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THE PENNSYLVANIA STATE UNIVERSITY

IONOSPHERIC RESEARCH

PSU-IRL-SAR-79/1

Semi-Annual Status Report

for period

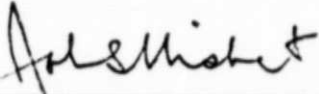**October 1, 1978 to March 31, 1979**

IONOSPHERE RESEARCH LABORATORY

University Park, Pennsylvania

Ionosphere Research

Semi-Annual Status Report No. 1

for the period

October 1, 1978 to March 31, 1979

Approved by: _____
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INTRODUCTION

This report is a statement of work currently in progress and is intended to meet contractural report requirements. Many of the topics discussed are part of M. S. and Ph. D. thesis programs, and great care should be taken in the use of this data. No part of the report should be quoted without the expressed permission of the author.

A. RESEARCH PROGRESS

1. Planetary Atmospheres

1.1 Thermospheric Energies and Densities - J. S. Nisbet, M. Griffis
C. H. Li, C. G. Stehle

The analysis of the thermal balance of the polar thermosphere
has continued. Work has been done on the relation between the energy
deposition in the cusp region and the densities of He O and Argon.
Figure 1 shows the peak altitude and maximum energy density deposited
by the electrons measured on A.E.C. compared with the densities of the
three thermospheric constituents. The effect of the combined large
energy density and large deposition altitude in the cusp region are
evident.

The analysis has been extended to lower latitudes to see how
the circulation cells close. Figure 1 shows a hemispheric plot of
the atomic oxygen densities normalized to 120 km which shows the
wind induced depletion at around 70-80° magnetic latitudes and
0 to 5 hours magnetic local time at lower latitudes. A uniform
treatment of the OGO 6 and AE data is being completed in magnetic
coordinates.

Work is continuing on the development of the model of the high
latitude current and electric field systems produced by the auroral
Birkeland Currents. Figure 2 shows in a compact way the assumptions
that have been used in the leading auroral models to date about the
input current and conductivity and the potential contours that
result. We feel that the assumptions of our model are very much more
realistic than any of the others due to the much higher resolution
we are able to obtain, the use of more accurate Chatanika conductivity
data and in the current models in region 1, region 2 and the cusp.
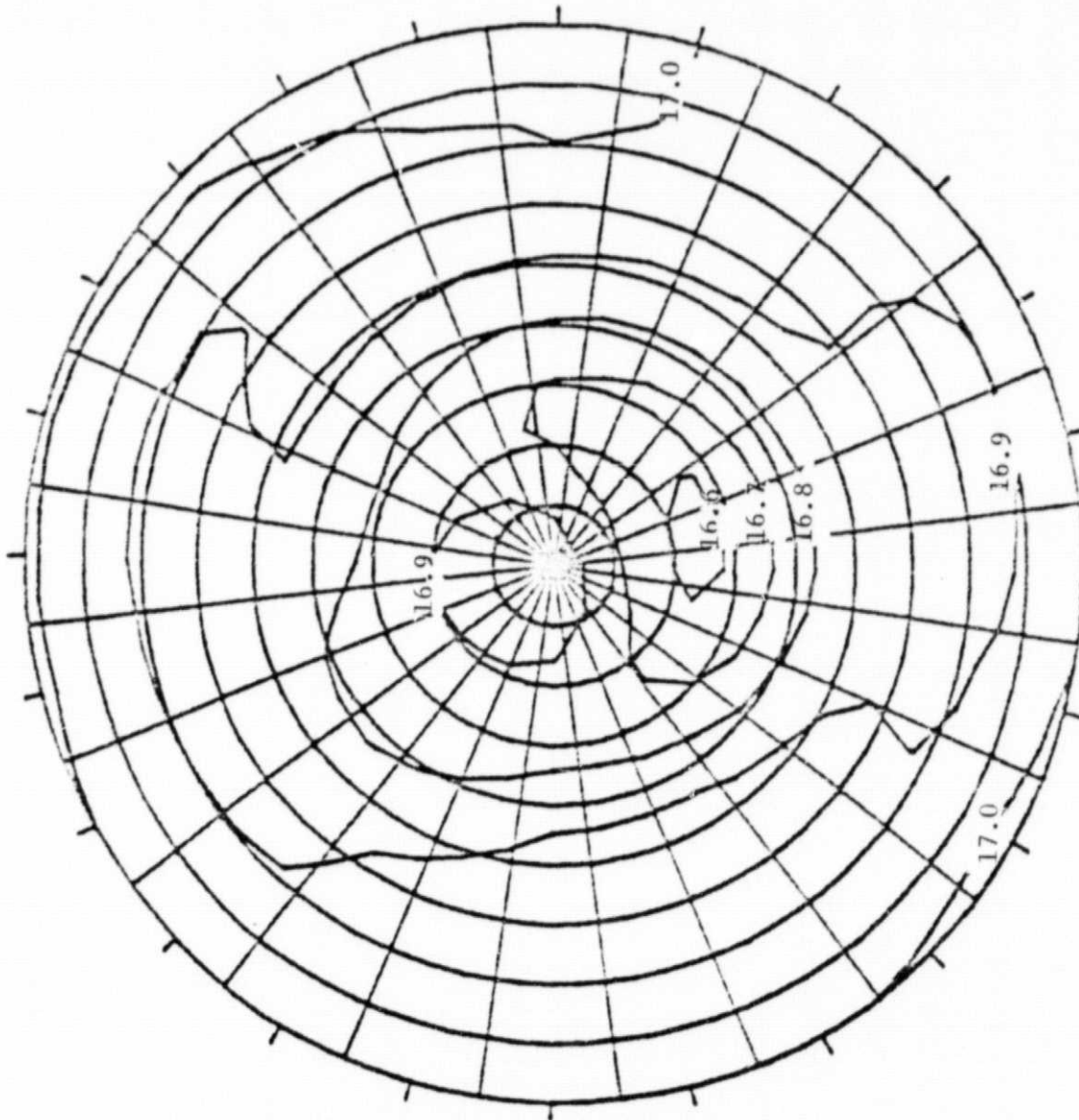
Figure 1: Isodensity contour generated from a spherical harmonic model of atomic oxygen densities as measured by AE-C. The contour shows $\log_{10} n(0)$ at 120 km for 1974, day 354 in the southern hemisphere with an Ap of 5 to 15.

MODEL	INPUT CURRENT	CONDUCTIVITY	POTENTIAL CONTOUR
Nisbet J.S. Miller M.J Carpenter L.A. (1978) Nisbet J.S. Li C.H. (1979)	CUSP CURRENT INVOLVD TOGETHER REGION 1 REGION 2	$\frac{H}{P} \approx 2$ OVAL OTHERS (VAR.)	DISTURBED QUIET
Gizler V.A. Semenov V.S. Troshichev O.A. (1979)	CUSP CURRENT INVOLVED SEPARATELY REGION 1 REGION 2	$\frac{H}{P} \approx 1$ OVAL OTHERS (VAR.)	DISTURBED QUIET
Yasuhara F. Kamide Y. Akasofu S.-I. (1975) Kamide Y. Yasuhara F. Akasofu S.-I. (1976) Yasuhara F. Akasofu S.-I. (1977)	CUSP CURRENT IS NOT INVOLVED REGION 1 REGION 2	$\frac{H}{P} = \{ \begin{matrix} 4 \\ 2 \end{matrix}$ OVAL OTHERS	DISTURBED QUIET
Nopper Jr. R.W. Carovillano R.J. (1979)	CUSP CURRENT IS NOT INVOLVED REGION 1 REGION 2	$\frac{H}{P} = 2$ OVAL OTHERS (VAR.)	DISTURBED QUIET
Atkison G. Hutchison D. (1978)	CUSP CURRENT IS NOT INVOLVED BOUNDARY CONDITION $\Phi = \phi_0 \sin\theta$ 12 18 00	$\frac{H}{P} = \frac{10}{6}$ OVAL OTHERS DON'T CARE	DISTURBED QUIET

FIG. 2: Comparison of the various models. (The absissa of figures is magnetic Local time (hr.))

