AD 667918

ECOM - 5168
December 1967
AD

A DATA REDUCTION TECHNIQUE FOR METEOROLOGICAL WIND DATA ABOVE 30 KILOMETERS

By

E. P. Avara

and

B. T. Miers

ATMOSPHERIC SCIENCES LABORATORY
WHITE SANDS MISSILE RANGE, NEW MEXICO

Distribution of this report is unlimited.

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND

29

A DATA REDUCTION TECHNIQUE
FOR METEOROLOGICAL WIND DATA
ABOVE 30 KILOMETERS

By

E. P. Avara

and

B. T. Miers

ECOM - 5168 December 1967

DA TASK 1T014501B53A-03

ATMOSPHERIC SCIENCES LABORATORY
White Sands Missile Range, New Mexico

ABSTRACT

The FPS-16 tracking systems superimpose undesired oscillations on the real position data resulting in rapidly fluctuating successive position points which are physically unrealistic. A linear digital filter of the form $\overline{Q}_K = \sum_{M=-58}^{M=58} W_M Q_{K+M}$ is applied separately to each component to smooth the data. The frequency response is given and the data are corrected by a method derived by Eddy et al. (1965). Undesired high frequency oscillations are effectively eliminated and successive wind profiles show good continuity.

CONTENTS

PRECEDING PAGE BLANK

INTRODUCTION

Atmospheric temperature, pressure, density, and wind data, derived from meteorological rocket soundings are used in meteorological research and for military projects requiring a knowledge of stratospheric behavior. Detailed wind profiles are often required for computing trajectories for ballistic rockets. This paper will describe the filtering and correction techniques used to derive winds from an FPS-16 radar track of a falling object.

FILTERING TECHNIQUE

Wind data derived from radar tracks of parachutes and spheres falling through the atmosphere are used as meteorological support data by several projects at White Sands Missile Range, New Mexico.

An FPS-16 radar tracks the sensor and records its position relative to the radar on a magnetic tape at the rate of twenty points per second. The meteorological wind reduction technique, however, uses only every other point, or ten points per second. These position points are specified by time and three space coordinates (slant range, azimuth angle, and elevation angle). A correction for refraction and earth curvature is then applied to the position points. A typical wind profile consists of about 18,000 data points and yields wind data from 25 km to about 65 km.

As is true with any tracking system, the system itself superimposes undesired oscillations (noise) on the real position data resulting in rapidly fluctuating successive position points which are physically unrealistic. To help compensate for this feature a linear digital filter, eq (1), in the form of a weighted running average over 117 points *(11.7 seconds) is applied separately to each component (slant range, azimuth angle, and elevation angle).

$$\overline{Q}_K = \sum_{M=-58}^{M=58} W_M Q_{K+M}, \qquad (1)$$

where W_M is the value of the Mth weight, Q_{K+M} is the (K+M)th unsmoothed value of a coordinate, and $\overline{Q}_K$ is the Kth smoothed value of the coordinate. The weights are symmetrically centered about $W_0 (W_N = W_{-N})$ and are shown in Figure 1. Assuming the unsmoothed coordinate values may be represented by a sum of sinusoidal oscillations of various amplitudes, phases, and frequencies, a frequency response (ratio of the amplitude of a sinusoidal wave in

* Table 1 shows the coefficients for the 117-point symmetrical filter.

Preceding Page Blank

TABLE 1

COEFFICIENTS FOR THE 117-POINT SYMMETRICAL FILTER.

WGT(0) =	0.35708064E-01
WGT(1) =	0.35636344E-01
WGT(2) =	0.35272675E-01
WGT(3) =	0.34784139E-01
WGT(4) =	0.34025734E-01
WGT(5) =	0.33167716E-01
WGT(6) =	0.32067885E-01
WGT(7) =	0.30898912E-01
WGT(8) =	0.29520595E-01
WGT(9) =	0.28107178E-01
WGT(10)=	0.26519604E-01
WGT(11)=	0.24932820E-01
WGT(12)=	0.23208045E-01
WGT(13)=	0.21520080E-01
WGT(14)=	0.19729587E-01
WGT(15)=	0.18010426E-01
WGT(16)=	0.16221950E-01
WGT(17)=	0.14536376E-01
WGT(18)=	0.12811107E-01
WGT(19)=	0.11216145E-01
WGT(20)=	0.96064442F-02
WGT(21)=	0.81493637E-02
WGT(22)=	0.66970661E-02
WGT(23)=	0.54140097E-02
WGT(24)=	0.41493890E-02
WGT(25)=	0.30646684E-02
WGT(26)=	0.20060650E-02
WGT(27)=	0.11321195E-02
WGT(28)=	0.28621851E-03
WGT(29)=	-0.37580166E-03
WGT(30) =	-0.10131001E-02
WGT(31) =	-0.14721988E-02
WGT(32) =	-0.19144034E-02
WGT(33) =	-0.21881496E-02
WGT(34) =	-0.24564068E-02
WGT(35) =	-0.25690121E-02
WGT(36) =	-0.26900660E-02
WGT(37) =	-0.26702617E-02
WGT(38) =	-0.26742817E-02
WGT(39) =	-0.25531311E-02
WGT(40) =	-0.24715428E-02
WGT(41) =	-0.22803228E-02
WGT(42) =	-0.21437710E-02
WGT(43) =	-0.19120444E-02
WGT(44) =	-0.17486000E-02
WGT(45) =	-0.15025814E-02
WGT(46) =	-0.13362864E-02
WGT(47) =	-0.10975813E-02
WGT(48) =	-0.94739597E-03
WGT(49) =	-0.73216618E-03
WGT(50) =	-0.61135714E-03
WGT(51) =	-0.42993361E-03
WGT(52) =	-0.34591034E-03
WGT(53) =	-0.20284763E-03
WGT(54) =	-0.15742585E-03
WGT(55) =	-0.51962753E-04
WGT(56) =	-0.42007490E-04
WGT(57) =	0.31125163E-04
WGT(58) =	0.12746845E-04

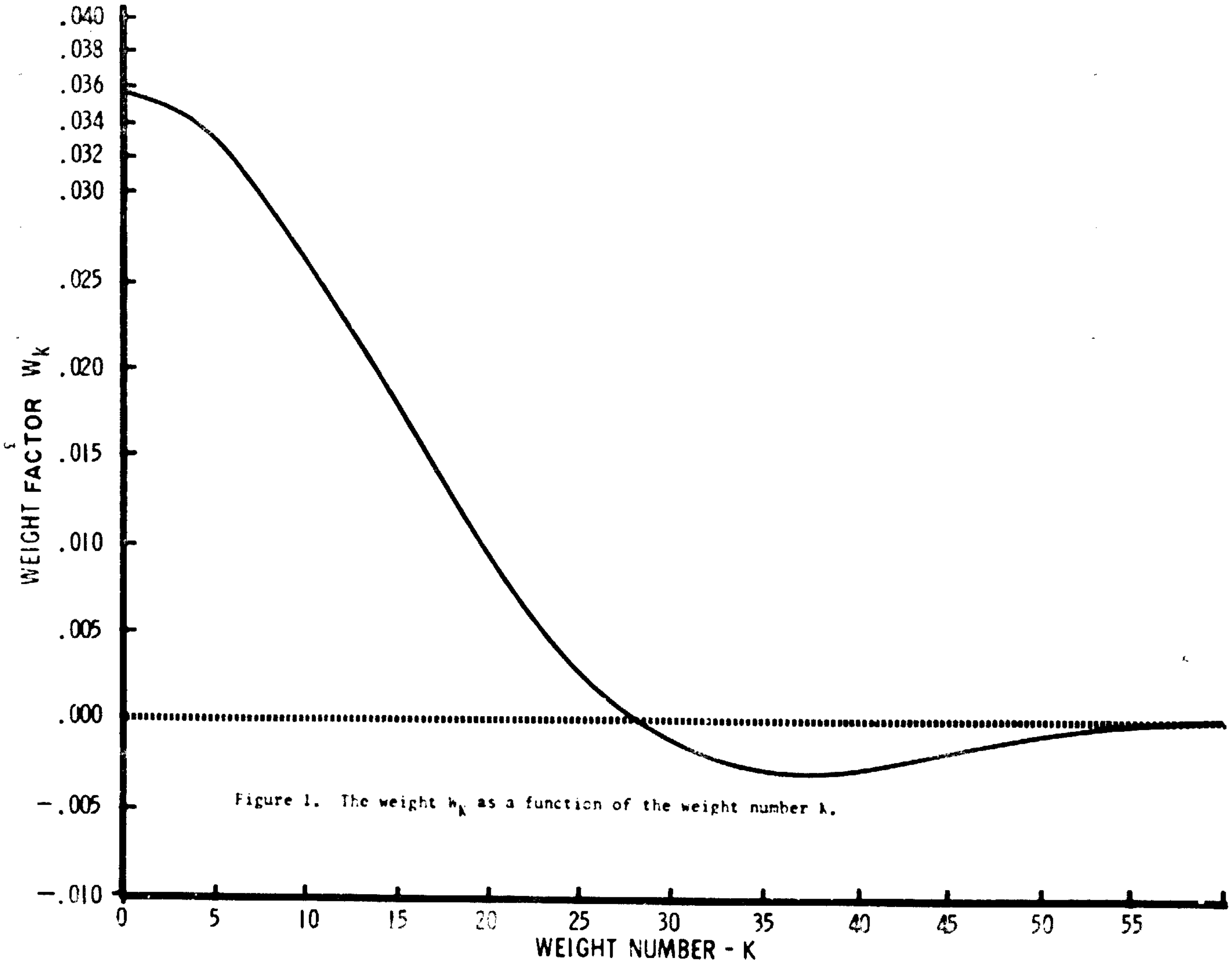

Figure 1. The weight w_k as a function of the weight number k.

