

AD-A041 076

ARMY ELECTRONICS COMMAND FORT MONMOUTH N J
MEASUREMENTS OF NET ATMOSPHERIC IRRADIANCE IN THE 0.7- TO 2.6-M--ETC(U)
MAY 77 R RUBIO, M IZQUIERDO
ECOM-5817

F/G 4/1

UNCLASSIFIED

NL

| OF |

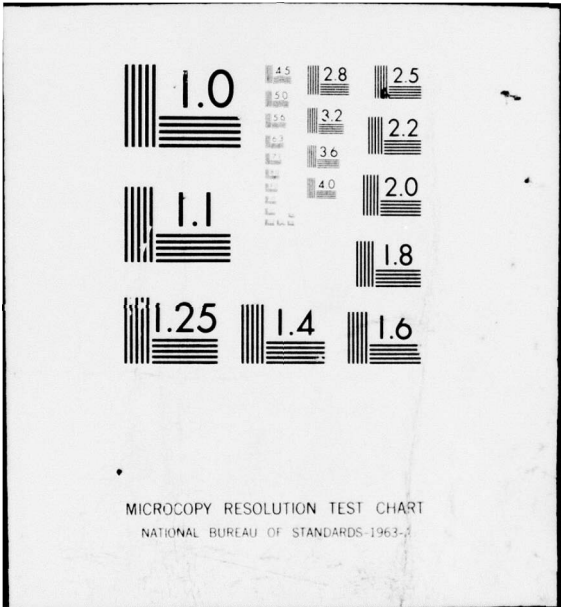
AD
A041 076



END

DATE
FILMED

7-77



12

AD

Reports Control Symbol
OSD-1366



ADA 041 076

RESEARCH AND DEVELOPMENT TECHNICAL REPORT
ECOM-5817

MEASUREMENTS OF NET ATMOSPHERIC IRRADIANCE IN THE 0.7- TO 2.8-MICROMETER INFRARED REGION

By

ROBERTO RUBIO

Atmospheric Sciences Laboratory

US Army Electronics Command
White Sands Missile Range, New Mexico 88002

and

MIKE IZQUIERDO

Electrical Engineering Department
University of Texas at El Paso
El Paso, Texas 79968

DDC
RECEIVED
JUN 30 1977
B

May 1977

Approved for public release; distribution unlimited.

DDC FILE COPY

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

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

ERRATA PAGE FOR ECOM-5817

MEASUREMENTS OF NET ATMOSPHERIC IRRADIANCE
IN THE 0.7- TO 2.8-MICROMETER INFRARED REGION

Page 2, second paragraph on page, eighth line in paragraph

Change "The combined electronics and noise
level..." to "The combined electronics
noise level..."

Page 4, first full paragraph, seventh line from bottom of paragraph

Change 1630 MST to 1636 MST

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------|
| 1. REPORT NUMBER 14 ECOM-5817 | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle) 6 MEASUREMENTS OF NET ATMOSPHERIC IRRADIANCE IN THE 0.7- TO 2.8-MICROMETER INFRARED REGION | 5. TYPE OF REPORT & PERIOD COVERED Research and development technical report | |
| | 6. PERFORMING ORG. REPORT NUMBER | |
| 7. AUTHOR(s) 10 Roberto Rubio Mike Izquierdo | 8. CONTRACT OR GRANT NUMBER(s) | |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Atmospheric Sciences Laboratory White Sands Missile Range, NM 88002 | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DA Task 1L161102D53A | |
| 11. CONTROLLING OFFICE NAME AND ADDRESS US Army Electronics Command Fort Monmouth, NJ 07703 | 12. REPORT DATE 11 May 1977 | 13. NUMBER OF PAGES 21 |
| 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 037 620 | | |
| 19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Irradiance Near infrared Pyranometer Balloon flight | | |
| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The objective of this experiment was to measure atmospheric irradiance within the 0.7- to 2.8-micrometer infrared wavelength region from a balloon platform at altitudes ranging from 5 to 39 kilometers. An Epply precision spectral pyranometer pointed in a general downward direction and equipped with a 7-degree field of view field stop was successfully employed to collect irradiance data for a period of 34 hours on 23, 24, and 25 September 1976. The results showed that at low solar zenith angles and in the absence of clouds the atmospheric | | |

100 cal/sq cm

20. ABSTRACT (cont)

cont:

irradiance values usually remained within 2.2×10^{-2} cal/cm² min and 2.6×10^{-2} cal/cm² min. Clouds attenuated the irradiance down to magnitudes below 4×10^{-4} cal/cm² min which was the combined noise level of the pyranometer and associated electronics. At high solar zenith angles, specular reflections of sunlight which entered the pyranometer's field view caused enhancements of the measured irradiance to reach magnitudes greater than the instrument could measure (3.5×10^{-2} cal/cm² min). No significant variations in irradiance were detected with changes in altitude above 5 kilometers or terrain viewed; therefore, the background intensity is attributed to the radiant emittance of the lower atmosphere.

