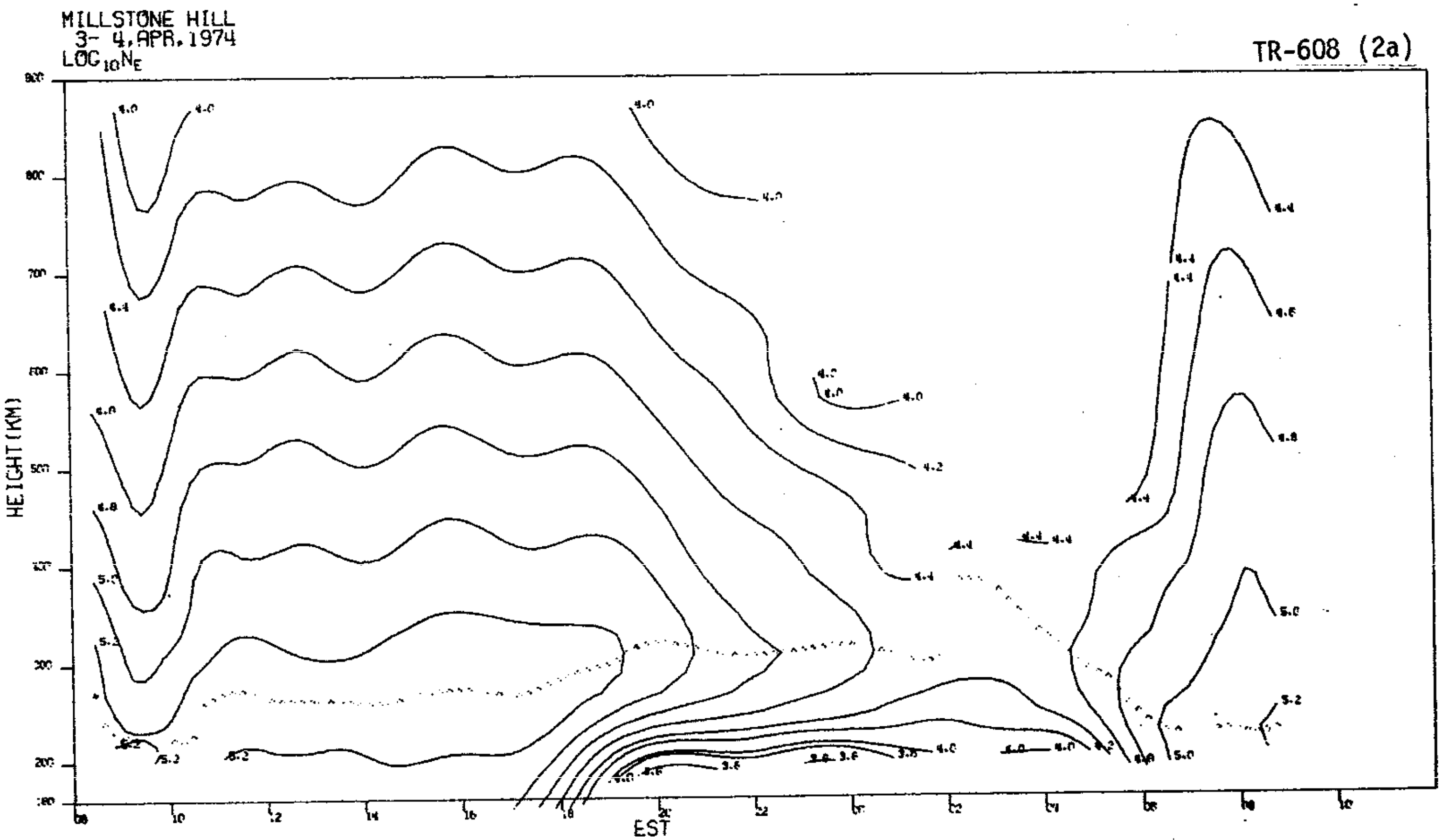
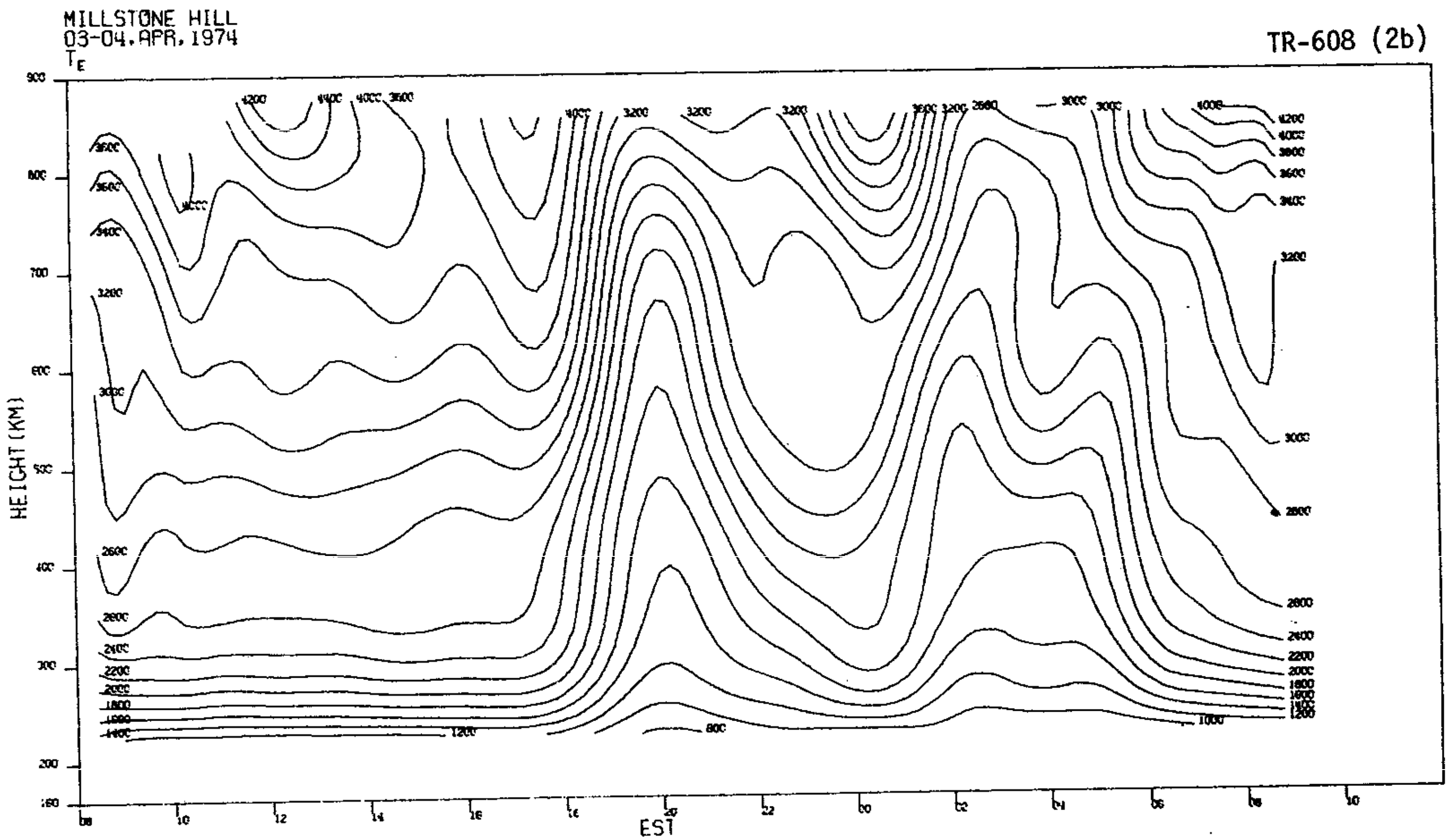


Figure 2a. Contours of $\mathrm{Log}_{10}\ N_e$ vs. height and time for 3-4 April 1974.



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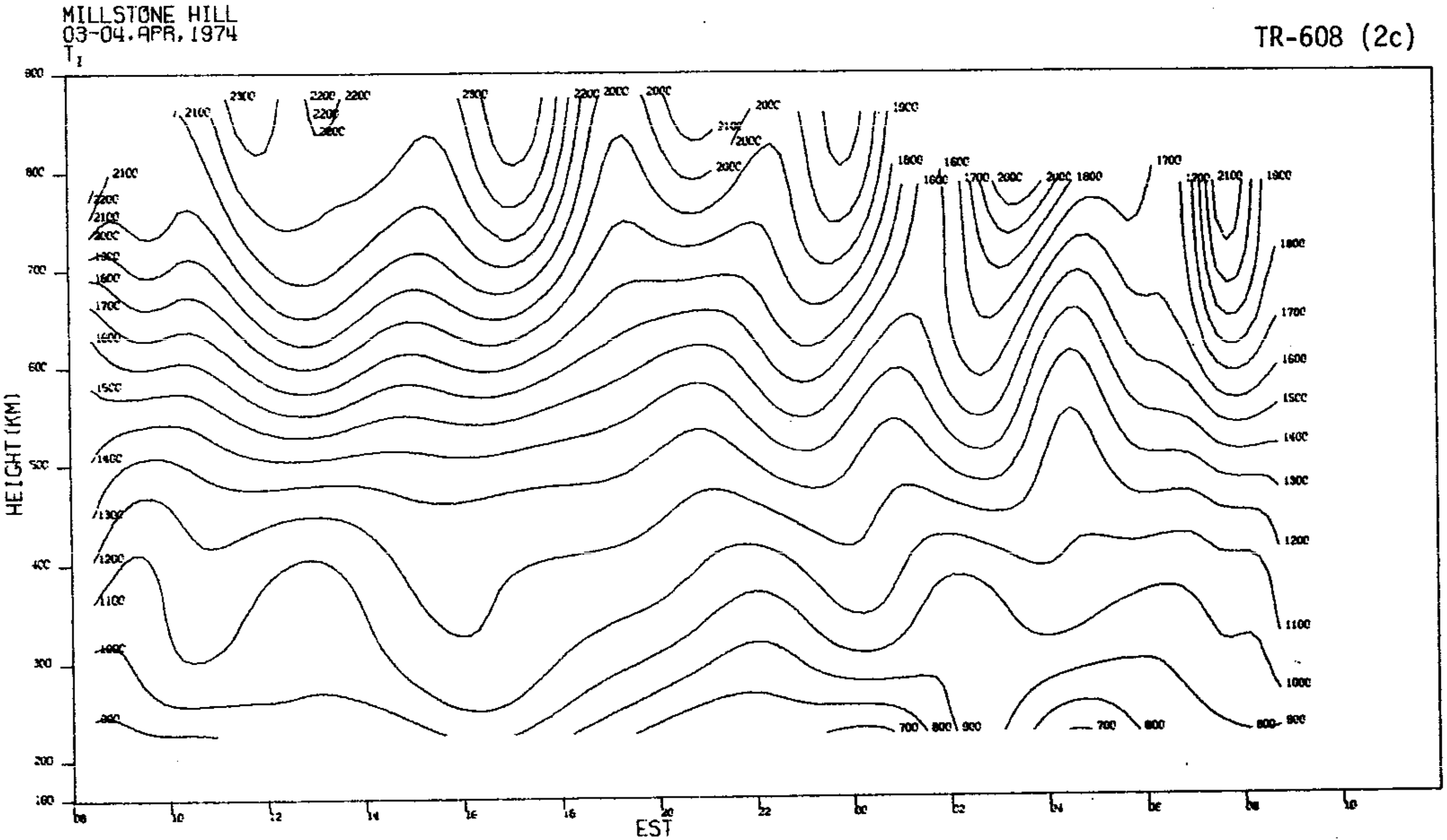
TR-608 (2c)



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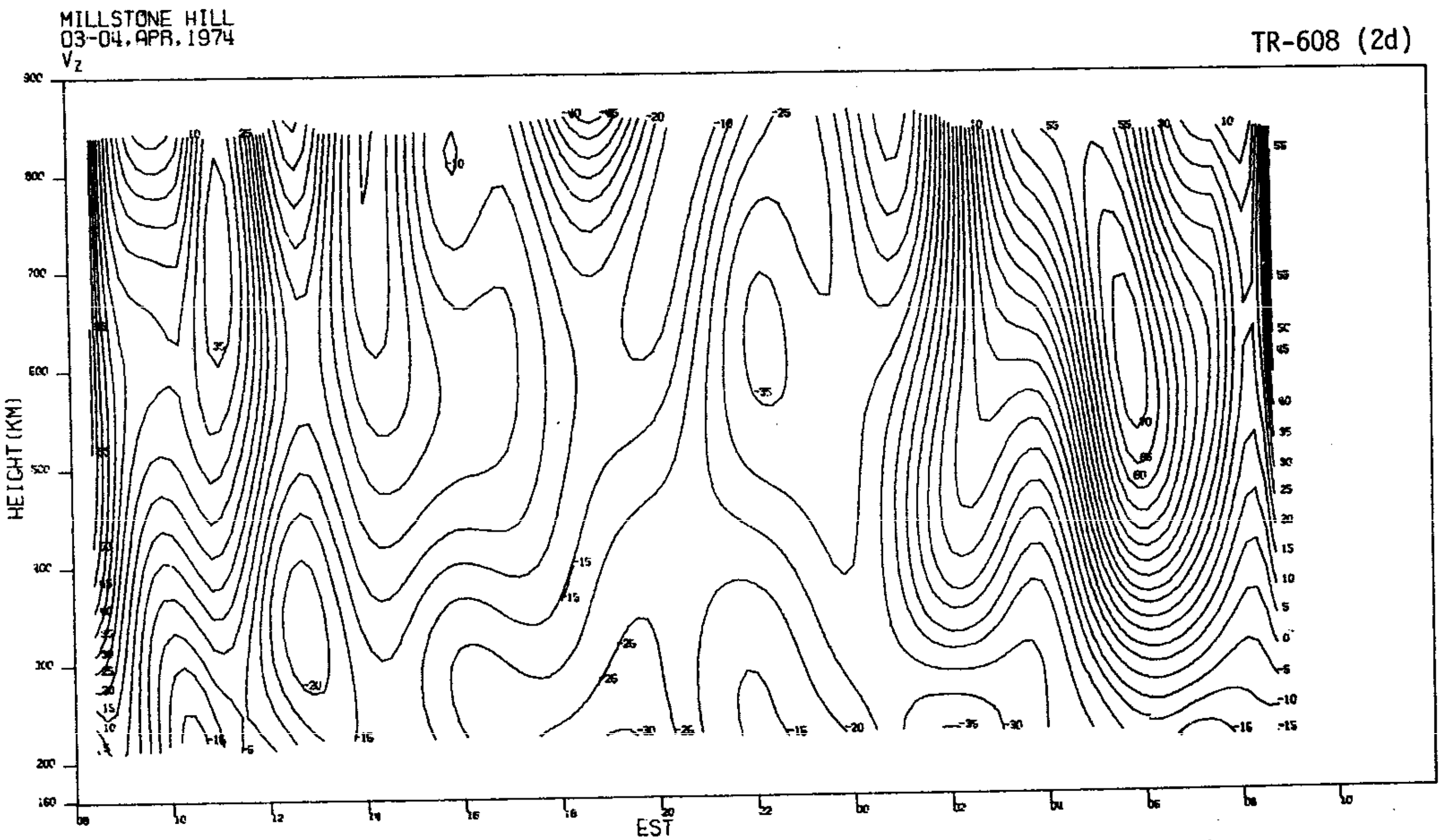

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TR-608 (3a)

