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COMPARISON OF IONOSPHERIC ELECTRON TEMPERATURE ROCKET MEASUREMENTS OVER NATAL, BRAZIL, WITH IRI MODEL

AUTORES/AUTHORSHIP

I.J. Kantor
P. Muralikrishna
M.A. Abdu

RESUMO - NOTAS / ABSTRACT - NOTES

A SONDA III rocket was launched from Natal on December 11, 1985, at 21:30 LT, with a Langmuir probe that measured the kinetic electron temperature in the ionosphere. The rocket reached approximately 524 km giving information on the E and F regions of the equatorial ionosphere over Natal, Brazil. The electron temperature was determined through the derivative of the current versus voltage characteristics of the Langmuir probe and the detection of the space potential. Results are compared with the IRI model, and the divergence of the results with the model is discussed.

OBSERVAÇÕES/ REMARKS

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COMPARISON OF IONOSPHERIC ELECTRON TEMPERATURE ROCKET MEASUREMENTS OVER NATAL, BRAZIL, WITH IRI MODEL

I.J. Kantor, P. Muralikrishna, M.A. Abdu

Instituto de Pesquisas Espaciais - INPE
C.P. 515, 12201-São José dos Campos, SP, Brazil

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INTRODUCTION

A sonda III rocket was launched from Natal (5.9°S, 324°E), on December 11, 1985, at 21:30 LT, with a Langmuir probe that measured the kinetic electron temperature in the ionosphere, and also a high frequency capacitance probe to measure the electron density. The electron temperature results are compared with the IRI model.

The International Reference Ionosphere (IRI) has been developed to provide a representation (rather than prediction), as function of height, geographic location, local time and sunspot number, of the quiet time ionospheric behaviour, and is based largely on the observed statistical behaviour of the ionosphere on a global basis. Since its first publication in 1978 by Rawer et al. (1978, see also Lincoln and Conkright, 1981) the IRI has undergone periodic modifications in attempts to improve its reliability as a global model for equatorial, low and mid-latitude ionospheres. These modifications have been mainly concerned with the topside electron density distribution over the equatorial low-latitude region within the equatorial ionization anomaly (see Bilitza, 1986; McNamara, 1984). Concerning the reliability of the model for different geographical zones there seems to be reasons to believe that it could be less realistic for regions in the southern hemisphere especially where the magnetic field declination has large values (Abdu et al., 1981) and in the regions of the South Atlantic Magnetic Anomaly, due to the sparsity of observational data in these regions. Therefore there is need for testing the validity of the IRI model predictions against the observational data available from these regions.

ELECTRON TEMPERATURE FROM LAGMUIR PROBE

The Langmuir probe consists of a metalic probe inside a plasma (in our case, the ionosphere), where the probe potential, V, is varied relative to the local plasma and the current, I, is measured. One, thus, obtains the probe characteristic curve I versus V.

In our present experiment, a sweep potential from -1V to 4V is applied to the Langmuir probe during 1/2 second, and the current is sampled 25 times, during each sweep (Figure 1).

Figure 2 shows the characteristic curve IxV. For very negative probe potentials, the current saturates positively due to the collection of positive ions and the repulsion of electrons, at the value

$$j = +n_o e v_s \qquad (1)$$

where j is the current density, n_o is the ion density, e is the electron charge, and v_s is the probe speed. For very positive probe potential, the current saturates negatively due to electron collection and positive ion repulsion, at the value

$$j = -n_o e \bar{v}_e \qquad (2)$$

where $\bar{v}_e$ is the electron thermal velocity, given by

$$\bar{v}_e = \sqrt{\frac{8kT_e}{\pi m_e}} \qquad (3)$$

where k is the Boltzmann constant, T_e is the electron temperature and m_e is the electron mass. The potential where the negative current begins its saturation is called the plasma potential, V_p. The potential where the current is null (equilibrium between electron and ion fluxes) is called floating potential, V_F, and is given by

$$V_F = -\frac{kT_e}{e} \ln \frac{\bar{v}_e}{v_s} + V_P \qquad (4)$$

Between V_F and V_p the probe current density can be described by

$$j = j_o \exp \frac{e(V-V_P)}{kT_e} \qquad (5)$$

where V is the potential applied to the Langmuir probe.

