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ABSTRACT

A distinct feature of the ion composition results from the OGO-2, 4, and 6 satellites is the light ion trough, wherein the mid latitude concentrations of H^+ and He^+ decrease sharply with latitude, dropping to levels of 10^3 ions/cm^3 or less near 60° dipole latitude (L=4). In contrast to the "main trough" in electron density, N_e, observed primarily as a nightside phenomenon, the light ion trough persists during both day and night. For daytime winter hemisphere conditions, and for all seasons during night, the mid latitude light ion concentration decrease is a pronounced feature. In the dayside summer and equinox hemispheres, the rate of light ion decrease with latitude is comparatively gradual, and the trough boundary is less well defined, particularly for quiet magnetic conditions. In response to magnetic storms, the light ion trough minimum moves equatorward, and deepens, consistent with earlier evidence of the contraction of the plasmasphere in response to storm time enhancements in magnetospheric plasma convection. The fact that a pronounced light ion trough is observed under conditions for which the dominant ion O^+ may exhibit little or no simultaneous decrease appears to explain why earlier studies of the "main trough" in topside distributions of N_e and N_i may, at times, have been .

inconclusive in relating the total ionization minimum with the mechanism of the plasmapause. In particular, the topside distribution of N_i appears to be the complex resultant of several variables within the ion composition, being governed by the competing processes of chemical production and loss, loss through magnetospheric convection, and large-scale dynamic transport resulting from neutral winds and electric fields. The net result is that in general, the light ion trough, rather than N_i, provides a more fundamental parameter for examining the structure and behavior of the plasmapause.

THE LIGHT ION TROUGH

1. INTRODUCTION

Beginning with the early results of Alouette I and the work of Muldrew [1965] considerable attention has been given to the apparent phenomenon of a "main trough" (hereafter designated MT) or abrupt depletion in the mid latitude distribution of total thermospheric ionization. Direct measurements of total ion density [Sharp, 1966] [Harris et al., 1967] and electron density [Miller and Brace, 1969] [Miller, 1970] as well as electron distributions derived from topside sounder studies [Thomas et al., 1966] [Thomas and Andrews, 1968] provide independent evidence of pronounced and often sharply defined depressions in N_e repeatedly occurring at mid to high latitudes particularly in the nighttime ionosphere. Although such results are sometimes loosely associated as related evidences of a "MT" phenomenon, there appears to be considerable variation in the observations reported to date, particularly with respect to details of structure and diurnal variation. As a result of differences in orbital coverage and measurement technique, as well as the scarcity of simultaneous correlative studies of this feature, it remains to be determined whether these previous results are indeed the manifestation of a common geophysical mechanism.

Certain characteristics frequently observed in the MT, including that it is observed most consistently during the night, and that the minimum is frequently observed at mid latitudes, in the vicinity of the average position of the boundary of the plasmasphere, have prompted studies of a possible correlative relationship between the total ionization decrease and the plasmapause. A statistical study of topside results from Alouette I by Rycroft and Thomas [1970] and Rycroft and Burnell [1970] indicates that during night, the respective positions of the MT and the plasmapause are closely related. Such studies, however, have not yet benefited from the availability of either (1) the complete ion composition data, or (2) simultaneous, in-situ detection of both the total ionization trough and the whistler knee evidence of the plasmapause.

In earlier studies of the OGO ion composition results, it has been shown that relative to the MT, a much more pronounced trough is observed in the midlatitude distributions of H^+ and He^+, leading to the identification of the 'light ion trough' (hereafter designated LIT) [Taylor et al., 1968]. The pronounced mid latitude depletion of hydrogen and helium ions, in which the concentration of these constituents may drop by as much as two orders of magnitude within 5-10° latitude, reaching minimum levels typically near L=4, appears to mark the interface between the plasmasphere and the auroral ionosphere. Correlation of whistler-deduced plasmapause results and the position of the light ion trough detected both at high altitudes in the magnetosphere [Carpenter et al., 1969] and in the topside region near 1000 km [Taylor et al., 1969] have shown a close agreement between the structure of the light ion depletion and the whistler cutoff. In Figure 1, a direct, simultaneous correlation between the ion and VLF results shows good agreement between the sharp decrease in whistler rate and associated onset of LHR activity, and the marked depletion in proton distribution with latitude.. A most important feature of Figure 1 is the evidence that the depletion in H^+ occurs in the <u>absence</u> of a significant variation in the major ion, O^+. Thus the plasmapause in this case is more closely related to the LIT, than to a MT in total ionization.

The LIT has been observed as a persistent feature of the ion composition results from OGO's 2, 4, and 6. In Figure 2 pole-to-pole distributions of O^+, H^+, and He^+ observed from OGO-6 during equinox and near dawn (0453 LT) reveal the characteristics of the LIT in hydrogen and helium representative of nighttime conditions.

A feature of these profiles, typical of much of the OGO data, is the similarity and near simultaneity of the troughs in both H^+ and He^+. In the results to be discussed later, although the relatively minor ion is omitted for simplicity, the trough structure described in the proton distributions is generally accompanied by similar structure in He^+.

In addition to the individual ion profiles of Figure 2, the total ion concentration, N_i, derived from the sum of all ion densities measured in the mass range 1-45 AMU, is given for contrast. It is clear from this illustration, that the rather gradual depression in total ion concentration observed near 60° dipole latitude is a much less prominent feature of the ion distribution than the major trough in H^+ and He^+. Furthermore, the N_i trough is produced <u>not</u> as a consequence of the fundamental behavior of a dominant ion, but rather as a result of the rapidly changing relationship between the latitudinal distributions of O^+ and H^+. Indeed, O^+ which becomes the dominant ion toward the poles, is sharply increasing through the LIT minimum!

Note that due to the lack of a sharply defined depletion in N_i, the identification of an 'exact' location for the 'MT" would be relatively arbitrary. It is clear from such data that misleading results might readily occur in an attempt to associate the precise position or structure of the total ionization with that of the LIT-plasmapause.

Thus there is preliminary evidence of important differences between the behavior of the light ion and total ionization troughs, in terms of intensity, position, and mechanism. In this paper we further identify several fundamental characteristics of the LIT, including evidence of diurnal variation, as well as response to magnetic disturbance. In describing these results we show that the LIT, rather than the total ionization trough, appears as a more meaningful indicator of the plasmapause and thus is a more fundamental parameter for studies of the formation and maintenance of the plasmasphere.

2. RESULTS

Data Selection

The data have been limited to observations from the Bennett Radio Frequency Ion Mass Spectrometer on OGO-6, during the period 1969-70, although extensive measurements with similar experiments on OGO's 2 and 4 fully support these observations. In selecting these results, particular care has been taken to minimize the interaction of parametric variations observed to be significant in large scale studies of the OGO ion composition data.

First, it has been shown that pronounced longitudinal variations are exhibited throughout the ion composition [Taylor et al., 1970, 1971]. These longitudinal variations complicate the identification of other parameters including altitudinal, latitudinal, diurnal, and seasonal variations.

An example of the longitudinal variation is given in Figure 3, where northern hemisphere equinox distributions of the proton trough and the total ion density are displayed as a function of longitude, for a series of orbits during September 22-27, 1969. As shown, there is considerable variation in both the intensity and position of the proton depletion, and in the distribution of N_i, between positions of contrasting longitude. For example, the H^+ trough minimum generally tends to be displaced equatorward at those longitudes for which the angle α (a solar-geomagnetic coordinate, measured in the noon local time plane as the angle between the earth-sun line and the magnetic equator) approaches maximum negative values. These profiles, obtained for similar conditions of altitude, local time, and magnetic activity, reflect the cyclical variation, or longitudinal 'wobble' observed as a persistent feature of the OGO topside ion composition results. This longitudinal variation, which is most strongly defined during seasonal extremes (i.e. for large values of α) indicates the significance of "solar-geomagnetic" seasonal control of the ion composition [Taylor, 1970, 1971].