the smoothed data to the amplitude of the same wave in the unsmoothed data) may be calculated, eq (2). This will give the effect of the filter on the data.

$$R(f) = \sum_{M=-58}^{M=58} W_M \cos\left(\frac{\pi f M}{5}\right) \text{ for } 0 \le f \le 5 \text{ sec}^{-1}, \tag{2}$$

where R(f) is the frequency response at frequency f. The frequency response of this filter is shown in Figure 2. The filter essentially eliminates oscillations which have frequencies greater than 0.3 sec^{-1} (periods less than three seconds). Figures 3, 4, and 5 show typical samples of the first differences in the smoothed and unsmoothed values of slant range, azimuth, and elevation angles at increments of 0.1 second.

The first and second derivatives of each coordinate are approximated by equations (3) and (4).

$$\dot{\overline{Q}}_K = 5(\overline{Q}_{K+1} - \overline{Q}_{K-1}), \tag{3}$$

$$\ddot{\overline{Q}}_K = 100(\overline{Q}_{K+1} - 2\overline{Q}_K + \overline{Q}_{K-1}), \tag{4}$$

where $\overline{Q}_K$, $\dot{\overline{Q}}_K$, and $\ddot{\overline{Q}}_K$ are the Kth values of the smoothed coordinate and its first and second derivatives, respectively. A transformation of coordinates is performed which gives position, velocity, and acceleration data in terms of components oriented north-south (y), east-west (x), and normal to the surface of the earth (z). The acceleration values of each component fluctuate excessively and are physically unacceptable. Ten weights are used to filter these data and are derived from equation (5),

$$\ddot{\overline{A}}_K = \sum_{M=0}^{9} W^*_M \ddot{A}_{K-10M}, \tag{5}$$

where $\ddot{\overline{A}}_K$ is the Kth value of the smoothed acceleration data, W^*_M the Mth weight, and $\ddot{A}_{K-10M}$ the (K-10M)th value of the unsmoothed acceleration data of one of the components*. Unsmoothed values one second apart instead of a tenth of a second apart are used in the smoothing. The amplitude of the frequency response may be calculated from equations (6), (7), and (8).

$$|R^*(f)| = (C[f]^2 + S[f]^2)^{1/2}, \tag{6}$$

$$C(f) = \sum_{M=0}^{9} W^*_M \cos(2\pi f M), \tag{7}$$

---

* Table 2 shows the coefficients for the 10-point non-symmetrical filter.

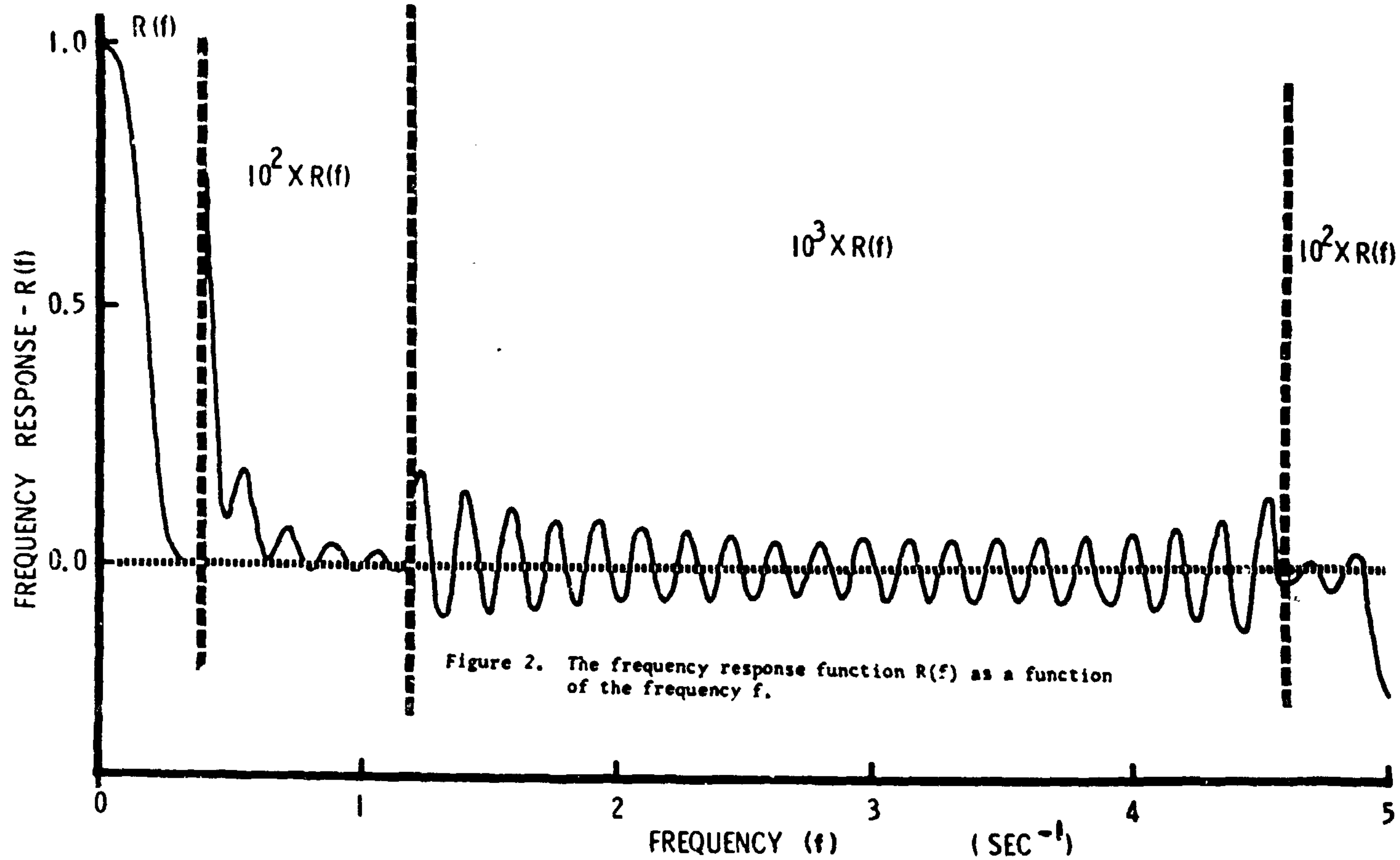

Figure 2. The frequency response function R(f) as a function of the frequency f.

