AD-A055 651 REGIS COLL RESEARCH CENTER WESTON MASS F/G 4/1

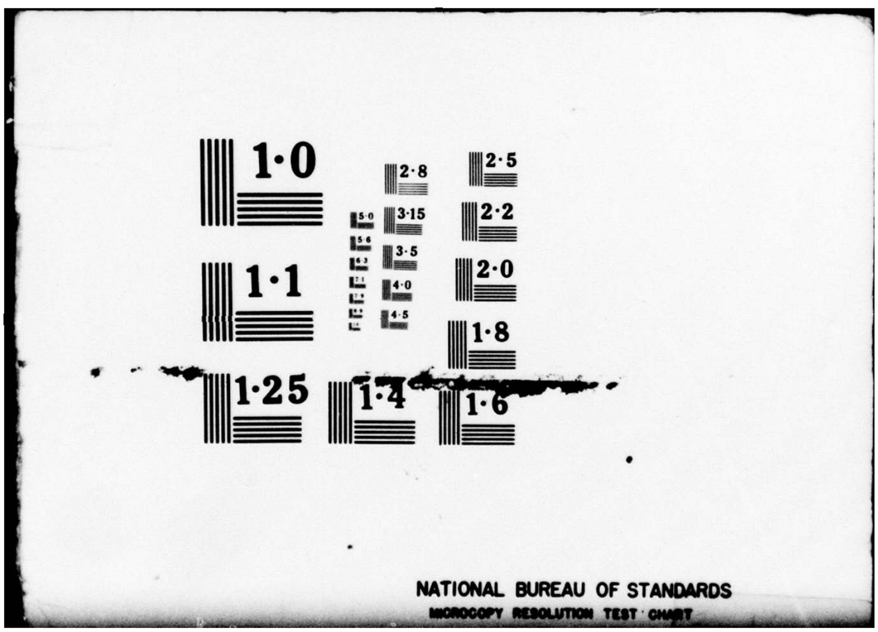
TOPSIDE IONOSPHERIC TROUGH MORPHOLOGY AT MID- AND HIGH-LATITUDE--ETC(U)

MAY 78 M AHMED, R C SAGALYN F19628-77-C-0122

UNCLASSIFIED SCIENTIFIC-2 AFGL-TR-78-0110 NL

1 OF 1
ADA
055651

END
DATE
FILMED
8-78
DDC


1·0
1·1
1·25
1·4
1·6
1·8
2·0
2·2
2·5
2·8
3·15
3·5
4·0
4·5
5·0
5·6
6·3
NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AD A055651

AD NO.

DDC FILE COPY

19 REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: 18 AFGL-TR-78-0110	2. GOVT ACCESSION NO.: 9 Rept. for 1 Oct 77-31 Mar 78	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): 6 TOPSIDE IONOSPHERIC TROUGH MORPHOLOGY AT MID- AND HIGH-LATITUDES		5. TYPE OF REPORT & PERIOD COVERED: Scientific Report No. 2; 01 OCT 77 - 31 MARCH 78
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): 10 M. Ahmed; R. C. Sagalyn		8. CONTRACT OR GRANT NUMBER(s): 15 F19628-77-C-0122
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Regis College Research Center, 235 Wellesley Street, Weston, Massachusetts 02193		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 61102F 16 2311; 2311G2AE 17 G2
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Geophysics Laboratories (PHR), Hanscom AFB, Massachusetts 01731, Monitor/Susan Bredesen		12. REPORT DATE: 11 May 1978
		13. NUMBER OF PAGES: 12 12 12p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office): 14 SCIENTIFIC-2		15. SECURITY CLASS. (of this report): Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distrubution unlimited

DDC
MAY 12 1978
F

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Reprinted from the Proceedings of IES, 1978 Symposium on the Effect of the Ionosphere on Space and Terrestrial Systems, Jointly sponsored by Naval Research Laboratory and the Office of Naval Research, January 24-26 1978.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

trough
ionosphere
plasma densities
plasmapause

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The main trough in the topside ionosphere has been studied using the thermal positive ion and electron densities meausured over a three year period (1969-1972) by means of spherical electrostatic analyzers aboard the ISIS I and INJUN V satellites in the 560-3600 km altitude range. The trough is found to be a persistent feature at night with an occurrence frequency of approximatley 95%. The occurrence frequency decreases to approximately 60% near the dawn-dusk meridian and to approximately 48% near local noon. At altitudes

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

409 491 JOB

20. (continued)

below about 1500 km during quiet to moderate conditions ($Kp \leq 3$) the trough equatorward boundary is found at $L = 3.5 \pm 1.0$ near local noon. The trough equatorward location on the nightside is in good agreement with published plasmapause locations. Near local noon the trough occurs at the equatorward edge of the magnetospheric cleft and is at significantly higher L values than those reported for the dayside plasmapause. The seasonal variation of the trough location at a given time is negligible near sunrise.

With increasing altitude between 1500 and 3600 km, the equatorial boundary of the trough moves to continually lower latitude during the night hours. The equatorward trough wall becomes a dominant feature of the trough often extending from 15° to 20° in width during quiet magnetic periods. The poleward edge of the trough becomes less well marked with increasing altitude often being defined only by a sharp spike in ionization extending a few degrees within the auroral zone. The amplitude of the dayside high latitude trough reduces gradually with increasing altitude. However, a second region of dayside plasma depletion is observed between L = 2 and 6 approximately 50% of the time. The equatorward wall of this depletion region probable represents partial flux tube filling in the outer plasmasphere.

