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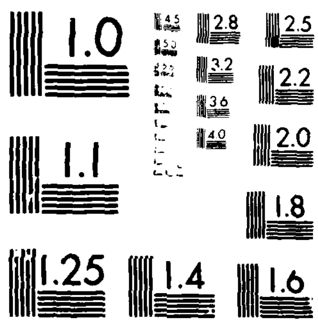

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Coordinated measurements of equatorial spread-F conducted during July 1979 at the Kwajalein Atoll have yielded the first definitive space- and time coincident radar and rocket observations of small scale irregularities and large scale plasma depletions. The results have shown that:

(a) Within a large-scale topside F-layer depletion radar backscatter energy is at a level much lower than that observed on the depletion's topside. The same is true of "in situ" irregularity observations, and

(Continues)

20. Abstract (Continued)

(b) Ion composition within a topside depletion can provide signatures of its bottomside source domain and estimates of average maximum vertical drift velocity. For long-lived depletions, molecular-ion signatures (NO^+ and O_2^+) can be lost while bottomside levels of N^+ can be maintained when $[O^+] \approx N_e \gg [NO^+] + [O_2^+]$, and finally,

(c) Large scale fluctuations of O^+ accompanied by a near-constant level of NO^+ and O_2^+ on the bottomside F-layer gradient suggests that neutral atmospheric turbulence is not a major source for bottomside ionospheric plasma irregularities.

CONTENTS

I. INTRODUCTION

Accumulated information regarding equatorial spread-F phenomena has pointed toward a definite causal relationship between the large scale depletions (also referred to as holes, bite-outs, or bubbles) and range-time-intensity observations of large ionospheric domains with strong radar backscatter returns from the much smaller (meter size) irregularities (called plumes). Woodman and LaHoz (1976) and Kelly, et al. (1976), have suggested that a plume was due to a rising bubble leaving behind a wake of short wavelength irregularities. Another proposal (Szuszczewicz, 1978), arising from considerations of chemistry and transport, suggested that the radar returns originate across the density gradients at the boundaries of large scale depletions. This concept is supported by the work of Ossakow, et al. (1979) where it is inferred that a bubble rising through the F-layer will bifurcate on its topside and produce shorter and shorter wavelength irregularities, either by a cascade or two-step mechanism. Experimental evidence to verify this position has come from an Altair radar experiment (Tsunoda, 1980a) which showed that backscatter maxima tend to occur at altitudes corresponding either to the electron density minima or the upper wall of the plasma depletion. More recently, Tsunoda (1980b) concluded that during the decay phase of meter scale backscatter plumes, the radar returns were maximum on the upper walls of the plasma depletions.

Note: Manuscript submitted February 22, 1980.

Efforts to examine the exact relationship between radar plumes and ionospheric depletions by performing simultaneous "in situ" and ground-based radar observations (Kelly, et al. 1976; Morse, et al. 1977) have been limited to conditions of bottomside spread-F and required extrapolations in space and time to establish correlations. As expected for bottomside spread-F, the "in situ" probes only observed plasma fluctuations along the portion of the trajectory below the F-layer peak density while the ionosphere above the peak was quite smooth.

The ion composition within the depletions has also been the subject of a number of investigations. Typically, satellite mass spectrometric observations (Brinton et al. 1975; McClure et al, 1977; Szuszczewicz, 1978) have shown that the ion composition can be vastly different inside and outside the bite-outs. Fe^+ ions may be enhanced or depleted, with molecular ions usually more abundant inside the bite-out. Brinton et al. (1975) and McClure et al. (1977) have found O^+ depleted by as much as a factor of 10^3 to a concentration below that of NO^+. The molecular ion NO^+ was found to be dominant in the O^+ depleted region, with the bite-outs varying from a few kilometers to tens of kilometers in width. An analysis of the Atmospheric Explorer-C data (Szuszczewicz, 1978) suggested that a given chemical volume on the bottomside F-layer ($[NO^+]$, $[O_2^+] > [O^+]$) could move upward through a stationary neutral atmosphere and appear at higher altitudes as a bite-out in the local plasma density. As the bottomside F-region plasma cell moved upward, the relative magnitudes of its ionic components would depend on transit time and on altitude through the height distribution of the neutral gases. This model was consistent with the satellite observations as well as the computational work of Scannapieco and Ossakow (1976).