10000 cal/sq cm



CONTENTS

| | <u>Page</u> |
|-----------------|-------------|
| INTRODUCTION | 2 |
| INSTRUMENTATION | 2 |
| IRRADIANCE DATA | 3 |
| CONCLUSIONS | 5 |
| REFERENCES | 11 |

EXPRESSION 1.7

| | | |
|---------------|---------------|-------------------------------------|
| NTIS | White Section | <input checked="" type="checkbox"/> |
| 308 | Buff Section | <input type="checkbox"/> |
| UNANNOUNCED | | <input type="checkbox"/> |
| JUSTIFICATION | | |

BY

DISTRIBUTION/AVAILABILITY CODES

| | | | |
|-------|--------|--------|---------|
| UNCL. | AVAIL. | 308/99 | SPECIAL |
| A | | | |

INTRODUCTION

The existence and causes of naturally occurring atmospheric infrared light emission with intensity magnitudes greater than those of the normal background have been important to the military services since the advent of remote sensing reconnaissance and surveillance systems. To supplement existent, but insufficient, data on atmospheric near infrared light emission or reflections, the experiment to be described in this report was designed as part of project STRATCOM VI-A. STRATCOM VI-A was a high-altitude balloon project consisting of a multi-instrument atmospheric-sensing payload designed to make simultaneous measurements of solar and atmospheric radiation, atmospheric composition, and the thermodynamic structure in the 5- to 40-kilometer altitude interval. The specific objective of this particular STRATCOM VI-A experiment was to acquire atmospheric irradiance data within the 0.7- to 2.8-micrometer wavelength region and to attempt to identify the cause of any intensity enhancements detected during the balloon flight.

INSTRUMENTATION

An Epply precision spectral pyranometer with an RG8 light filter (0.7- to 2.8-micrometer window) was used to measure atmospheric irradiance. A field stop machined to limit the field of view to 7 degrees was attached to the pyranometer. Inclusion of the field stop reduced the pyranometer sensitivity to 0.38 millivolt/(cal/cm² min). Thus to provide a voltage signal sufficiently large to telemeter, the sensor output was amplified by two cascaded operational amplifiers enclosed in a temperature controlled container. The combined electronics and noise level was measured to be 0.1 microvolt; this value is equivalent to an irradiance level of 4×10^{-4} cal/cm² min. Based on previous data [1] rounded off to the next higher order of magnitude, the Epply pyranometer sensitivity and its viewing solid angle of 0.01 steradian, the maximum anticipated irradiance level was calculated to be 3×10^{-2} cal/cm² min. This corresponds to an equivalent pyranometer output voltage of approximately 10 microvolts. Accordingly, the total gain of the operational amplifiers was set to accentuate the sensor output voltages between 0.1 and 10 microvolts. Because of the high amplifier gain employed, sensor output voltages above 13.3 microvolts saturated the modulation signal; therefore, all irradiance data which produced a sensor output voltage larger than 13.3 microvolts were electronically limited to the corresponding value of 3.5×10^{-2} cal/cm² min.

The pyranometer and its appendage were located at the bottom side of the balloon's instrumentation platform. Its optical axis pointed toward the earth at an angle of 17.6 degrees below the horizontal plane defined by the platform base. All irradiance data were recorded after the payload platform had been lowered 300 meters below the balloon.

IRRADIANCE DATA

Net atmospheric irradiance data were intermittently recorded for a period of approximately 34 hours. During balloon ascension, the pyranometer sensed slanted atmospheric path lengths ranging from 17.5 to 130 kilometers. The first data sample (Fig. 1(a), 2312 MST), recorded at an altitude of 5.3 kilometers, corresponds to the 17.5-kilometer slant path; while the eighth data sample (Fig. 1(b), 0230 MST), recorded at an altitude of 39 kilometers, corresponds to the 130-kilometer path. During this balloon climb phase, the irradiance background magnitudes did not vary as a function of the observed path length, as can be seen in Figs. 1(a) and 1(b). This is attributed to the fact that when the initial data sample was obtained, the pyranometer was already sensing a large majority of the air mass and most of the precipitable water vapor, both of which were located in the region of the atmosphere with the highest temperature where the bulk of the atmosphere's radiant emittance occurs. Other than the third data sample, obtained at 0005 MST, 24 September, the irradiance remained within 2.3×10^{-2} cal/cm² min and 2.6×10^{-2} cal/cm² min. The abrupt decrease in intensity to less than 4×10^{-4} cal/cm² min recorded at 0005 MST was probably produced by cloud attenuation of the low-altitude atmospheric radiance. However, due to the lack of precise information on cloud locations at 0005, it cannot be unequivocally stated that a cloud obscured the pyranometer's field of view.

Investigation of the balloon's projected ground trajectory and the type of earth surface terrain traversed by this trajectory revealed that variations in the recorded irradiances were uncorrelated to changes in the type of observed terrain. Observed terrains consisted of flat desert, semibarren mountains, forested mountains and valleys, and small lakes. Calculation of the earth's radiant emittance, at a temperature of 25°C, and unity emissivity, within the 0.7- to 2.8-micrometer region, yielded an irradiance value of 1.5×10^{-4} cal/cm² min. This intensity is below the operating signal threshold of the instrumentation employed here. Thus the small changes in irradiance brought about by changes in terrain temperatures and emissivities went undetected.