——— , H , Integrated Hall conductivity ,   currents into Ionospher ,

- - - - , P , Integrated Peterson conductivity ,   currents away from Ionosphere .

This appears to be borne out in the comparisons we have made so far with ground based and satellite observations.

Work has continued on the modeling of the ionopause of Mars and Venus. It is now apparent based on the Pioneer Venus observation that the ion fluxes across the ionopause are greatly affected by the wave particle interactions in the region and by the differing ion gyro radii of the shocked solar wind protons and the ionosphere ions. There seems to be no way of keeping solar wind protons from entering the ionosphere where their long mean free path and large gyro radius will allow them to penetrate to an altitude where charge transfer with neutrals is possible.

The nightside ionopause is apparently produced not by solar wind ions brought around the back of the planets but by ionospheric ions leaking out of the ionopause sheath.

1.2 Neutral Densities in the Polar Regions - C. G. Stehle

Data analysis of neutral densities measured by the AE-C spacecraft has almost been completed. The behavior of atomic oxygen in the polar regions as a function of magnetic local time and magnetic latitude closely resembles that reported by Nisbet and Glenar (1977) on the basis of OGO 6 measurements. The structure of thermospheric helium, while more variable, maintains close qualitative agreement with atomic oxygen. Both constituents undergo a decrease in their diffusive equilibrium values at 120 km when magnetic activity (i.e. K_p) increases.

Following Nisbet and Glenar (1977), a study of the wind system which corresponds to the observed helium variations has begun. Since helium is lighter than atomic oxygen, larger vertical velocities would be expected. Also, the larger variation in helium densities indicates

more variation in the vertical velocities. In a manner analogous to that of helium, it would be possible to estimate the vertical velocities which correspond to variations in density of argon with respect to diffusive equilibrium values. Although measurements of thermospheric argon densities are scarcer than helium and atomic oxygen, it seems that sufficient data exist to allow velocity estimates to be made. The use of argon as well as helium also provides a valuable consistency check on the assumptions made.

1.3 General - M. Griffis

A paper was presented by J. S. Nisbet on October 6 at the Atmosphere Explorer Symposium in Bayse, Virginia. The paper dealt with the problems of obtaining a solution to the energy balance of the polar thermosphere, where Joule and particle heating are important.

Since that time I have been looking at correlations of Atmospheric Explorer particle and neutral density data in the polar magnetospheric cusp region. The neutral density variations in the region of the cusp indicate that it is a highly localized, but important heat source in the lower thermosphere.

Using neutral density measurements and continuity equations for N_2, O, Ar, and He, we are working toward a set of vertical wind profiles which is consistent with density observations in the polar region. These profiles will then be used with measurements over the cusp to infer wind structure and heating from density perturbations.

AE charged particle measurements are being analyzed for the purpose of obtaining a quantitative estimate of the magnitude, particle energy spectrum, and spatial structure of the cusp particle deposition region.

1.4 Tropospheric and Ionospheric Electric Fields Generated By Thunderstorm Activity - R. Caverly

Work has continued on a computer model of thunderstorm electric fields and their effect on the ionosphere, notably the D-region. The model was tested against calculations made by Dejnakarintra (1974) and Park and Dejnakarintra (1973). These authors made their calculation based on an exponential variation in conductivity with altitude. An identical conductivity profile was used in the model and the calculations showed good agreement with those of the other authors.

In our model, a composite conductivity is used in the calculations. Figure 3 shows a typical conductivity profile used in electric field calculations. Below 30 km, a conductivity extrapolation by Gish [See Israel, 1973] is used. From 40 km to 70 km rocket probe measurements of the conductivity are used [Hale, private communication]. Above 80 km, the direct conductivities, based on calculations using CIRA 1972, are used. Using the conductivity profile in Figure 3, the vertical current densities and electric fields calculated are illustrated in Figures 4a and b. The different curves show distances (in km) away from the storm center. A generator corresponding to a typical thunderstorm ($\sim$25 coulombs) was also used in the model. Using the data in Figures 3 and 4a, plus values of D-region low latitude electron densities, the downward electron velocities were approximately 15 km/sec, 3 km/sec and 23 m/sec at 60 km, 70 km, and 80 km, respectively, for a dip angle of 45°.

References

Dejnakarintra, M., "A Theoretical Study of Electrical Coupling Between the Troposphere, Ionosphere, and Magnetosphere", Technical Report No. 3454-3, Radio Science Laboratory, Stanford University, December 1974.
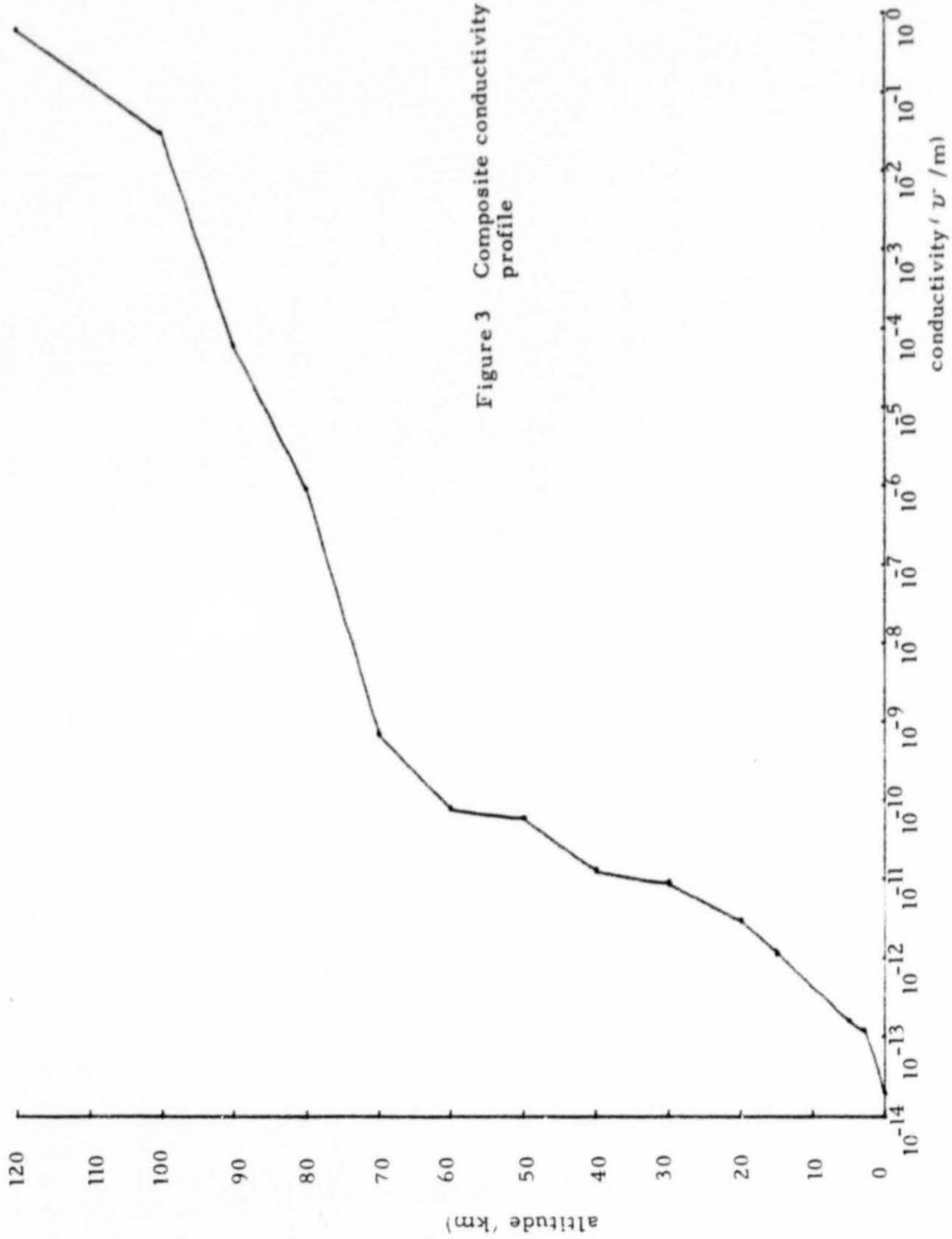
Figure 3   Composite conductivity profile