So the relation between the log (current) and the potential is linear, and given by e/kT_e.

Two processes for determination of the electron temperature with Langmuir probe are possible (Boyd, 1974; Ratcliffe, 1972; Aikin and Bauer, 1968): from the characteristic curve gradient and by the plasma potential detection.

From the characteristic curve gradient, one measures the linear relation between log I and V. Equation (5) gives

$$\log I = \log I_o + \frac{eV}{kT_e} \log \varepsilon \qquad (6)$$

where ε is the natural logarithm base and the inclination m is given by

$$m = \frac{e \log \varepsilon}{kT_e} \qquad (7)$$

Expression (7) in MKS units gives

$$T_e(^oK) = 5039/m \qquad (8)$$

In the plasma potential detection method, one measures (V_F-V_p), and from (4) and (3) in MKS units one can get

$$T_e = 11604\ (V_p-V_F)\ /\ \ln\ (6.213 \times 10^3 \sqrt{T_e}/v_s) \qquad (9)$$

The temperature T_e, can be iteratively calculated if the probe speed v_s is known.

LANGMUIR PROBE MEASUREMENTS

During the present flight, a sweep potential V (Figure 1) was applied, obtaining 25 samples along each sweep. The floating potential was about 1.2V, and the plasma potential around 2V. Figure 3 presents logI measurements for probe potentials at 1.4V, 1.6V, 1.8V, 2.0V and 2.2V with height. The data oscillation is being studied. With the same height scale, the local electron density, N, is shown for comparison (Muralikrishna and Abdu, 1987). An increase in current, I, above 250km is observed, where N increases.

The altitude of the probe, h (in km), is given from empirical rocket trajectory data as function of flighttime (in seconds) by

$$h = -0.00415496t^2 + 3.1652485t - 78.4299 \qquad (10)$$

and the probe speed is thus given by

$$v_s = -2 \times 0.00415496t + 3.1652485 \qquad (11)$$

Figure 4 presents data obtained between 301.486 and 325.178 seconds from flight start. This represents 10 sweeps betweeen 498.2 and 511.5 km (h=13.3km, shown in Fig. 3) during ascent. At 500km height the probe speed, v_s, from (11) is 672 m/s.

The plasma potential, Vp, is estimated to be in the range 1.95V and 2.0V. Below 1.4V the current, I, is positive. The probe electronics gives only $|I|$.

The data linear fit between 1.3 and 2.0V, gives m=3.91±0.16, and from (8), $T=(1288\pm53)^oK$ is obtained.

Figure 5 presents the IxV characteristics curve between 0.7 and 1.5V in linear current scale, in order to estimate the floating potential. The floating potential, V_F, is estimated to be in the range 1.2V and 1.35V. Considering the extreme values of V_F and V_p, $(V_p-V_F)=(0.7\pm0.1)V$, and from (9) the temperature $T_e=(1389\pm183)^oK$ is obtained.

So, for the rocket ascent, at 500km, one obtains, by the characteristics curve gradient method, T_e between 1238^{o}K and 1344^{o}K, and by the floating potential method, T_e between 1206^{o}K and 1572^{o}K. These results are compatible with each other.

Figure 6 presents T_e results obtained by the characteristics curve gradient method for the rocket ascent (solid bar) and descent (dashed bar), as a function of height.

COMPARISON WITH THE IRI-10

The Sonda III rocket was launched from Natal (5.9°S, 324°E) on December 11, 1985, at 21:30LT (23:30 UT). The rocket was launched with 82° elevation and 75° azimuth, reaching more than 500 km distance in 720s (12 minutes). The maximum height was 524.4 km. The measured electron temperature with height is presented in Fig. 6.

The electron temperature using IRI-10 model was calculated for Natal (5.9°S, 35.2°W), december, 21:30LT and sunspot number R=17.3. The result is shown also in Fig. 6.

