AD-A041 799 ARMY ELECTRONICS COMMAND FORT MONMOUTH N J F/G 4/1
POSITIVE IONS IN THE MIDDLE ATMOSPHERE DURING SUNRISE CONDITION--ETC(U)
MAY 77 J D MITCHELL, R S SAGAR, R O OLSEN
UNCLASSIFIED ECOM-5819 NL

1 OF 1
AD
A041799

END
DATE
FILMED
8-77

AD
Reports Control Symbol
OSD-1366

RESEARCH AND DEVELOPMENT TECHNICAL REPORT
ECOM-5819

POSITIVE IONS IN THE MIDDLE ATMOSPHERE DURING SUNRISE CONDITIONS

By

J.D. MITCHELL
R.S. SAGAR
Electrical Engineering Department
The University of Texas at El Paso
El Paso, Texas 79968

and

R.O. OLSEN
Atmospheric Sciences Laboratory
US Army Electronics Command
White Sands Missile Range, New Mexico 88002

May 1977

Approved for public release; distribution unlimited.

ECOM
UNITED STATES ARMY ELECTRONICS COMMAND - FORT MONMOUTH, NEW JERSEY 07703

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

Disposition

Destory this report when it is no longer needed. Do not return it to the originator.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ECOM-5819	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) POSITIVE IONS IN THE MIDDLE ATMOSPHERE DURING SUNRISE CONDITIONS		5. TYPE OF REPORT & PERIOD COVERED R & D Technical Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. D. Mitchell R. S. Sagar R. O. Olsen		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Atmospheric Sciences Laboratory White Sands Missile Range, New Mexico 88002		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L161102B53A-SA2
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Electronics Command Fort Monmouth, New Jersey 07703		12. REPORT DATE May 1977
		13. NUMBER OF PAGES 16
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ion conductivity
Gerdien condenser
Ion mobility
Ion number density
Ionization processes
Conductivity probe

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

Two subsonic Gerdien condenser experiments were recently conducted at White Sands Missile Range, New Mexico, to study upper atmospheric ionization processes during morning twilight conditions. The same instrument was flown on 15 July 1975 at 0618 MST (χ = 75 deg) and 26 September 1975 at 0600 MST (χ = 90 deg). Electrical conductivity data from two subsonic blunt probe experiments (9 June 1971 at 0809 MST (χ = 53 deg) and 28 July 1971 at 0705 MST (χ = 68 deg)) are also included in this study.

next page chi

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

20. Abstract (cont)

cond

At 30 km, the positive ion conductivity data for the four flights are generally in good agreement, thus indicating no particular discrepancies due to differences in launch dates or measurement techniques. Above 60 km, the buildup in conductivity with respect to the launch times presumably reflects an increase in positive ion number density associated with solar ultraviolet ionization. The most noticeable buildup, however, occurs between 35 and 60 km where the positive ion conductivity values increase during the early morning period by as much as an order of magnitude (between 45 and 50 km). The Gerdien condenser measurements indicate that this buildup in conductivity is related to an increase in positive ion mobility, thus suggesting the presence during the early morning hours of a solar dependent process for forming smaller, more mobile positive ions.

CONTENTS

INTRODUCTION

Two subsonic Gerdien condenser experiments were recently conducted at White Sands Missile Range (WSMR), New Mexico (32° N, 106° W), to study ionization processes in the middle atmosphere during the morning twilight period. Previous studies [1] involving mid-latitude blunt probe electrical conductivity data obtained during the midday period have indicated day-to-day conductivity variations in some cases of a factor of two to three in the 30 to 60 km altitude region. A strong correlation was observed between positive ion conductivity (the electrical conductivity associated with positive ions) and temperature, particularly in the 48 to 58 km region where the temperature coefficient for this parameter was found to be typically 4%/°K. These variations in conductivity are thought to be at least partly attributed to the dependence of ion mobility on temperature.

Since the ionization variability studies using blunt probes have primarily concentrated on the midday time period, it was decided to extend this research by considering the early morning period at a mid-latitude site. Gerdien condenser experiments, which have the advantage over blunt probe experiments of being able to measure charge number density and ion mobility in addition to electrical conductivity, were conducted on two mornings during 1975. The first Gerdien condenser was launched from WSMR on 15 July at 0618 MST (χ = 75°). The instrument was successfully recovered and flown again on 26 September at 0600 MST (χ = 90°).

To supplement this study, data obtained from two previous subsonic blunt probe experiments conducted at WSMR during the early morning period are also included [2]. These experiments were launched on 9 June 1971 at 0809 MST (χ = 53°) and 28 July 1971 at 0705 MST (χ = 68°). The launch parameters for these rocket experiments are summarized in the following table:

Date	Time (MST)	Solar Zenith Angle (°)	Experiment	Apogee (km)
9 Jun 71	0809	53	Blunt Probe	79
28 Jul 71	0705	68	Blunt Probe	78
15 Jul 75	0618	75	Gerdien Condenser	69
26 Sep 75	0600	90	Gerdien Condenser	75

THE GERDIEN CONDENSER EXPERIMENT

The Gerdien condenser is an instrument capable of measuring electrical conductivity, charge number density and ion mobility [3,4]. Recent rocket experiments utilizing this technique either subsonically or supersonically have been reported by Rose and Widdel [5]; Conley [6]; Farrokh [7]; Croskey [8]; and Widdel, Rose, and Borchers [9]. The particular Gerdien condenser used in this research was flown on a stabilized parachute system after separation at apogee from a rocket. Figure 1 shows a picture of the instrument.