altitude / km)

conductivity / σ^- / m)

Figure 4a Vertical current density
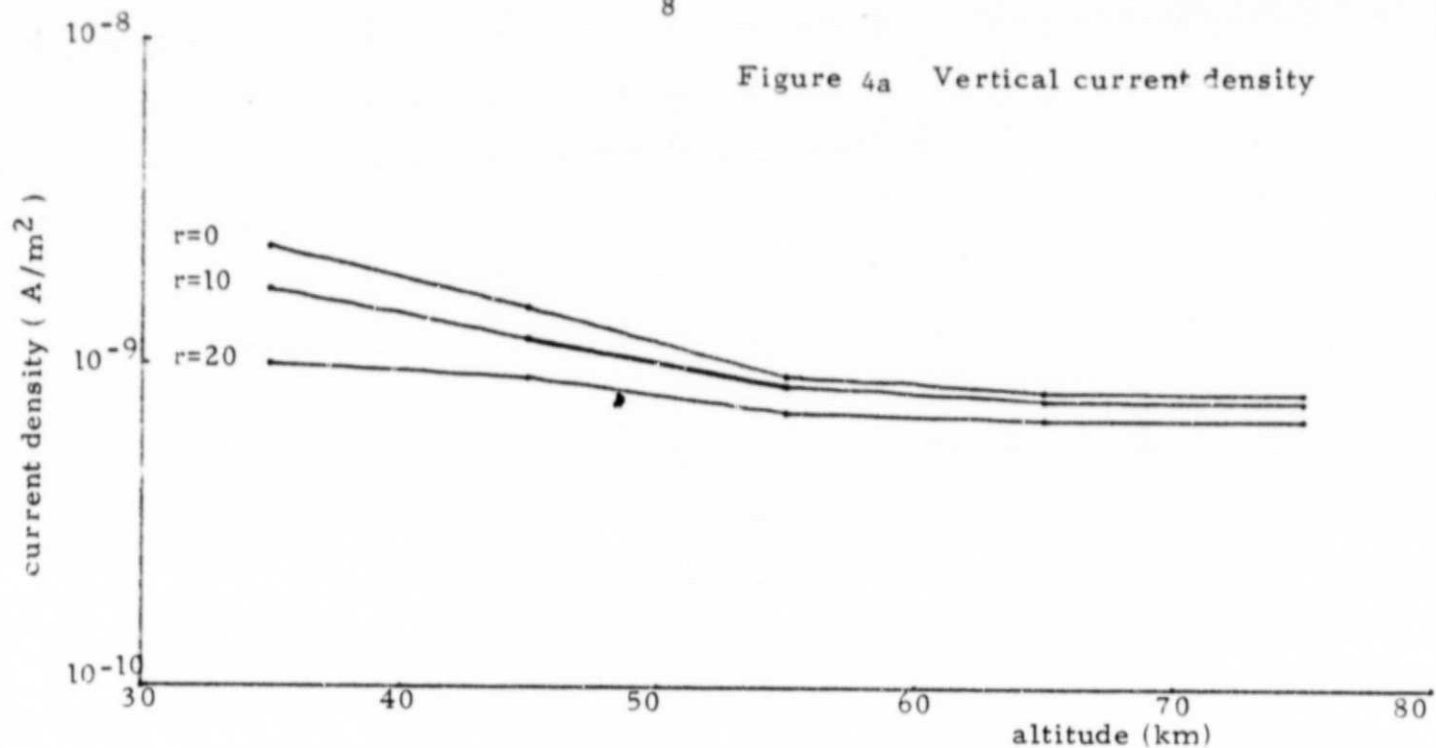
Figure 4b Vertical electric field
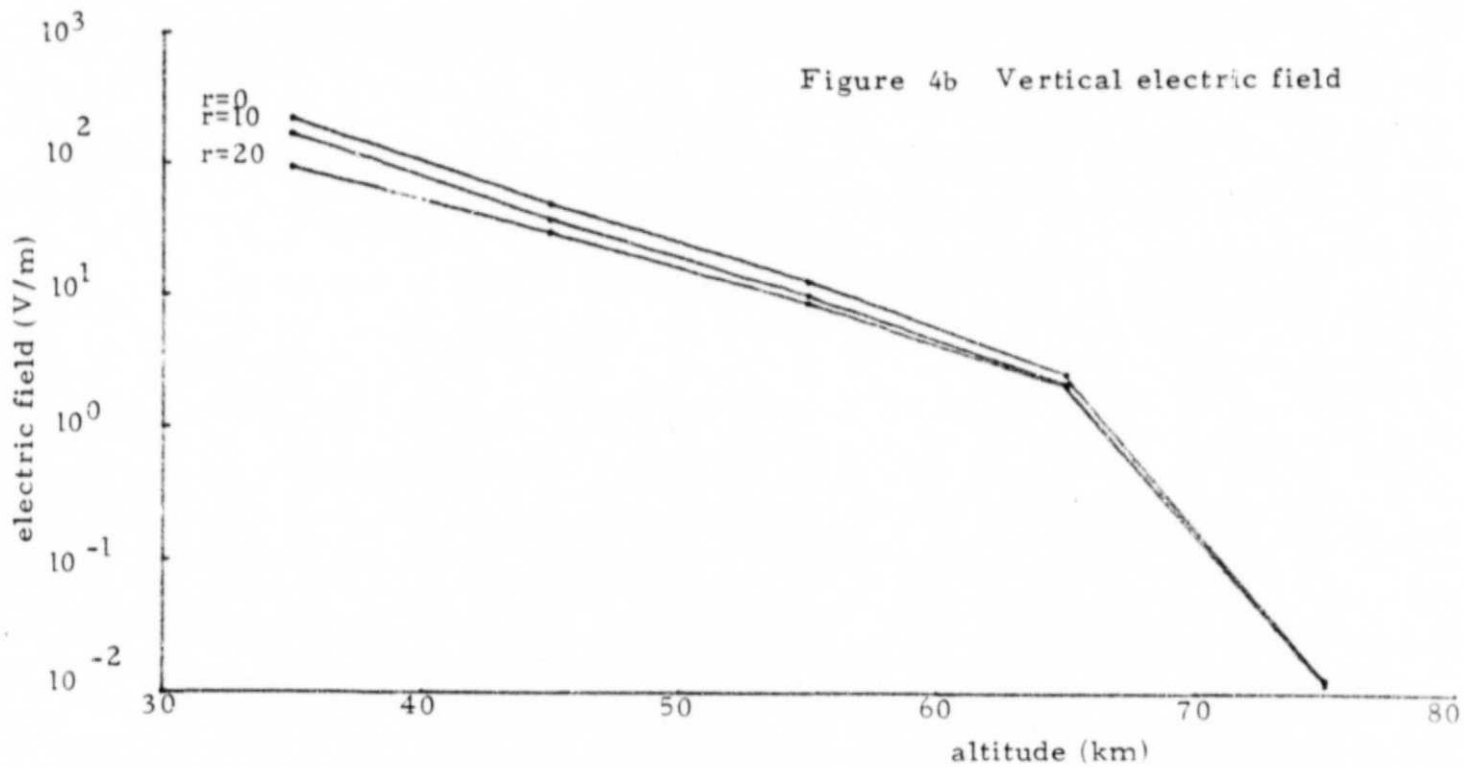
Israel, H., Atmospheric Electricity Volume II, (English Translation),
    Keter Press, p. 383, 1973.

