Electron Density Trough in the Topside Ionosphere &
Its Relationship with the Plasmapause Position*

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The ionospheric trough observed around 60° latitude has been suggested by several earlier
workers to be a field-aligned extension of the magnetospheric 'knee' (or 'plasmapause')
phenomenon. The Langmuir probe data obtained from the Tiros-7 satellite are used in the
present work to study this relationship. These ionospheric data are compared with published
whistler data for the same period. The trough is observed to move to higher L values during
night-time in response to increasing scale heights in the topside ionosphere. The discrepancy
between the trough and knee positions is, however, reduced for moderately high magnetic
activity. The theoretically predicted plasmapause position from plasma convection speed
considerations shows better agreement with Tiros-7 observations than with the whistler data
during quiet and disturbed periods.

Introduction

The Tiros-7 satellite, which was launched on
June 19, 1963 into a near-circular orbit at an
altitude of about 650 km, carried a cylindrical
electrostatic probe for measuring local electron
densities. The satellite also carried on board a tape
recorder so that data from a complete orbit was
available on interrogation. The inclination of the
satellite was 58° and the satellite could reach
geomagnetic latitudes of up to 70°. These features,
combined with the high spatial resolution of
measurements (a few data points in every degree
of latitude), made the data uniquely suitable for
studying the midlatitude trough of the ionosphere
at the altitude of 650 km. Due to a fortunate
coincidence, data on the position of the plasmapause
during the same period during July 1963 were
obtained by Carpenter from whistlers recorded at
Eights and Byrd stations in Antarctica. This en-
abled a very realistic comparison of the plasmapause
and the ionospheric trough during quiet and disturbed times.

Though the first indication of a faster decrease of
ionization at large altitudes came from the ion-trap
measurements conducted from the Soviet Luna
probes, the dramatic realization of the 'knee'
phenomenon was established later in 1963 by Car-
penter using the whistler technique. This feature
has since been studied in detail by direct satellite
measurements with the aid of ion mass spectrometers. The first extensive study of the iono-
spheric trough at the F2-peak was done by Muldrew in 1965 who suggested that the trough is a fieldaligned extension of the knee phenomenon. At F2-
peak, however, the trough was not obvious during
daylight hours, probably because of the dominance
of local production. From Explorer-22 measure-
ments, Brace and Reddy reported in 1965 that the
trough exists during day and night at 1000 km,
though the gradients are more marked during night-
time. Rycroft and Thomas have recently com-
pared the plasmapause data of Carpenter and the
trough data at 1000 km (from Alouette-I), and have
concluded from the morphology that both are
related phenomena.

Results and Discussion

The 'Trough' from Actual Data Points

The cylindrical electrostatic probe has been
successively employed on several rockets and satel-
lites and the experimental details of this particular
payload have been described elsewhere. Fig. 1

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shows a plot of three passes in July 1963 during night-time. The steep gradients in electron density and the consistency of these gradients is obvious from Fig. 1 which also illustrates the usual pattern of shift in the trough position as the local time and longitude change from pass to pass. It has also been observed that the apparently random shift of the trough position is minimized if $L$ values (McIlwain's parameter) are used rather than the geomagnetic coordinates, and accordingly the subsequent figures are based on the $L$ coordinate system. This naturally proves the magnetic shell control of the trough phenomenon.

**Local Time Variation in the 'Trough' and 'Knee' Positions**

The local time variations of the trough location in the $L$ system is shown in Fig. 2. The position of the knee (plasmapause) as derived from the whistler measurements in the same period is also shown by the thin curve for comparison. However, all the data points in the diagram pertain only to the trough data from Tiros-7.

The striking features that can be noticed from diagram are:

1. The scatter of the data points during nighttime is very large compared to the daytime. This may be because the $L$ values of the night-time trough position are rather large and at high latitudes even small latitudinal variations result in larger $L$ variations because of the high divergence of the terrestrial magnetic field.

2. The discrepancy between the knee and the trough positions is large during the night-time and is negligible between 1100 and 1700 hrs local time. This discrepancy can easily be understood at least at this altitude from scale height considerations. At the altitudes in question, considerable changes in ion mass will occur from day to night with little change in temperature at the trough latitudes. So, the decreasing mean ion mass after sunset will increase the scale height so that the electron density above the F$_2$-peak does not decrease rapidly with altitude, which means the low density region at 650 km is pushed to higher latitudes.

3. Around 1700 hrs local time, the increase in the knee position is much more rapid than the trough position. This seems to lend support to Nishida's theory of the solar wind-induced magnetospheric convective motion with the superposed effect of the earth's rotation. Nishida contends that the velocity shear at the 1800 hrs meridian promotes the generation of whistler ducts owing to the field-aligned density inhomogeneity. This shear turbulence extends higher beyond the real plasmapause, and whistlers, being sensitive only to the high density ducts but not to the surrounding ambient plasma, give a higher value of $L$ for the plasmapause.

**$K_p$ Variation of Trough and Knee Positions**

Fig. 3 shows the variation of the trough position in $L$ parameter with varying magnetic activity ($K_p$). For a good statistical study, the data presented in Fig. 3 have been restricted only to the night side, because of data limitations on the day side. This is again compared with the results obtained by Carpenter for the plasmapause position around the same period. It may be noted from the figure that Carpenter's results are at variance with the trough data obtained from Tiros-7 except for moderately disturbed periods. The large values of $L$ for the trough position can partly be attributed to the fact that daytime data were excluded in the figure, and as was evident in Fig. 2, the night-time $L$ values of the trough are, in general, much higher than for the knee. However, it seems certain that the trough position is much more sensitive to magnetic activity than the position of the plasmapause.

Nishida has theoretically calculated the position of the plasmapause for varying values of plasma...
One of the conflicts as observed from Tiros-7 data is the very large $L$ values for the trough position during the night and early morning hours. Yet another major conflict is the much greater dependence of the trough position on magnetic activity than the position of the plasmapause. This is to be expected because the high latitude ionization greatly depends on the magnetic activity at the ionospheric levels. However, rather unexpectedly the plasmapause position calculated from the plasma convection speed agrees better with the ionospheric trough position than with the observed knee position. It may also be noted in this connection that it is known from other studies that the trough position did not change significantly with increasing solar activity. If the plasmapause is an approximate boundary between the open and the closed magnetic field lines, the knee and the trough positions might be expected to be affected significantly with solar activity. It has been observed on several occasions, especially during disturbed daytime, that the position of the trough approaches $L$ values less than 3 and it will be impossible to explain such low values on the basis of the boundary between open and closed field lines. Coordinated experiments to monitor the trough position, the knee position, and the boundary between open and closed field lines (for example, the photoelectron flux experiment) will have to be conducted to understand these phenomena.

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