DISCLAIMER NOTICE

AFGL-TR-78-0110

TOPSIDE IONOSPHERIC TROUGH MORPHOLOGY AT MID- AND HIGH-LATITUDES

M. Ahmed
Regis College
Weston, MA 02193

and

R.C. Sagalyn
Air Force Geophysics Laboratory
Hanscom AFB, MA 01731

ABSTRACT

ABSTRACT

The main trough in the topside ionosphere has been studied using the thermal positive ion and electron densities measured over a three year period (1969-1972) by means of spherical electrostatic analyzers aboard the ISIS I and INJUN V satellites in the 560-3600 km altitude range. The trough is found to be a persistent feature at night with an occurrence frequency of approximately 95%. The occurrence frequency decreases to approximately 60% near the dawn-dusk meridian and to approximately 48% near local noon. At altitudes below about 1500 km during quiet to moderate conditions ($Kp \le 3$) the trough equatorward boundary is found at $L = 3.5 \pm 0.5$ near midnight and $L = 12.5 \pm 1.0$ near local noon. The trough equatorward location on the nightside is in good agreement with published plasmapause locations. Near local noon the trough occurs at the equatorward edge of the magnetospheric cleft and is at significantly higher L values than those reported for the dayside plasmapause. The seasonal variation of the trough location at a given local time is negligible except near sunrise.

< OR =

+ OR − + OR −

ABSTRACT

With increasing altitude between 1500 and 3600 km, the equatorial boundary of the trough moves to continually lower latitudes during the night hours. The equatorward trough wall becomes a dominant feature of the trough often extending from 15° to 20° in width during quiet magnetic periods. The poleward edge of the trough becomes less well marked with increasing altitude often being defined only by a sharp spike in ionization extending over a few degrees within the auroral zone. The amplitude of the dayside high latitude trough reduces gradually with increasing altitude. However, a second region of dayside plasma depletion is observed between L = 2 and 6 approximately 50% of the time. The equatorward wall of this depletion region probably represents partial flux tube filling in the outer plasmasphere.

INTRODUCTION

Mid-latitude troughs or depressions in the F layer ionization were first reported by Muldrew (1965) and Sharp (1966). Further studies of trough characteristics have been carried out by a number of workers including Miller and Brace (1969), Rycroft and Thomas (1970), Tulunay and Sayers (1971), Taylor et al. (1975) and Grebowsky et al. (1976). Statistical studies of the relation of the trough to the plasmasphere (Thomas and Andrews, 1968, Tulunay and Sayers, 1971, and Grebowsky et al. 1976), have shown that mid-latitude charge density depletions occur near the same L shells as the average plasmapause position on the nightside. Rycroft and Thomas (1970) and Tulunay and Sayers (1971) established that the trough position varies with Kp in a manner similar to the plasmapause dependence upon magnetic activity. Taylor et al. (1974) have shown that the trough exists in the individual ion species H^+, He^+ and O^+.

Studies of the diurnal, seasonal and altitude variation of the trough characteristics have led to confusing results (Wrenn and Raitt, (1975). Miller (1974), for example, reported that dayside troughs persisted above 2500 km while below they were seldom detectable. There are several reasons for the differences in trough results. These include use of a limited data base, widely varying altitude of the measurements, varying spatial resolutions of the measurement from a few km to nearly 1000 km, difficulties in detecting dayside features due to photoelectrons as well as varying criteria used to define the trough location. Tulunay and Sayers (1971) for example, used the trough minimum, while Brace and Theis (1974) used a density level of 10^3 electrons/cm^3 along the equatorial trough wall.

The present study seeks to contribute new knowledge of the trough characteristics as a function of local time, season and altitude. The trough occurrence frequency is also presented as a function of local time. The study is based on the examination of thirty-seven months of ISIS I positive ion and INJUN V electron probe data. The relation of the trough to the plasmapause is examined at all local times.

THE EXPERIMENT

ISIS I thermal charged particle measurements were obtained with a spherical electrostatic analyzer that measured the thermal ion density, the ion energy distribution from 0 to 50 eV, *the satellite potential*, and the ratio of the ion mass to the ion temperature. The sensor mounted on a 96 cm boom, consists of three concentric spherical electrodes with radii of 1.90, 2.54 and 3.18 cm respectively. The operation of the probe is based on the motion of charged particles in a central force field (Sagalyn, et al., 1963, Sagalyn and Smiddy, 1967, Smiddy and Stuart, 1969, Whitteker et al., 1972). The sensitivity range of the instrument is $10\text{-}10^6$ ions cm^{-3}, in sunlight, however, photoelectron currents limit the lower sensitivity to about 700 ions cm^{-3}. Ion densities were sampled 60 times per second, corresponding to a spatial resolution of 150 m. The ratio of mass to temperature was sampled once per minute, and the energy distribution was samples once every 2 min. The results in this report are based on the ISIS I ion density mode of operation and also on measurements made with a two electrode spherical probe flown on INJUN V with a spatial resolution of 2 km.

DATA BASE

The ISIS I satellite served as an ideal platform for the study of diurnal and seasonal morphology of the trough, since its orbital plane precessed nearly one hour of local time per week, providing a complete 24 hour coverage in about 3 months. Data obtained within 45 days of the equinox and solstice periods were utilized for the seasonal study.

The statistical portion of the study reported here utilizes thermal positive ion density measurements on about 12,000 ISIS I orbits between Febraury 1969 and March 1972. The measurements have a spatial resolution of 150 meters and are well suited for the study of trough characteristics. In addition, thermal ion and electron densities measured by similar instruments aboard the INJUN V satellite on about 3000 orbits between November 1968 and November 1970 were used to improve the data base within a few hours of local noon. The data cover the altitude range 550-3600 km and all local times and seasons.

For the diurnal studies of trough characteristics about 20 to 25 clearly identifiable troughs were available in each hour of local time in each season. Seasonal variations were deduced utilizing data collected in three successive years. Northern hemisphere data obtained during magnetically quiescent and slightly disturbed conditions i.e. $Kp \leq 3$ were used in the statistical portion of this study.