The inner electrode of the condenser, which was recessed to reduce possible fringing effects, was used as the collecting electrode and had a length of 6.35 cm and a radius of 1.11 cm. The radius of the outer return electrode was 3.81 cm. The voltage applied to the collector was swept over a range from approximately -5 to +5 V.

DATA

Positive Ion Conductivity

Positive ion conductivity profiles for the four rocket experiments discussed previously (above table) are given in Figure 2. The general agreement between the conductivity profiles at 30 km suggests that no appreciable variations resulted from either differences in launch dates or measurement techniques. Between 45 and 55 km, the positive ion conductivity values are observed to progressively increase as the solar zenith angle decreases, with an overall enhancement of an order of magnitude observed in the 45 to 50 km altitude region. Possibly, some of these conductivity variations are attributed to the differences in launch dates; however, an order of magnitude change is much greater than that typically associated with either day-to-day variations [1] or variations with respect to solar activity [10]. Also, the temperature variations associated with the launch dates are not sufficient to explain the changes in conductivity.

The positive ion conductivity profile for 9 June 1971 (χ = 53°) is indicative of the mid-latitude, midday blunt probe conductivity values between 30 and 60 km [1], and thus the early morning buildup in this altitude region would presumably diminish for solar zenith angles considerably less than 53°.

The three conductivity profiles for χ = 75°, 68°, and 53° show a rather well-defined knee in the region above 55 km, indicating the altitude above which ionization by solar ultraviolet radiation is considered to be an important production mechanism for positive ions [2]. The differences in positive ion conductivity above 60 km, particularly evident in the profiles for χ = 68° and 53°, are probably associated with differences in solar ultraviolet ionization.

Ion Mobility

Figure 3 shows ion mobility data for the two Gerdien condenser experiments. On 26 September at least two distinct groups of positive ion mobilities were observed in the 50 to 60 km altitude region, as are indicated by the shaded and light circles. The shaded circles represent the mobility values for the less mobile positive ions. The positive ion mobility values for both days tend to fall off with decreasing height and have an altitude dependence which is approximately inversely proportional to that for neutral number density. The positive ion mobility values for 15 July (χ = 75°) are generally larger than the corresponding values for 26 September (χ = 90°), particularly below 50 km where there is typically a factor of two difference. Telemetry dropout was experienced on the 15 July flight, thus limiting the number of ion mobility measurements and making it difficult to determine if additional smaller ion mobility groups were present.

In the 40 to 45 km altitude region, the positive ion mobility values for both flights were observed to noticeably shift to the left with decreasing altitude. Since the ion mobility values below 45 km were too small to be measured by the 26 September Gerdien condenser experiment, the dashed line has been constructed to show the limit of the instrument's sensitivity as an upper limit for the positive ion mobility values in that region. A similar shift in positive ion mobility was observed previously on a subsonic Gerdien condenser flight reported by Rose and Widdel [5].

Ion Number Density

Figure 4 shows the positive ion number density measurements for the two subsonic Gerdien condenser experiments. The light and shaded circles are again associated with the more and less mobile ions, respectively, measured on 26 September. For the cases between 50 and 60 km in which different ion mobility groups were observed, the concentration of less mobile positive ions was consistently greater than the corresponding number density of more mobile ions. The total concentration of positive ions in the 45 to 65 km altitude region for both days was on the order of 10^2 cm^{-3}, with no discernible trend evident as to which of the 2 days had the higher total number densities. Below 45 km, the comparatively larger ion number density values for 15 July are associated with the less mobile ions observed in that altitude region.

DISCUSSION

In the 45 to 55 km altitude region, where the principal source for positive ions is due to ionization by galactic cosmic rays, the positive ion conductivity profiles (Figure 2) appear to be displaying a solar dependence. This is further demonstrated in Figure 5 where the secant of the solar zenith angle is plotted as a function of positive ion conductivity. The number of data points is limited by the number of experiments; however, linear relationships are indicated at 50 and 55 km for the data at solar zenith angles of 53°, 68°, and 75°. The data for χ = 90° would obviously not fit these linear relationships, and previous blunt probe data obtained later in the morning (1050 MST, 13 October 1971 [χ = 44°]) did not fit well either. Thus, from what data are available, the solar dependence of positive ion conductivity appears to be an early morning phenomenon.

Combining the Gerdien condenser positive ion conductivity data with the ion mobility (Figure 3) and charge number density (Figure 4) measurements for 15 July (χ = 75°) and 26 September (χ = 90°) shows that the increase in conductivity corresponding to a change in solar zenith angle from 90° to 75° is principally associated with an increase in ion mobility. Such behavior could be explained by a process involving photodissociation of larger positive ions into smaller, more mobile ions. Further evidence demonstrating such behavior has been observed in Croskey's [8] recent Gerdien condenser measurements in which enhancements in positive ion conductivity resulting from a Lyman-α ionization source were found to be directly attributed to enhancements in ion mobility.

