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Study of TEC & Equivalent Slab Thickness & Their Relationship with Ion Drifts & Ionospheric Temperatures

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The relationships of daytime total electron content and equivalent slab thickness with ion drifts and ionospheric electron temperature, respectively, have been examined. The data have been taken from the incoherent scatter radar measurements at Arecibo (lat., 18.3°N; long., 66.7°W) for the period Aug. 1974-May 1977. Some 800 profiles of electron density, electron temperature and ion drifts have been analyzed. The electron content is found to increase with increase in the vertical ion drift. There is, however, a time lag between the change in the ion drift velocity and the effect on electron content and this time lag varies from a few minutes to several hours, depending upon the height of the F-layer peak. The daytime equivalent slab thickness is seen to increase with the increase in electron temperature.

1 Introduction

Measurements of the electron content of the ionosphere have been made mostly by using the radio beacons on the low orbiting and geostationary satellites. An important result on the electron content has been its large variability from one day to the next and this could only be identified from the long continuous records obtained from the geostationary satellites[1-3] like Syncom-3, ATS-3 and ATS-6. While this variability, by and large, reflects changes in peak electron density, another important parameter which can cause this variability is the equivalent slab thickness, which is the ratio of electron content and peak electron concentration. Unfortunately, the radio beacons do not give information on any other parameter which controls the electron content and the slab thickness. It is now known from theory that the F-region electron content, in addition to the familiar loss and production mechanisms, is significantly controlled by the ion drifts. The incoherent scatter technique simultaneously measures the electron concentration, electron and ion temperatures, and ion drifts. In this paper we shall study the behaviour of electron content and equivalent slab thickness in relation to these simultaneously observed parameters by using the incoherent scatter measurements at Arecibo (18.3°N, 66.7°W).

2 Experimental Data

The incoherent scatter data used in the present analysis have been taken from radar measurements at Arecibo for the period Aug. 1974-May 1977. The measurements were made under the I9/I29 observation program of the Arecibo Ionospheric Observatory, as described by Harper and Ganguli[4].

The data have been obtained from the World Data Center A for Solar and Terrestrial Physics, Boulder, Colorado, USA. The electron and ion temperatures were deduced assuming a pure O^+ ionic composition[5] above 250 km. The Arecibo measurements gave (N/N_{max}) as a function of height. The peak electron density was read from an on-site ionosonde and thus the true electron density profile was obtained.

As the electron density profiles were available only up to an altitude of 500 km, we obtained the total electron content (TEC) during daytime (0800-1600 hrs), by performing the numerical integration of the electron density profile up to 500 km only. This procedure obviously results in underestimating the electron content. But as major contribution to the electron content comes from heights around the F2 peak, the underestimation may not be very significant since the contribution from heights above 500 km is perhaps not more than 15%.

As the incoherent scatter radar directly measures the normalized electron density profile (N/N_{max}), the integrated normalized profile gives the equivalent slab thickness directly and, therefore, the slab thickness is a more reliable parameter from the incoherent scatter radar measurements. The vertical ion drift velocity (V_z) and electron temperature (T_e) data have been taken for a height of 261 km to represent approximately the conditions around the height of F2 peak.

3 Variations of TEC and V_z

Fig. 1 shows the daytime variation of TEC and V_z for three days, one each during winter, equinox and summer seasons of the year 1976. The height of the peak electron concentration is also plotted in Fig. 1. As we know, the upward ion drift will take the ionospheric

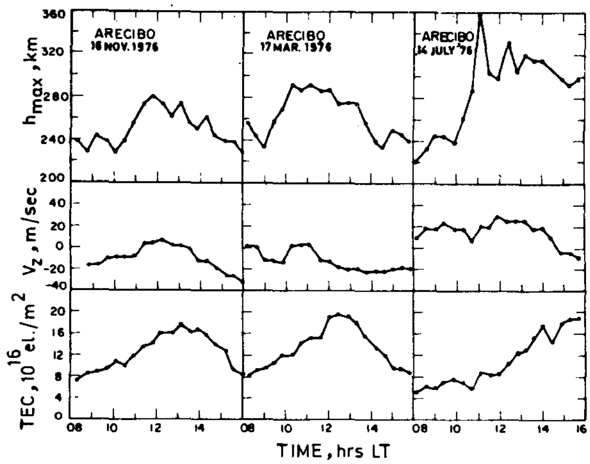

Fig. 1—Daytime variations of TEC, vertical component of ion drift velocity (V_z) at 261 km altitude and height of the peak electron density at Arecibo