RESULTS BELOW 1500 km

a. Definition of Trough Parameters

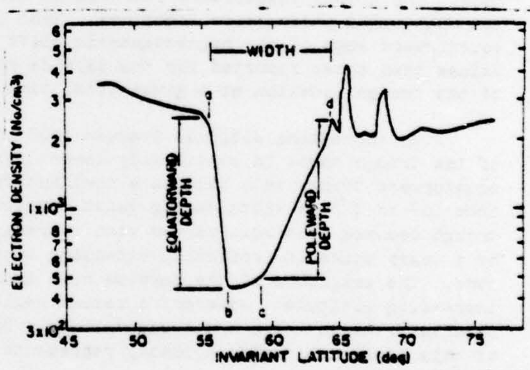
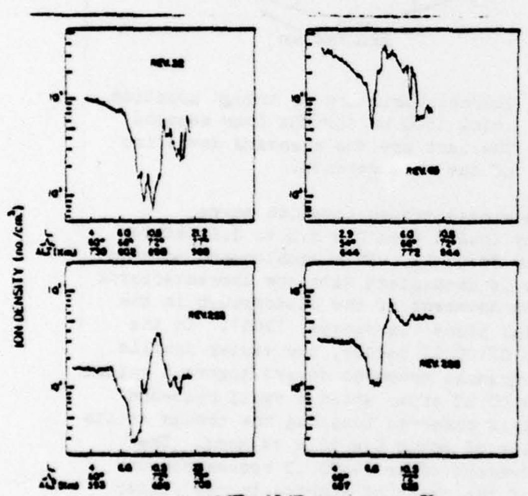


Fig. 1. Example of low altitude trough (<1500 km) where points 'a' and 'b' denote the location of top and base of the equatorial edge respectively. Points 'c' and 'd' denote the location of the base and top of the poleward edge.

A representative low altitude trough is shown in Fig. 1. Point 'a' denotes the location of the trough equatorward edge. It is the point marking the onset of a major decrease in ionization density with increasing latitude.

'b' denotes the base of the equatorward wall, 'c' the base of the trough poleward wall. The top of the poleward edge, point 'd' is the intersection of lines drawn along the trough poleward wall and through the first ionization maximum in the precipitation region. The ratio of the densities at *points a/b* and *d/c* represent the trough amplitudes at the equatorward and poleward edges respectively.

While there is considerable variation in the trough amplitude, width and gradient from orbit to orbit as illustrated in Figs. 2, 3 and 4, points *'a' through 'd' can usually* be readily measured for altitudes below about 1500 km. The widths of the equatorward and poleward walls typically range from 1^{o} to 4^{o}. The high latitude precipitation region extends over several degrees and is highly structured The trough width and amplitude are consistently smaller on the dayside than on the nightside as illustrated in Figs. 4 and 2, respectively. The equatorward edge of the trough wall point 'a' of Fig. 1, was taken as the trough location for the study of results below 1500 km.



MLT. = 22 hrs $\pm$ 30 min

Fig. 2. Nighttime low altitude (<1000 km) trough examples.

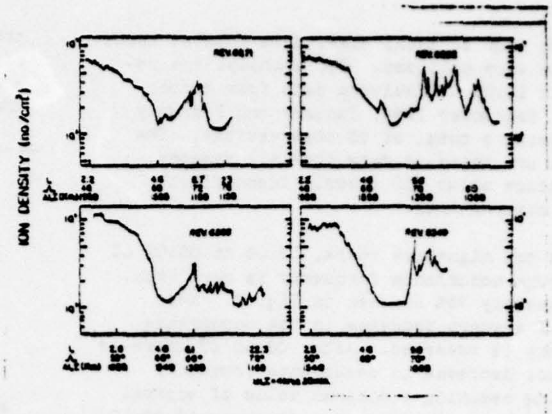


Fig. 3. Examples of troughs between 1000 and 1600 km within 4 hours of midnight.

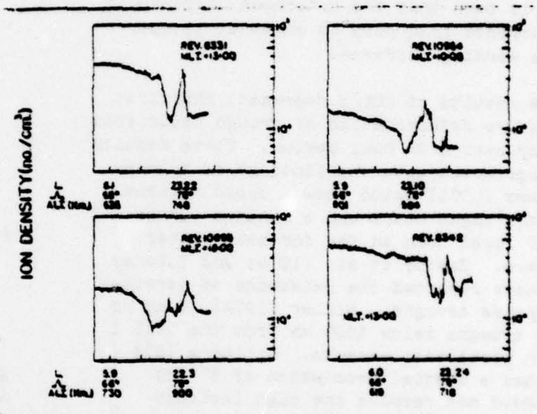


Fig. 4. Low altitude (<1000 km) daytime trough examples within 3 hours of noon.

b. Trough Occurrence Frequency

The trough occurrence frequency as a function of local time is given in Fig. 5 for altitudes below 1500 km.

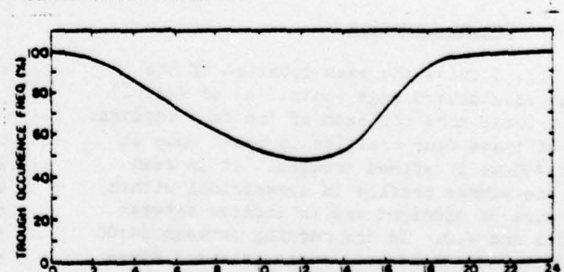


Fig. 5. The trough occurrence frequency versus local time for altitudes $\leq$1500 km.

For each hour of local time, data from at least 3 months were utilized. For example, the results at 19:00 LT includes data from March, August, September 1969, January and February 1970 giving a total of 65 observations. The results are based on data from all seasons and include about 830 clearly identifiable trough observations.

In the nighttime hours, 19:00 to 05:00 LT the trough occurrence frequency is very high, approximately 96% as seen in Fig. 5. Near 05:00 LT a sharp decrease in the occurrence frequency is observed. After 08:00 LT there is a gradual decrease in occurrence frequency with time reaching a minimum value of approximately 48% near local noon. At about 13:00 LT the occurrence frequency begins to increase reaching the maximum nighttime value at 19:00 LT. It is seen that the afternoon increase in the occurrence frequency is somewhat steeper than the morning decrease.