In a continuing effort to understand the detailed relationships involving large scale plasma depletions, meter-size irregularities and associated ion-chemical signatures, a rocket payload instrumented with a plasma diagnostics complement (plasma probes, electric field sensors, mass spectrometer and a two-frequency beacon experiment) was launched into the topside F-region ionosphere above Roi-Namur in the Kwajalein Atoll (4.3° N dip latitude). The investigation was part of a major effort which coordinated rocket and Altair radar observations with bottomside soundings and ground-based photometric measurements of F-region winds. We present here the initial coordinated observations of the radar plumes and the "in situ" measurements of the rocket-borne plasma probes and mass spectrometer.

II. EXPERIMENTAL RESULTS

A. Ionospheric Conditions and Radar Maps

By 2100 hr LT on the night of the rocket launch, ionograms showed that the nominal bottomside of the F-layer had risen to an altitude of 400 km. At that point, the F-layer began drifting downward with an almost immediate occurrence of spread-F. The downward drifting continued (as did the spread-F) at an approximate average velocity of 10m/sec with the bottomside F-layer having descended to an altitude near 270 km when the rocket was launched (12:31:30 UT on day 198; 00:31:30, 17 July 1979, LT).

Operating at 155.5 Mhz radar backscatter returns from 1 m ionospheric irregularities) the Altair radar executed consecutive east-west scans in a plane that included the penetration of the rocket's upleg trajectory. Figure 1 presents the contours of constant backscatter strength plotted in 10 dB increments. (For details of the Altair system see Tsunoda et al., 1979). The first panel in Figure 1 shows a backscatter plume just moving out of the radar's eastern-most field of view. That plume, with its highest and most intense backscatter region near 510 km, is connected to backscatter domains extending down to the bottomside of the F-layer. The second panel, with a center scan time 137 seconds later than the first, shows the intense backscatter region further to the east, having drifted there with an approximate west-east velocity of 160m/sec. In the third panel the plume has nearly moved completely out of the radar's field of view and the intense region near 510 km has decayed.

B. Rocket Profile and Comparison with Radar

The rocket payload that was launched into the spread-F conditions depicted in Figure 1 carried a quadrupole ion mass spectrometer (from the Air Force Geophysics Laboratory) a pair of pulsed plasma probes (from the Naval Research Laboratory), vector electric field sensors (from Utah State University) and a two-frequency beacon experiment (SRI International). The pair of pulsed probes simultaneously tracked ion and electron saturation currents while generating conventional Langmuir probe characteristics (see e.g., Szuszczewicz and Holmes, 1977). Figure 2 displays the upleg measurements of relative electron density as presented by correlated ion and electron saturation currents. The ordinate has a linear scale for time-after-launch with altitude superimposed at 50 second increments. (Because ion and electron saturation currents have significantly different sensitivities to velocity, sheath and magnetic field effects (e.g., Szuszczewicz and Takacs, 1979) data points not corroborated by both polarity currents were attributed to the various aspect sensitivities and therefore were not included in Figure 1. This approach facilitates quick look analysis and establishes credibility in the interpretation of the curves as relative electron density profiles.)

The profile shows that the payload entered the very bottom of the F-layer at $t \simeq 103$ sec ($Z \simeq 240$ km). From that point, to an apogee near 590 km, the "in situ" measurements revealed a number of plasma depletions depicted in the figure as regions C, D-E, F-G, H-I, and J-K. The largest depletion was in region H-I where $\Delta N_e/N_e^o \simeq 0.85$ with a halfminimum vertical extent approximatley equal to 23 km.

