



TR-0101

LEVEL II

AD

Reports Control Symbol
OSD - 1366

12

**CALIBRATION OF KNOLLENBERG FSSP LIGHT—SCATTERING
COUNTERS FOR MEASUREMENT OF CLOUD DROPLETS**

December 1981

By

R. G. Pinnick
D. M. Garvey
L. D. Duncan

DTIC
ELECTRONICS
FEB 05 1982
S E

AD A110498

DISC FILE COPY

Approved for public release; distribution unlimited.



US Army Electronics Research and Development Command

Atmospheric Sciences Laboratory

White Sands Missile Range, NM 88002

82 02 04 051

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.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ASL-TR-0101	2. GOVT ACCESSION NO. AD-A110498	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) CALIBRATION OF KNOLLENBERG FSSP LIGHT- SCATTERING COUNTERS FOR MEASUREMENT OF CLOUD DROPLETS		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. G. Pinnick L. D. Duncan D. M. Garvey*		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Atmospheric Sciences Laboratory White Sands Missile Range, NM 88002		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DA Task No. 1L161102B53A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Electronics Research and Development Command Adelphi, MD 20783		12. REPORT DATE December 1981
		13. NUMBER OF PAGES 65
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 *National Research Council Senior Research Associate on leave from Colorado State University, Fort Collins, Colorado, when this work was performed.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Calibration of light-scattering counters Measurement of cloud droplets		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) It is well known that atmospheric fog degrades the performance of DOD electro- optic sensors. A quantitative assessment of these effects generally requires knowledge of droplet size distributions, which can have considerable spacial and temporal variations. An attractive approach to measuring fog (or cloud) drop sizes is the use of light-scattering counters. In this paper we evaluate the response characteristics of the Knollenberg model FSSP-100 light- scattering counter, which is well-suited for measurement of particles as large		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE]

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (cont)

as fog droplets. This instrument has been widely used throughout DOD for aerosol measurement, without adequate understanding of its response characteristics. In this paper we find that measurement of cloud drop size distributions using the manufacturer's calibration can lead to artificial bumps or knees in the distributions at about $0.6\mu\text{m}$, and sometimes at $2\mu\text{m}$ to $4\mu\text{m}$ radius. These artifacts are a consequence of the instrument having multivalued or slowly changing response in these regions of particle size. We have developed a modified calibration procedure that removes these artifacts, so that the true droplet size distribution can be obtained. We also have found that measurement of slightly nonspherical particles with refractive indexes characteristic of those of atmospheric aerosols will generally lead to under-sizing if the FSSP manufacturer-supplied calibration is used, but likely by not more than a factor 2.

ACKNOWLEDGEMENT

The computer programming efforts of Chris Ham and Joanne Esparza are gratefully acknowledged.

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution	
Availability Codes	
Avail and/or	
Dist	Special
A	



CONTENTS

LIST OF TABLES.....	6
LIST OF FIGURES.....	7
INTRODUCTION.....	9
FSSP RESPONSE CALCULATIONS.....	10
FSSP FOG MEASUREMENTS.....	11
FSSP MEASUREMENTS OF OTHER SPHERICAL PARTICLES.....	12
FSSP MEASUREMENTS OF IRREGULAR PARTICLES.....	13
FSSP SAMPLING LOSSES.....	14
CONCLUSION.....	14
TABLE.....	15
FIGURES.....	16
REFERENCES.....	23
APPENDIX A - FSSP RESPONSE FOR VARIOUS COLLECTING ANGLES.....	25
APPENDIX B - THE MANUFACTURER'S FSSP CALIBRATION.....	29
APPENDIX C - FSSP MEASUREMENTS OF FOG DROP SIZE DISTRIBUTIONS.....	33
APPENDIX D - CALCULATIONS OF EXTINCTION COEFFICIENTS AND LIQUID WATER CONTENTS BASED ON FSSP DATA.....	37

LIST OF TABLES

1.	Particle Size Channel Widths (Radii in Micrometers) for the Knollenberg FSSP Light Scattering Aerosol Counter.....	15
B-1.	FSSP-100 Manufacturer Calibration.....	31

LIST OF FIGURES

1.	Comparison of the Knollenberg FSSP response.....	16
2.	Relation between the FSSP response and water drop size as predicted by theory (smooth curve), and as advertised by the manufacturer (points).....	17
3.	Comparison of FSSP fog drop size distributions obtained in two ways.....	18
4.	FSSP response curves for particles with refractive indexes characteristic of those of atmospheric constituents.....	19
5.	Same as figure 3, except in this case oil droplets (with $m = 1.45-0i$) were measured rather than fog.....	20
6.	Scanning electron microscope micrographs of slightly non-spherical pollens and spores used to measure the FSSP response characteristics.....	21
7.	Measurements of the FSSP response to slightly nonspherical pollen and spore particles (some of which are shown in figure 6)...	22
A-1.	Schematic of the FSSP-100 optical system.....	27
A-2.	FSSP response curves for water drops ($m = 1.33-0i$) for three slightly different solid angles subtended by the light-collecting optics.....	28
C-1.	Comparison for sample taken at 00:11:07, 22 Feb 1978.....	34
C-2.	Comparison for sample taken at 01:29:23, 22 Feb 1978.....	34
C-3.	Comparison for sample taken at 02:47:18, 22 Feb 1978.....	35
C-4.	Comparison for sample taken at 02:53:09, 22 Feb 1978.....	35
D-1.	Comparison of fog extinction coefficients calculated from FSSP drop size distributions measured during February 1978 in Meppen, Germany.....	37
D-2.	Comparison of fog liquid water content calculated from FSSP drop size distributions measured during February 1978 in Meppen, Germany.....	39

INTRODUCTION

A number of investigators have used^{1 2 3 4 5} or are presently using (several papers in the proceedings of the 8th International Cloud Physics Conference, Clermont-Ferrand, France, 15-19 July 1980) the Knollenberg Forward Scattering Spectrometer Probe (FSSP) to determine the drop size distribution or liquid water content in atmospheric cloud. (This device is manufactured by Particle Measurement Systems, Boulder, Colorado.) As droplets flow through an illuminated volume within the device, laser-light scattered by a single drop into a particular near-forward solid angle is measured and used to determine droplet size by electronically classifying response pulses according to their magnitude. Determination of drop size from the response is indirect because of the dependence of the response on factors other than particle size, namely, the refractive index of the drop and the lens geometry of the counter optical system.

In the previously reported studies the manufacturer-supplied calibration was used to determine the drop size (and by integrating the drop size, liquid water content) from the instrument response voltages. We show in this paper that this procedure can result in the drop size spectrum displaying artificial peaks that are peculiar to the instrument, and we offer a calibration procedure (slightly different than that supplied by the manufacturer) that removes these instrumental artifacts. Our calibration procedure, which has been described for the similar Knollenberg CSASP-100 counter in an earlier paper,⁶ involves grouping size channels so that regions of multivalued responses are avoided. As a result, the size resolution of the instrument is somewhat

¹Stephens, G. L., G. W. Paltridge, and C. M. R. Platt, "Radiation Profiles in Extended Water Clouds. III: Observations," J Atmos Sci, 35:2133-2141, 1978.

²Heymsfield, A. J., C. A. Knight, and J. E. Dye, "Ice Initiation in Unmixed Updraft Cores in Northeast Colorado Cumulus Congestus Clouds," J Atmos Sci, 36:2216-2229, 1979.

³Low, R. D. H., L. D. Duncan, and Y. Y. Roger R. Hsiao, Microphysical and Optical Properties of California Coastal Fogs at Fort Ord, ASL-TR-0034, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 1979.

⁴Low, R. D. H., Fog Evolution in the Visible and Infrared Spectral Regions and its Meaning in Optical Modeling, ASL-TR-0046, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 1979.

⁵Duncan, L. D., and R. D. H. Low, Bimodal Size Distributions Models for Fogs at Meppen, Germany, ASL-TR-0056, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 1980.

⁶Pinnick, R. G., and H. J. Auvermann, "Response Characteristics of Knollenberg Light-Scattering Aerosol Counters," J Aerosol Sci, 10:55-74, 1979.

reduced (as compared to that inferred from the manufacturer-supplied calibration), particularly for droplets in the 0.5 μ m to 4 μ m radius range. For larger particles our calibration differs little from the manufacturer's, in agreement with the findings of Cannon and Grotewold.⁷

Our calibration is based on Mie calculations of the instrument's response (to water drops). These calculations have been experimentally verified for various kinds of uniform particles. In section 2, this verification is discussed. In section 3, data collected with an FSSP in atmospheric fog is reduced to drop size distribution in two ways: using the manufacturer's calibration and using our Mie calibration. Differences are greatest in the 0.5 μ m to 2 μ m radius range, where particles are comparable in size to the wavelength of the FSSP (He-Ne) laser source. In section 4, calibration of the FSSP instrument for measurement of spherical particles other than water droplets is discussed. In section 5, some results and comments are offered on measurement of slightly irregular particles. Finally, in section 6, FSSP sampling losses are investigated.

FSSP RESPONSE CALCULATIONS

Our conjecture is that the FSSP response can be calculated assuming plane wave scattering by a sphere; that is, by assuming the well-known Mie theory. Of course, these calculations must take into account the particle size and refractive index, the wavelength of the FSSP laser source, and the geometry of the instrument optics. Although such calculations are straightforward and have been reported previously,⁶ appendix A addresses some minor complications that are caused by focusing of the laser source and have not been considered before.

To check the validity of the response calculations, we measured the FSSP response to uniform particles of known size and refractive index: spherical particles of polystyrene, polyvinyltoluene and styrene divinylbenzene latex, glass beads, and aluminum. The results are summarized in figure 1, where the theoretical response is expressed in cross-section per particle and the measured response in volts per particle. The experimental scale has been normalized to the theoretical scale to achieve best agreement between experiment and theory for the latex particles. The resulting normalization factor ($C = 2.8 \times 10^6 \text{ V cm}^{-2}$) was used for the remaining experimental data.

It is clearly evident in figure 1 that the theoretical response for the FSSP is corroborated by measurements of uniform particles having three markedly

⁷Cannon, T. W., and W. W. Grotewold, "Improved Drop Generators for Calibration of Drop Spectrometers and Use in Laboratory Cloud Physics Experiments," J Appl Meteorol, 19:901-905, 1980.

⁶Pinnick, R. G., and H. J. Auvermann, "Response Characteristics of Knollenberg Light-Scattering Aerosol Counters," J Aerosol Sci, 10:55-74, 1979.

different indexes of refraction and having radii $1\mu\text{m}$ to $20\mu\text{m}$. In particular, note that the second latex resonance around $1\mu\text{m}$ radius (where a number of latex particle sizes are available) is borne out well by the measurements. Further, similar measurements on uniform latex particles with a different FSSP instrument agree with these results (S. G. Jennings, private communication, 1980). Thus, the theoretical response calculations adequately predict the FSSP response for spheres, regardless of effects caused by multimode operation of the instrument laser source that might invalidate the plane wave assumption in Mie theory.

When making cloud or fog measurements with the FSSP, we should therefore rely on the theoretical response curve for water particles shown in figure 2, rather than the manufacturer-suggested calibration, which is also shown in the figure, for comparison. (Appendix B explains how the manufacturer's calibration is plotted in figure 2.) A word of caution is required concerning use of the theoretical curve to redefine size channels. Channels should be grouped with less size resolution than the response curve dictates because, in practice, spectra broadening effects result in some cross-channel sensitivity. Thus, channels set near regions of multivalued response and narrow size channels, where the response curve is steep, should be avoided.

A comparison of the manufacturer's calibration and our calibration, which takes into account the theoretical response curve for water and the spectra broadening considerations, is presented in table 1. We caution the reader that our calibration shown in table 1 can only be used for FSSP instruments with discriminator levels set as they are for our particular instrument. FSSP instruments with different discriminator level settings would of course require different channel groupings and size definitions (see appendix B).

FSSP FOG MEASUREMENTS

To demonstrate the difference between invoking the manufacturer's calibration and our Mie calibration for some real data, we chose some fog measurements made during February and April, 1978, near Meppen, Germany. The measurements were made with an aspirated FSSP operated 2 m above ground level in a range-cycling mode allowing maximum use of the dynamic range of the instrument. In this mode droplets in four overlapping size ranges are measured sequentially, and we have combined the data for a 5-min time interval into a single size distribution. Actually, the instrument completed a cycle of measurements in only 50 s, but we chose to integrate over a longer period because the fog was relatively stable and we wanted to reduce statistical counting errors.

The drop size distributions obtained from these measurements are displayed in figure 3; the dashed curve derives from the manufacturer's calibration, and the solid curve from our Mie calibration. (In both distributions the data from the first channel [of range 3] has been ignored because it was suspect.) Numerous other size distribution comparisons are given in appendix C. We note that the distribution derived from our calibration has fewer size channels, which results from the fact that we cannot use pulse height discriminator levels set in regions of multivalued response--such channels must be

grouped together to avoid these regions. In fact, we suggest that the peaks around $0.6\mu\text{m}$ and $2\mu\text{m}$ radius which appear in the distribution derived from the manufacturer's calibration are a consequence of particle pile-up in channels where the response is multivalued or slowly changing. Thus, the overall shape of the distribution derived from the manufacturer's calibration is correct, but it contains artificial humps, knees and points of inflection near sizes where the Mie response function oscillates. These artifacts can only be expected to appear if the instrument is properly aligned and calibrated; otherwise, the Mie resonances may not be resolvable. Additionally, the artifacts will likely not appear for haze aerosol unless the particles are homogeneous and spherical.

The fact that the drop size distributions derived from the manufacturer's calibration in the $10\mu\text{m}$ to $15\mu\text{m}$ region show a more pronounced peak is the result of the slightly different character of the response curves in this region (see figure 2).

Finally, we note that the liquid water contents for the distributions in figure 3 differ by only 16 percent (the Mie calibration resulting in lower liquid content), suggesting the manufacturer's calibration is adequate for liquid water content determinations in cloud and fog. The differences in extinction coefficients calculated from these distributions are also small; we found the extinction coefficient to be 28 percent lower for the Mie calibration at a wavelength $\lambda = 0.55\mu\text{m}$, 26 percent lower at $\lambda = 4\mu\text{m}$, and 16 percent lower at $\lambda = 10\mu\text{m}$. Comparisons of liquid water content and extinction coefficients for a wide range of fog measurements, contained in appendix D, show similar differences.

FSSP MEASUREMENTS OF OTHER SPHERICAL PARTICLES

Measurement of particles other than fog or cloud with the FSSP requires a different calibration. If the particles are homogeneous spheres, then the calibration can easily be worked out from the response curves (by grouping channels together to avoid regions of multivalued response) in much the same way as for water. Examples of response curves for several refractive indexes characteristic of atmospheric aerosol constituents are shown in figure 4. As is evident from the figure, the positions of the resonances are refractive index-dependent. The manufacturer's calibration very roughly approximates the general form of these response curves, except for absorptive particles with radii greater than $3\mu\text{m}$.

To demonstrate our calibration procedure for homogeneous particles with refractive index $m = 1.45 - 0i$ we measured in the laboratory an aerosol of Dow Corning 200 fluid. The resulting size distributions inferred from the data appear in figure 5. For this aerosol the artifacts in the distribution derived from the manufacturer's calibration move to slightly smaller particle sizes (as compared to fog, figure 3), since the oscillations in the response functions are shifted (compare the theoretical response curves for $m = 1.33 - 0i$ and $m = 1.45 - 0i$ in figures 2 and 4). We have not made independent measurements of the Dow oil drop size distribution, so this figure by itself does not prove that our calibration procedure is more valid than that supplied by the

manufacturer. However, it is unlikely that our technique of aerosol generation (a nebulizer) would result in the bimodal distribution of droplets that results from invoking the manufacturer's calibration.