The results of Fig. 5 represent the first quantitative determination of trough occurrence frequency over a 24 hour period. These results are in agreement with the findings of Tulunay and Sayers (1971) which show a broad maximum during the night hours and a minimum within $\pm$ 3 hours of local noon in the northerm winter hemisphere. Taylor et al. (1970) and Tulunay (1973) have reported the existence of persistent daytime troughs. Miller (1974) found no daytime troughs below 2500 km from the ISIS I electron probe measurements. Miller's ISIS I sensor had a spatial resolution of 9° and hence could not resolve the high latitude troughs with widths typically ranging from 2° to 6°.

Brinton et al (1969 and 1970) have shown that the ion composition in the topside ionosphere at mid and high latitudes consists predominantly of O^+ on the dayside. The midday occurrence frequency of 48% shows that the production of O^+ by solar UV radiation frequently dominates over ion depletion mechanisms.

c. Trough Location

Fig. 6 shows the mean location of the trough equatorward edge (point 'a' of Fig. 1) versus local time for each of the four seasons. Each of these four profiles is based upon at least 400 well defined troughs. It is seen that the summer profile is symmetrical within $\pm$ 4 hours of midnight and is located between $L = 3.3$ and 4.0. In the morning between 04:00 and 07:00 LT, there is a sharp poleward movement with an increase of 3 L units. In the dawn-noon sector, the summer profile gradually moves to higher L values reaching a maximum of $L = 12.5 \pm 1.0$ around 11:30 LT. Within 4 hours of local noon, the trough is found to be located at the equatorward edge of the cusp precipitation region. In the afternoon sector, the trough moves gradually equatorward to a value of $L = 5$ near dusk. The summer trough location profile is nearly elliptical in shape except for the LT period, 04:00 to 07:00 LT.

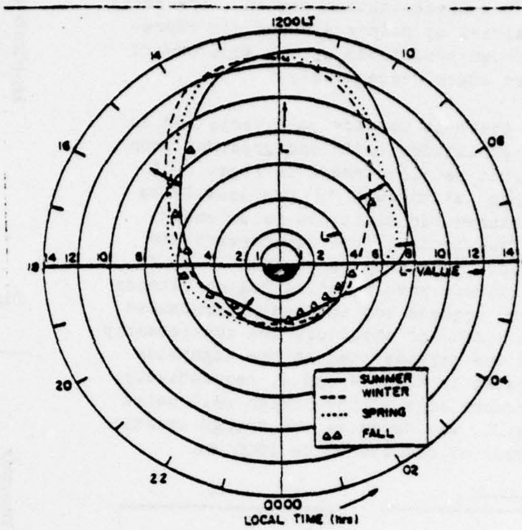


Fig. 6. Diurnal variation of trough location below 1500 km for the four seasons. The bars are the standard deviation of the measurements.

The winter trough location moves gradually inward from $L = 5.5$ to 3.5 between 18:00 and 04:00 LT. This equatorward movement at night is consistent with the characteristic nighttime movement of the plasmapause in the equatorial plane (Carpenter, 1966). In the 04:00 to 07:00 LT sector, the winter profile shows a gradual movement toward higher L values until 09:00 LT after which a rapid poleward movement is observed locating the trough at its peak value of about $L = 12.5$ at noon. The rapid movement after 09:00 LT represents the effect of the onset of sunrise in the winter hemisphere. In the noon-dusk sector, the winter trough profile moves gradually from $L = 12.5$ to 5.5. The winter profile is also elliptical in form.

The spring and fall trough profiles shown in Fig. 6 are similar in form to the summer and winter profiles and generally lie within the envelope defined by the summer and winter locations throughout a 24 hour period. The profiles for all the four seasons approach their highest L values near noon.

The standard deviations of the measured trough locations are shown as bars in Fig. 6; they were deduced using all trough data available in a specific hour of LT in a given season. They are of the order of $\pm$ 1 L unit during the daytime and ± 0.4 L near midnight.

The standard deviation calculations show that there is no significant seasonal variation in the trough location except in the 04:00 to 09:00 LT sector, where the effect of the onset of sunrise with season is large.

d. Comparison with Other Trough Measurements

Since the seasonal effects are small, the mean trough location over all seasons was calculated for a comparison with published trough data (Fig. 7). The trough location deduced by Muldrew (1965) from f_oF_2 observations from the Alouette 1 Topside Sounder from September 1962 to March 1963 is also shown in Fig. 7.

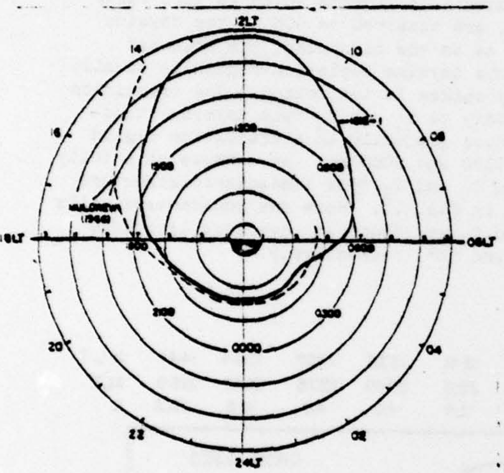


Fig. 7. Comparison of the diurnal variation of the trough location averaged over all seasons with the trough measurements of Muldrew (1965) (<1500 km).

Between 14:00 and 18:00 LT the two profiles have similar shapes although Muldrew's curve is located 1 to 2 L units higher. From 18:00 to 05:00 LT, the two profiles follow one another very closely. It should be noted that there is no "evening bulge" in the trough location in the two results as has been observed in the equatorial plasmapause location by Carpenter (1966), Chappell (1972) and others. The results are also in agreement with the low altitude trough studies of Tulunay and Sayers (1971) and Tulunay and Grebowski (1975) on the nightside. The last two investigations were confined to regions of L < 7 and hence the high latitude daytime troughs would be outside the range of these investigations.