In the regions of the large-scale depletions, the "in situ" measurements also revealed much smaller scale irregularities. The central plot of "irregularity intensity" in Figure 2 identifies the regions of smaller irregularities and attempts to establish a preliminary quantification for their intensity. ("Irregularity intensities" were scaled directly from probe current fluctuations about an estimated mean. As an illustration, the -4.5 to +4.5 irregularity intensity within region C represents a factor of 9 in the largest peak-to-peak fluctuation measured in that region. (If vehicle potential, plasma temperature and ion composition were constant during the irregularity measurements, then $I \propto N_e$.) More quantitative analyses along with power spectral densities will be determined for future publication.) The results show that the most intense irregularities occurred on the bottomside gradient (region C) with corresponding measurements at all other altitudes at a much lower level. We note that the fluctuations in the largest depletion (region H-I) are smaller than those at "C". The data also indicate that the more intense fluctuations occur on positive density gradients (C,D,E, and I).

The payload's upleg trajectory has been superimposed on the radar maps in Figure 1 with domains A through K (and their associated times of observation) identified on the panel best matched for time coincidence with the radar results. A step-wise comparison of "in situ" irregularity observations (Fig. 2) with the radar maps reveals some interesting correlations:

Point "A" corresponds to the lowest position of the bottomside F-layer, while "B" is midway up the steep bottomside and very near the point of maximum positive density gradient. Region "C" is at the boundary of the third highest backscatter level (30 dB), and appears to represent the mid-phase development of large scale Rayleigh-Taylor turbulence. Observations at "D", "E", "F" and "G" occur along the western "wall" of the plume, and encompass an altitude domain identified with the F-layer peak. Point "G" represents the payload's entry into the large scale depletion centered near 240 sec (490 km) on the upleg trajectory. The payload's transit from "G" to "I" is marked by a positive gradient in backscatter radar energy, with the maximum return occurring on the topside (region "I" and above) of the H-I depletion. Above the large scale depletion, observations "K" and "J" begin to track the western "wall" of the plume in the topside F-region.

C. Ion Composition

O^+ was observed to be the dominant ion component throughout the entire F-region. From points of view focussed on turbulence and transport the chemical constituency of two regions are worthy of note:

In the H-I depletion on the topside F-layer the major observed ion components were $[O^+] \simeq 0.998\ N_e$, $[N^+] \simeq 0.002\ N_e$ and $([NO^+] + [O_2^+]) < 10^{-4} N_e$. In the adjacent domains there was a different distribution of ions, i.e., outside the depletion we found $[O^+] \simeq 0.992\ N_e$, $[N^+] \simeq 0.007\ N_e$ and $([NO^+] + [O_2^+]) < 2\ (10^{-5})\ N_e$, a distribution typical of the zero-order ionosphere at those altitudes.

The ion composition within the H-I depletion suggests that it may have originated at or near the bottomside F-region where $[O^+] \simeq [O^+]_{H-I}$. Such a region exists at 112 sec ($Z \simeq 262$ km) on the upleg trajectory where it was observed that $[NO^+]$ and $[O_2^+]$ were 1-2% of N_e and the $[O^+]/[N^+]$ ratio was nearly identical to that observed in the H-I domain. This points to N^+ as a long-lived tracer ion for bottomside source regions of topside depletions. The fact that the source region levels of NO^+ and O_2^+ have not been preserved in the topside hole results from their losses by dissociative recombination and a simultaneous loss in production by ion-atom interchange and charge exchange reactions since $[N_2]$ and $[O_2]$ decrease markedly with altitude. The longer it takes a bottomside depletion to move upward into the topside F-layer, the more likely the elimination of molecular ion signatures when $[O^+] \approx N_e >> ([NO^+] + [O_2^+])$. In the case of the H-I depletion, a vertical transport time greater than 360 seconds would account for the molecular ion deficiency. (To arrive at this estimate we assumed an instaneous dis-placement of the bottomside ion composition to the H-I altitude and calculated that in about 6 minutes the molecular ions would decrease to a concentration less than 5 cm^{-3}.) This time estimate suggests an upper limit of about 600 m/sec for the depletion's average vertical drift velocity, a value which is consistent with the wide range in predicted bubble rise velocities (Ossakow and Chaturvedi, 1978; Ossakow et al., 1979; Anderson and Haerendel, 1979). (While this conclusion is correct in its own right, we note that Altair data prior to that shown in Fig. 1 reveal that the backscatter plume was at the nominal altitude shown in Figure 1 for more than 30 minutes.)