In order to minimize the complication of the longitudinal variation, we have selected orbits such that the angle α, is nearly identical for the data sets to be compared. For this reason, and also to avoid the additional complexities of extreme seasonal variations, we have limited the data sample to cases for which the magnitude of α is relatively low, ($\alpha \leq 22°$).

Another factor influencing the choice of data is the altitudinal variation. Since the variables associated with the chemistry dominated region of the lower thermosphere are observed to complicate the studies of the trough and plasmapause, we restrict ourselves to the apogee portion of the orbit, from 600 to 1100 km. In addition, while the relatively large scale height of the light ions is such that altitude variations along an apogee arc do not seriously confuse the identification of latitudinal features, such is not always the case for the heavier ion O^+. For this reason, we have selected wherever possible orbits for which the altitude-latitude relationship is most similar, within the latitude range of interest, thus minimizing possible confusion resulting from this variable.

Finally, to satisfy the requirements outlined above, and to obtain tentative evidence of the diurnal variation, we have restricted ourselves to a dawn-dusk data set with apogee centered on the dipole equator, and an evening-morning data set which has apogee near the north pole, so that maximum altitude symmetry is available for the comparison of the contrasting local time regions. In this way, we believe we have identified as rigorously as possible the most definitive data set available for evidence of the diurnal variation in the LIT.

Diurnal Variations

A comparison of the day to night variation observed in the LIT characteristics for moderate magnetic conditions (Kp = 2-3) is shown in Figure 4. The ion profiles observed during September 1969 near local dawn and during March 1970 near local dusk are representative of nighttime and daytime equinox conditions, respectively. The sharply defined depletions in both H^+ and He^+ observed near 60° dipole latitude on the dawn profiles are found persistently throughout the nighttime topside ionosphere, consistent with the evidence for a well defined plasmapause boundary during nighttime conditions. The sharply defined nighttime trough is in contrast to a relatively slowly varying latitudinal decrease during daytime hours, as shown by the dusk profiles, which typify the daytime character.

As shown in the March 20 data, the high latitude (>60°) H^+ concentrations drop to levels consistent with the nightside H^+ trough concentrations of $\sim 10^3$ ions/cm^3, providing evidence for the plasmapause near 60° dipole latitude. In contrast, however, the dayside mid latitude (30-60°) H^+ concentrations are much <u>lower</u> than at night, and thus the low latitude edge of the LIT is not sharply defined. This is a rather typical feature of dayside proton distributions observed <u>near equinox</u> and during quiet magnetic conditions. Other dayside cases, observed in the winter hemisphere, and/or for conditions of disturbed magnetic activity, exhibit much more pronounced and identifiable trough-plasmapause locations.

Another important feature of the data presented in Figure 4 is the contrast in behavior exhibited between N_i and H^+ both during day and night. In the nighttime profiles, the N_i distribution does show noticeable depletions in both the northern and southern hemispheres, near 60° dipole latitude. These depletions are, however, much less pronounced and thus more difficult to pinpoint than the precipitous decreases exhibited by the H^+ profiles. As shown, the location of the plasmapause characterized by the sharp decrease in the proton distribution is much more specific than that which might be inferred in the depletions from N_i. In the dayside case, no depletion in N_i exists near the expected location of the plasmapause, and although the rate of decrease in H^+ is much less pronounced than during nighttime hours, the proton distribution does indeed provide the only indication of the possible plasmasphere boundary, as H^+ decreases to about the 10^3 ions/cm^3 level, near 60°.

The day-night contrast in the steepness of the LIT is further identified in Figure 5 where we examine sequential evening-morning profiles obtained when OGO-6 apogee was located above the north magnetic pole, permitting an immediate comparison of day-night differences. These profiles provide altitude-latitude symmetry, with α = 22°, corresponding to solar-geomagnetic seasonal conditions which approach northern hemisphere summer, i.e. the sun is higher in the northern magnetic hemisphere relative to the data of Figure 4. From Figure 5, it is clear that for conditions representative of summer, the day-night contrast in the H^+ trough is even more pronounced than for the previous case at lower α. The steep nighttime trough is much more identifiable than the dayside depletion, which is almost monotonic. Again, by comparing N_i (which is composed primarily of O^+) and H^+, it is clear that a sharply defined H^+ trough may exist essentially in the absence of a simultaneous, significant depletion in N_i. Thus, even as a secondary ion in an oxygen dominated ionosphere, H^+ clearly identifies the plasmasphere boundary, at night, near 60° latitude. In contrast, on the dayside, the low and midlatitude concentrations of H^+ are relatively less pronounced, and the plasmapause is not so clearly identified.

Magnetic Storm Effects

As might be expected from the relationship between the LIT and the plasmapause, it is observed that the light ion trough responds in a pronounced manner to significant changes in geomagnetic activity. In preliminary studies of OGO 2 and 4 results [Taylor et al., 1968] it was observed from topside hydrogen and helium ion distributions that the plasmasphere exhibits a contraction in response to strong enhancements in geomagnetic activity. Pronounced longitudinal variations in the pole-to-pole proton distributions, however, as suggested in Figure 3, require that a rigorous examination of the details of the response to magnetic activity must be made with a minimum of longitudinal separation. In Figure 6, we compare O^+, H^+ and N_i distributions obtained for two apogee passes for which the altitude-latitude relationship was very similar, and for which the longitude and thus solar-geomagnetic orientation was nearly identical. A comparison of the two H^+ profiles shows that on September 30, closely following a very disturbed magnetic condition, the proton distribution has undergone a pronounced contraction, with the trough minimum moving equatorward by as much as 15° in both the northern and southern hemispheres. In addition, as is typical of the nighttime proton results, the lower latitude edge of the H^+ trough becomes steeper, dropping to lower concentration levels in the trough in response to magnetic disturbances.

Since H^+ is the dominant low and mid latitude topside ion during the night, the N_i profiles of Figure 6 naturally tend to show relatively good agreement with the H^+ profiles, in terms of reflecting the influence of magnetic disturbance. Although interesting and no doubt significant changes occur in the low latitude distribution of O^+ in response to the storm, this is essentially hidden by the fact that O^+ is the minor ion in this range. Toward mid and high latitudes, however, changes in the O^+ distribution do begin to modify the N_i behavior. Near the light ion trough, the O^+ distribution increases in response to the storm, while H^+ is decreasing. Poleward of -60°, there is some evidence of a trough in O^+, which becomes deeper and broader subsequent to the magnetic disturbance, further complicating the N_i distribution.

Although irregular structure of O^+ above about 50° latitude in both hemispheres confuses the N_i distribution, it is nevertheless clear than an N_i trough, resulting primarily from the interaction between O^+ and H^+, moves to lower latitudes and becomes more pronounced in response to enhanced magnetic activity. Consistent with the previous results, however, it is shown that compared to the total ionization, the proton distributions provide a much clearer and more fundamental indication of the location of the boundaries of the plasmasphere, and its response to changes in magnetic activity.

The importance of the LIT for describing the plasmasphere behavior relative to magnetic disturbances is emphasized further in an examination of dayside proton distributions, obtained near mid morning local time. In Figure 7, we compare proton distributions observed near solar-geomagnetic equinox ($\alpha \cong 1°$) between three periods of strongly contrasting magnetic activity: before, during, and after a magnetic storm which had its peak at Kp=6 on August 27, 1969. In the center panel of Figure 7, on August 27, near the height of the storm, the proton distribution in the northern hemisphere exhibits a sharply defined decrease near 53°, (L = 2.9), while at lower latitudes, this same H^+ distribution reflects a strong <u>increase</u> in concentration, relative to the quiet time H^+ profiles. This distribution is in sharp contrast to the quiet time profiles of August 24 and 30, which exhibit the normal midlatitude gradual decrease in H^+ dropping to trough zone concentrations of $\sim 2 \times 10^3$ ions/cm^3, which are at least a factor of 2 higher than the storm time trough level. Thus with these and other daytime results, we have observed that even during daytime hours near solar-geomagnetic equinox, the proton distributions may exhibit a sharply defined trough structure, following periods of enhanced magnetic activity.