The precursory ions for such a process could possibly be cluster ions with mobilities so small that they were undetected by the Gerdien condenser. The existence of such large ions, possibly in the form of charged ice particulates, has been considered in the analysis of previous blunt probe data by Chesworth and Hale [11]. If this were the case, the mobilities of these ions would probably be even somewhat smaller than those previously reported by Rose and Widdel [5] and Farrokh [7]. The presence of such relatively immobile ions would also help reconcile the somewhat lower number density values measured in these experiments with the Gerdien condenser ion number density data reported by other experimenters [5-9].

CONCLUSIONS

In summary, evidence has been presented to suggest that positive ion conductivity during sunrise conditions at mid-latitudes is a solar dependent parameter in the altitude region above 30 km. Appreciable conductivity variations with respect to solar zenith angle were observed in the region where ionization by solar ultraviolet radiation is not considered to be relatively significant. Subsonic Gerdien condenser and blunt probe experiments measured as much as an order of magnitude increase in ion conductivity at some altitudes (45 to 50 km) over a change in solar zenith angle from 90° to 53°. Ion mobility data from the Gerdien condenser experiments indicated that the increase in ion conductivity primarily resulted from an increase in ion mobility, thus suggesting the presence of a photodissociation process for positive ions during the early morning period which results in smaller, more mobile ions.

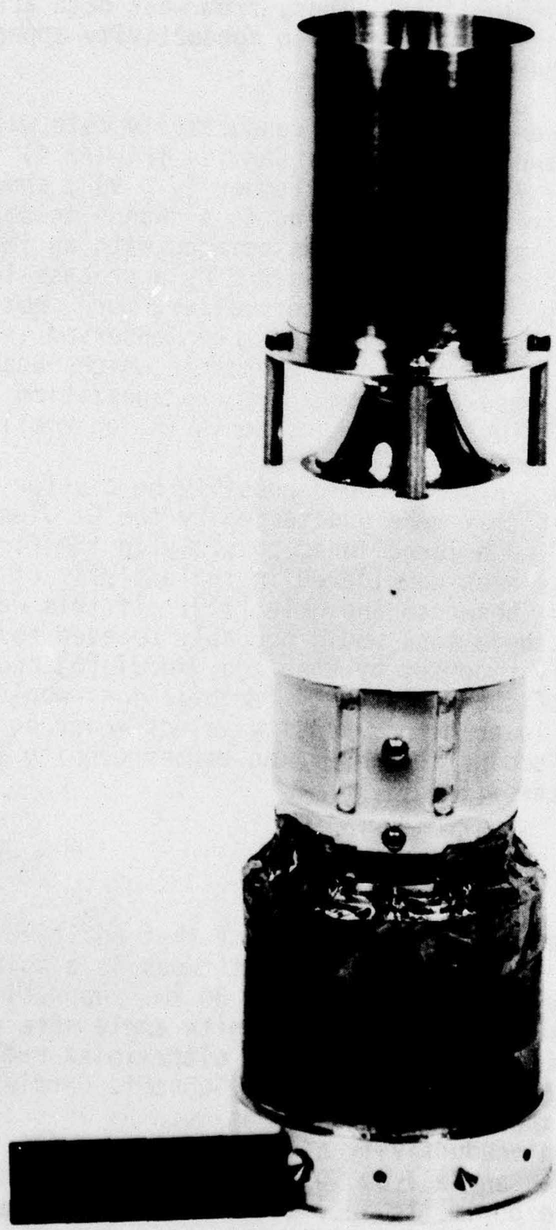

Figure 1. Gerdien condenser payload.

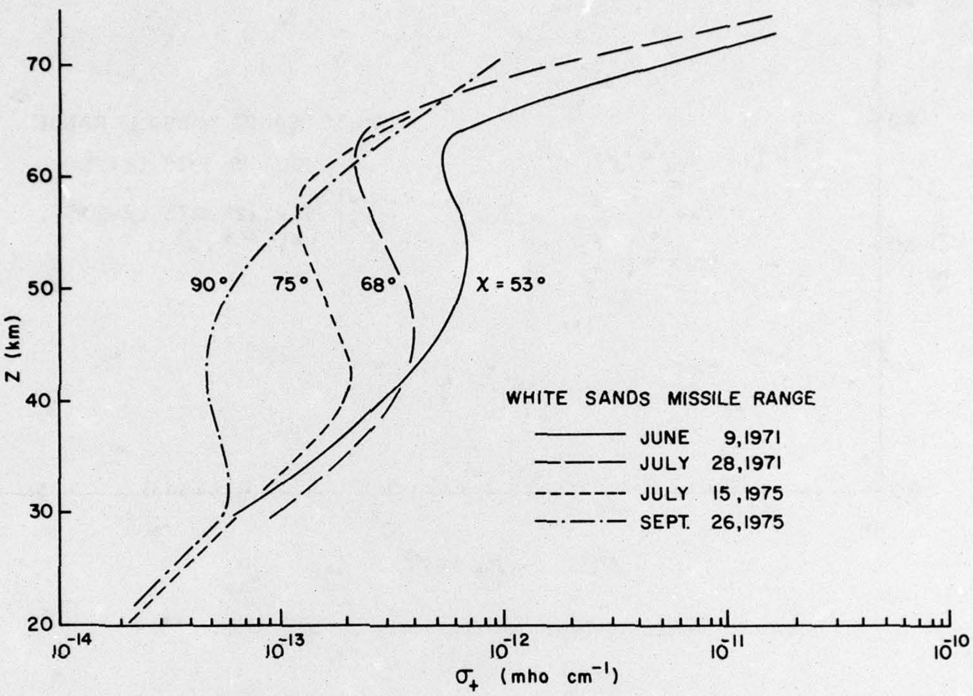

Figure 2. Positive ion conductivity profiles for WSMR morning rocket launches.