The second region of special note is "C" where it was observed that O^+ followed the intense plasma density fluctuations while the molecular ions NO^+ and O_2^+ (representing @0.5-1.0% N_e) did not. Such a result has a possible explanation in an assumption that requires steady state chemical equilibrium in an O^+ dominant domain. (Molecular ions in region "C" can achieve equilibrium concentrations in less than 10 minutes.) Under this condition, molecular ion concentrations are independent of O^+ and vary only with the scale height of the neutral atmospheric constituents N_2 and O_2. The observations conform to this model with a standard zero-order atmospheric distribution, suggesting that neutral atmospheric turbulence is not a major source for the observed plasma fluctuations on the bottomside F-region.

D. North-South Extent of the Depletions

Figure 3 presents the up- and downleg profiles of relative electron density as measured by "in situ" probe electron-saturation currents. (The integrity of the downleg profile was established by the same procedure utilized in Figure 2.) A comparison of the profiles shows very good agreement in the two observations of plasma depletions. Attention is directed to the large scale depletion of the topside (region H-I):

The up- and downleg measurements of the large topside hole were separated in time by approximately 340 seconds and in range by 112 km. During this 340 second interval Altair radar measurements of plume movement showed an average easterly drift at a 160 m/sec rate resulting in a total eastward displacement of 54 km. Adding 14 km to account for depletion alignment along the magnetic meridian (9^{o}E of true azimuth) yields a calculated total E-W displacement of 68 km between the times of the two rocket observations of the hole. During this time interval the payload had an eastward range velocity approximately equal to 215 m/sec, resulting in an east-west separation in the up- and downleg observations of region H-I equal to 73 km. From this we can conclude near-perfect up- and downleg targeting of the hole. The agreement in the two observations of the H-I domain therefore suggests that the depletion is aligned with the magnetic field for at least 112 km. (Parallel arguments dealing with the depletion at $(t,Z) \simeq$ (153s, 350 km) would suggest a field alignment at least as great as 163 km, while the radar observations of Tsunoda [1980b] showed plasma bubble alignment can extend to 1100 km.)

III. COMMENTS AND CONCLUSIONS

Space- and time coincident measurements of equatorial spread-F conducted during July 1979 at the Kwajalein Atoll have yielded the first definitive observations of small scale irregularities (@1 meter) and large scale plasma depletions as measured independently throughout the F-region by ground-based radar and "in situ" plasma instrumentation. Preliminary analysis of the results leads to the following comments and conclusions:

(a) Within a large-scale, decay-phase, topside F-layer depletion where "in situ" irregularities were reduced (compared with the depletion's topside wall), the radar's backscatter energy was also reduced (compared with the top-side wall). This result suggests the co-location of maximum radar returns with the upper regions of a depletion (its topside wall and above) and not with the depletion minimum or bottomside wall.

(b) The "in situ" measurements established field alignment of large scale depletions to distances at least as great as 163 km. This result supports the topside sounder data of Dyson and Benson (1968), the airglow observations of Weber et al., (1978), the recent radar measurements of Tsunoda (1980 a,b) and the assumption of depleted flux tubes in the theoretical considerations of Anderson and Haerendel (1979).

(c) Ion composition measurements within a topside depletion showed little evidence of bottomside molecular tracer ions (i.e., NO^+ and O_2^+). This result points to the requirement for rapid bubble rise velocities and/or low plasma densities ($N_e << 10^4\ cm^{-3}$) within the hole if the bottomside molecular ion composition is to be maintained as bubbles drift upward through the F-region (Szuszczewicz, 1978). However, the measurements did reveal N^+ as a longer lived tracer ion. This helped identify the lower altitude source region to be on the bottomside F-layer gradient.

(d) Strong irregularities on the bottomside F-region gradient showed O^+ following large scale density fluctuations while the molecular ions NO^+ and O_2^+ were relatively constant. Preliminary analysis of this result suggests chemical equilibrium and eliminates neutral atmospheric turbulence as a major source of the bottomside plasma irregularities.