Park, C., and Dejnakarintra, M., "Penetration of Thundercloud Electric
    Fields into the Ionosphere and Magnetosphere", 1. Middle and
    Sub Auroral Latitudes, J. Geophys. Res., 78, 6623, 1973.

1.5 General - D. Glenar

Construction of the diode laser infrared heterodyne
spectrometer at Goddard Space Flight Center has been largely completed.
The tunable diode laser local oscillator currently in use with the
system operates at wavelengths between 7.5 and 8.5 microns, with output
power sufficient for shot noise limited operation. This allows efficient
heterodyne operation in this wavelength range. Preliminary heterodyne
measurements have been performed against a laboratory blackbody source
and a signal to noise ratio of approximately 150 has been achieved. This
performance is comparable with current CO_2 based heterodyne systems and
equals or exceeds that of previous diode laser heterodyne attempts.

1.6 The Effect of Energetically Produced O_2^+ on the Ion
Temperatures of the Martian Thermosphere - R. Rohrbaugh

In the Martian ionosphere the dominant solar ionization products
are O^+ and CO_2^+. These ions are rapidly converted to O_2^+ by ion neutral
reactions resulting in O_2^+ as the dominant ion. As O_2^+ has a lower
ionization potential, each reaction results in approximately 1.2 eV
of energy to be shared by the reaction products. The kinetic energy
given to the O_2^+ will affect the ion temperatures. Calculations have
been made of the ion heating rates and temperatures which result from the
degradation of these energetic ions for various energy production
distributions for conditions similar to those encountered by Viking 1.
It is shown that the thermalization of the energetic O_2^+ can greatly
increase the ion temperatures above 200 km compared to those calculated
using only the ambient electron heating source. The effect of small

horizontal magnetic fields, as predicted by current solar wind interaction models on the ion thermal balance was also investigated. These fields act to restrict the ion thermal conductivity and thus also increase the upper altitude ion temperatures. The combination of the heating by the energetic O_2^+ and the effect of the magnetic field provide a partial agreement with the Viking 1 measurements.

A paper was written and accepted for publication in Journal of Geophysical Research.

1.7 Mesospheric Processes - J. J. Olivero

The ground based water vapor microwave radiometer is nearing completion. The 8 foot parabolic dish antenna and solar tracking mount have been installed on the roof of the Walker Building (housing the Department of Meteorology, among others, and in which I have both an office and lab space). We are attempting to find the means to support a one year sabbatical here at Penn State for Dr. Chris Gibbins of The Appleton Laboratory, Slough, England. The following are some of his interests and accomplishments which are coincident with our own: he has been closely associated with Dr. David Croom and his (their) pioneering efforts to detect upper atmospheric water vapor from the surface; he is interested in "anomolous absorption" problems and the measurement of water dimer populations in the atmosphere; he is eager to participate in joint experiments such as those that will be possible for us in monitoring the middle atmosphere above Wallops Island, VA; and finally he is quite interested in the development and utilization of mathematical and statistical inversion techniques for the acquisition of profile information. Our target date to begin is October 1979.

The mesospheric particle layer study is continuing in the area of

the water budget of the middle atmosphere. From our particle model we immediately come out with estimates of the total mass of the ice spheres, which can be 2 or 3 orders of magnitude larger than the local vapor mass in the same layer. We will attempt to determine whether reasonable water vapor fluxes through the polar mesopause can infact build up the particle layer in the time frame observed. This will place an additional constraint on the total water mass and hence on the particular size distributions which are physically realizable.

1.8 Microparticles in the Mesosphere - R. Bevilacqua

During this six month period a paper entitled, "Ice Particles in the Mesosphere" by myself and Dr. Olivero has been completed, and submitted for publication to the Journal of the Atmospheric Sciences. The paper essentially summarizes the results of our study concerning the physical properties affecting the existence and lifetimes of pure ice particles in the mesosphere. Our major conclusion is that mesospheric ice particles can only exist in the cold trap of the summer polar mesopause, this is the noctilucent cloud region. However the evidence, pertaining to the electrical structure of the D-region of the ionosphere, for the existence of small volatile particles throughout the mesosphere is indeed convincing. We have shown that these particles are most likely not pure ice crystals. While ice particles are the simplest type of such volatile particles, they are by no means the only one possible. The mesospheric particle phenomena could be attributed to more complicated structures such as vapor phase clathrates or extended water cluster ions. I have been doing preliminary, investigative work attempting to ascertain the feasability, and practicality of a full scale study of these more complicated particle models.

1.9 <u>Noctilucent Cloud Models</u> - D. F. Young

A paper entitled, "Noctilucent Cloud Models and Their Implications on Water Vapor in the Middle Atmosphere" (authors--D. F. Young and J. J. Olivero) is being prepared for presentation at the Spring AGU Meeting in Washington. In this paper, we examine the objection raised by Gasden to noctilucent cloud models based on particles smaller than 0.1 microns. We find that considerations of the light scattering properties of the layer, the particle existence region based on the mesospheric temperatures and humidity and the total water vapor flux into the region consistently support the small particle models.

During this period I have also begun working with Dr. Hale; we are examining measurements of vertical electric fields in the middle atmosphere.

2. E and F-Region

2.1 F-Region Dynamics - L. Carpenter

Data was collected on two periods at Arecibo Observatory for use in analysis of Spread F. A simultaneous observation of continuous scan incoherent-scatter radar determination of electron densities and drift velocities and Febry-Perot interferometer determination of east-west neutral wind velocities is the goal of this work. Dr. John Meriwether of Arecibo Observatory is in charge of the interferometer measurements. Dr. Klevans was present during one of these observation periods and I was there for the other.

The first observation period, December 28 - January 3, 1979 had three evening periods for observations. The radar measurements were satisfactory but the data-logger for the interferometer failed on all three occasions and no data for the east-west neutral wind drifts were obtained. Thus, a second period of observations, February 28 - March 2, 1979 was arranged for simultaneous observations. Again satisfactory radar measurements were made but the interferometer did not work properly. This has been disappointing. It is hoped to arrange more simultaneous measurements at Arecibo next Fall and Winter.

Richard Bachman is going to analyze the results this summer and then go to Arecibo during winter term for measurements with the continuous scan velocities and the Febry-Perot interferometers.

2.2 Polar Current Systems - C. H. Li

Based on earlier works, the integrated Peterson and Hall conductivities have been furthermore improved in our polar current system model, in terms of the electron density profiles obtained by incoherent scatter radar in Chatanika (Vondrak, 1978).