Measurements recorded during the balloon's first float altitude of approximately 39 kilometers covered the time interval from 0256 MST to 1142 MST, 25 September. Within this time span, the atmosphere was sensed during night, sunrise, and daylight hours. The recorded data are shown in Figs. 1(c), 1(d), and 1(e). Irradiance levels generally remained between 2.3×10^{-2} cal/cm² min and 2.6×10^{-2} cal/cm² min without any noticeable variations during sunrise. Orientation of the pyranometer's field of view was such that it never faced the sun directly. The intensity enhancement expected at sunrise was that due to the clear sky atmospheric scattering of the near infrared light. However, a post-flight computation based on the data of [1] indicated that the additional

irradiance due to clear sky atmospheric scattering of 0.7 to 2.8 micrometers energy was 3×10^{-4} cal/cm² min or less, clearly a magnitude less than the instrument's noise level. The gradual decreases in intensity registered at 0330 MST and 0451 MST are attributed to the attenuation effects of clouds entering the pyranometer's field of view. While the sky on the morning of 24 September may be described as generally clear (less than 0.1 coverage), the afternoon was characterized by increased cloudiness which intermittently obscured the pyranometer's field of view.

In the time frame from 1030 MST to approximately 1850, eight irradiance data samples were acquired while the balloon descended from 38 to 27.4 kilometers. The last of these samples was 2 hours long so that not only this experiment but also other STRATCOM experiments would record continuous data during sunset. The irradiance amplitudes did not change appreciably during sunset. All the variations observed were comparable to the small changes already recorded throughout most of the flight when the amplitudes were centered about 2.4×10^{-2} cal/cm² min. In contrast, before sunset, beginning at 1631 MST large variations in irradiance levels were observed. Because of the increased cloudiness on this afternoon and with the sun's attainment of a high zenith angle, cloud specular reflection of sunlight entered the pyranometer's field of view and enhanced the irradiance amplitudes to values greater than 3.5×10^{-2} cal/cm² min. These enhancements are shown in Figs. 1(f) and 1(g). As previously mentioned, values greater than 3.5×10^{-2} cal/cm² min are not plotted because the electronics became saturated at this magnitude. Consequently, it may be stated only that the values registered at 1630 MST and 1821 MST were greater than 3.5×10^{-2} cal/cm² min. Since preflight calculations of solar energy scattering (diffused light) of 0.7 to 2.8 micrometers light from sunlit clouds yielded a maximum irradiance of only 3×10^{-2} cal/cm² min, it is maintained that the enhancements recorded at 1630 MST and 1821 are indeed specular cloud reflections. When clouds were in the pyranometer's field of view, the balloon platform's slow motion caused the pyranometer to sense in sequence either solar specular reflections or atmospheric irradiance attenuated by the same clouds. This process effectively introduced the irradiance fluctuations recorded in Figs. 1(f) and 1(g). At sunset all enhancements ceased.

During the remainder of the balloon flight, eight more samples were obtained as the balloon rose to 39 kilometers. Most of these data, plotted in Figs. 1(h), 1(i), and 1(j) were recorded at night. Other than the decreases in irradiance recorded at 2004 MST and 2114 MST on 24 September and at 0550 MST on 25 September, the intensity levels did not significantly deviate from 2.5×10^{-2} cal/cm² min. Sunrise effects were again found to be negligible. All values recorded after 0558 MST, last data point in Fig. 1(j), also remained close to a value of 2.5×10^{-2} cal/cm² min.

CONCLUSIONS

Net lower atmosphere 0.7- to 2.8-micrometer irradiance data were successfully recorded for a period of 34 hours from altitudes ranging from 5.3 to 39 kilometers. An irradiance background level which usually remained between 2.3×10^{-2} cal/cm² min and 2.6×10^{-2} cal/cm² min existed during both day and night. This irradiance level is in general agreement with data reported by K. YA. Kondratyev [2] when only that fraction of energy due to the near infrared is obtained from Kondratyev's total irradiance. Since no appreciable variations in irradiance with increases in altitude were observed between 5.3 and 39 kilometers, it is concluded that the aforementioned irradiance levels are maintained by air mass in the lower atmosphere. Changes in the radiant emittance of the earth's surface terrain were too small to be detectable. Clouds entering the sensor's field of view acted as attenuators of the lower atmosphere irradiance. More importantly, it was established that the existence of clouds located in a position to specularly reflect sunlight into a sensor can cause intensity enhancement well above the background irradiance.

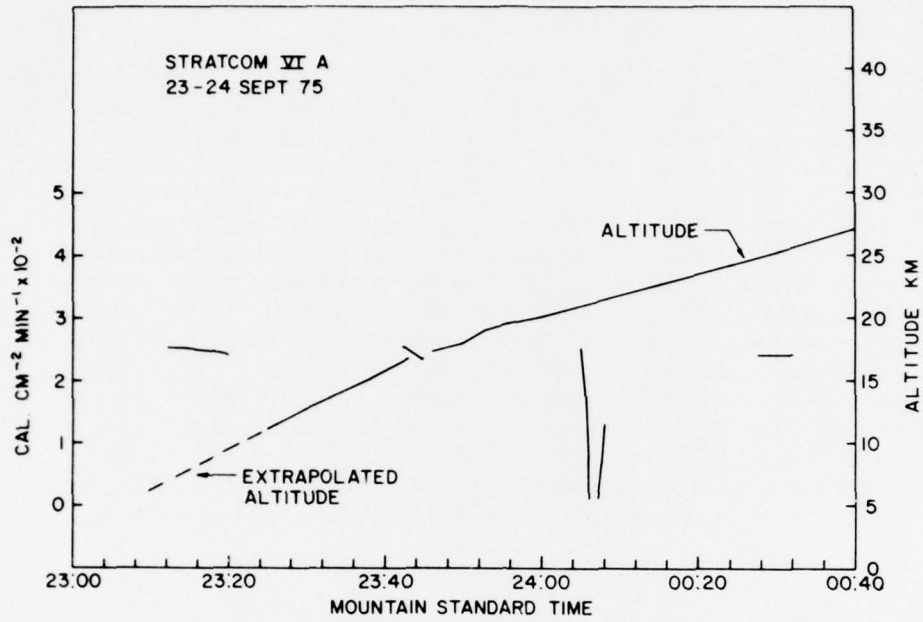


FIGURE 1 (a) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE.