(e) An estimate of bubble rise velocity was arrived at by preliminary ion chemical analysis of composition within the hole. The analysis suggests an upper limit of 600 m/sec for the average vertical velocity of an 85% depleted domain (85% on the topside, 100% at the F-peak) as it drifted upward from its bottomside source region near 260 km to the topside F-layer at 490 km. This upper limit is consistent with the wide range in predicted values (Ossakow and Chaturvedi, 1978; Ossakow et al., 1979; Anderson and Haerendel, 1979).

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REFERENCES

Anderson, D.N., and G. Haerendel, "The motion of depleted plasma regions in the equatorial ionosphere," J. Geophys. Res., 84, 4251, 1979.

Brinton, H.C., H. G. Mayr, and G. P. Newton, "Ion composition in the nighttime equatorial F-region: Implications for chemistry and dynamics" (abstract), Eos Trans. AGU, 56, 1038, 1975.

Dyson, P.L., and R.F. Benson, "Topside sounder observations of equatorial bubbles," Geophys. Res. Lett. 5, 795, 1978.

Kelly, M.C., G. Haerendel, H. Kappler, A. Valenzuela, B.B. Balsley, D.A. Carter, W.L. Ecklund, C.W. Carson, B. Hausler, and R. Torbert, "Evidence for a Rayleigh-Taylor type instability and upwelling of depleted density regions during equatorial spread F," Geophys. Res. Lett., 3, 448, 1976.

McClure, J.P., W.B. Hanson, and J.H. Hoffman, "Plasma bubbles and irregularities in the equatorial ionosphere," J. Geophys. Res., 82, 2650, 1977.

Morse, F. A., B.C. Edgar, H.C. Koons, C.J. Rice, W.J. Heikkila, J.H. Hoffman, B.A. Tinsley, J.D. Winningham, A.B. Christensen, R.F. Woodman, J. Pomalaza, and N.R. Teizeira, "Equion, and equatorial ionospheric irregularity experiment," J. Geophys. Res., 82, 578, 1977.

Ossakow, S. L., and P.K. Chaturvedi, "Morphological studies of rising equatorial spread-F bubbles," J. Geophys. Res., 83, 2084, 1978.

Ossakow, S.L., S.T. Zalesak, B.E. McDonald, and P.K. Chaturvedi, "Nonlinear equatorial spread F: Dependence on altitude of the F peak and bottomside background electron density scale length," J.Geophys. Res. 84, 17, 1979.

Scannapieco, A.J., and S.L. Ossakow, "Nonlinear equatorial spread F," Geophys. Res. Lett., 3, 451, 1976.

Szuszczewicz, E.P. and J.C. Holmes, "Observations of electron temperature gradients in mid-latitude E_s layers," J. Geophys. Res., 82, 5073, 1977.

Szuszczewicz, E.P., "Ionospheric holes and equatorial spread-F: Chemistry and transport," J. Geophys. Res. 83, 2665, 1978.

Szuszczewicz, E.P., and P.Z. Takacs, "Magnetosheath effects on cylindrical Langmuir probes," Phys. Fluids 22, 2424, 1979.

Tsunoda, R.T., M.J. Baron, J. Owen and D.M. Towle, "Altair: An Incoherent scatter radar for equatorial spread-F studies," Radio Sci., 14, in press, 1979.

Tsunoda, R.T., "On the spatial relationship of 1-m equatorial spread-F irregularities and plasma bubbles," J. Geophys. Res. 85, (in press, 1980a).

Tsunoda, R.T., "Magnetic-field-aligned characteristics of plasma bubbles in the nighttime equatorial ionosphere," J. Atmos. Terr. Phys. (submitted, January 1980).

Weber, E.J., J. Buchau, R.H. Eather, and S.B. Mende, "North-south aligned equatorial airglow depletions," J. Geophys. Res., 83, 712, 1978.

Woodman, R.F., and C. LaHoz, "Radar observations of F region equatorial irregularities," J. Geophys. Res., 81, 5447, 1976.