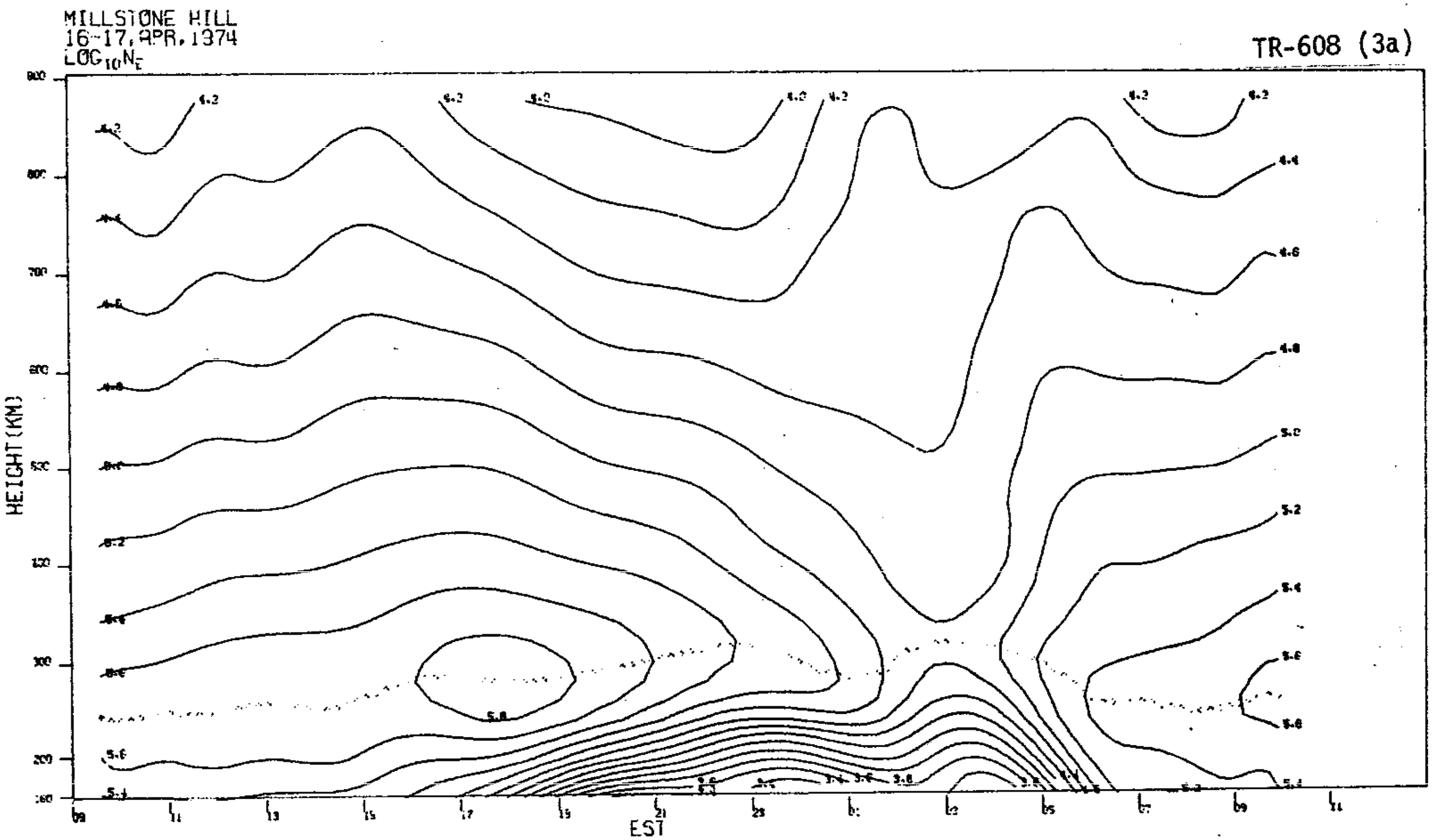


Figure 3a. Contours of $Log_{10} N_e$ vs. height and time for 16-17 April 1974.

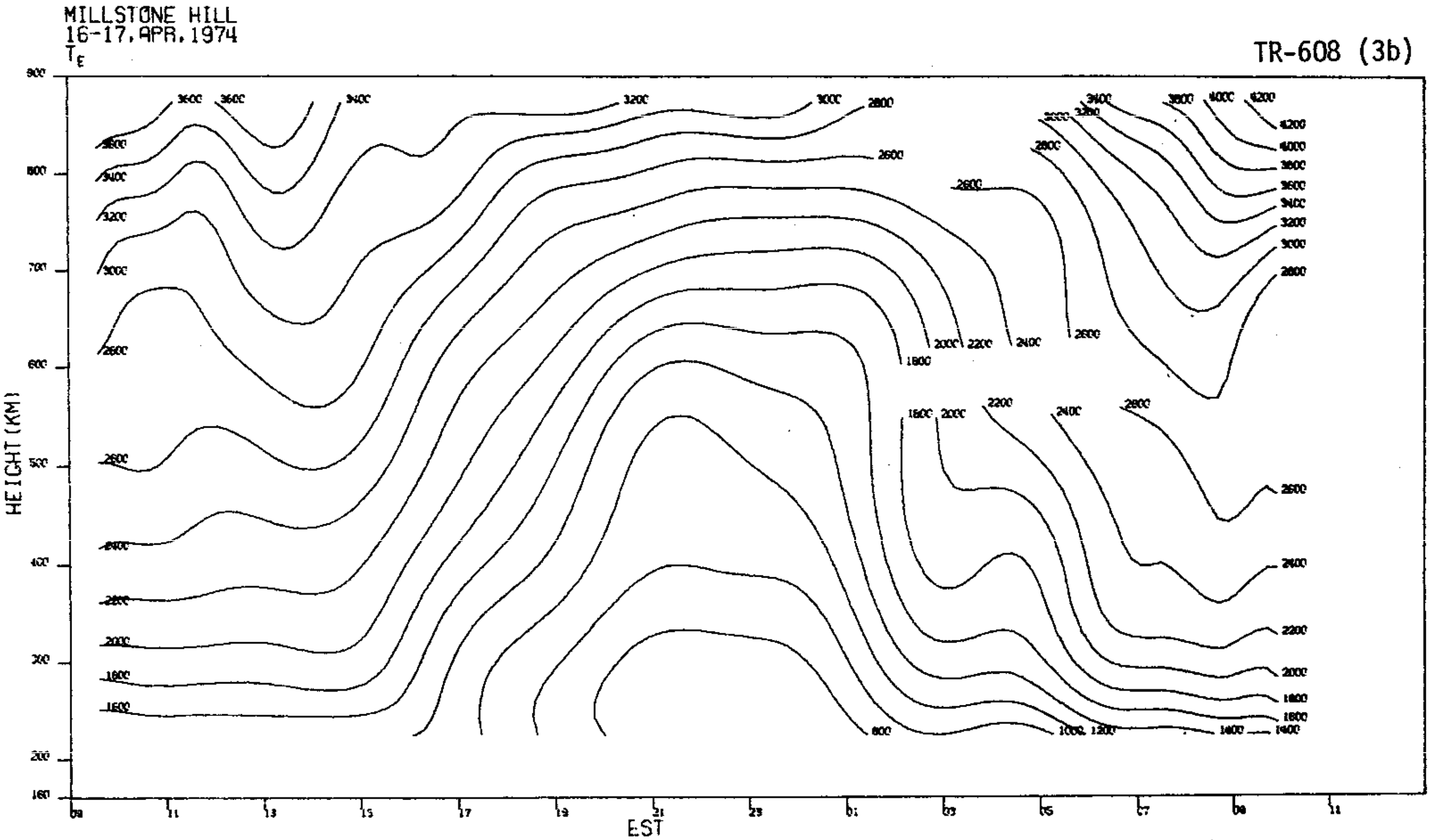
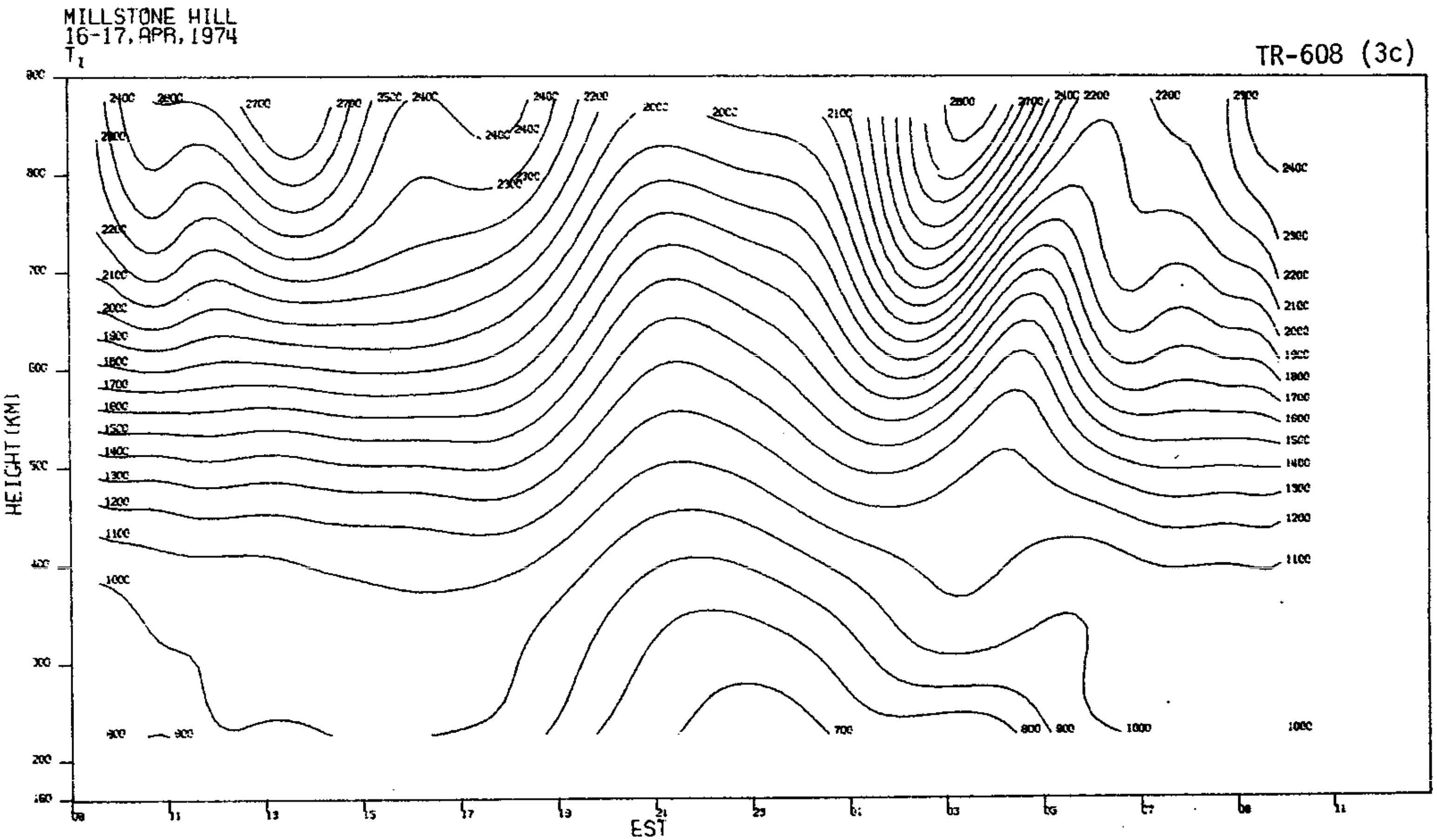


Figure 3b. Contours of electron temperature T_e vs. height and time for 16-17 April 1974.



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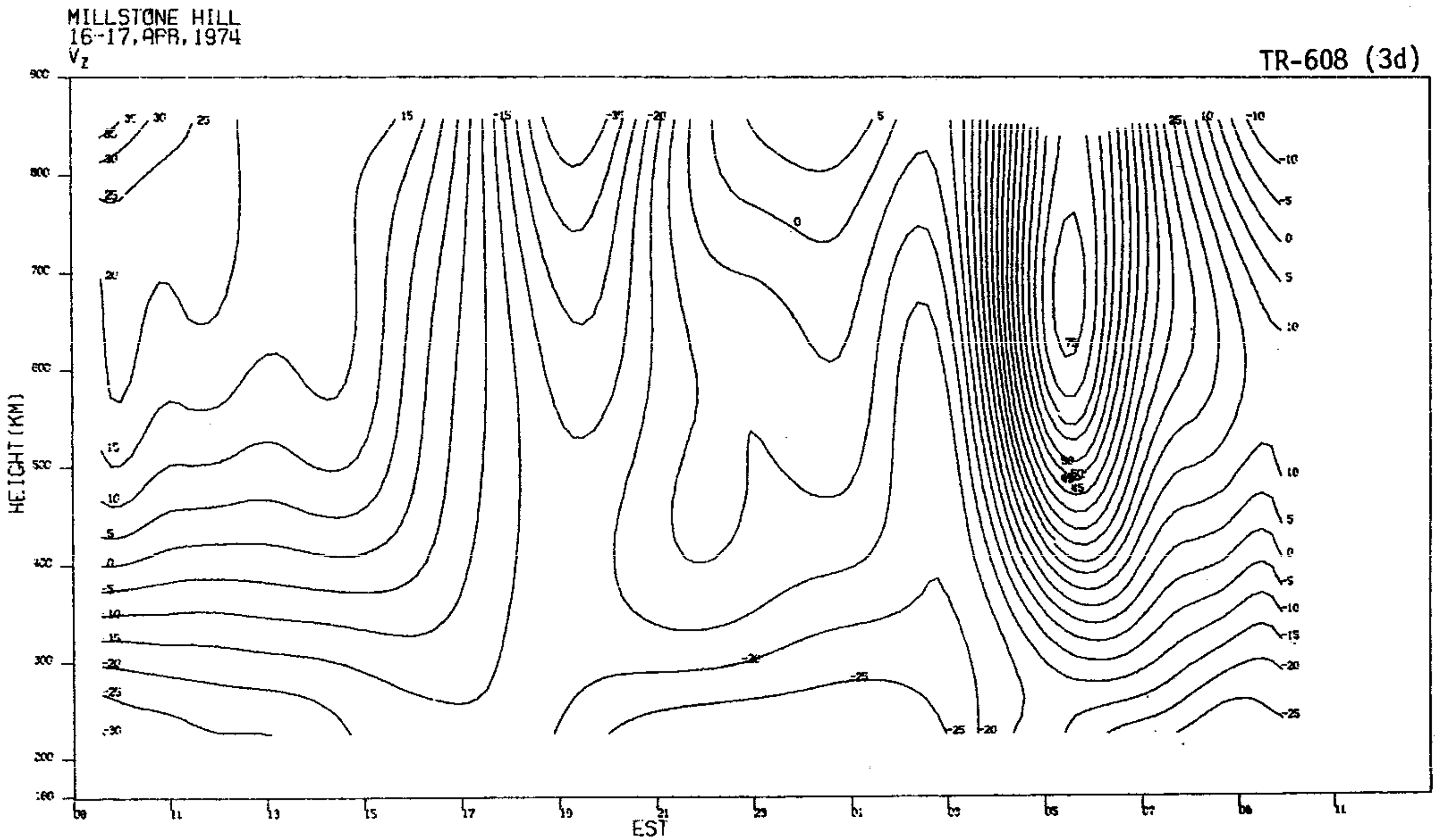


Figure 3d. Contours of vertical velocity V_z vs. height and time for 16-17 April 1974.

