THE PENNSYLVANIA
STATE UNIVERSITY

IONOSPHERIC RESEARCH

PSU-IRL-SAR-75/2

Semi-Annual Status Report No. 2

for the period

April 1, 1975 to September 30, 1975

(NASA-CR-146137) IONOSPHERIC RESEARCH N76-16683
Semiannual Status Report, 1 Apr. - 30 Sep. 1975 (Pennsylvania State Univ.) 54 p HC
$4.50 CSCL 04A Unclas
G3/46 09952

IONOSPHERE RESEARCH LABORATORY

University Park, Pennsylvania

PSU-IRL-SAR-75/2

Ionosphere Research

Semi-Annual Status Report No. 2

for the period

April 1, 1975 to September 30, 1975

Approved by: ______________________________

John S. Nisbet, Professor of Electrical Engineering
Director, Ionosphere Research Laboratory

Ionosphere Research Laboratory

College of Engineering

The Pennsylvania State University

University Park, Pennsylvania 16802

TABLE OF CONTENTS

Page

INTRODUCTION

This report is a statement of work currently in progress and is intended to meet contractual 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.

The work reported in this document was supported by The National Aeronautics and Space Administration under grants NGR 39-009-032, NGR 39-009-218, NGL 39-009-003, NGL 39-009-002 and NAS6-2602; by the Office of Naval Research under grant N00014-67-A-0385-0014; by the National Science Foundation under grants GR 41854 and GA-33446X2; and by The Department of the Army under grant DAHC04-75-G-0031.

A. RESEARCH PROGRESS

1. D-Region Theory

1.1 General - A. J. Ferraro

During April, operations of cross-modulation were made at the Arecibo Observatory for the purpose of 1) comparing with D-region backscatter results; 2) identifying tides, gravity waves, and acoustical waves in the D-region; 3) testing the new form of cross-modulation technique known as complementary cross-modulation.

Three papers were written and two accepted so far. Proposals were prepared for ONR and NSF. We continue to work with Dr. Gordon on the proposal of the new heater facility at Arecibo.

1.2 General - L. C. Hale

Three developmental rounds of the Super Loki-Dart parachute-borne blunt conductivity probe were launched from Wallops Island on May 1 and from White Sands Missile Range on September 25 and October 1 (See Croskey, 5.2). An Astrobee-D with an electrical structure/nitric oxide payload was launched from White Sands on July 15. The data from these firings are currently being evaluated.

A paper was presented on August 30 at the ICAE Symposium on the High Atmosphere and Space, Problems of Atmospheric Electricity; held in conjunction with the IUGG/IAGA meeting in Grenoble, France. Gerdien condenser measurements in the mesosphere and upper stratosphere were presented which tend to confirm the existence of condensation nuclei in the region above 40 km illuminated by hard ultraviolet light. It was suggested that these particulates could grow and fall and provide a possible coupling mechanism through the stratosphere.

1.4 General - M. Nicolet

The first draft on "Atmospheric Ozone: An Introduction to its study" which was written during the last winter, has been corrected. The manuscript has been typed in its final form. It will be published as a Scientific Report of IRL. It has been accepted last May as an invited paper for publication in Review of Geophysics and Space Physics. The edited manuscript has been checked during July-August and the galley proofs have been corrected at the beginning of September. It should be published in November.

1.5 General - A. P. Mitra

The flare study has been concerned with the ionosphere as a whole, from 60 km to at least 1000 km, and as far as possible from simultaneous use of several quantitative techniques (as offered to routine patrol techniques). The quantitative techniques considered included: wave interaction, partial reflection LF-VLF plus multifrequency riometer combination for D-region studies, and incoherent scatter, HF doppler and satellite radio beacon measurements for heights above 100 km. Several outstanding flare events for which ionospheric information for both D and F regions are reasonably complete have been identified and examined. These are

July 7, 1966	0025-0.135/2b
May 23, 1967	(three phases starting at 1803, 1835, 1932 UT)

July 8, 1968	Two consecutive phases
Aug. 1972 events	(F1 on August 2 at 0310 UT F2 on August 2 at 1959 UT F3 on August 4 at 0619 UT F4 on August 7 at 1515 UT)

The work has been principally concerned with the two most important applications of quantitative SID studies:

a) abilities of the D-region SIDs to serve as a probe of the basic chemical processes operating in the D-region

b) the abilities of the F-region SIDs to successfully monitor the time variations in EUV flux and any relative changes in fluxes in the competing bands.

A book entitled "Ionospheric Effects of Solar Flares" written by me has been brought out by D. Reidel Publishing Co., Holland. The book includes much of the D-region flare work carried out with Penn State Wave Interaction Facility.

1.7 <u>Mesospheric Processes</u> - J. J. Olivero

Our studies are continuing on the properties and effects of small particles in the mesosphere and the measurement of important trace constituents, especially water vapor above 30 km. These are also discussed below in Sections 1.9 and 1.10.

Richard Longbothum has completed a Scientific Report entitled "A feasibility study of a microwave water vapor measurement from a space probe along an occultation path" (Longbothum, 1975). In this study, using a crude, initial model, we have been able to show that water vapor measurements are possible throughout the mesosphere for the smallest mixing ratios predicted (10^{-7} by volume). A far more realistic radiative transfer model has been developed incorporating many of the important microwave lines of O_2, O_3, CO, and N_2O as well as the 22 GHz and 183 GHz lines of H_2O. Extensive investigation of the line structure parameters has been completed and a full Voigt function line has been incorporated where appropriate. In accomplishing this, we have developed an empirical expression for the width of the Voigt line as a function of the pressure and Doppler line widths (Olivero and Longbothum, 1975).

We are presently designing a multichannel radiometer suitable for use at both water vapor line frequencies for typical stratospheric and mesospheric line width conditions. We plan to complete a measurement modelling study, from radiation source through data retrieval, within the next reporting period.

The mesospheric scattering layer study has continued to model the effects of the layer on the transmission of solar radiation through the atmosphere in the summer polar regions. The model has been improved with the additions of time-dependent calculations of the following quantities: layer particle concentration; polar surface area directly illuminated; and area weighted solar zenith angle for use in calculation of the atmospheric extinction. Each of these quantities is available as a function of day-number throughout the summer half-year. With the proper geometry the surface temperature perturbation reaches a maximum ahead of solstice with values in the 0.1 - 1.0° C range corresponding to the range of estimates of particle absorption (imaginary index of refraction). These results have been presented at the Spring AGU meeting (Hummel and Olivero, 1975a) and have also been submitted for publication (Hummel and Olivero, 1975b).

The next steps to be taken in the radiative transfer model are the inclusions of the wavelength dependence of the real and imaginary indices of refraction for ice and micrometeoridal debris, and of an upward, return flux of solar radiation, due to reflection at the surface, incident on the scattering layer from below.

We continue to hypothesize the existence of a continuous background population of microparticles ($10^{-3}\mu$-$10^{-2}\mu$) throughout the normal stratosphere and mesosphere. We also continue to seek non-controversial evidence for the existence of these particles. At the Spring AGU meeting we presented a paper (Chesworth and Olivero, 1975) in which we suggested that such evidence might consist of an ultraviolet (uv) scattering anomaly. We were able to find a number of such incidents in the literature. These generally involved measurements of UV scattering or absorption by mesospheric ozone or the determination of the UV albedo of the atmosphere as seen from above. In each case the data had been analyzed suggesting ozonospheric structure, in both day and night cases, which are inconsistent with present accepted photochemical-transport models. The most prevalent altitude region for this effect was found to be 50-70 km.

We intend to begin developing physical models of the microparticle size and altitude distribution in the next reporting period. Our primary criterion will be the D-region structural evidence from recent blunt probe-conductivity and Gerdien condenser mobility measurements by L. C. Hale and his colleagues.

References:

Chesworth, E. T. and J. J. Olivero, "Ultraviolet Scattering from Mesospheric Aerosols," Spring AGU meeting, Washington, June 1975.

Hummel, J. R. and J. J. Olivero, "Climatological Implications of the Mesospheric Scattering Layer," Spring AGU meeting, Washington, June 1975a.

Hummel, J. R. and J. J. Olivero, "Satellite Observations of the Mesospheric Scattering Layer and Implied Climatic Consequences," submitted to J. Geophys. Res., 1975b.

Longbothum, R. L., "A Feasibility Study of a Microwave Water Vapor Measurement from a Space Probe Along an Occultation Path," Scientific Report 434, April 1975.

Olivero, J. J. and R. L. Longbothum, "The Voigt Line Width; An Empirical Fit," submitted to J.Q.S.R.T., 1975.