The comparison between the results shows that the IRI model presents values much lower than the Langmuir probe measurements. However, electron density measurements for the same flight (Abdu et al., 1988) presents very good agreement. Although a single measurement cannot be very representative, it is possible that the IRI model is not very realistic for Natal region, where the magnetic field declination is very large and there is much sparsity of observation data. Oyama and Schlegel (1984) present evidences that present models do not represent well electron temperatures in equatorial regions.

CONCLUSIONS

The ionospheric electron temperature was measured for the first time over Natal, Brazil using a brazilian made Langmuir probe and a SONDA III rocket.

The electron temperature measurements using two distinct methods agreed well between themselves, but did not agree well with the IRI model.

Further rocket launches are being made with improved payload configurations to obtain better results.

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REFERENCES

Abdu, M.A., Bittencourt, J.A., Batista, I.S., "Magnetic declination control of the equatorial F-region dynamo field development and spread F", J. Geophys. Res., 86, 11443-11446, 1981.

Abdu, M.A., Muralikrishna, P., de Paula, E.R., Kantor, I.J., "Rocket borne measurements of Equatorial Ionospheric Electron Densities and their comparison with IRI-10 Predictions, to be presented in the XXVII COSPAR Meeting, Helsinki, Finalnd, 1988.

Aikin, A.C., Bauer, S.J., "The ionosphere", in HESS, W.N. and MEAD, G.D. Ed. Introduction to Space Science, Gordon and Breach, New York, 133-178, 1968.

Bilitza, D. "International reference ionosphere: Recent developments", Radio Sci., 21, 3, 343-346, 1986.

Boyd, R.L.F., "Space Physics; the Study of plasmas in space", Clarendon Press, Oxford, 1974.

Lincoln, J.V. and Conkrigtht, R.O. (Eds.), "International Reference Ionosfere IRI 79", Rep. UAG-82, World Data Center A. Boulder, Colo. 1981.

McNamara, L.F., "Prediction of total electron content using the International Reference Ionosphere", Adv. Space Res., 4, 25-30, 1984.

Muralikrishna, P. Abdu, M.A., "Private Communication", 1987.

Oyama, K.I., Schlegel, K., "Anomalous electron temperatures above the South American magnetic field anomaly", Planetary Space Science, 32(12):1513-1522, 1984.

Ratcliffe, J.A., "An introduction to the ionosphere and magnetosphere", Cambridge Univ. Press, 1972.

Rawer, K., Ramakrishnan, S., Bilitza, D. " International Reference Ionosphere", URSI, 1978.

FIGURE CAPTIONS

Fig. 1 - Langmuir probe potential with time.

Fig. 2 - Langmuir probe IxV characteristic curve.

Fig. 3 - Probe current, I, measurements during rocket ascent of probe potentials 1.4V, 1.6V, 1.8V, 2.0V, 2.2V with height, and electron density N with height.

Fig. 4 - Probe current data (I,V), around 500km during rocket ascent. The straight lines are linear fit to data.

Fig. 5 - IxV data, around 500km altitude during rocket ascent. Scales are linear.

Fig. 6 - Ionospheric electron temperature by the characteristic curve gradient method for the rocket ascent (solid bar) and descent (dashed bar), as a function of height. The dashed line presents the electron temperature using IRI-10 model.