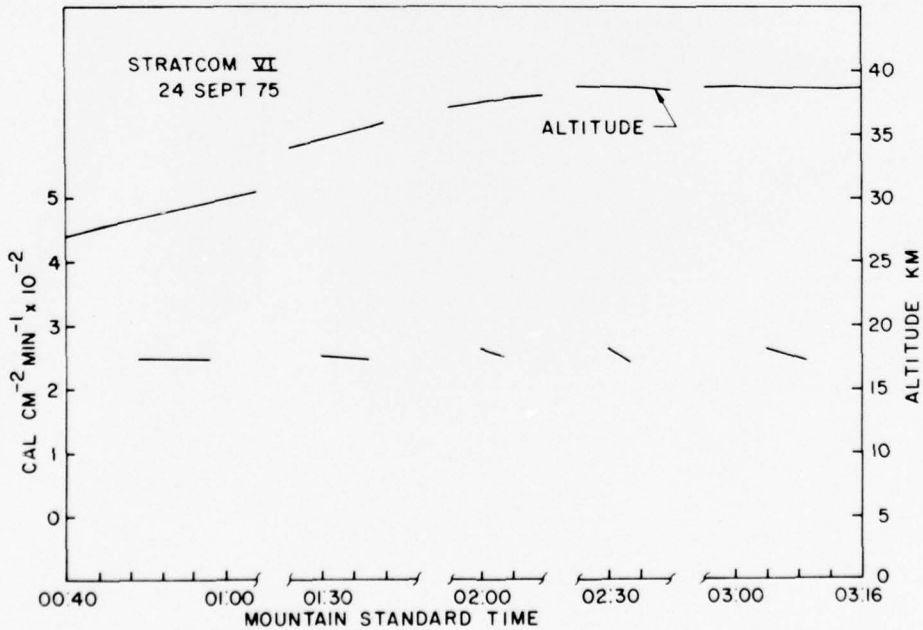


FIGURE 1 (b) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE.

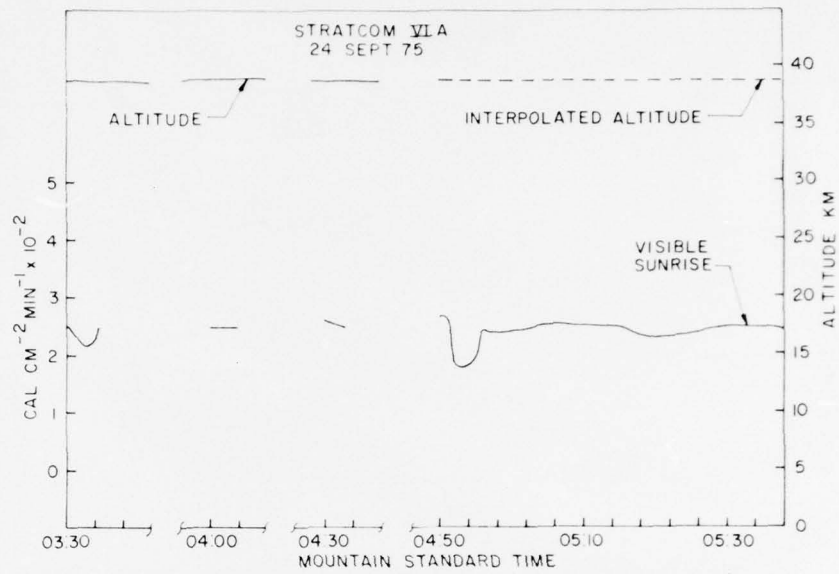


FIGURE 1 (c) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE.

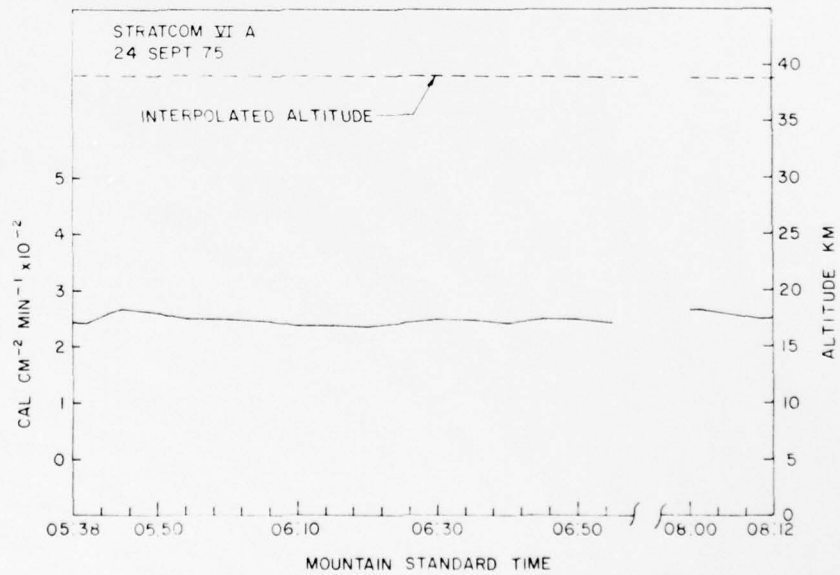


FIGURE 1 (d) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE.