1.9 Upper Atmospheric Water Vapor - R. Longbothum

My work during this period has been directed into developing a computer model of a microwave radiometer suitable for stratospheric and mesospheric water vapor measurements. The model is now being incorporated into the existing radiative transfer program. The total model will then be used to examine the various measurement schemes in order to determine the accuracy and resolution of each method. The first draft of the thesis is now in preparation.

1.10 Aerosol Layer Studies - J. Hummel

During the last period my master's thesis was completed. The study, Satellite Observations of the Mesospheric Scattering Layer and Implied Climates Consequences was reported on at the Spring AGU meeting by Dr. Olivero and has been submitted to JGR for publication. The summer was spent attending the National Center for Atmospheric Research colloquium on the chemistry, physics, and dynamics of the stratosphere and mesosphere.

1.11 Arecibo Wave Interaction Measurements - M. Sulzer

Research is proceeding in three areas:

1) Analysis of data obtained in the spring in Aricibo: Better methods of Fourier analysis are being developed so that trends may be removed to allow the tides and waves to be studied.

2) Background noise analysis. Two all day runs with W-transmitter and without D-transmitter have been executed at Scotia. The purpose is to establish the systems and ionosphere background noise level in order to determine the reliability of the tide and wave data.

3) Tide and wave data from Scotia. Two all day runs at Scotia using both transmitters have been executed. Data from the first was lost when the tape was found to be completely blank. No tape recorder malfunction was found. The data from the second day is to be analyzed using John Terry's program.

1.13 D-Region Theory and Measurements Below 70 km - A. Tomko

During this report period I have completed work on a master's thesis entitled "A Study of the Electron Density Distribution in the Lower D-region and its Aeronomic Implications. An abstract of this work is given below:

This study attempts to estimate the electron density distribution in the D-region below 70 km on the basis of steep incidence VLF radio wave propagation data at frequencies between 8-22 KHz and positive ion concentration measurements for $\chi = 60^{o}$ and a moderate level of solar activity. The electron density, N_e, is estimated from the VLF data by a trial and error modification technique which employs a full wave solution of the field equations governing the propagation of plane waves in an inhomogeneous anisotropic medium. It is found the $N_e < 20\ cm^{-3}$ at 60 km and $N_e = 50 - 200\ cm^{-3}$ near 65 km when the electron density is constrained to an acceptable empirical range above 70 km. At least one reversal of dN_e/dz within the X = Y region at 8-22 KHz is required to reproduce the wave frequency variation of the VLF propagation coefficients.

The electron density is estimated from observed positive ion density values, N_+ on negative ion detachment through numerical solution of the steady state ion-electron continuity equations. Observed values of N_+ are used to define an upper limit on the bulk negative ion detachment rate, γ_X, which in turn places a maximum value on N_e. It is found that $N_e < 22\ cm^{-3}$ at 60 km in agreement with the VLF result. However, at 65 km the positive ion data requires that $N_e \lesssim 45,\ cm^{-3}$ in contradiction of the VLF findings.

I have also completed some preliminary calculations of changes in the D-region electron density from HF radio wave heating. Holway and Meltz (1973) have shown that HF heating can produce a localized increase in the electron temperature, T_e, as large as a factor of 10 above the neutral temperature, T_n. An increase in T_e of this magnitude will significantly modify the D-region ion chemistry through the dissociative recombination rate, $\alpha_D(T_e)$, and the electron attachment rate, $\beta_{O_2^-}(T_e)$. Above 60 km, HF heating increases N_e via decreased $\alpha_D(T_e)$ while below 60 km N_e can decrease due to increasing $\beta_{O_2^-}(T_e)$.

Reference:

Holway, L. H. and G. Meltz, J. Geophys. Res., 78, 8402-8408, 1973.

1.14 Digitalization of WI and PR Experiments - K. Swanson

After the field testing of the digitalized wave interaction equipment at Arecibo this spring, it was decided that several modifications to the system would considerably ease the data collection process. The main modification would be the addition of a programmable automatic controller. This device would automatically sequence the equipment through the various steps of the experiment. Two advantages of having this controller would be elimination of operator error and production of a more uniform data output to simplify the data analysis programming. The controller is now being built and should soon be in service.

2. E and F-Region

2.1 General - J. S. Nisbet

2.1.A Program on the Thermosphere and F Region-J. S. Nisbet

Major progress has been made in the study of the thermosphere. The basic problem with the CIRA 1965 and 1972 reference atmospheres is that they were based on total density measurements alone. It has been known for some time that they did not model the seasonal and magnetic activity variations in the neutral density and the effects of transport in modifying the distributions were understood qualitatively. Hedin et al. (1973) developed a model for quiet magnetic and moderately active solar conditions based on the mass spectrometer data from OGO VI. When these models were checked against measured wind velocities it was determined that the north south pressure gradients appeared to be too large whereas the CIRA (1972) values were much too small.

We have recently completed a study in which the 6300 Å airglow temperatures measured by Blamont's group have been combined with the mass spectrometer densities measured by Goddard Space Flight Center. Figure 1 shows a comparison of the temperatures compared with temperatures derived from the total density for a very disturbed period. As can be seen the temperatures from the total density show very little difference from equator to pole in agreement with the conclusions derived from satellite orbital decay. The reason is not that the exospheric temperature remains

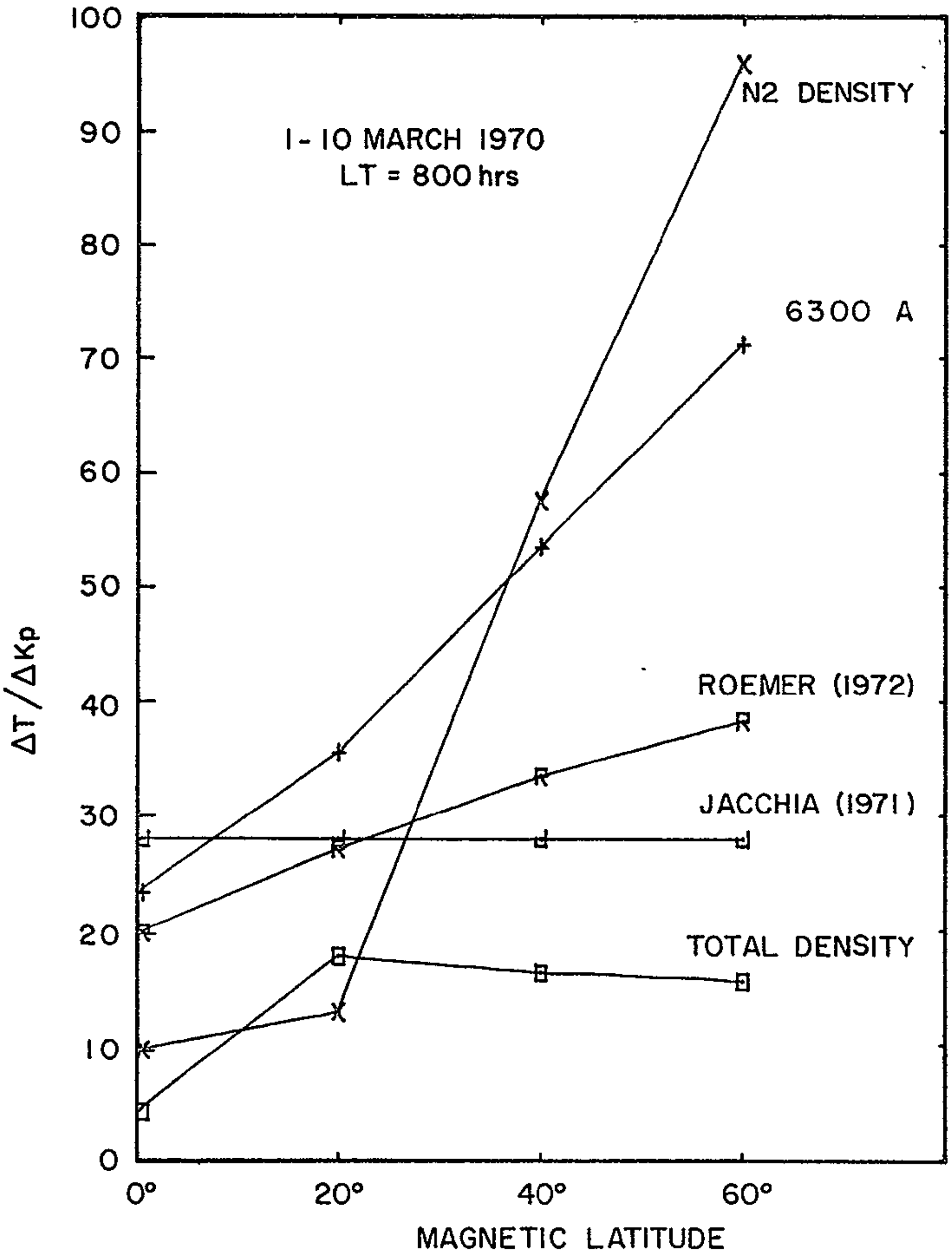

Figure 1 $\Delta T / \Delta Kp$ versus magnetic latitude derived from 6300 A temperatures, N_2 and total density derived temperatures, Jacchia (1971) and Roemer (1972), for 1970 March AM local time constant as is shown by the 6300 Å measurements but in boundary changes induced by the winds. The densities derived from the N_2 measurements show good general agreement with the 6300 Å temperatures. There is however a very much steeper gradient in the N_2 derived temperature than for the 6300 Å temperature causing the pressure gradient to be lower than would be predicted from the N_2 densities alone.