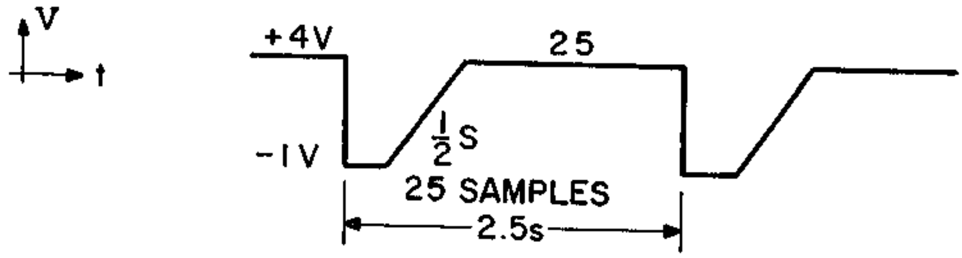


Fig. 1

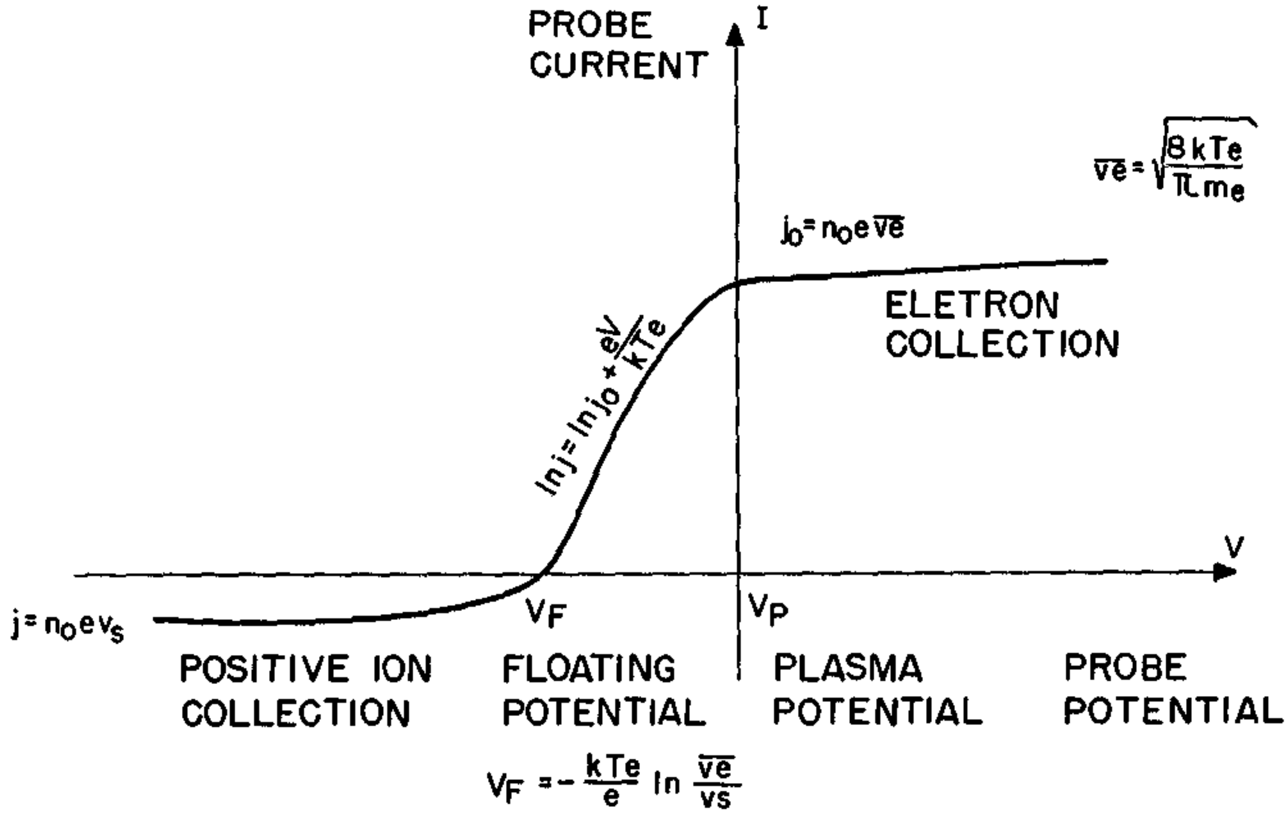

PROBE
CURRENT
I
$\overline{ve} = \sqrt{\frac{8kTe}{\pi m_e}}$
$j_0 = n_0 e \overline{ve}$
ELETRON
COLLECTION
$\ln j = \ln j_0 + \frac{eV}{kTe}$
V
V_F
V_P
$j = n_0 e v_s$
POSITIVE ION
COLLECTION
FLOATING
POTENTIAL
PLASMA
POTENTIAL
PROBE
POTENTIAL
$V_F = -\frac{kTe}{e} \ln \frac{\overline{ve}}{vs}$