In contrast to the nighttime situation, however, the N_i, distributions of Figure 7 reveal that on the dayside, where O^+ is strongly dominant, the light ion trough, emphasized in response to magnetic disturbance, is not accompanied by a significant trough in total ion density. It is important to note, however, that the N_i (largely O^+ above 40°) distribution near the height of the storm does indeed reflect evidence of some depletion in the light ion trough zone, in contrast to the quiet N_i profiles, which reveal no evidence of a trough. Thus, while the N_i distribution is not as sensitive a barometer of the storm effect as is H^+, there is certainly some evidence that O^+ is somehow depleted, or redistributed, as a result of the storm.

3. DISCUSSION

Diurnal Variation of the Light Ion Trough

The observed contrast in the day to night characteristics of the LIT appears to result largely from the fact that the mid latitude proton distributions leading up to the trough zone near 60° latitude are found to be much more pronounced during night than during day. Since the trough minimum concentrations are observed to be rather similar during night and day, at a concentration level of about 10^3 ions/cm^3 during equinox, the net result is that the low latitude boundary of the night-side ion trough is much more pronounced than during the day. To appreciate the complexity of this apparent diurnal variation in the LIT and its implication for studies of the plasmasphere, it is necessary to examine the competing processes of ion production, loss, and dynamic transport, including several parameters which are not well understood.

Considering the production process alone, it is evident that the source function for thermal protons may well exhibit a very complex behavior. The charge transfer relationship

$$O^+ + H \rightleftarrows H^+ + O \qquad \text{Eq. 1}$$

which leads to the equation

$$H^+ \propto \frac{[O^+][H]}{[O]} \quad \text{, which} \qquad \text{Eq. 2}$$

shows that the production of H^+ is dependent not only upon the density of O^+, which is comparatively well documented, but also upon the distributions of neutral hydrogen and oxygen, which are not well understood.

During the night, photoionization of O^+ ionization is lost, and accordingly the supply of H^+ through charge transfer is significantly reduced. Nevertheless, given sufficient diurnal variation in the concentrations of H and O, of appropriate phase, the nighttime decrease in the supply of O^+ might in part be cancelled out. The recent results of Brinton and Mayr [1971] in describing the diurnal variation in H observed from Explorer 32, do indeed identify a nighttime increase in H which would be in the direction of supplanting the H^+ loss resulting from the decrease in O^+. Similarly, although measurement results are not yet available, it might be predicted that the neutral oxygen concentrations would decrease at night, in effect also tending to maintain the nighttime proton concentrations. Unfortunately, the diurnal variations of these parameters are not well known, particularly with respect to latitudinal variations. Thus, even from the relatively simple viewpoint of source and loss, it is difficult to develop a rigorous argument for explaining the observed LIT structural variations.

Competing simultaneously with the chemical production and loss mechanisms are the dynamic transport effects associated with magnetospheric convection and thermospheric neutral winds.

Plasma convection models derived by Nishida [1966] and by a number of others, show that thermal plasma is drained from the ionosphere as a result of convection onto field lines which become open to the magnetotail, providing an extensive ionization sink. Although this mechanism for light ion plasma escape is generally accepted, there is very little published evidence available to describe the diurnal variation in ionospheric structure which would be expected to result from this mechanism. Studies by Park [1970] and by Banks et al. [1971] suggest that the field tubes near the trough zone may be in a virtually continual dynamic state, as a result of the competing processes of convective plasma loss and replenishment from the lower ionosphere. From such studies, it is clear that the diurnal variation in the transport of thermal protons near the light ion trough may be quite complex. In addition to the relatively slow filling in process of a depleted field tube, which might require four to five days [Park, 1970] resulting in a continuing upward flux of protons from the lower ionosphere, a diurnal variation flux may be superimposed, as a result of the tendency for the protonosphere to subside during nighttime hours. A further complication of this picture seems to result from the probability that the magnetospheric convection events do not produce a uniform diurnal loss rate in the high latitude light ion distributions. Plasma loss may occur both on the dayside and nightside, and there is some evidence that the nightside plasmasphere may react more quickly to magnetic disturbances [Sharp et al., 1971]. As shown in the present results, there is some evidence that the dayside proton distributions may also be strongly influenced by magnetic storms, although the time response is not known. It is clear that considerable additional evidence will be required to identify a complete diurnal pattern for the light ion loss processes associated with magnetospheric convection events.

Dynamic transport of ionization resulting from the flow of thermospheric neutral winds appears as still another complication to the interpretation of the observed LIT structure. It has been shown that ion drag induced by the flow of neutral winds may produce a significant effect in the redistribution of the O^+-H^+ transition level [Brinton et al., 1970], and in the midlatitude distributions of N_e [Brace et al., 1970]. Similar arguments could be extended to explain in part the observed diurnal variation in LIT structure. During day, winds blowing toward the pole would tend to depress the mid latitude proton distributions, while the opposite effect would occur during night, apparently consistent with the observed increase in the nighttime mid latitude proton distributions.

In summary, it is quite likely that a number of simultaneous processes compete in regulating the diurnal variation of the latitudinal distribution of hydrogen and helium ions. In view of the many unknowns in this situation, perhaps the most significant result in the observed trough behavior is that the trough minimum deepens significantly and shifts equatorward in response to magnetic disturbance, both during day and during night. This evidence appears to support the conclusion that the convective loss process is enhanced as a result of the magnetic storm; and that the low latitude side of the LIT indeed marks the plasmasphere boundary.

Light Ion Trough-Main-Trough-Plasmapause Relationships

The result indicating a closer relationship between the LIT-plasmapause as contrasted to the MT appears to be straightforward considering the fact that the plasmasphere is, after all, primarily composed of the light ions H^+ and He^+. The foregoing complications suggested for the diurnal variation notwithstanding, there is considerable evidence that the mechanisms responsible for the formation of the plasmapause boundary observed at high altitudes in the magnetosphere are equally effective in regulating the distributions of the light ions near the topside. Correlative studies of the magnetospheric plasmapause observed from the Bennett ion spectrometer on OGO 3 and the LIT observed by the same experiment on OGO-4 [Grebowsky et al., 1970; Mayr et al., 1970] indicate a direct relationship between these two phenomena, suggesting that a strong upward flux of ions in the LIT region would provide the necessary coupling to account for the evident geophysical link between these two observed features. Direct evidence for such a pronounced upward flux of light ions has indeed been identified by the Bennett spectrometer results on Explorer 32 [Brinton et al., 1971] which identify an upward flux of protons in the trough zone of 1.5×10^8 cm-2 sec-1. This evidence of a light ion upward flux or "trough wind" in the trough region appears to be consistent with the theoretical model for the polar wind [Banks and Holzer, 1969] and with the results of Hoffmann [1969].

The fact that the LIT is clearly a much more sensitive barometer of the behavior of the plasmasphere is also not surprising, in view of the production, loss, and transport processes discussed above. Since the total ion density, and presumably N_e, reflect the compound variations of two or more component ions, it is clear that the total ionization distribution is not a fundamental parameter for studies of the plasmasphere.

It has been shown that on the dayside, where N_i and N_e reflect the behavior of the dominant ion O^+, the LIT structure is generally not identified in the total ionization distribution. This appears to be consistent with the dayside production of O^+, which apparently is so strong that the average convective loss rate of H^+ is not sufficient to impact the O^+ source through the charge exchange reaction. This may in part be supported by the evidence that under sufficiently disturbed magnetic conditions, a small O^+ depression does begin to appear in the location of the LIT. Although earlier calculations [Kamiyama 1968] indicate that the dayside O^+ source should not be affected by upward H^+ fluxes, it is nevertheless tempting to speculate as to whether the extreme conditions associated with a significant magnetic storm might temporarily overcome the O^+ ionization reserve. Nevertheless, it is clear that other storm related mechanisms, including enhanced neutral wind, ion temperature, and electric field effects might also be responsible for the observed storm enhanced depression in N_i.