In cases where the FSSP is used to measure aerosol of unknown or mixed composition (and refractive index), we suggest that the manufacturer's calibration be used, with corrections for error in particle size determined by an envelope encompassing the possible response curves. Under the constraint that no large ($> 3\mu\text{m}$ radius) absorptive particles are present, these errors can be expected to be on the order of a factor 2 or less.

FSSP MEASUREMENTS OF IRREGULAR PARTICLES

The FSSP calibration for irregular particles is not so clear-cut as it is for spheres. One problem is that the intensity of light scattered by a nonspherical particle depends on its orientation with respect to the laser beam direction, so that even identical nonspherical particles measured with the FSSP may result in markedly different response pulses. This will obviously degrade the size resolution of the instrument. There is also the complication of deciding what equivalent radius to assign to irregular particles which might have rather complex morphology--such particles commonly occur in the atmosphere.

We decided to make only a superficial investigation of the FSSP response to irregular particles by limiting our measurements to only slightly nonspherical pollens and spores. Figure 6 shows micrographs of some of these particles, which include puff ball spores, paper mulberry, ragweed, lycopodium, sweet vernal, and pecan pollens. The measured response to these particles, shown compared to the calculated response for spheres of equal cross section, are presented in figure 7. Also shown for comparison is the FSSP manufacturer's calibration. The comparison suggests that the FSSP responds to slightly nonspherical particles very nearly as it would to spheres of equal cross section and refractive index. We can also conclude that application of the manufacturer's calibration to measurements of slightly nonspherical atmospheric aerosols (which generally have refractive indexes close to that of pollens and spores) will lead to undersizing of the particles, but probably by not more than a factor 2. (We realize of course that the manufacturer did not intend that his calibration be used for atmospheric aerosols.)

Our speculation regarding the FSSP response to ice particles (which have refractive index 1.30-0i) is that if the particles are only slightly irregular (like the pollen particles of figure 6) their response can be approximated by that of water spheres. However, it is doubtful that their response characteristics would evidence resonance structure. Therefore, we cannot recommend our calibration procedure over that supplied by the manufacturer in this case.

FSSP SAMPLING LOSSES

In its normal configuration the FSSP is aircraft-mounted. However, it can be purchased with an aspirator and horn for ground or laboratory use. Since the FSSP is capable of sensing particles that have appreciable fall speeds, the question of nonisokinetic sampling losses was investigated. To accomplish this, a mixture of relatively small ($7\mu\text{m}$ mean diameter) puff ball spores and rather large ($40\mu\text{m}$ mean diameter) glass beads were sprinkled into the ambient air within about 5 cm of the FSSP horn. (The aspirator fan draws air through the horn and FSSP inlet [which has minimum diameter 1.9 cm] at a rate of 0.5 l s^{-2}). The proportion of spores to beads measured by the FSSP (for either vertical or horizontal horn orientations) was in good agreement (within 50 percent) with that determined by counting the number of spores and beads in the mixture sprinkled onto a microscope slide. It should be mentioned that there is considerable uncertainty in determining the proportion of spores to beads in both FSSP and microscope measurements because a significant fraction of the spores stick to the larger beads. In any case, assuming that the $7\mu\text{m}$ spores are sampled with 100 percent efficiency under calm air conditions (which is a reasonable assumption), these results suggest a similar efficiency for the larger beads (and cloud droplets at least $40\mu\text{m}$ in diameter).

CONCLUSION

In summary, utilization of the FSSP manufacturer-supplied calibration will lead to fairly accurate values of cloud or fog liquid water content, but the true cloud or fog drop size distributions will be distorted. These distortions are evident in the form of bumps or knees in the size distribution at about $0.6\mu\text{m}$ and $2\mu\text{m}$ radii and are a consequence of the instrument having multivalued or slowly varying response in these regions of particle size. We have offered an alternative calibration procedure that removes these artifacts in the drop size distribution. This calibration procedure can be applied with slight modification to FSSP measurements of polydispersions of particles other than water, providing they are spherical and uniform in composition. For measurement of slightly irregular particles or particles of mixed composition, the manufacturer's calibration will generally lead to under-sizing of particles, but likely by not more than a factor 2.

TABLE 1. PARTICLE SIZE CHANNEL WIDTHS (RADIUS IN MICROMETERS) FOR THE KNOLLEBERG FSSP LIGHT SCATTERING AEROSOL COUNTER*

Channel	Instrument Range											
	0		1		2		3					
	a	b	a	b	a	b	a	b	a	b	a	b
1	1.0-2.5	-	1.0-2.0	-	0.5-1.0	0.5	0.25-0.5	-				
2	2.5-4.0	-	2.0-3.0	1.4	1.0-1.5	1.4	0.50-0.75	0.5				
3	4.0-5.5	3.2 - 5.4	3.0-4.0	3.1	1.5-2.0	1.4	0.75-1.0	-				
4	5.5-7.0	5.4	4.0-5.0	3.1	2.0-2.5	1.4	1.00-1.25	-				
5	7.0-8.5	7.6	5.0-6.0	5.8	2.5-3.0	3.3	1.25-1.5	-				
6	8.5-10	7.6	6.0-7.0	5.8	3.0-3.5	3.3	1.50-1.75	1.4				
7	10-11.5	10.7	7.0-8.0	7.1	3.5-4.0	5.1	1.75-2.0	1.4				
8	11.5-13	10.7	8.0-9.0	7.1	4.0-4.5	5.1	2.00-2.25	-				
9	13-14.5	14.2	9.0-10	8.7	4.5-5.0	6.4	2.25-2.5	-				
10	14.5-16	14.2	10-11	8.7	5.0-5.5	6.4	2.50-2.75	-				
11	16-17.5	18.0	11-12	11.3	5.5-6.0	6.4	2.75-3.0	-				
12	17.5-19	18.0	12-13	11.3	6.0-6.5	7.5	3.00-3.25	-				
13	19-20.5	21.4	13-14	13.5	6.5-7.0	7.5	3.25-3.5	2.5				
14	20.5-22	21.4	14-15	13.5	7.0-7.5	7.5	3.5-3.75	-				
15	22-23.5	24.6	15-16	16.2	7.5-8.0	7.5	3.75-4.0	3.6				

* (a) As specified by FMS

(b) Present work, under the assumption particles are water droplets

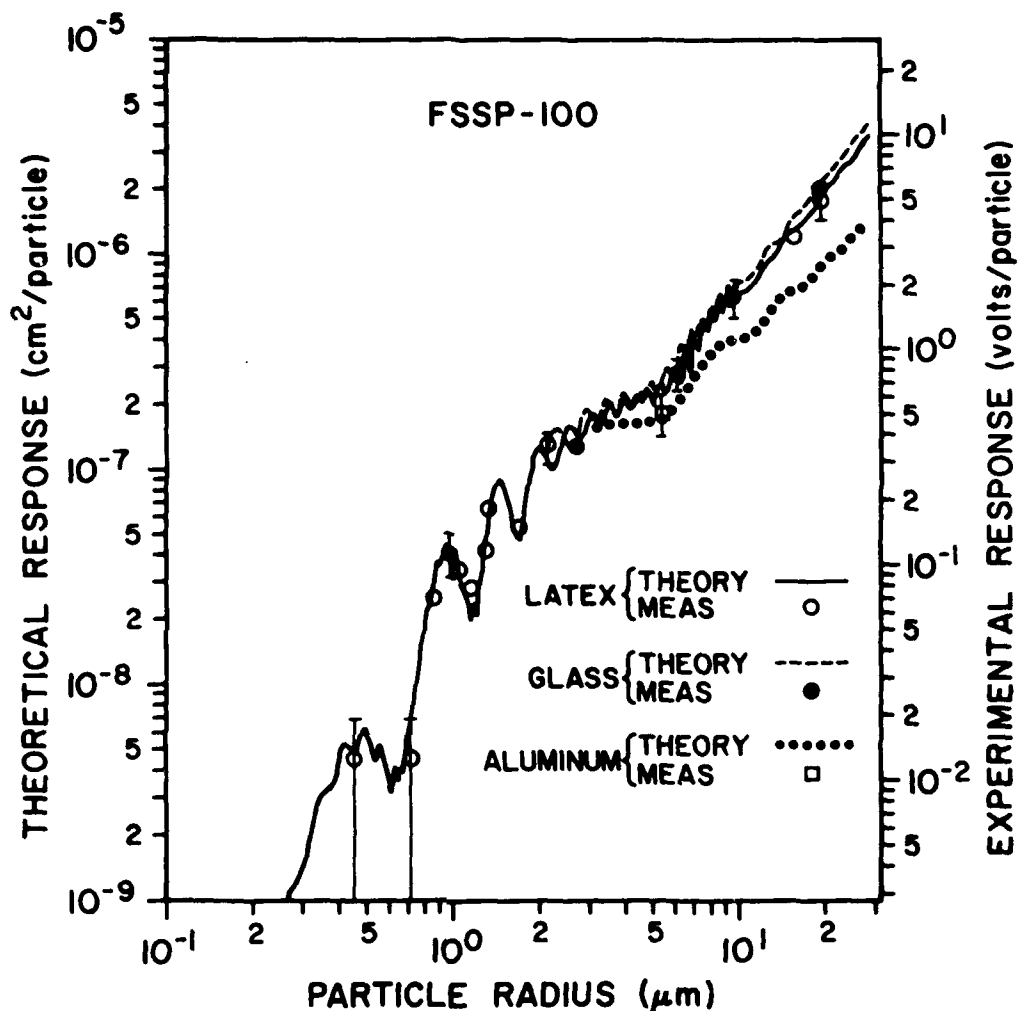


Figure 1. Comparison of the Knollenberg FSSP response: measured for latex spheres with refractive index $m = 1.588 - 0i$ (open circles), glass beads with $m = 1.51 - 0i$ (closed circles), and aluminum spheres with $m = 1.44 - 3.69i$ (square); and calculated using Mie scattering theory (smooth curves). The latex particles used include particle diameters $0.945\mu\text{m}$, $1.48\mu\text{m}$, $1.74\mu\text{m}$, $32.2\mu\text{m}$, $40\mu\text{m}$ polystyrene; $2.02\mu\text{m}$, $2.154\mu\text{m}$, $2.35\mu\text{m}$ polyvinyltoluene; and $2.70\mu\text{m}$, $2.77\mu\text{m}$, $3.44\mu\text{m}$, $4.33\mu\text{m}$ styrene divinylbenzene. The theoretical curves for glass beads and aluminum only extend down to about $3\mu\text{m}$ radius.

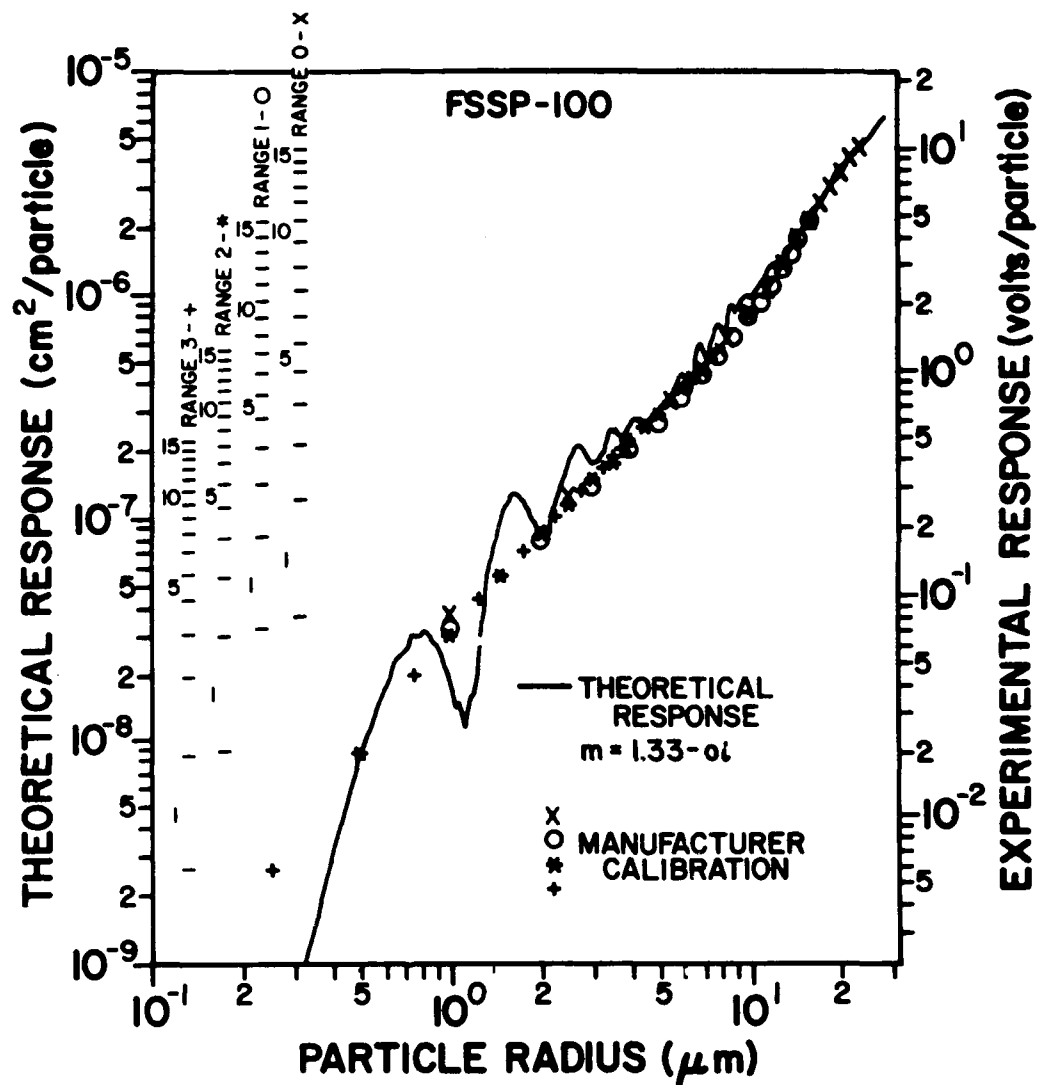


Figure 2. Relation between the FSSP response and water drop size as predicted by theory (smooth curve), and as advertised by the manufacturer (points). The pulse height discriminator level settings (for ranges 0, 1, 2, and 3) used in this particular instrument are also shown.