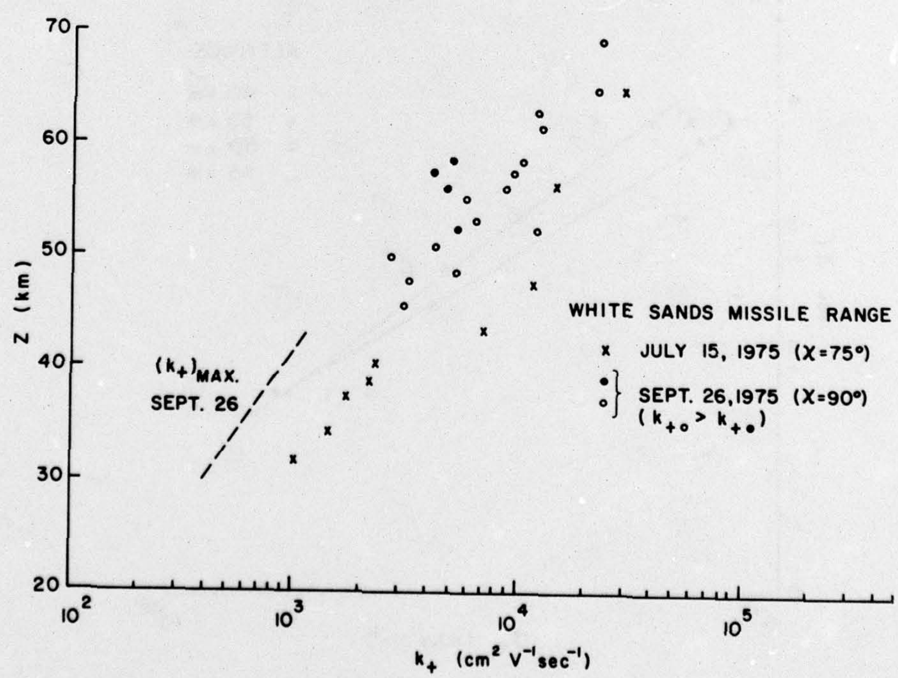

Figure 3. Gerdien condenser positive ion mobility data.

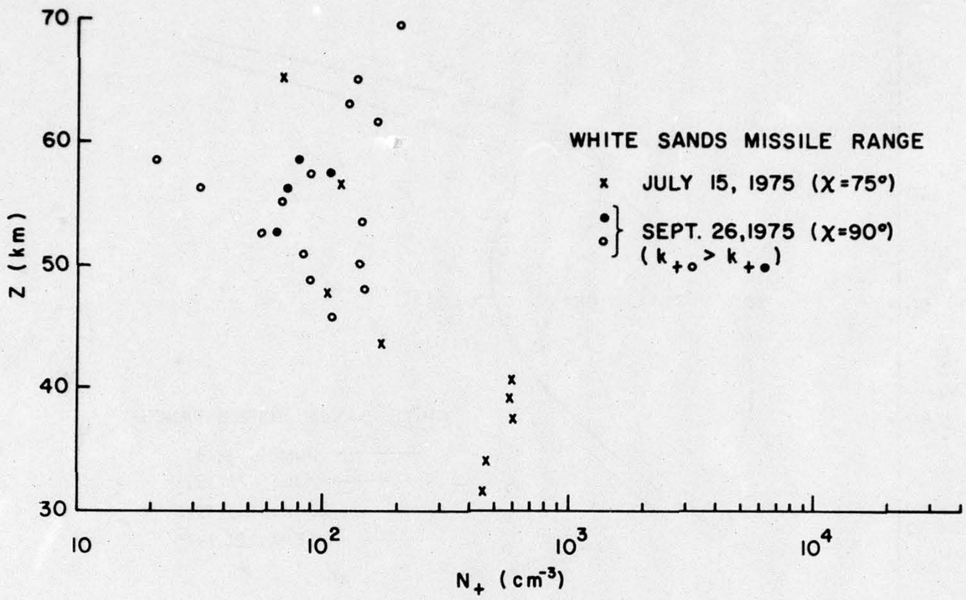

Figure 4. Gerdien condenser positive ion number density data.

