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Temperature of the $F2$ region of the Ionosphere over Kodaikanal

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ABSTRACT. In this paper noon temperature of the $F2$ region of the ionosphere over Kadaikanal has been computed by the scale height method for the months of June and December of the years 1953 and 1954, the period of low sunspot activity of the present solar cycle. The mean temperature at a height of 400 km is found to be about 1500°K. It is also observed that winter temperatures are higher than summer temperatures. This summer to winter warming up may be due to the winds in the ionosphere.

1. Introduction

In a previous paper the night-time temperature of the F region of the ionosphere over Kodaikanal (Lat. 10°.2 N, Long. 77°.5 E and Geomag. Lat. 0°.6 N) as computed from the Ionospheric Scale Height has been found to be about 1200°K at a height of 300 km (Venugopal 1960). This investigation was undertaken for the summer and winter months of the years 1955 to 1958, which form the period of high sunspot activity of the present solar cycle. Day-time temperatures could not be computed for the same period since the bifurcation of the $F1$ and $F2$ layers is not clear in the day-time ionograms of the Kodaikanal Observatory due to the thickening of the layers. The parameters of the lower layers are required for applying the the retardation correction for the computation of the $F2$ region scale height and the height of maximum ionization during the day.

In the present paper day-time temperatures of the $F2$ region of the ionosphere over Kodaikanal for the summer and winter months of the years 1953 and 1954, the period of very low sunspot activity of the present solar cycle, when the bifurcation of the $F1$ and $F2$ layers is fairly well marked in the Kodaikanal ionograms are determined by the Ionospheric Scale Height method.

2. Data and analysis

The scale height H and the absolute temperature T of the region at a height Z_0 are connected by the relation—

$$H = \frac{kT}{\mu m_0 g}\left(1 + \frac{Z_0}{R_0}\right)^2 \qquad (1)$$

where μ and m_0 are respectively the mean molecular weight of the region and the mass of an atom of Hydrogen (*i.e.*, the product μm_0 gives the mean molecular mass of the region), g the acceleration due to gravity at the earth's surface, R_0 the radius of the earth and k the Boltzmann constant. In the case of the region under consideration the oxygen is atomic and therefore μ=24.

The scale height H (which is half of the semi-thickness τ) and the height of maximum ionization Z_0 are obtained using the method due to Booker and Seaton (1940).

Retardation correction of $F2$ observations for the presence of the E region is found to be negligible. The $F1$ region is assumed to consist of half of a parabolic maximum of electron density and observations of virtual height for $F2$ region are corrected for the presence of $F1$ region. This is done by subtracting from the virtual height of $F2$ region at wave frequency f an amount $\tau\phi\ (f/f_0)$ where τ and f_0 are

TABLE 1

Height (km)	Temperatures (°K)	
	June	December
375	1050	1450
400	1400	1750

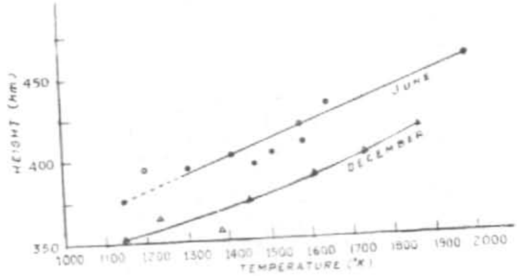

Fig. 1. Showing the variation of temperature with height

respectively the semi-thickness and critical penetration frequency deduced for the $F1$ region.

The values for the function $\phi\ (f/f_0)$ are taken from Table 1 given by Booker and Seaton (1940).