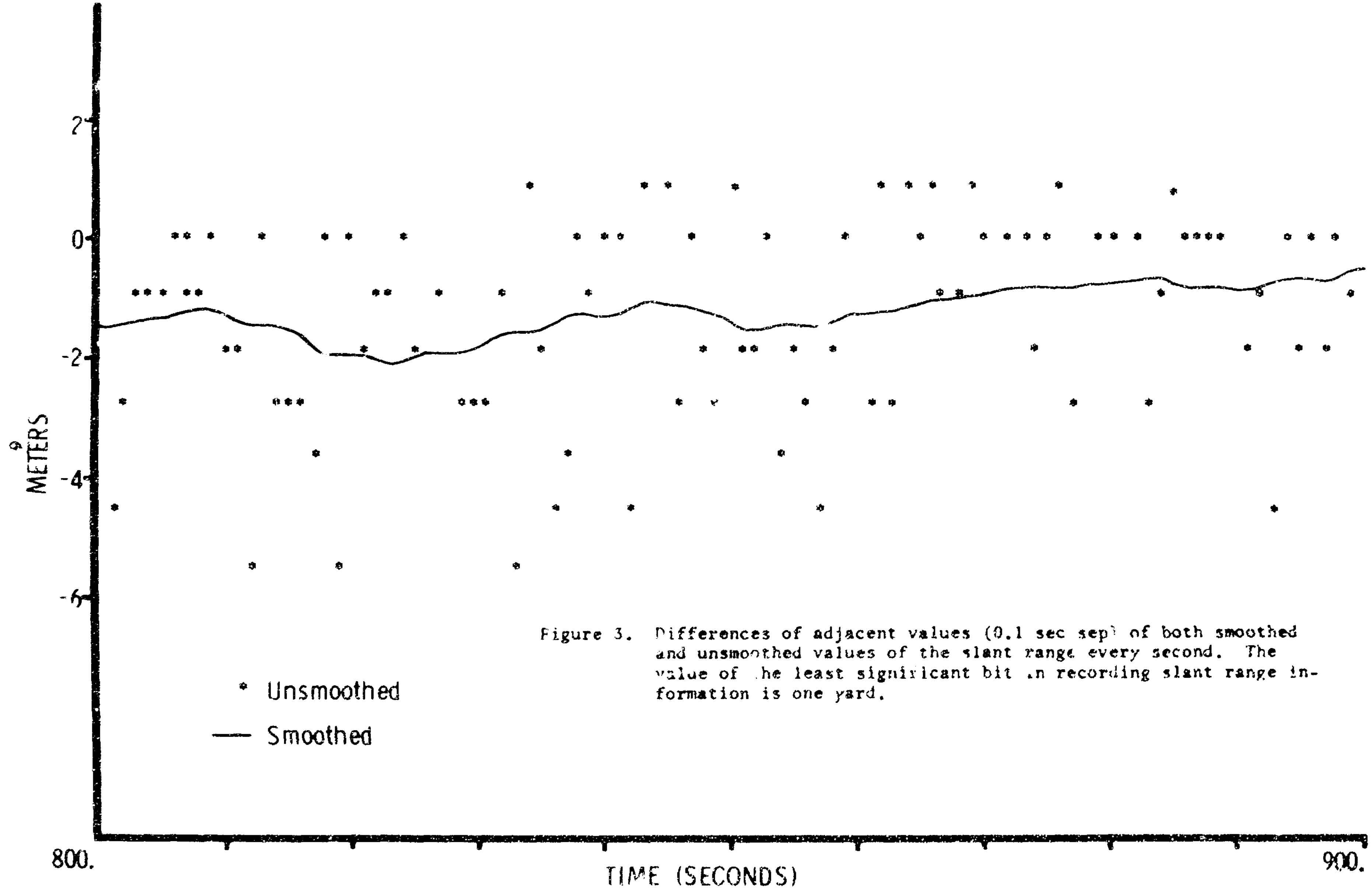

Figure 3. Differences of adjacent values (0.1 sec sep) of both smoothed and unsmoothed values of the slant range every second. The value of the least significant bit in recording slant range information is one yard.

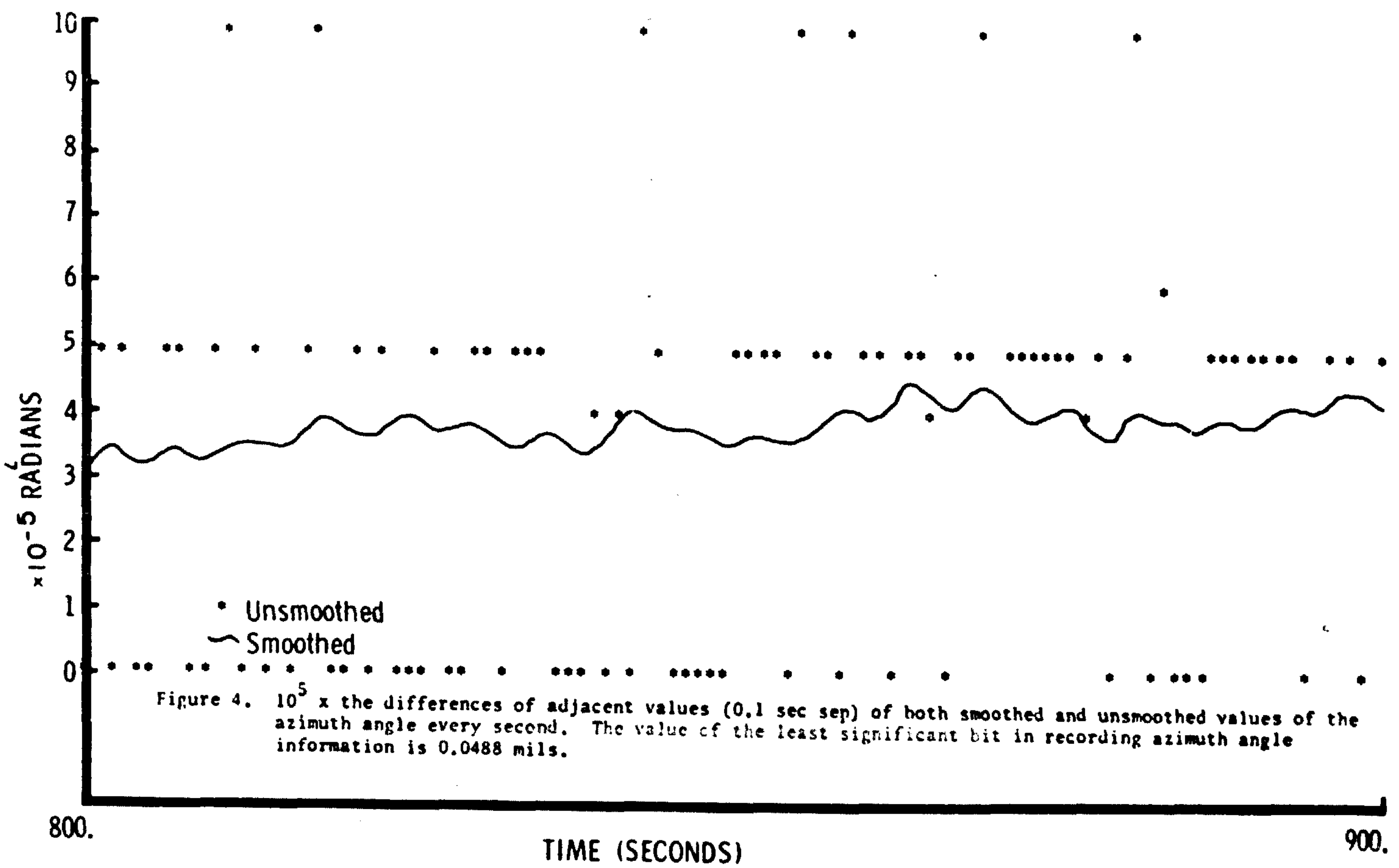

Figure 4. 10^5 x the differences of adjacent values (0.1 sec sep) of both smoothed and unsmoothed values of the azimuth angle every second. The value of the least significant bit in recording azimuth angle information is 0.0488 mils.