RESULTS ABOVE 1500 km

a. Nightside

The region of significant nightside ionization depletion extends to lower latitudes with increasing altitude. Above 2000 km the equatorial wall of the trough frequently extends 15°-20° in latitude with highly variable shapes. Fig. 8 shows some typical examples of trough density variations. It is seen that there may be a uniform decrease of density with increasing latitude or two or more changes in slope. The high latitude boundary becomes more difficult to define. The poleward edge of the depletion region is marked by one or several sharp spikes in the ionization, each having a width of 1°-2°. The nightside high altitude trough is found on over 95% of the orbits examined.

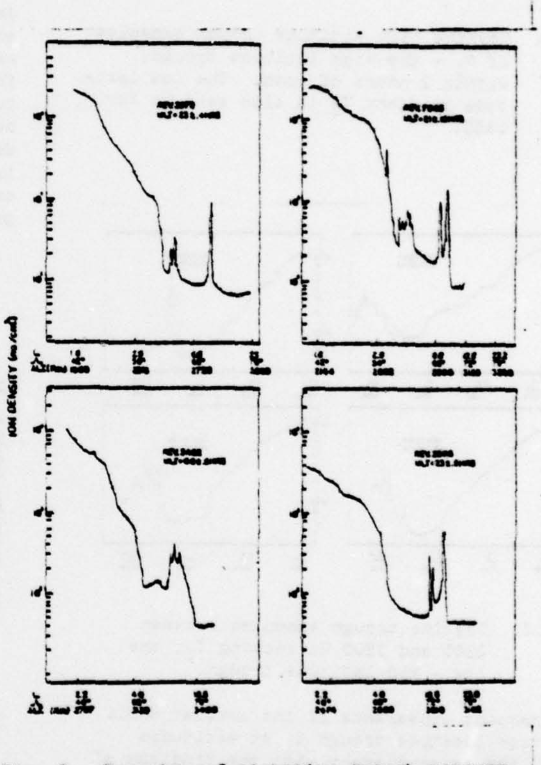


Fig. 8. Examples of nighttime trough measurements at altitudes greater than 2300km.

b. Dayside

Examples of thermal ion density observations near local noon at altitudes greater than 1500 km are given in Figs. 9 and 10. The amplitude of the high latitude trough (hereafter referred to as T_1), which was approximately 3 for altitudes less than 1500 (Fig. 4) gradually reduces to values less than 2 for altitudes greater than 2000 km (Fig. 9).

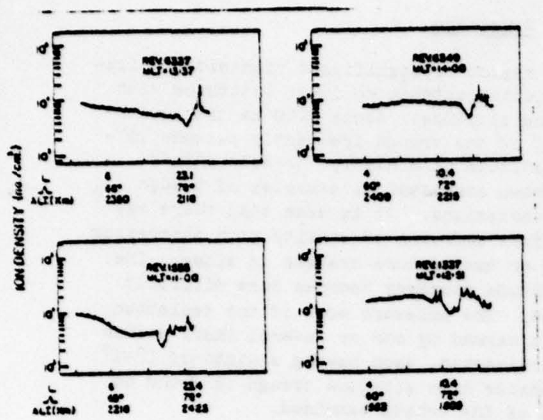


Fig. 9. Daytime high altitude trough examples of T_1 - the high latitude trough, within 2 hours of noon. The low latitude gradient T_2 is also seen on Rev. 1555.

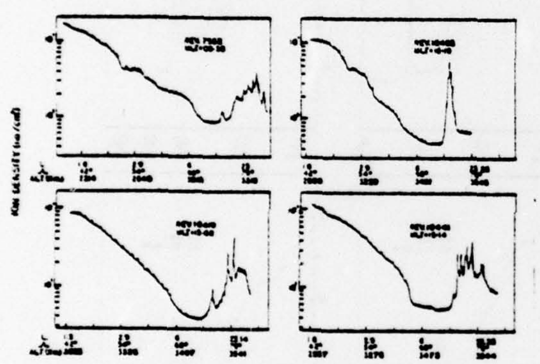


Fig. 10. Daytime trough examples between 2300 and 3500 km showing T_2, the low - mid latitude trough.

The frequent appearance of the smaller amplitude high latitude trough T_1 at altitudes above 1500 is consistent with the findings of Münch et al., (1977) based on INJUN V results. Simultaneous comparison of the trough densities with INJUN particles and electric field measurements showed that T_1 is located at the equatorial edge of the cusp where there are found sharp electric field reversals which indicate shifts in the plasma convection velocity. Increases in the electron temperature by factors of 2 to 3 and a shift from isotropic high energy particles to lower energy anisotropic magnetosheath-like electrons and protons were also observed.

Schunk et al. (1975) have shown that the existence of horizontal electric fields and elevated electron and ion temperatures produce depletions of O^+, a major ion at high latitudes, by increasing the ion loss rate, increasing the ion scale height and by changes in chemical composition. The present results together with the INJUN measurements reported by Münch et al. (1977) strongly support the conclusion of Schunk et al. (1975) that electric fields and enhanced charged particle temperatures make a significant contribution to the formation of the dayside high latitude trough.

Significant daytime gradients are also found to develop between L = 2 and 6 with increasing altitude (Fig. 10). These lower latitude gradients or troughs which we will refer to as T_2, are observed on 50% of the dayside orbits. As on the nightside, the poleward edge of the daytime depletion region is usually marked by spikes in ionization. The transition from T_1 only to T_1 and T_2 type dayside structures occurs gradually in a transition region between 1300 and 2000 km. An example of a fully developed T_1 and T_2 type ionospheric structure is given in Fig. 11. Here the equatorward walls of T_1 and T_2 are found at invariant latitudes of 78.5 and 54°, respectively.