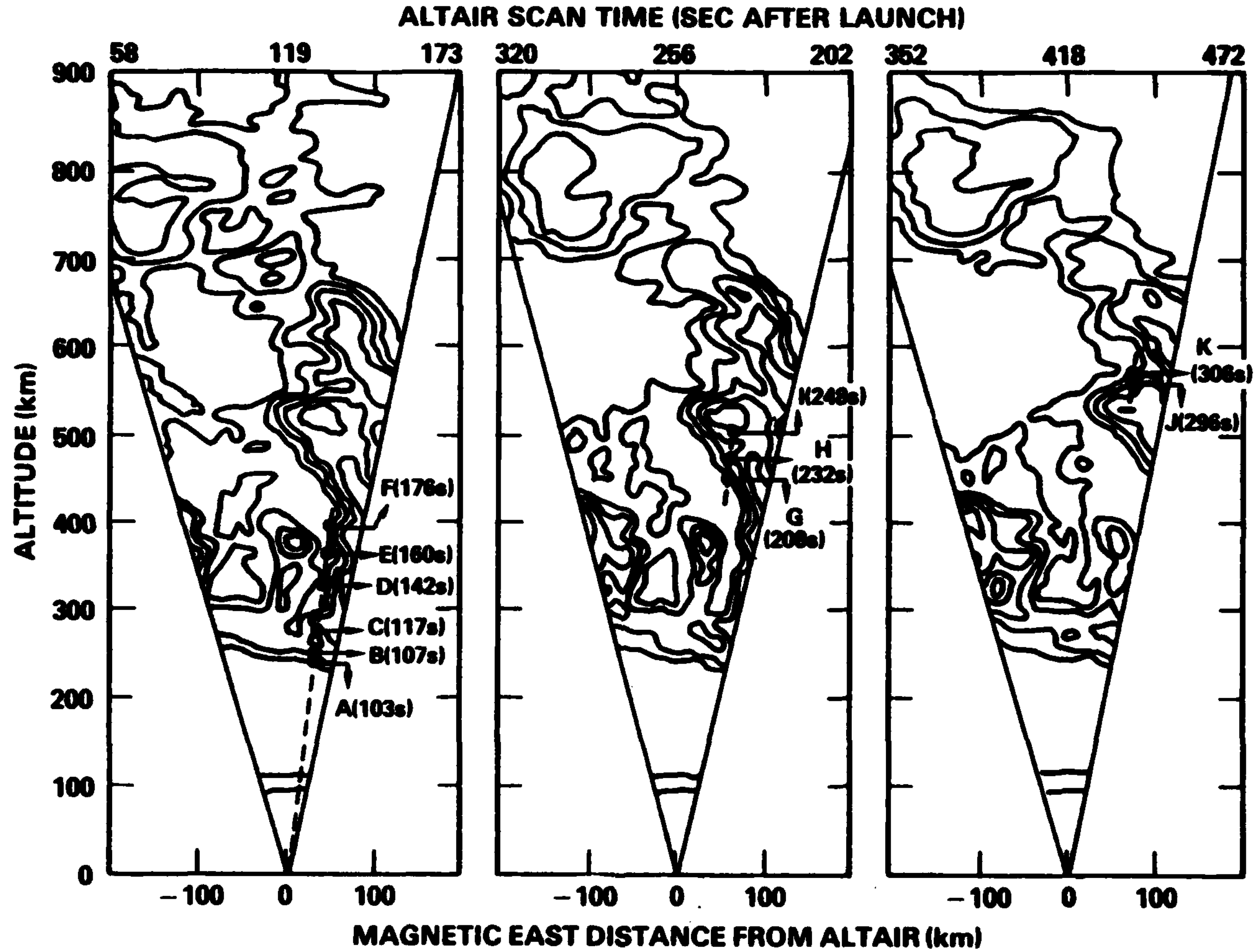

Fig. 1 — Backscatter intensity contour maps (contours are in 10 dB increments) with superposition of the rocket trajectory. The times identified with observations "A" through "K" are included for a more complete representation of temporal correlation with the successive radar scans.