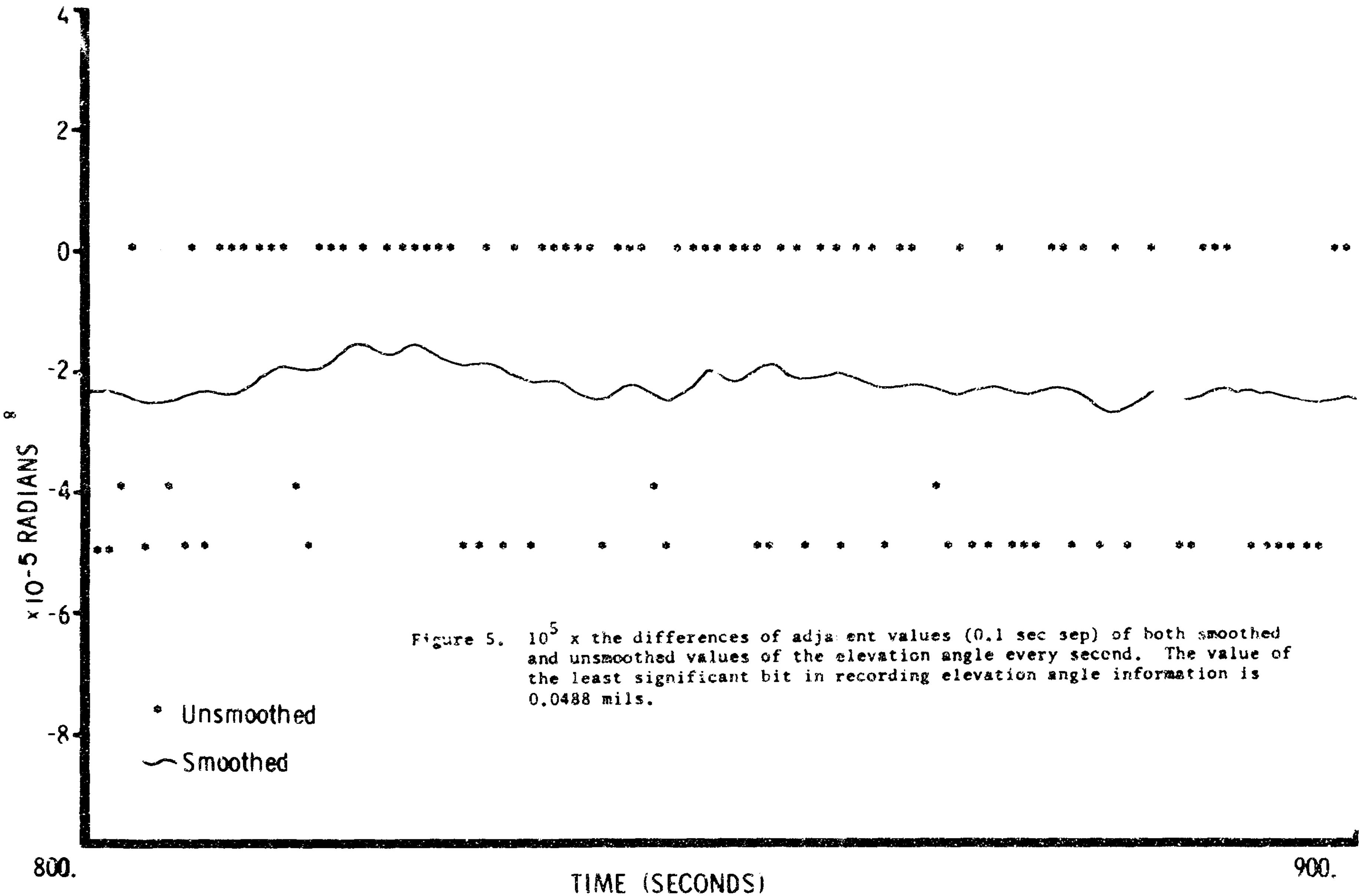

Figure 5. 10^5 x the differences of adja ent values (0.1 sec sep) of both smoothed and unsmoothed values of the elevation angle every second. The value of the least significant bit in recording elevation angle information is 0.0488 mils.

TABLE 2

COEFFICIENTS FOR THE 10-POINT NON-SYMMETRICAL FILTER

WGT(0)	=	0.93263928E-01
WGT(1)	=	0.10963999E 00
WGT(2)	=	0.12145806E 00
WGT(3)	=	0.1278C346E 00
WGT(4)	=	0.12803132E 00
WGT(5)	=	0.12177899E 00
WGT(6)	=	0.10896906E 00
WGT(7)	=	0.89803061E-01
WGT(8)	=	0.64746658E-01
WGT(9)	=	0.34506476E-01

$$S(f) = \sum_{M=0}^{9} W_M^* \sin(2\pi f M) \qquad (8)$$

for $0 \leq f \leq 0.5 \text{ sec}^{-1}$ where $|R^*(f)|$ is the magnitude of the frequency response at frequency f. The weights are shown in Figure 6 and $|R^*(f)|$ in Figure 7.

CORRECTION TECHNIQUE

Another error of the system must be corrected, namely the sensor's ability to respond to the actual wind. The faster the sensor falls, the less likely it will respond to the actual wind. In other words, small-scale wind oscillations will have little effect on the sensor while those with longer periods will be observed with greater accuracy. Therefore, the wind sensor itself becomes a time varying filter applied to the wind data. Eddy et al. (1965) designed a correction technique which theoretically eliminates this effect, eq (9).

$$\dot{\bar{X}}_K = \dot{X}_K - \frac{\ddot{X}_K \dot{Z}_K}{\ddot{Z}_K + g} , \qquad (9)$$

where $\dot{\bar{X}}_K$, $\dot{X}_K$, $\ddot{X}_K$, $\dot{Z}_K$, and $\ddot{Z}_K$ are the Kth values of the east-west wind component, sensor velocity, sensor acceleration, sensor vertical velocity, and sensor vertical acceleration, respectively, and g the gravity constant. An analogous equation is also applied to the north-south component. $\dot{\bar{Z}}_K$ is always assumed to be zero. This correction technique has been experimentally verified by Kays and Olsen (1966). Typical north-south and east-west wind component profiles in final filtered and corrected form are shown in Figure 8.

CONCLUSION

The wind reduction technique discussed is most applicable when the sensor is a point source and is tracked by a radar capable of at least a ten points per second sampling rate. Undesired high frequency oscillations are effectively eliminated, and successive wind profiles show good continuity. This technique is currently used at White Sands Missile Range, New Mexico, by the Atmospheric Sciences Laboratory.

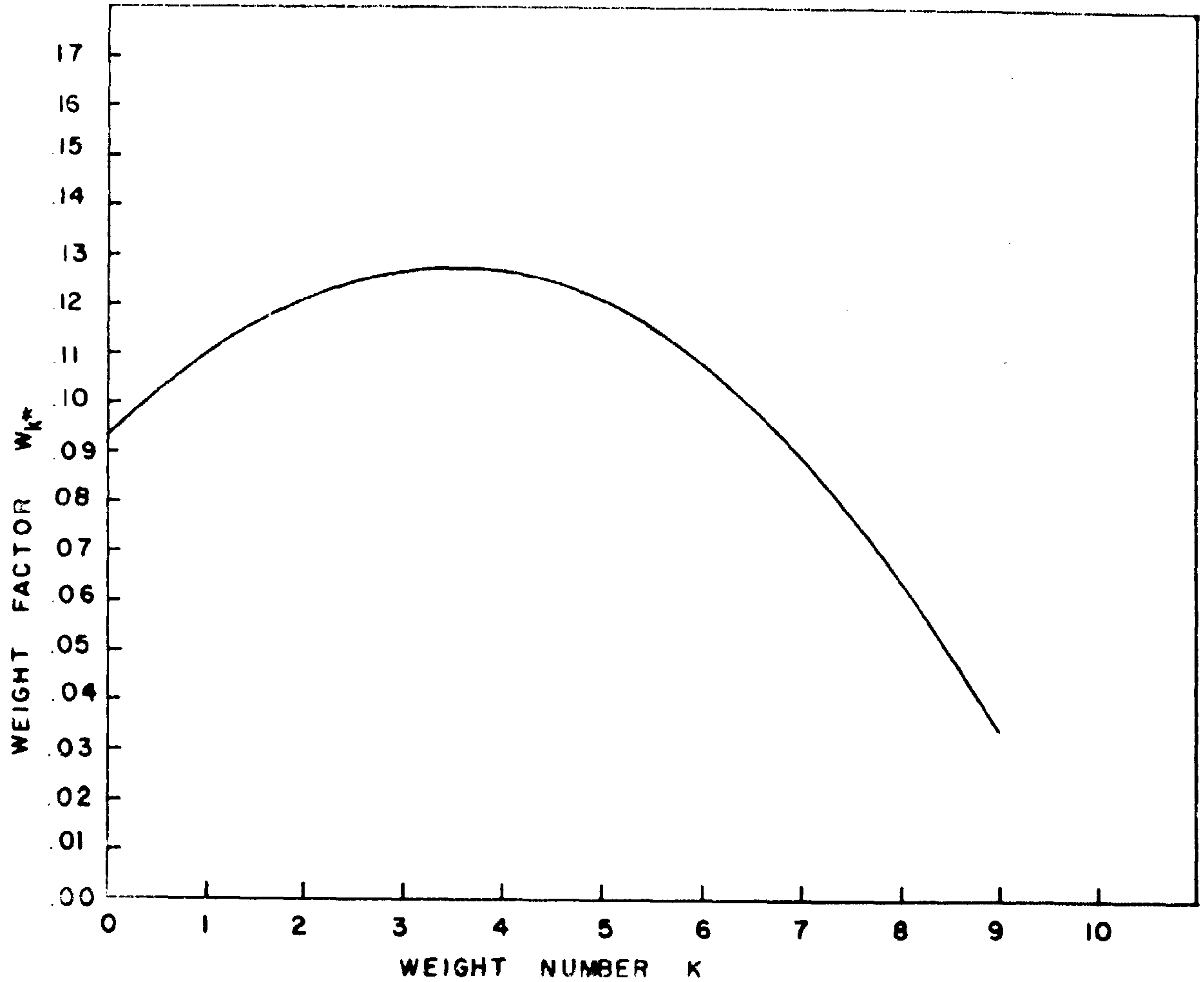

Figure 6. The weight W_K^* as a function of the weight number K.