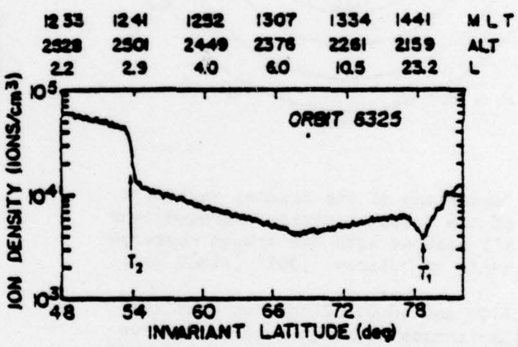


Fig. 11. An observation of both high and low latitude troughs, T_1 and T_2 respectively. Altitude 2100 to 2500 km.

The statistically derived location of the top and base of the "equatorward trough wall" of T_2, vs local time for altitudes above 2000 km is shown in Fig. 12. It is seen that on the nightside the top of the trough wall is consistently located close to L = 2.0 (invariant latitude ≈ 45°) and its base is found at L = 4.4 ($\Lambda \approx 61°$). On the dayside the base of the ion depletion region, T_2, is found at slightly higher latitudes. At local noon it is located at L = 6.5 (Λ = 67°). The equatorward wall is the dominant feature of the high altitude ionization depletion region.

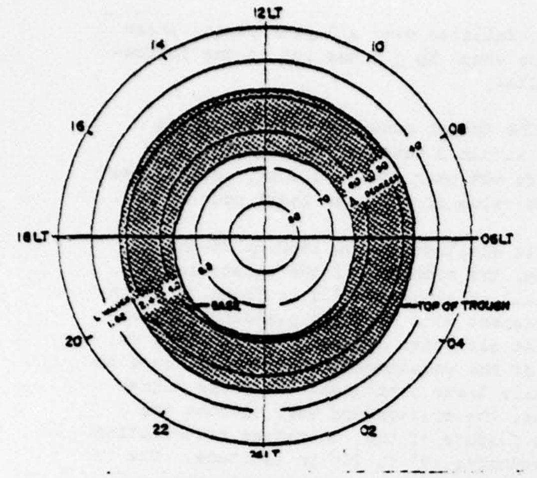


Fig. 12. Mean location of the top and base of the high altitude trough wall (T_2) versus local time for altitudes between 2000 and 3600 km.

As illustrated in Figs. 8 and 10 the ion density frequently changes by two orders of magnitude between the top and the base of the wall. This is much greater than the change in density below 1000 km, either day or night (Figs. 4 and 2). The high latitude trough wall T_2, of Fig. 12 corresponds to the plasmapause reported by Brace and Theis (1974) from ISIS I electron probe measurements above 2500 km. They identified the location of an ionization level of 10^3 electrons/cm^3 along the trough wall as the plasmapause, and obtained a nearly circular plasmapause boundary at about L = 4. As would be expected from the Brace and Theis plasmapause criteria their results lie in the shaded area of Fig. 12. T_2 also corresponds to the high altitude ISIS I dayside trough reported by Miller (1974). The T_2 type of ionization gradients were also observed by an electron sensor aboard the polar orbiting satellite OV3-1 in the 3000-5700 km altitude region between L = 2 and 6 (Bewersdorff and Sagalyn, 1971 and 1972).

We consider that the trough wall of Fig. 12 between about L = 2 and 6.5 is the result of partial filling and/or erosion of the outer plasmasphere. The combined effect of magnetic substorms (Park and Banks, 1974 and 1975) and of diurnal plasma depletions and replenishments prevent the outer shells of the plasmasphere from reaching saturation density.

DISCUSSION: TROUGH LOCATION AND THE PLASMAPAUSE

Nishida (1966 and 1967) first explained the formation of the plasmapause in terms of a magnetospheric convection model. Thomas and Andrews (1968), Rycroft and Thomas (1970), Tulunay (1972) and Tulunay and Grebowsky (1975) have all demonstrated a close relationship between the plasmapause and the mid-latitude trough at night. However, there are disagreements among these workers regarding the details of this association. Nishida and Thomas and Andrews, consider the equatorward trough-edge — to be the physically more significant part of the trough and have shown it to be correlated with the equatorial plasmapause, while Rycroft and Thomas (1970), Tulunay (1972) and Tulunay and Grebowsky (1975) have shown the trough minimum location to be correlated with the plasmapause. Tulunay and Hughes (1973) have shown that the location of the trough minimum is partially influenced by the location and movement of the auroral precipitation region at night and hence recommend the use of the more precisely measurable trough equatorward edge.

In Fig. 13 the trough location identified as the low latitude edge of the equatorward trough wall, for altitudes below 1500 km is compared with the plasmapause position deduced by Chappell et al. (1972), Carpenter (1966) and Taylor et al. (1970). At night the trough and plasmapause variations are very similar although the ISIS I trough locations are slightly equatorward of the plasmapause position. Thomas and Andrews (1968) obtained similar results. Since the trough equatorward wall is typically 1^o to 4^o wide, the equatorial trough base is located approximately 0.3 to 1 L unit poleward of the results shown. These results strongly suggest that the mid-point of the trough wall is an excellent indicator of the plasmapause during the *night hours* at *low altitudes*.

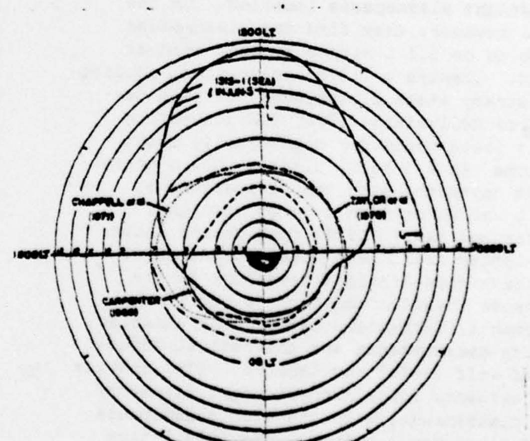


Fig. 13. Comparison of the mean location of the low altitude trough (<1500 km) versus local time with the plasmapause measurements of Carpenter (1966), Taylor et al. (1970) and Chappell et al. (1972).