In view of the variety of parameters which may influence the distributions of O^+ and H^+, it seems clear that there may be considerable variability between the total ionization trough and the light ion trough. From our results, it appears quite evident that there may be cases for which the two trough positions may closely agree, reflecting a single location for the plasmapause. Under other circumstances, however, the proton distribution may sharply differ in degree and position from the depression in N_i and thus indicate a significantly <u>different</u> position for the plasmapause.

These observations may explain some of the apparent difficulties encountered in attempts to correlate the position of the main trough as observed by the topside sounder with independent although not fully simultaneous, in-situ observations of the whistler plasmapause [Rycroft, 1970]. Using primarily nighttime results from Alouette I, this study shows a relatively good correlation between the main trough position and the average position of the plasmapause deduced from vlf observations, although appreciable variability was observed with regard to exact L position of the plasmapause. Our results suggest that a statistical comparison between the positions of the LIT and the plasmapause should yield a more accurate result.

In summary, our results emphasize that the ion composition as a whole must be examined in detail for a more complete understanding and description of basic ionospheric features, such as the ionization trough, or plasmapause. As we have shown, a separate investigation of an individual ion specie, and more particularly the total ion density, may provide misleading, or confusing results. In addition, it is clear that longitudinal variations must be sorted out to properly identify the complete behavior of the ion composition. Overall, these results encourage a deliberate and cautious approach to the analysis of ionospheric features, as well as to the processing of observational data selected for reference ionospheres.

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REFERENCES

Banks, P. M. and Holzer, T. E. (1969). High latitude plasma transport: the polar wind, J. geophys. Res., 74, 6317.

Banks, P. M., Nagy, A. F, and Axford, W. I. (1971). Dynamical behavior of thermal protons in the mid latitude ionosphere and magnetosphere, Planet. Space Sci., 19, 1053.

Brace, L. H., Mayr, H. G. and Mahajan, K. K. (1970). A polar maximum of electron concentration at 1000 km. altitude, J. Atmos. Terr. Phys., 32, 1945.

Brinton, H. C., Mayr, H. G., Pickett, R. A. and Taylor, H. A., Jr. (1970). The effect of atmospheric winds on the O^+-H^+ transition level, Space Res. X, 652.

Brinton, H. C., Grebowsky, J. M., and Mayr H. G. (1971). Altitude variation of ion composition in the midlatitude trough region, evidence for upward plasma flow, J. geophys. Res., 76, 3738.

Carpenter, D. L., Park, C. G., Taylor, H. A., Jr., and Brinton, H. C. (1969). Multi-experiment detection of the plasmapause from EOGO satellites and Antarctic ground stations, J. geophys. Res., 74.

Grebowsky, J. M., Rahman, N. K., and Taylor, H. A. Jr., (1970). Comparison of coincident OGO-3 and OGO-4 ion composition measurements, Planet. Space Sci., 18, 965.

Harris, K. K., Sharp, G. W., and Knudsen, W. C. (1967). Ion temperature and relative ion composition measurements from a low-altitude polar-orbiting satellite, J. geophys. Res., 72, 5939-5948.

Hoffman, J. H. (1969). Ion mass spectrometer on Explorer 31 satellite, Proc. IEEE, 57, 1063.

Kamiyama, H. (1968). Multi-component diffusion in the topside ionosphere, Rept. Ionosphere Space Res. Japan, 22, 249.

Mayr, H. G., Grebowsky, J. M., and Taylor, H. A. Jr. (1970). Study of the thermal plasma on closed field lines outside the plasmasphere, Planet. Space Sci., 18, 1123.

Miller, N. J. (1970). The main electron trough during the rising solar cycle, J. geophys. Res., 74, 7175-7181.

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

Muldrew, D. B. (1965). F-Layer ionization troughs deduced from Alouette data, J. geophys. Res., 70, 2635-2650.

Nishida, A. (1966). Formation of plasmapause, or magnetospheric plasma knee, by the combined action of magnetospheric convection and plasma escape from the tail, J. geophys. Res., 71, 5669.

Park, C. G. (1970). Whistler observations of the interchange of ionization between the ionosphere and the protonosphere, J. geophys. Res., 75, 4249.

Rycroft, M. J. (1970). The magnetospheric plasmapause and the electron density trough at the Alouette-1 orbit, Planet. Space Sci., 18, 65.

Rycroft, M. J., and Burnell, S. J. (1970). Statistical analysis of movements of the ionospheric trough and the plasmapause, J. geophys. Res., 75, 5600-5604.

Rycroft, M. J. and Thomas, J. O., (1970). The magnetospheric plasmapause and the electron density trough at the Alouette 1 orbit, Planet. Space Sci., 18, 65-80.

Sharp, G. W. (1966). Midlatitude trough in the night ionosphere, J. geophys. Res., 71, 1345-1356.

Sharp, G. W., Chappell, C. R. and Harris, K. K. (1972). The plasmapause as measured in positive ions, presented at the 'Magnetosphere-Ionosphere Interactions" Meeting, held at Estedalen, Norway, April 14-22, 1971, and to be published in the Proceedings of the Meeting by Universitetsforlaget, Oflo, edited by Kr. Folkestad.

Taylor, H. A., Jr., Brinton, H. C., Pharo, M. W., III, and Rahman, N. K. (1968). Thermal ions in the exosphere; evidence of solar and geomagnetic control, J. geophys. Res., 73, 5521.

Taylor, H. A., Jr., Brinton, H. C., Carpenter, D. C., Bonner, F. M. and Heyborne, R. L. (1969). Ion depletion in the high latitude exosphere; simultaneous OGO-2 observations of the light ion trough and the vlf cutoff, J. geophys. Res., 74, 3517.

Taylor, H. A., Jr., Brinton, H. C., and Mayr, H. G. (1970). Observations of hydrogen and helium ions during a period of rising solar activity, Space Research X.

Taylor, H. A., Jr., (1971). Evidence of solar geomagnetic seasonal control of the topside ionosphere, Planet. Space Sci., 19, 77.

Thomas, J. O., Rycroft, M. J., Colin, L. and Chan, K. L. (1966). The topside ionosphere, 2, Experimental results from the Alouette I satellite, in Electron Density Profiles in the Ionosphere and Exosphere, edited by Jon Frihagen, p. 322, North-Holland Publishing Company, Amsterdam.

Thomas, J. O., and Andrews, M. K. (1968). Transpolar exospheric plasma 1. Plasmasphere termination, J. geophys. Res., 73, 7407-7417.

FIGURES

FIGURE 1: A comparison of simultaneous in-situ measurements of the light ion trough and VLF whistler cutoff at the plasmapause near L=4. The lower VLF data panel provides high resolution for the time period near the plasmapause, showing the last whistler occurring near 1127:10, in the midst of the steepest part of the H^+ depletion.

FIGURE 2: Pole-to-pole topside distributions of O^+, He^+, and H^+, plotted with N_i, derived as the sum of all positive ions in the mass range 1-45 AMU. The angle α is defined as the angle between the earth-sun line and the plane of the magnetic equator, measured in the noon meridian. The notation Kp (-6) refers to the maximum value of the planetary magnetic index K_p measured within the 6 hour interval preceding the UT at the beginning of the pass. The local time notation refers to the position of the orbit as the satellite crosses the magnetic equator.

FIGURE 3: An isometric projection of H^+ and N_i profiles observed near 0500 LT in the interval September 22-25, 1969. Pairs of profiles are shown for the longitudes corresponding to each pass. The altitude curve shown for the profiles at -160° longitude is typical for the remainder of the longitude positions shown.