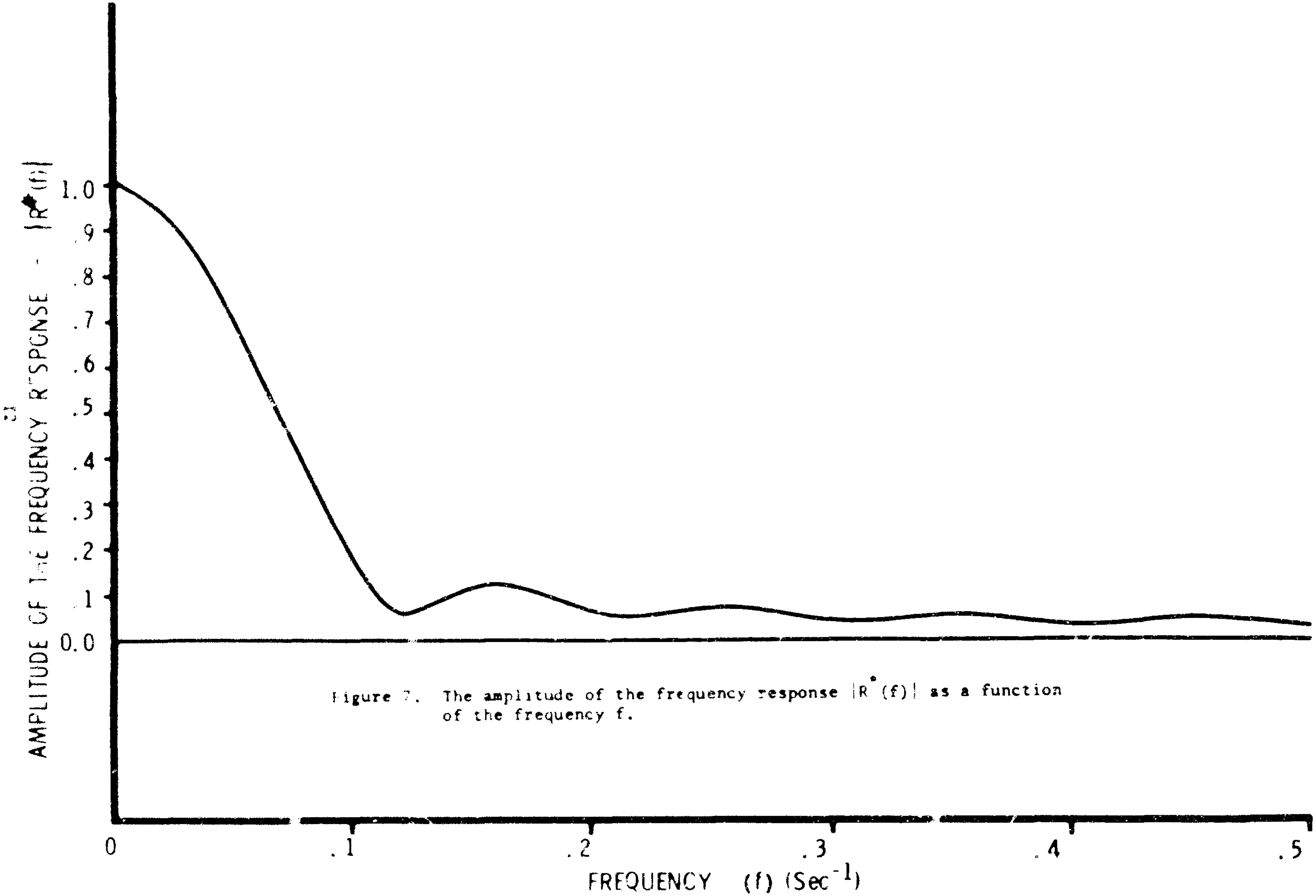

Figure 7. The amplitude of the frequency response $|R^*(f)|$ as a function of the frequency f.

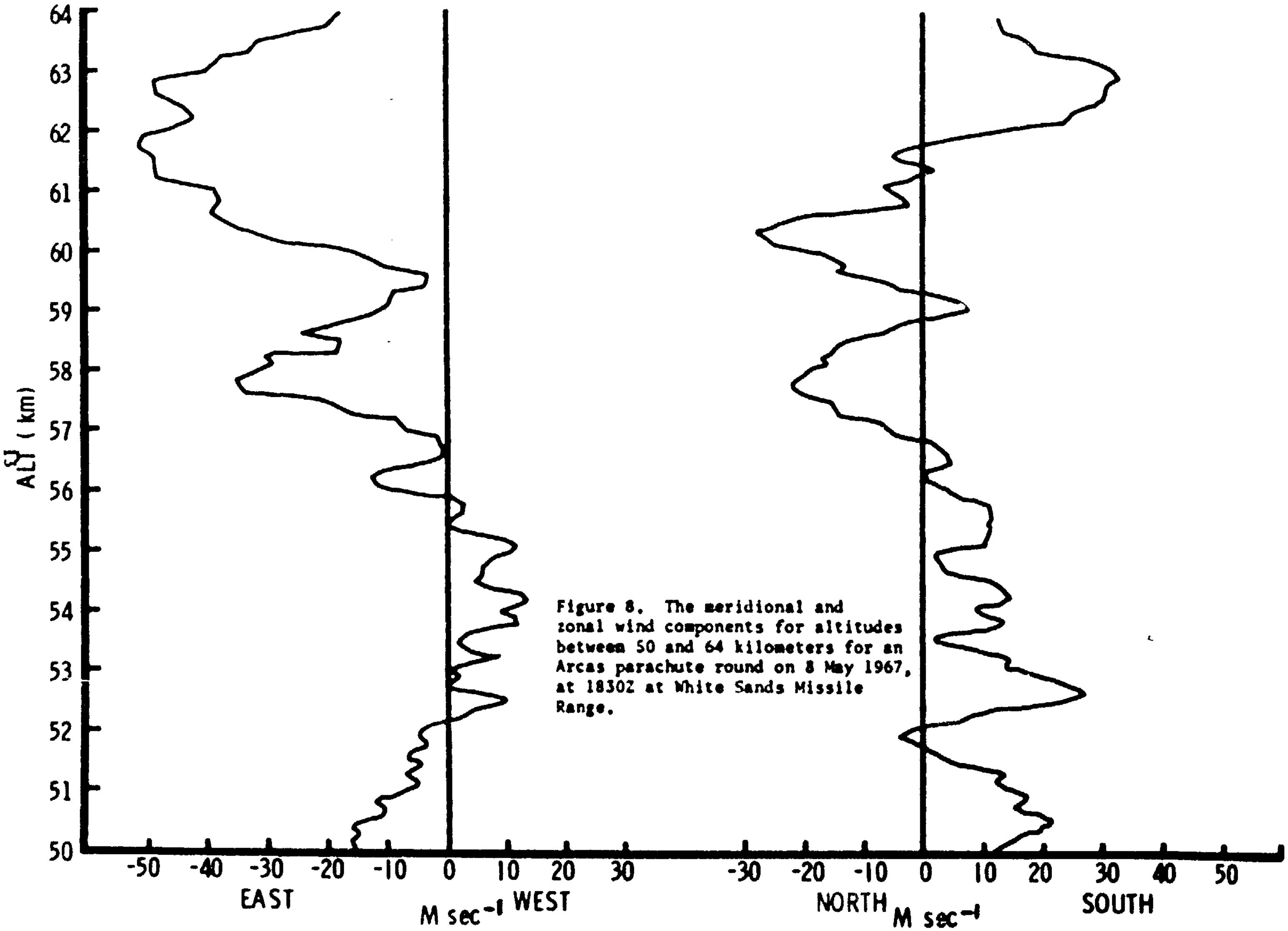

Figure 8. The meridional and zonal wind components for altitudes between 50 and 64 kilometers for an Arcas parachute round on 8 May 1967, at 1830Z at White Sands Missile Range.

REFERENCES

Eddy, A., C. E. Duchon, F. M. Haase, and D. R. Haragan, 1965: "Determination of Winds from Meteorological Rocketsondes", Atmospheric Sciences Group Report No. 2, College of Engineering, the University of Texas, Austin, Texas.

Kays, M. D., and R. O. Olsen, 1966: "Improved Rocketsonde Parachute-Derived Wind Profiles", Atmospheric Sciences Laboratory, ECON-5086, White Sands Missile Range, New Mexico.