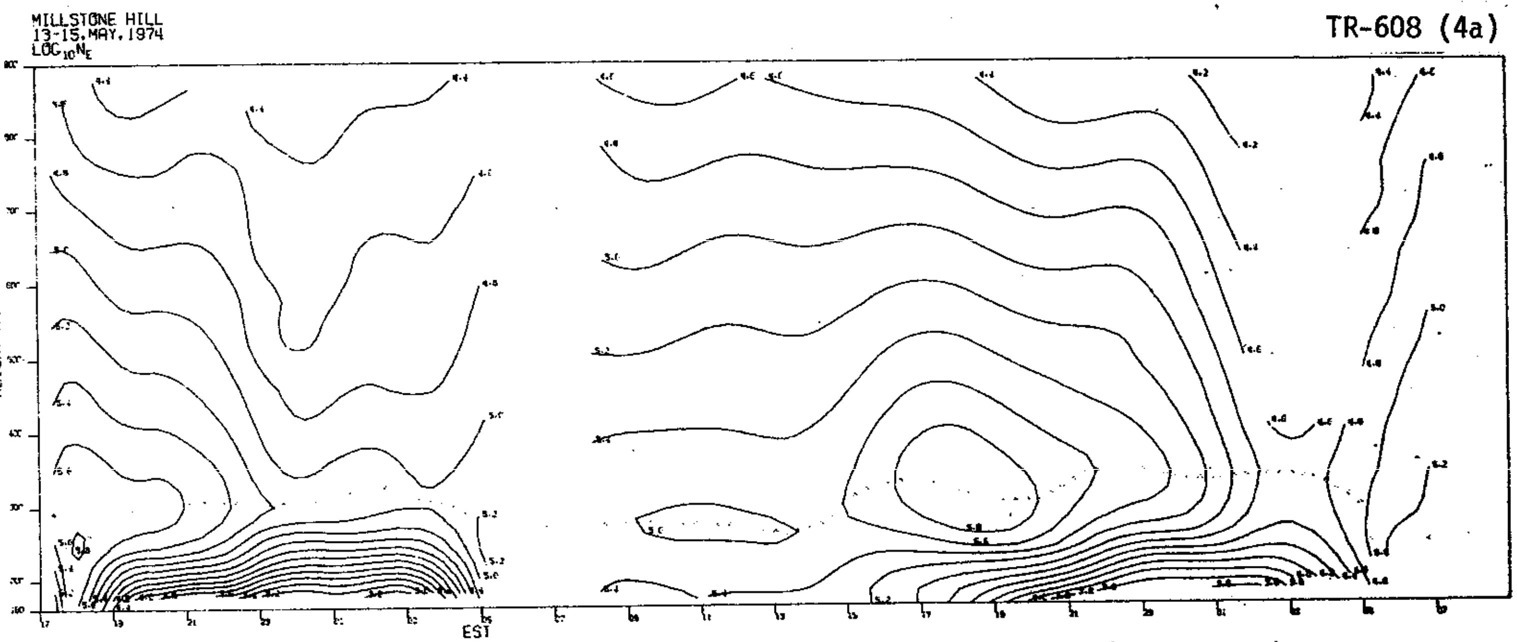


Figure 4a. Contours of $\text{Log}_{10}\ N_e$ vs. height and time for 13-15 May 1974.

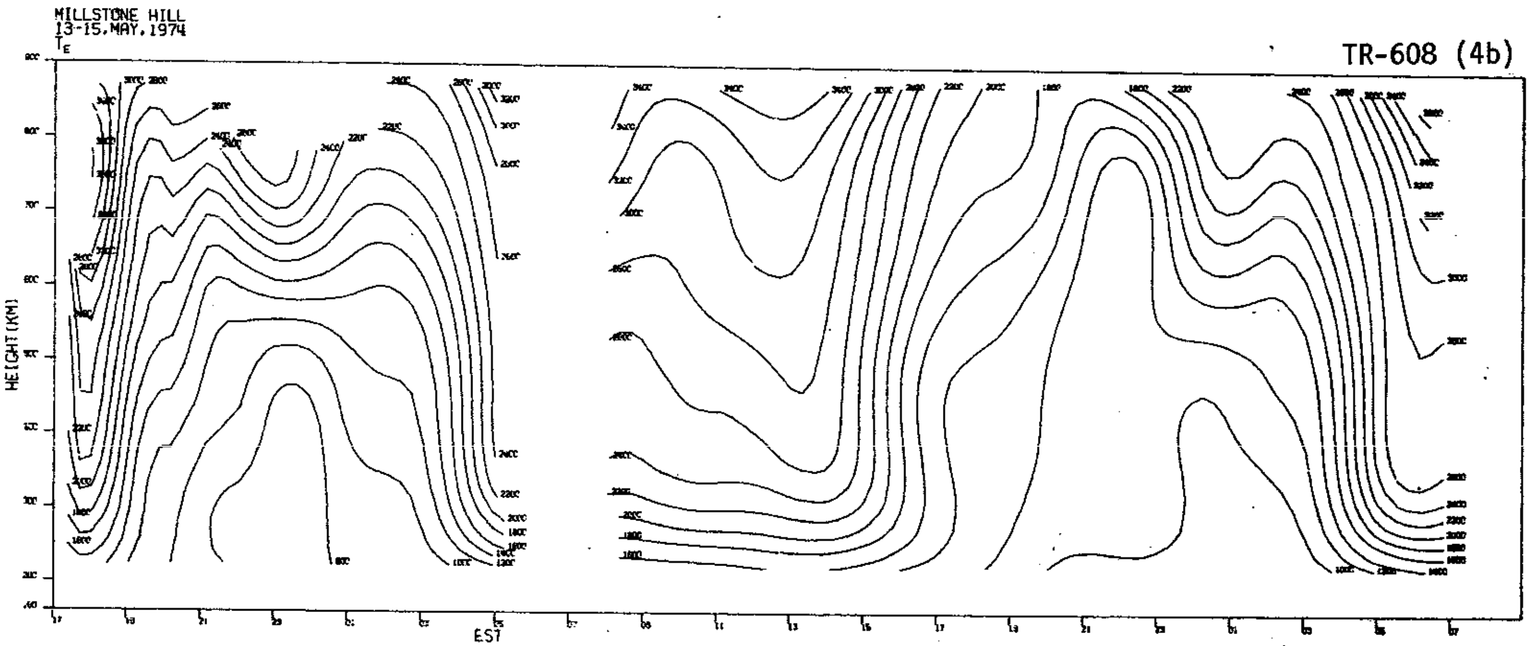
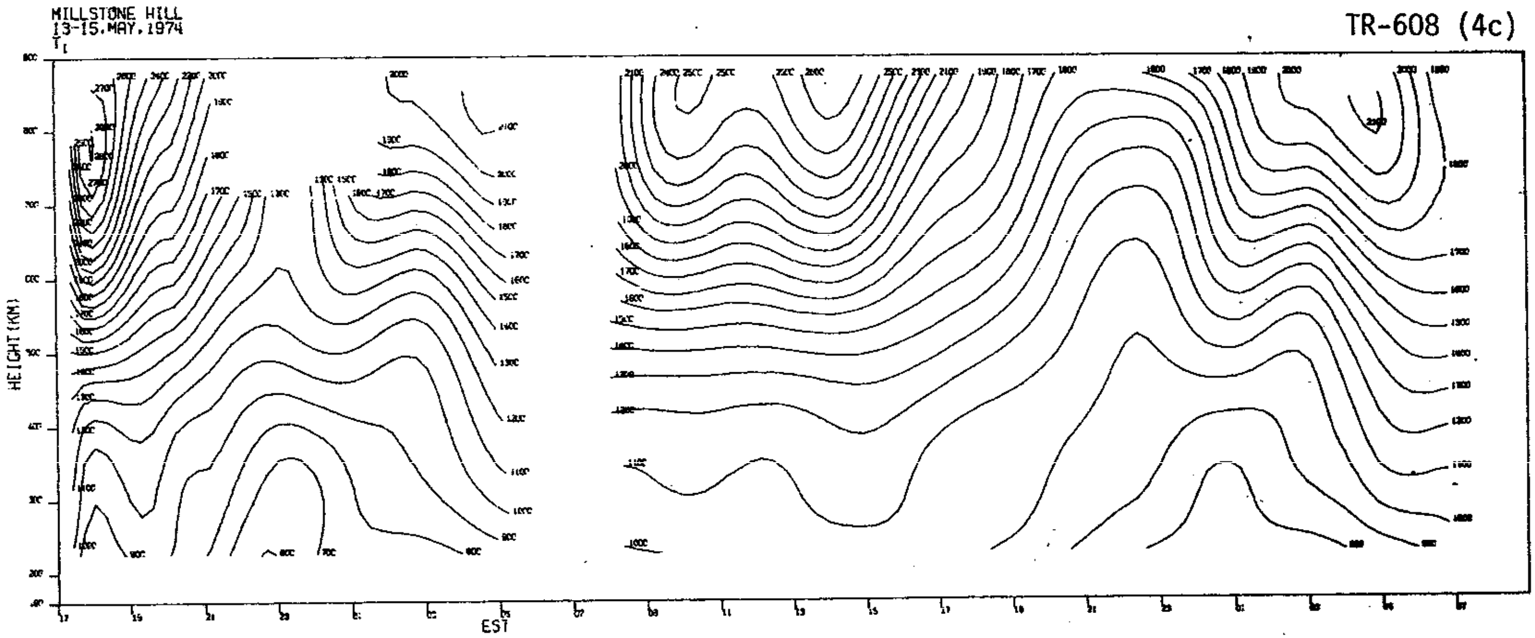


Figure 4b. Contours of electron temperature T_e vs. height and time for 13-15 May 1974.

TR-608 (4c)



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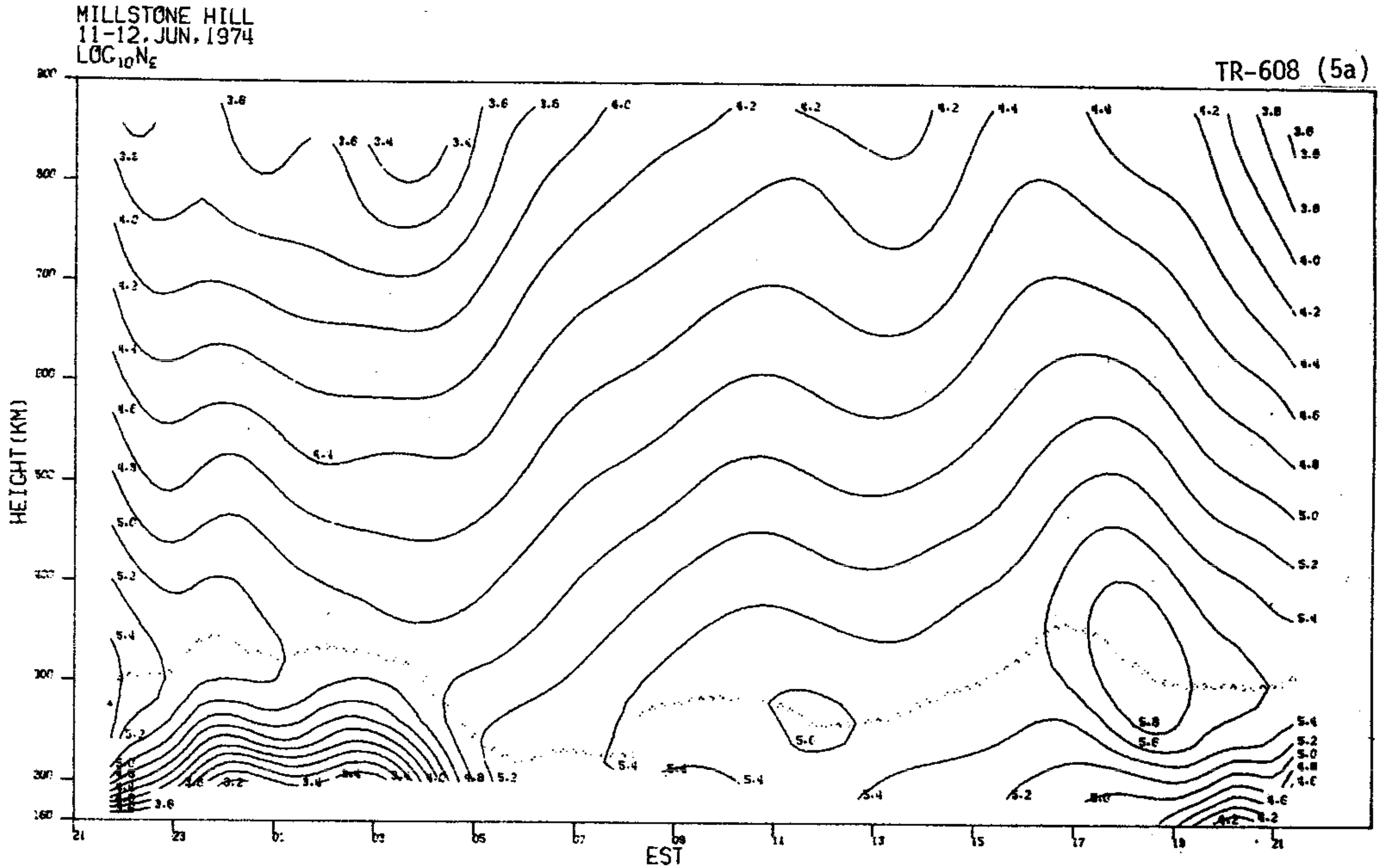


Figure 5a. Contours of Log_{10} N_e vs. height and time for 11-12 June 1974.

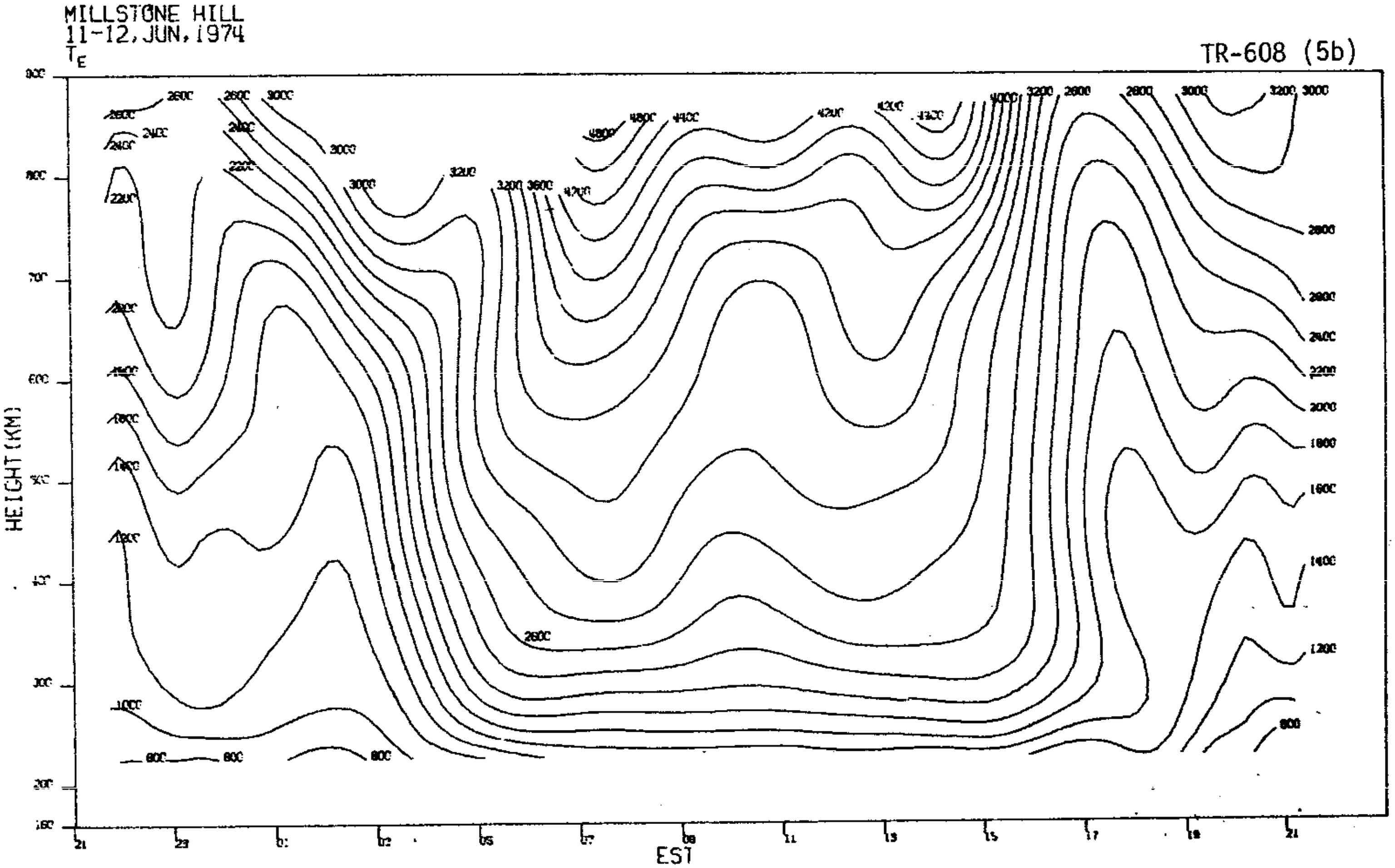


Figure 5b. Contours of electron temperature T_e vs. height and time for 11-12 June 1974.