The corresponding polar current systems during the magnetic quiet conditions and the disturbed conditions have been compared as follows:

(1) $K_p = 0$, $|AL| < 100\gamma$, without cusp current,

(2) $K_p = 0$, $|AL| < 100\gamma$, with cusp current,

(3) $K_p = 3$, $|AL| < 100\gamma$, without cusp current,

(4) $K_p = 3$, $|AL| < 100\gamma$, with cusp current,

(5) $K_p = 3$, $|AL| < 100\gamma$, without cusp current,

(6) $K_p = 3$, $|AL| < 100\gamma$, with cusp current,

(7) $K_p = 5$, $|AL| < 100\gamma$, without cusp current,

(8) $K_p = 5$, $|AL| < 100\gamma$, with cusp current.

Some positive results have been found after comparing our model with the published results of observation in the oval. It has been basically demonstrated the reliability of our model.

2.3 <u>General</u> - E. Klevans

Behavior of the nighttime ionosphere at Arecibo for the nights March 3, 1977 and February 24, 1977 has been analyzed to study space and time behavior. The rotational density data has been examined by adding ten successive profiles together and fitting a parabola to the peak. This yields peak height and density. Profiles were also studied. Gradients in density and wave structure have been found at various times during each night. This material will be prepared for a report.

During this period I went to Arecibo for data taking on the nights of February 27 and 28, 1979. The interferometer was working on these

nights, so comprehensive data should be available. No Spread F

was observed, however.

3. <u>D-Region</u>

    3.1 <u>General</u> - L. C. Hale

A paper entitled, "Recent Middle Atmospher Electrical Structure Measurements" with co-authors C. L. Croskey and J. D. Mitchell was presented at the American Geophysical Union Meeting in San Francisco on December 7 (Pearl Harbor Day).

The winter was then occupied with the preparation, and testing of two rocket payloads, incorpating conductivity probes, ultraviolet and visible lamps, and an electric field sensor. These were successfully fired during and after the solar eclipse of February 26 in Northwestern Ontario.

    3.2 <u>General</u> - A. J. Ferraro

Major effort has been in preparing wave interaction equipment for operation at Arecibo during the ionospheric modification experiments. The use of a microcomputer and mini-disk eliminates two racks of rather old digital equipment. The experiment will be under software control of the microcomputer. New wave interaction detector boards have been completed and will undergo testing.

    3.3 <u>General</u> - H. S. Lee

A comprehensive final report for the Office of Naval Research, Contract No. N000 14-77-C-0041, was prepared and distributed. The report described an experimental work on the measurement of combination frequencies originating from the D-region ionosphere as the result of non-linearities associated with high-power HF heating.

Also included in the report was the outcome a theoretical
feasibility study made on VLF-ELF generations through high-power
HF heating of D-region ionosphere.

3.4 General - A. Tomko

During this report period I presented a paper entitled,
"Wave Interaction Effects During High Power Heating", at the
November URSI Meeting in Boulder, Colorado. I have recently completed
a paper called, "A Theoretical Model of the D-Region Electron Density
Variation During High Power Radio Wave Heating". An Abstract is given
below:

A time dependent version of the six ion model of Mitra and Row
(1972) is used to study ion chemistry modifications in the D-Region
caused by high power, continuous radio wave heating of the ionosphere.
It is found that the time scale for negative ion changes is much
smaller than that for the dominant positive ion type. This allows
one to develop an analytic expression for the electron density variation
during CW heating. It is shown that the electron density in the lower
D-region decreases rapidly in response to a heating induced increase
in the electron attachment rate. This is followed by a long term
recovery of the electron density towards its ambient level due to
decreased ion-electron recombination. In the upper D-region, where
negative ions are unimportant, the electron density increases from
its ambient level during CW heating, again, due to decreased
recombination. When CW heating is terminated, the depressed electron
density in the lower D-region increases rapidly and can overshoot
its ambient level by a significant amount. This overshoot phenomena
may help explain the unusually long time required for HF absorption
to return to ambient following periods of CW heating.

3.5 <u>Arecibo H. F. Facility</u> - J. Breakall

During this period I have been continuing work on Arecibo incoherent scatter data. I have obtained nitric oxide profiles from D-region electron density duirnal results for three complete days of data. These along with other D-region results will form the basis for a paper currently in joint preparation with Case Western Reserve University.

4. Mass Spectrometer Measurements

4.1 Ion Analysis with Mass Spectrometers - General - B. Kendall

Various types of nonmagnetic mass spectrometers are being studied with a view to establishing their value for measuring the ionic composition of the lower ionosphere. Their possible use for measurements in the upper stratosphere is also being studied.

Much of the work during this reporting period has been devoted to a detailed proposal to be submitted to the NASA Lewis Research Center. It proposes a study of the ions and neutral particles given off during the breakdown of insulating surfaces on spacecraft and would be carried out using a large time-of-flight mass spectrometer operating inside one of the Lewis Research Center space simulation chambers. A 125 liter vacuum chamber with a turbo-molecular pump has been designed and constructed for use in testing some of the ideas put forward in this proposal. Initial testing has been satisfactory.

Work on the Eiber-Loeb mass filter has been continued. Further information is given in Section 4.4.

Discussions were held with John Olivero and others regarding the possibility of determining the water adsorption properties of meteoritic dust.

4.2 Ion Analysis in the D-Region - B. Kendall

A detailed literature search is revealing additional evidence of discrimination against heavy mass ions in particle-multiplier ion detectors. Since this kind of ion detector is used almost universally in stratospheric and D-region mass spectrometers, there are important

implications for the interpretation of results obtained with such instruments.

4.3 <u>Brownian Motion/Diamagnetic Levitation</u> - R. Friesenhahn

An experimental study of factors affecting the motion of small particles in a low-density gaseous environment is continuing. A paper on this topic appeared in VACUUM, <u>27</u>, 589, (1977). Efforts are being currently concentrated on the problems of automatic launching of particles and their subsequent levitation in an ultra-high vacuum environment, necessary for operation as an ultra-high vacuum gauge.

The original equipment used by R. S. Butler and S. M. Rossnagel has been extensively modified, with design and testing of an entirely new magnet configuration providing very high levitation stability and increased accessibility.

The movements of submicroscopic particles may have relevance to the transport of aerosols in the upper atmosphere, and provide absolute measurements of gas density and temperature in ultra-high vacuum environments. Interest in the levitation configuration has also been expressed by H. Deckman of the Laboratory for Laser Energetics for work associated with the inertial confinement fusion program.

4.4 <u>Mass Filters</u> - F. Schwab

Developmental work continues on the simple mass filter of the Eiber-Loeb type. This filter holds promise for use on rocket-borne probes of the atmosphere down to 50 km without the need for pumps or complicated electronics.

An improved R. F. feed circuit for the filter grid has been built and tested. A tuned, center-tapped transformer provides a symmetrical

above-and-below ground R. F. potential for the deflecting field.
Higher voltages and a closer impedence match between the R. F. source
and the grid structure of the mass analyzer are realized using this system.

Consistent and repeatable data using singly-charged ions of
K^+ and Cs^+ at high vacuum (10^{-6} Torr) with R. F. frequencies
of 3.5 and 7.0 MHz has been collected. This data shows the
transmission coefficient (fraction of ions transmitted through applied
R. F. field compared to fraction transmitted through ground filter) to
be approximately linearly dependent on the R. F. amplitude, with slope
inversely proportional to ionic mass. Changing the R. F. frequency
from 7.0 MHz to 3.5 MHz shifts the transmission curves toward lower
filter potentials. It is seen that by halving the frequency, the
filter voltage necessary to cause a specific transmission coefficient
is also halved. The resolution of the instrument does not appear
to be dependent upon the R. F. frequency, allowing the operator to
choose any convenient frequency, within reason.