ATMOSPHERIC SCIENCES RESEARCH PAPERS

1. Webb, W.L., "Development of Droplet Size Distributions in the Atmosphere," June 1954.
2. Hansen, F. V., and H. Rachele, "Wind Structure Analysis and Forecasting Methods for Rockets," June 1954.
3. Webb, W. L., "Net Electrification of Water Droplets at the Earth's Surface," *J. Meteorol.*, December 1954.
4. Mitchell, R., "The Determination of Non-Ballistic Projectile Trajectories," March 1955.
5. Webb, W. L., and A. McPike, "Sound Ranging Technique for Determining the Trajectory of Supersonic Missiles," #1, March 1955.
6. Mitchell, R., and W. L. Webb, "Electromagnetic Radiation through the Atmosphere," #1, April 1955.
7. Webb, W. L., A. McPike, and H. Thompson, "Sound Ranging Technique for Determining the Trajectory of Supersonic Missiles," #2, July 1955.
8. Barichivich, A., "Meteorological Effects on the Refractive Index and Curvature of Microwaves in the Atmosphere," August 1955.
9. Webb, W. L., A. McPike and H. Thompson, "Sound Ranging Technique for Determining the Trajectory of Supersonic Missiles," #3, September 1955.
10. Mitchell, R., "Notes on the Theory of Longitudinal Wave Motion in the Atmosphere," February 1956.
11. Webb, W. L., "Particulate Counts in Natural Clouds," *J. Meteorol.*, April 1956.
12. Webb, W. L., "Wind Effect on the Aerobee," #1, May 1956.
13. Rachele, H., and L. Anderson, "Wind Effect on the Aerobee," #2, August 1956.
14. Beyers, N., "Electromagnetic Radiation through the Atmosphere," #2, January 1957.
15. Hansen, F. V., "Wind Effect on the Aerobee," #3, January 1957.
16. Kershner, J., and H. Bear, "Wind Effect on the Aerobee," #4, January 1957.
17. Hoidale, G., "Electromagnetic Radiation through the Atmosphere," #3, February 1957.
18. Querfeld, C. W., "The Index of Refraction of the Atmosphere for 2.2 Micron Radiation," March 1957.
19. White, Lloyd, "Wind Effect on the Aerobee," #5, March 1957.
20. Kershner, J. G., "Development of a Method for Forecasting Component Ballistic Wind," August 1957.
21. Layton, Ivan, "Atmospheric Particle Size Distribution," December 1957.
22. Rachele, Henry and W. H. Hatch, "Wind Effect on the Aerobee," #6, February 1958.
23. Beyers, N. J., "Electromagnetic Radiation through the Atmosphere," #4, March 1958.
24. Prosser, Shirley J., "Electromagnetic Radiation through the Atmosphere," #5, April 1958.
25. Armendariz, M., and P. H. Taft, "Double Theodolite Ballistic Wind Computations," June 1958.
26. Jenkins, K. R. and W. L. Webb, "Rocket Wind Measurements," June 1958.
27. Jenkins, K. R., "Measurement of High Altitude Winds with Loki," July 1958.
28. Hoidale, G., "Electromagnetic Propagation through the Atmosphere," #6, February 1959.
29. McLardie, M., R. Helvey, and L. Traylor, "Low-Level Wind Profile Prediction Techniques," #1, June 1959.
30. Lamberth, Roy, "Gustiness at White Sands Missile Range," #1, May 1959.
31. Beyers, N. J., B. Hinds, and G. Hoidale, "Electromagnetic Propagation through the Atmosphere," #7, June 1959.
32. Beyers, N. J., "Radar Refraction at Low Elevation Angles (U)," Proceedings of the Army Science Conference, June 1959.
33. White, L., O. W. Thiele and P. H. Taft, "Summary of Ballistic and Meteorological Support During IGY Operations at Fort Churchill, Canada," August 1959.
34. Hainline, D. A., "Drag Cord-Aerovane Equation Analysis for Computer Application," August 1959.
35. Hoidale, G. B., "Slope-Valley Wind at WSMR," October 1959.
36. Webb, W. L., and K. R. Jenkins, "High Altitude Wind Measurements," *J. Meteorol.*, 16, 5, October 1959.

37. White, Lloyd, "Wind Effect on the Aerobee," #9, October 1959.
38. Webb, W. L., J. W. Coffman, and G. Q. Clark, "A High Altitude Acoustic Sensing System," December 1959.
39. Webb, W. L., and K. R. Jenkins, "Application of Meteorological Rocket Systems," J. Geophys. Res., 64, 11, November 1959.
40. Duncan, Louis, "Wind Effect on the Aerobee," #10, February 1960.
41. Helvey, R. A., "Low-Level Wind Profile Prediction Techniques," #2, February 1960.
42. Webb, W. L., and K. R. Jenkins, "Rocket Sounding of High-Altitude Parameters," *Proc. GM Rel. Symp.*, Dept. of Defense, February 1960.
43. Armendariz, M., and H. H. Monahan, "A Comparison Between the Double Theodolite and Single-Theodolite Wind Measuring Systems," April 1960.
44. Jenkins, K. R., and P. H. Taft, "Weather Elements in the Tularosa Basin," July 1960.
45. Beyers, N. J., "Preliminary Radar Performance Data on Passive Rocket-Borne Wind Sensors," IRE TRANS, MIL ELECT, MIL-4, 2-3, April-July 1960.
46. Webb, W. L., and K. R. Jenkins, "Speed of Sound in the Stratosphere," June 1960.
47. Webb, W. L., K. R. Jenkins, and G. Q. Clark, "Rocket Sounding of High Atmosphere Meteorological Parameters," *IRE Trans. Mil. Elect.*, MIL-4, 2-3, April-July 1960.
48. Helvey, R. A., "Low-Level Wind Profile Prediction Techniques," #3, September 1960.
49. Beyers, N. J., and O. W. Thiele, "Meteorological Wind Sensors," August 1960.
50. Armijo, Larry, "Determination of Trajectories Using Range Data from Three Noncolinear Radar Stations," September 1960.
51. Carnes, Patsy Sue, "Temperature Variations in the First 200 Feet of the Atmosphere in an Arid Region," July 1961.
52. Springer, H. S., and R. O. Olsen, "Launch Noise Distribution of Nike-Zeus Missiles," July 1961.
53. Thiele, O. W., "Density and Pressure Profiles Derived from Meteorological Rocket Measurements," September 1961.
54. Diamond, M. and A. B. Gray, "Accuracy of Missile Sound Ranging," November 1961.
55. Lamberth, R. L. and D. R. Veith, "Variability of Surface Wind in Short Distances," #1, October 1961.
56. Swanson, R. N., "Low-Level Wind Measurements for Ballistic Missile Application," January 1962.
57. Lamberth, R. L. and J. H. Grace, "Gustiness at White Sands Missile Range," #2, January 1962.
58. Swanson, R. N. and M. M. Hoidale, "Low-Level Wind Profile Prediction Techniques," #4, January 1962.
59. Rachele, Henry, "Surface Wind Model for Unguided Rockets Using Spectrum and Cross Spectrum Techniques," January 1962.
60. Rachele, Henry, "Sound Propagation through a Windy Atmosphere," #2, February 1962.
61. Webb, W. L., and K. R. Jenkins, "Sonic Structure of the Mesosphere," *J. Acous. Soc. Amer.*, 34, 2, February 1962.
62. Tourin, M. H. and M. M. Hoidale, "Low-Level Turbulence Characteristics at White Sands Missile Range," April 1962.
63. Miers, Bruce T., "Mesospheric Wind Reversal over White Sands Missile Range," March 1962.
64. Fisher, E., R. Lee and H. Rachele, "Meteorological Effects on an Acoustic Wave within a Sound Ranging Array," May 1962.
65. Walter, E. L., "Six Variable Ballistic Model for a Rocket," June 1962.
66. Webb, W. L., "Detailed Acoustic Structure Above the Tropopause," *J. Applied Meteorol.*, 1, 2, June 1962.
67. Jenkins, K. R., "Empirical Comparisons of Meteorological Rocket Wind Sensors," *J. Appl. Meteor.*, June 1962.
68. Lamberth, Roy, "Wind Variability Estimates as a Function of Sampling Interval," July 1962.
69. Rachele, Henry, "Surface Wind Sampling Periods for Unguided Rocket Impact Prediction," July 1962.
70. Traylor, Larry, "Coriolis Effects on the Aerobee-Hi Sounding Rocket," August 1962.
71. McCoy, J., and G. Q. Clark, "Meteorological Rocket Thermometry," August 1962.
72. Rachele, Henry, "Real-Time Prelaunch Impact Prediction System," August 1962.

73. Beyers, N. J., O. W. Thiele, and N. K. Wagner, "Performance Characteristics of Meteorological Rocket Wind and Temperature Sensors," October 1962.