Figure 2 shows one of the graphs of the temperature in the polar region plotted as a function of geomagnetic latitude and geomagnetic time. Similar analyses have been made for solstice and equinox conditions at three magnetic activity levels. This type of plot is of use in relating the neutral temperatures to the energy inputs during auroral events. It is apparent that the neutral temperature distributions, unlike the total density does not decrease poleward of the auroral oval. Temperatures decrease under all conditions in the geomagnetic noon sector as would be expected and are largest in the pre-midnight sector.

There has been considerable uncertainty about the mechanism of transfer of the very considerable amounts of energy deposited in the polar regions during times of magnetic activity to lower latitudes and about the amounts transferred. Two major candidates for the dominant transfer mechanism are thermospheric winds and gravity waves. A study is now being made which allows the density depletions in the auroral zone, the mean southward wind at

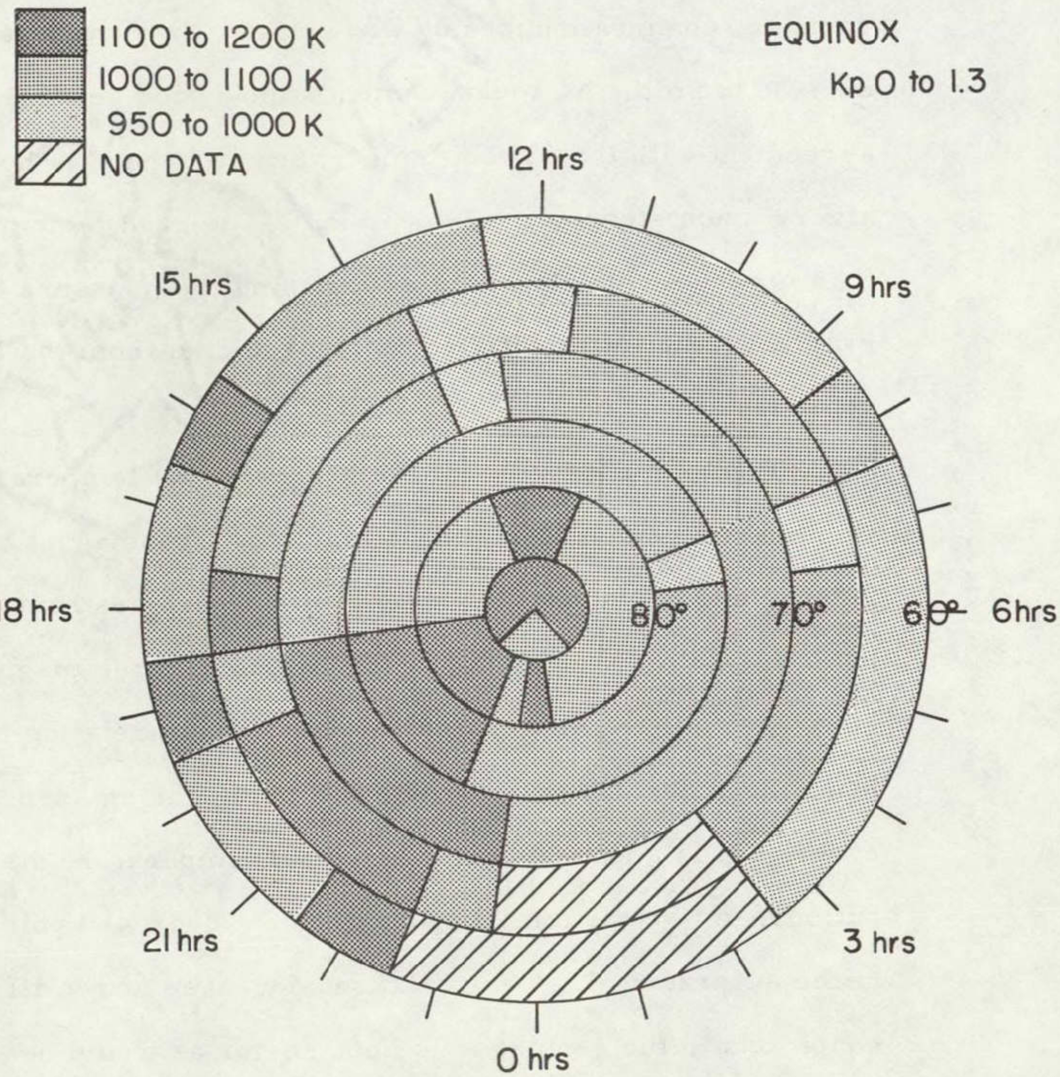

Figure 2 Exospheric temperature as a function of geomagnetic latitude and geomagnetic time for K_p range of 0 to 1.3 at equinox

mid-latitudes in the thermosphere and the energy transported by the wind system to be related in a quantitative manner. Such a study is necessary to the development of "soft" lower boundary conditions for three dimensional thermospheric models.

Reference:

Wydra, B., Global exospheric temperatures and densities under active solar conditions, PSU-IRL-SCI-436, The Pennsylvania State University, October, 1975.

2.1.B "Sluggishness" of the E-Region - J. S. Nisbet

Interest in the E-region has been reviving with the advent of high resolution incoherent scatter measurements and the AE satellite coordinated measurements of electron and ion densities, solar fluxes and neutral densities. The region is one in which knowledge has been sadly lacking. Symptomatic of the problems in this region are that the two CIRA (1972) neutral atmospheric models are inconsistent in the region and exhibit constant desnities and temperatures. In contrast measurements show that temperature fluctuations in the course of a few hours of 30% and density fluctuation of a factor of two are observed frequently. The main cause of these variations is the semidiurnal tide. Figure 3 shows electron densities measured at St. Santin compared with model calculations in which the neutral densities calculated from the observed collision frequencies and the observed temperatures were used. This work is important because the global morphology of the tide is not understood and electron density fluctuations appear to provide a simple way