Studies at low vacuum (10^{-3} Torr) have begun to demonstrate the
effectiveness of the filter at these higher background gas pressures.
Two-component curves using a combined $K^+ + Cs^+$ ion beam have been
obtained, showing the expected change in slope as the less massive
K^+ ions are attenuated first.

It is intended to experiment with ions of greater mass and to
apply methods of signal processing for interpretation of the results.
Also, different configurations of the grid structure and alignment
will be studied.

5. Direct Measurements

5.1 Methods of Minor Constituent Measurements - C. Croskey

The major research activity for this period was the construction of two multiple lamp, blunt probes for use during the February, 1979 Solar Eclipse in Ontario, Canada. This Astrobee-D payload has a flat blunt probe collection geometry with its collector surrounded by a ring of lamps--three UV, Krypton R. F. discharge lamps and 180 watts of incandescent visible lights. In addition, a vertical electric field antenna was used on the lanyard.

Environment testing was conducted in early January at Wallops Island, Virginia. Later in the month a return trip was made to help the staff there with the construction of several Super Loki conductivity, blunt probes for use during the eclipse.

The last part of February was used in field support of the solar eclipse rocket program. The parachute for the flight during the eclipse did not function. The second payload was launched pre-dawn the following day. Both payloads functioned properly, however the eclipse data is somewhat limited due to the ballastic trajectory.

Also during this period, work has continued on the 22 GHz radiometer--mainly on the phased- lock loops and a stepper motor drive for the eight foot steerable dish.

6. Atmospheric Reactions

6.1 The Reactions of CH_3O_2 with SO_2 and NO - R. Simonaitis

The reactions of CH_3O_2 with SO_2 and NO have been studied by steady photolysis of azomethane in the presence of O_2-SO_2-NO mixtures at $296^{\circ}K$. The quantum yield of NO oxidation by CH_3O_2 radicals is increased substantially when SO_2 is added to the system indicating an SO_2 induced chain oxidation of NO. From this observation and others a general mechanism for the oxidation of SO_2 in the presence of NO by CH_3O_2 radicals is proposed.

$$CH_3O_2 + SO_2 \ (+M) \rightarrow CH_3O_2SO_2 \ (+M) \qquad 3$$

$$CH_3O_2SO_2 + O_2 \ (+M) \rightarrow CH_3O_2SO_2O_2 \ (+M) \qquad 4$$

$$CH_2O_2SO_2O_2 + NO \rightarrow CH_3O_2SO_3 + NO_2 \qquad 5$$

$$CH_3O_2SO_3 \rightarrow CH_3O_2 + SO_3 \qquad 6$$
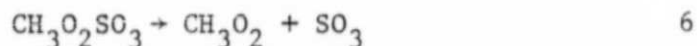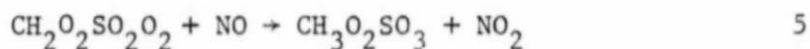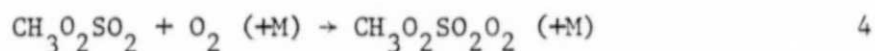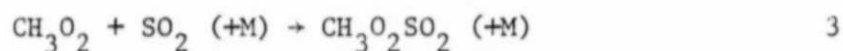
From a study of the competitive kinetics, $k_1/k_2 = (2.5 \pm 0.5) \times 10^{-3}$ is obtained, where reaction 2 is

$$CH_3O_2 + NO \rightarrow CH_3O + NO_2 \qquad 2$$
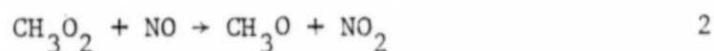
Combining this ratio with the absolute value of $k_1 = 8.2 \times 10^{-15} \ cm^3$ sec^{-1} determined earlier in our laboratory using a flash photolysis-kinetic spectroscopy technique gives $k_2 = 10^{-11.5 \pm 0.2} \ cm^3 \ sec^{-1}$.

6.2 The Kinetic Study of the Chemiluminescence of Cl-NO_2-O_3 System and the Mechanism of Cl-NO_2-M System - W. Stuper

Chlorine atoms are known to add readily to NO_2. However few studies of this reaction have been done. We have observed that when Cl_2 is photolyzed at 366 nm at temperatures $< 296^{\circ}K$ in the presence of NO_2 a strong chemiluminescence in the red is observed if during irradiation a portion of the photolysis mixture is passed through a

capillary into a stream of ozonized oxygen. Presumable an unstable intermediate is formed from the reaction of Cl atoms with NO_2 which reacts with O_3 in a chemiluminescent reaction. The kinetics of this chemiluminescence and the mechanism of the reaction of chloride atoms with NO_2 were studied.

The paper presenting our results was submitted to Journal of Physical Chemistry.

Two papers were published: (1) "The Cl_2 Photosensitized Decomposition of O_3: The reactions of ClO and OClO with O_3", J. Phot. Chem., 10, 163, 1979. (2) "The Reaction of ClOO with NO", Geophys. Res. Lett., 5, 1005, 1978.

6.3 Ultraviolet Absorption Spectrum of $CCl_3O_2NO_2$ - O. Morel

$CCl_3O_2NO_2$ was pr pared from the photolysis of Cl_2 at 366 nm in the presence of $HCCl_3$, O_2, and NO_2 via the sequence of reactions

$$Cl_2 + h\nu \rightarrow 2Cl$$

$$Cl + HCCl_3 \rightarrow HCl + CCl_3$$

$$CCl_3 + O_2 \;(+ M) \rightarrow CCl_3O_2 \;(+ M)$$

$$CCl_3O_2 + NO_2 \;(+ M) \rightleftarrows CCl_3O_2NO_2 \;(+ M)$$
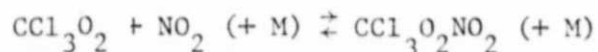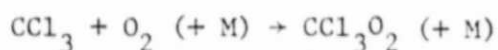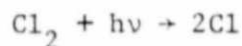
The ultraviolet spectrum was measured in a double beam UV spectrometer with a deuterium lamp source. Preliminary results for the absorption cross sections at $294^{\circ}K$ are:

Wavelength nm	cross section $\sigma \times 10^{19}/cm^2 molec^{-1}$
220	15.7
230	11.4
240	7.7
250	5.0
260	3.6
270	2.0
280	1.4

7. Particle Collection and Ionosphere Composition Studies Using Rocket Borne Probes

7.1 General - T. M. York

A number of efforts on this problem area that had been initiated earlier were being brought to a conclusion during this reporting period. First, in the study of electron collection by blunt probes in ionosphere type plasmas, two efforts were completed; they are: (1) the attempt to develop an analytical formulation of electron collection has resulted in an approximate model, which when used with ionosphere data shows good agreement with other diagnostics (See 7.3, below); (2) the experimental studies of electron collection in specific scaled laboratory experiments were completed and data is being reduced and analyzed (See 7.3a, below). Both these efforts will result in M. S. thesis reports in the future. Also, an AIAA paper is being prepared on the electron collection theory work, as it has been accepted for presentation at the AIAA 12Th Fluid and Plasmadynamics Conference to be held July 24, in Williamsburg, Virginia. Second, an effort to develop techniques to use blunt probe ionosphere data as an electron density indicator between 40 and 80 km altitudes has been completed. This work was reported in IRL-IR-67 "Measurement of Electron Densities in the Middle Atmosphere using Rocket Borne Blunt Probes", and it will be issued separately as a report by the Atmospheric Sciences Laboratory, White Sands Missile Range. Third, the use of an RF source to generate and sustain plasma discharges as a source for ionosphere-type plasmas was abandoned. Preliminary tests indicated

the discharges could be generated up to 20 mT, but electron temperatures were excessively high (> 10 eV). H. J. Tarng, who was conducting this research, had resigned from his position as a Graduate Assistant on this project in September 1978.