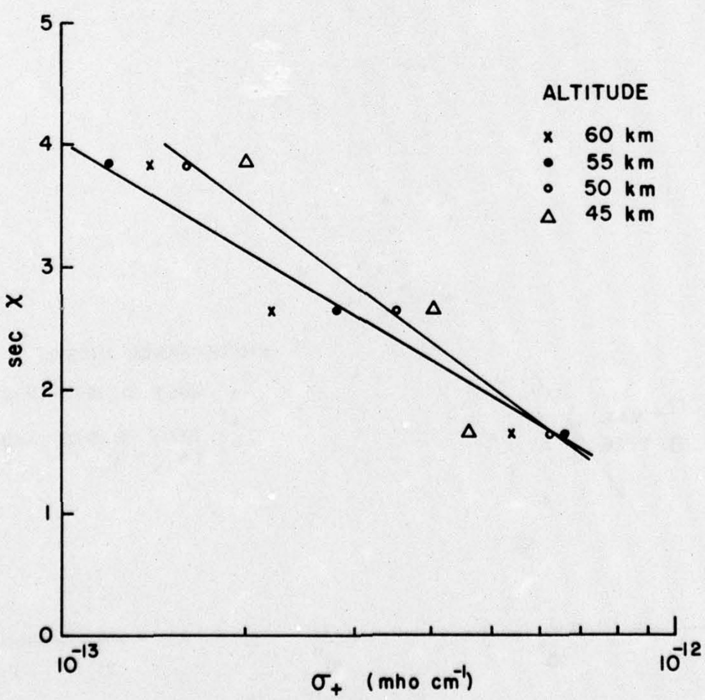

Figure 5. Solar dependence of WSMR morning positive ion conductivity values.

REFERENCES

1. Cipriano, J. P., L. C. Hale and J. D. Mitchell, 1974, "Relations Among Low Ionosphere Parameters and A3 Radio Wave Absorption," J. Geophys. Res., 79, 2260-2265.

2. Mitchell, J. D. and L. C. Hale, 1973, "Observations of the Lowest Ionosphere," Space Research XIII, 471-475.

3. Gerdien, H., 1905, "Demonstration Eines Apparates zur Absoluten Messung der Electreschen Leitfahigut der Luft," Terr. Magn. Atmos. Elec., 10, 65-79.

4. Pedersen, A., 1964, "Measurement of Ion Concentration in the D-Region of the Ionosphere with a Gerdien Condenser Rocket Probe," Research Institute of National Defence, Stockholm, Sweden, FOA 3 Report A607.

5. Rose, G. and H. U. Widdel, 1972, "Results of Concentration and Mobility Measurements for Positively and Negatively Charged Particles taken between 85 and 22 km in Sounding Rocket Experiments," Radio Sci., 7, 81-87.

6. Conley, T. D., 1974, "Mesospheric Positive Ion Concentration Mobility and Loss Rates Obtained from Rocket-Borne Gerdien Condenser Measurements," Radio Sci., 9, 575-592.

7. Farrokh, H., 1975, "Design of a Simple Gerdien Condenser for Ionospheric D-Region Charged Particle Density and Mobility Measurements," Scientific Report No. 433, Ionosphere Research Laboratory, The Pennsylvania State University.

8. Croskey, C., 1976, "In Situ Measurements of the Mesosphere and Stratosphere," Scientific Report No. 442, Ionosphere Research Laboratory, The Pennsylvania State University.

9. Widdel, H. U., G. Rose and R. Borchers, 1976, "The Variation of Electric Conductivity and Ion Mobility in the Mesosphere Between High and Low Solar Activity Measured with a Rocket Borne Parachute Gerdien Aspiration Analyzer Probe Experiment," Report No. MPAE-W-47-76-09, Max-Planck-Institut fur Aeromonie.

10. Velinov, P., 1968, "On Ionization in the Ionospheric D-Region by Galactic Cosmic Rays," J. Atmos. Terr. Phys., 30, 1891-1905.