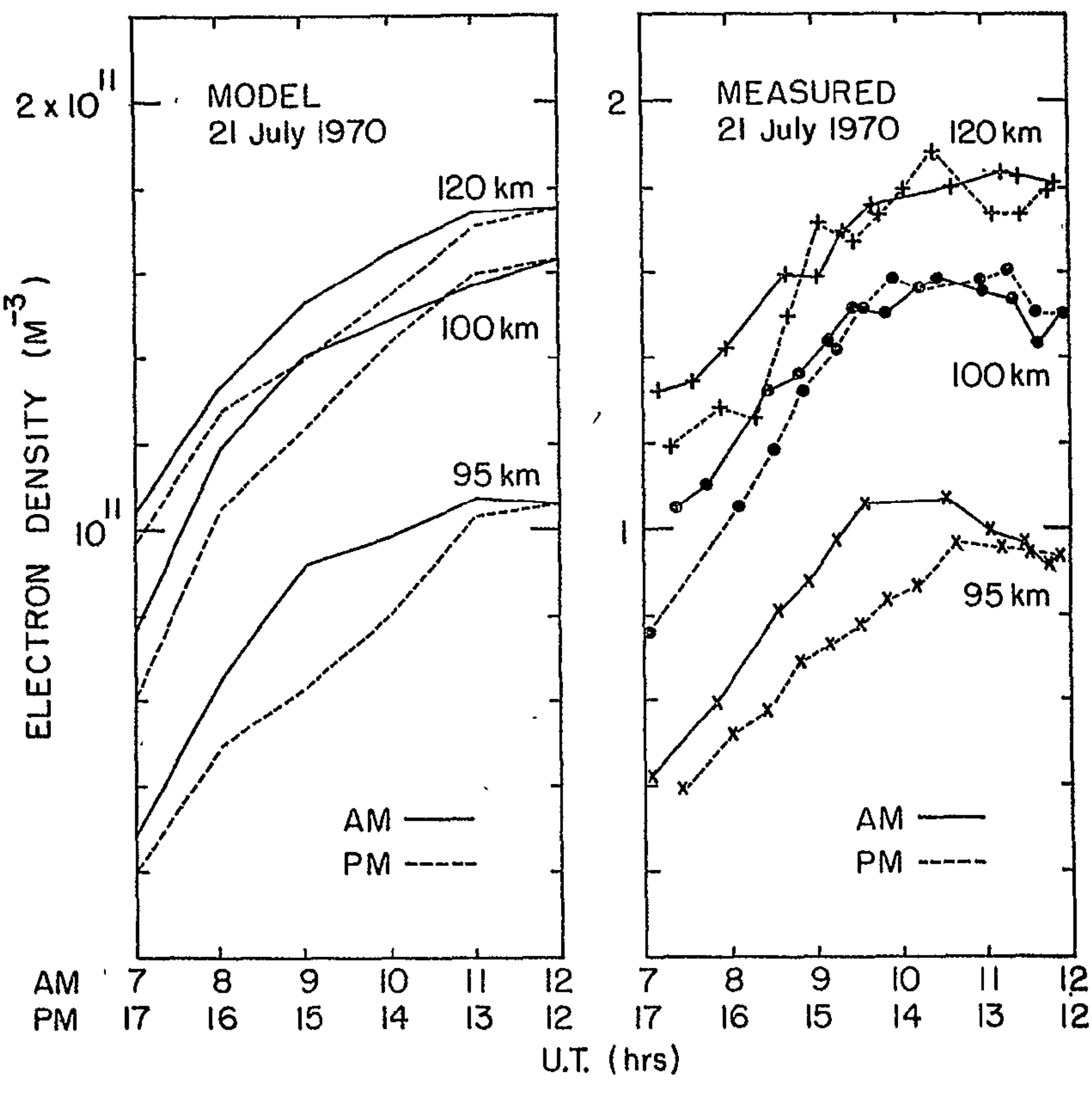

Figure 3 Comparison of measured E region electron densities with model values based on observed neutral densities and temperatures

of obtaining global coverage and in particular of investigating the southern hemisphere. We are currently using the much larger data base from the high resolution Arecibo measurements which with AE densities and solar fluxes will allow the remaining variables to be specified. The large global data base compiled using ionogram measurements, will then be used to study the tidal modes on a global basis.

Reference:

Monro, P. E., J. S. Nisbet and T. L. Stick, Effects of tidal oscillations in the electron density and neutral atmospheres in the E region, accepted J. Atmos. Terr. Phys., 1975.

2.1.C Airglow Emissions from Mars and Venus - R. Rohrbaugh

A comprehensive study of the ultraviolet airglow emission from Mars and Venus is being undertaken in cooperation with Dr. Herman of Goddard Space Flight Center and is proceeding through the following stages:

1) A comprehensive literature search is being made for experimental and theoretical information for determining photon and photoelectron ionization and excitation rates as well as the de-excitation rates. It includes references for concepts in the area of spectroscopy, quantum mechanics and excited state kinetics.

2) A computer program to generate neutral atmos atmospheres for Mars and Venus based upon thermospheric temperature profiles and boundary density values (constituents of interest: CO_2, CO, O_2, O, N_2, N, H, He) is being developed.

3) Photoionization and photoexcitation rates will be calculated based upon a model of the solar fluxes, the above neutral mode, and available absorption, ionization and excitation cross section and probabilities.

Once the ionization rate is calculated the continuity equation is to be solved in order to obtain static models of the ionization densities (ions of interest: CO_2^+, CO^+, O_2^+, N_2^+, O^+). The photoelectron loss rate and hence the excitation rates by photoelectrons can then be obtained.

4) The excited state kinetics for both neutral and ionized constituents are being studied. For this the production (or population rate) of the excited states is equated to the loss rate of corresponding excited states to obtain the population distribution of the states. Once this is done the volume airglow emission can be obtained.

5) These data will then be used with the radiative transfer equations to relate the local airglow emissions with remote measurements. This will require knowledge of the absorption, re-emission and fluorescence of the UV airglow. (Fluorescence will also have to be taken into account in order to obtain the amount of sunlight scattered into the measuring instruments view.)

2.2 F-Region Scintillations - W. J. Ross

There has been little progress in advancing the model studies of neutral wind/plasma interactions in the thermasphere and of relating the inhomogeneity fields which may result from these interactions to the characteristics of radio wave scintillation. The continuing impasse is in the realistic modelling of the electrical conductivity profiles in the critical region of the lower thermosphere.

It is interesting to note the revival by Booker in JATP of the concept of extensive field elongation of inhomogeneities in plasma density and of the interpretation of UHF scintillation in terms of weak multiple scattering. This model has severe difficulties in accommodating some of the experimental observations of rapidly transiting sources, but it may be that these two scintillation features are not normally present simultaneously.

2.3 F-Region Dynamics - L. A. Carpenter

A paper "Nighttime electric fields and meridional neutral winds at mid-latitudes" was presented at the Spring AGU Meeting, June 16-19, 1975 in Washington, D.C., in the special session on "Electrodynamics and tides in the lower thermosphere." Another paper on "Magnetospheric electric fields at L= 3.2 measured with incoherent scatter radar" was presented by Volker Kirchhoff. In the first paper the nighttime electric fields were described and the neutral winds were calculated and compared with different thermospheric models. The calculated neutral wind was somewhat greater than previous authors have found and the maximum occurred between 2 and 3 L.T. rather than midnight. In the second paper, the effects of magnetic activity on midlatitude electric fields was examined. The average pattern appears perturbed in a manner in accordance with the convection electric field for days where the summation of the

Kp index is greater than 24. This is a northward electric field around 1300 when the electric field is usually southward.

Two weeks were spent at Millstone Hill and about 70 hours of data was taken on July 11-13 and 25-27. During this time continuing discussions were held with John Evans and Joe Salah about current research. The drift velocity measurements appear consistent with the other incoherent-scatter measurements (such as the E-region tidal studies of Joe Salah).

Volker Kirchhoff's thesis work was continued during this period. Particularly important to his thesis was the approach used in modeling the E and F electric fields and also the magnetospheric component.

A midlatitude electric field model has been developed with an equivalent circuit representation that includes the conjugate coupling and the F-region dynamo. For the local and conjugate E-region a height-integrated Pedersen resistor is used with a local and conjugate generator due to E-region tidal winds and a Hall generator that depends and the conductivities and currents in the circuit. In the F-regions, a height-integrated Pedersen resistor is used along with a generator due to the thermospheric winds. Similar circuits are used in the north-south and east-west magnetospheric electric field contribution deduced from DP2 variations.

The E-region dynamo is found to be dominant in the daytime while the F-region dynamo and magnetospheric electric field control the nighttime behavior. Including the conjugate region provides stability to the model so that different wind systems do not generate grossly different electric fields. The model is compared with incoherent-scatter measurements of horizontal velocity around 300 km at Millstone Hill Observatory and the agreement is better than with previous models.

Bernie Wydra's thesis on "Global Exospheric Temperatures and Density under Active Solar Conditions" was completed during this period.

2.4 F-Region Theory - P. Stubbe

Man-made modification of the ionosphere by means of intense radio waves offers a promising means to study plasma phenomena not accessible in laboratory investigations and to draw conclusions on the natural state of the atmosphere as well as on certain collision and chemical rates.

Our efforts will be mainly concentrated on the following subjects:

1. Heating of the D-Region

If the effective radiated power is of the order 100 MW and the frequency around 3 to 4 MHz, the electron temperature in the D-region may be raised by as much as a factor 10. This results in an appreciable change of the electron density, due to the temperature dependence of the recombination rate within a wide range. This is especially important for recombination of the cluster ions $H_3O^+(H_2O)_n$ which predominate below about 80 km.

2. Kinetic Plasma Theory

The most advanced theory of wave propagation in a magneto-plasma, the Sen-Wyller-theory, is restricted to low-power waves which cause only small plasma-perturbations. For high-power waves causing strong temperature changes, the Sen-Wyller-theory needs to be generalized by taking into account inelastic collisions which are almost exclusively responsible for the energy exchange, while elastic collisions take care of nearly all of the momentum exchange.

3. Non-linear Radio-wave Propagation

Certain non-linear wave propagation effects, like cross-modulation, self-modulation and demodulation, are well known and have been extensively studied. In addition, there are other, much finer, effects which, consequently, are much more more difficult to detect. One of these effects is that a strong wave ω_1 impresses the combination frequencies $\omega_2 \pm \omega_1$ on a second wave ω_2. This effect contains detailed information on the electron velocity distribution function and is thus appropriate for testing the results of Section 2.