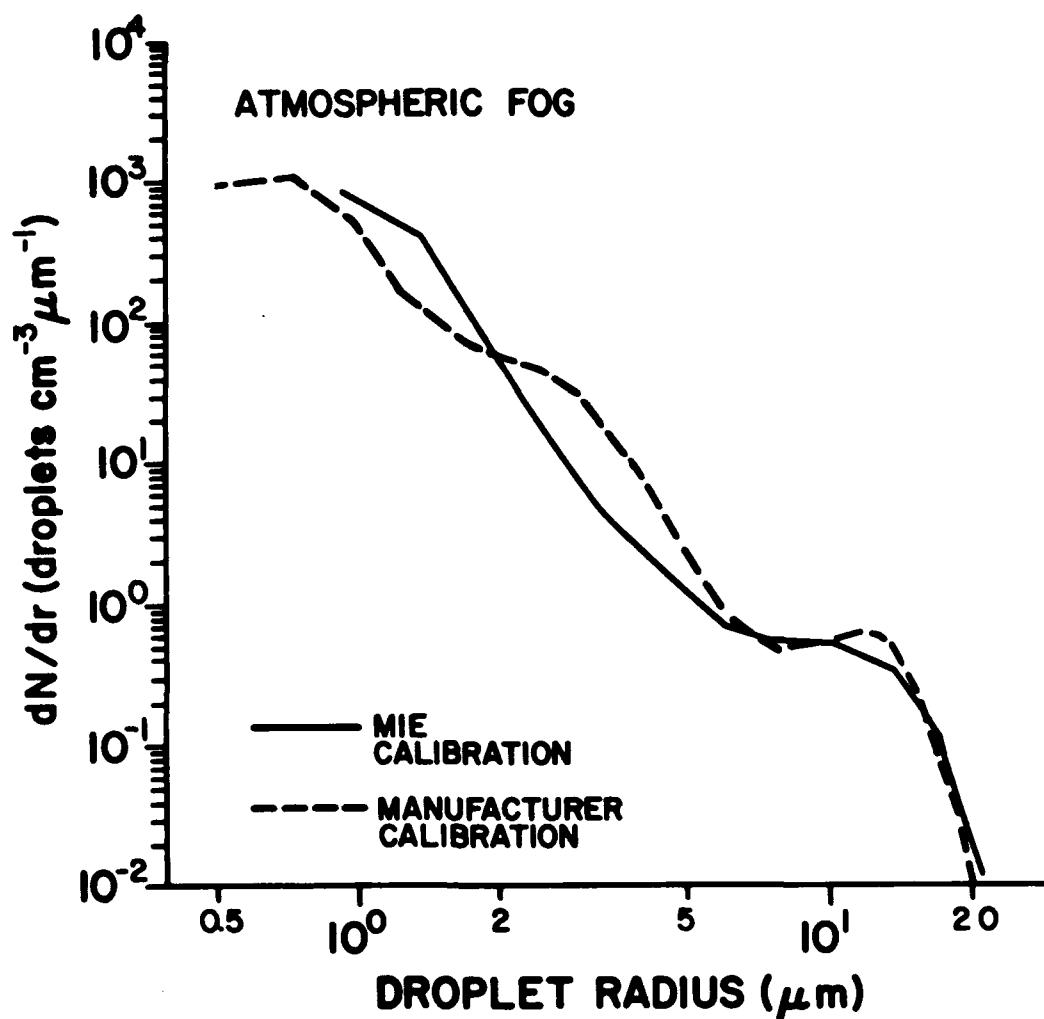


Figure 3. Comparison of FSSP fog drop size distributions obtained in two ways: one using the manufacturer-supplied calibration (dashed curve) and the other using our suggested calibration based on the theoretical response curve of figure 2 (solid curve). The peaks that appear around 0.6 μ m and 2 μ m radius in the dashed-curve distribution are believed to be artifacts caused by multivalued response characteristics of the FSSP instrument.

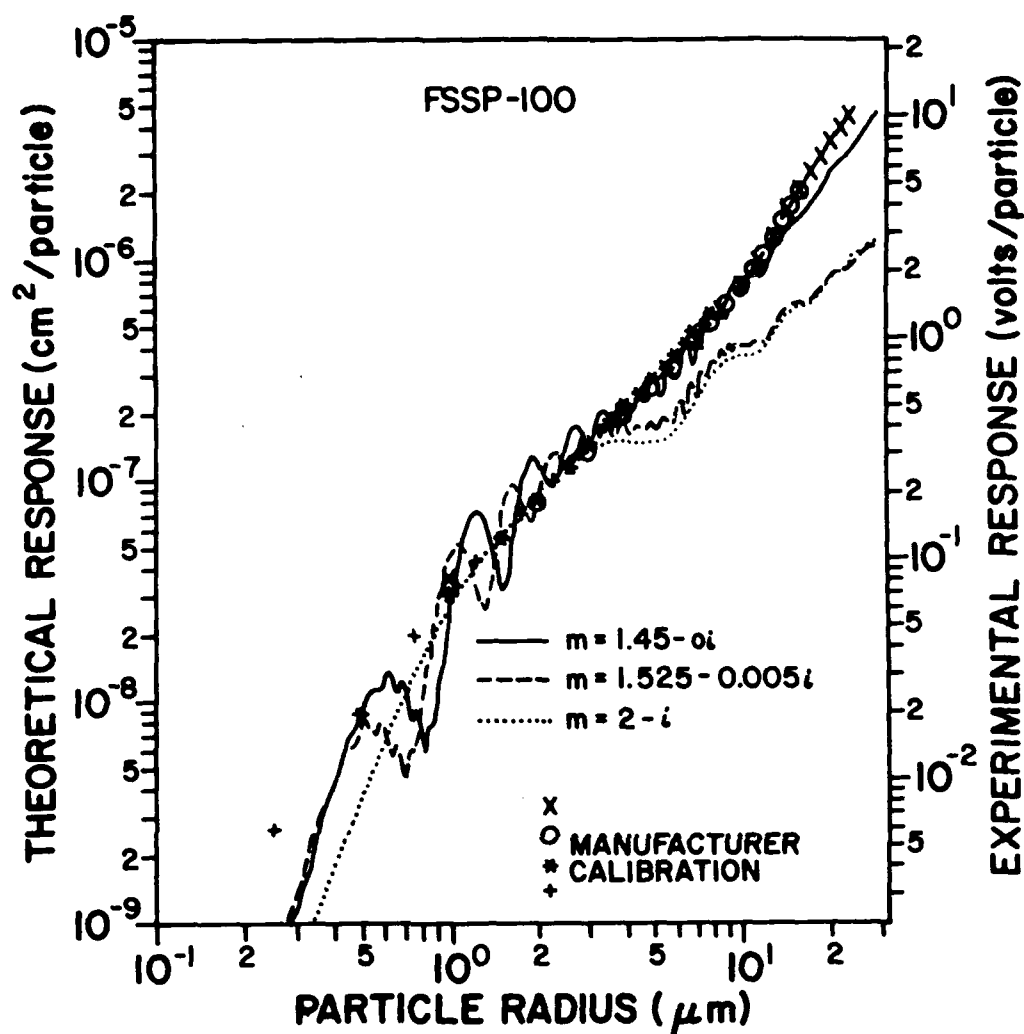


Figure 4. FSSP response curves for particles with refractive indexes characteristic of those of atmospheric constituents: soil-derived aerosols with $m = 1.525 - 0.005i$,^a desert aerosols with $m = 1.45 - 0i$,^a and carbonaceous aerosol with $m = 2 - i$. The manufacturer-supplied calibration relating instrument response to particle size is shown for comparison.

^aGrams, G. W., I. H. Blifford, Jr., D. A. Gillette, and P. B. Russell, "Complex Index of Refraction of Airborne Soil Particles," J Appl Meteorol, 13:459-471, 1974.

^bReagan, J. A., D. M. Byrne, M. D. King, J. D. Spinhirne, and B. M. Herman, "Determination of the Complex Refractive Index and Size Distribution of Atmospheric Particulates From Bistatic-Monostatic Lidar and Solar Radiometer Measurements," J Geophys Res, 85:1591-1599, 1980.

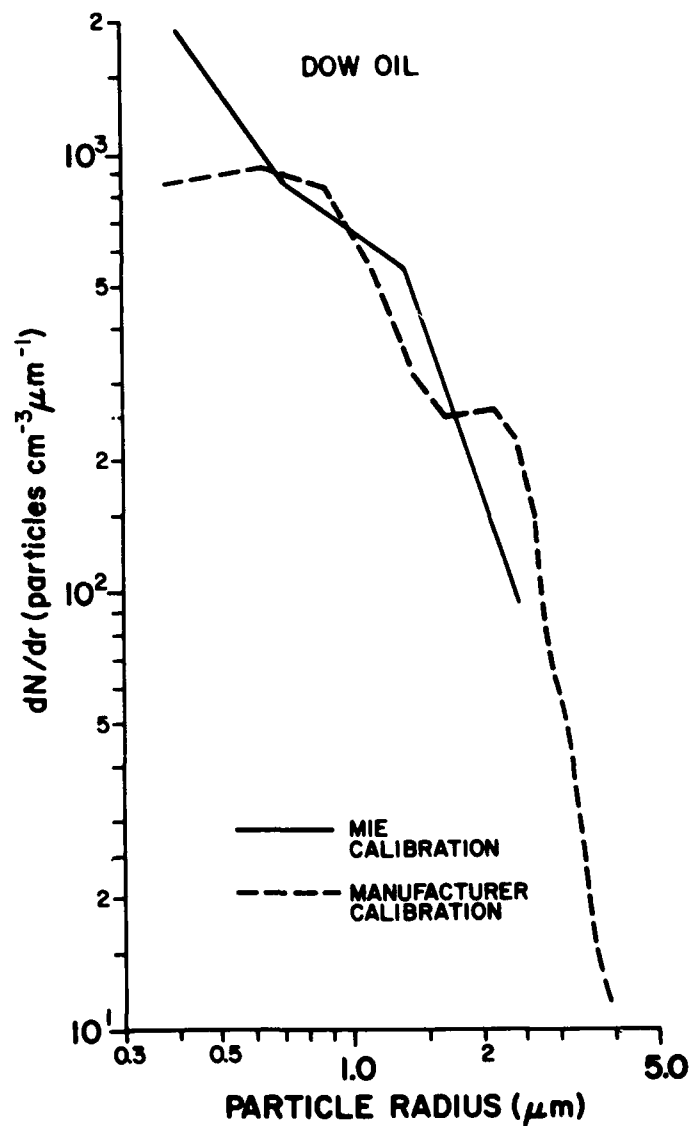


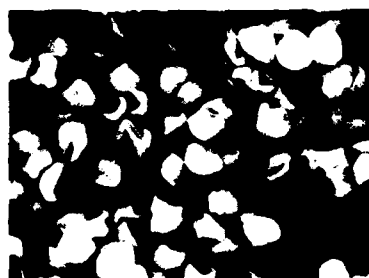
Figure 5. Same as figure 3, except in this case oil droplets (with $m = 1.45-0i$) were measured rather than fog. The bumps in the size distribution derived from the manufacturer-supplied calibration (dashed curve) again are believed to be artifacts caused by multivalued response characteristics of the FSSP. The bumps are shifted to slightly smaller sizes (as compared to fog) in accordance with the shift in the positions of the oscillations in the response curve.



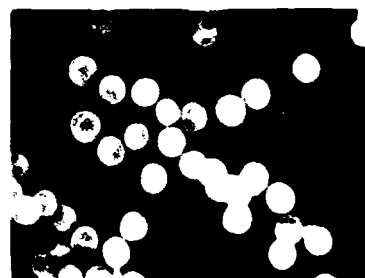
10 μ m
puff ball spores



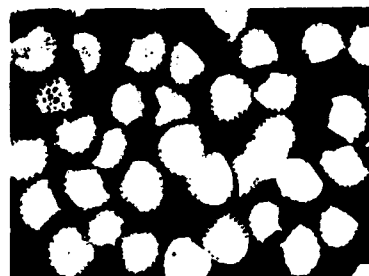
10 μ m
puff ball spores



50 μ m
paper mulberry



50 μ m
ragweed



50 μ m
lycopodium



50 μ m
pecan

Figure 6. Scanning electron microscope micrographs of slightly nonspherical pollens and spores used to measure the FSSP response characteristics.

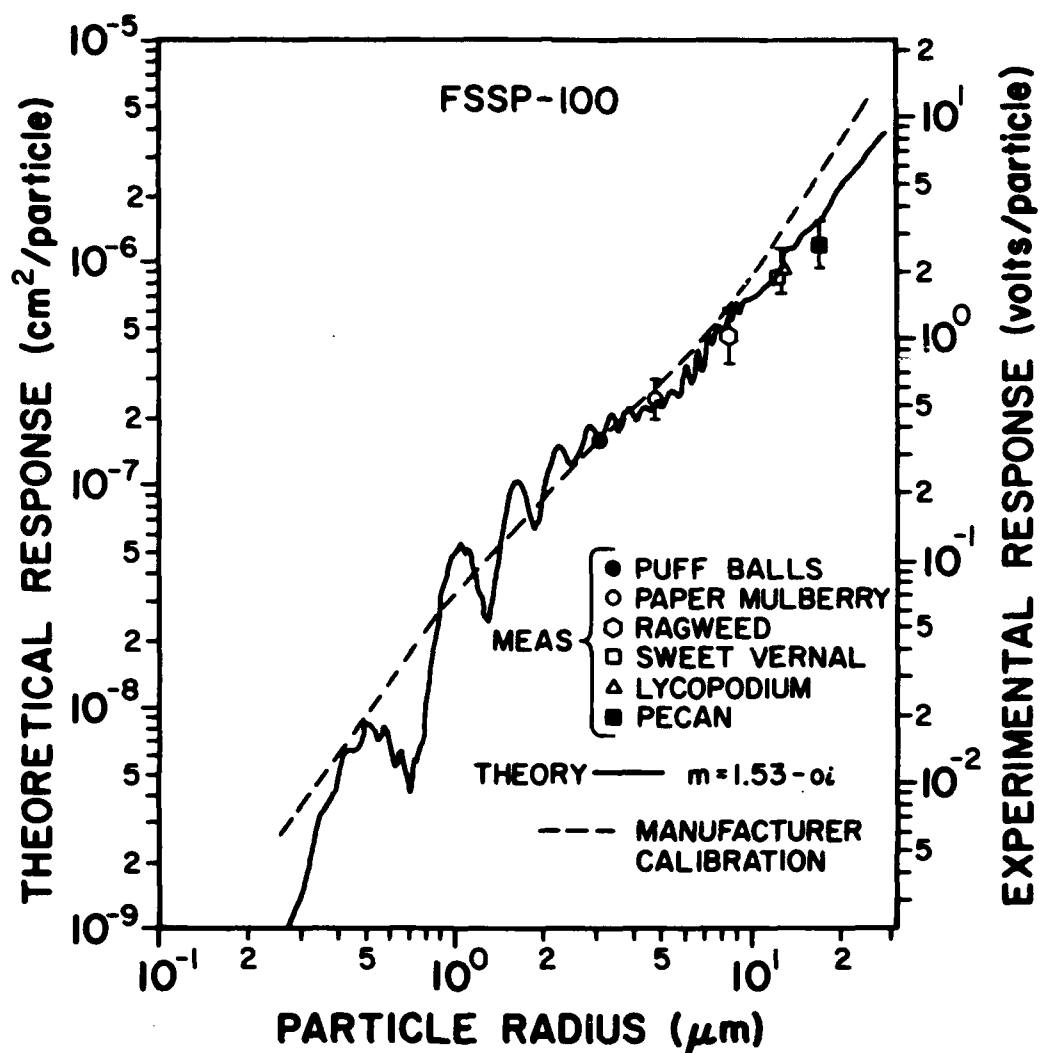


Figure 7. Measurements of the FSSP response to slightly nonspherical pollen and spore particles (some of which are shown in figure 6). The measurements are compared to the theoretical response for spheres of equal cross section (smooth curve) and to the manufacturer-supplied calibration (dashed curve).

REFERENCES

1. Stephens, G. L., G. W. Paltridge, and C. M. R. Platt, "Radiation Profiles in Extended Water Clouds. III: Observations," J Atmos Sci, 35:2133-2141, 1978.
2. Heymsfield, A. J., C. A. Knight, and J. E. Dye, "Ice Initiation in Unmixed Updraft Cores in Northeast Colorado Cumulus Congestus Clouds," J Atmos Sci, 36:2216-2229, 1979.
3. Low, R. D. H., L. D. Duncan, and Y. Y. Roger R. Hsiao, Microphysical and Optical Properties of California Coastal Fogs at Fort Ord, ASL-TR-0034, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 1979.
4. Low, R. D. H., Fog Evolution in the Visible and Infrared Spectral Regions and its Meaning in Optical Modeling, ASL-TR-0046, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 1979.
5. Duncan, L. D., and R. D. H. Low, Bimodal Size Distributions Models for Fogs at Meppen, Germany, ASL-TR-0056, US Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM, 1980.
6. Pinnick, R. G., and H. J. Auvermann, "Response Characteristics of Knollenberg Light-Scattering Aerosol Counters," J Aerosol Sci, 10:55-74, 1979.
7. Cannon, T. W., and W. W. Grotewold, "Improved Drop Generators for Calibration of Drop Spectrometers and Use in Laboratory Cloud Physics Experiments," J Appl Meteorol, 19:901-905, 1980.
8. Grams, G. W., I. H. Blifford, Jr., D. A. Gillette, and P. B. Russell, "Complex Index of Refraction of Airborne Soil Particles," J Appl Meteorol, 13:459-471, 1974.
9. Reagan, J. A., D. M. Byrne, M. D. King, J. D. Spinhirne, and B. M. Herman, "Determination of the Complex Refractive Index and Size Distribution of Atmospheric Particulates From Bistatic-Monostatic Lidar and Solar Radiometer Measurements," J Geophys Res, 85:1591-1599, 1980.