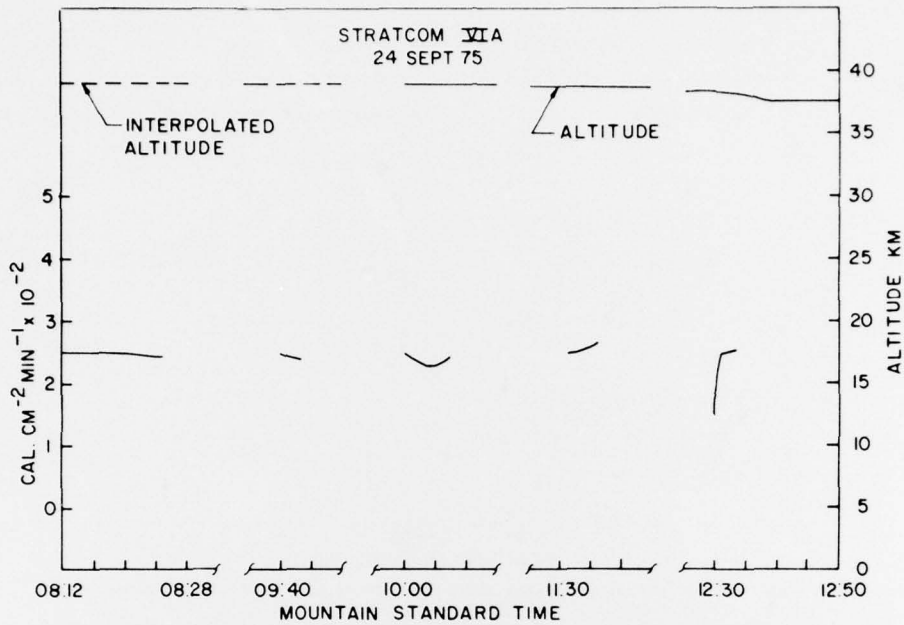


FIGURE 1 (e) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE.

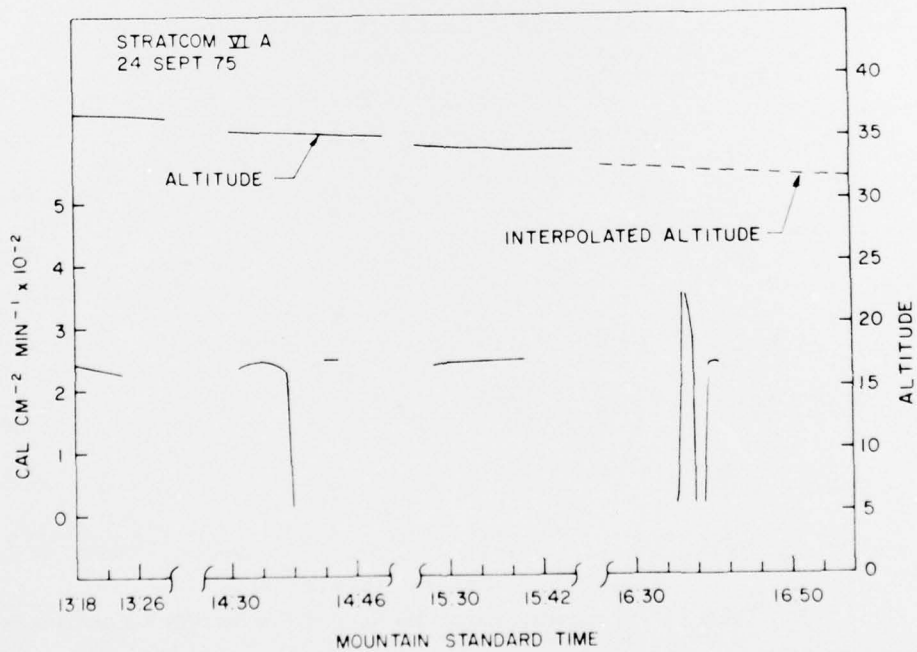


FIGURE 1 (f) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE.