FIGURE 4: The comparison of night (0453 LT) versus day (1751 LT) variations in the distributions of N_i and H^+. Both sets of data were obtained for equinox, with α=7°. The magnetic activity for the six hours preceding each set of data was very similar.

FIGURE 5: A comparison of morning versus evening characteristics in the high latitude distributions of N_i and H^+ observed on the same day, August 24, 1969. The angle α at 22° is indicative of northern hemisphere near 'summertime' conditions. The local times specified refer to the orbit-magnetic equator crossings on either side of the earth.

FIGURE 6: A comparison of the storm time response in the H^+, O^+ and N_i troughs, observed following periods of sharply contrasting magnetic activity. These results observed near 0415 local time are representative of nighttime conditions.

FIGURE 7: A comparison of H^+ and N_i storm-time response on the dayside, near 0830 LT. The arrows indicate the approximate UT of each of the three passes occurring before, during and after the magnetic storm which reached its peak on August 27. The solar-geomagnetic coordinate for each of these passes was nearly identical with α in the range of -1 to +3°. The altitude range for each pass was also nearly identical, spanning the range 700 to 1100 km.

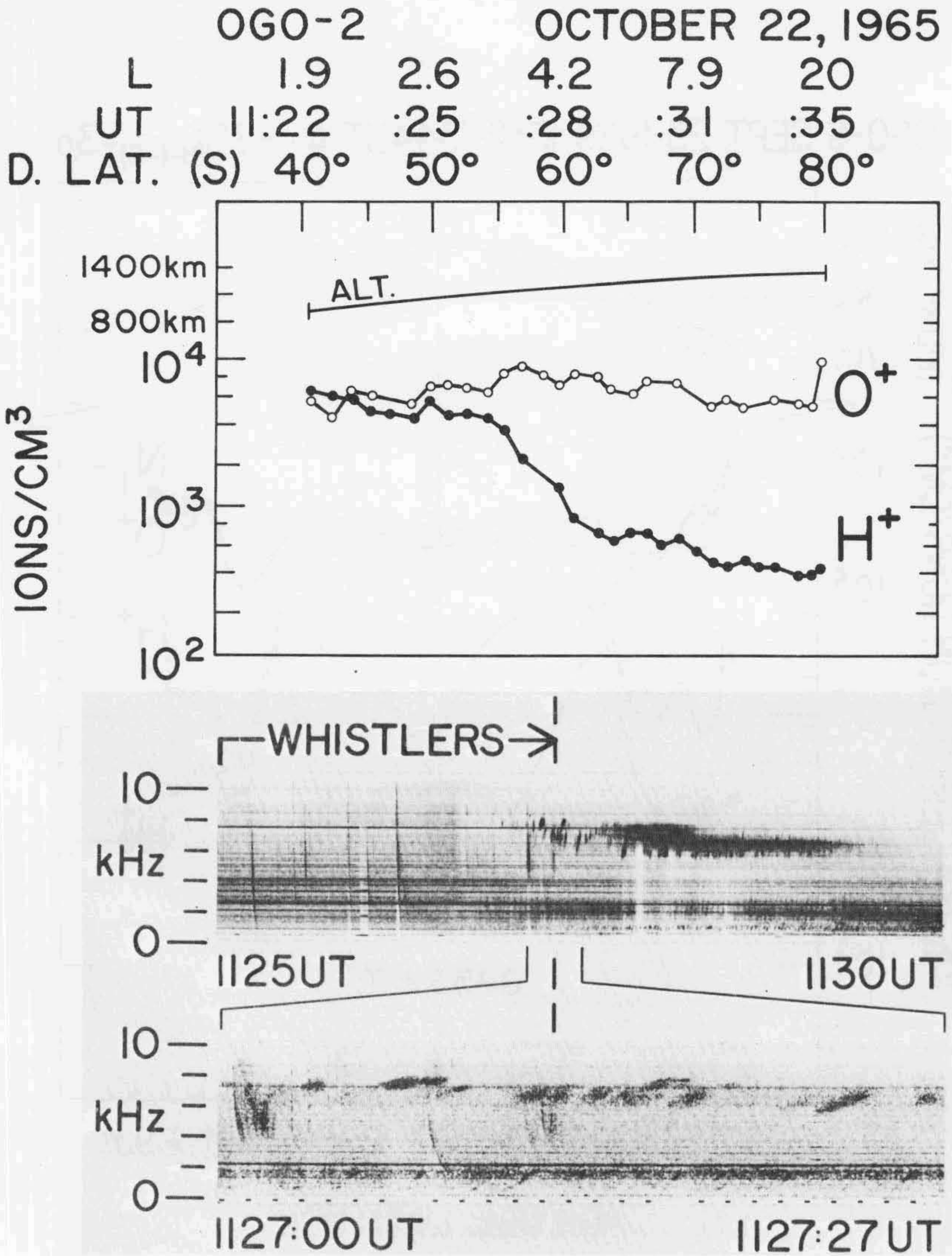
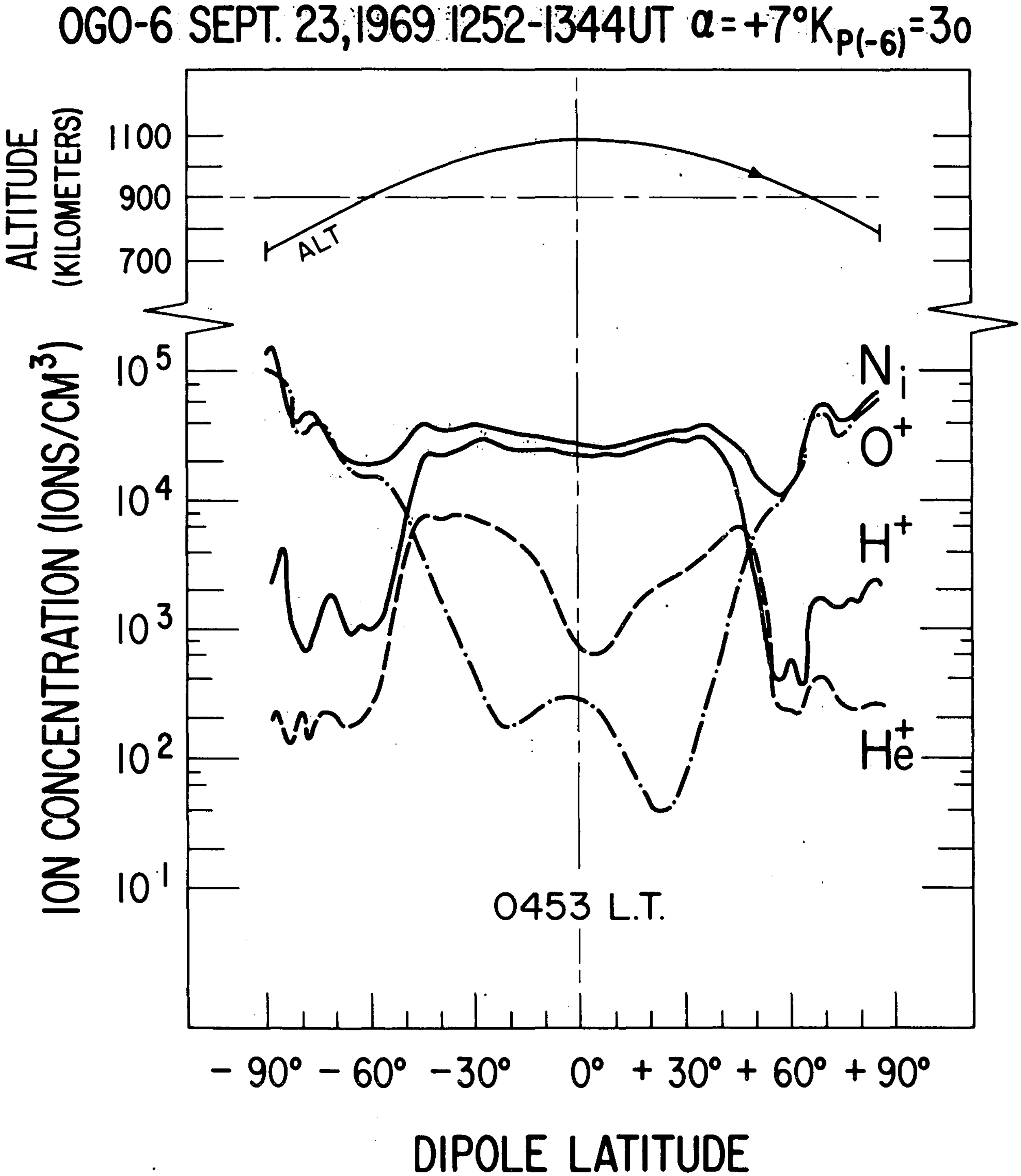
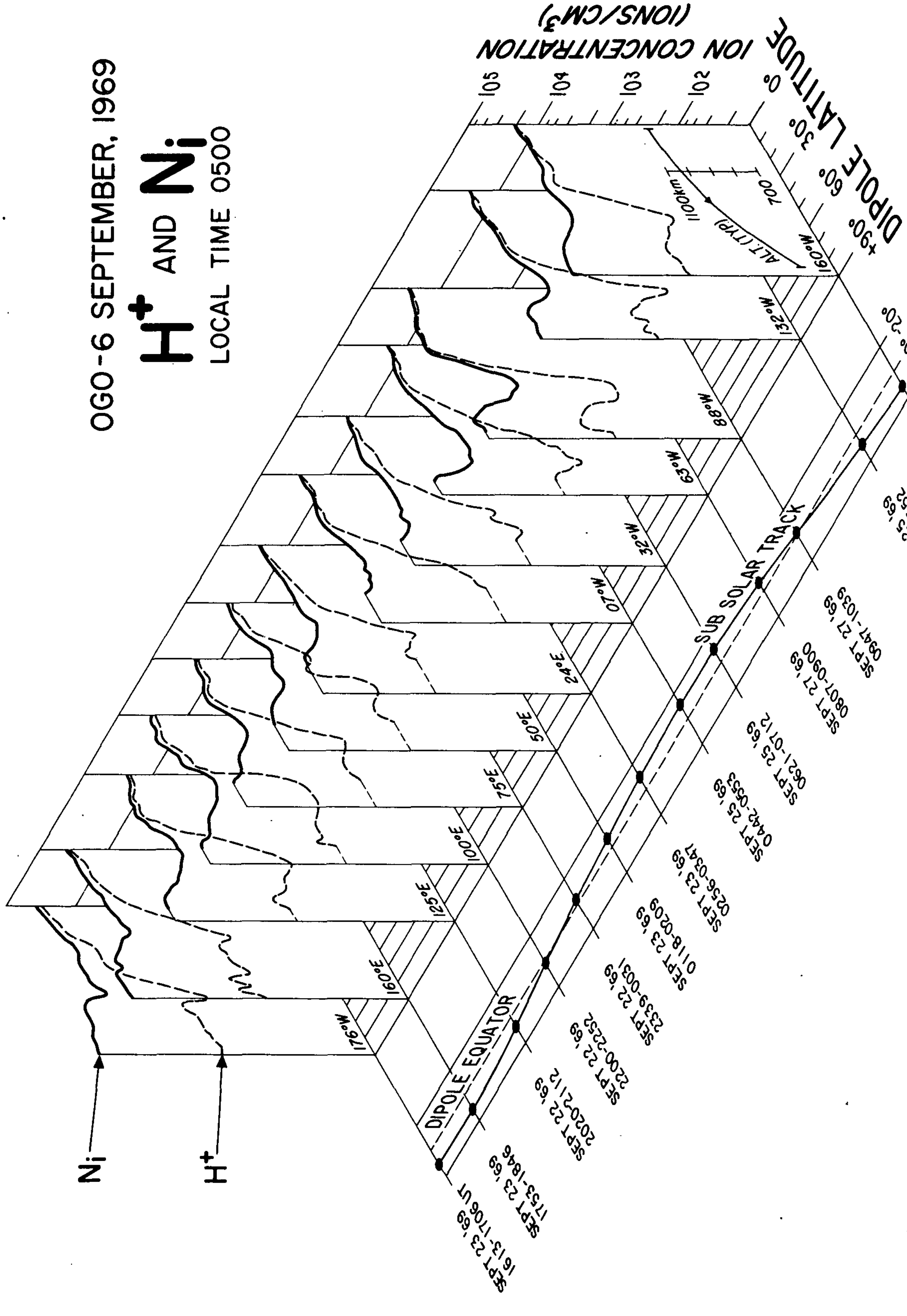