Fig. 2

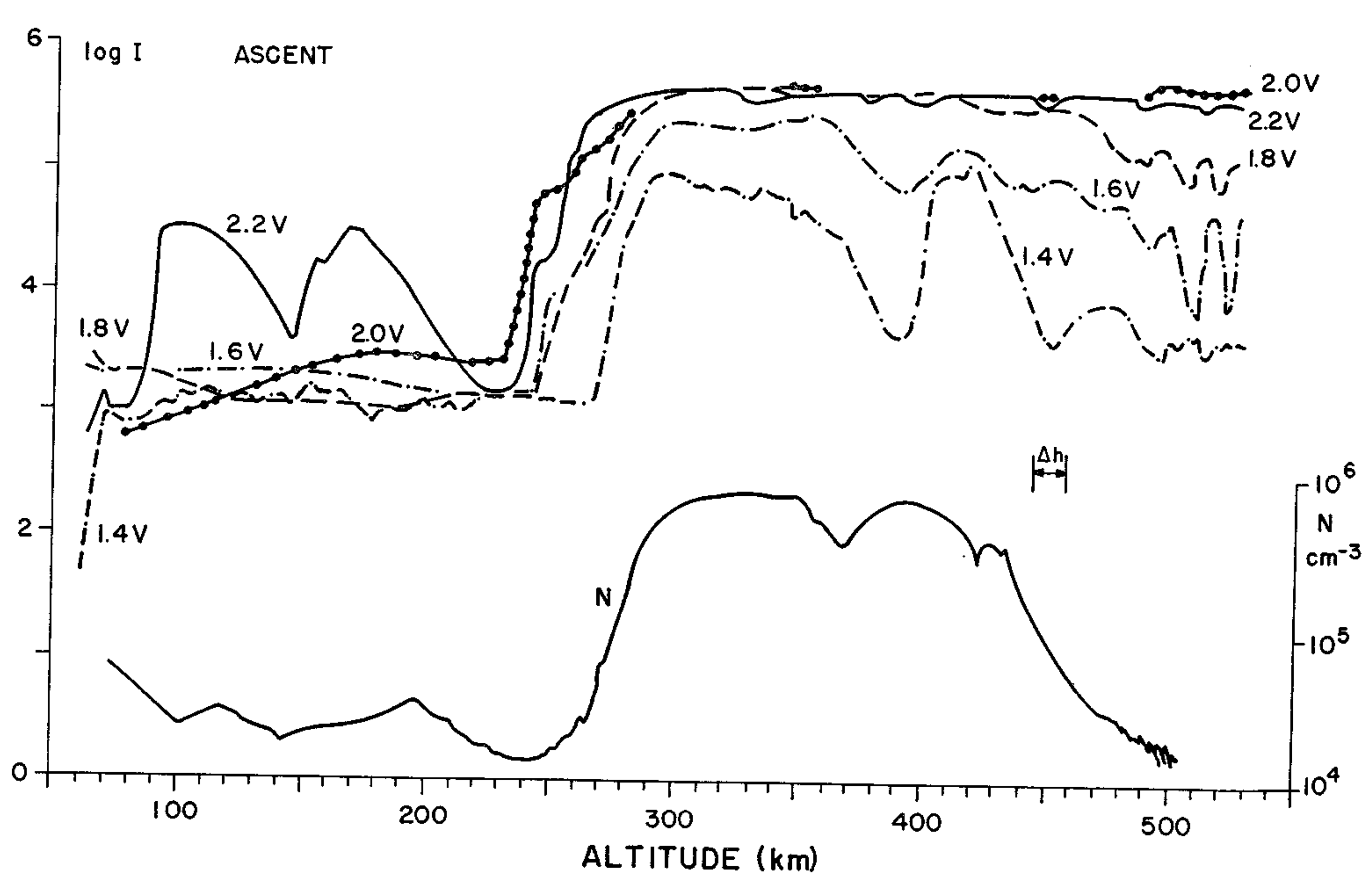

log I
ASCENT
6
4
2
0
2.2V
2.0V
1.8V
1.6V
1.4V
N
Δh
10^6
N
cm^{-3}
10^5
10^4
100
200
300
400
500
ALTITUDE (km)