4. Parametric Excitation of Plasma Waves

Electromagnetic waves of sufficiently high intensity may decay into a pair of longitudinal plasma waves, the first being an electron-plasma wave (or Langmuir-wave), the second an ion-acoustic wave. Application of the frequency and wave number selection rules and of the Langmuir-wave dispersion relation shows that the parametric excitation preferentially occurs slightly below the reflection level of the electromagnetic wave. The longitudinal plasma waves may be detected by coherent scatter of diagnostic waves from the phase-surfaces of the plasma waves. This process is subject to a Bragg condition, so that the diagnostic wave selects a certain propagation direction and wavelength out of the spectrum of plasma waves. Plasma waves and the accompanying plasma instabilities are responsible for field aligned irregularities, and thus spread-F, and for an airglow enhancement. The latter may be used for determining the neutral wind velocity and the $O(^1D)$ quenching coefficient. The theory of parametric plasma wave excitation needs to be extended, especially with respect to gyro-effects, to plasma waves propagating at large angles to the magnetic field and to excitation effects in the lower F-region and E-region where collisions with neutral particles become important.

2.7 <u>Planetary Escape Mechanisms</u> - R. Rohrbaugh

The planetary atmosphere modeling program has been modified to generate the rates of ion and primary photoelectron production. Additional subroutines have been added to calculate the equilibrium ion and electron densities from the ion continuity equations, based upon ion production, loss, and vertical transport. The velocities necessary for the transport term were obtained by solving the momentum equations.

A "photoelectron" program by Wes Swartz has been investigated and adapted for use in conjunction with the photoelectron production rate to obtain the equilibrium photoelectron densities over intervals of altitude and energy. These densities will then be used to obtain excitation rates and thus emission rates of various atmospheric constituents.

Work has begun in obtaining the emission rate for the CO fourth positive band system in the Martian atmosphere.

2.8 Modeling the Mid-Latitude Trough - B. Halcrow

A model of the electron density through the F_2 nighttime mid-latitude trough will be developed for incorporation with the gobal CCIR of F_2 peak electron density.

The electron densities in the trough will be delineated in terms of ionospheric variables, geographic location and time.

2.10 Incoherent Scatter Measurements of Electric Fields - V. Kirchhoff

Four papers co-authored by Dr. Carpenter have been presented at the spring AGU meeting reporting on nighttime electric field measurements and measurements during magnetic active periods. The work on the comparison of high and low latitude electric fields measured at Chatanika and Millstone Hill has been published in the May issue of JGR.

My doctorate program has been completed with the approval of the committee of a thesis entitled "Electric fields in the ionosphere." Measurements are discussed and an electric field model is developed based on an electric equivalent circuit concept. This work is available as SCI-438.

2.11 Thermospheric Neutral Temperature Variations - B. Wydra

Master's thesis (Scientific Report 436) entitled "Global Exospheric Temperatures and Densities Under Active Solar Conditions" has been completed. The abstract is as follows:

Temperatures measured by the OGO-6 satellite using the 6300 A airglow spectrum are compared with temperatures derived from total densities and N_2 densities. It is shown that while the variation of the total densities with latitude and magnetic activity agree well with values used for CIRA (1972), the temperature behavior is very different. While the temperatures derived from the N_2 density were in much better agreement there were several important differences which radically affect the pressure gradients. The variation of temperature with magnetic activity indicated a seasonal and local time effect and also a latitude and delay time variation different from previous density derived temperatures. A new magnetic index is proposed that is better correlated with the observed temperatures. The temperature variations at high latitudes were examined for three levels of magnetic activity for both solstices and equinox conditions. A temperature maximum in the pre-midnight sector and a minimum in the noon sector were noted and seasonal and geomagnetic time and latitude effects discussed. Neutral temperature, density, pressure and boundary oxygen variations for the great storm of March 8, 1970 are presented.

A paper on this work will be presented at the fall AGU meeting.

2.12 E-Region Variations - T. Stick

In the past six months, I have been working with an E-region model comparing measured data of temperature, neutral density and wind velocity with measured values of electron density. The data used was obtained from the back-scatter station at St. Santin, France. The results were prepared for publication. Since then I have been working with data obtained from the backscatter facility at Arecibo. I plan to do a similar analysis on it.

2.13 Spread F - G. Imel

Work is continuing in the extension of the Perkins model of temperate latitide spread F (Perkins, F. W., JGR, (78), 218, 1973) to include Hall conductivity effects. It is felt that the + K^2 (K is the wavenumber) obtained for the growth rate at short wavelenghts is not physical (damping is expected). The error of the model probably lies in the fact that higher order (in $\frac{\nu in}{\omega ci}$) terms in the equation for the time evolution of the Hall conductance were neglected that may be dominant at short wavelengths. The effects of these terms are being investigated.

2.14 F-Region Models - M. Miller

A detailed comparison of the Stubbe ionospheric model and the Naval Research Laboratory ionospheric model was made. Both models were run in an identical case where solar and geomagnetic activity were the same. Electron density profiles of both models were compared and parameters such as reaction rates, cross sections, neutral atmosphere densities and solar flux were changed in Stubbe's model to agree with the Navy model.

3. Wave Propagation Studies

3.1 General - H. S. Lee

A trip was made to make week-long wave interaction measurements at Arecibo. The measurements were made with many different modes of operation and the results obtained from the trip formed an important part of new research proposals submitted to NSF and ONR.

Final manuscript of the paper on critical intercomparison of wave interaction and partial reflection experiments was completed and submitted to JATP for publication.

Initial computation of the effect of gyro-disturbing frequency on wave interaction has been made in connection with the investigation on possible means of perturbing ionospheric medium for radio communications.

3.13 Satellite Recording and Analysis - W. J. Ross

This program has been suspended for some time and it is not planned to re-activate it.

3.18 Artificial Modification of the Ionosphere - P. J. Moser

P. J. Moser has graduated and has obtained a Ph.D. degree and a final report has been prepared.

4. Mass Spectrometer Measurements

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

Several types of mass spectrometers are being studies from both theoretical and experimental viewpoints, with a view to establishing their value for measuring the ionic composition in the D and lower E regions of the ionosphere. During this reporting period the main effort has again been devoted to work on time-of-flight analyzers having cylindrical and hemispherical electrodes.

Analysis of data from the May 1974 Nike-Apache flight (No. 14.482) is still being done. Data analysis done so far continues to point to a high proportion of the ions in the upper D-region having extremely high masses. Even though the mass spectrometer upper, mass limit had been extended well beyond

250 atomic mass units on this flight, substantial currents produced by ions of even higher masses seem to have been present. Processing of the data from the mass spectrometer, the three different ion probes, and the neutral density gauge on this flight is continuing. A more detailed discussion of the results so far obtained is given in Sections 4.2 and 4.5.

A paper entitled "Bonded electrodes for use on the external surfaces of spacecraft," by B. Kendall and J. O. Weeks, appeared in Review of Scientific Instruments during this reporting period and a paper entitled "Miniature time-of-flight mass spectrometer for ion composition measurements in the lower ionosphere" by B. Kendall and R. F. Reiter was delivered at American Society for Mass Spectrometry Conference in Houston, Texas during May.

The new apparatus for measuring outgassing characteristics of materials has been used to evaluate a proposed gold-plating technique to be used on the exterior surfaces of the next D-region mass spectrometer package. It has also been used to determine thermal lag corrections for thermocouple pressure gauges on this and the pervious (14.482) flight.

A second look at the results from an earlier flight (15.46) shows that there are patches of useful data buried in the noise resulting from a weak telemetry transmitter. The day of this flight was unusually quiet as far as ionospheric characteristics were concerned. At least 80% of the ions collected appeared to have masses greater than 275 amu.

4.2 Ion Analysis in the D and E Regions - R. Reiter

During the last reporting period the majority of my time has been spent on the reduction of the mass spectrometer data from NASA flight 14.482. A sampling program for analog-to-digital conversion of the telemetry data was completed by Brad Kuhn of the Hybrid Computer Facility. This program (and several associated programs) were run successfully. A program written by myself for telemetry voltage to ion current conversion was also completed and run. Several problems with the experiment package telemetry outputs delayed the completion of these programs until near the end of this reporting period.

A detailed analysis of the mass spectrometer current output has now begun. Special emphasis is being placed on the deduction of the background current ratios (defined in the preceding semi-annual report). The background current ratios measured at apogee, for reference, indicate a partial failure in the mass spectrometer gating barrier during the flight. This partial failure will not effect the meaning of the background current ratio.

When laboratory measurements of background current ratios are compared to the 14.482 ratios, they indicate a high proportion of very heavy ions (>500 amu) in the D-region ionosphere. However, the exact proportion of heavy ions and an altitude profile for the heavy ions are still in doubt. There are three serious effects which need to be understood before a reasonable conclusion can be made.

The first problem is the density enhancement behind the shock wave of any vehicle moving through the atmosphere. The flow regime of the 14.482 experiment package can be deduced at most altitudes, but the relatively large angle of attack (~15°) throughout the D-region makes it extremely difficult to calculate the exact shock wave shape, its detachment distance and the location of the stagnation point (if one exists). A knowledge of these three parameters will make it possible to calculate the number density in the mass spectrometer. The background current ratio calculations and the mass spectrometer sensitivity depend directly on the number density.