APPENDIX A

FSSP RESPONSE FOR VARIOUS COLLECTING ANGLES

The solid angle over which scattered light is detected in the FSSP depends on the size of the dump spot located on the right angle prism and the dimension of the prism itself (see figure A-1). According to the manufacturer, the dump spot has a radius of 2 mm and light is collected out to a radius of 8.7 mm on the prism face. Since the prism face is 38 mm away from the particle plane, the limits of the solid angle over which light is detected are easily calculated: $\alpha = \arctan\left(\frac{2}{38}\right) \approx 3^\circ$, $\beta = \arctan\left(\frac{8.7}{38}\right) \approx 13^\circ$. These are the values used by Pinnick and Auvermann.¹

Because it is likely that these dimensions are not identical on every instrument, and because it is possible that for some instruments the laser beam may not be accurately centered on the dump spot, sensitivity calculations were made to determine the effects on the calculated response curve for small changes in α and β . Thus, response curves for water ($m = 1.33-0i$) were determined for the angle pairs $\alpha = 2.5^\circ$, $\beta = 14^\circ$; $\alpha = 3^\circ$, $\beta = 14^\circ$; and $\alpha = 3.5^\circ$, $\beta = 14^\circ$ (see figure A-2). It was found that increasing β by 1° results in a negligible change in the calculated response curve, but that changing α by 0.5° affects the response curve markedly. As α decreases from 3.5° to 2.5° , the response of the instrument is significantly enhanced for particles with radii greater than $\sim 2\mu\text{m}$ and the "knee" in the response curve moves from $\sim 3.5\mu\text{m}$ to $\sim 7\mu\text{m}$. These effects can be attributed to the forward "diffraction" lobe. For intermediate-sized particles the lobe becomes more sharply peaked in the forward direction, so that an appreciable fraction of the scattered light will be found between 2.5° and 3.5° . For larger particles the lobe becomes even more sharply peaked and the fraction of scattered light between 2.5° and 3.5° , while still appreciable, is reduced.

An additional factor not taken into account in calculating the FSSP response curves is the focusing of the incident laser light. Using an analytical expression derived by Hodkinson and Greenfield,² Cooke and Kerker³ have considered this effect for various optical counters in which the light is highly focused. Their formulation is based on the assumption that the light is

¹Pinnick, R. G., and H. J. Auvermann, "Response Characteristics of Knollenberg Light-Scattering Aerosol Counters," J Aerosol Sci, 10:55-74, 1979.

²Hodkinson, J. R., and J. R. Greenfield, "Response Calculations for Light-Scattering Aerosol Counters and Photometers," Appl Opt, 4:1463-1474, 1965.

³Cooke, D. D., and Milton Kerker, "Response Calculations for Light-Scattering Aerosol Particle Counters," Appl Opt, 14:734-739, 1975.

focused to a dimension that is large compared to the sizes of the particles, but sufficiently small that a photon passing the particle plane is equally likely to have "originated" from any point on the focusing lens. In the FSSP the light is focused to a diameter of $\sim 200\mu\text{m}$ at the particle plane. The half-angle of the focusing cone can be calculated as follows: $\alpha/2 = \arctan(\frac{1.5}{60}) \approx 1.4^\circ$, where the diameter of the laser beam at the condensing lens is 3 mm and the focal length of the condensing lens is 60 mm. The FSSP response curve for water, calculated using the expressions of Cooke and Kerker and normalized to unit intensity at the particle plane, generally falls between the curves for $\alpha = 2.5^\circ$, $\beta = 14^\circ$, and $\alpha = 3^\circ$, $\beta = 14^\circ$ in figure A-2. (It is closer to the latter curve.) The effect of the converging beam is thus to spread the detecting solid angle beyond the lower and upper limits of α and β .

The curve for $\alpha = 2.5^\circ$ and $\beta = 14^\circ$ probably places an upper bound on the actual response curve of the instrument. In this work the values $\alpha = 3^\circ$ and $\beta = 14^\circ$ have been used in calculating response curves for various refractive indexes. The curves do not differ in any significant way from those presented by Pinnick and Auvermann.¹

¹Pinnick, R. G., and H. J. Auvermann, "Response Characteristics of Knollenberg Light-Scattering Aerosol Counters," J Aerosol Sci, 10:55-74, 1979.

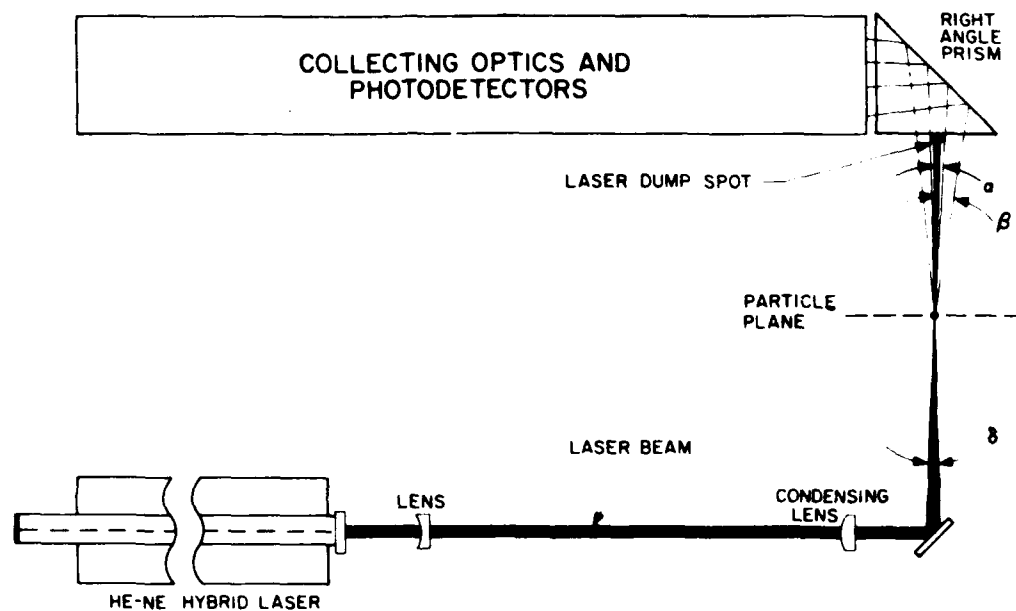


Figure A-1. Schematic of the FSSP-100 optical system.

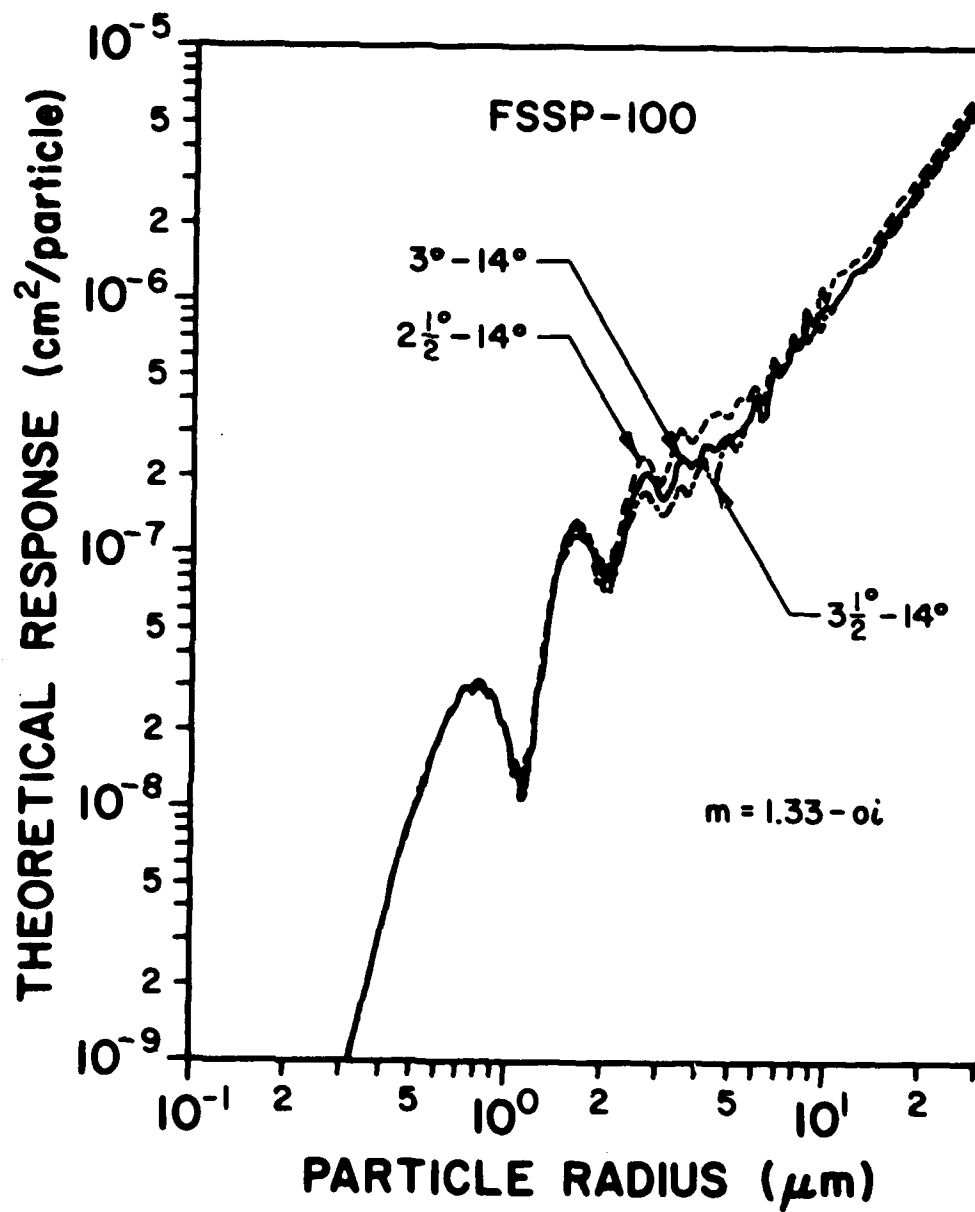


Figure A-2. FSSP response curves for water drops ($m = 1.33 - 0i$) for three slightly different solid angles subtended by the light-collecting optics. The solid angles are defined by the angle pairs $\alpha - \beta$ (see figure A-1).

APPENDIX B

THE MANUFACTURER'S FSSP CALIBRATION

In this appendix we show how the manufacturer's calibration for the FSSP is plotted relative to the theoretical response curve for water in figure 2. The problem is to determine the positions of the instrument discriminator level settings (which are given in the manual in terms of voltages) relative to the theoretical response (in centimeters²/particle).

Our first step is to determine the values of the discriminator level voltages (DL) for the different ranges of the instrument relative to each other (and worry later about the normalization to theoretical results). For convenience, we choose the top of channel 15, range 0 to be 10 V. The remaining discriminator levels in range 0 can then be taken to first order directly from the manual. To find the voltage levels for the remaining ranges (1, 2, and 3) the gain ratios (GR) for the corresponding preamplifiers must be deduced from the appropriate resistance values given in the manual. Once this gain ratio is found for a particular range, the voltage level for the top of channel 15 for that range can be calculated relative to 10 V (the top of channel 15, range 0). The remaining discriminator levels in that range can then again be determined from the corresponding voltages given in the manual.

A slight modification of this procedure is required because of the negative bias offset voltages (BO) employed in the processing of particle signals. Unfortunately, these bias offset voltages are different for different ranges and for different instruments, and may not be given in the manual. (They can be easily measured, however.) According to the manufacturer (private communication), the effective offset (EO) for each discriminator level is scaled according to the following equation:

$$EO = \left(\frac{10-DL}{10}\right)BO \quad (B-1)$$

where all voltages are in volts.

In order for a signal to achieve a voltage level above a given discriminator level, the amplified pulse due to a particular particle must first overcome this effective bias offset. Thus, the relative discriminator level settings (denoted MC for manufacturer calibration) can be calculated according to the following formula:

$$MC = \frac{DL + \left(\frac{10-DL}{10}\right)BO}{GR} \quad (B-2)$$

In this formula the value of MC is again normalized to 10 V at the top discriminator level of channel 15, range 0. These discriminator level settings (which depend on the preamplifier bias offsets for each range, the discriminator level voltages for each range, and the gain ratios) together with the particle size definitions given in the manual constitute the "manufacturer calibration" and are given in table B-1 for our particular FSSP instrument. It is important to note that there may be differences in bias offsets, discriminator level voltages, and gain ratios for FSSP's of different vintage; calibration of other instruments must necessarily take these differences into account.

The plot of relative discriminator level settings MC (in volts) versus particle size R is fixed by the above procedure. The normalization constant relating the experimental response (in volts) to the theoretically calculated scattering cross section (in centimeters²) can then be determined by using the experimentally derived response voltages for spherical particles of known size and index of refraction. Using this normalization, the manufacturer's calibration can be plotted relative to the theoretical response curve for the aerosol to be measured.

The normalization constant for our FSSP instrument, providing it is "in calibration" according to the manual, is $C = 2.2 \times 10^6 \text{ V cm}^{-2}$. As it turned out, our particular FSSP was slightly out of calibration during this study (latex particles peaked in a slightly higher channel than advertised in the manual), necessitating use of a slightly different normalization constant (we used $2.8 \times 10^6 \text{ V cm}^{-2}$). The normalization constant $C = 2.2 \times 10^6 \text{ V cm}^{-2}$ has been used in figures 2, 4, and 7 in order to avoid confusion regarding the application of these results for a particular instrument at a particular time to the more general problem of using the manufacturer's calibration for other FSSP. The response of similar instruments which are, in fact, in calibration according to the PMS instrument manual can be compared with any of the theoretical response curves given in this paper by using the value $C = 2.2 \times 10^6 \text{ V cm}^{-2}$. (The experimental response measurements shown in figures 1 and 7 are plotted using the normalization constant peculiar to our instrument $C = 2.8 \times 10^6 \text{ V cm}^{-2}$.)

TABLE B-1. FSSP-100 MANUFACTURER CALIBRATION

Channel	Range 0		Range 1		Range 2		Range 3	
	Radius (μm)	MC* (V)	Radius (μm)	MC (V)	Radius (μm)	MC (V)	Radius (μm)	MC (V)
16	23.5	10.0	16.0	4.562	8.0	1.260	4.0	0.497
15	22.0	8.785	15.0	3.905	7.5	1.146	3.75	0.455
14	20.5	7.651	14.0	3.331	7.0	1.037	3.5	0.414
13	19.0	6.579	13.0	2.829	6.5	0.933	3.25	0.375
12	17.5	5.567	12.0	2.390	6.0	0.833	3.0	0.336
11	16.0	4.620	11.0	2.011	5.5	0.738	2.75	0.298
10	14.5	3.703	10.0	1.688	5.0	0.646	2.5	0.262
9	13.0	2.868	9.0	1.412	4.5	0.559	2.25	0.226
8	11.5	2.223	8.0	1.172	4.0	0.475	2.0	0.192
7	10.0	1.715	7.0	0.960	3.5	0.397	1.75	0.159
6	8.5	1.309	6.0	0.772	3.0	0.322	1.5	0.127
5	7.0	0.978	5.0	0.601	2.5	0.251	1.25	0.0973
4	5.5	0.692	4.0	0.446	2.0	0.184	1.0	0.0690
3	4.0	0.459	3.0	0.305	1.5	0.123	0.75	0.0445
2	2.5	0.263	2.0	0.178	1.0	0.0671	0.5	0.0198
1	1.0	0.0789	1.0	0.0697	0.5	0.0199	0.25	0.0059

*MC denotes the relative discriminator level setting and was calculated according to equation B-2 using discriminator level voltages DL from the instrument manual; gain ratios GR of 1.00, 2.192, 7.935, 20.1 (for ranges 0, 1, 2, 3); and bias offsets BO of 20 mV, 25 mV, 30 mV, 60 mV (for ranges 0, 1, 2, 3).