11. Chesworth, E. T. and L. C. Hale, 1974, "Ice Particulates in the Mesosphere," Geophys. Res. Lett., 1, 347-350.

ATMOSPHERIC SCIENCES RESEARCH PAPERS

1. Lindberg, J.D., "An Improvement to a Method for Measuring the Absorption Coefficient of Atmospheric Dust and other Strongly Absorbing Powders," ECOM-5565, July 1975.
2. Avara, Elton, P., "Mesoscale Wind Shears Derived from Thermal Winds," ECOM-5566, July 1975.
3. Gomez, Richard B. and Joseph H. Pierluissi, "Incomplete Gamma Function Approximation for King's Strong-Line Transmittance Model," ECOM-5567, July 1975.
4. Blanco, A.J. and B.F. Engebos, "Ballistic Wind Weighting Functions for Tank Projectiles." ECOM-5568, August 1975.
5. Taylor, Fredrick J., Jack Smith, and Thomas H. Pries, "Crosswind Measurements through Pattern Recognition Techniques," ECOM-5569, July 1975.
6. Walters, D.L., "Crosswind Weighting Functions for Direct-Fire Projectiles," ECOM-5570, August 1975.
7. Duncan, Louis D., "An Improved Algorithm for the Iterated Minimal Information Solution for Remote Sounding of Temperature," ECOM-5571, August 1975.
8. Robbiani, Raymond L., "Tactical Field Demonstration of Mobile Weather Radar Set AN/TPS-41 at Fort Rucker, Alabama," ECOM-5572, August 1975.
9. Miers, B., G. Blackman, D. Langer, and N. Lorimier, "Analysis of SMS/GOES Film Data," ECOM-5573, September 1975.
10. Manquero, Carlos, Louis Duncan, and Rufus Bruce, "An Indication from Satellite Measurements of Atmospheric CO_2 Variability," ECOM-5574, September 1975.
11. Petracca, Carmine and James D. Lindberg, "Installation and Operation of an Atmospheric Particulate Collector," ECOM-5575, September 1975.
12. Avara, Elton P. and George Alexander, "Empirical Investigation of Three Iterative Methods for Inverting the Radiative Transfer Equation," ECOM-5576, October 1975.
13. Alexander, George D., "A Digital Data Acquisition Interface for the SMS Direct Readout Ground Station—Concept and Preliminary Design," ECOM-5577, October 1975.
14. Cantor, Israel, "Enhancement of Point Source Thermal Radiation Under Clouds in a Nonattenuating Medium," ECOM-5578, October 1975.
15. Norton, Colburn and Glenn Hoidale, "The Diurnal Variation of Mixing Height by Month over White Sands Missile Range, NM," ECOM-5579, November 1975.
16. Avara, Elton P., "On the Spectrum Analysis of Binary Data," ECOM-5580, November 1975.
17. Taylor, Fredrick J., Thomas H. Pries, and Chao-Huan Huang, "Optimal Wind Velocity Estimation," ECOM-5581, December 1975.
18. Avara, Elton P., "Some Effects of Autocorrelated and Cross-Correlated Noise on the Analysis of Variance," ECOM-5582, December 1975.
19. Gillespie, Patti S., R.L. Armstrong, and Kenneth O. White, "The Spectral Characteristics and Atmospheric CO_2 Absorption of the Ho^{+3}:YLF Laser at 2.05μm," ECOM-5583, December 1975.
20. Novlan, David J., "An Empirical Method of Forecasting Thunderstorms for the White Sands Missile Range," ECOM-5584, February 1976.
21. Avara, Elton P., "Randomization Effects in Hypothesis Testing with Autocorrelated Noise," ECOM-5585, February 1976.
22. Watkins, Wendell R., "Improvements in Long Path Absorption Cell Measurement," ECOM-5586, March 1976.
23. Thomas, Joe, George D. Alexander, and Marvin Dubbin, "SATTEL — An Army Dedicated Meteorological Telemetry System," ECOM-5587, March 1976.
24. Kennedy, Bruce W. and Delbert Bynum, "Army User Test Program for the RDT&E-XM-75 Meteorological Rocket," ECOM-5588, April 1976.

25. Barnett, Kenneth M., "A Description of the Artillery Meteorological Comparisons at White Sands Missile Range, October 1974 — December 1974 ('PASS' — Prototype Artillery [Meteorological] Subsystem)," ECOM-5589, April 1976.
26. Miller, Walter B., "Preliminary Analysis of Fall-of-Shot From Project 'PASS'," ECOM-5590, April 1976.
27. Avara, Elton P., "Error Analysis of Minimum Information and Smith's Direct Methods for Inverting the Radiative Transfer Equation," ECOM-5591, April 1976.
28. Yee, Young P., James D. Horn, and George Alexander, "Synoptic Thermal Wind Calculations from Radiosonde Observations Over the Southwestern United States," ECOM-5592, May 1976.
29. Duncan, Louis D. and Mary Ann Seagraves, "Applications of Empirical Corrections to NOAA-4 VTPR Observations," ECOM-5593, May 1976.
30. Miers, Bruce T. and Steve Weaver, "Applications of Meterological Satellite Data to Weather Sensitive Army Operations," ECOM-5594, May 1976.
31. Sharenow, Moses, "Redesign and Improvement of Balloon ML-566," ECOM-5595, June 1976.
32. Hansen, Frank V., "The Depth of the Surface Boundary Layer," ECOM-5596, June 1976.
33. Pinnick, R.G. and E.B. Stenmark, "Response Calculations for a Commercial Light-Scattering Aerosol Counter," ECOM-5597, July 1976.
34. Mason, J. and G.B. Hoidale, "Visibility as an Estimator of Infrared Transmittance," ECOM-5598, July 1976.
35. Bruce, Rufus E., Louis D. Duncan, and Joseph H. Pierluissi, "Experimental Study of the Relationship Between Radiosonde Temperatures and Radiometric-Area Temperatures," ECOM-5599, August 1976.
36. Duncan, Louis D., "Stratospheric Wind Shear Computed from Satellite Thermal Sounder Measurements," ECOM-5800, September 1976.
37. Taylor, F., P. Mohan, P. Joseph and T. Pries, "An All Digital Automated Wind Measurement System," ECOM-5801, September 1976.
38. Bruce, Charles, "Development of Spectrophones for CW and Pulsed Radiation Sources," ECOM-5802, September 1976.
39. Duncan, Louis D. and Mary Ann Seagraves, "Another Method for Estimating Clear Column Radiances," ECOM-5803, October 1976.
40. Blanco, Abel J. and Larry E. Traylor, "Artillery Meteorological Analysis of Project Pass," ECOM-5804, October 1976.
41. Miller, Walter and Bernard Engebos, "A Mathematical Structure for Refinement of Sound Ranging Estimates," ECOM-5805, November, 1976.
42. Gillespie, James B. and James D. Lindberg, "A Method to Obtain Diffuse Reflectance Measurements from 1.0 to 3.0μm Using a Cary 17I Spectrophotometer," ECOM-5806, November 1976.
43. Rubio, Roberto and Robert O. Olsen, "A Study of the Effects of Temperature Variations on Radio Wave Absorption," ECOM-5807, November 1976.
44. Ballard, Harold N., "Temperature Measurements in the Stratosphere from Balloon-Borne Instrument Platforms, 1968-1975," ECOM-5808, December, 1976.
45. Monahan, H.H., "An Approach to the Short-Range Prediction of Early Morning Radiation Fog." ECOM-5809. January 1977.
46. Engebos, Bernard Francis, "Introduction to Multiple State Multiple Action Decision Theory and Its Relation to Mixing Structures," ECOM-5810, January 1977.
47. Low, Richard D.H., Effects of Cloud Particles on Remote Sensing from Space in the 10-Micrometer Infrared Region, ECOM-5811, January 1977.
48. Bonner, Robert S. and R. Newton, "Application of the AN/GVS-5 Laser Rangefinder to Cloud Base Height Measurements," ECOM-5812, February 1977.