OGO-2
OCTOBER 22, 1965
L 1.9 2.6 4.2 7.9 20
UT 11:22 :25 :28 :31 :35
D. LAT. (S) 40° 50° 60° 70° 80°
1400km
800km
ALT.
IONS/CM3
10^4
10^3
10^2
O+
H+
WHISTLERS
10
kHz
0
1125UT
1130UT
1127:00UT
1127:27UT

FIG. 1



OGO-6 SEPT. 23, 1969 1252-1344UT α=+7° K P(-6)=3o
ALTITUDE (KILOMETERS)
1100
900
700
ALT
ION CONCENTRATION (IONS/CM3)
10 5
10 4
10 3
10 2
10 1
Ni
O+
H+
He+
0453 L.T.
- 90° - 60° -30° 0° + 30° + 60° + 90°
DIPOLE LATITUDE

FIG. 2



OGO-6 SEPTEMBER, 1969
H+ AND Ni
LOCAL TIME 0500
ION CONCENTRATION
(IONS/CM3)
105
104
103
102
DIPOLE LATITUDE
+90°
60°
30°
0°
Q
+20° 0° -20°
ALT. (TYP)
1100km
700
160°W
132°W
88°W
63°W
32°W
07°W
24°E
50°E
75°E
100°E
125°E
160°E
176°W
SUB SOLAR TRACK
DIPOLE EQUATOR
Ni
H+
SEPT 22,'69 1518-1611 UT
SEPT 25,'69 1259-1352
SEPT 27,'69 0947-1039
SEPT 27,'69 0807-0900
SEPT 25,'69 0621-0712
SEPT 25,'69 0442-0533
SEPT 23,'69 0256-0347
SEPT 23,'69 0118-0209
SEPT 22,'69 2339-0031
SEPT 22,'69 2200-2252
SEPT 22,'69 2020-2112
SEPT 23,'69 1753-1846
SEPT 23,'69 1613-1706 UT