74. Coffman, J., and R. Price, "Some Errors Associated with Acoustical Wind Measurements through a Layer," October 1962.

75. Armendariz, M., E. Fisher, and J. Serna, "Wind Shear in the Jet Stream at WSMR," November 1962.

76. Armendariz, M., F. Hansen, and S. Carnes, "Wind Variability and its Effect on Rocket Impact Prediction," January 1963.

77. Querfeld, C., and Wayne Yunker, "Pure Rotational Spectrum of Water Vapor, I: Table of Line Parameters," February 1963.

78. Webb, W. L., "Acoustic Component of Turbulence," *J. Applied Meteorol.*, 2, 2, April 1963.

79. Beyers, N. and L. Engberg, "Seasonal Variability in the Upper Atmosphere," May 1963.

80. Williamson, L. E., "Atmospheric Acoustic Structure of the Sub-polar Fall," May 1963.

81. Lamberth, Roy and D. Veith, "Upper Wind Correlations in Southwestern United States," June 1963.

92. Sandlin, E., "An analysis of Wind Shear Differences as Measured by AN/FPS-16 Radar and AN/GMD-1B Rawinsonde," August 1963.

83. Diamond, M. and R. P. Lee, "Statistical Data on Atmospheric Design Properties Above 30 km," August 1963.

84. Thiele, O. W., "Mesospheric Density Variability Based on Recent Meteorological Rocket Measurements," *J. Applied Meteorol.*, 2, 5, October 1963.

85. Diamond, M., and O. Essenwanger, "Statistical Data on Atmospheric Design Properties to 30 km," *Astro. Aero. Engr.*, December 1963.

86. Hansen, F. V., "Turbulence Characteristics of the First 62 Meters of the Atmosphere," December 1963.

87. Morris, J. E., and B. T. Miers, "Circulation Disturbances Between 25 and 70 kilometers Associated with the Sudden Warming of 1963," *J. of Geophys. Res.*, January 1964.

88. Thiele, O. W., "Some Observed Short Term and Diurnal Variations of Stratospheric Density Above 30 km," January 1964.

89. Sandlin, R. E., Jr. and E. Armijo, "An Analysis of AN/FPS-16 Radar and AN/GMD-1B Rawinsonde Data Differences," January 1964.

90. Miers, B. T., and N. J. Beyers, "Rocketsonde Wind and Temperature Measurements Between 30 and 70 km for Selected Stations," *J. Applied Meteorol.*, February 1964.

91. Webb, W. L., "The Dynamic Stratosphere," *Astronautics and Aerospace Engineering*, March 1964.

92. Low, R. D. H., "Acoustic Measurements of Wind through a Layer," March 1964.

93. Diamond, M., "Cross Wind Effect on Sound Propagation," *J. Applied Meteorol.*, April 1964.

94. Lee, R. P., "Acoustic Ray Tracing," April 1964.

95. Reynolds, R. D., "Investigation of the Effect of Lapse Rate on Balloon Ascent Rate," May 1964.

96. Webb, W. L., "Scale of Stratospheric Detail Structure," *Space Research V*, May 1964.

97. Barber, T. L., "Proposed X-Ray-Infrared Method for Identification of Atmospheric Mineral Dust," June 1964.

98. Thiele, O. W., "Ballistic Procedures for Unguided Rocket Studies of Nuclear Environments (U)," Proceedings of the Army Science Conference, June 1964.

99. Horn, J. D., and E. J. Trawle, "Orographic Effects on Wind Variability," July 1964.

100. Hoidale, G., C. Querfeld, T. Hall, and R. Mireles, "Spectral Transmissivity of the Earth's Atmosphere in the 250 to 500 Wave Number Interval," #1, September 1964.

101. Duncan, L. D., R. Ensey, and B. Engebos, "Athena Launch Angle Determination," September 1964.

102. Thiele, O. W., "Feasibility Experiment for Measuring Atmospheric Density Through the Altitude Range of 60 to 100 KM Over White Sands Missile Range," October 1964.

103. Duncan, L. D., and R. Ensey, "Six-Degree-of-Freedom Digital Simulation Model for Unguided, Fin-Stabilized Rockets," November 1964.

104. Hoidale, G., C. Querfeld, T. Hall, and R. Mireles, "Spectral Transmissivity of the Earth's Atmosphere in the 250 to 500 Wave Number Interval," #2, November 1964.
105. Webb, W. L., "Stratospheric Solar Response," *J. Atmos. Sci.*, November 1964.
106. McCoy, J. and G. Clark, "Rocketsonde Measurement of Stratospheric Temperature," December 1964.
107. Farone, W. A., "Electromagnetic Scattering from Radially Inhomogeneous Spheres as Applied to the Problem of Clear Atmosphere Radar Echoes," December 1964.
108. Farone, W. A., "The Effect of the Solid Angle of Illumination or Observation on the Color Spectra of 'White Light' Scattered by Cylinders," January 1965.
109. Williamson, L. E., "Seasonal and Regional Characteristics of Acoustic Atmospheres," *J. Geophys. Res.*, January 1965.
110. Armendariz, M., "Ballistic Wind Variability at Green River, Utah," January 1965.
111. Low, R. D. H., "Sound Speed Variability Due to Atmospheric Composition," January 1965.
112. Querfeld, C. W., 'Mie Atmospheric Optics," *J. Opt. Soc. Amer.*, January 1965.
113. Coffman, J., "A Measurement of the Effect of Atmospheric Turbulence on the Coherent Properties of a Sound Wave," January 1965.
114. Rachele, H., and D. Veith, "Surface Wind Sampling for Unguided Rocket Impact Prediction," January 1965.
115. Ballard, H., and M. Izquierdo, "Reduction of Microphone Wind Noise by the Generation of a Proper Turbulent Flow," February 1965.
116. Mireles, R., "An Algorithm for Computing Half Widths of Overlapping Lines on Experimental Spectra," February 1965.
117. Richart, H., "Inaccuracies of the Single-Theodolite Wind Measuring System in Ballistic Application," February 1965.
118. D'Arcy, M., "Theoretical and Practical Study of Aerobee-150 Ballistics," March 1965.
119. McCoy, J., "Improved Method for the Reduction of Rocketsonde Temperature Data," March 1965.
120. Mireles, R., "Uniqueness Theorem in Inverse Electromagnetic Cylindrical Scattering," April 1965.
121. Coffman, J., "The Focusing of Sound Propagating Vertically in a Horizontally Stratified Medium," April 1965.
122. Farone, W. A., and C. Querfeld, "Electromagnetic Scattering from an Infinite Circular Cylinder at Oblique Incidence," April 1965.
123. Rachele, H., "Sound Propagation through a Windy Atmosphere," April 1965.
124. Miers, B., "Upper Stratospheric Circulation over Ascension Island," April 1965.
125. Rider, L., and M. Armendariz, " A Comparison of Pibal and Tower Wind Measurements," April 1965.
126. Hoidale, G. B., "Meteorological Conditions Allowing a Rare Observation of 24 Micron Solar Radiation Near Sea Level," *Meteorol. Magazine*, May 1965.
127. Beyers, N. J., and B. T. Miers, "Diurnal Temperature Change in the Atmosphere Between 30 and 60 km over White Sands Missile Range," *J. Atmos. Sci.*, May 1965.
128. Querfeld, C., and W. A. Farone, "Tables of the Mie Forward Lobe," May 1965.
129. Farone, W. A., Generalization of Rayleigh-Gans Scattering from Radially Inhomogeneous Spheres," *J. Opt. Soc. Amer.*, June 1965.
130. Diamond, M., "Note on Mesospheric Winds Above White Sands Missile Range," *J. Applied Meteorol.*, June 1965.
131. Clark, G. Q., and J. G. McCoy, "Measurement of Stratospheric Temperature," *J. Applied Meteorol.*, June 1965.
132. Hall, T., G. Hoidale, R. Mireles, and C. Querfeld, "Spectral Transmissivity of the Earth's Atmosphere in the 250 to 500 Wave Number Interval," #3, July 1965.
133. McCoy, J., and C. Tate, "The Delta-T Meteorological Rocket Payload," June 1964.
134. Horn, J. D., "Obstacle Influence in a Wind Tunnel," July 1965.
135. McCoy, J., "An AC Probe for the Measurement of Electron Density and Collision Frequency in the Lower Ionosphere," July 1965.
136. Miers, B. T., M. D. Kays, O. W. Thiele and E. M. Newby, "Investigation of Short Term Variations of Several Atmospheric Parameters Above 30 KM," July 1965.