TR-608 (5c)

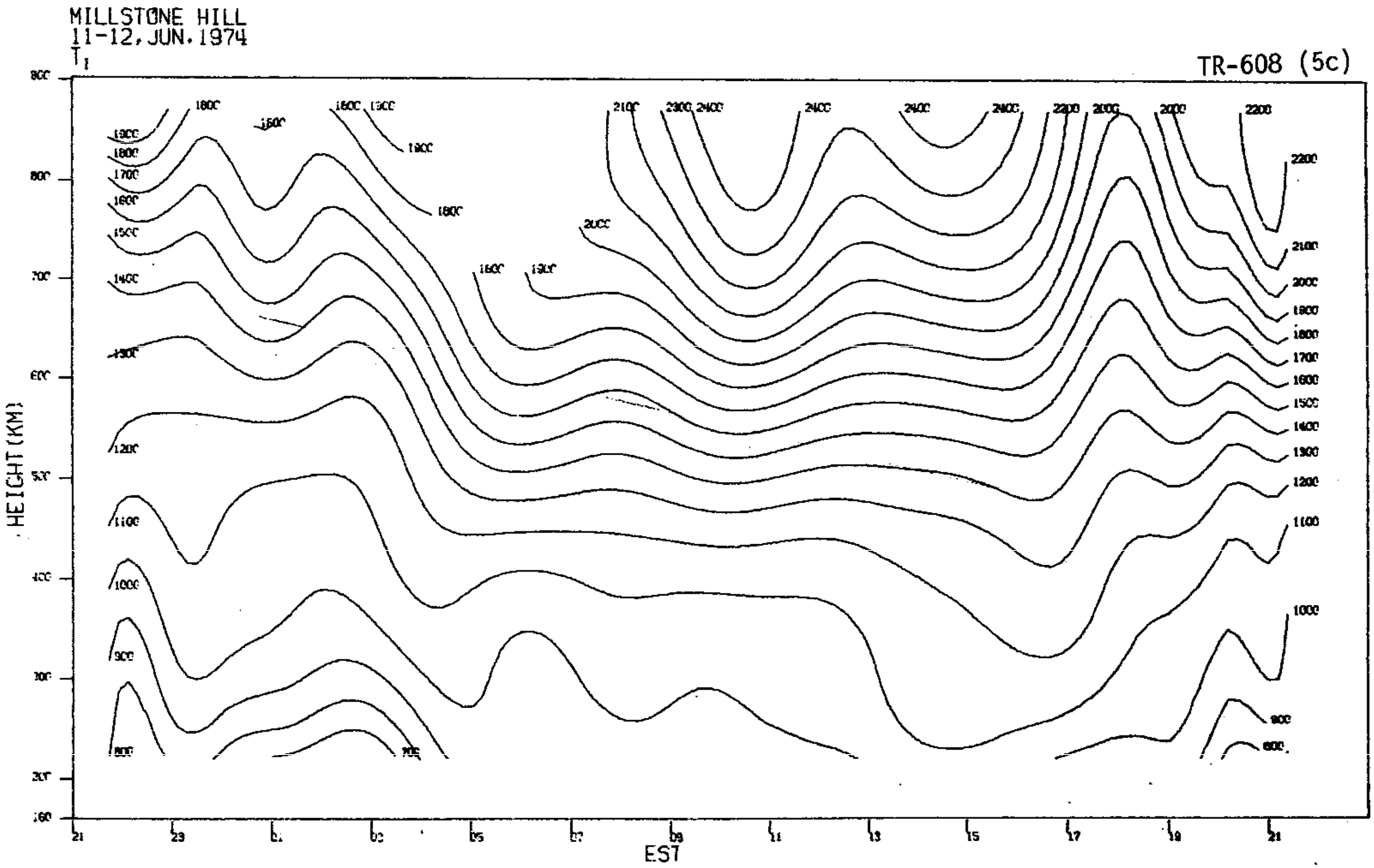


Figure 5c. Contours of ion temperature T_i vs. height and time for 11-12 June 1974.

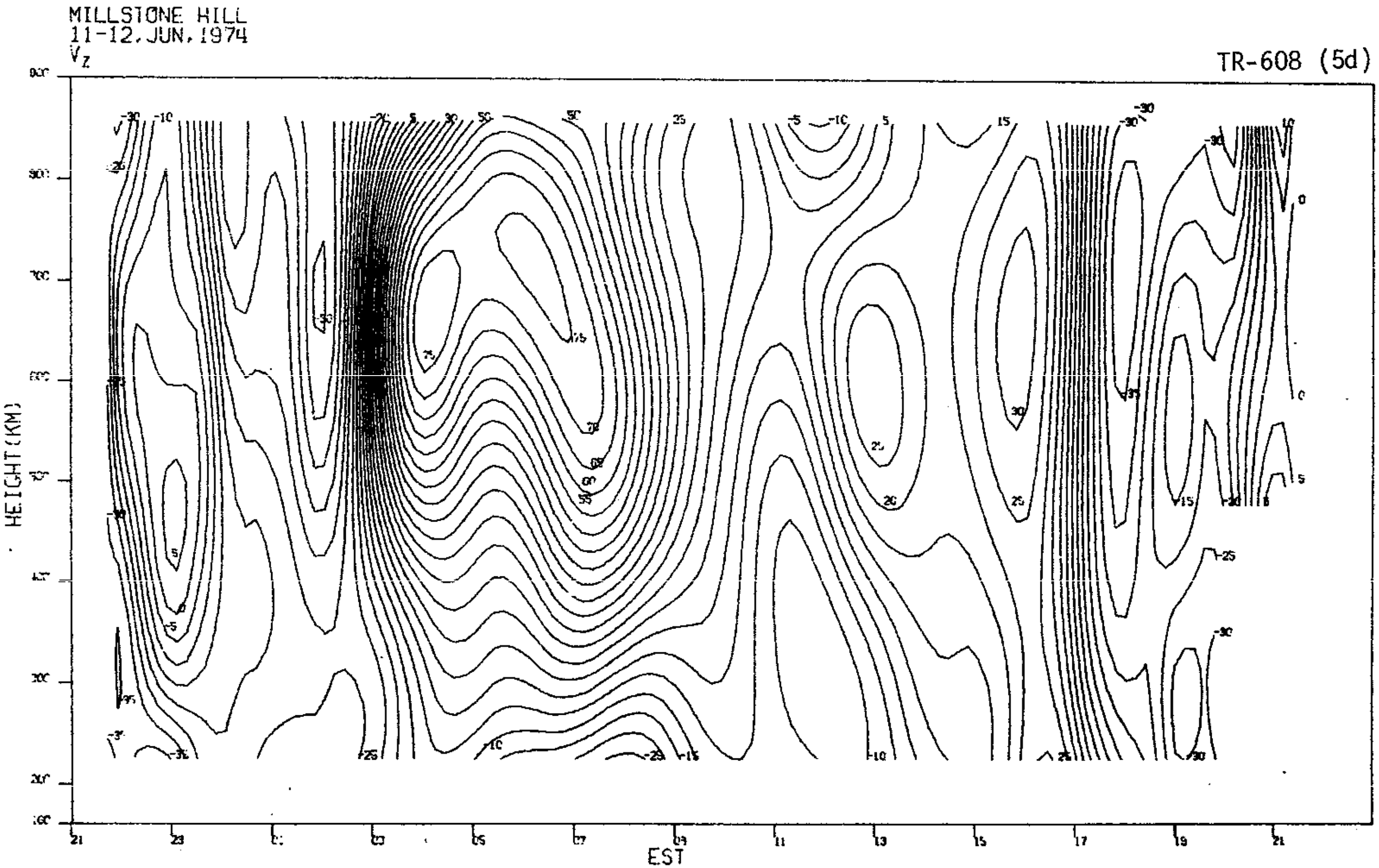


Figure 5d. Contours of vertical velocity V_Z vs. height and time for 11-12 June 1974.

TR-608 (6a)

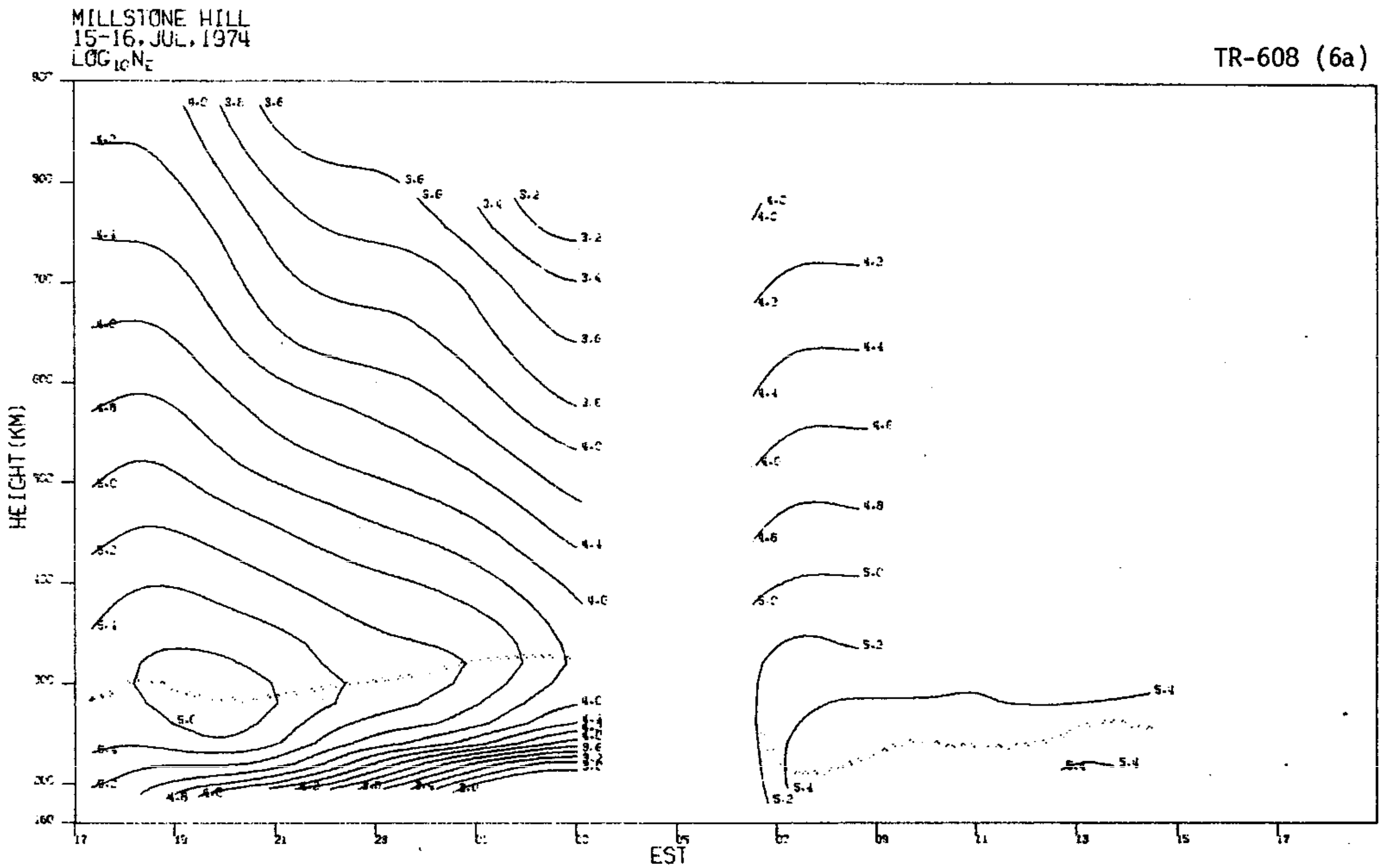


Figure 6a. Contours of $\text{Log}_{10}\ N_e$ vs. height and time for 15-16 July 1974.

TR-608 (6b)