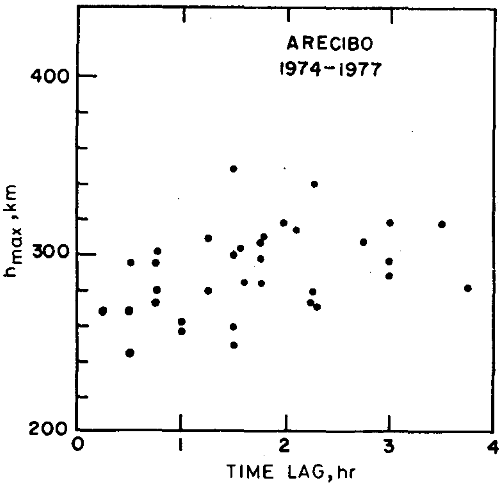

Fig. 2—Plot of the time lag between peaks of electron content and V_z as against h_{max}

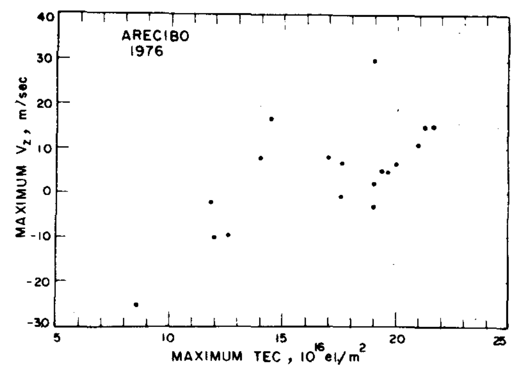

Fig. 3—Scatter plot of daytime maximum TEC and maximum V_z for all the days during 1976

F-region to higher heights to regions of lower electron loss rates, thus resulting in an increase in electron concentration (and TEC) during daytime. It can be noted that on all the 3 days the daytime electron content increases with increase in the vertical ion drift velocity and decreases with decreasing vertical ion drift velocity. There is, however, a time lag between the change in the ion drift velocity and its effect on TEC variation. This time lag is different for the three days and depends mainly on the height of peak electron density (h_{max}) as can be noted from the diagram where h_{max} is also plotted. During the winter day, when h_{max} was low, TEC variation responded rather fast to changes in V_z, i.e. the time delay between changes in V_z and corresponding changes in TEC was quite small (of the order of few minutes), as can be noted for the case of 16 Nov. 1976. The peak in V_z occurred around 1215 hrs and the peak in TEC around 1300 hrs, i.e. the time lag was about 45 min. On the day during equinox, when h_{max} was a little higher than the winter day, this time lag increased, as can be seen from the case of 17 Mar. 1976. The peak in V_z occurred around 1100 hrs and in TEC it occurred around 1230 hrs. On the day during summer when h_{max} was the highest, the time lag was maximum as can be seen for 14 July 1976 (Fig. 1). The peak in V_z occurred around noontime and the variation of TEC could not show the occurrence of clear peak, even at 1600 hrs. Further, to study the dependence of time lag (i.e. electron loss coefficient) on the height of peak electron density (h_{max}), we have examined all the data on electron density and V_z for the period Aug. 1974-May 1977. Diurnal plots of V_z and electron content were obtained for all days during this period for local times between 0800 and 1600 hrs. We then selected only those cases where diurnal peaks could be found both in V_z and electron content. The time lag between these two peaks were then plotted against the h_{max}, corresponding to the time of the V_z peak, as shown in Fig. 2. It is clear from the scatter plot that a positive correlation exists between h_{max} and time lag, thereby demonstrating that electron loss rates are high at lower heights and decrease with height.

It is difficult to study the relationship of TEC and V_z for long term variations, as one cannot unambiguously account for the changes in the response time due to changes in h_{max}, following the V_z changes. We have, however, attempted to study this correlation by plotting the maximum daytime values of TEC against maximum daytime values of V_z for the year 1976 as shown in Fig. 3. However, it was ascertained, that the time lag between the occurrence of peaks of these two parameters was consistent with the electron loss rate expected at h_{max}. There is a fair correlation between maximum TEC and maximum V_z during daytime, thus demonstrating the effect of ion drifts on TEC.