The second problem is mass discrimination in the mass spectrometer gating system. This problem is being studied through computer modeling. Preliminary results are still tentative but indicate the discrimination effects begin at about 500 amu for the gating system used in the 14.482 mass spectrometer. The results of these studies will have a direct bearing on the conclusion drawn from the background current ratio calculations.

The third problem was indicated by the presence of anomalous results for particular sets of mass spectrometer and forward facing ion probes draw-in voltages. There is an apparent interference between these instruments in sampling ions within the plasma sheath. This effect is negligible above about 100 km but is extremely important through the D-region.

Studies of all three problems are continuing so we can reduce the results of the 14.482 flight. Improvements are being discussed for implimentation in the next sounding rocket (NASA flight 10.317).

Computer modeling and laboratory work aimed at improving the resolution in the miniature time-of-flight mass spectrometer developed at Penn State were carried on during this period. Computer models showed the possibility of improving resolution by giving ions in the mass spectrometer source initial velocities depending on their distance from the collector. Actual lab measurements using a cylindrical electrode instrument produced a resolution improvement from 12 to 20 at 133 amu. Further improvement is possible if suitable pulse circuitry can be developed.

Construction was completed on a sub-miniature planar time-of-flight mass spectrometer with a total ion path of 4 mm. This configuration was analyzed using computer models and the results showed a probable resolution as good as the larger instruments reported previously. This new mass spectrometer can be operated in a mode which is significantly less susceptible to initial ion energy spreads. A mass spectrometer of this size would be very useful in D-region ionosphere studies where the mean free path is so short. It could also be placed on a sounding rocket package in a position which could eliminate any shock wave effects.

The completion of my thesis has been delayed by the problems discussed earlier in this report. Work on it will continue into the next reporting period.

4.3 Ion Dynamics of Pulsed Mass Analyzers - B. Kendall

This project was temporarily inactive following the completion of R. Stein's Ph.D. thesis and the publication of key portions of it during 1974. It has recently been revived by R. F. Reiter and S. Rossnagle, who are using digital and analog computer techniques, respectively.

4.4. Deconvolution - B. Kendall

It has been definitely established that deterioration of the performance of the electrostatic resolution enhancement apparatus used for this work has been caused by corrosion on the moving copper-plated platen which carries the memory capacitors. This caused variations in surface potential which caused a large increase in background noise level. It was found that these false signals could be greatly reduced by gold plating. Two methods of gold plating were evaluated and the better of them was used to recondition all of the corroded components in this apparatus.

4.5 Ion Probes - W. Cuirle

With the help of Dr. York, a technique has been developed for determining atmospheric neutral number density with a thermocouple gauge on board a supersonic sounding rocket. For the data of NA 14.482, the measurements are within a few percent of CIRA 1972 mean from 70 to 90 km. Although the procedure is based on continuum flow theory, the package was technically in the transition regime at these altitudes. The success of the procedure would therefore seem to allow extension of continuum principles to more rarefied flows in this case. A further result of this work was the determination of shock standoff distance and pressure ratios allowing a more accurate estimate of pressure corrections to the mass spectrometer sensitivity, along with flow conditions around the forward probes and the mass spectrometer source region.

An abundance of heavy ions were detected by NA 14.482. Since ion mass will affect mobility and hence the ion density estimates, a three component model atmosphere based on CIRA 1972 and available data was constructed. The crucial item is the heavy ion mass, for which little data is available. The mass spectrometer on NA 14.482 could not resolve above 500 amu and gives information only on the overall abundance of heavy ions. Other types of instrument, notably quadrupoles, are probably susceptible to break up of cluster ions and therefore not entirely reliable. The only remaining source is Gerdien condensor measurements, of which some were supersonic and some were at high latitudes and therefore eliminated. There remain two published sets of measurements: that of Rose and Widdel, and Hashem Farrokh. The best estimate to date of the heavy ion mass, based on Farrokh's data, assumes a heavy ion mass density equal to that of water and yields a result of about 360 amu. This mass is inside the range of the mass spectrometer of NA 14.482 and should have been observed. On the other hand, the 1972 data of Rose and Widdel yield mass estimates ranging from 950 to 1200 amu. This discrepancy will have to be resolved before the model can be applied with any reliability.

4.6 Constant-Momentum Mass Analyzers - B. Kendall

This project is being revived with the aid of Mr. Yee Seung Ng who will make future reports on this subject.

4.7 Molecular - Flow Networks - B. Kendall

Temporarily inactive due to lack of funding.

4.8 Brownian Motion/Diamagnetic Levitation - B. Kendall

A joint paper with R. S. Butler is being prepared for publication in Vacuum. Improvements to the apparatus are being made by S. Rossnagel and J. O. Weeks.

4.11 Water Vapor in the Lower Ionosphere - B. Kendall

An expanded version of our original proposal for a study of direct measurement techniques is being prepared.

4.12 Infra-Sound Measurements at Ground Level - B. Kendall and J. J. Olivero

Sample recordings made with our apparatus have been made and sent to D. ReVelle in Ottawa for comment. Intermittent shifts in the frequency distribution of atmospheric pressure flustrations, negative transients of 20μtorr magnitude, and slow sinnsoidal variations have been observed. The low-frequency cut off of the apparatus is about 0.15 Hz.

5. Direct Measurements

5.2 Methods of Minor Constituent Measurements - C. Croskey

During this period several payload designs were completed. The first Super Loki Blunt Probe, SLBP, was successfully launched on May 1, 1975 from Wallops Island, Virginia. Detailed assembly drawings and a payload construction manual have been developed for the SLBP. Several additional payloads were constructed with the help of Bob Scott and Charlie Gardner. Two additional SLBP's have been launched at the end of September at White Sands Missile Range as part of a Middle Atmospheric Sounding Studies program.

Also during this time period, the Astrobee-D, flashing UV lamp, Gerdian Condensor was environment tested at Wallops Island. This payload was successfully launched by Dr. Hale at White Sands in July.

Field support was also given to the Penn State experiment (blunt probe, Gerdian condensor, flashing UV lamp) aboard the Stratcom 6 high altitude balloon launched from Holloman AFB, during the recent SLBP launchings.

5.3 D-Region Ionization Sources - J. Bassi

Analysis of the Peru (23-24 May, 1975) Blunt Probe Data has begun. Specifically, we are presently constructing conductivity vs height profiles in an attempt to investigate the proposed (Ananthakrishnan, 1969) effect of Galactic X-ray sources on D-region ionization. However, since some authors (Whitten and Poppoff, 1969) doubt that these X-ray sources would have a measurable effect in the lower ionosphere, this is still a controversial issue. The results of this research may aid in resolving this interesting question.

References:

Ananthan Krishnan, Nature, 223, 488, 1969.
Whitten and Poppoff, Nature, 224, 1187, 1969.

5.6 Data Acquisition System - C. Gardner

Upon entering the IRL on June 11, 1975, I have spent a great deal of time familiarizing myself with the possible problems which need attention. After learning the operations of the lab, my problem was reduced to the reduction of noise in the received data.

Since definition of the problem, I have been investigating possible solutions along with analyzing data from past flights and building payloads for future flights.

5.7 Synoptic Payload Design - R. Scott

Having just started in June, I have taken time to familiarize myself with the IRL and its proceedures. I have worked in conjunction with Professor Hale in investigating a multitude of possible methods of attacking the problem of noisy data received from rocket payloads. Together we have narrowed my area of investigation to a few specific topics and I am presently searching out the most practical topic at present.

5.9 Gerdien Condenser Data Analysis - S. Leiden

The final touches to the routine reduction of data from the Aladdin Project of 1974 is being completed. A new approach (using calculus) to analyzing the continuum of conductivities is also being investigated. The final result of this should yield a better understanding of Dregion model parameters -- especially the reactions occuring in the ionosphere during the day.

6. Atmospheric Reactions

6.1 The Reactions of HO_2 with NO and NO_2 - R. Simonaitis

The reaction of HO_2 with NO

$$HO_2 + NO \rightarrow NO_2 + OH \qquad 1a$$

was studied in competition with

$$2HO_2 \rightarrow H_2O_2 + O_2 \qquad 3$$

over the temperature range of 245°K - 296°K, and the reactions of HO_2 with NO_2

$$HO_2 + NO_2 \rightarrow HNO_2 + O_2 \qquad 2a$$

$$HO_2 + NO_2(+M) \rightarrow HO_2NO_2(+M) \qquad 2b$$

were studied in competition with the reactions with NO over the temperature range of 245°K - 323°K. The reactions were monitored by following NO removal via the chemiluminescent detection of NO. The HO_2 radicals were produced by N_2O photolysis at 213.9 nm in the presence of O_2 and excess H_2.