APPENDIX C

FSSP MEASUREMENTS OF FOG DROP SIZE DISTRIBUTIONS

The data shown in these figures are for 5-min samples taken in Meppen at the dates and times indicated. Comparisons of FSSP fog drop size distributions were obtained in two ways: one using the manufacturer-supplied calibration (dashed curve) and the other using our suggested calibration based on the theoretical response curve of figure 2 (solid curve). The peaks that appear around $0.6\mu\text{m}$ and $2\mu\text{m}$ radius in the dashed-curve distributions are believed to be artifacts caused by multivalued response characteristics of the FSSP instrument.

PRECEDING PAGE BLANK-NOT FILMED

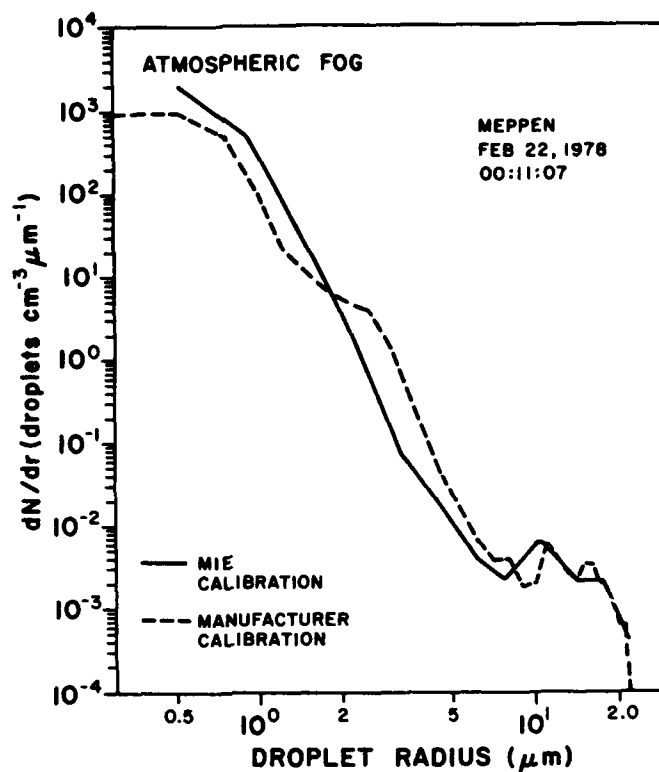


Figure C-1. Comparison for sample taken at 00:11:07, 22 Feb 1978.

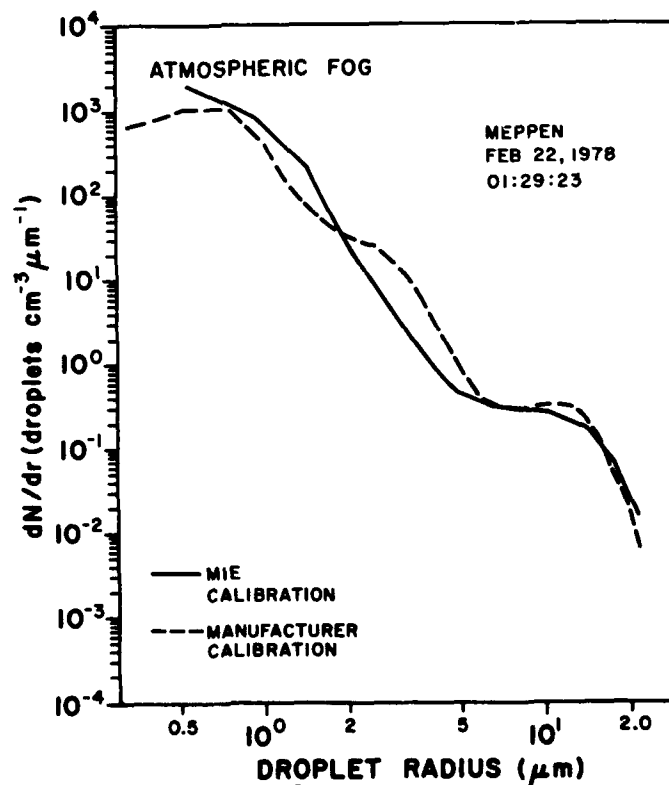


Figure C-2. Comparison for sample taken at 01:29:23, 22 Feb 1978.

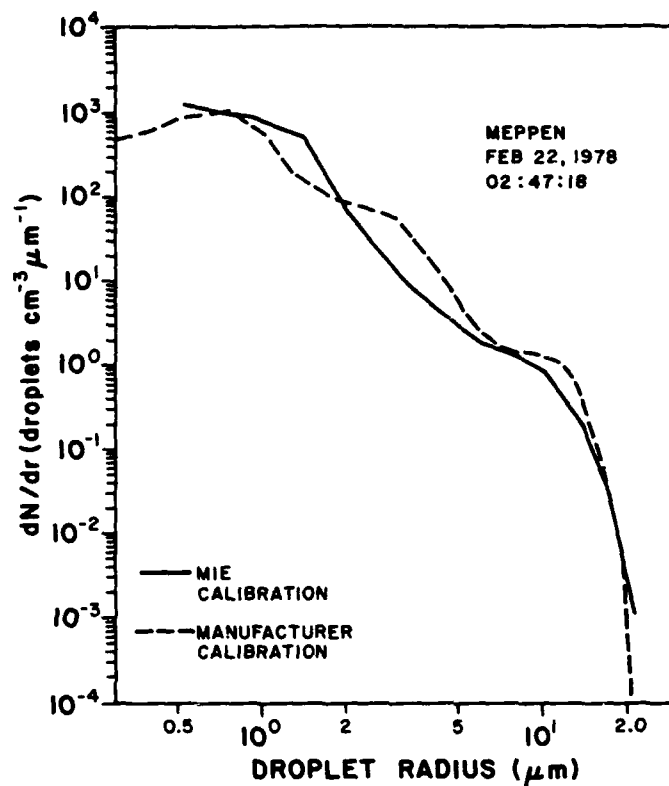


Figure C-3. Comparison for sample taken at 02:47:18, 22 Feb 1978.

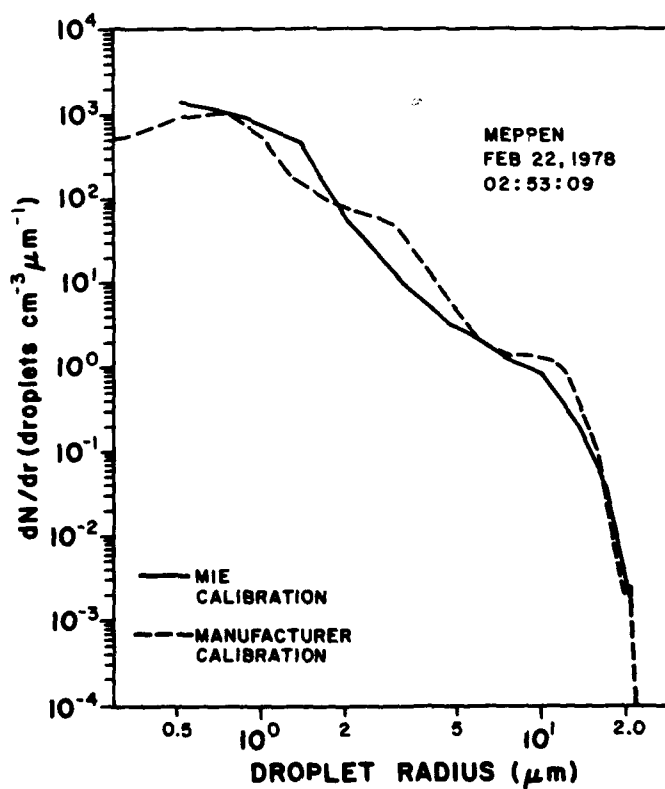
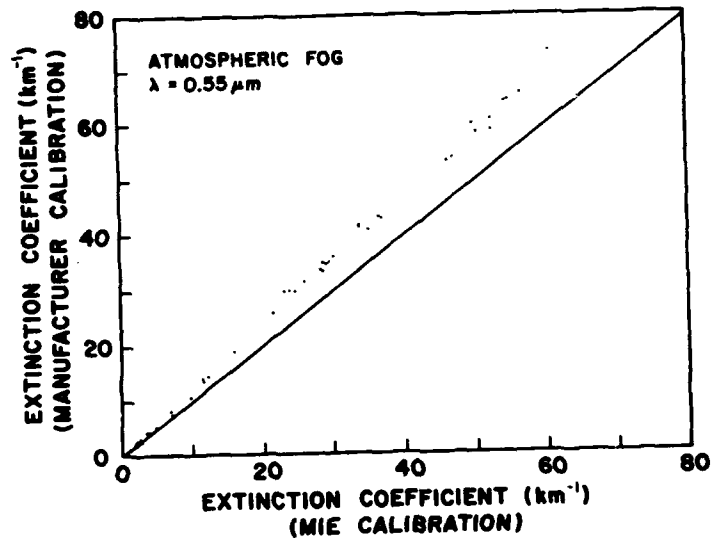


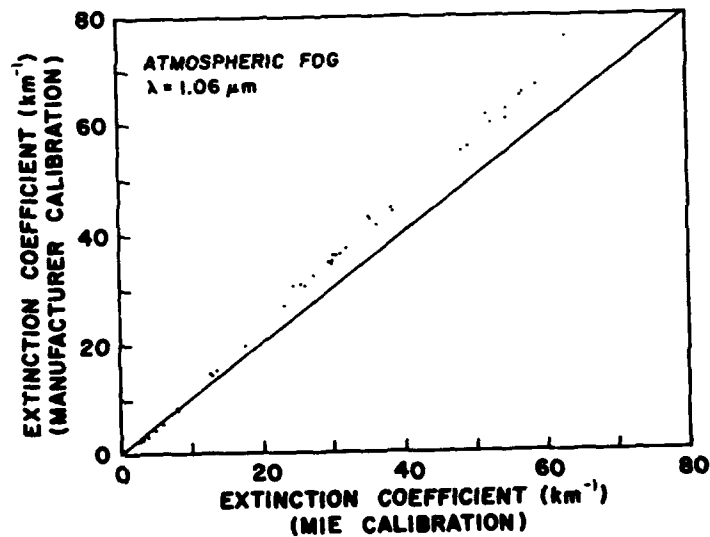
Figure C-4. Comparison for sample taken at 02:53:09, 22 Feb 1978.

APPENDIX D

CALCULATIONS OF EXTINCTION COEFFICIENTS AND LIQUID WATER CONTENTS BASED ON FSSP DATA

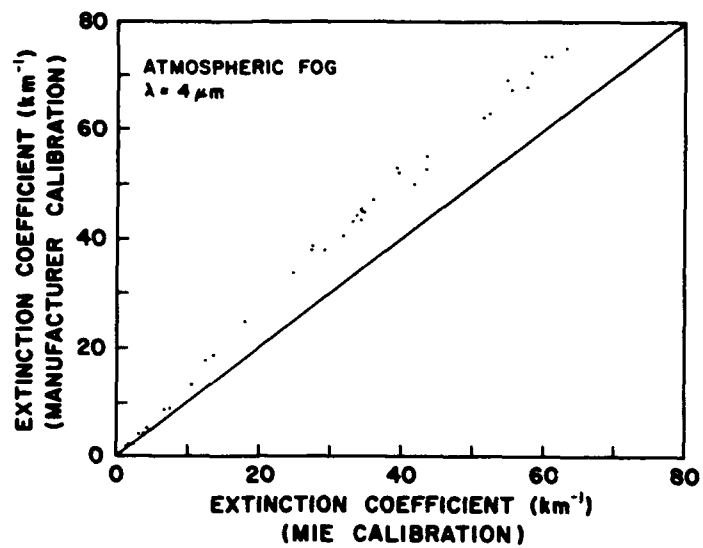


(a)

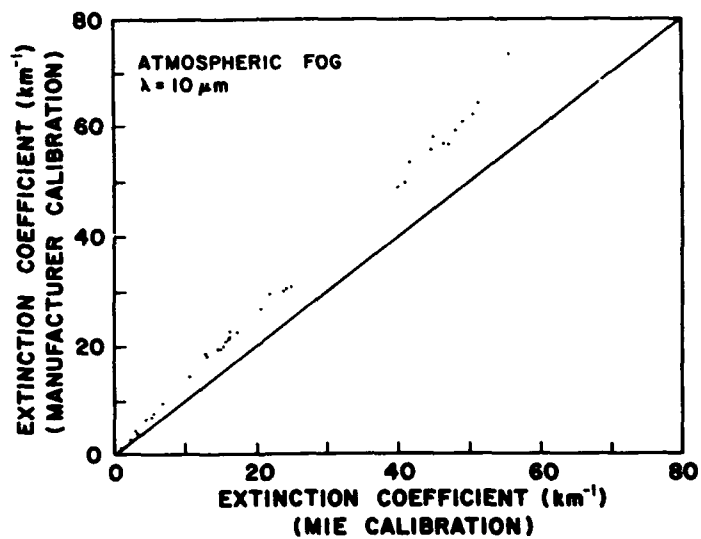


(b)

Figure D-1. Comparison of fog extinction coefficients calculated from FSSP drop size distributions measured during February 1978 in Meppen, Germany. Extinction coefficients are calculated for each case in two ways: one is based on the FSSP manufacturer-supplied calibration and the other is based on our Mie calibration given in table 1. The results show the extinction coefficients derived from the manufacturer calibration are overestimated compared to those based on our Mie calibration, but not by more than 20 percent.



(c)



(d)

Figure D-1. (cont)

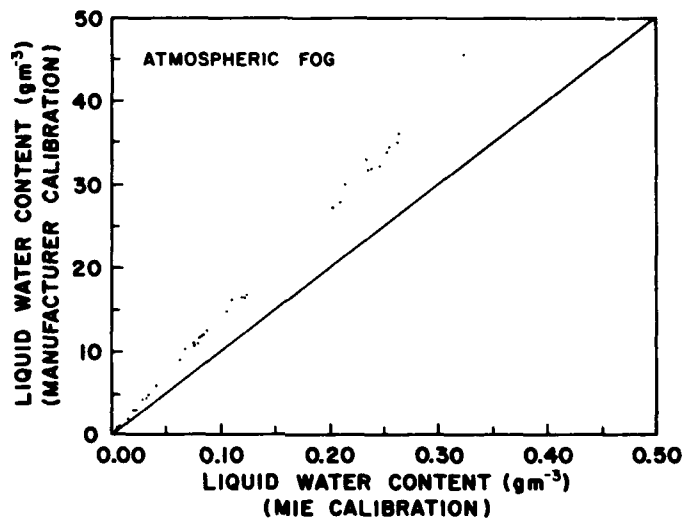


Figure D-2. Comparison of fog liquid water content calculated from FSSP drop size distributions measured during February 1973 in Meppen, Germany. Liquid water content values are calculated in each case two ways: one is based on the FSSP manufacturer-supplied calibration and the other is based on our Mie calibration given in table 1. The results show the liquid water contents derived from the manufacturer calibration are overestimated compared to those based on our Mie calibration, but not by more than 25 percent.