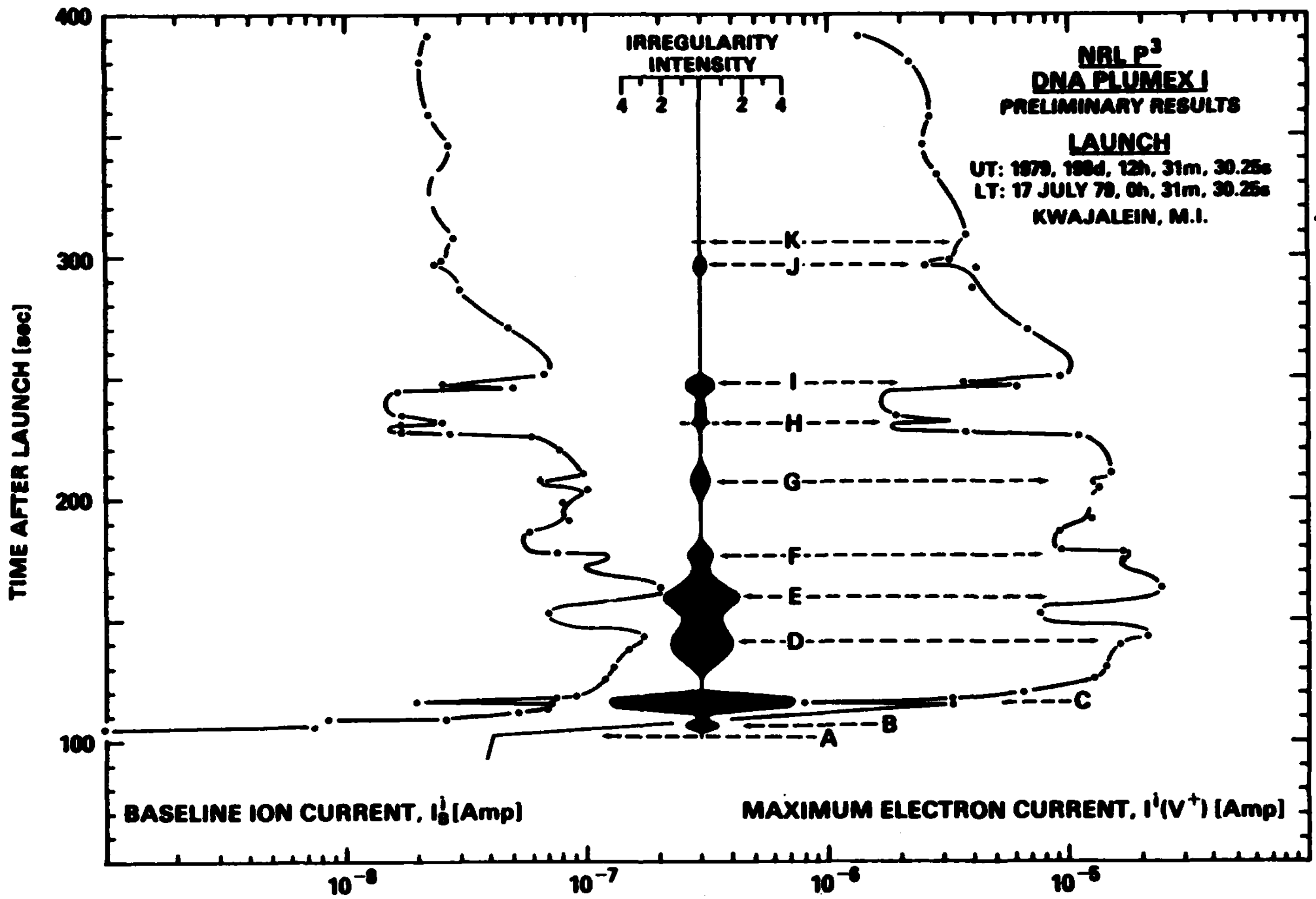

Fig. 2— Relative electron density profile as measured simultaneously by ion and electron saturation probe currents collected on the upleg trajectory. The "irregularity intensity" provides an approximate measure of smaller scale structure as scaled from analog strip chart records of probe current fluctuations.