At low $[NO]/I_a^{1/2}$ ($< 14\ cm^{-3/2}sec^{-1}$) the oxidation proceeds by the mechanism:

$$N_2O + h\nu\ (213.9\ nm) \rightarrow N_2 + O(^1D)$$

$$O(^1D) + H_2 \rightarrow OH + H \qquad 5$$

$$OH + H_2 \rightarrow H_2O + H \qquad 6$$

$$H + O_2 + M \rightarrow HO_2 + M \qquad 7$$

$$HO_2 + NO \rightarrow NO_2 + OH \qquad 1a$$

$$2HO_2 \rightarrow H_2O_2 + O_2 \qquad 3$$

According to this mechanism the rate law for NO removal is

$$-\Phi_i\{NO\} = k_{1a}[NO]/(k_3 I_a)^{1/2} \qquad a$$

From plots of $\Phi_i\{NO\}$ vs $[NO]/I_a^{1/2}$ the Arrhenius expression $k_{1a}/k_3^{1/2} = 6.4 \times 10^{-6} \exp\{-1400/RT\}$ was obtained.

Addition of NO_2 to the N_2O-O_2-H_2-NO photolysis system (at any value of $[NO]/I_a^{1/2}$) inhibits the oxidation of NO. The inhibition is a strong function of the temperature. The effect is most pronounced at low temperatures and becomes progressively less important as the temperature increases. Furthermore, at higher temperatures ($\geq$ 285°K) the oxidation of NO exhibits an induction period and the oxidation continues even after irradiation is terminated.

From these observations it is concluded that the dominant reaction between NO_2 and HO_2 is to form pernitric acid via reaction 2b and that at higher temperatures the pernitric acid is unstable and decomposes via

$$HO_2NO_2 \rightarrow HO_2 + NO_2 \qquad -2b$$

$$\rightarrow HONO + O_2 \qquad 10b$$

Under conditions such that HO_2NO_2 is stable (245°K) the detailed mechanism predicts that

$$\Phi_i\{NO\}^{-1} - k_{1a}\beta/2k_1 = k_{1b}/2k_1 + k_2[NO_2]/2k_1[NO]$$

where $k_1 \equiv k_{1a} + k_{1b}$; $k_2 \equiv k_{2a} + k_{2b}$; $\beta \equiv k_4[NO] + k_{11}[NO_2]/k_6[H_2]$ and k_{1b}, k_4 and k_{11} refer to the reactions

$$HO_2 + NO + M \rightarrow HONO_2 + M \qquad 1b$$

$$OH + NO + M \rightarrow HONO + M \qquad 4$$

$$OH + NO_2 + M \rightarrow HONO_2 + M \qquad 11$$

From a plot of $\Phi_i\{NO\}^{-1}$ vs $[NO_2]/[NO]$, $k_2/k_1 = 0.74$ and $k_{1b}/k_1 \sim 0.03$ were obtained at 245°K. The temperature dependence of the inhibition indicates that $k_{2a}/k_2 \leq 0.05$. At present a complete analysis of the temperature dependence data of the oxidation in the presence of NO_2 has not yet been carried out, but as soon as this work is completed, values of k_{-2b} and k_{10b} as a function of temperature in the range of 245-323°K will be available.

6.3 <u>The Oxidation of HCO Radicals and the Photoxidation of Formaldehyde</u> - T. Osif

HCO radical chemistry was studied by irradiating mixtures of Cl_2, O_2, CH_2O, and sometimes N_2 or H_e at 3660 Å to photodecompose the Cl_2. The chlorine atoms abstract a hydrogen atom from CH_2O to produce HCO radicals which can do the following:

$$(M) + HCO + O_2 \rightarrow HCO_3 + (M) \quad 1a$$

$$\rightarrow CO + HO_2 \quad 1b$$

$$\rightarrow CO_2 + HO \quad 1c$$

$$HCO + Cl_2 \rightarrow Cl + HCClO \quad 3a$$

$$\hookrightarrow HCl + CO$$

$$\rightarrow \text{Termination } (H1OCl_2?) \quad 3b$$

$$\frac{k_{1a}}{k_{1b}} = 5 \pm 1; \quad \frac{k_{1c}}{k_{1b}} \leq 0.18; \quad \frac{k_{3a}}{k_{3b}} \sim 7.5; \quad \frac{k_{3b}}{k_{1b}} = 6(+7, -2).$$

The above rate coefficient ratios were measured at $\sim 23^{\circ}C$ and $-7^{\circ}C$. No pressure dependence was seen (down to 50 torr) on reaction 1a, but results from the photooxidation of CH_2O suggest a pressure dependence with a half quenching pressure of ~ 70 torr.

6.4 <u>The Reaction of NH_2 with NO and O_2 - R. Jayanty</u>

The reaction of NH_2 initiated by the photolysis of NH_3 with 213.9 nm light in the presence of NO and O_2 was studied at 298 k. The primary objective was to determine the reaction paths of NH_2 with O_2. With NO present the products measured were N_2, H_2, and N_2O, and for $[NH_3] = 5.6 - 7.2$ torr, their respective quantum yields were 1.05 ± 0.03, 0.33 ± 0.03, and 0.09 ± 0.02. At $[NH_3] = 11$ for pressure, the yields are somewhat smaller.

With O_2 present, N_2 and N_2O were produced with quantum yields of $\Phi\{N_2\} = 0.23 \pm 0.02$, $\Phi\{N_2O\} = 0.06 \pm 0.01$ for $[O_2] < 2$ torr and 0.09 ± 0.01 for $[O_2] > 20$ torr. The quantum yield of

NH_3 removal was 0.49 ± 0.03. The oxidation of the NH_3 radical proceeds mainly, if not exclusively, (> 98%) by addition

$$NH_2 + O_2 + M \rightarrow NH_2O_2 + M$$

The products observed are then explained in terms of the sequence of reactions

$$2NH_2O_2 \rightarrow 2NH_2O + O_2$$

$$NH_2O_2 + NH_2O \rightarrow N_2O + 2H_2O$$

$$2NH_2O \rightarrow N_2 + 2H_2O$$

$$NH_2O_2 + HO_2 \rightarrow NH_3 + 2O_2$$

B. SUPPORTING OPERATIONS

102.1 R. Divany

Final processing of the series of ionograms for June 1958 using the Visicon system was completed. A very high percentage of them were processed automatically by our true height program with no difficulty. A program was written to allow fast visual checking of all ionograms for one station for a three day period. Another program was written to do a Fourier fit to HMF2, NMF2, or NE (at any selected height). After editing, the data was delivered to the World Data Center.

The Vest thermospheric model was run with new initial conditions. The output is being studied.

Some backscatter data from Arecibo was processed and stored on tape.

Data from a series of cross-modulation experiments conducted at Arecibo was processed. A number of different programs were needed to do this due to the fact that several different experiments were performed. Some noise data was gathered at Scotia and is being processed for comparison.

102.2 B. Beiswenger

Reduction of 2056 ionograms from thirty-six stations was completed, catalogued, and put on tape. When processing the virtual height data through Bob Divany's true height reduction program it was found that some ionograms had to be retaped and some incorrect data had to be edited. All h'f output data was compared with the ionograms as a check for errors before proceeding further. After reduction the nh data was run through another program to compare all the ionograms for each station to point out the obvious problem ionograms, some of which were corrected. Fifteen ionograms had no ordinary trace and forty-two others were unacceptable; these were discarded. The hard copies of all above data were collated.

Use was made of the virtual height and frequency of all ES and ES2 traces for the stations to find a factor by which the height markers on the ionograms might be off. A notebook of final relative sunspot numbers, Ra, from 1948 to the present was compiled. Data from Aricebo electron density profiles were tabulated and processed for Dr. Lee. Colored graphs of OGO airglow temperature data according to geomagnetic latitude and time were done for Dr. Nisbet. Three ionograms were manually converted to h'f data to produce nh data for Bob Reiter, and various plots were made for Dr. Nisbet, Terry Stick, Bernie Wydra, and Bob Reiter. The data for Report 400, "Classified Listing of I.R.L. Scientific Reports," was proofread, corrected and updated, and an IBM copy put in the library.

103 Drafting

103.1 A. Ott

No report available for this period.

104 Library

104.1 W. Askey

The following book was received and placed in the library:

The Learner's Russian-English Dictionary, by B. A. Lapidus and S. V. Shevtsova.

Six reprints written by staff members have been received into the library.