FIG. 3

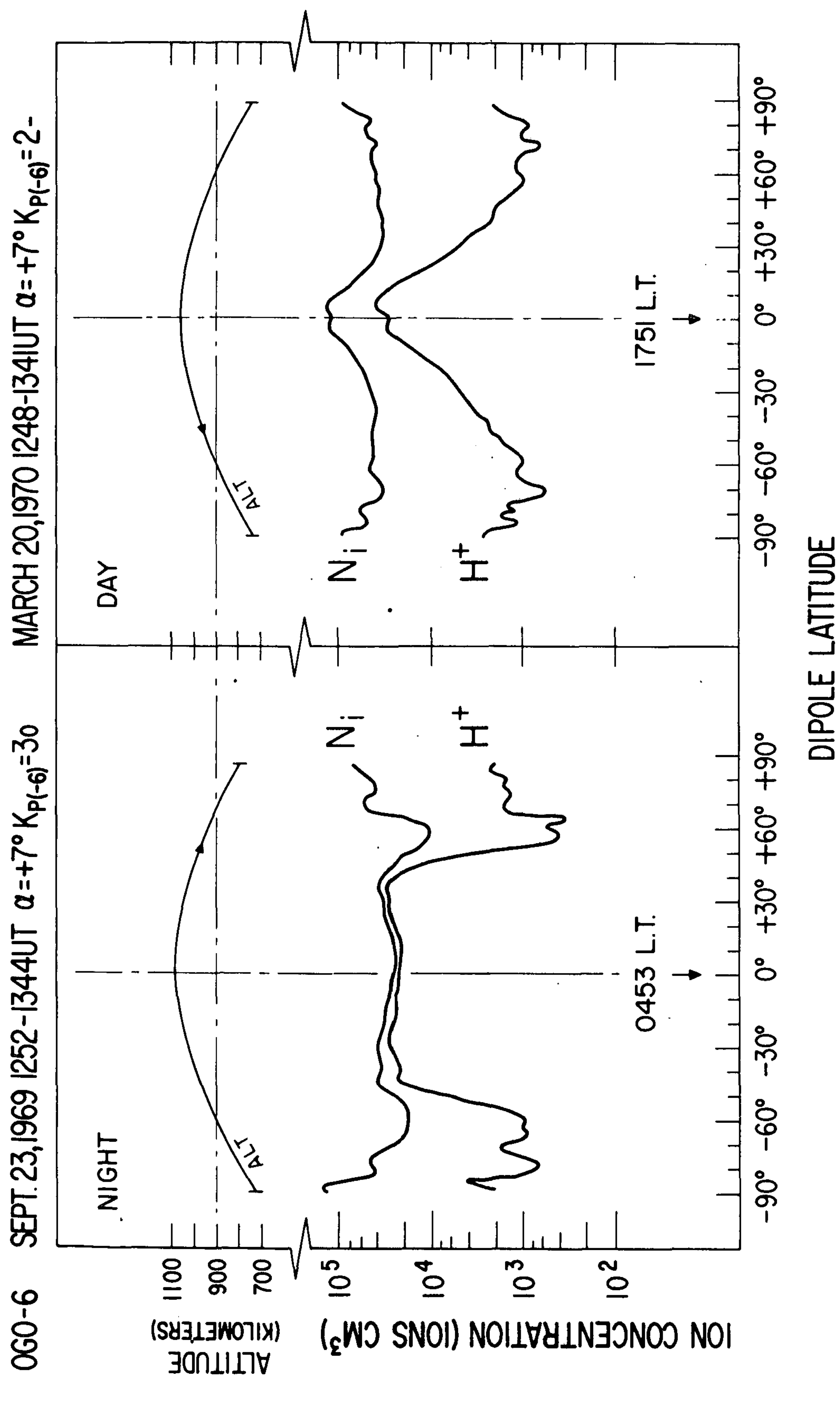

OGO-6
ALTITUDE (KILOMETERS)
ION CONCENTRATION (IONS CM^3)
1100
900
700
10^5
10^4
10^3
10^2
SEPT. 23, 1969 1252-1344UT α=+7° $K_{P(-6)}$=3o
MARCH 20, 1970 1248-1341UT α=+7° $K_{P(-6)}$=2-
NIGHT
DAY
ALT
N_i
H^+
0453 L.T.
1751 L.T.
-90° -60° -30° 0° +30° +60° +90°
DIPOLE LATITUDE