49. Rubio, Roberto, "Lidar Detection of Subvisible Reentry Vehicle Erosive Atmospheric Material," ECOM-5813, March 1977.

50. Low, Richard D.H. and J.D. Horn, "Mesoscale Determination of Cloud-Top Height: Problems and Solutions," ECOM-5814, March 1977.

51. Duncan, Louis D. and Mary Ann Seagraves, "Evaluation of the NOAA-4 VTPR Thermal Winds for Nuclear Fallout Predictions," ECOM-5815, March 1977.

52. Randhawa, Jagir S., M. Izquierdo, Carlos McDonald and Zvi Salpeter, "Stratospheric Ozone Density as Measured by a Chemiluminescent Sensor During the Stratcom VI-A Flight," ECOM-5816, April 1977.

53. Rubio, Roberto and Mike Izquierdo, "Measurements of Net Atomospheric Irradiance in the 0.7- to 2.8-Micrometer Infrared Region," ECOM-5817, May 1977.

54. Ballard, Harold N., José M. Serna, and Frank P. Hudson Consultant for Chemical Kinetics, "Calculation of Selected Atmospheric Composition Parameters for the Mid-Latitude, September Stratosphere," ECOM-5818, May 1977.

55. Mitchell, J.D., R.S. Sagar, and R.O. Olsen, "Positive Ions in the Middle Atmosphere During Sunrise Conditions," ECOM-[illegible], May 1977.

DISTRIBUTION LIST

Director
US Army Ballistic Research Laboratory
ATTN: DRDAR-BLB, Dr. G. E. Keller
Aberdeen Proving Ground, MD 21005

Air Force Weapons Laboratory
ATTN: Technical Library (SUL)
Kirtland AFB, NM 87117

Commander
Headquarters, Fort Huachuca
ATTN: Tech Ref Div
Fort Huachuca, AZ 85613

6585 TG/WE
Holloman AFB, NM 88330

Commandant
US Army Field Artillery School
ATTN: Morris Swett Tech Library
Fort Sill, OK 73503

Commandant
USAFAS
ATTN: ATSF-CD-MT (Mr. Farmer)
Fort Sill, OK 73503

Director
US Army Engr Waterways Exper Sta
ATTN: Library Branch
Vicksburg, MS 39180

Commander
US Army Electronics Command
ATTN: DRSEL-CT-S (Dr. Swingle)
Fort Monmouth, NJ 07703
03

CPT Hugh Albers, Exec Sec
Interdept Committee on Atmos Sci
Fed Council for Sci & Tech
National Sci Foundation
Washington, DC 20550

Inge Dirmhirn, Professor
Utah State University, UMC 48
Logan, UT 84322

HQDA (DAEN-RDM/Dr. De Percin)
Forrestal Bldg
Washington, DC 20314

Commander
US Army Aviation Center
ATTN: ATZQ-D-MA
Fort Rucker, AL 36362

CO, USA Foreign Sci & Tech Center
ATTN: DRXST-ISI
220 7th Street, NE
Charlottesville, VA 22901

Director
USAE Waterways Experiment Station
ATTN: Library
PO Box 631
Vicksburg, MS 39180

US Army Research Office
ATTN: DRXRO-IP
PO Box 12211
Research Triangle Park, NC 27709

Mr. William A. Main
USDA Forest Service
1407 S. Harrison Road
East Lansing, MI 48823

Library-R-51-Tech Reports
Environmental Research Labs
NOAA
Boulder, CO 80302

Commander
US Army Dugway Proving Ground
ATTN: MT-S
Dugway, UT 84022

HQ, ESD/DRI/S-22
Hanscom AFB
MA 01731

Head, Atmospheric Rsch Section
National Science Foundation
1800 G. Street, NW
Washington, DC 20550

Office, Asst Sec Army (R&D)
ATTN: Dep for Science & Tech
HQ, Department of the Army
Washington, DC 20310

Commander
US Army Satellite Comm Agc
ATTN: DRCPM-SC-3
Fort Monmouth, NJ 07703

Sylvania Elec Sys Western Div
ATTN: Technical Reports Library
PO Box 205
Mountain View, CA 94040