The ionograms obtained at the Kodaikanal Observatory using the National Bureau of Standards (U.S.A.) C-3 Type Vertical Sounding Multifrequency Ionosphere Recorder are used for determining the critical penetration frequencies f_0 of the $F1$ and $F2$ layers and the virtual heights h' corresponding to the wave frequencies $0{\cdot}969\,f_0$, $0{\cdot}925\,f_0$, $0{\cdot}887\,f_0$, $0{\cdot}834 f_0$ and $0{\cdot}757 f_0$. The height of maximum ionization Z_0 and semi-thickness τ are obtained by substituting any two values of h' corresponding to any two values of (f/f_0) in the equation

$$h' = Z_0 + \tau\phi\ (f/f_0) \qquad (2)$$

and solving simultaneously.

Values of Z_0 and H are obtained thus for the five half hours centred round local noon for all the quiet days of June and December of 1953 and 1954. The average values of Z_0 and H for each day are evaluated and the temperature computed using equation (1).

Curves connecting heights and temperatures for both the summer and winter months are drawn (Fig. 1).

From the curves the temperatures for different heights for the two seasons are read off: these are tabulted in Table 1.

3. Results and discussion

From the values of Z_0 obtained for the various days it is seen that the average height of maximum ionization at noon during the period under consideration (1953, 1954) is about 400 km and the average temperature at that height is round about 1500°K. From Table 1 of the previous paper (Venugopal 1960) it is seen that the average night temperature at a height of 400 km is round about 1500°K. This, however, should not lead to the conclusion that night and day temperatures are equal. It should be borne in mind that in the present paper the noon temperatures are computed for the lowest solar activity period (relative sunspot number almost zero) whereas the night-time temperatures given in the earlier paper (Venugopal 1960) are for the increased solar activity period (1955 to 1958). A comparison of the electron densities during the two periods considered will make this clear. Whereas the average night-time electron density at a height of 400 km given in the earlier communication is $9{\cdot}9 \times 10^5$/c.c. nearly, that at noon at the same height computed from observations of critical frequency used in this investigations is about $5{\cdot}4 \times 10^5$/c.c. Baral and Mitra (1951) have calculated the temperature of the $F2$ region over Calcutta and have found that for the period of high solar activity the temperature varies from 700°K in winter to 1200°K in summer and during the period of low solar activity from 500°K in winter to 900°K in summer. Hence, it can be inferred that the average temperature is higher during periods of high solar activity. Also, this is suggestive of diurnal temperature variations with day-time temperatures higher than those of the night as against the observation of

Gerson (1951) that no large diurnal temperature variations are found in the altitude range 100 km to 400 km.

Since the average noon temperature of the $F2$ region of the ionosphere over Kodaikanal during the period of very low solar activity (relative sunspot number almost zero) has been found to be about 1500°K and since the temperature is also known to increase with solar activity temperatures of the order of 2000°K can be expected at noon at the levels of the $F2$ layers during the period of maximum solar activity. This agrees fairly well with the temperatures deduced purely on theoretical considerations by Das (1936, 1937). He has outlined a tentative theory on the assumption that neutral atomic oxygen absorbs out of the solar radiation the forbidden lines λ 2972, λ 5577, λ 6300 and λ 6364 and attains a high equilibrium temperature at which the absorbed radiations can be re-emitted and has shown that the day-time temperature of the upper atmosphere can range from 1400° to 2900°K.

It is also seen from the curves and Table 1 that winter temperatures are higher than summer temperatures. A similar observation has been made for the night temperatures also (Venugopal 1960) and it has been suggested that the winds in the ionosphere may be responsible for the apparent summer to winter warming. Ramachandra Rao and Bhagiratha Rao (1959) from their studies of horizontal drifts in the $F1$ and $F2$ regions of the ionosphere over the low latitude station Waltair (Lat. 17° 43′N, Long. 83°18′E and Geomag. Lat. 9° 30′N) have shown that the winter drift speeds are in general higher than the summer values increasing from 75 m/sec in summer to 95 m/sec in winter. Systematic measurements of winds in the $F2$ region at Kodaikanal, if undertaken, will help to check this tentative conclusion that the winds in the ionosphere may be responsible for the higher winter temperatures compared to those of summer.

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