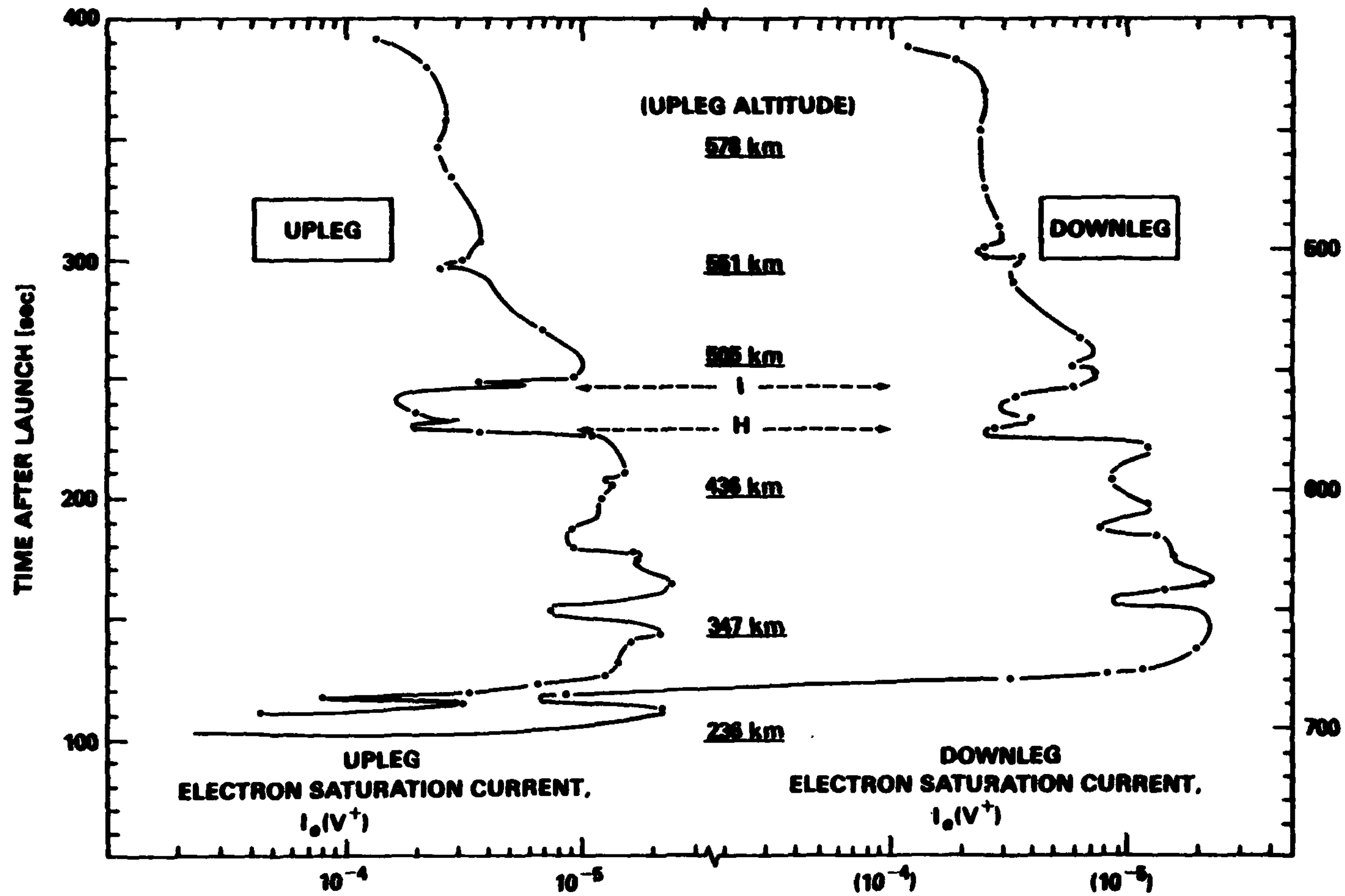

Fig. 3— Comparison of up- and downleg plasma profiles

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