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# INVESTIGATION OF LOW ENERGY SPACE PLASMA

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by

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## ANALYSIS TECHNIQUES AND SOFTWARE DEVELOPMENT

Refinements have been made to the fitting of the density versus spacecraft potential curve. In order to limit the RIMS data influencing the fit to those in which we have the most confidence,without using subjective judgments, we have place a three sigma (standard deviation) envelope about our initial curve and used only data within those limits to determine the final fit. This seems to produce a good fit to all the data, and particularly to the best data, without resorting to an arbitrarily selected subset to obtain it. The technique for using this relationship to maintain consistency between total density and spacecraft potential was reported to the DE Science Team Meeting and will be presented to the AGU Spring Meeting (Ref. 1); a draft paper is in preparation (Ref. 2).

Software development for automated analysis of RIMS data is in a 'cleanup' mode. As more data is analyzed, additional problems arise and new 'traps' have to be developed in order to assure a clean data set. After extensive comparisons between end head and radial head results, the empirical model group decided to use the +Z head as the default option for automated analysis. These results are at least as 'good' as the -Z head results (using the radial head as a reference) and because of the potential difference between the two heads, fluxes to the +Z head are higher, sometimes making it possible to analyze a time period which could not be done for the -Z head.

## DATA ANALYSIS AND MODELING

* Plasmasphere Morphology

In the area of plasmasphere morphology, we have performed the direct comparison of the Low-Energy Ion Transition (LEIT), determined from RIMS, with electron density measurements from the Plasma Wave Instrument (PWI) upper hybrid determinations. We have examined the relative L-shell separations between the LEIT and the locations of the 10 and 100 e/cc electron density levels, and also the sharp density gradient location. We have also examined the density level at the LEIT. We have found that the LEIT is generally located inside the 10 e/cc position, but beyond the 100 e/cc location, and that the density at the LEIT was normally around 60 e/cc, depending somewhat on local time. We incorporated this investigation as a section in a paper (Ref. 3) dealing with statistical trends in density profile types and locations of various features including the LEIT. After review by co-authors, it was decided to alter the LEIT definition to be simply the outer boundary of detectable thermal plasma (this makes some difference in location for some of the dayside profiles). Over the next few months, we hope to rewrite this paper, incorporating this new LEIT definition.

* Plasmasphere-Ionosphere Coupling

In the area of plasmasphere-ionosphere coupling, two papers have appeared in the Journal of Geophysical Research (Ref. 4, 5) Reference 4 was the long-awaited study on the heavy ion density enhancements in the outer plasmasphere. Reference 5 was mainly a statistical study of the relationship between ionospheric electron temperature peaks or ledges and plasmaspheric density gradients("plasmapause"), finding that such ionospheric electron temperature features are indeed correlated with density gradients at all local times. It is also found that in the dusk-evening sector, where multiple-plateau type profiles are often found, significant electron temperature peaks occur on field lines threading the inner density gradients.

The next major step in plasmasphere-ionosphere coupling is to incorporate topside ionosphere ion composition, temperatures and parallel drifts from DE-2 observations into comparisons which have previously involved only electron temperatures and densities from the ionosphere and RIMS ion measurements at high altitudes. We have received, for approximately twelve DE-1/2 comparison passes, ionospheric electron density and temperature data plotted linearly vs. invariant latitude and have plotted RIMS ion densities vs. invariant latitude as well. We have also received

DE-2 ion composition and temperatures for several of these passes, initially plotted linearly vs. universal time. To make proper comparisons, we require these data to be plotted linearly vs. invariant latitude. We are hoping to receive these improved format data soon. However, it is interesting at this stage to note that the topside ionosphere data show very high He+/H+ ratios, often in the range 10 to 1. This may help us to understand the relatively high plasmaspheric ratios of He+ to H+ observed by RIMS.

* He+ in the Plasmasphere

A detailed study of He+ has been initiated, comparing RIMS observations to the output of the Torr-Richards (Field Line Interhemispheric Plasma or FLIP) model . Initially this investigation will be focused on low L-shells (L ~ 2), where densities will be near 'saturation' values and diffusive equilibrium should prevail. Some interesting preliminary results have been obtained. Along the L = 2 filed line, RIMS observations show the He+/H+ ratio to vary from near 50% at the lowest observed altitudes to about 20% at high altitudes. Using extremes of solar activity and magnetic activity during the period of the observations to provide bracketing profiles, we find that the model underestimates the He+ by a small amount. This is found to be associated with an underestimate of the plasmaspheric ion temperatures. When an additional heat source, in terms of 20% per cent of the ionospheric photoelectrons considered to be trapped, the ion temperatures increase and likewise the He+. Agreement with the observations is then fairly good. What remains puzzling is the trend for the He+/H+ ratio to level off near the 20% level with increasing altitude and increasing L-shell. Results from this initial part of the investigation will be prepared as a M. S. thesis (Ref. 6) by I. T. Newberry; later they will be reworked into a journal article.

* Ion Trajectory Studies

The paper (Ref. 7) by Swinney et al. (1988) dealing with centrifugal acceleration is under review by the Journal of Geophysical Research. We hope that the next revision will be accepted. An invited talk (Ref. 8) on kinetic modeling of ion transport in the magnetosphere will be given to the Cambridge Workshop in Theoretical Geoplasma Physics by Dr. Horwitz. Tim Reyes has completed his thesis draft and taken his defense on a Master's Thesis (Ref. 9) entitled "The Acceleration of Ionospheric Ions in a Three-Dimensional Model of Electric Fields at High Latitudes". In this study, Mr. Reyes incorporated model electric potential configurations that sought to replicate the principal features of auroral arc potentials into the three-dimensional trajectory code developed by Swinney. He finds a number of interesting results, including a significant mass-dependence on the location and amount of acceleration of ions in the vicinity of these auroral arc potential regions. We hope to wrap the thesis up within the next two months and use this material to prepare a publication.