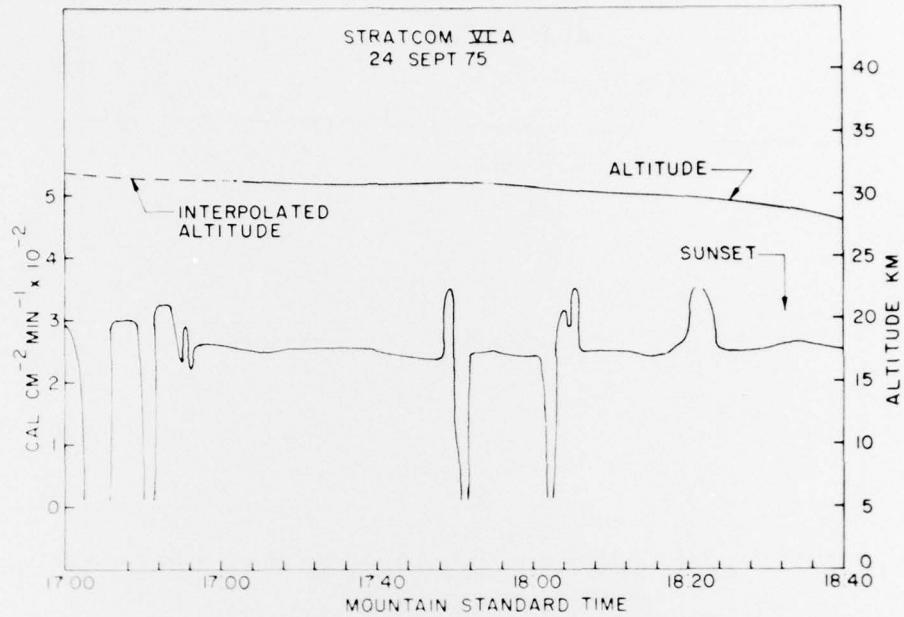


FIGURE 1 R NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 28 MICRON REGION AS A FUNCTION AND ALTITUDE

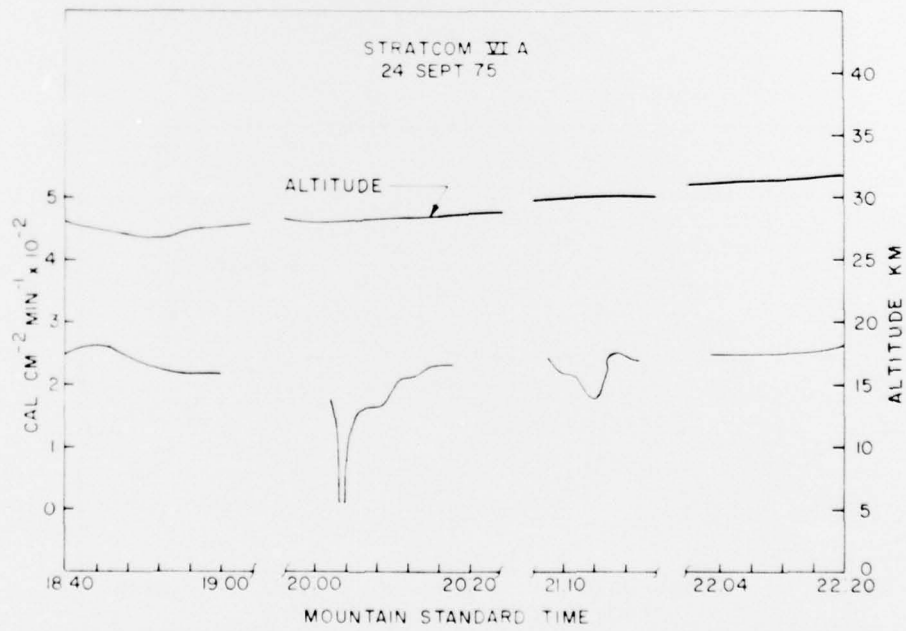


FIGURE 1 H NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 28 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE