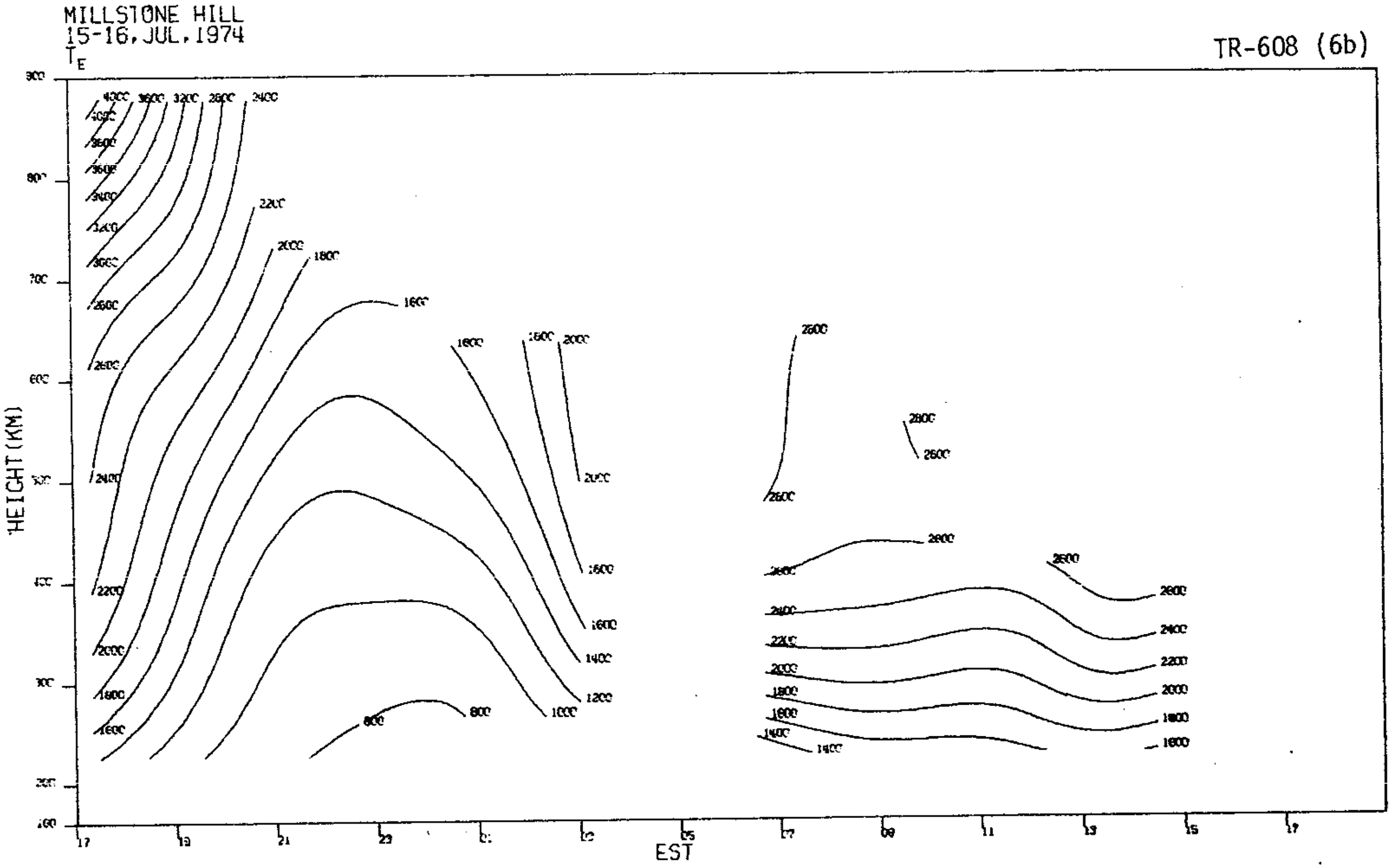
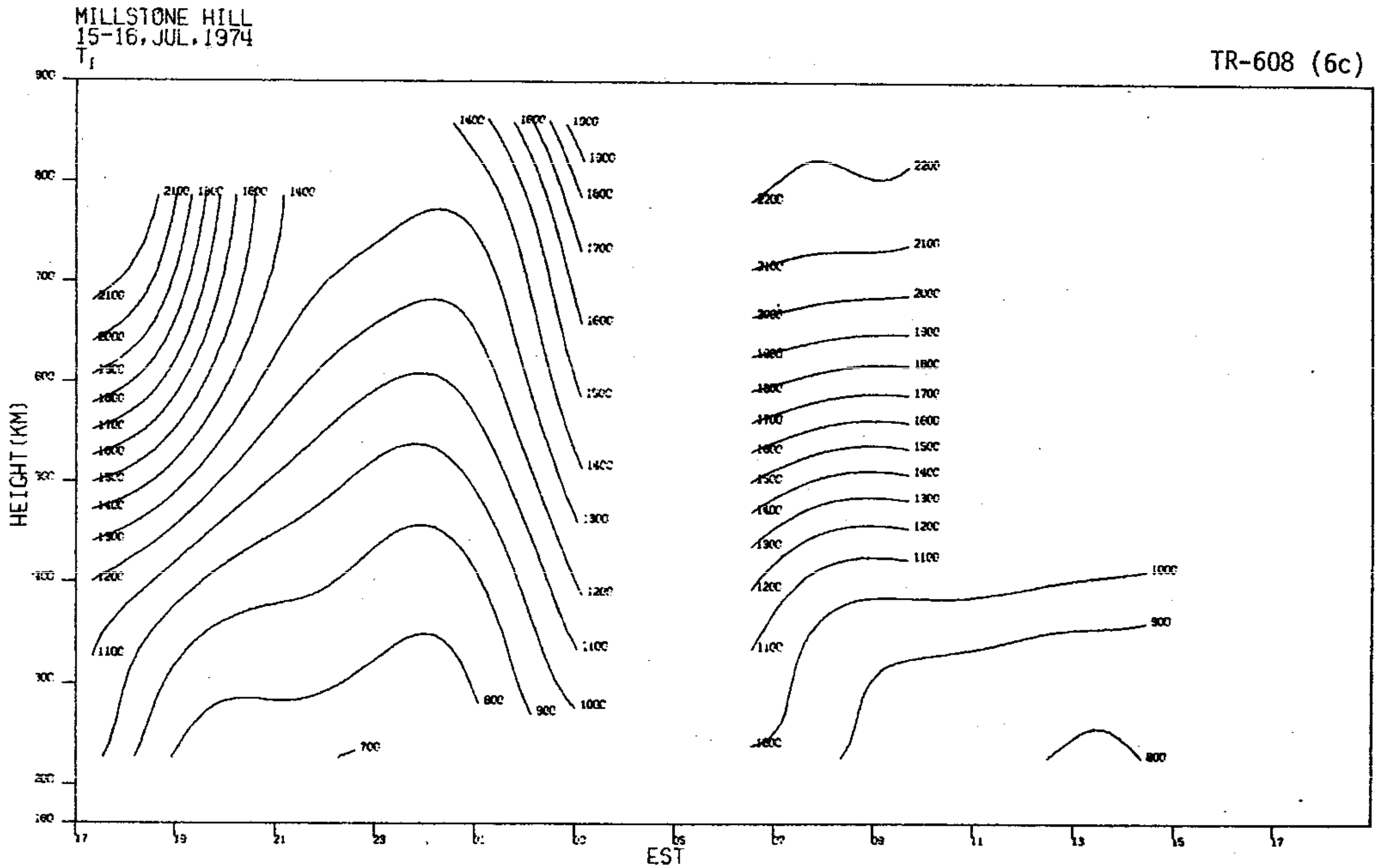


Figure 6b. Contours of electron temperature T_e vs. height and time for 15-16 July 1974.

TR-608 (6c)



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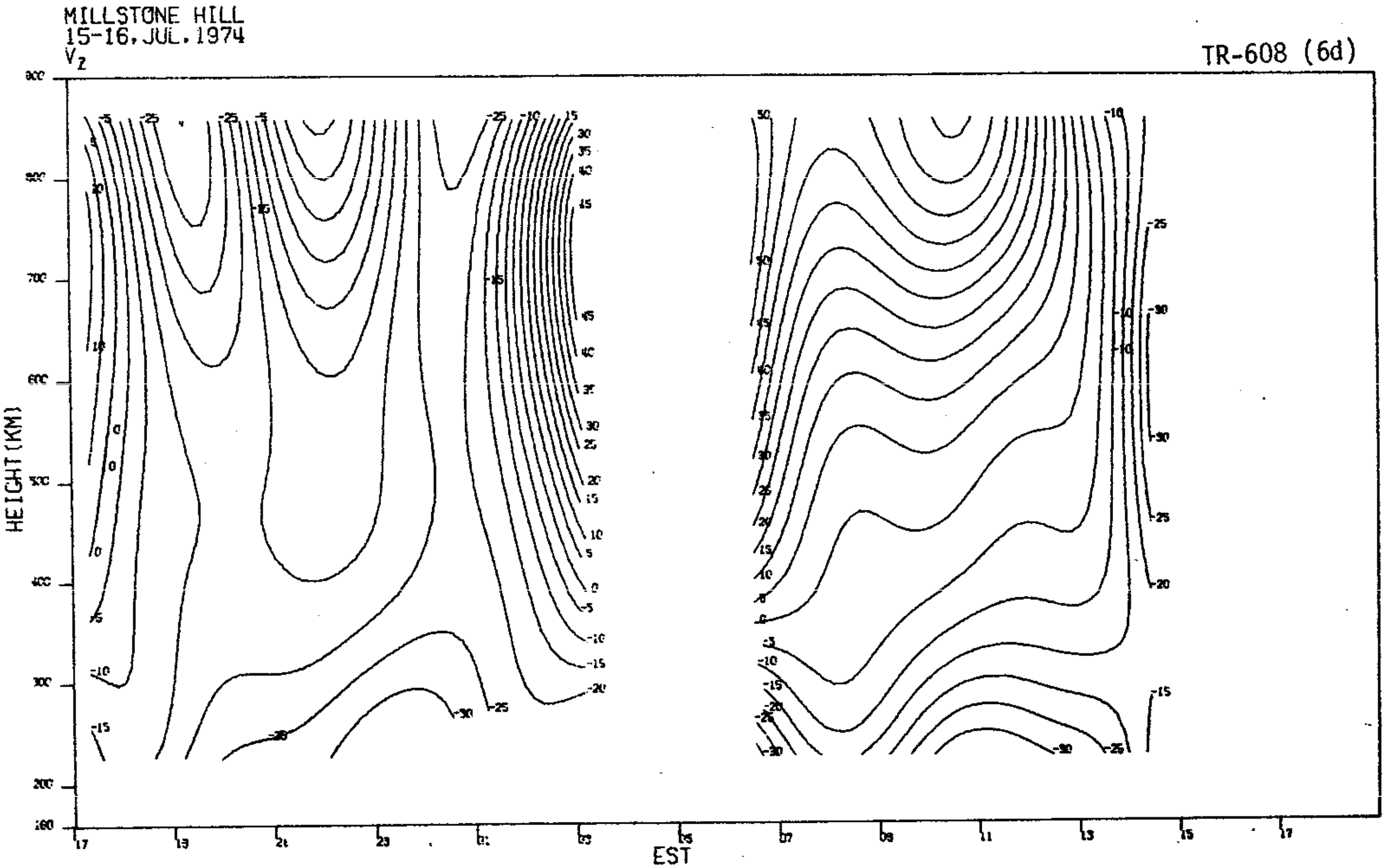

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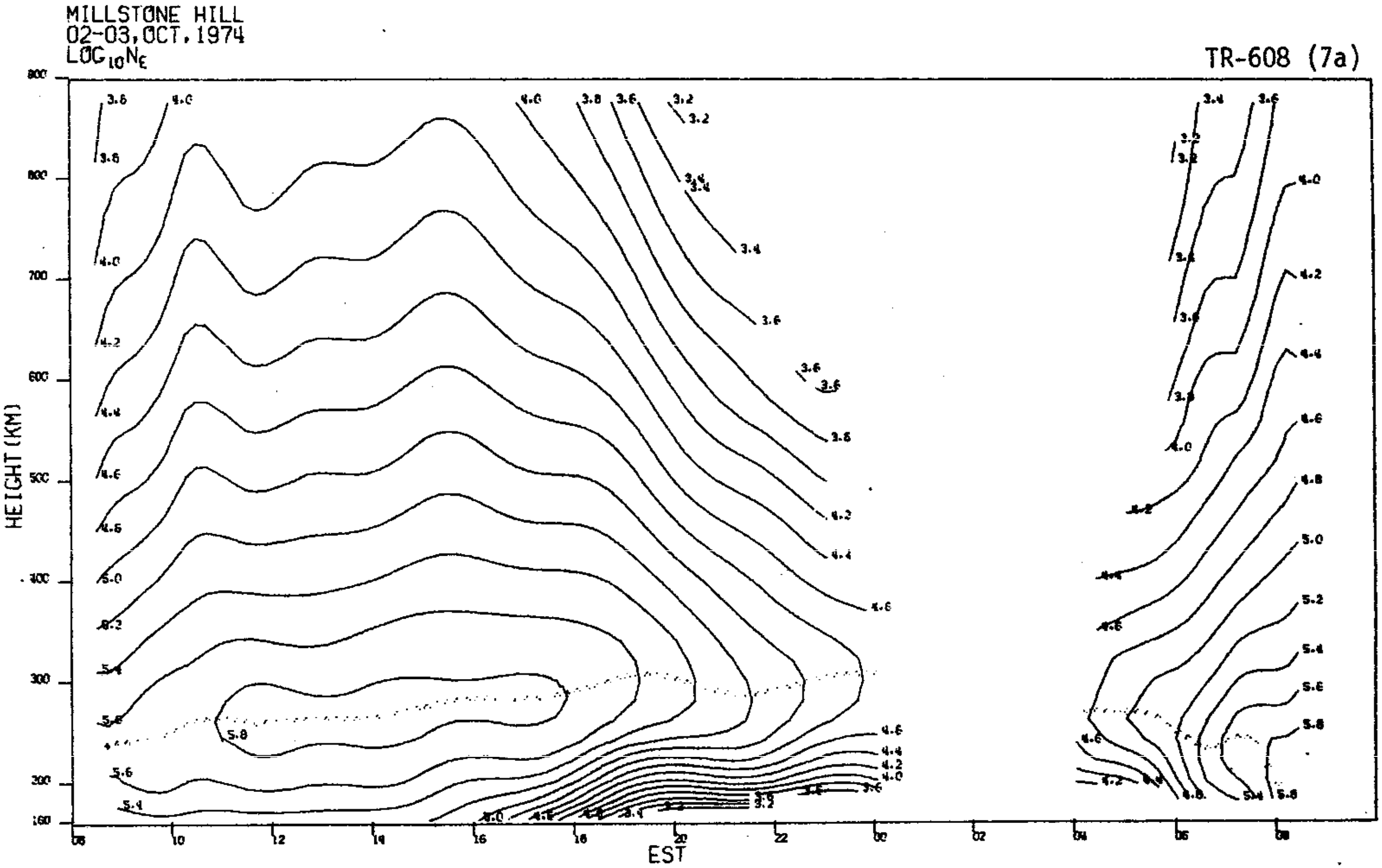


Figure 7a. Contours of $Log_{10}\ N_e$ vs. height and time for 2-3 October 1974.

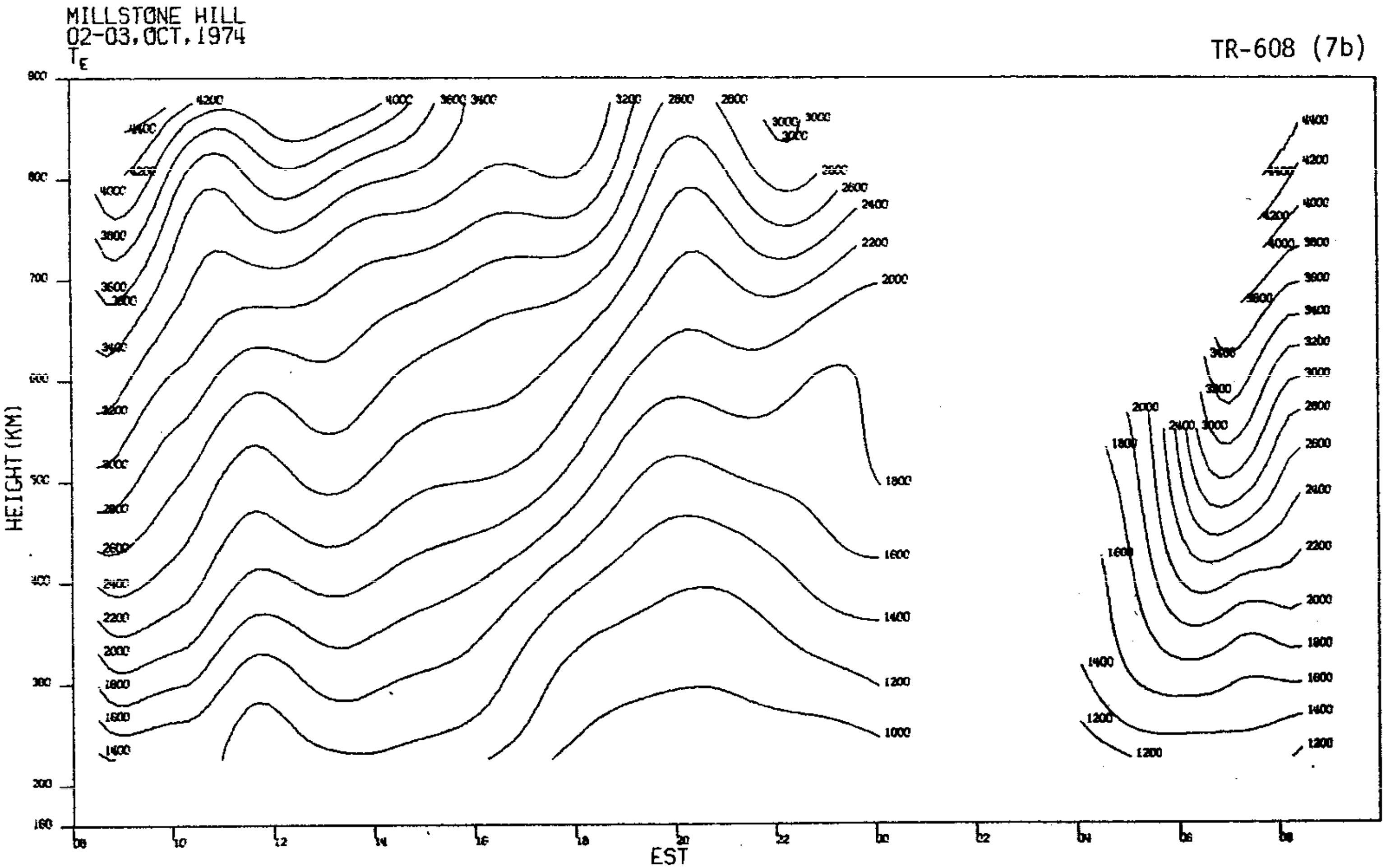
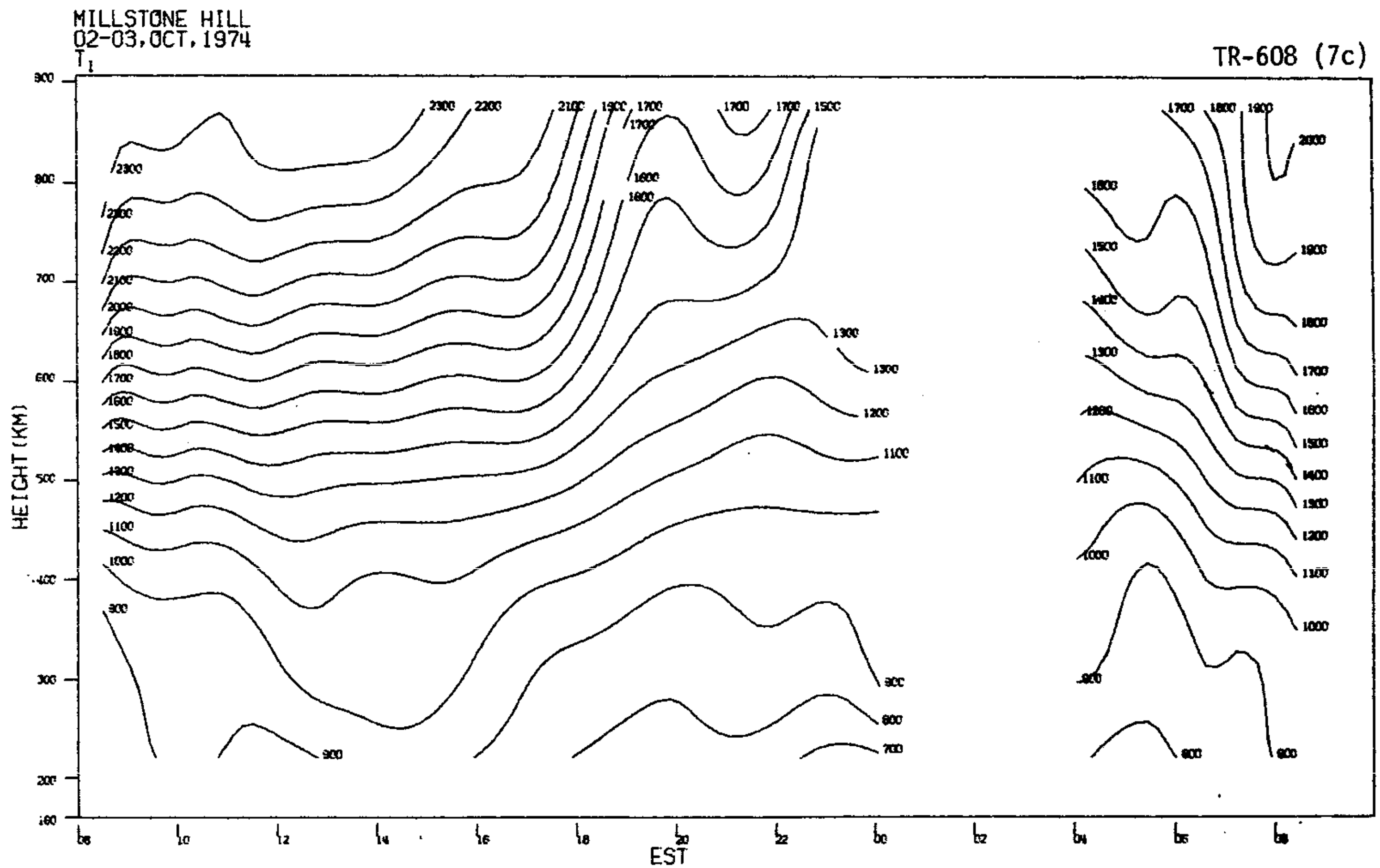