The study of particle collection in a Gerdien-type probe geometry continued during this reporting period. Specific problems with the technique of generating body profiles in a numerical code, and the inclusion of slip flow conditions have been successfully solved. (See 7.2, below).

Also, there has been the initiation of an evaluative study of electron gun type plasma sources for ionosphere plasmas during this reporting period. This work was conducted by two Aerospace Engineering Department undergraduate students, W. Guzik and M. Foti; Mr. Foti is continuing this work at the present time. It is anticipated that an internal report will be prepared to clearly identify the results of this study.

Finally, it will be noted that Dr. York participated in the 1979 U. S. - Canadian Solar Eclipse Program. This effort was initiated to work with data gathered by Hale at Penn State, Olson at White Sands, Mitchell at UTEP, and others, and to evaluate a matrix of electron density data for this event.

7.2 Numerical Study of Particle Collection in a Gerdien
    Probe - S. Chang

During this period, analysis of the flow field in a blunt center body Gerdien condenser has been analyzed. A numerical code has been developed to fully predict velocity fields for specific shape center bodies for input flow conditions appropriate for rocket-borne Gerdien trajectories.

Examination of flow regimes reveals that above about 70 km, the molecular mean free path is not negligible compared to the characteristic length, which for a Gerdien condenser is the outer diameter. Thus, in the region above 70 km the conventional no-slip boundary conditions have been relaxed to allow slip flow to occur on the probe surface.

In the continum solution of Gerdien flow, the viscous solution can be divided into three parts: the axisymmetric boundary layer solution is employed near the stagnation point; the Pohlhausen method is used to formulate the flow field about the central afterbody; and the flat plate boundary layer solution is assumed to be a reasonable approximation near the outer cylinder. These solutions and the potential solution for the center body are matched together to yield a complete aerodynamic solution.

The work described above is presently being prepared in report form. The analysis of electric field effects is now being formulated to predict ion collection.

7.3 Electron Collection by Blunt Probes - C. Wu

An approximate method of predicting electron collection processes has been developed, and has been used to derive electron densities from blunt probe I-V data. It is expected that this work will be prepared as an M. S. thesis in Nuclear Engineering.

Mr. Wu completed his research work in February 1979.

7.3a Laboratory Studies of Blunt Probe Particle
Collection - R. Brasfield

Experimental work on studying electron collection in a scaled laboratory experiment has been completed. A glow discharge

plasma source generated plasmas in static and subsonic flow situations. Single and double Langmuir probes were used as reference diagnostics. Impact pressure measurements were made of the test jest. Current-voltage data was taken with a scaled blunt probe at scaled altitudes of 90, 80, and 70 km. This data is presently being analyzed, and a report will be prepared on a requirement for the M. S. in Aerospace Engineering.

Mr. Brasfield completed his research work in August 1978,

B. SUPPORTING OPERATIONS

102 Programming

102.1 - R. Divany

We continued to study the problem of measuring water
vapor in the upper atmosphere. We modified our radiative transfer
program to allow a multi-parameter water vapor profile and began
looking at the 22 GHz H_2O line to study effects of changes in the
water vapor profile. Using a variety of sources, a realistic water
vapor profile from ground level to 100 Km was obtained and used
as our standard conditions. We then did a series of runs with the
amount of water vapor varying smoothly over a region of about 10 Km
by up to 50%. Plots were made of the ratio of the calculated
antenna temperature for perturbed data to that of the standard.

A lot of curve fitting and plotting of X-ray data was done
for Dr. Nisbet and Dr. Sengupta. The program to calculate
conductivities was modified to accept Chatanika electron density data
in place of the Ching & Chui model for Mr. Li.

A magnetic tape containing ozone data was received and processed
for Dr. Olivero.

Using listings of NCAR programs to produce contour maps of data
from rectangular arrays we proceeded to develop an easy to use
contouring program compatible with our QDGS graphics software.
The resulting contour maps may be circular or rectangular, using
solid or dashed lines either plain or bold. Documentation is now
available.

A trip was made to Arecibo to assist Dr. Carpenter in making
measurements during the Christmas break.

A test tape from the Wave Interaction recorder was received from Dave Landis and checked out to insure the hardware was operating correctly after being repaired.

Some three-dimensional plots were done for Mr. Li.

Improvements were made to our graphics software. Among these were updating the Tektronix 4662 package to output optimized X, Y coordinates and to handle messages sent to the terminal while plotting. All features of the package should now be compatible from the user's point of view for our H-P 7202A, our Tektronix 4010-1, or the Tektronix 4662 plotters at the computation center.

Some significant improvements have been made to our GRAPHIC program. GRAPHIC is the IRL main program for producing X-Y plots. These improvements include automatic determination of "nice" scaling parameters for linear axes. This includes determining the exact number of decimal places to display. Another improvement to GRAPHIC is the addition of a new option called EZPLOT, which allows a very abbreviated (15 column) plot control card to be used for selecting all the attributes of an X-Y plot. A new write up for GRAPHIC has been completed as well as a document, "How to Do an X-Y Plot".

Data from AE-C was rewritten to include the neutral temperature from the MSIS model for Mark Griffis.

The OGO-VI neutral density tapes were rewritten with revised geomagnetic coordinates and a new technique of dividing the data into bins. A new program to process these tapes will soon follow.

We have begun looking into the measurement of upper atmospheric ozone and are busy with modifications to the atmospheric radiative

transfer program to allow changing the ozone profile.

A new antenna modeling program was received and added to our library.

102.2 - B. Beiswenger

Eighteen tapes from Goddard with Atmospheric Explorer C experiments LEE, PES, CEP, RPA were received, translated for IBM compatibility, coupled with the MSIS neutral thermosphere model, and new tapes made for M. Griffis.

Sets of data were typed and plotted with fits for Dr. Sengupta, various graphs were done for R. Rohrbaugh, fits to data were run and plotted for Dr. Bleuler.

The radiative transfer program was run for absorption and emission for many zenith angles and altitudes and a couple hundred plots made, including frequency _vs_ antenna temperature, frequency offset _vs_ antenna temperature, frequency offset _vs_ a ratio of temperatures. The program, modified for ozone, was run with profiles and other data plotted. Tape OZ201 from Wallops Island was translated onto IRL128.

The program TANGLE from R. Vondrak at S.R.I. was keypunched. Corrections to BIGAMP, the antenna modeling program for up to 1500 segments, were made.

Work continued for the global model of the ionospheric currents and electric fields. Profiles of electron density from Chatanika were plotted and that data used at latitudes $\pm\ 68^{\circ}$, 70°, 72° to recalculate the 5 conductivities for Equinox. The multi-step processing and all the standard plotting were done using these and previous conductivities for current models X,Y,Z and several variations of

these three using different cusp currents. Birkeland currents were introduced for comparison. A new program, by Bob, plotted the Eastward and southward electric fields in polar form for the 3 latitudes modified by Chatanika data. Two attacks were made to produce three-dimensional plots of the integrated Hall and Pederson conductivities, our version of HIDE being chosen over our version of IRL 3-D graphics. The Chatanika conductivities were modified by Bank's suggestion at $\pm 68^{\circ}$, hours 2000 and 2200 and the results processed and plotted for current models Y and Z, with and without cusps. Current models X and Y were used with Solstice conductivities modified by Heppner's results for processing to obtain plots and to compare the model with Nagata and Kokubun's results.