The daytime trough location below 1500 km deduced from ISIS I and INJUN V measurements shown in Fig. 13 is considerably different from the reported plasmapause profiles. The ISIS I low altitude troughs are found at substantially higher latitudes ($L = 12.5 \pm 1^o$), just equatorward of the cusp precipitation region. The trough moves gradually to lower latitudes toward dusk while the plasmapause position lies between $L = 4$ and 7 from dawn to 1600 LT. The three sets of plasmapause locations in Fig. 13 do not show marked asymmetry between night and day while it is quite pronounced in the ISIS I trough location. The results of Tulunay (1973) and Tulunay and Grebowsky (1975) indicate a similar assymetry.

Examination of the location of the high altitude equatorward trough wall, T_2, (Fig. 12) shows that it is the base which may be reasonably compared with the plasmapause locations shown in Fig. 13. The base located at $L = 4.4$ near midnight and at $L = 6.5$ at noon is in good agreement with the plasmapause measurements. However, it should be noted in agreement with the finding of Brace and Theis (1974) that the trough shows no afternoon bulge.

Recent measurements by Gringauz and Bezrukikh (1976) using ion traps aboard Prognoz and Prognoz 2 satellites led them to conclude "a considerably higher latitude for the plasmapause at noon compared to that at midnight as a typical feature of the quiet magnetosphere". Their noon-midnight measurements of May 8 and August 24, 1972, for example, show a difference of approx. 3.5 L in the noon-midnight plasmapause location. On the average, however, they find the plasmapause location to be 1.5 L higher at noon than at midnight. Lemaire's (1976) theoretical studies of the steady state plasmapause position deduced from McIlwain's (1974) E3H convection electric field model for magnetically quiet conditions ($Kp = 1$ to 2) clearly show a noon-midnight asymmetry with the plasmapause at higher L values at noon than at midnight. Carpenter and Seely (1976) from recent quiet time Whistler drift path observations noted significant noon-midnight asymmetry in the plasmapause location contrary to earlier measurements (Carpenter, 1966). The whistler, satellite measurements and theoretical deductions of Wolf (1974) and Lemaire (1976) provide strong evidence for a noon-midnight asymmetry of the plasmapause, with the noon plasmapause located at higher L values. The ISIS I high altitude measurements of T_2 show that the base of the high altitude trough wall is in good agreement with these recent plasmapause results.

SUMMARY AND CONCLUSIONS

Examination of thermal ion and electron troughs in the topside ionosphere obtained by means of instruments flown on the ISIS-I and INJUN V satellites over a 3 year period under conditions when $Kp \leq 3$ has led to the following results:

1. The trough occurrence frequency is over 90% within 3 hours of midnight, it decreases to 60% near dawn and dusk, and reaches a minimum value of 48% near local noon.

2. At altitudes below 1500 km on the nightside, the midpoint of the equatorial trough wall at about $L = 3.8$ is found to be in good agreement with reported plasmapause positions. At altitudes between 1500 and 3500 km, the top of the equatorward trough wall moves to continually lower latitudes. At these higher altitudes, the equatorward wall becomes the dominant feature of the ionization distribution often extending 15^o to 20^o in latitude. The poleward edge of the trough becomes less well defined at high altitudes and is marked by ionization spikes 1^o to 2^o in width.

3. On the dayside below 1500 km the mean location of the trough T_1 at noon is $L = 12.5 \pm 1.0$, much higher than the dayside plasmapause location. T_1 persists above 1500 km with decreasing amplitude above this level.

4. The diurnal variation of the trough location was not found to vary with season except near sunrise.

5. The ISIS I data and simultaneous INJUN V measurements of electron density, ion & electron temperature, horizontal electric fields and particle measurements show that the high latitude trough, T_1, is located at the equatorward edge of the cusp. It is concluded that electric fields and enhanced thermal electron and ion temperature contribute to the formation of T_1 by increasing ion loss rates, ion scale height, and producing changes in the chemical composition of the region, in agreement with the theoretical analysis of Schunk et al. (1975).

6. At all altitudes above 1500 km a second ionization depletion region or trough T_2, is observed between $L = 2$ and 6.

7. The base of the high altitude trough wall (T_2 on the dayside) is found to lie between $L = 4$ and 6 in good agreement with plasmapause locations in the equatorial plane.

REFERENCES

Bewersdorff, A.B. and R.C. Sagalyn, Evidence of an evening ionization anomaly within the plasmasphere, Space Research XI, p. 1289, Akademic-Verlag, Berlin, 1971.

Bewersdorff, A.B., and R.C. Sagalyn, Spatial and temporal variations of the thermal plasma between 3000 and 5700 km at L = 2 to 4, J. Geophys. Res., 77, 4734, 1972.

Brace, L.H. and R.F. Theis, The behavior of the plasmapause at mid-latitudes, J. Geophys. Res. 79, 1871-1884, 1974.

Brinton, H.C., R.A. Pickett, and H.A. Taylor, Diurnal and seasonal variations of atmospheric ion composition; correlation with solar zenith angle, J. Geophys. Res., 74, 4064, 1969.

Brinton, H.C., J.M. Grebowsky, and H. Mayr, Altitude variation of ion composition in the mid-latitude trough region - Evidence for upward plasma flow, J. Geophys. REs., 76, 3738, 1971.

Carpenter, D.L., Whistler studies of the plasmapause in the magnetosphere, 1. Temporal variations in the position of the knee and some evidence on plasma motions near the knee, J. Geophys. Res., 71, 693, 1966.

Carpenter, D.L. and N.T. Seely, Cross L plasma drifts in the outer plasmasphere: Quiet time patterns and some substorm effects, J. Geophys. Res., 81, 2728-2736, 1976.