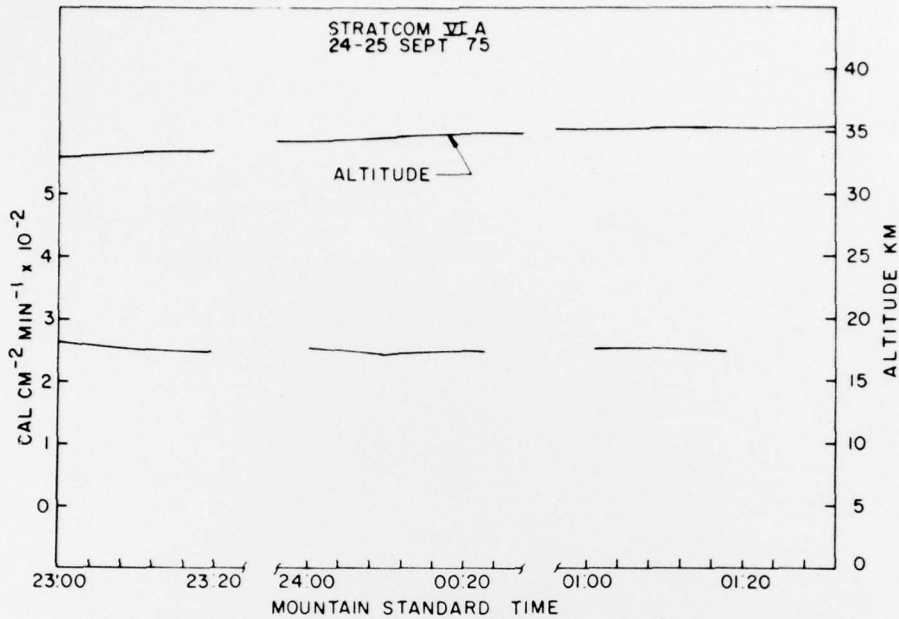


FIGURE 1 (i) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE

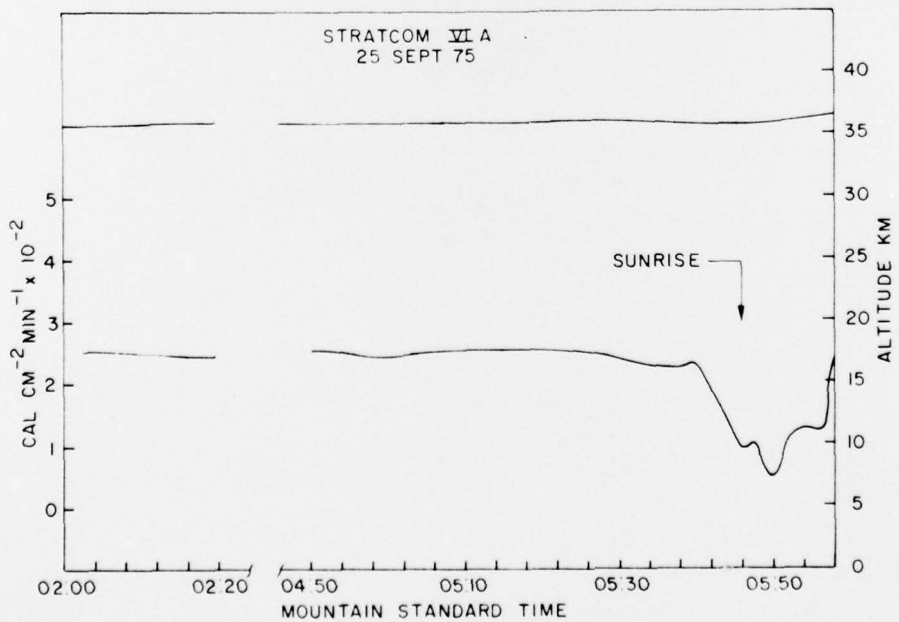


FIGURE 1 (ii) NET ATMOSPHERIC RADIATION WITHIN THE 0.7 TO 2.8 MICRON REGION AS A FUNCTION OF TIME AND ALTITUDE

REFERENCES

1. Wolfe, W. L., Editor, 1965, Handbook of Military Infrared Technology, Chapter 5, US Government Printing Office, Washington, D.C.
2. Kondratyev, K. YA., 1969, Radiation in the Atmosphere, Chapter 9, Academic Press, New York, NY.

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 CO₂ 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 CO₂ Absorption of the Ho⁺:YLF Laser at 2.05 μ m," 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 Meteorological 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 3.0 μm 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 Atmospheric Irradiance in the 0.7- to 2.8-Micrometer Infrared Region," ECOM-5817, May 1977.

DISTRIBUTION LIST

Commanding Officer
Picatinny Arsenal
ATTN: SARPA-TS-S, #59
Dover, NJ 07801

Chief, Technical Services Div
DCS/Aerospace Sciences
ATTN: AWS/DNTI
Scott AFB, IL 62225

Commanding Officer
Harry Diamond Laboratory
ATTN: Library
2800 Powder Mill Road
Adelphi, MD 20783

Air Force Cambridge Rsch Labs
ATTN: LCH (A. S. Carten, Jr.)
Hanscom AFB
Bedford, MA 01731

Commander
US Army Electronics Command
ATTN: DRSEL-RD-D
Fort Monmouth, NJ 07703

Department of the Air Force
16WS/DO
Fort Monroe, VA 23651

Naval Surface Weapons Center
Code DT 21 (Ms. Greeley)
Dahlgren, VA 22448

Director
US Army Ballistic Research Lab
ATTN: DRXBR-AM
Aberdeen Proving Ground, MD 21005

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

Geophysics Division
Code 3250
Pacific Missile Test Center
Point Mugu, CA 93042

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

National Center for Atmos Res
NCAR Library
PO Box 3000
Boulder, CO 80303

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

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

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

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

Environmental Protection Agency
Meteorology Laboratory
Research Triangle Park, NC 27711

Head, Rsch and Development Div (ESA-131)
Meteorological Department
Naval Weapons Engineering Support Act
Washington, DC 20374

Commander
US Army Electronics Command
ATTN: DRCDE-R
5001 Eisenhower Avenue
Alexandria, VA 22304

Marine Corps Dev & Educ Cmd
Development Center
ATTN: Cmd, Control, & Comm Div (C³)
Quantico, VA 22134

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

Commander
US Army Missile Command
ATTN: DRSMI-RFGA, B. W. Fowler
Redstone Arsenal, AL 35809

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

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

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

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

Dir, Elec Tech and Devices Lab
US Army Electronics Command
ATTN: DRSEL-TL-D, Bldg 2700
Fort Monmouth, NJ 07703

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

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

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

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

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

Commander
US Army Missile Command
ATTN: DRSMI-RR
Redstone Arsenal, AL 35809

Commandant
US Army Field Artillery School
ATTN: Met Division
Fort Sill, OK 73503

Meteorology Laboratory
AFCRL/LY
Hanscom AFB
Bedford, MA 01731

Commander
US Army Engineer Topographic Lab
(STINFO CENTER)
Fort Belvoir, VA 22060

Commander
US Army Electronics Command
ATTN: DRSEL-MS-TI
Fort Monmouth, NJ 07703

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

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

Air Force Avionics Lab
ATTN: AFAL/TSR
Wright-Patterson AFB, Ohio 45433

Dr. Robert Durrenberger
Dir, The Lab of Climatology
Arizona State University
Tempe, AZ 85281