Part 1 of a proposed internal report on IRL plotting hardware and software was completed.

We adapted a contour plotting package from NCAR to IRL graphics and completed a write up for its use, available in room 301. The GRAPHIC write up was completly revised with new additions and changes included. It now is in two parts: file rld01.PLOTALK 1 describes all basic information you need to produce a plot, and file rld01.PLOTALK 2 has detailed descriptions. The copies on our wall have the minimal knowledge you need in yellow highlight. A handy key for typing GRAPHIC data cards was made, with copies in rld01.PLOTTER, posted at each terminal, and available as handouts. A complete demonstration with directions, "How to Do an X-Y Plot" is also available. An up-to-date bulletin on graphics changes and editions by date is posted, and is accessible through RJE by listing file bab01.PLOTNEWS.

103 Library

103.1 - D. Thompson

Two Scientific Reports have been received and distributed.

Three reprints written by staff members have been

received into the library.

C. OTHER ACTIVITIES

201 Publications and Presentations

201.1 Scientific Reports

460 Bevilacqua, Richard M., "Ice Particles in the Mesosphere".

461 Sulzer, Michael P., "The Detection of Atmospheric Gravity
Waves by Means of the Wave Interaction Experiment".

201.2 Papers Published

78-1 Glenar, David A., E. Bleuler, and J. S. Nisbet, "The Energy
Balance of the Nighttime Thermosphere", Journal of Geophysical
Research, No. A12, December 1978.

78-3 Nisbet, John S., "Ion Exchange with the Solar Wind for Planets
with Negligible Intrinsic Magnetic Fields", Planetary and
Space Science, December 1978.

78-4 Nisbet, John S., "Operational Physical Models of the
Ionosphere", AGARD, Reprinted from Conference Proceedings
No. 238, 1978

201.3 Papers Presented

Nisbet, John S., and M. Griffis, "Energy Deposition and High
Latitude Neutral Thermospheric Densities", AE Symposium,
October 1978.

Nisbet, John S. and C. G. Stehle, "A Comparison of the High Latitude Thermosphere Under High and Low Solar Activity Conditions", AE Symposium, October 1978.

202 Seminars

Ron Rohrbaugh, Ionosphere Research Laboratory, "The Effect of Energetically Produced O_2^+ on the Ion Thermal Balance of Mars", October 27, 1978.

Dr. C. J. Gibbons, Appleton Laboratory, Slough, England, "Radiometric Measurements of the Upper Atmosphere", October 30, 1978.

Dr. P. R. Sengupta, Chief, Institute of Applied Manpower Research, New Delhi, India, November 13, 1978.

203 Visitor

Dr. C. J. Gibbons, Appleton Laboratory, Slough, England on October 30, 1978.

PERSONNEL

Name	Title	Percent Funded Time	Problem
The National Aeronautics and Space Administration			
Grant NGL 39-009-003 - NASA IRL MD - 5944			
J. S. Nisbet	Prof. of Elec. Eng. Director, IRL	12.0	1.1, 1.2, 1.3
E. Bleuler	Prof. of Physics	--	1.4.1
J. Heicklen	Prof. of Chemistry	--	--
J. Olivero	Assoc. Prof. of Meteorology	1.0	1.6, 1.7
R. Caverly	Graduate Assistant	50.0	--
D. Glenar	Graduate Assistant	50.0	1.4
C. Li	Graduate Assistant	50.0	2.2
R. Rohrbaugh	Graduate Assistant	50.0	1.5
W. Stuper	Graduate Assistant	50.0	6.2
Grant NGR 39-009-032 - NASA CMMS XIII - 5901			
B. R. F. Kendall	Prof. of Physics	--	4.1, 4.7
Grant NSG-6004 - NASA MAP - 5956			
L. C. Hale	Prof. of Elec. Eng.	18.0	3.1
Grant NSG-5212 - NASA POLAR EXPLORER - 5958			
J. S. Nisbet	Prof. of Elec. Eng. Director, IRL	--	1.1, 1.2, 1.3
M. Griffis	Graduate Assistant	50.0	--
C. Stehle	Graduate Assistant	50.0	--
The National Science Foundation			
Grant ATM76-03144-A01 - NSF FOUNDATION - 6305			
J. S. Nisbet	Prof. of Elec. Eng. Director, IRL	--	1.1, 1.2, 1.3
S. Gonguly	Consultant	--	--
T. Kostiuk	Consultant	--	--

Name	Title	Percent Funded Time	Problem
M. Nicolet	Consultant	--	--
P. Sengupta	Consultant	--	--
Y. Somajajulu	Consultant	--	--
P. Stubbe	Consultant	--	--

Grant ATM76-14277-A01 - NSF D-REGION - 6224

Name	Title	Percent Funded Time	Problem
A. J. Ferraro	Prof. of Elec. Eng.	--	3.2
H. S. Lee	Prof. of Elec. Eng.	--	3.3

Grant ATM78-19964 - NSF D-REGION/ARECIBO - 6226

Name	Title	Percent Funded Time	Problem
A. J. Ferraro	Prof. of Elec. Eng.	17.0	3.2
H. S. Lee	Prof. of Elec. Eng.	--	3.3
J. Breakall	Graduate Assistant	16.7	3.6
A. Tomko	Graduate Assistant	16.7	3.5

Grant ATM76-81004-A01 - NSF PROBE FLOWS - 6656

Name	Title	Percent Funded Time	Problem
L. C. Hale	Prof. of Elec. Eng.	8.0	3.1
T. York	Prof. of Aerospace Engineering	15.0	--
Shih-Kao Chang	Graduate Assistant	50.0	--
Chung-I Wu	Graduate Assistant	50.0	--

Grant ATM78-16832 - NSF CROSS SECTIONS - 6213

Name	Title	Percent Funded Time	Problem
J. S. Nisbet	Prof. of Elec. Eng. Director, IRL	--	1.1, 1.2, 1.3
R. Simonaitis	Research Associate	50.0	6.1

Grant ATM77-06718 - NSF SPREAD F - 6775

Name	Title	Percent Funded Time	Problem
L. A. Carpenter	Asst. Prof. of Elec. Eng.	9.0	2.1
E. H. Klevans	Assoc. Prof. of Nuclear Eng.	2.0	2.3
J. McCowan	Graduate Assistant	16.7	--

Name	Title	Percent Funded Time	Problem
The Office of Naval Research			
Grant N00014-77-C-0041 - DN INTERACTION #4 - 7025			
A. J. Ferraro	Prof. of Elec. Eng.	--	3.2
H. S. Lee	Prof. of Elec. Eng.	--	3.3
Department of the Army			
Grant DAAG29-78-G-0083 - DA MINCON - 4500			
J. J. Olivero	Assoc. Prof. of Meteorology	11.0	1.6, 1.7
R. Bevilacqua	Graduate Assistant	16.7	1.8
D. Young	Graduate Assistant	50.0	--
Grant DAA629-78-G-0129 - DA SOL - 4547			
L. C. Hale	Prof. of Elec. Eng.	29.0	3.1
C. Croskey	Postdoctoral Scholar	63.0	5.1