4 Variations of Slab Thickness and T_e

Fig. 4 shows the variation of daytime (0800-1600 hrs) slab thickness and electron temperature on 3 days,

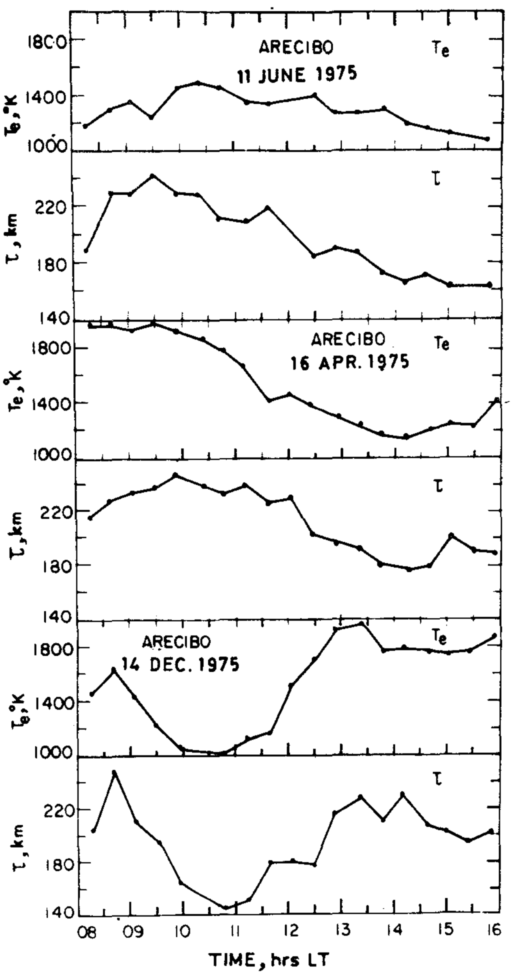

Fig. 4—Daytime variations of equivalent slab thickness and electron temperature at an altitude of 261 km on three days during 1975

one each in winter, equinox and summer during 1975. It can be noted that during all the seasons, changes in T_e are faithfully reflected in changes in slab thickness. On 14 December 1975, there are two peaks in T_e variation occurring around 0845 and 1400 hrs and the variation in slab thickness shows the occurrence of similar peaks, exactly at the same local time. The nature of variations in slab thickness and electron temperature is identical in equinox and summer seasons also.

Fig. 5 shows the scatter plot of equivalent slab thickness against electron temperature for noontime (1100-1300 hrs) for all the available days during 1975 and 1976. The temperature values were taken for a height of 261 km. From the scatter of points it is clearly noted that a fair positive correlation exists between

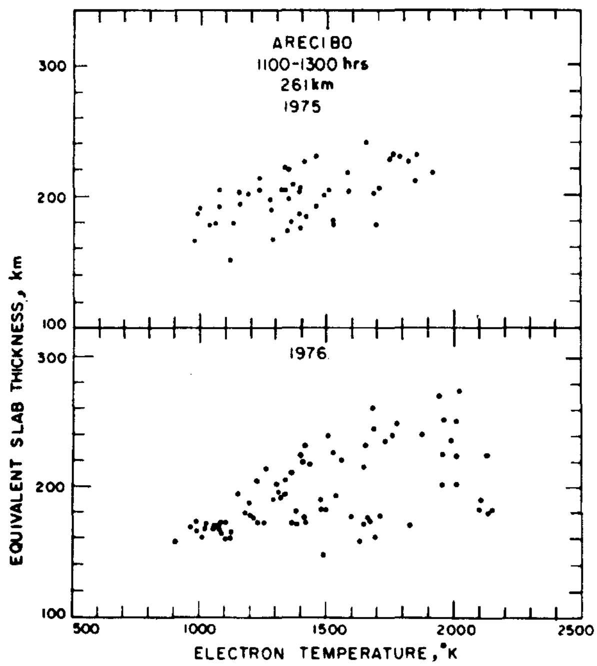

Fig. 5—A scatter plot of noontime electron temperature at an altitude of 261 km and equivalent slab thickness during 1975 and 1976

these two parameters. This correlation between slab thickness and T_e was reported by Mahajan *et al.*[6] from the earliest measurements at Arecibo.

Thus from the short term as well as long term variations of τ and T_e during daytime, it is seen that the slab thickness can be taken as an index of ionospheric electron temperature around the F2 peaks.

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