Figure 7b. Contours of electron temperature T_e vs. height and time for 2-3 October 1974.



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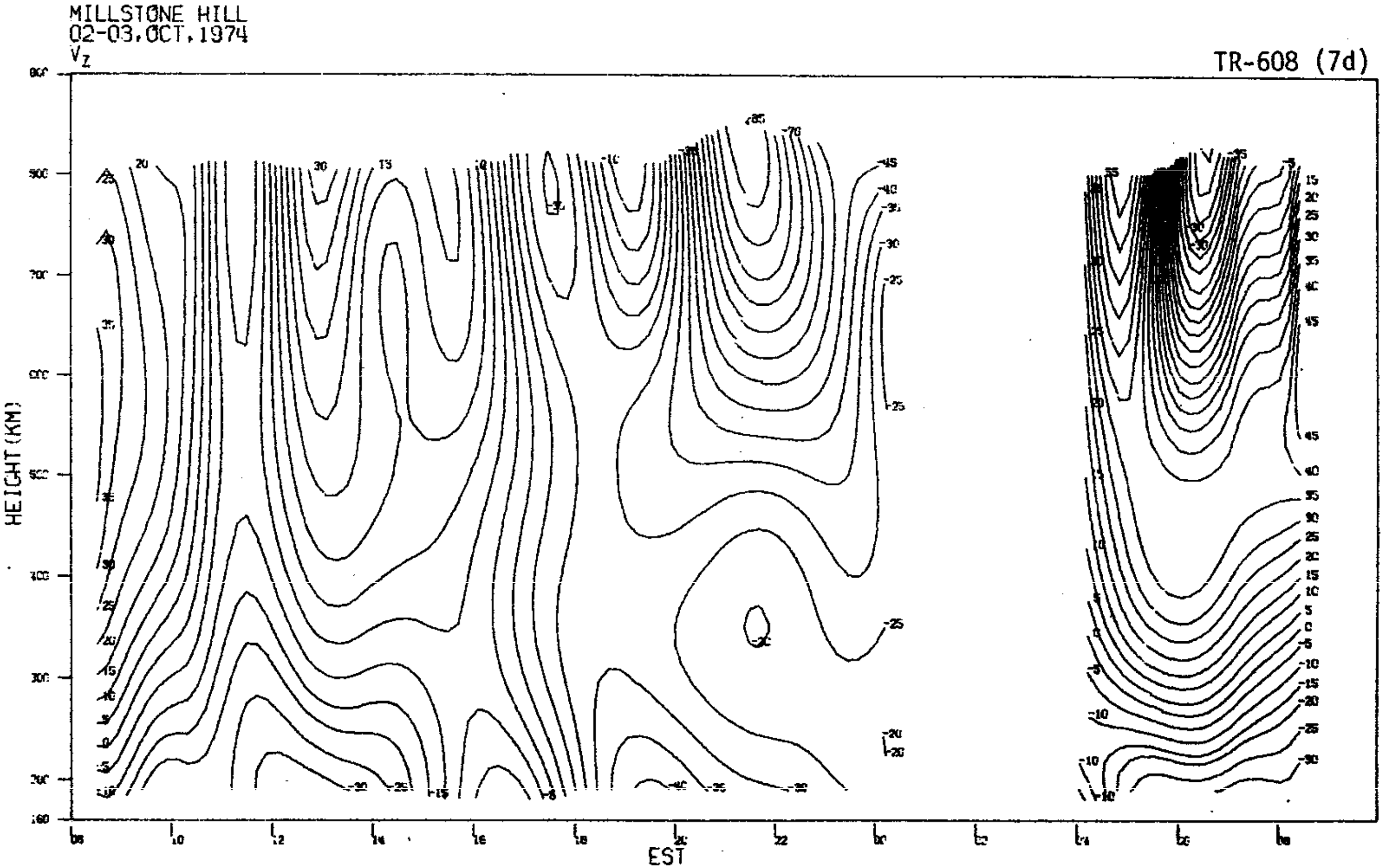

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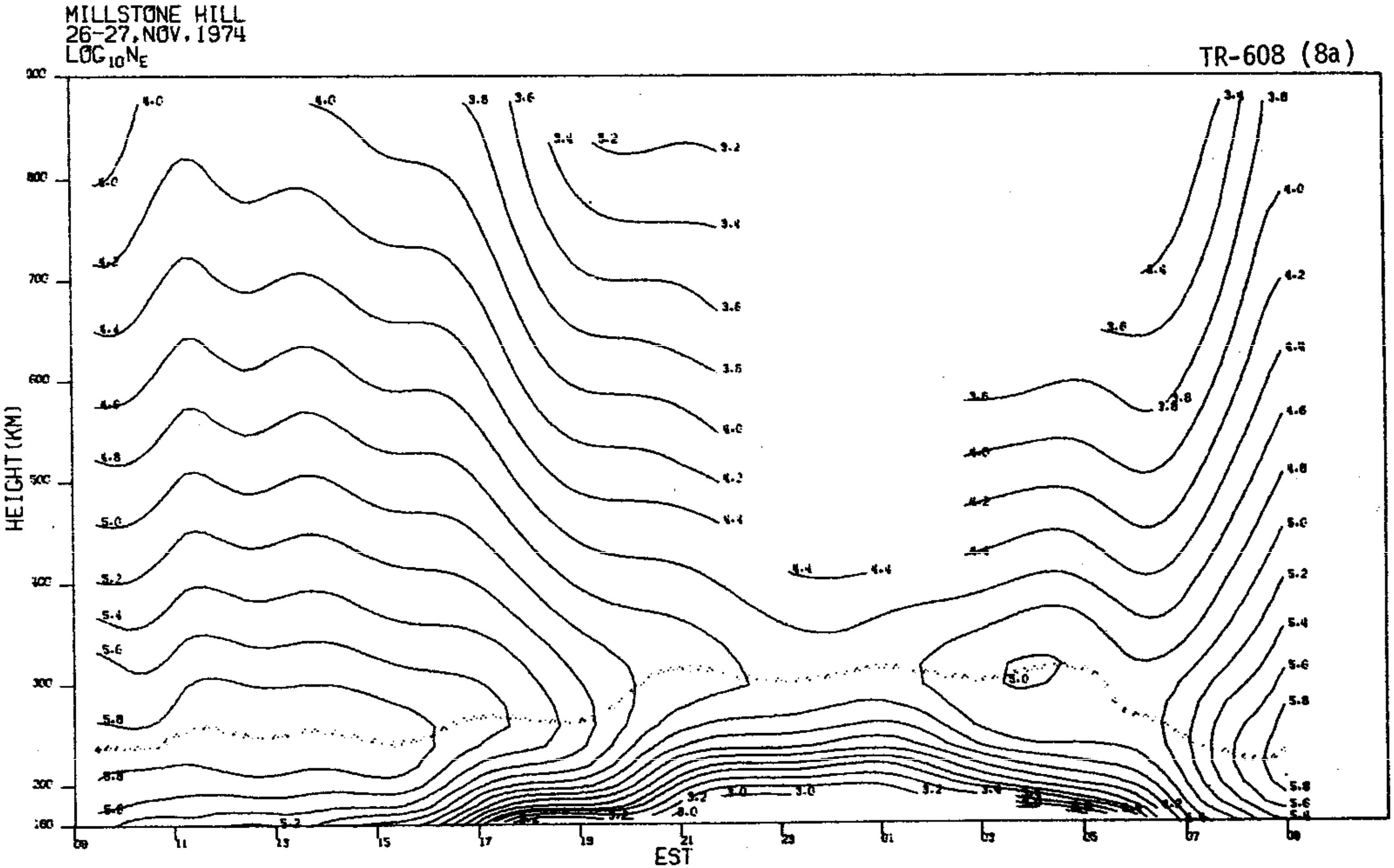


Figure 8a. Contours of $\text{Log}_{10}\ N_e$ vs. height and time for 26-27 November 1974.

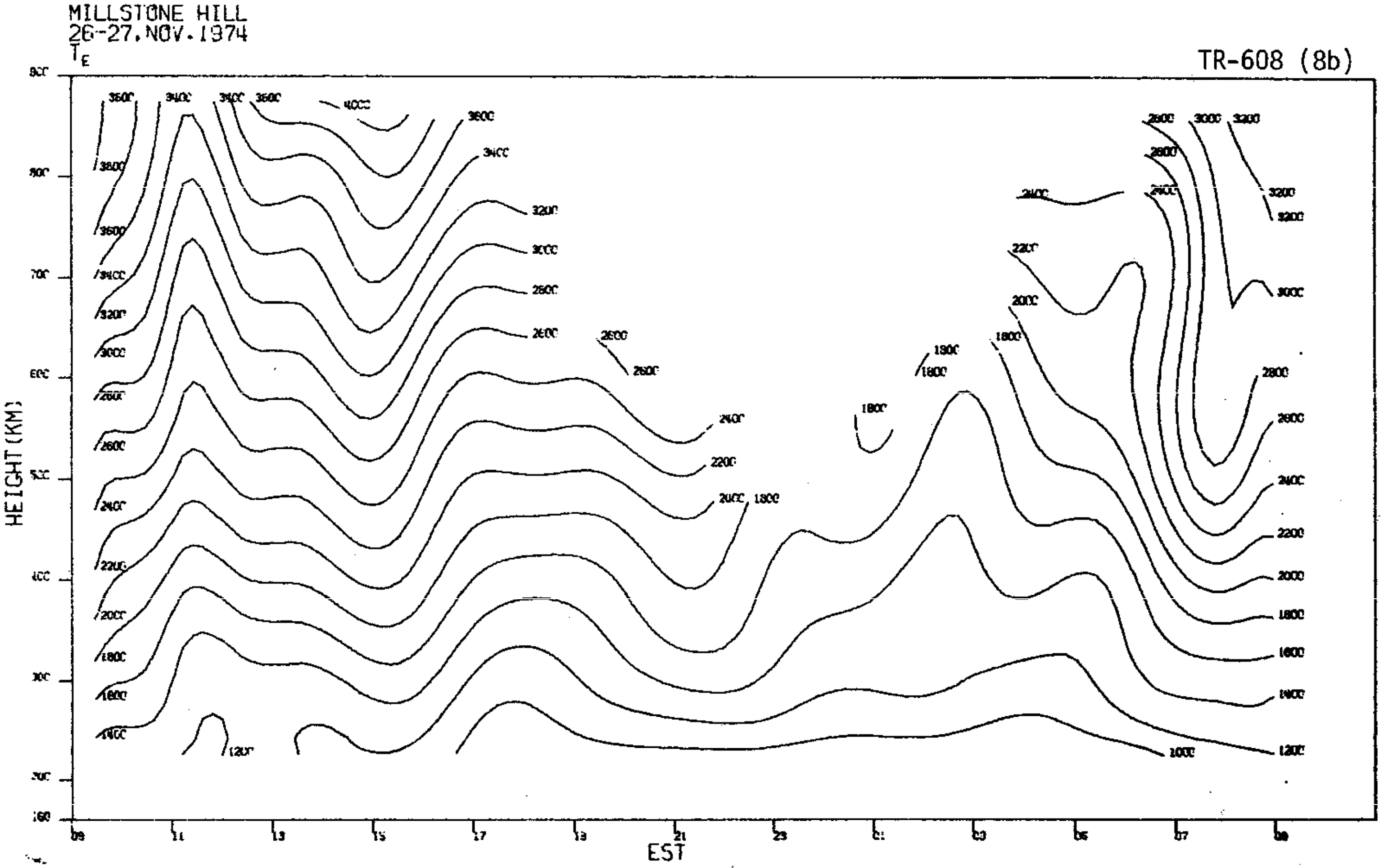


Figure 8b. Contours of electron temperature T_e vs. height and time for 26-27 November 1974.