William Peterson
Research Association
Utah State University, UNC 48
Logan, UT 84322

Defense Communications Agency
Technical Library Center
Code 205
Washington, DC 20305

Dr. A. D. Belmont
Research Division
PO Box 1249
Control Data Corp
Minneapolis, MN 55440

Commander
US Army Electronics Command
ATTN: DRSEL-WL-D1
Fort Monmouth, NJ 07703

Commander
ATTN: DRSEL-VL-D
Fort Monmouth, NJ 07703

Meteorologist in Charge
Kwajalein Missile Range
PO Box 67
APO
San Francisco, CA 96555

The Library of Congress
ATTN: Exchange & Gift Div
Washington, DC 20540
2

US Army Liaison Office
MIT-Lincoln Lab, Library A-082
PO Box 73
Lexington, MA 02173

Dir National Security Agency
ATTN: TDL (C513)
Fort George G. Meade, MD 20755

Director, Systems R&D Service
Federal Aviation Administration
ATTN: ARD-54
2100 Second Street, SW
Washington, DC 20590

Commander
US Army Missile Command
ATTN: DRSMI-RRA, Bldg 7770
Redstone Arsenal, AL 35809

Dir of Dev & Engr
Defense Systems Div
ATTN: SAREA-DE-DDR
H. Tannenbaum
Edgewood Arsenal, APG, MD 21010

Naval Surface Weapons Center
Technical Library & Information
Services Division
White Oak, Silver Spring, MD
20910

Dr. Frank D. Eaton
PO Box 3038
Universtiy Station
Laramie, Wyoming 82071

Rome Air Development Center
ATTN: Documents Library
TILD (Bette Smith)
Griffiss Air Force Base, NY 13441

National Weather Service
National Meteorological Center
World Weather Bldg - 5200 Auth Rd
ATTN: Mr. Quiroz
Washington, DC 20233

USAFETAC/CB (Stop 825)
Scott AFB
IL 62225

Director
Defense Nuclear Agency
ATTN: Tech Library
Washington, DC

Director
Development Center MCDEC
ATTN: Firepower Division
Quantico, VA 22134

Environmental Protection Agency
Meteorology Laboratory
Research Triangle Park, NC
27711

Commander
US Army Electronics Command
ATTN: DRSEL-GG-TD
Fort Monmouth, NJ 07703

Commander
US Army Ballistic Rsch Labs
ATTN: DRXBR-IB
APG, MD 21005

Dir, US Naval Research Lab
Code 5530
Washington, DC 20375

Mil Assistant for
Environmental Sciences
DAD (E & LS), 3D129
The Pentagon
Washington, DC 20301

The Environmental Rsch
Institute of MI
ATTN: IRIA Library
PO Box 618
Ann Arbor, MI 48107

Armament Dev & Test Center
ADTC (DLOSL)
Eglin AFB, Florida 32542

Range Commanders Council
ATTN: Mr. Hixon
PMTC Code 3252
Pacific Missile Test Center
Point Mugu, CA 93042

Commander
Eustis Directorate
US Army Air Mobility R&D Lab
ATTN: Technical Library
Fort Eustis, VA 23604

Commander
Frankford Arsenal
ATTN: SARFA-FCD-O, Bldg 201-2
Bridge & Tarcony Sts
Philadelphia, PA 19137

Director, Naval Oceanography and
Meteorology
National Space Technology Laboratories
Bay St Louis, MS 39529

Commander
US Army Electronics Command
ATTN: DRSEL-CT-S
Fort Monmouth, NJ 07703

Commander
USA Cold Regions Test Center
ATTN: STECR-OP-PM
APO Seattle 98733

Redstone Scientific Information Center
ATTN: DRDMI-TBD
US Army Missile Res & Dev Command
Redstone Arsenal, AL 35809

Commander
AFWL/WE
Kirtland AFB, NM 87117

Naval Surface Weapons Center
Code DT-22 (Ms. Greeley)
Dahlgren, VA 22448

Commander
Naval Ocean Systems Center
ATTN: Research Library
San Diego, CA 92152

Commander
US Army INSCOM
ATTN: IARDA-OS
Arlington Hall Station
Arlington, VA 22212

Commandant
US Army Field Artillery School
ATTN: ATSF-CF-R
Fort Sill, OK 73503

Commander
US Army Tropic Test Center
ATTN: STETC-MO (Tech Library)
APO New York 09827

Commanding Officer
Naval Research Laboratory
Code 2627
Washington, DC 20375

Defense Documentation Center
ATTN: DDC-TCA
Cameron Station (Bldg 5)
Alexandria, Virginia 22314
12

Commander
US Army Test and Evaluation Command
ATTN: Technical Library
White Sands Missile Range, NM 88002

US Army Nuclear Agency
ATTN: MONA-WE
Fort Belvoir, VA 22060

Commander
US Army Proving Ground
ATTN: Technical Library
Bldg 2100
Yuma, AZ 85364

Office, Asst Sec Army (R&D)
ATTN: Dep for Science & Tech
HQ, Department of the Army
Washington, DC 20310

☆ U.S. GOVERNMENT PRINTING OFFICE: 1977—777-022/27