ELECTRO-OPTICS DISTRIBUTION LIST

Commander
US Army Aviation School
Fort Rucker, AL 36362

Commander
US Army Aviation Center
ATTN: ATZQ-D-MA (Mr. Oliver N. Heath)
Fort Rucker, AL 36362

Commander
US Army Aviation Center
ATTN: ATZQ-D-MS (Mr. Donald Wagner)
Fort Rucker, AL 36362

NASA/Marshall Space Flight Center
ATTN: ES-83 (Otha H. Vaughan, Jr.)
Huntsville, AL 35812

NASA/Marshall Space Flight Center
Atmospheric Sciences Division
ATTN: Code ES-81 (Dr. William W. Vaughan)
Huntsville, AL 35812

Nichols Research Corporation
ATTN: Dr. Lary W. Pinkley
4040 South Memorial Parkway
Huntsville, AL 35802

John M. Hobbie
c/o Kentron International
2003 Byrd Spring Road
Huntsville, AL 35802

Mr. Ray Baker
Lockheed-Missile & Space Company
4800 Bradford Blvd
Huntsville, AL 35807

Commander
US Army Missile Command
ATTN: DRSMI-OG (Mr. Donald R. Peterson)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-OGA (Dr. Bruce W. Fowler)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REL (Dr. George Emmons)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REO (Huey F. Anderson)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REO (Mr. Maxwell W. Harper)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-REO (Mr. Gene Widenhofer)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RHC (Dr. Julius Q. Lilly)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
Redstone Scientific Information Center
ATTN: DRSMI-RPRD (Documents Section)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RRA (Dr. Oskar Essenwanger)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RRO (Mr. Charles Christensen)
Redstone Arsenal, AL 35809

Commander
US Army Missile Command
ATTN: DRSMI-RRO (Dr. George A. Tanton)
Redstone Arsenal, AL 35809

Commander
US Army Communications Command
ATTN: CC-OPS-PP
Fort Huachuca, AZ 85613

Commander
US Army Intelligence Center & School
ATTN: ATSI-CD-CS (Mr. Richard G. Cundy)
Fort Huachuca, AZ 85613

Commander
US Army Intelligence Center & School
ATTN: ATSI-CD-MD (Mr. Harry Wilder)
Fort Huachuca, AZ 85613

Commander
US Army Intelligence Center & School
ATTN: ATSI-CS-C (2LT Coffman)
Fort Huachuca, AZ 85613

Commander
US Army Yuma Proving Ground
ATTN: STEYP-MSA-TL
Bldg 2105
Yuma, AZ 85364

Northrop Corporation
Electro-Mechanical Division
ATTN: Dr. Richard D. Tooley
500 East Orangethorpe Avenue
Anaheim, CA 92801

Commander
Naval Weapons Center
ATTN: Code 3918 (Dr. Alexis Shlanta)
China Lake, CA 93555

Hughes Helicopters
Army Advanced Attack Helicopter Weapons
ATTN: Mr. Charles R. Hill
Centinela and Teale Streets
Bldg 305, MS T-73A
Culter City, CA 90230

Commander
US Army Combat Developments
Experimentation Command
ATTN: ATEC-PL-M (Mr. Gary G. Love)
Fort Ord, CA 93941

SRI International
ATTN: K2060/Dr. Edward E. Uthe
333 Ravenswood Avenue
Menlo Park, CA 94025

SRI International
ATTN: Mr. J. E. Van der Laan
333 Ravenswood Avenue
Menlo Park, CA 94025

Joane May
Naval Environmental Prediction
Research Facility (NEPRF)
ATTN: Library
Monterey, CA 93940

Sylvania Systems Group,
Western Division
GTE Products Corporation
ATTN: Technical Reports Library
P.O. Box 205
Mountain View, CA 94042

Sylvania Systems Group
Western Division
GTE Products Corporation
ATTN: Mr. Lee W. Carrier
P.O. Box 188
Mountain View, CA 94042

Pacific Missile Test Center
Geophysics Division
ATTN: Code 3250-3 (R. de Violini)
Point Mugu, CA 93042

Pacific Missile Test Center
Geophysics Division
ATTN: Code 3253 (Terry E. Battalino)
Point Mugu, CA 93042

Effects Technology Inc.
ATTN: Mr. John D. Carlyle
5383 Hollister Avenue
Santa Barbara, CA 93111

Commander
Naval Ocean Systems Center
ATTN: Code 532 (Dr. Juergen Richter)
San Diego, CA 92152

Commander
Naval Ocean Systems Center
ATTN: Code 5322 (Mr. Herbert G. Hughes)
San Diego, CA 92152

Commander
Naval Ocean Systems Center
ATTN: Code 4473 (Tech Library)
San Diego, CA 92152

The RAND Corporation
ATTN: Ralph Huschke
1700 Main Street
Santa Monica, CA 90406

Particle Measuring Systems, Inc.
ATTN: Dr. Robert G. Knollenberg
1855 South 57th Court
Boulder, CO 80301

US Department of Commerce
National Oceanic and Atmospheric Admin
Environmental Research Laboratories
ATTN: Library, R-51, Technical Reports
325 Broadway
Boulder, CO 80303

US Department of Commerce
National Oceanic and Atmospheric Admin
Environmental Research Laboratories
ATTN: R45X3 (Dr. Vernon E. Derr)
Boulder, CO 80303

US Department of Commerce
National Telecommunications and
Information Administration
Institute for Telecommunication Sciences
ATTN: Code 1-3426 (Dr. Hans J. Liebe)
Boulder, CO 80303

AFATL/DLODL
Technical Library
Eglin AFB, FL 32542

Commanding Officer
Naval Training Equipment Center
ATTN: Technical Information Center
Orlando, FL 32813

Georgia Institute of Technology
Engineering Experiment Station
ATTN: Dr. Robert W. McMillan
Atlanta, GA 30332

Georgia Institute of Technology
Engineering Experiment Station
ATTN: Dr. James C. Wiltse
Atlanta, GA 30332

Commandant
US Army Infantry Center
ATTN: ATSH-CD-MS-E (Mr. Robert McKenna)
Fort Benning, GA 31805

Commander
US Army Signal Center & Fort Gordon
ATTN: ATZHCD-CS
Fort Gordon, GA 30905

Commander
US Army Signal Center & Fort Gordon
ATTN: ATZHCD-O
Fort Gordon, GA 30905

USAFETAC/DNE
ATTN: Mr. Charles Glauber
Scott AFB, IL 62225

Commander
Air Weather Service
ATTN: AWS/DNDP (LTC Kit G. Cottrell)
Scott AFB, IL 62225

Commander
Air Weather Service
ATTN: AWS/DOOF (MAJ Robert Wright)
Scott AFB, IL 62225

Commander
US Army Combined Arms Center
& Ft. Leavenworth
ATTN: ATZLCA-CAA-Q (Mr. H. Kent Pickett)
Fort Leavenworth, KS 66027

Commander
US Army Combined Arms Center
& Ft. Leavenworth
ATTN: ATZLCA-SAN (Robert DeKinder, Jr.)
Fort Leavenworth, KS 66027

Commander
US Army Combined Arms Center
& Ft. Leavenworth
ATTN: ATZLCA-SAN (Mr. Kent I. Johnson)
Fort Leavenworth, KS 66027

Commander
US Army Combined Arms Center
& Ft. Leavenworth
ATTN: ATZLCA-WE (LTC Darrell Holland)
Fort Leavenworth, KS 66027

President
USAARENBD
ATTN: ATZK-AE-TA (Dr. Charles R. Leake)
Fort Knox, KY 40121

Commander
US Army Armor Center and Fort Knox
ATTN: ATZK-CD-MS
Fort Knox, KY 40121

Commander
US Army Armor Center and Fort Knox
ATTN: ATZK-CD-SD
Fort Knox, KY 40121

Aerodyne Research Inc.
ATTN: Dr. John F. Ebersole
Crosby Drive
Bedford, MA 01730

Commander
Air Force Geophysics Laboratory
ATTN: OPA (Dr. Robert W. Fenn)
Hanscom AFB, MA 01731

Commander
Air Force Geophysics Laboratory
ATTN: OPI (Dr. Robert A. McClatchey)
Hanscom AFB, MA 01731

Massachusetts Institute of Technology
Lincoln Laboratory
ATTN: Dr. T. J. Goblick, B-370
P.O. Box 73
Lexington, MA 02173

Massachusetts Institute of Technology
Lincoln Laboratory
ATTN: Dr. Michael Gruber
P.O. Box 73
Lexington, MA 02173

Raytheon Company
Equipment Division
ATTN: Dr. Charles M. Sonnenschein
430 Boston Post Road
Wayland, MA 01778

Commander
US Army Ballistic Research Laboratory/
ARRADCOM
ATTN: DRDAR-BLB (Mr. Richard McGee)
Aberdeen Proving Ground, MD 21005

Commander/Director
Chemical Systems Laboratory
US Army Armament Research
& Development Command
ATTN: DRDAR-CLB-PS (Dr. Edward Stuebing)
Aberdeen Proving Ground, MD 21010

Commander/Director
Chemical Systems Laboratory
US Army Armament Research
& Development Command
ATTN: DRDAR-CLB-PS (Mr. Joseph Vervier)
Aberdeen Proving Ground, MD 21010

Commander/Director
Chemical Systems Laboratory
US Army Armament Research
& Development Command
ATTN: DRDAR-CLY-A (Mr. Ronald Pennsyle)
Aberdeen Proving Ground, MD 21010

Commander
US Army Ballistic Research Laboratory/
ARRADCOM
ATTN: DRDAR-TSB-S (STINFO)
Aberdeen Proving Ground, MD 21005

Commander
US Army Electronics Research
& Development Command
ATTN: DRDEL-CCM (W. H. Pepper)
Adelphi, MD 20783

Commander
US Army Electronics Research
& Development Command
ATTN: DRDEL-CG/DRDEL-DC/DRDEL-CS
2800 Powder Mill Road
Adelphi, MD 20783

Commander
US Army Electronics Research
& Development Command
ATTN: DRDEL-CT
2800 Powder Mill Road
Adelphi, MD 20783

Commander
US Army Electronics Research
& Development Command
ATTN: DRDEL-PAO (M. Singleton)
2800 Powder Mill Road
Adelphi, MD 20783

Project Manager
Smoke/Obscurants
ATTN: DRDPM-SMK
(Dr. Anthony Van de Wal, Jr.)
Aberdeen Proving Ground, MD 21005

Project Manager
Smoke/Obscurants
ATTN: DRDPM-SMK-T (Mr. Sidney Gerard)
Aberdeen Proving Ground, MD 21005

Commander
US Army Test & Evaluation Command
ATTN: DRSTE-AD-M (Mr. Warren M. Baity)
Aberdeen Proving Ground, MD 21005

Commander
US Army Test & Evaluation Command
ATTN: DRSTE-AD-M (Dr. Norman E. Pentz)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-AAM (Mr. William Smith)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-CS (Mr. Philip H. Beavers)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-GB (Wilbur L. Warfield)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-GP (Mr. Fred Campbell)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-GP (H. Stamper)
Aberdeen Proving Grounds, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-GS
(Mr. Michael Starks/Mr. Julian Chernick)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-J (Mr James F. O'Bryon)
Aberdeen Proving Ground, MD 21005

Director
US Army Materiel Systems Analysis Activity
ATTN: DRXSY-LM (Mr. Robert M. Marchetti)
Aberdeen Proving Ground, MD 21005

Commander
Harry Diamond Laboratories
ATTN: Dr. William W. Carter
2800 Powder Mill Road
Adelphi, MD 20783

Commander
Harry Diamond Laboratories
ATTN: DELHD-R-CM (Mr. Robert McCoskey)
2800 Powder Mill Road
Adelphi, MD 20783

Commander
Harry Diamond Laboratories
ATTN: DELHD-R-CM-NM (Dr. Robert Humphrey)
2800 Powder Mill Road
Adelphi, MD 20783

Commander
Harry Diamond Laboratories
ATTN: DELHD-R-CM-NM (Dr. Z. G. Sztankay)
2800 Powder Mill Road
Adelphi, MD 20783

Commander
Harry Diamond Laboratories
ATTN: DELHD-R-CM-NM (Dr. Joseph Nemerich)
2800 Powder Mill Road
Adelphi, MD 20783

Commander
Air Force Systems Command
ATTN: WER (Mr. Richard F. Picanso)
Andrews AFB, MD 20334

Martin Marietta Laboratories
ATTN: Jar Mo Chen
1450 South Rolling Road
Baltimore, MD 21227

Commander
US Army Concepts Analysis Agency
ATTN: CSCA-SMC (Mr. Hal E. Hock)
8120 Woodmont Avenue
Bethesda, MD 20014

Director
National Security Agency
ATTN: R52/Dr. Douglas Woods
Fort George G. Meade, MD 20755

Chief
Intelligence Materiel Development
& Support Office
US Army Electronic Warfare Laboratory
ATTN: DELEW-I (LTC Kenneth E. Thomas)
Fort George G. Meade, MD 20755

The Johns Hopkins University
Applied Physics Laboratory
ATTN: Dr. Michael J. Lun
John Hopkins Road
Laurell, MD 20810

Dr. Stephen T. Hanley
1720 Rhodesia Avenue
Oxon Hill, MD 20022

Science Applications Inc.
ATTN: Mr. G. D. Currie
15 Research Drive
Ann Arbor, MI 48103

Science Applications Inc.
ATTN: Dr. Robert E. Turner
15 Research Drive
Ann Arbor, MI 48103

Commander
US Army Tank-Automotive Research
& Development Command
ATTN: DRDTA-ZSC (Mr. Harry Young)
Warren, MI 48090

Commander
US Army Tank Automotive Research
& Development Command
ATTN: DRDTA-ZSC (Mr. Wallace Mick, Jr.)
Warren, MI 48090

Dr. A. D. Belmont
Research Division
Control Data Corporation
P.O. Box 1249
Minneapolis, MN 55440

Director
US Army Engr Waterways Experiment Station
ATTN: WESEN (Mr. James Mason)
P.O. Box 631
Vicksburg, MS 39180

Dr. Jerry Davis
Department of Marine, Earth
and Atmospheric Sciences
North Carolina State University
Raleigh, NC 27650

Commander
US Army Research Office
ATTN: DRXRO-GS (Dr. Leo Alpert)
P.O. Box 12211
Research Triangle Park, NC 27709

Commander
US Army Research Office
ATTN: DRXRO-PP (Brenda Mann)
P.O. Box 12211
Research Triangle Park, NC 27709

Commander
US Army Cold Regions Research
& Engineering Laboratory
ATTN: CRREL-RD (Dr. K. F. Sterrett)
Hanover, NH 03755

Commander/Director
US Army Cold Regions Research
& Engineering Laboratory
ATTN: CRREL-RG (Mr. George Aitken)
Hanover, NH 03755

Commander
US Army Cold Regions Research
& Engineering Laboratory
ATTN: CRREL-RG (Mr. Roger H. Berger)
Hanover, NH 03755

Commander
US Army Armament Research
& Development Command
ATTN: DRDAR-AC (Mr. James Greenfield)
Dover, NJ 07801

Commander
US Army Armament Research
& Development Command
ATTN: DRDAR-TSS (Bldg #59)
Dover, NJ 07801

Commander
US Army Armament Research
& Development Command
ATTN: DRCPM-CAWS-EI (Mr. Peteris Jansons)
Dover, NJ 07801

Commander
US Army Armament Research
& Development Command
ATTN: DRCPM-CAWS-EI (Mr. G. H. Waldron)
Dover, NJ 07801

Deputy Joint Project Manager
for Navy/USMC SAL GP
ATTN: DRCPM-CAWS-NV (CPT Joseph Miceli)
Dover, NJ 07801

Commander/Director
US Army Combat Surveillance & Target
Acquisition Laboratory
ATTN: DELCS-I (Mr. David Longinotti)
Fort Monmouth, NJ 07703