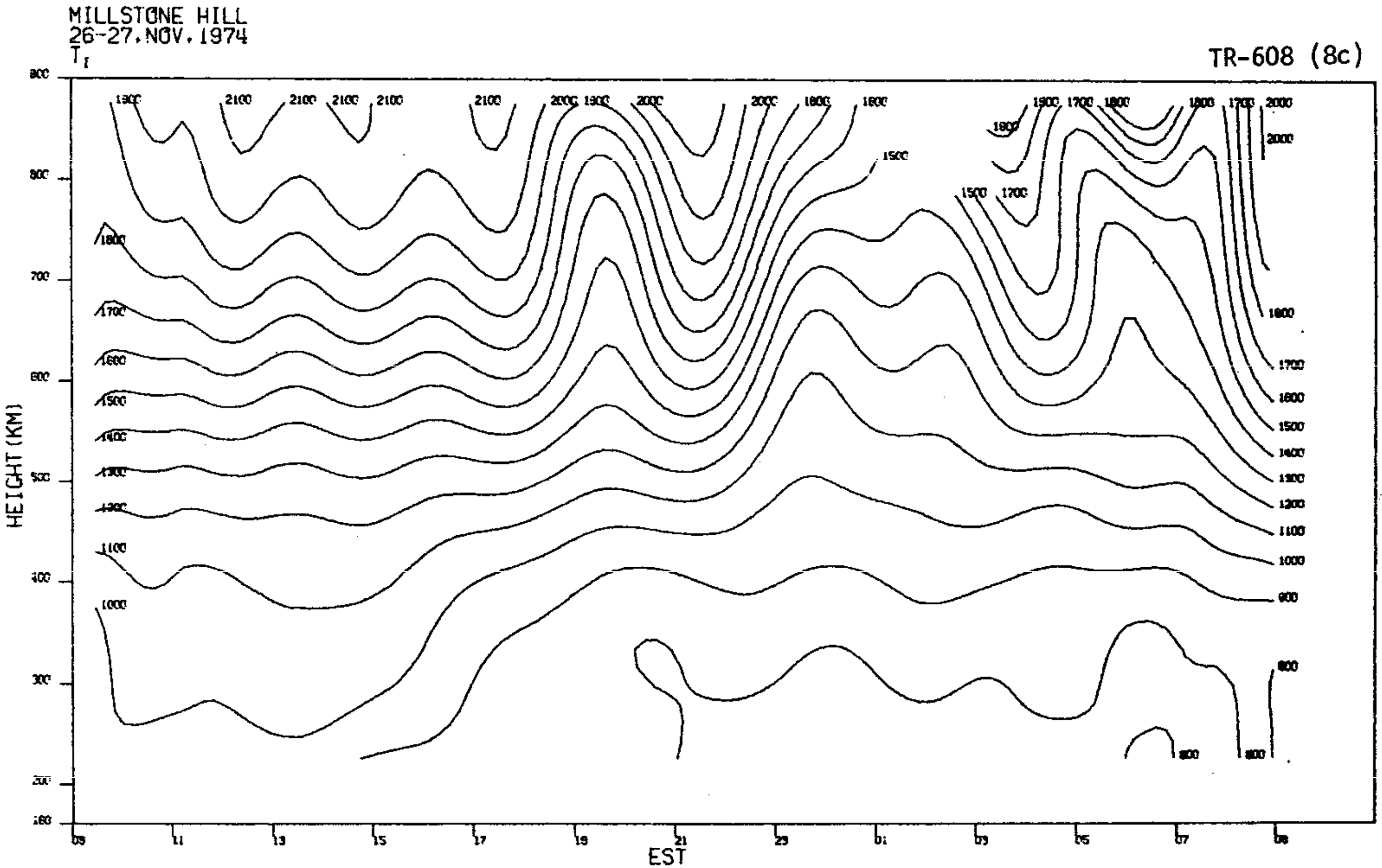
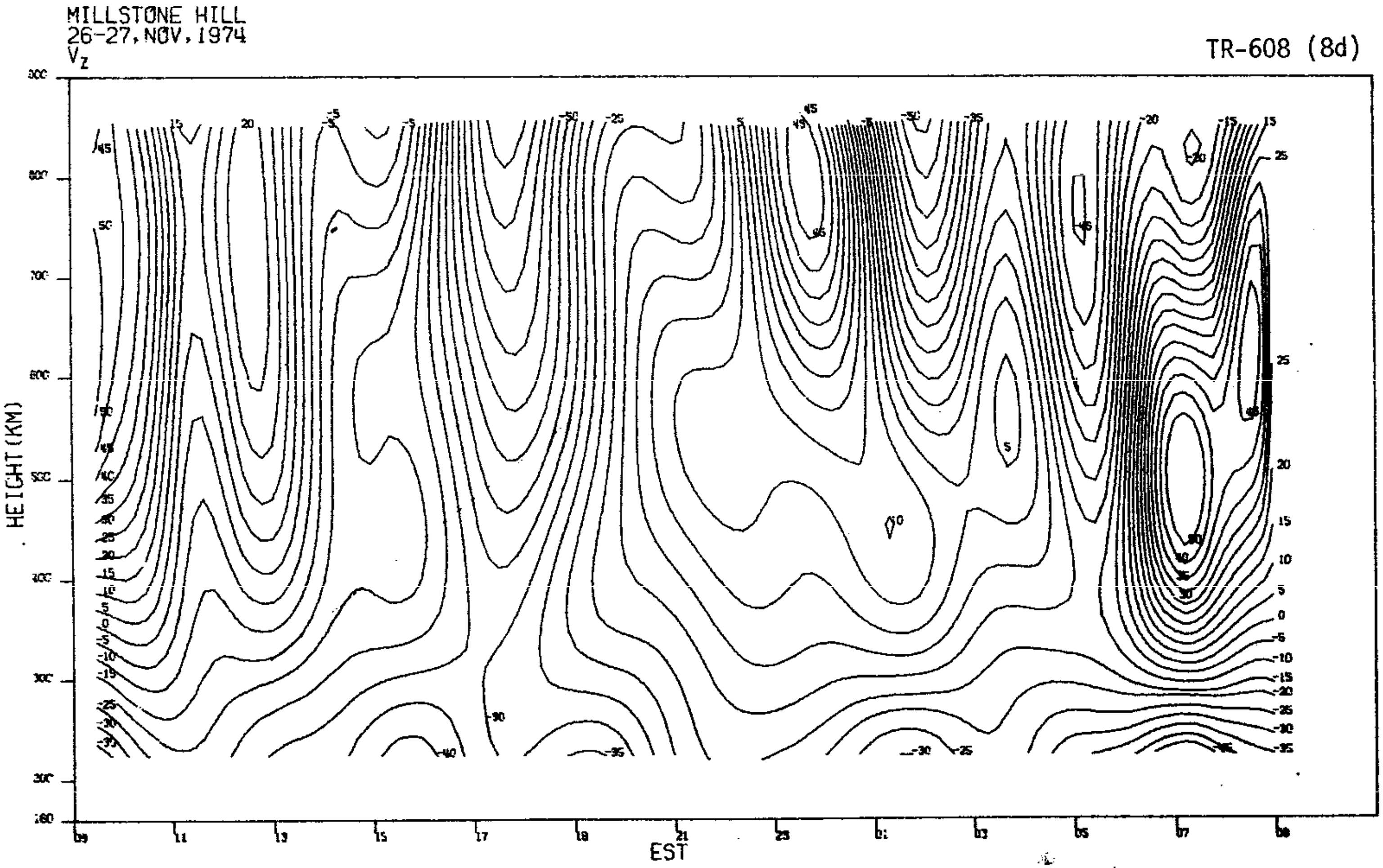


Figure 8c. Contours of ion temperature T_i vs. height and time for 26-27 November 1974.



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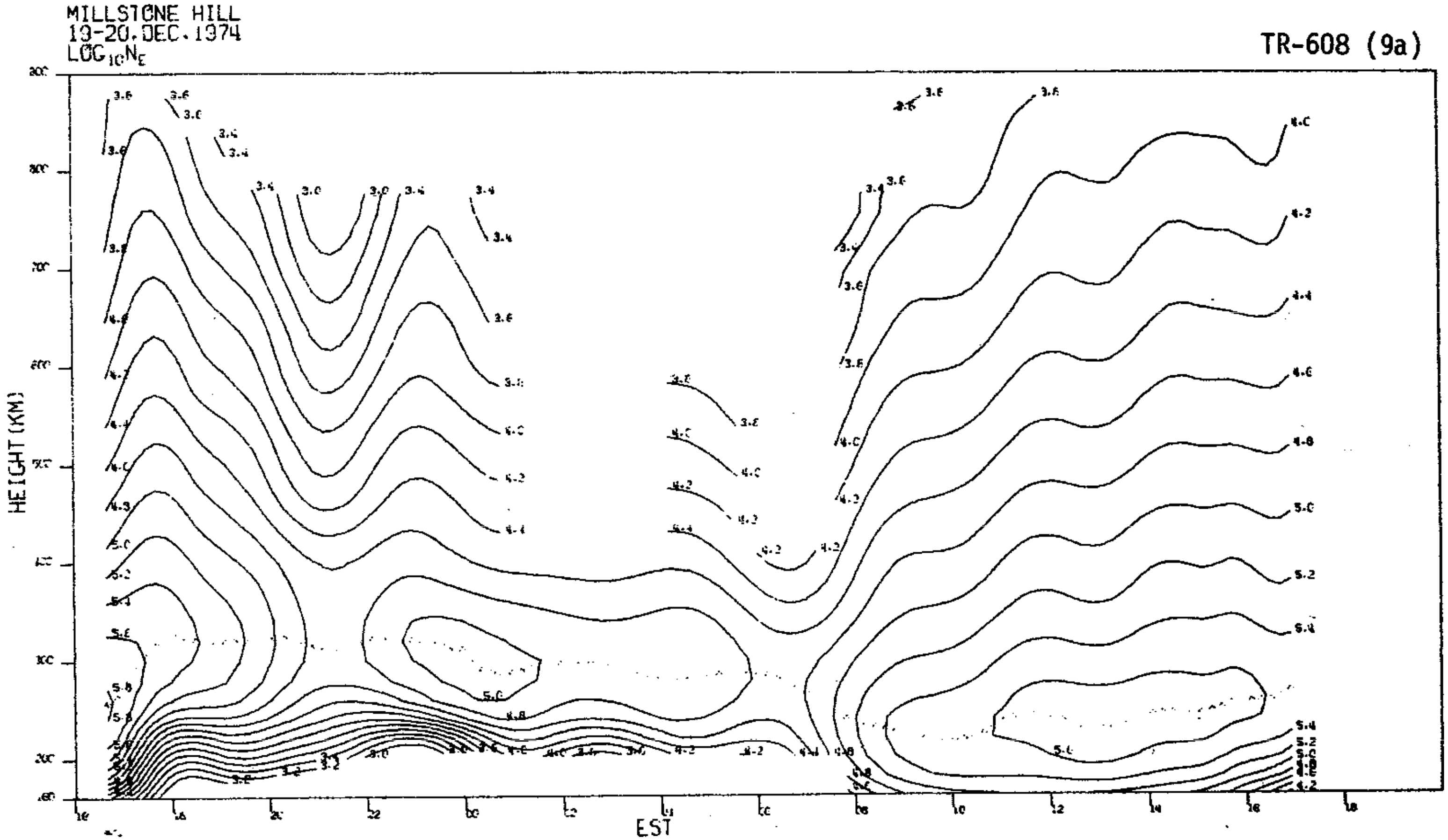

Figure 9a. Contours of Log_{10} N_e vs. height and time for 19-20 December 1974.

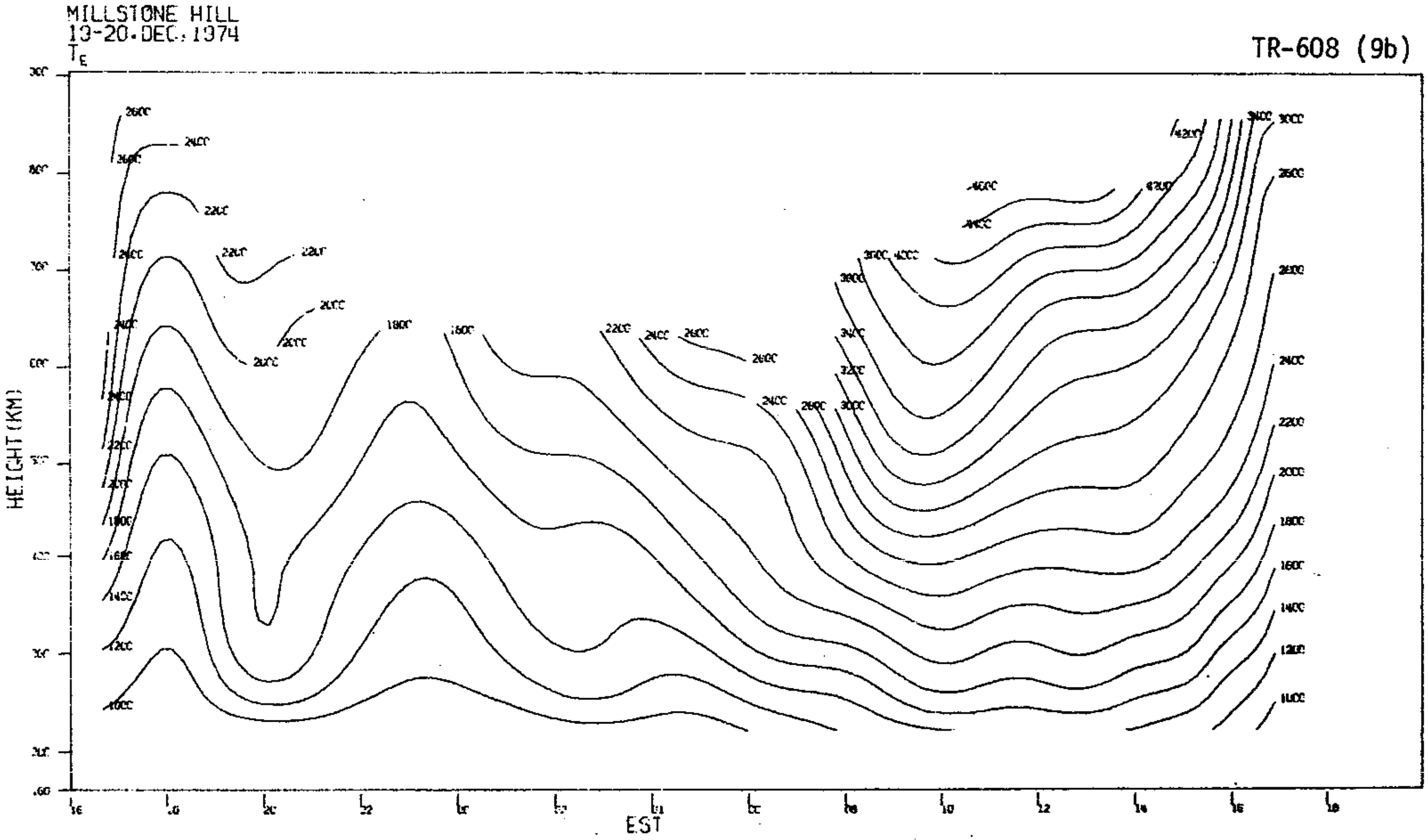

Figure 9b. Contours of electron temperature T_e vs. height and time for 19-20 December 1974.