Commander
US Army Electronics Command
ATTN: DRSEL-VL-D
Fort Monmouth, NJ 07703

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

Commander
USAICS
ATTN: ATSI-CTD-MS
Fort Huachuca, AZ 85613

Field Artillery Consultants
1112 Becontree Drive
ATTN: COL Buntyn
Lawton, OK 73501

E&R Center
Bureau of Reclamation
ATTN: Bldg 67, Code 1210
Denver, CO 80225

Commander
US Army Nuclear Agency
ATTN: ATCA-NAW
Building 12
Fort Bliss, TX 79916

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

Director
Atmospheric Physics & Chem Lab
Code 31, NOAA
Department of Commerce
Boulder, CO 80302

Commander
Air Force Weapons Laboratory
ATTN: AFWL/WE
Kirtland AFB, NM 87117

Dr. John L. Walsh
Code 5503
Navy Research Lab
Washington, DC 20375

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

Commander
US Army Air Defense School
ATTN: C&S Dept, MSLSCI Div
Fort Bliss, TX 79916

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

USAF EPAC/CBT (Stop 825)
ATTN: Mr. Burgmann
Scott AFB, IL 62225

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

Commander
US Army Ballistic Rsch Labs
ATTN: DRXBR-IB
Aberdeen Proving Ground, MD 21005

Director
Naval Research Laboratory
Code 2627
Washington, DC 20375

Commander
Naval Elect Sys Cmd HQ
Code 51014
Washington, DC 20360

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

CO, US Army Tropic Test Center
ATTN: STETC-MO-A (Tech Lib)
APO New York 09827

Commander
Naval Electronics Lab Center
ATTN: Library
San Diego, CA 92152

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

Director
US Army Ballistic Research Lab
ATTN: DRXBR-AM, Dr. F. E. Niles
Aberdeen Proving Ground, MD 21005

Commander
Frankford Arsenal
ATTN: Library, K2400, Bldg 51-2
Philadelphia, PA 19137

Director
US Army Ballistic Research Lab
ATTN: DRXBR-XA-LB
Bldg 305
Aberdeen Proving Ground, MD 21005

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

Commander
Office of Naval Research
Code 460-M
Arlington, VA 22217

Commander
Naval Weather Service Command
Washington Navy Yard
Bldg 200, Code 304
Washington, DC 20374

Technical Processes Br
D823
Room 806, Libraries Div NOAA
8060 13th St
Silver Spring, MD 20910

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

Redstone Scientific Info Center
ATTN: Chief, Documents
US Army Missile Command
Redstone Arsenal, AL 35809

Commander
Edgewood Arsenal
ATTN: SAREA-TS-L
Aberdeen Proving Ground, MD 21010

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

Commander
US Army Security Agency
ATTN: IARD-OS
Arlington Hall Station
Arlington, VA 22212
2

President
US Army Field Artillery Board
Fort Sill, OK 73503

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

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

Commander, Naval Ship Sys Cmd
Technical Library, Rm 3 S-08
National Center No. 3
Washington, DC 20360

Commandant
US Army Signal School
ATTN: ATSN-CD-MS
Fort Gordon, GA 30905

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

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

Commander
Frankford Arsenal
ATTN: J. Helfrich PDSP 65-1
Philadelphia, PA 19137

Director
Defense Nuclear Agency
ATTN: Tech Library
Washington, DC 20305

Department of the Air Force
5WW/DOX
Langley AFB, VA 23665

Commander
US Army Missile Command
ATTN: DRSMI-RER (Mr. Haraway)
Redstone Arsenal, AL 35809

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

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

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

Commander
US Army Training & Doctrine Cmd
ATTN: ATCD-SC
Fort Monroe, VA 23651

Commander
US Army Arctic Test Center
ATTN: STEAC-OP-PL
APO Seattle 98733

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

Commander
US Army Electronics Command
ATTN: DRSEL-GS-H (Stevenson)
Fort Monmouth, NJ 07703

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

Commander
USACACDA
ATTN: ATCA-CCC-W
Fort Leavenworth, KS 66027

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

Commander
US Army Test & Eval Cmd
ATTN: DRSTE-FA
Aberdeen Proving Ground, MD 21005

Commander
US Army Materiel Command
ATTN: DRCRD-SS (Mr. Andrew)
Alexandria, VA 22304

Air Force Cambridge Rsch Labs
ATTN: LKI
L. G. Hanscom Field
Bedford, MA 01730

Commander
Frankford Arsenal
ATTN: SARFA-FCD-0, Bldg 201-2
Bridge & Tarcony Sts
Philadelphia, PA 19137

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

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

USAFETAC/CB (Stop 825)
Scott AFB
IL 62225

Chief, Aerospace Environ Div
Code ES41
NASA
Marshall Space Flight Center, AL 35802

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

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

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

Commander
Holloman Air Force Base
6585 TG/WE
Holloman AFB, NM 88330

Commandant
USAFAS
ATTN: ATSF-CD-MT (Mr. Farmer)
Fort Sill, OK 73503
2

Commandant
USAFAS
ATTN: ATSF-CD-C (Mr. Shelton)
Fort Sill, OK 73503
2

Commander
US Army Electronics Command
ATTN: DRSEL-CT-S (Dr. Swingie)
Fort Monmouth, NJ 07703
3