Three Scientific Reports have been received and distributed (436, 437, and 438). Scientific Reports numbered 439 ("Calculation of Conductivities and Currents in the Ionosphere," by Volker W. J. H. Kirchhoff and Lynn A. Carpenter, November, 1975) and 440 ("Stratospheric Ozone: An Introduction of its Study," by Marcel Nicolet, November 19, 1975) are being prepared.

C. OTHER ACTIVITIES

201 Publications and Presentations

201.1 Scientific Reports

436 Wydra, Bernard J., "Global Exospheric Temperatures and Densities Under Active Solar Conditions," October 3, 1975.

437 Carpenter, L. A. and Kirchhoff, V. W. J. H., "F-region Drift Velocities from Incoherent-Scatter Measurements at Millstone Hill," October 17, 1975.

438 Kirchhoff, Volker W. J. H., "Electric Fields in the Ionosphere," October 4, 1975.

201.2 Papers Published

450 Kuis, Susan, R. Simonaitis, and Julian Heicklen, "Temperature Dependence of the Photolysis of Ozone at 3130 Å," Journal of Geophysical Research, vol. 80, No. 10, April 1, 1975.

451 Sanhueza, Eugenio and Julian Heicklen, "The Oxidation of CFClCFCl and CF_2CCl_2," International Journal of Chemical Kinetics, vol. VII, 399-415 (1975).

452 Sanjueza, Eugenio and Julian Heicklen, "The Hg $6(^3P)$-Sensitized Photo-Oxidation of C_2Cl_3H," Journal of Photochemistry, 4 (1975) 161-169.

453 Jayanty, R. K. M., R. Simonaitis and Julian Heicklen, "The Photolysis of CCl_4 in the Presence of O_2 or O_3 at 213.9 nm, and the Reaction of $O(^1D)$ with CCl_4," Journal of Photochemistry, 4 (1975) 203-213.

454 Landreth, Ronald, Rosa G. dePena, and Julian Heicklen, "Thermodynamics of the Reaction of Ammonia and Sulfur Dioxide in the Presence of Water Vapor," Journal of Physical Chemistry, 79, 1785 (1975).

455 Simonaitis, R. and Julian Heicklen, "Reactions of CH_3, CH_3O, and CH_3O_2 Radicals with O_3," Journal of Physical Chemistry, 79, 298 (1975).

201.3 Papers Presented

Chesworth, E. T. and J. J. Olivero, "Ultraviolet Scattering from Mesospheric Aerosols," Spring AGU Meeting, Washington, C. C., June 16 - 20, 1975.

Hummel, J. and J. J. Olivero, "Climatological Implications of the Mesospheric Scattering Layer, "Spring AGU Meeting, Washington, D. C., June 16 - 20, 1975.

Carpenter, L. A. and V. W. J. H. Kirchhoff, "Night-time Electric Fields and Meridional Neutral Winds at Mid-Latitudes," Spring AGU Meeting, Washington, D. C., June 16 - 20, 1975.

Kirchhoff, V. W. J. H. and L. A. Carpenter, "Magnetospheric Electric Fields at L = 3.2 Measured with Incoherent Scatter Radar, "Spring AGU Meeting, Washington, D. C., June 16 - 20, 1975.

Croskey, C. L., H. Farrokh, L. C. Hale, S. C. Leiden, and V. Vyas, "Recent Measurements in the Stratosphere and Mesosphere, "Spring AGU Meeting, Washington, D. C., June 16 --20, 1975.

Hale, L. C., "Middle Atmosphere Ion Mobility Measurements," IUGG-IAGA, Symposium on Atmospheric Electricity, Grenoble, France, August 30, 1975.

202 Seminars

Dr. Marcel Nicolet, Director, Institut d'Aeronomie, Brussels, Belgium, April 4, 1975.

Dr. K. D. Cole, La Trope University, Melbourne, Australia, April 25, 1975.

Dr. Pierre Bauer, Research Associate, Goddard Space Flight Center and CNET, France, May 16, 1975.

Dr. Joseph F. L. Lemaire, Institut d'Aeronomie Spatiale De Belgique Belgium and Goddard Space Flight Center, August 1, 1975.

203 Visitors

Dr. Pierre Bauer, Goddard Space Flight Center and CNET, France, May 16, 1975.

Dr. K. D. Cole, La Trope University, Melbourne, Australia, April 25, 1975.

Dr. Joseph F. L. Lemaire, Institute d'Aeronomie Spatiale De Belgique Belgium and Goddard Space Flight Center, August 1, 1975.

Dr. A. P. Mitra, National Physics Laboratory, New Delhi, 12, India, July 17 - August 5, 1975.

Dr. G. N. Zinchenko, Radiophysical Department, Kharkov State University, USSR, September 1975 - May 1976.

D. PERSONNEL

Name	Title	Percent Funded Time	Problem
The National Aeronautics and Space Administration			
Grant NGL 39-009-003 - NASA IRL MD - 5932			
J. S. Nisbet	Prof. of Elec Eng. Director, IRL	28.3	2.1
G. Fleming	Prof. of Physics	--	--
J. Heicklen	Prof. of Chemistry	12.5	--
L. A. Carpenter	Asst. Prof. of Elec. Eng.	43.1	2.3
J. J. Olivero	Asst. Prof. of Meteorology	16.3	1.7
R. Simonaitis	Research Associate	--	6.1
R. Jayanty	Postdoctoral Scholar	--	6.4
G. Imel	Graduate Assistant	50.0	4.10
M. Miller	Graduate Assistant	100.0	2.13
R. Rohrbaugh	Graduate Assistant	25.0	2.7
T. Stick	Graduate Assistant	100.0	2.12
Grant NGL 39-009-002 - NASA SATELLITE - 5972			
W. J. Ross	Prof. of Elec. Eng.	6.7	2.2, 3.13
E. H. Klevans	Associate Prof. of Nuclear Eng.	12.5	3.4
G. Imel	Graduate Assistant	50.0	4.10
R. Longbothum	Graduate Assistant	75.0	1.9
Grant NGR 39-009-032 - NASA CMMS IX - 5918			
B. R. F. Kendall	Prof. of Physics	--	4.1, 4.7

Name	Title	Percent Funded Time	Problem
Grant NAS6 2602 - NASA DART - 5922			
L. C. Hale	Prof. of Elec. Eng.	16.0	1.2
C. Croskey	Graduate Assistant	100.0	5.2
C. Gardner	Graduate Assistant	25.0	5.6
R. Scott	Graduate Assistant	100.0	5.7
Grant NGR 39-009-218 - NASA MESO III - 5941			
L. C. Hale	Prof. of Elec. Eng.	6.7	1.2
C. Gardner	Graduate Assistant	75.0	5.6
S. Leiden	Graduate Assistant	75.0	5.9

The National Science Foundation

Name	Title	Percent Funded Time	Problem
Grant CA 33446 X2 - NSF FOUNDATION - 6303			
J. S. Nisbet	Prof. of Elec. Eng. Director, IRL	--	2.1
A. P. Mitra	Consultant	36 days	1.5
M. Nicolet	Consultant	6 days	1.4
O. E. H. Rydbeck	Consultant	--	--
P. Stubbe	Consultant	--	2.4
R. Longbothum	Graduate Assistant	25.0	1.9
T. Osif	Graduate Assistant	100.0	6.3
R. Rohrbaugh	Graduate Assistant	75.0	2.7
Grant GR 41854 - NSF D-REGION MEASUREMENTS - 6243			
A. J. Ferraro	Prof. of Elec. Eng.	26.7	1.1
H. S. Lee	Prof. of Elec. Eng.	26.7	3.1
J. R. Mentzer	Prof. of Eng. Sci.	--	--

Name	Title	Percent Funded Time	Problem
Grant GR 41854 - NSF D-REGION MEASUREMENTS - 6243 (Con't)			
J. Breakall	Graduate Assistant	100.0	1.12
M. Sulzer	Graduate Assistant	100.0	1.11
K. Swanson	Graduate Assistant	100.0	1.14
A. Tomko	Graduate Assistant	100.0	1.13

The Office of Naval Research

Name	Title	Percent Funded Time	Problem
Grant N00014-67-A-0385-0014 - DN INTERACTION - 7073			
A. J. Ferraro	Prof. of Elec. Eng.	15.8	1.1
H. S. Lee	Prof. of Elec. Eng.	15.8	3.1
Grant N00014-75-C-0971 DN D-REGION - 7132			
A. J. Ferraro	Prof. of Elec. Eng.	8.3	1.1
H. S. Lee	Prof. of Elec. Eng.	8.3	3.1

Department of the Army

Name	Title	Percent Funded Time	Problem
Grant DAHCO4-75-G-0031 - DA AERO - 4400			
L. C. Hale	Prof. of Elec. Eng.	22.7	1.2
S. Leiden	Graduate Assistant	25.0	5.9