TR-608 (9c)

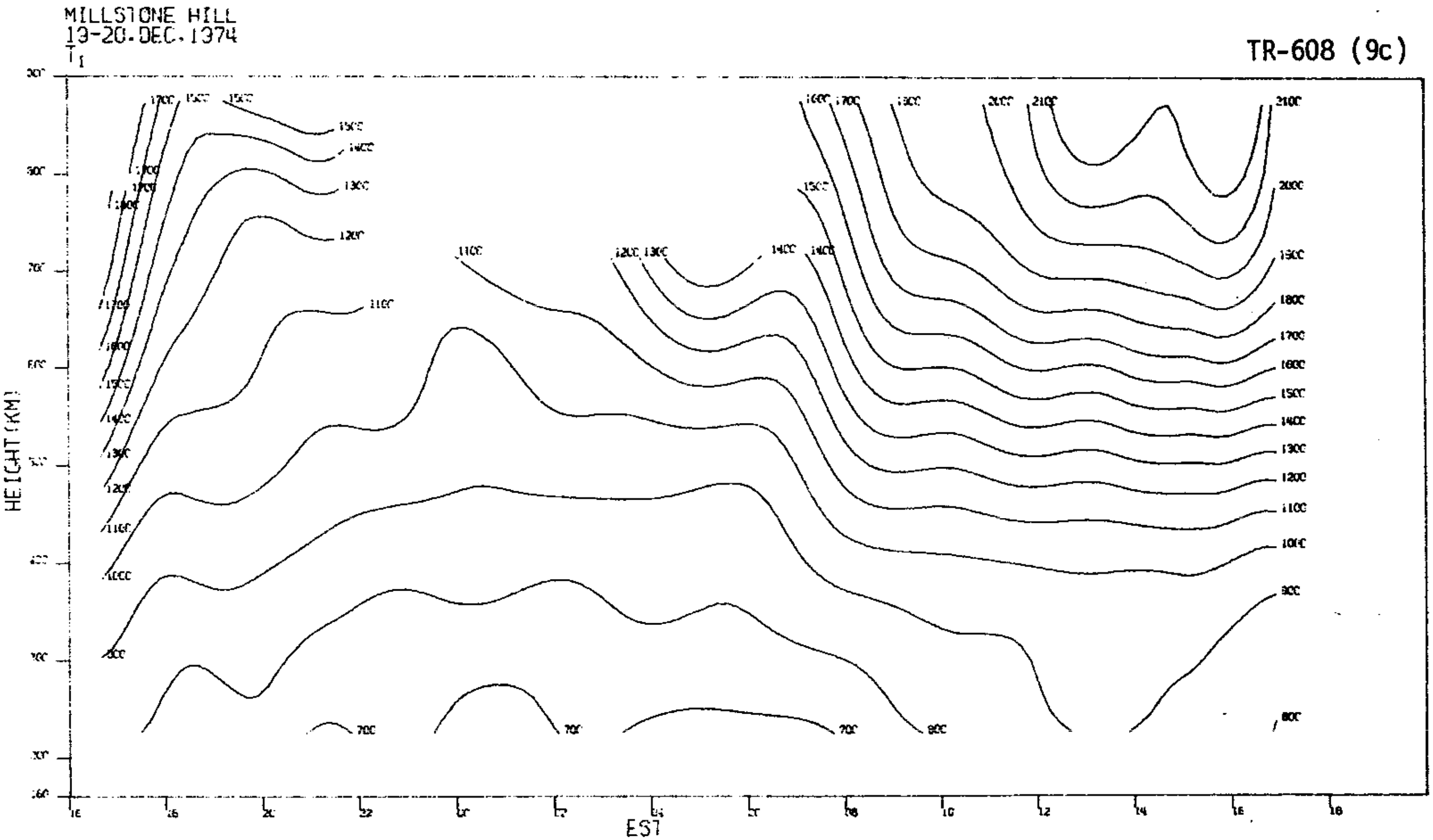

Figure 9c. Contours of ion temperature T_i vs. height and time for 19-20 December 1974.

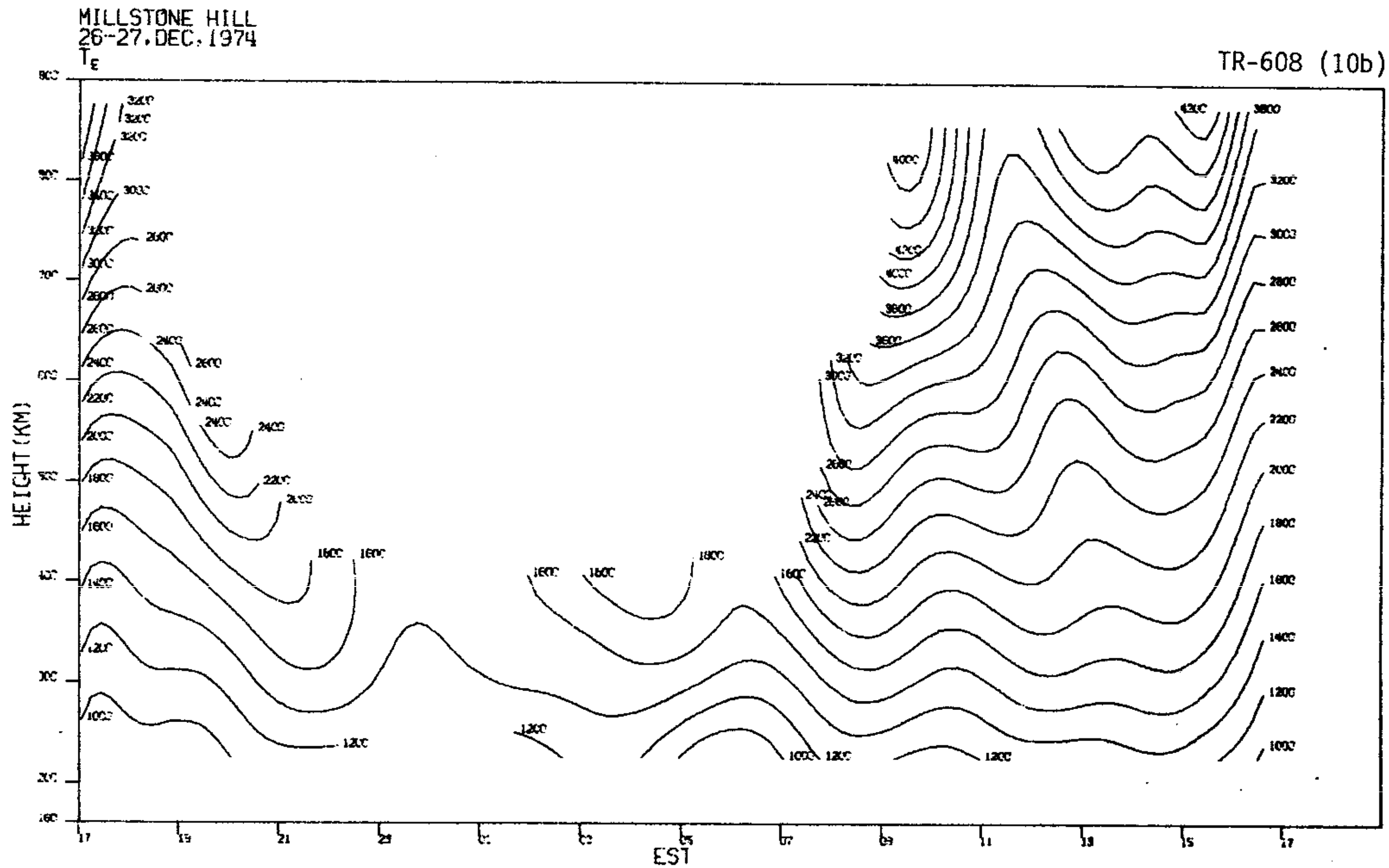

Figure 10b. Contours of electron temperature T_e vs. height and time for 26-27 December 1974.

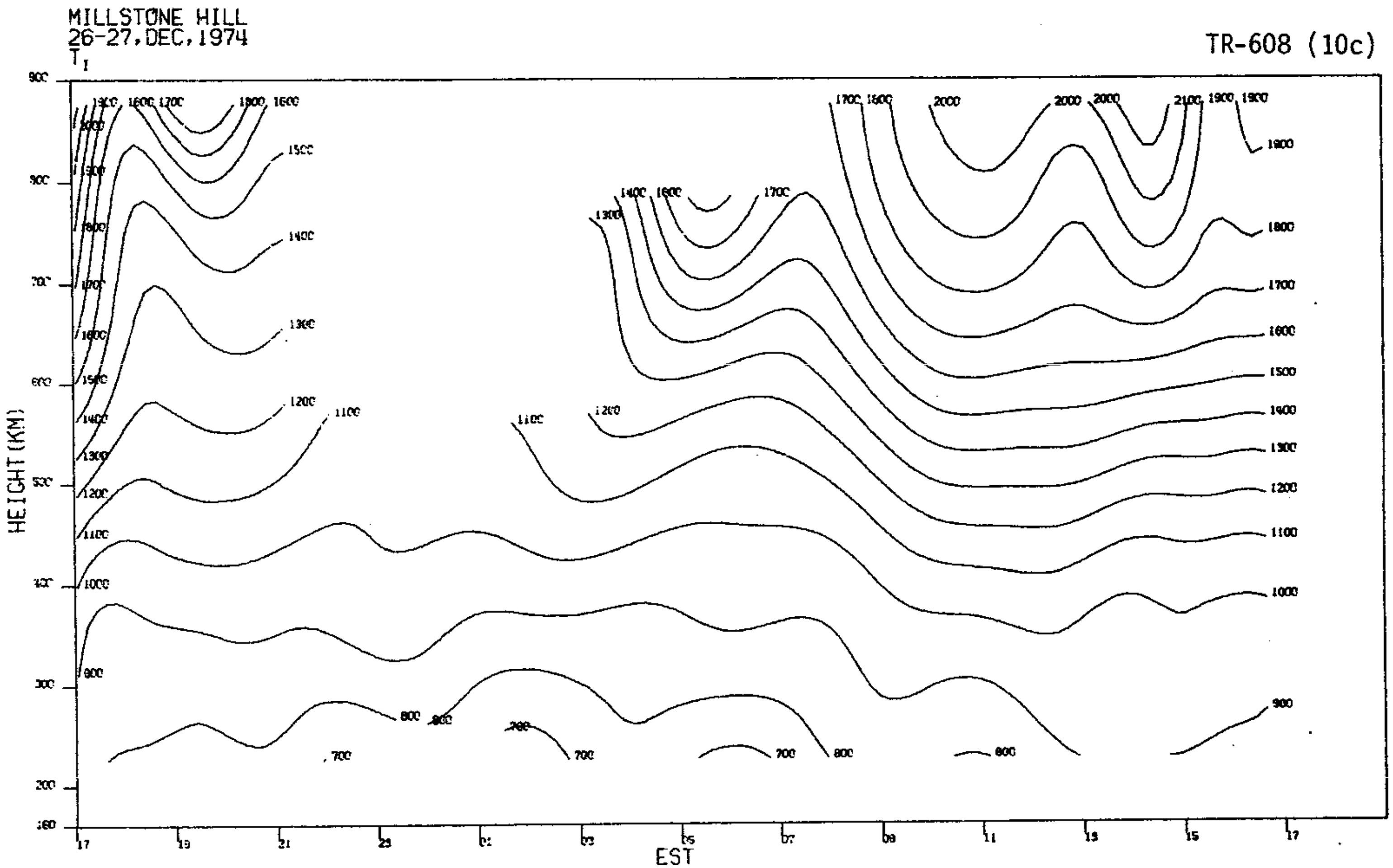

Figure 10c. Contours of ion temperature T_i vs. height and time for 26-27 December 1974.

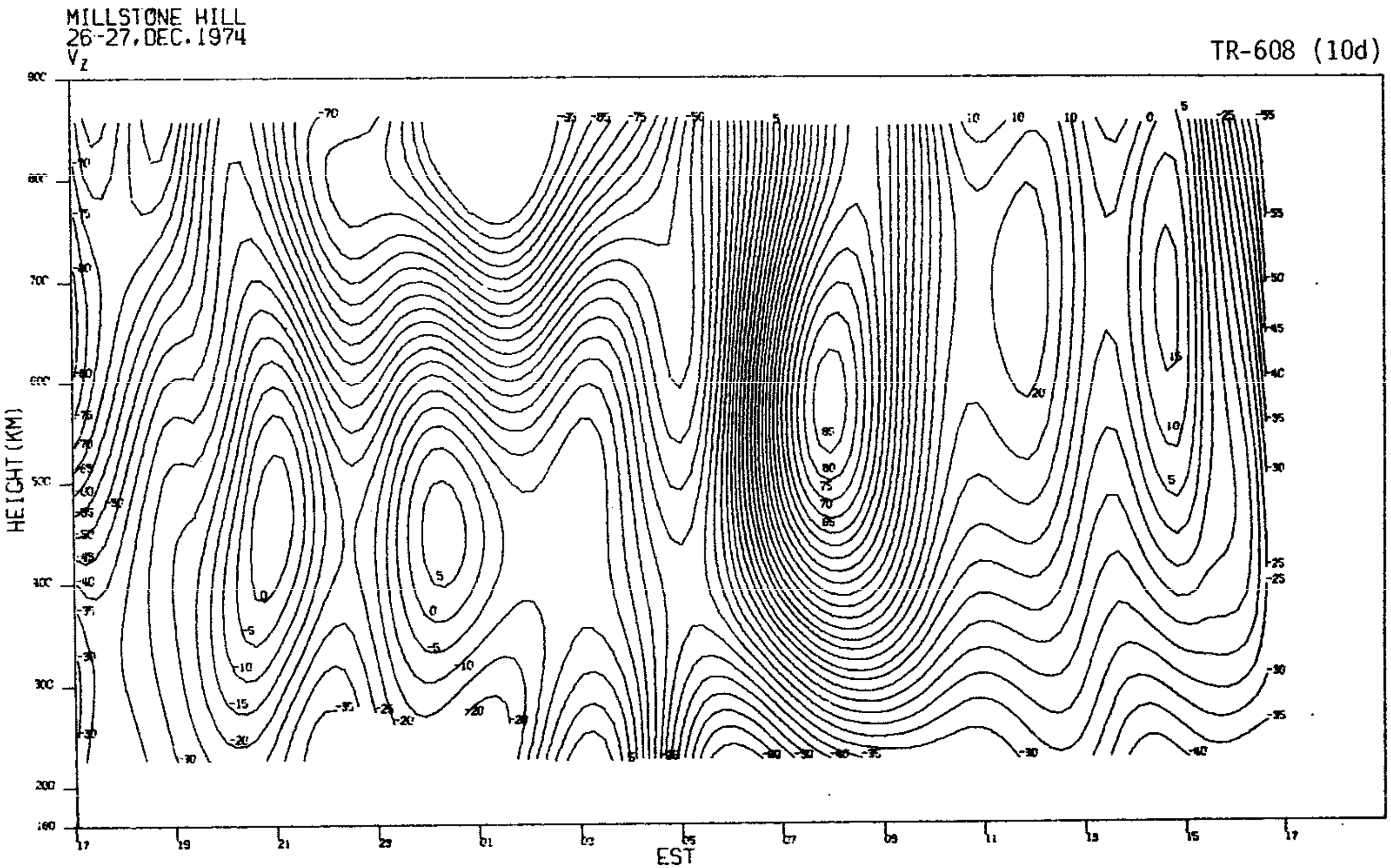

Figure 10d. Contours of vertical velocity V_z vs. height and time for 26-27 December 1974.

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7. Author(s) J.V. Evans, J.M. Holt			8. Performing Organization Rapt. No. Technical Report 608
9. Performing Organization Nams and Address Haystack Observatory Massachusetts Institute of Technology Westford, Massachusetts			10. Project/Task/Work Unit No. 11. Contract/Grant No. ATM75-22193 ATM79-09189
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15. Supplementary Notes

16. Abstracts

During 1973, the vertically-directed incoherent scatter radar at Millstone Hill (42.6°N, 71.5” W) was employed to measure electron density, electron and ion temperature and vertical ion velocity in the F-region over periods of 24 hours one or two times per month. The observations spanned the height interval 200-900 km approximately, and achieved a time resolution of about 30 minutes. This report presents the results of the measurements made using single long pulses in a set of contour diagrams. The behavior observed during these observations is discussed briefly in terms of the diurnal, seasonal, sunspot cycle, and magnetic disturbance variations reported previously and which now are believed to be largely understood.

17. Key Words and Document Analysis. 17a. Descriptors

Millstone radar
F-region
Diurnal variations
Electron density
Ionospheric scatter
seasonal variations
temperature effects
magnetosphere
proton flux

17b. Identifiers/Open-Endod Terms

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 64
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