Fig. 3

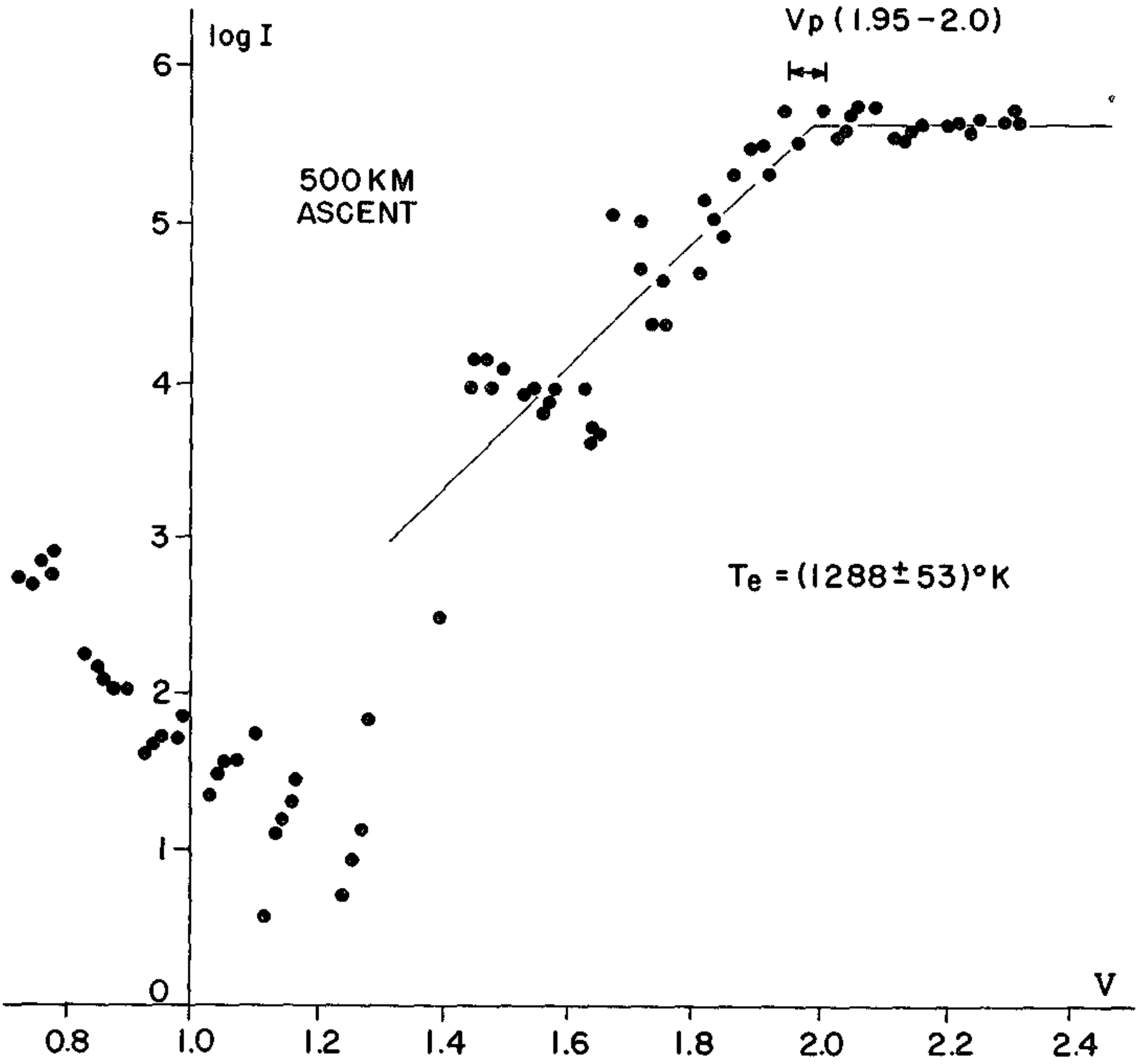