Commander/Director
US Army Combat Surveillance & Target
Acquisition Laboratory
ATTN: DELCS-PE (Mr. Ben A. Di Campli)
Fort Monmouth, NJ 07703

Commander/Director
US Army Combat Surveillance & Target
Acquisition Laboratory
ATTN: DELCS-R-S (Mr. Donald L. Foiani)
Fort Monmouth, NJ 07703

Director
US Army Electronics Technology &
Devices Laboratory
ATTN: DELET-DD (S. Danko)
Fort Monmouth, NJ 07703

Project Manager
FIREFINDER/REMBASS
ATTN: DRCPM-FFR-TM (Mr. John M. Bialo)
Fort Monmouth, NJ 07703

Commander
US Army Electronics Research
& Development Command
ATTN: DRDEL-SA (Dr. Walter S. McAfee)
Fort Monmouth, NJ 07703

OLA, 2WS (MAC)
Holloman AFB, NM 88330
Commander
Air Force Weapons Laboratory
ATTN: AFWL/WE (MAJ John R. Elrick)
Kirtland, AFB, NM 87117

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-SL
White Sands Missile Range, NM 88002

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-SL (Dolores Anguiano)
White Sands Missile Range, NM 88002

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-TDB (Mr. Louie Dominguez)
White Sands Missile Range, NM 88002

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-TDB (Mr. William J. Leach)
White Sands Missile Range, NM 88002

Director
USA TRADOC Systems Analysis Activity
ATTN: ATAA-TGP (Mr. Roger F. Willis)
White Sands Missile Range, NM 88002

Director
Office of Missile Electronic Warfare
ATTN: DELEW-M-STO (Dr. Steven Kovel)
White Sands Missile Range, NM 88002

Office of the Test Director
Joint Services EO GW CM Test Program
ATTN: DRXDE-TD (Mr. Weldon Findley)
White Sands Missile Range, NM 88002

Commander
US Army White Sands Missile Range
ATTN: STEWS-PT-AL (Laurel B. Saunders)
White Sands Missile Range, NM 88002

Commander
US Army R&D Coordinator
US Embassy - Bonn
Box 165
APO New York 09080

Grumman Aerospace Corporation
Research Department - MS A08-35
ATTN: John E. A. Selby
Bethpage, NY 11714

Rome Air Development Center
ATTN: Documents Library
TSLD (Bette Smith)
Griffiss AFB, NY 13441

Dr. Roberto Vaglio-Laurin
Faculty of Arts and Science
Dept. of Applied Science
26-36 Stuyvesant Street
New York, NY 10003

Air Force Wright Aeronautical Laboratories/
Avionics Laboratory
ATTN: AFWAL/AARI-3 (Mr. Harold Geltmacher)
Wright-Patterson AFB, OH 45433

Air Force Wright Aeronautical Laboratories/
Avionics Laboratory
ATTN: AFWAL/AARI-3 (CPT William C. Smith)
Wright-Patterson AFB, OH 45433

Commandant
US Army Field Artillery School
ATTN: ATSF-CF-R (CPT James M. Watson)
Fort Sill, OK 73503

Commandant
US Army Field Artillery School
ATTN: ATSF-CD-MS
Fort Sill, OK 73503

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

Commandant
US Army Field Artillery School
ATTN: NOAA Liaison Officer
(CDR Jeffrey G. Carlen)
Fort Sill, OK 73503

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

Commander
Naval Air Development Center
ATTN: Code 301 (Mr. George F. Eck)
Warminster, PA 18974

The University of Texas at El Paso
Electrical Engineering Department
ATTN: Dr. Joseph H. Pierluissi
El Paso, TX 79968

Commandant
US Army Air Defense School
ATTN: ATSA-CD-SC-A (CPT Charles T. Thorn)
Fort Bliss, TX 79916

Commander
HQ, TRADOC Combined Arms Test Activity
ATTN: ATCAT-OP-Q (CPT Henry C. Cobb, Jr.)
Fort Hood, TX 76544

Commander
HQ, TRADOC Combined Arms Test Activity
ATTN: ATCAT-SCI (Dr. Darrell W. Collier)
Fort Hood, TX 76544

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-L
Dugway, UT 84022

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-M (Mr. Paul E. Carlson)
Dugway, UT 84022

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-T (Mr. John Trethewey)
Dugway, UT 84022

Commander
US Army Dugway Proving Ground
ATTN: STEDP-MT-DA-T (Mr. William Peterson)
Dugway, UT 84022

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

Ballistic Missile Defense Program Office
ATTN: DACS-BMT (Colonel Harry F. Ennis)
5001 Eisenhower Avenue
Alexandria, VA 22333

Defense Technical Information Center
ATTN: DDA-2 (Mr. James E. Shafer)
Cameron Station, Bldg 5
Alexandria, VA 22314

Commander
US Army Materiel Development
& Readiness Command
ATTN: DRCBSI-EE (Mr. Albert Giambalvo)
5001 Eisenhower Avenue
Alexandria, VA 22333

Commander
US Army Materiel Development
& Readiness Command
ATTN: DRCLDC (Mr. James Bender)
5001 Eisenhower Avenue
Alexandria, VA 22333

Defense Advanced Rsch Projects Agency
ATTN: Steve Zakanyez
1400 Wilson Blvd
Arlington, VA 22209

Defense Advanced Rsch Projects Agency
ATTN: Dr. James Tegnolia
1400 Wilson Blvd
Arlington, VA 22209

Institute for Defense Analyses
ATTN: Mr. Lucien M. Biberman
400 Army-Navy Drive
Arlington, VA 22202

Institute for Defense Analyses
ATTN: Dr. Ernest Bauer
400 Army-Navy Drive
Arlington, VA 22202

Institute for Defense Analyses
ATTN: Dr. Hans G. Wolfhard
400 Army-Navy Drive
Arlington, VA 22202

System Planning Corporation
ATTN: Mr. Daniel Friedman
1500 Wilson Boulevard
Arlington, VA 22209

System Planning Corporation
ATTN: COL Hank Shelton
1500 Wilson Boulevard
Arlington, VA 22209

US Army Intelligence & Security Command
ATTN: Edwin Speakman, Scientific Advisor
Arlington Hall Station
Arlington, VA 22212

Commander
US Army Operational Test
& Evaluation Agency
ATTN: CSTE-ED (Mr. Floyd I. Hill)
5600 Columbia Pike
Falls Church, VA 22041

Commander and Director
US Army Engineer Topographic Laboratories
ATTN: ETL-GS-A (Mr. Thomas Neidringhaus)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-L (Dr. Rudolf G. Buser)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-L (Dr. Robert S. Rodhe)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Mr. Joseph R. Moulton)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Luanne P. Obert)
Fort Belvoir, VA 22060

Director
US Army Night Vision
& Electro-Optics Laboratory
ATTN: DELNV-VI (Mr. Thomas W. Cassidy)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Mr. Richard J. Bergemann)
Fort Belvoir, VA 22060

Director
US Army Night Vision &
Electro-Optics Laboratory
ATTN: DELNV-VI (Dr. James A. Ratches)
Fort Belvoir, VA 22060

Commander
US Army Training & Doctrine Command
ATTN: ATCD-AN
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-AN-M
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-F-A (Mr. Chris O'Connor, Jr.)
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-IE-R (Mr. David M. Ingram)
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATCD-M-I/ATCD-M-A
Fort Monroe, VA 23651

Commander
US Army Training & Doctrine Command
ATTN: ATDOC-TA (Dr. Marvin P. Pastel)
Fort Monroe, VA 23651

Department of the Air Force
OL-I, AWS
Fort Monroe, VA 23651

Department of the Air Force
HQS 5 Weather Wing (MAC)
ATTN: 5 WW/DN
Langley Air Force Base, VA 23655

Commander
US Army INSCOM/Quest Research Corporation
ATTN: Mr. Donald Wilmot
6845 Elm Street, Suite 407
McLean, VA 22101

General Research Corporation
ATTN: Dr. Ralph Zirkind
7655 Old Springhouse Road
McLean, VA 22102

Science Applications, Inc.
8400 Westpark Drive
ATTN: Dr. John E. Cockayne
McLean, VA 22102

US Army Nuclear & Chemical Agency
ATTN: MONA-WE (Dr. John A. Berberet)
7500 Backlick Road, Bldg 2073
Springfield, VA 22150

Director
US Army Signals Warfare Laboratory
ATTN: DELSW-EA (Mr. Douglas Harkleroad)
Vint Hill Farms Station
Warrenton, VA 22186

Director
US Army Signals Warfare Laboratory
ATTN: DELSW-OS (Dr. Royal H. Burkhardt)
Vint Hill Farms Station
Warrenton, VA 22186

Commander
US Army Cold Regions Test Center
ATTN: STECR-TD (Mr. Jerold Barger)
APO Seattle, WA 98733

HQDA (SAUS-OR/Hunter M. Woodall, Jr./
Dr. Herbert K. Fallin)
Rm 2E 614, Pentagon
Washington, DC 20301

COL Elbert W. Friday, Jr.
OUSDRE
Rm 3D 129, Pentagon
Washington, DC 20301

Defense Communications Agency
Technical Library Center
Code 222
Washington, DC 20305

Director
Defense Nuclear Agency
ATTN: Technical Library (Mrs. Betty Fox)
Washington, DC 20305

Director
Defense Nuclear Agency
ATTN: RAAE (Dr. Carl Fitz)
Washington, DC 20305

Director
Defense Nuclear Agency
ATTN: SPAS (Mr. Donald J. Kohler)
Washington, DC 20305

Defense Intelligence Agency
ATTN: DT/AC (LTC Robert Poplawski)
Washington, DC 20301

HQDA (DAMA-ARZ-D/Dr. Verderame)
Washington, DC 20310

HQDA (DAMI-ISP/Mr. Beck)
Washington, DC 20310

Department of the Army
Deputy Chief of Staff for
Operations and Plans
ATTN: DAMO-RQ
Washington, DC 20310

Department of the Army
Director of Telecommunications and
Command and Control
ATTN: DAMO-TCZ
Washington, DC 20310

Department of the Army
Assistant Chief of Staff for Intelligence
ATTN: DAMI-TS
Washington, DC 20310

HQDA (DAEN-RDM/Dr. de Percin)
Casimir Pulaski Building
20 Massachusetts Avenue
Room 6203
Washington, DC 20314

National Science Foundation
Division of Atmospheric Sciences
ATTN: Dr. Eugene W. Bierly
1800 G. Street, N.W.
Washington, DC 20550

Director
Naval Research Laboratory
ATTN: Code 4320 (Dr. Lothar H. Ruhnke)
Washington, DC 20375

Commanding Officer
Naval Research Laboratory
ATTN: Code 6009 (Dr. John MacCallum, Jr.)
Washington, DC 20375

Commanding Officer
Naval Research Laboratory
ATTN: Code 6530 (Mr. Raymond A. Patten)
Washington, DC 20375

Commanding Officer
Naval Research Laboratory
ATTN: Code 6533 (Dr. James A. Dowling)
Washington, DC 20375

ATMOSPHERIC SCIENCES RESEARCH REPORTS

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⁺³: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. Taylor, "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 and 3.0 μ m Using a Cary 171 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.
54. Ballard, Harold N., Jose 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-5819, May 1977.
56. White, Kenneth O., Wendell R. Watkins, Stuart A. Schleusener, and Ronald L. Johnson, "Solid-State Laser Wavelength Identification Using a Reference Absorber," ECOM-5820, June 1977.
57. Watkins, Wendell R., and Richard G. Dixon, "Automation of Long-Path Absorption Cell Measurements," ECOM-5821, June 1977.

58. Taylor, S. E., J. M. Davis, and J. B. Mason, "Analysis of Observed Soil Skin Moisture Effects on Reflectance," ECOM-5822, June 1977.
59. Duncan, Louis D., and Mary Ann Seagraves, "Fallout Predictions Computed from Satellite Derived Winds," ECOM-5823, June 1977.
60. Snider, D. E., D. G. Murcray, F. H. Murcray, and W. J. Williams, "Investigation of High-Altitude Enhanced Infrared Background Emissions," (U), SECRET, ECOM-5824, June 1977.
61. Dubbin, Marvin H., and Dennis Hall, "Synchronous Meteorological Satellite Direct Readout Ground System Digital Video Electronics," ECOM-5825, June 1977.
62. Miller, W., and B. Engebos, "A Preliminary Analysis of Two Sound Ranging Algorithms," ECOM-5826, July 1977.
63. Kennedy, Bruce W., and James K. Luers, "Ballistic Sphere Techniques for Measuring Atmospheric Parameters," ECOM-5827, July 1977.
64. Duncan, Louis D., "Zenith Angle Variation of Satellite Thermal Sounder Measurements," ECOM-5828, August 1977.
65. Hansen, Frank V., "The Critical Richardson Number," ECOM-5829, September 1977.
66. Ballard, Harold N., and Frank P. Hudson (Compilers), "Stratospheric Composition Balloon-Borne Experiment," ECOM-5830, October 1977.
67. Barr, William C., and Arnold C. Peterson, "Wind Measuring Accuracy Test of Meteorological Systems," ECOM-5831, November 1977.
68. Ethridge, G. A., and F. V. Hansen, "Atmospheric Diffusion: Similarity Theory and Empirical Derivations for Use in Boundary Layer Diffusion Problems," ECOM-5832, November 1977.
69. Low, Richard D. H., "The Internal Cloud Radiation Field and a Technique for Determining Cloud Blackness," ECOM-5833, December 1977.
70. Watkins, Wendell R., Kenneth O. White, Charles W. Bruce, Donald L. Walters, and James D. Lindberg, "Measurements Required for Prediction of High Energy Laser Transmission," ECOM-5834, December 1977.
71. Rubio, Robert, "Investigation of Abrupt Decreases in Atmospherically Backscattered Laser Energy," ECOM-5835, December 1977.
72. Monahan, H. H., and R. M. Cionco, "An Interpretative Review of Existing Capabilities for Measuring and Forecasting Selected Weather Variables (Emphasizing Remote Means)," ASI-TR-0001, January 1978.

73. Heaps, Melvin G., "The 1979 Solar Eclipse and Validation of D-Region Models," ASL-TR-0002, March 1978.
74. Jennings, S. G., and J. B. Gillespie, "M.I.E. Theory Sensitivity Studies - The Effects of Aerosol Complex Refractive Index and Size Distribution Variations on Extinction and Absorption Coefficients, Part II: Analysis of the Computational Results," ASL-TR-0003, March 1978.
75. White, Kenneth O., et al, "Water Vapor Continuum Absorption in the 3.5 μ m to 4.0 μ m Region," ASL-TR-0004, March 1978.
76. Olsen, Robert O., and Bruce W. Kennedy, "ABRES Pretest Atmospheric Measurements," ASL-TR-0005, April 1978.
77. Ballard, Harold N., Jose M. Serna, and Frank P. Hudson, "Calculation of Atmospheric Composition in the High Latitude September Stratosphere," ASL-TR-0006, May 1978.
78. Watkins, Wendell R., et al, "Water Vapor Absorption Coefficients at HF Laser Wavelengths," ASL-TR-0007, May 1978.
79. Hansen, Frank V., "The Growth and Prediction of Nocturnal Inversions," ASL-TR-0008, May 1978.
80. Samuel, Christine, Charles Bruce, and Ralph Brewer, "Spectrophone Analysis of Gas Samples Obtained at Field Site," ASL-TR-0009, June 1978.
81. Pinnick, R. G., et al., "Vertical Structure in Atmospheric Fog and Haze and its Effects on IR Extinction," ASL-TR-0010, July 1978.
82. Low, Richard D. H., Louis D. Duncan, and Richard B. Gomez, "The Microphysical Basis of Fog Optical Characterization," ASL-TR-0011, August 1978.
83. Heaps, Melvin G., "The Effect of a Solar Proton Event on the Minor Neutral Constituents of the Summer Polar Mesosphere," ASL-TR-0012, August 1978.
84. Mason, James B., "Light Attenuation in Falling Snow," ASL-TR-0013, August 1978.
85. Blanco, Abel J., "Long-Range Artillery Sound Ranging: 'PASS' Meteorological Application," ASL-TR-0014, September 1978.
86. Heaps, M. G., and F. E. Niles, "Modeling of Ion Chemistry of the D-Region: A Case Study Based Upon the 1966 Total Solar Eclipse," ASL-TR-0015, September 1978.