Chappell, C.R., Recent satellite measurements of the morphology and dynamics of the plasmasphere, Rev. of Geophys. Space Physics, 10, 951, 1972.

Grebowsky, J.M., N.C. Maynard, Y.K. Tulunay and L.J. Lanzorotti, Coincident observation of ionospheric troughs and the equatorial plasmapause, Planet. Space Science, 24, 1177, 1976.

Gringauz, K.L. and V.V. Bezrukikh, Asymmetry of the earth's plasmasphere in the direction noon-midnight from data of measurements of satellites Prognoz and Prognoz 2, J. Atmos. Terr. Phys., 38, 1071, 1976.

Lemaire, J., Steady state plasmapause positions deduced from McIlwain's electric field models, J. Atmos. Terr. Phys., 38, 1039, 1976.

McIlwain, C.E., Magnetospheric Physics, Edited by B.M. McCormack, Reidel Publishing Co., Dordrecht, Holland, p. 143, 1974.

Miller, N.J., and L.H. Brace, Some winter characteristics of the northern high latitude ionosphere, J. Geophys. Res., 74, 5752, 1969.

Miller, N.J., The dayside mid-latitude plasmatrough, J. Geophys. Res., 79, 3795, 1974.

Muldrew, D.B., F-layer ionization troughs deduced from Alouette data, J. Geophys. Res., 70, 2635, 1965.

Münch, J.W., H.J. Braun, G.R. Pilkington, R.C. Sagalyn, and P.J.L. Wildman, Thermal electron densities and temperatures in the dayside cusp, J.A.T.P., 39, 699, 1977.

Nishida, A., Formation of plasmapause or magnetospheric knee by the combined action of magnetospheric convection and plasma escape from the tail, J. Geophys. Res., 5699, 1966.

Nishida, A., Average structure and storm-time change of the polar topside ionosphere at sunspot minimum, J. Geophys. Res., 72, 6051, 1967.

Park, C.G., and P.M. Banks, Influence of thermal plasma flow on the mid-latitude nighttime F_2 layer; Effects of electric fields and neutral winds inside the plasmasphere, J. Geophys. Res., 79, 4661, 1974.

Park, C.G., and P.M. Banks, Influence of thermal plasma flow on the daytime F_2 layer J. Geophys. Res., 80, 2819, 1975.

Rycroft, M.J. and J.O. Thomas, The magnetospheric plasmapause and the electron density trough at the Alouette I orbit, Planet, Space Sci., 18, 65, 1970.

Sagalyn, R.C., M. Smiddy and J. Wisnia, Measurement and interpretation of ion density distributions in the daytime F regions, J. Geophys. Res., 68, 199, 1963.

Sagalyn, R.C. and M. Smiddy, Charged particle measurements by means of electrostatic probes, electron density and temperature measurements in the ionosphere. COSPAR Tech. Manuals, p. 90, Commun. Space Res., Paris, 1967.

Sagalyn, R.C., M. Smiddy and M. Ahmed, High latitude irregularities in the topside ionosphere based on ISIS-I thermal ion probe data, J. Geophys. REs., 79, 4252, 1974.

Sharp, G.W., Midlatitude trough in the night ionosphere, J. Geophys. Res., 71, 1345, 1966.

Schunk, R.W., W.J. Raitt, and P.M. Banks, Effect of electric fields on the daytime high latitude E and F regions, J. Geophys. Res., 80, 3121, 1975.

Smiddy, M. and R.C. Stuart, An analysis of the behavior of a multigrid spherical sensor in a drifting Maxwellian plasma, Rep. AFCRL-69-0013, Phys. Sci. Res. Paper 364, U.S. Air Force Cambridge Res. Labs., Bedford, MA, 1969.

Taylor, H.A., H.C. Brinton and A.R. Deshmukh, Observations of irregular structure in thermal ion distributions in the dusk side magnetosphere, J. Geophys. Res., 75, 2481, 1970.

Taylor, H.A. and G.R. Cordier, In-situ observations of irregular ionospheric structure associated with the plasmapause, Planet. Space Sci., 22, 1289, 1974.

Taylor, H.A., J.M. Grebowsky, and A.J. Chen, Ion composition irregularities and ionoshperic-plasmaspheric coupling: Observations of a high latitude ion trough, J. Atmos. Terr. Phys., 37, 613, 1975.

Thomas, J.O. and M.K. Andrews, Transpolar Ionospheric Plasma, 1. Plasmasphere Termination, J. Atmos. Terr. Phys., 37, 613, 1975.

Tulunay, Y. and J. Sayers, Characteristics of the mid-latitude trough as determined by the electron density experiment on Ariel III, J. Atmos. Terr. Phys., 33, 1737, 1971.

Tulunay, Y., Magnetically symmetric detection of the mid-latitude electron density trough by Ariel III satellite, J. Atmos. Terr. Phys. 34, 1547, 1972.

Tulunay, Y., Global electron density distributions from the Ariel III satellite at mid-latitudes during quiet magnetic periods, J. Atmos. Terr. Phys., 35, 233, 1973.

Tulunay, Y. and A.R.W. Hughes, A satellite study of the mid-latitude trough in electron density and VLF radio emissions during the magnetic storm of 25-27 May 1967, J. Atmos. Terr. Phys., 35, 1973.

Tulunay, Y. and J.M. Grebowsky, Temporal variations in the dawn and dusk mid-latitude trough positions measured (Ariel III, Ariel IV) and modelled, Ann. Geophys., t. 31, fasc. 1, 29, 1975.

Wolf, R., Calculations of magnetospheric electric fields in magnetospheric physics (Ed. B.M. McCormac, D. Reidel Pub. Col., Dordrecht, Holland), p. 167, 1974.

Wrenn, G.L. and W.J. Raitt, In-situ observations of mid-latitude ionospheric phenomena associated with the plasmapause, Ann. de Geophys., 31, 17, 1975.