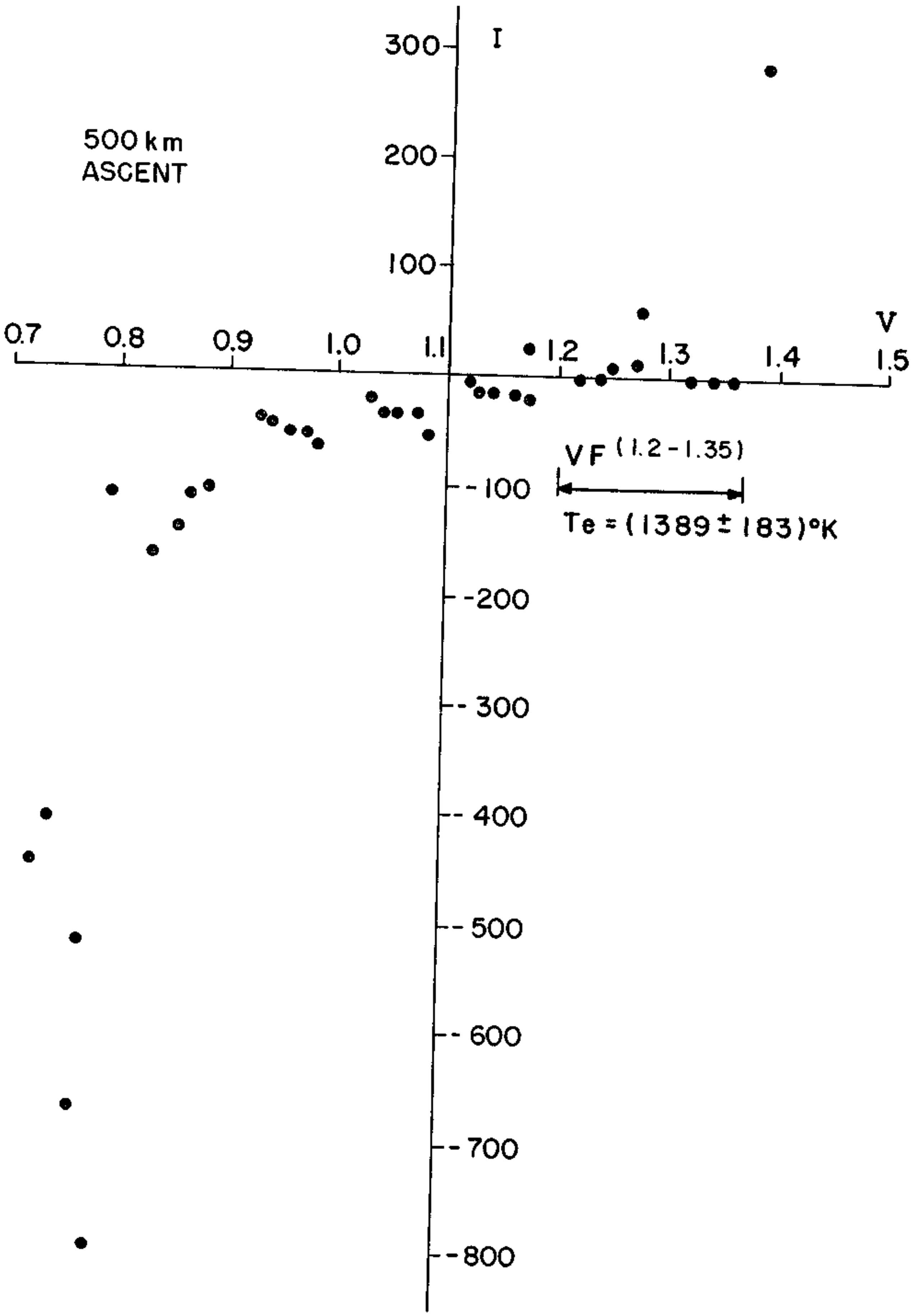