* Effect of Low Altitude Ion Heating on Polar Ion Outflow

A self-consistent, semi-kinetic model has been used to describe the steady state collisionless outflow of ions along diverging magnetic field lines at high altitude. The model is similar to that used by Barakat and Schunk (1983), but modified to: (1) allow for anisotropic ion temperatures at the lower boundary, and (2) eliminate lower boundary potential jumps ('double layers'). The model has been used to determine what happens to a typical, predominantly light-ion, outflow when either the perpendicular or parallel (or both) ion temperatures are raised at the exobase lower boundary (4500 km altitude). We have also investigated cases with plasma densities, bulk velocities, and temperatures characteristic of ion upwelling events (Moore et al., 1986). The escape flux of O+ ions for various combinations of electron and ion temperatures was determined. It is found that the escape flux can be increased, to levels as high as obtained by Barakat and Schunk (1983) with electron temperatures of 10**4 K, by raising instead the ion temperatures, although to values considerably less than those observed by Moore et al. (1986). These results have been included in a manuscript submitted to JGR (Ref. 10).

Currently we are extending this study by considering time-dependent ion outflow. This is necessary since the time that the foot of a flux tube spends in an ion upwelling region is small compared to the ion flight time through the tube. Work is in progress developing a time-dependent semi-kinetic ion outflow model.

In the area of DE-based polar ion beam studies, we have written up a very rough draft of a paper (Ref. 11) which examines ion outflows in the polar magnetosphere, using RIMS, EICS, PWI, SAI, HAPI and LAPI data. One promising area in which we would like to come up with more definitive results is a comparison between field-aligned potential drops determined from photo-electron measurements by DE-2/LAPI. FLAG

* The Interaction of Saturn's Ionosphere with its Rings

Radio occultation observations of Saturn's ionosphere show that it differs significantly, in magnitude and location of the electron peak, from what is predicted by models based on Saturn's similarity to Jupiter. Connerney and Waite (1984) show that much of the discrepancy can be accounted for if a planet-wide flux of about $4 \times 10^7$ molecules per $cm^2$-sec enters the ionosphere from some external source. Since the rings are composed of water they presumably are the source, although direct atmospheric entry of interplanetary meteoroids (of cometary origin) may also contribute. The most productive means of removing water from the rings is estimated to be hypervelocity impacts between interplanetary meteoroids and icy ring particles.

We are investigating, in detail, some of the aspects of the transport of water from the rings to the ionosphere. We are studying the chemical and ionization processes likely to occur in the hypervelocity impact debris clouds to determine (1) what fraction of the impact vapor is likely to be ionized, (2) what type of ions will be produced, and (3) what charge the submicrometer ice impact fragments will have. The subsequent movement of the ions and charged dust grains (as well as neutral fragments) in Saturn's inner magnetosphere, will be investigated next to determine if, where, and at what rate they are lost to the atmosphere. In addition to a knowledge of Saturn's magnetic and gravitational fields, a knowledge of the plasma density and temperature, and field (magnetic) aligned electric fields in the inner magnetosphere are necessary in order to determine the fate of the impact fragments. The plasma parameters and electric fields are currently being determined. In a previous study the electric fields within and at the ring's surface were studied. Finally, a model has been developed to describe the entrance of icy meteoroids into Saturn's upper atmosphere. It has been used to determine a volume production rate of water molecules within Saturn's ionosphere produced by pure water cometary meteoroids whose interplanetary flux is given by the estimates in Morfill et al. (1983).

## LABORATORY PLASMA FLOW STUDIES

The dual ion plasma expansion study has been completed. Dr. K. H. Wright, Jr. received his Ph. D. degree after completing his dissertation (Ref. 12) based on this investigation. A journal article on this study is in preparation. Following completion of degree requirements, Dr. Wright accepted an NRC Associateship with NASA/MSFC to continue plasma flow studies.

## MEETINGS

Dr. Horwitz attended the IEEE simulation meeting in Huntsville, AL in October, 1987, where he described his his code for the kinetic modeling of ionospheric ion transport into the magnetosphere. Dr. Comfort attended the DE Science Team Meeting and Computer Users Meeting March 9-11, 1988 at Goddard Space Flight Center.

## PUBLICATIONS

In addition to the those noted above, the following papers are at the indicated stage of the publication cycle:

* Papers published during this period are those on: comparisons of plasma wake models (Ref.13), MHD wave breaking in the outer plasmasphere (Ref. 14), perpendicular ion heating effects on refilling (Ref. 15), observations of particle and field signatures of SAR arc field lines (Ref. 16), electron beam experiments at high altitudes (Ref. 17), and electrostatic noise emissions near the shuttle orbiter (Ref. 18).

* Papers accepted for publication and in press are those on: magnetic mirror force in plasma fluid models (Ref. 19), kinetic approach in global plasma transport modeling (Ref. 20), outer plasmasphere modeling (Ref. 21), equatorial trapped plasma models (Ref. 22), dynamic evolution of low energy magnetospheric ions (Ref. 23), and plasmaspheric ion properties (Ref. 24).

* Papers submitted for publication and in review are those on: theory/observation comparison of plasma expansion into a satellite wake (Ref. 25), reply to comment (Ref. 26), the tail lobe ion spectrometer (Ref. 27), and the electrostatic charging of thin dust clouds (Ref. 28).

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