87. Jennings, S. G., and R. G. Pinnick, "Effects of Particulate Complex Refractive Index and Particle Size Distribution Variations on Atmospheric Extinction and Absorption for Visible Through Middle-Infrared Wavelengths," ASL-TR-0016, September 1978.
88. Watkins, Wendell R., Kenneth O. White, Lanny R. Bower, and Brian Z. Sojka, "Pressure Dependence of the Water Vapor Continuum Absorption in the 3.5- to 4.0-Micrometer Region," ASL-TR-0017, September 1978.
89. Miller, W. B., and B. F. Engebos, "Behavior of Four Sound Ranging Techniques in an Idealized Physical Environment," ASL-TR-0018, September 1978.
90. Gomez, Richard G., "Effectiveness Studies of the CBU-88/B Bomb, Cluster, Smoke Weapon," (U), CONFIDENTIAL ASL-TR-0019, September 1978.
91. Miller, August, Richard C. Shirkey, and Mary Ann Seagraves, "Calculation of Thermal Emission from Aerosols Using the Doubling Technique," ASL-TR-0020, November 1978.
92. Lindberg, James D., et al, "Measured Effects of Battlefield Dust and Smoke on Visible, Infrared, and Millimeter Wavelengths Propagation: A Preliminary Report on Dusty Infrared Test-I (DIRT-I)," ASL-TR-0021, January 1979.
93. Kennedy, Bruce W., Arthur Kinghorn, and B. R. Hixon, "Engineering Flight Tests of Range Meteorological Sounding System Radiosonde," ASL-TR-0022, February 1979.
94. Rubio, Roberto, and Don Hooek, "Microwave Effective Earth Radius Factor Variability at Wiesbaden and Balboa," ASL-TR-0023, February 1979.
95. Low, Richard D. H., "A Theoretical Investigation of Cloud/Fog Optical Properties and Their Spectral Correlations," ASL-TR-0024, February 1979.
96. Pinnick, R. G., and H. J. Auvermann, "Response Characteristics of Knollenberg Light-Scattering Aerosol Counters," ASL-TR-0025, February 1979.
97. Heaps, Melvin G., Robert O. Olsen, and Warren W. Berning, "Solar Eclipse 1979, Atmospheric Sciences Laboratory Program Overview," ASL-TR-0026, February 1979.
98. Blanco, Abel J., "Long-Range Artillery Sound Ranging: 'PASS' GR-8 Sound Ranging Data," ASL-TR-0027, March 1979.
99. Kennedy, Bruce W., and Jose M. Serna, "Meteorological Rocket Network System Reliability," ASL-TR-0028, March 1979.

100. Swingle, Donald M., "Effects of Arrival Time Errors in Weighted Range Equation Solutions for Linear Base Sound Ranging," ASL-TR-0029, April 1979.
101. Umstead, Robert K., Ricardo Pena, and Frank V. Hansen, "KWIK: An Algorithm for Calculating Munition Expenditures for Smoke Screening/Obscuration in Tactical Situations," ASL-TR-0030, April 1979.
102. D'Arcy, Edward M., "Accuracy Validation of the Modified Nike Hercules Radar," ASL-TR-0031, May 1979.
103. Rodriguez, Ruben, "Evaluation of the Passive Remote Crosswind Sensor," ASL-TR-0032, May 1979.
104. Barber, T. L., and R. Rodriguez, "Transit Time Lidar Measurement of Near-Surface Winds in the Atmosphere," ASL-TR-0033, May 1979.
105. Low, Richard D. H., Louis D. Duncan, and Y. Y. Roger R. Hsiao, "Micro-physical and Optical Properties of California Coastal Fogs at Fort Ord," ASL-TR-0034, June 1979.
106. Rodriguez, Ruben, and William J. Vechione, "Evaluation of the Saturation Resistant Crosswind Sensor," ASL-TR-0035, July 1979.
107. Ohmstede, William D., "The Dynamics of Material Layers," ASL-TR-0036, July 1979.
108. Pinnick, R. G., S. G. Jennings, Petr Chylek, and H. J. Auvermann, "Relationships between IR Extinction Absorption, and Liquid Water Content of Fogs," ASL-TR-0037, August 1979.
109. Rodriguez, Ruben, and William J. Vechione, "Performance Evaluation of the Optical Crosswind Profiler," ASL-TR-0038, August 1979.
110. Miers, Bruce T., "Precipitation Estimation Using Satellite Data," ASL-TR-0039, September 1979.
111. Dickson, David H., and Charles M. Sonnenschein, "Helicopter Remote Wind Sensor System Description," ASL-TR-0040, September 1979.
112. Heaps, Melvin G., and Joseph M. Heimerl, "Validation of the Dairchem Code, I: Quiet Midlatitude Conditions," ASL-TR-0041, September 1979.
113. Bonner, Robert S., and William J. Lentz, "The Visioceilometer: A Portable Cloud Height and Visibility Indicator," ASL-TR-0042, October 1979.
114. Cohn, Stephen L., "The Role of Atmospheric Sulfates in Battlefield Obscurations," ASL-TR-0043, October 1979.

115. Fawbush, E. J., et al, "Characterization of Atmospheric Conditions at the High Energy Laser System Test Facility (HELSTF), White Sands Missile Range, New Mexico, Part I, 24 March to 8 April 1977," ASL-TR-0044, November 1979.
116. Barber, Ted L., "Short-Time Mass Variation in Natural Atmospheric Dust," ASL-TR-0045, November 1979.
117. Low, Richard D. H., "Fog Evolution in the Visible and Infrared Spectral Regions and its Meaning in Optical Modeling," ASL-TR-0046, December 1979.
118. Duncan, Louis D., et al, "The Electro-Optical Systems Atmospheric Effects Library, Volume I: Technical Documentation," ASL-TR-0047, December 1979.
119. Shirkey, R. C., et al, "Interim E-O SAEL, Volume II, Users Manual," ASL-TR-0048, December 1979.
120. Kobayashi, H. K., "Atmospheric Effects on Millimeter Radio Waves," ASL-TR-0049, January 1980.
121. Seagraves, Mary Ann, and Louis D. Duncan, "An Analysis of Transmittances Measured Through Battlefield Dust Clouds," ASL-TR-0050, February 1980.
122. Dickson, David H., and Jon E. Ottesen, "Helicopter Remote Wind Sensor Flight Test," ASL-TR-0051, February 1980.
123. Pinnick, R. G., and S. G. Jennings, "Relationships Between Radiative Properties and Mass Content of Phosphoric Acid, HC, Petroleum Oil, and Sulfuric Acid Military Smokes," ASL-TR-0052, April 1980.
124. Hinds, B. D., and J. B. Gillespie, "Optical Characterization of Atmospheric Particulates on San Nicolas Island, California," ASL-TR-0053, April 1980.
125. Miers, Bruce T., "Precipitation Estimation for Military Hydrology," ASL-TR-0054, April 1980.
126. Stenmark, Ernest B., "Objective Quality Control of Artillery Computer Meteorological Messages," ASL-TR-0055, April 1980.
127. Duncan, Louis D., and Richard D. H. Low, "Bimodal Size Distribution Models for Fogs at Meppen, Germany," ASL-TR-0056, April 1980.
128. Olsen, Robert O., and Jagir S. Randhawa, "The Influence of Atmospheric Dynamics on Ozone and Temperature Structure," ASL-TR-0057, May 1980.

129. Kennedy, Bruce W., et al, "Dusty Infrared Test-II (DIRT-II) Program," ASL-TR-0058, May 1980.
130. Heaps, Melvin G., Robert O. Olsen, Warren Berning, John Cross, and Arthur Gilcrease, "1979 Solar Eclipse, Part I - Atmospheric Sciences Laboratory Field Program Summary," ASL-TR-0059, May 1980
131. Miller, Walter B., "User's Guide for Passive Target Acquisition Program Two (PTAP-2)," ASL-TR-0060, June 1980.
132. Holt, E. H., editor, "Atmospheric Data Requirements for Battlefield Obscuration Applications," ASL-TR-0061, June 1980.
133. Shirkey, Richard C., August Miller, George H. Goedecke, and Yugal Behl, "Single Scattering Code AGAUSX: Theory, Applications, Comparisons, and Listing," ASL-TR-0062, July 1980.
134. Sojka, Brian Z., and Kenneth O. White, "Evaluation of Specialized Photoacoustic Absorption Chambers for Near-Millimeter Wave (NMMW) Propagation Measurements," ASL-TR-0063, August 1980.
135. Bruce, Charles W., Young Paul Yee, and S. G. Jennings, "In Situ Measurement of the Ratio of Aerosol Absorption to Extinction Coefficient," ASL-TR-0064, August 1980.
136. Yee, Young Paul, Charles W. Bruce, and Ralph J. Brewer, "Gaseous/Particulate Absorption Studies at WSMR using Laser Sourced Spectrophones," ASL-TR-0065, June 1980.
137. Lindberg, James D., Radon B. Loveland, Melvin Heaps, James B. Gillespie, and Andrew F. Lewis, "Battlefield Dust and Atmospheric Characterization Measurements During West German Summertime Conditions in Support of Grafenwohr Tests," ASL-TR-0066, September 1980.
138. Vechione, W. J., "Evaluation of the Environmental Instruments, Incorporated Series 200 Dual Component Wind Set," ASL-TR-0067, September 1980.
139. Bruce, C. W., Y. P. Yee, B. D. Hinds, R. G. Pinnick, R. J. Brewer, and J. Minjares, "Initial Field Measurements of Atmospheric Absorption at 9 μ m to 11 μ m Wavelengths," ASL-TR-0068, October 1980.
140. Heaps, M. G., R. O. Olsen, K. D. Baker, D. A. Burt, L. C. Howlett, L. L. Jensen, E. F. Pound, and G. D. Allred, "1979 Solar Eclipse: Part II Initial Results for Ionization Sources, Electron Density, and Minor Neutral Constituents," ASL-TR-0069, October 1980.
141. Low, Richard D. H., "One-Dimensional Cloud Microphysical Models for Central Europe and their Optical Properties," ASL-TR-0070, October 1980.

142. Duncan, Louis D., James D. Lindberg, and Radon B. Loveland, "An Empirical Model of the Vertical Structure of German Fogs," ASL-TR-0071, November 1980.
143. Duncan, Louis D., "EOSAEL 80, Volume I, Technical Documentation," ASL-TR-0072, January 1981.
144. Shirkey, R. C., and S. G. O'Brien, "EOSAEL 80, Volume II, Users Manual," ASL-TR-0073, January 1981.
145. Bruce, C. W., "Characterization of Aerosol Nonlinear Effects on a High-Power CO₂ Laser Beam," ASL-TR-0074, February 1981.
146. Duncan, Louis D., and James D. Lindberg, "Air Mass Considerations in Fog Optical Modeling," ASL-TR-0075, February 1981.
147. Kunkel, Kenneth E., "Evaluation of a Tethered Kite Anemometer," ASL-TR-0076, February 1981.
148. Kunkel, K. E., et al, "Characterization of Atmospheric Conditions at the High Energy Laser System Test Facility (HELSTF) White Sands Missile Range, New Mexico, August 1977 to October 1978, Part II, Optical Turbulence, Wind, Water Vapor Pressure, Temperature," ASL-TR-0077, February 1981.
149. Miers, Bruce T., "Weather Scenarios for Central Germany," ASL-TR-0078, February 1981.
150. Cogan, James L., "Sensitivity Analysis of a Mesoscale Moisture Model," ASL-TR-0079, March 1981.
151. Brewer, R. J., C. W. Bruce, and J. L. Mater, "Optoacoustic Spectroscopy of C₂H₄ at the 9 μ m and 10 μ m C¹²O₂ Laser Wavelengths," ASL-TR-0080, March 1981.
152. Swingle, Donald M., "Reducible Errors in the Artillery Sound Ranging Solution, Part I: The Curvature Correction" (U), SECRET, ASL-TR-0081, April 1981.
153. Miller, Walter B., "The Existence and Implications of a Fundamental System of Linear Equations in Sound Ranging" (U), SECRET, ASL-TR-0082, April 1981.
154. Bruce, Dorothy, Charles W. Bruce, and Young Paul Yee, "Experimentally Determined Relationship Between Extinction and Liquid Water Content," ASL-TR-0083, April 1981.
155. Seagraves, Mary Ann, "Visible and Infrared Obscuration Effects of Ice Fog," ASL-TR-0084, May 1981.

156. Watkins, Wendell R., and Kenneth O. White, "Wedge Absorption Remote Sensor," ASL-TR-0085, May 1981.
157. Watkins, Wendell R., Kenneth O. White, and Laura J. Crow, "Turbulence Effects on Open Air Multipaths," ASL-TR-0086, May 1981.
158. Blanco, Abel J., "Extending Application of the Artillery Computer Meteorological Message," ASL-TR-0087, May 1981.
159. Heaps, M. G., D. W. Hoock, R. O. Olsen, B. F. Engebos, and R. Rubio, "High Frequency Position Location: An Assessment of Limitations and Potential Improvements," ASL-TR-0088, May 1981.
160. Watkins, Wendell R., and Kenneth O. White, "Laboratory Facility for Measurement of Hot Gaseous Plume Radiative Transfer," ASL-TR-0089, June 1981.
161. Heaps, M. G., "Dust Cloud Models: Sensitivity of Calculated Transmittances to Variations in Input Parameters," ASL-TR-0090, June 1981.
162. Seagraves, Mary Ann, "Some Optical Properties of Blowing Snow," ASL-TR-0091, June 1981.
163. Kobayashi, Herbert K., "Effect of Hail, Snow, and Melting Hydrometeors on Millimeter Radio Waves," ASL-TR-0092, July 1981.
164. Cogan, James L., "Techniques for the Computation of Wind, Ceiling, and Extinction Coefficient Using Currently Acquired RPV Data," ASL-TR-0093, July 1981.
165. Miller, Walter B., and Bernard F. Engebos, "On the Possibility of Improved Estimates for Effective Wind and Temperature," (U), SECRET, ASL-TR-0094, August 1981.
166. Heaps, Melvin G., "The Effect of Ionospheric Variability on the Accuracy of High Frequency Position Location," ASL-TR-0095, August 1981.
167. Sutherland, Robert A., Donald W. Hoock, and Richard B. Gomez, "An Objective Summary of US Army Electro-Optical Modeling and Field Testing in an Obscuring Environment," ASL-TR-0096, October 1981.
168. Pinnick, R. G., et al, "Backscatter and Extinction in Water Clouds," ASL-TR-0097, October 1981.
169. Cole, Henry P., and Melvin G. Heaps, "Properties of Dust as an Electron and Ion Attachment Site for Use in D Region Ion Chemistry," ASL-TR-0098, October 1981.

170. Spellicy, Robert L., Laura J. Crow, and Kenneth O. White, "Water Vapor Absorption Coefficients at HF Laser Wavelengths Part II: Development of the Measurement System and Measurements at Simulated Altitudes to 10 KM," ASL-TR-0099, November 1981.
171. Cohn, Stephen L., "Transport and Diffusion Solutions for Obscuration Using the XM-825 Smoke Munition," ASL-TR-0100, November 1981.
172. Pinnick, R. G., D. M. Garvey, and L. D. Duncan, "Calibration of Knollenberg FSSP Light-Scattering Counters for Measurement of Cloud Droplets," ASL-TR-0101, December 1981.