log I
Vp (1.95-2.0)
500 KM
ASCENT
Te = (1288 ± 53)°K
V
6
5
4
3
2
1
0
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4

Fig. 4



I
300
200
100
500 km
ASCENT
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
V
VF (1.2 - 1.35)
Te = (1389 ± 183)°K
-100
-200
-300
-400
-500
-600
-700
-800

Fig. 5

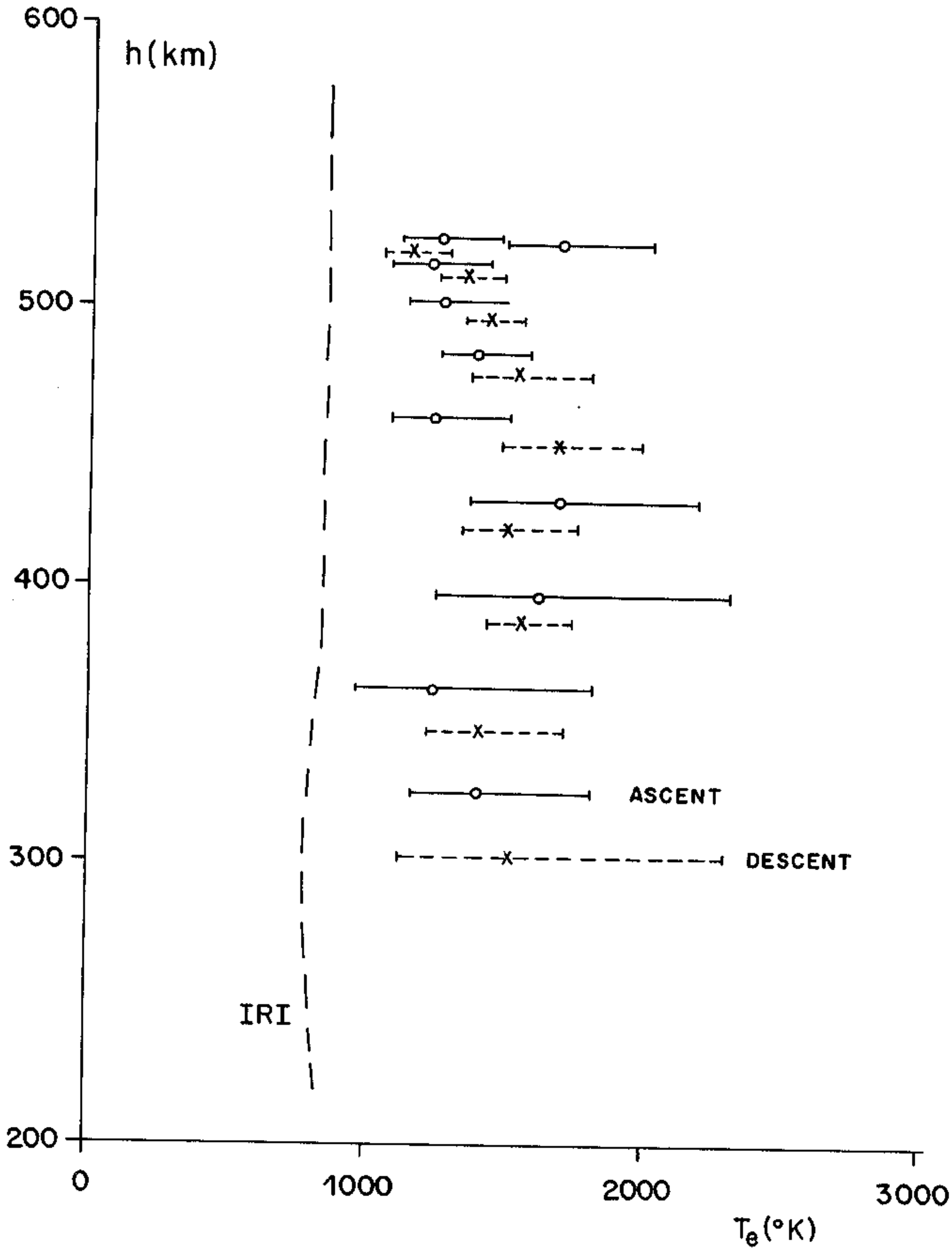

600
h(km)
500
400
300
200
ASCENT
DESCENT
IRI
0
1000
2000
3000
Te(°K)

Fig. 6