FIG.4

OGO-6 AUG. 24, 1969 1606-1657UT α=+22° $K_{P(-6)}$=2+

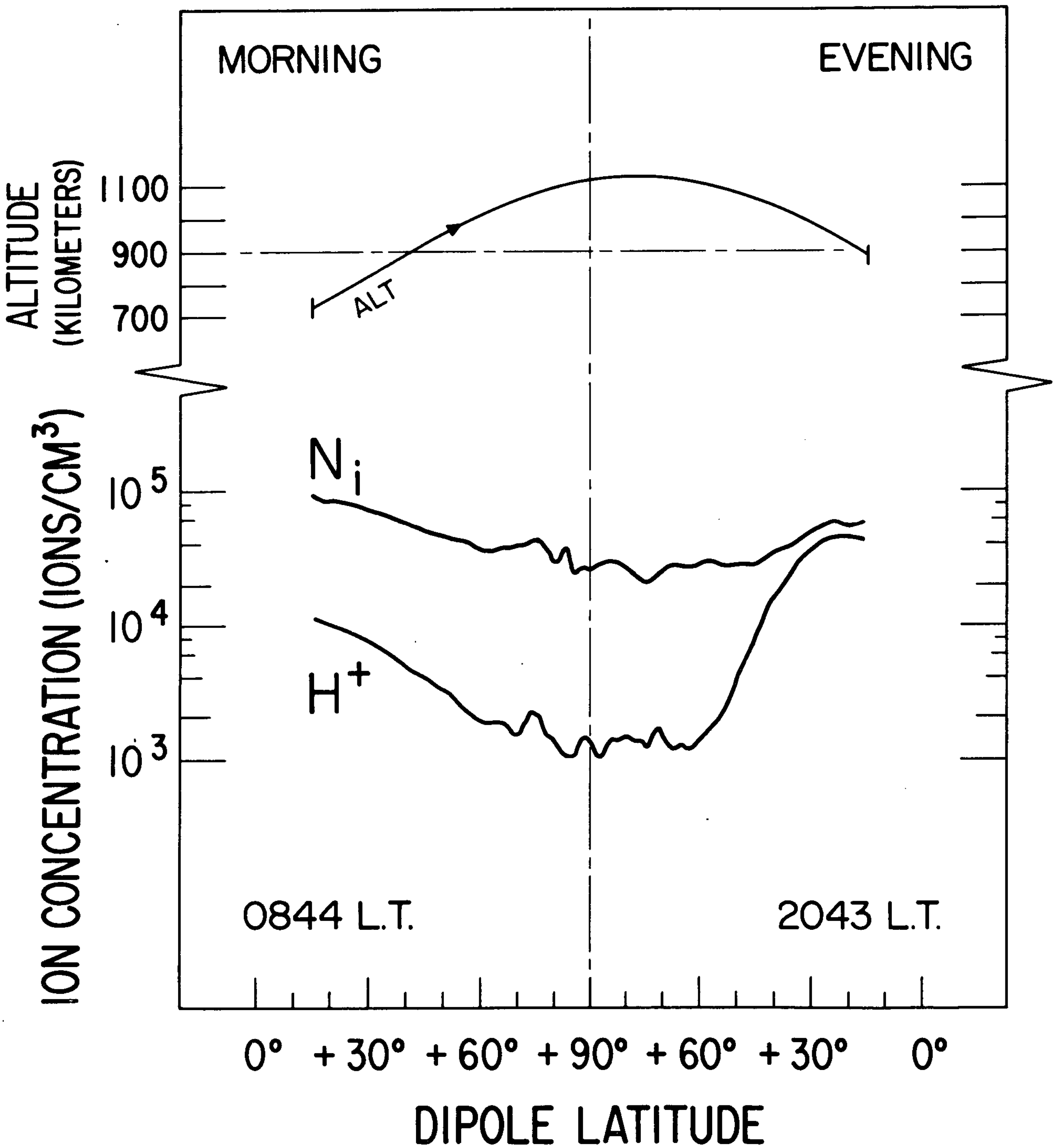
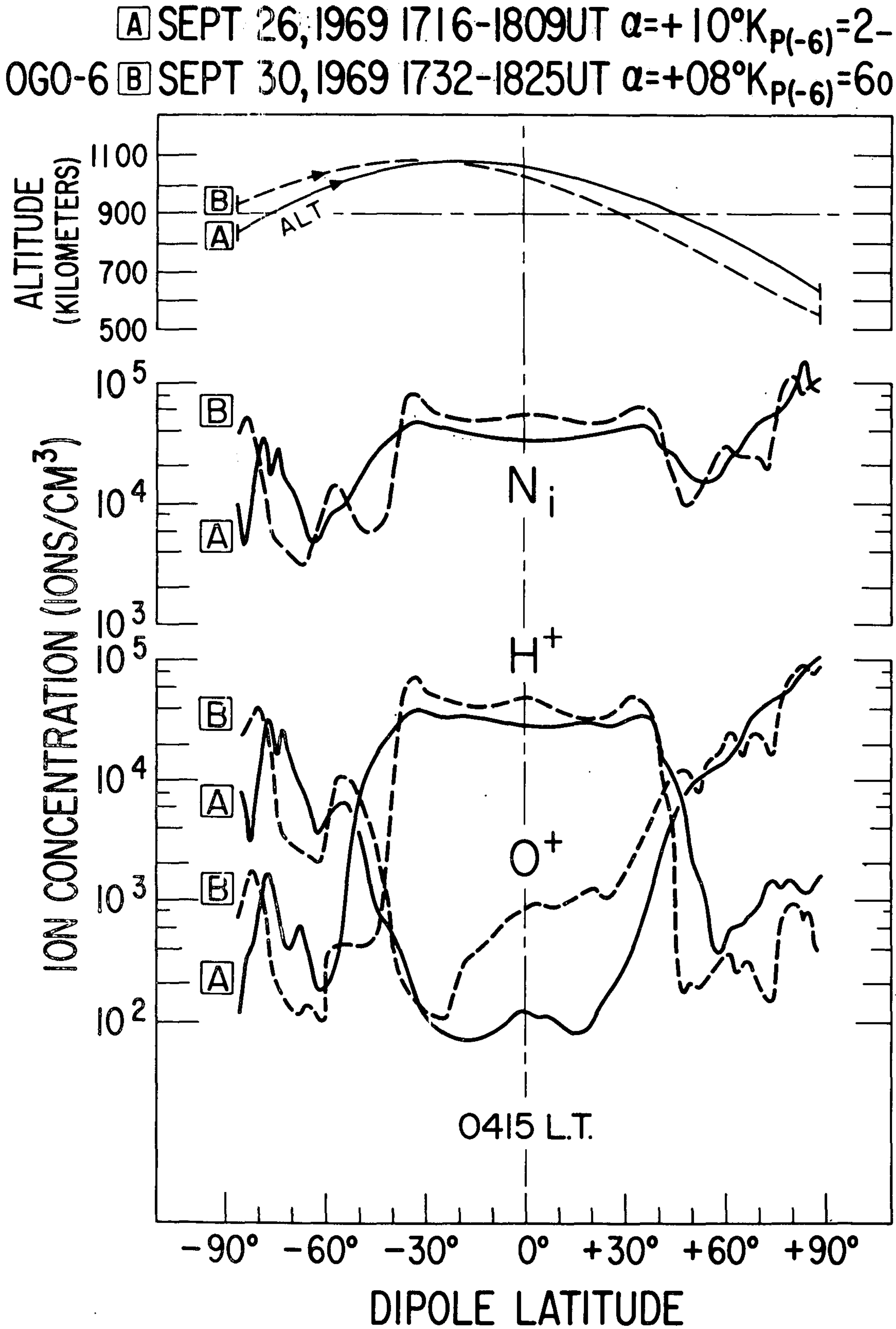
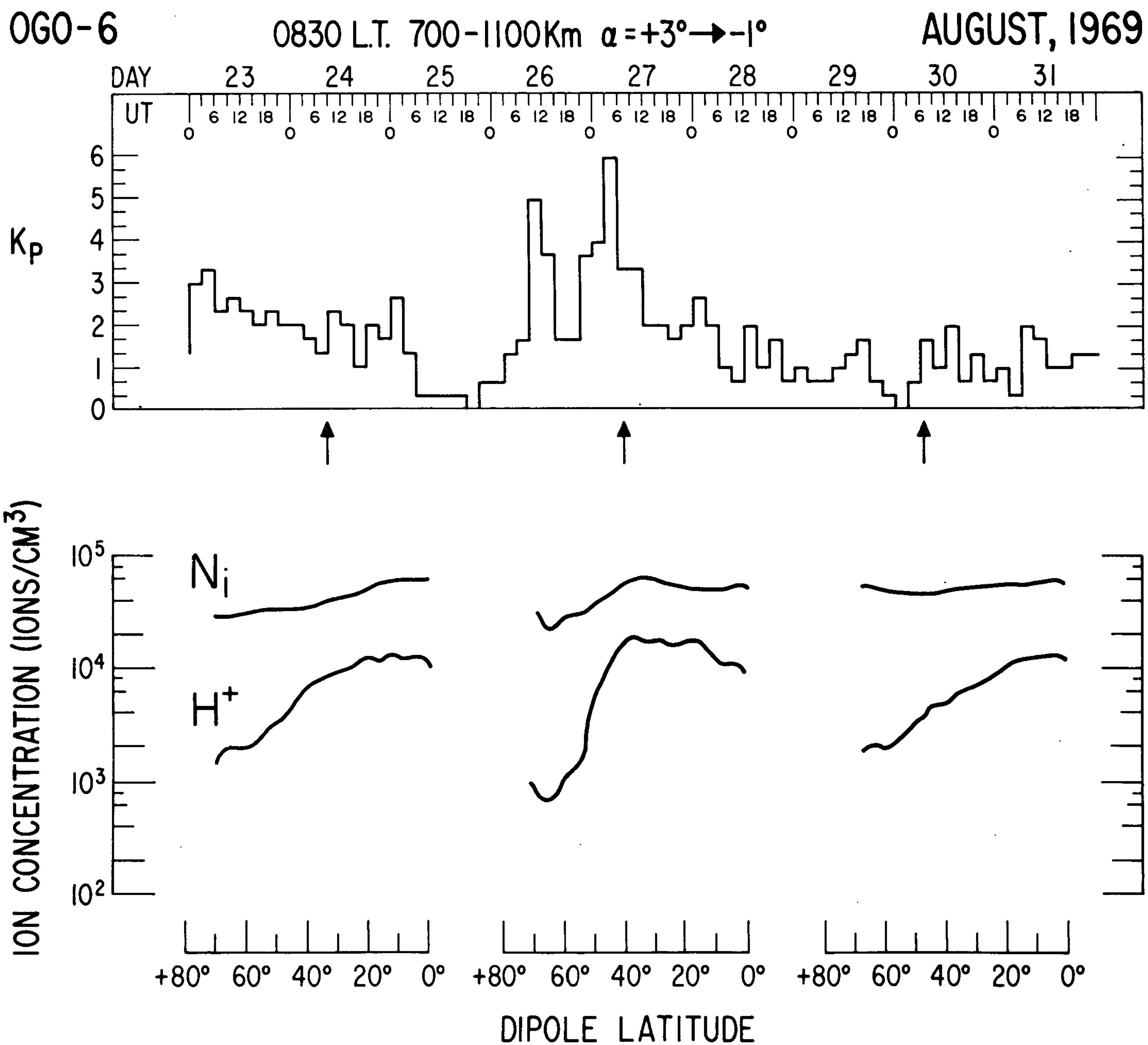


FIG. 5



OGO-6 A SEPT 26, 1969 1716-1809UT α=+10° $K_{P(-6)}$=2-
B SEPT 30, 1969 1732-1825UT α=+08° $K_{P(-6)}$=6o
ALTITUDE (KILOMETERS)
1100
900
700
500
B
A
ALT
ION CONCENTRATION (IONS/CM³)
10^5
10^4
10^3
10^2
N_i
H^+
O^+
0415 L.T.
-90° -60° -30° 0° +30° +60° +90°
DIPOLE LATITUDE

FIG. 6



OGO-6
0830 L.T. 700-1100Km α=+3°→-1°
AUGUST, 1969
DAY
23
24
25
26
27
28
29
30
31
UT
0 6 12 18
Kp
6
5
4
3
2
1
0
ION CONCENTRATION (IONS/CM³)
10⁵
10⁴
10³
10²
Ni
H⁺
+80° 60° 40° 20° 0°
DIPOLE LATITUDE

FIG. 7