137. Serna, J., "An Acoustic Ray Tracing Method for Digital Computation," September 1965.
138. Webb, W. L., "Morphology of Noctilucent Clouds," *J. Geophys. Res.*, 70, 18, 4463-4475, September 1965.
139. Kays, M., and R. A. Craig, "On the Order of Magnitude of Large-Scale Vertical Motions in the Upper Stratosphere," *J. Geophys. Res.*, 70, 18, 4453-4462, September 1965.
140. Rider, L., "Low-Level Jet at White Sands Missile Range," September 1965.
141. Lamberth, R. L., R. Reynolds, and Morton Wurtele, "The Mountain Lee Wave at White Sands Missile Range," *Bull. Amer. Meteorol. Soc.*, 46, 10, October 1965.
142. Reynolds, R. and R. L. Lamberth, "Ambient Temperature Measurements from Radiosondes Flown on Constant-Level Balloons," October 1965.
143. McCluney, E., "Theoretical Trajectory Performance of the Five-Inch Gun Probe System," October 1965.
144. Pena, R. and M. Diamond, "Atmospheric Sound Propagation near the Earth's Surface," October 1965.
145. Mason, J. B., "A Study of the Feasibility of Using Radar Chaff For Stratospheric Temperature Measurements," November 1965.
146. Diamond, M., and R. P. Lee, "Long-Range Atmospheric Sound Propagation," *J. Geophys. Res.*, 70, 22, November 1965.
147. Lamberth, R. L., "On the Measurement of Dust Devil Parameters," November 1965.
148. Hansen, F. V., and P. S. Hansen, "Formation of an Internal Boundary over Heterogeneous Terrain," November 1965.
149. Webb, W. L., "Mechanics of Stratospheric Seasonal Reversals," November 1965.
150. U. S. Army Electronics R & D Activity, "U. S. Army Participation in the Meteorological Rocket Network," January 1966.
151. Rider, L. J., and M. Armendariz, "Low-Level Jet Winds at Green River, Utah," February 1966.
152. Webb, W. L., "Diurnal Variations in the Stratospheric Circulation," February 1966.
153. Beyers, N. J., B. T. Miers, and R. J. Reed, "Diurnal Tidal Motions near the Stratopause During 48 Hours at WSMR," February 1966.
154. Webb, W. L., "The Stratospheric Tidal Jet," February 1966.
155. Hall, J. T., "Focal Properties of a Plane Grating in a Convergent Beam," February 1966.
156. Duncan, L. D., and Henry Rachele, "Real-Time Meteorological System for Firing of Unguided Rockets," February 1966.
157. Kays, M. D., "A Note on the Comparison of Rocket and Estimated Geostrophic Winds at the 10-mb Level," *J. Appl. Meteor.*, February 1966.
158. Rider, L., and M. Armendariz, " A Comparison of Pibal and Tower Wind Measurements," *J. Appl. Meteor.*, 5, February 1966.
159. Duncan, L. D., "Coordinate Transformations in Trajectory Simulations," February 1966.
160. Williamson, L. E., "Gun-Launched Vertical Probes at White Sands Missile Range," February 1966.
161. Randhawa, J. S., Ozone Measurements with Rocket-Borne Ozonesondes," March 1966.
162. Armendariz, Manuel, and Laurence J. Rider, "Wind Shear for Small Thickness Layers," March 1966.
163. Low, R. D. H., "Continuous Determination of the Average Sound Velocity over an Arbitrary Path," March 1966.
164. Hansen, Frank V., "Richardson Number Tables for the Surface Boundary Layer," March 1966.
165. Cochran, V. C., E. M. D'Arcy, and Florencio Ramirez, "Digital Computer Program for Five-Degree-of-Freedom Trajectory," March 1966.
166. Thiele, O. W., and N. J. Beyers, "Comparison of Rocketsonde and Radiosonde Temperatures and a Verification of Computed Rocketsonde Pressure and Density," April 1966.
167. Thiele, O. W., "Observed Diurnal Oscillations of Pressure and Density in the Upper Stratosphere and Lower Mesosphere," April 1966.
168. Kays, M. D., and R. A. Craig, "On the Order of Magnitude of Large-Scale Vertical Motions in the Upper Stratosphere," *J. Geophy. Res.*, April 1966.
169. Hansen, F. V., "The Richardson Number in the Planetary Boundary Layer," May 1966.

170. Ballard, H. N., "The Measurement of Temperature in the Stratosphere and Mesosphere," June 1966.
171. Hansen, Frank V., "The Ratio of the Exchange Coefficients for Heat and Momentum in a Homogeneous, Thermally Stratified Atmosphere," June 1966.
172. Hansen, Frank V., "Comparison of Nine Profile Models for the Diabatic Boundary Layer," June 1966.
173. Rachele, Henry, "A Sound-Ranging Technique for Locating Supersonic Missiles," May 1966.
174. Farone, W. A., and C. W. Querfeld, "Electromagnetic Scattering from Inhomogeneous Infinite Cylinders at Oblique Incidence," *J. Opt. Soc. Amer.* 56, 4, 476-480, April 1966.
175. Mireles, Ramon, "Determination of Parameters in Absorption Spectra by Numerical Minimization Techniques," *J. Opt. Soc. Amer.* 56, 5, 644-647, May 1966.
176. Reynolds, R., and R. L. Lamberth, "Ambient Temperature Measurements from Radiosondes Flown on Constant-Level Balloons," *J Appl. Meteorol.*, 5, 3, 304-307, June 1966.
177. Hall, James T., "Focal Properties of a Plane Grating in a Convergent Beam," *Appl. Opt.*, 5, 1051, June 1966
178. Rider, Laurence J., "Low-Level Jet at White Sands Missile Range," *J. Appl. Meteorol.*, 5, 3, 283-287, June 1966.
179. McCluney, Eugene, "Projectile Dispersion as Caused by Barrel Displacement in the 5-Inch Gun Probe System," July 1966.
180. Armendariz, Manuel, and Laurence J. Rider, "Wind Shear Calculations for Small Shear Layers," June 1966.
181. Lamberth, Roy L., and Manuel Armendariz, "Upper Wind Correlations in the Central Rocky Mountains," June 1966.
182. Hansen, Frank V., and Virgil D. Lang, "The Wind Regime in the First 62 Meters of the Atmosphere," June 1966.
183. Randhawa, Jagir S., "Rocket-Borne Ozonesonde," July 1966.
184. Rachele, Henry, and L. D. Duncan, "The Desirability of Using a Fast Sampling Rate for Computing Wind Velocity from Pilot-Balloon Data," July 1966.
185. Hinds, B. D., and R. G. Pappas, "A Comparison of Three Methods for the Correction of Radar Elevation Angle Refraction Errors," August 1966.
186. Riedmuller, G. F., and T. L. Barber, "A Mineral Transition in Atmospheric Dust Transport," August 1966.
187. Hall, J. T., C. W. Querfeld, and G. B. Hoidale, "Spectral Transmissivity of the Earth's Atmosphere in the 250 to 500 Wave Number Interval," Part IV (Final), July 1966.
188. Duncan, L. D. and B. F. Engebos, "Techniques for Computing Launcher Settings for Unguided Rockets," September 1966.
189. Duncan, L. D., "Basic Considerations in the Development of an Unguided Rocket Trajectory Simulation Model," September 1966.
190. Miller, Walter B., "Consideration of Some Problems in Curve Fitting," September 1966.
191. Cermak, J. E., and J. D. Horn, "The Tower Shadow Effect," August 1966.
192. Webb, W. L., "Stratospheric Circulation Response to a Solar Eclipse," October 1966.
193. Kennedy, Bruce, "Muzzle Velocity Measurement," October 1966.
194. Traylor, Larry E., "A Refinement Technique for Unguided Rocket Drag Coefficients," October 1966
195. Nusbaum, Henry, "A Reagent for the Simultaneous Microscope Determination of Quartz and Halides," October 1966.
196. Kays, Marvin and R. O. Olsen, "Improved Rocketsonde Parachute-derived Wind Profiles," October 1966.
197. Engebos, Bernard F. and Duncan, Louis D., "A Nomogram for Field Determination of Launcher Angles for Unguided Rockets," October 1966.
198. Webb, W. L., "Midlatitude Clouds in the Upper Atmosphere," November 1966.
199. Hansen, Frank V., "The Lateral Intensity of Turbulence as a Function of Stability," November 1966.
200. Rider, L. J. and M. Armendariz, "Differences of Tower and Pibal Wind Profiles," November 1966.
201. Lee, Robert P., "A Comparison of Eight Mathematical Models for Atmospheric Acoustical Ray Tracing," November 1966.
202. Low, R. D. H., et al., "Acoustical and Meteorological Data Report SOTRAN I and II," November 1966.

203. Hunt, J. A. and J. D. Horn, "Drag Plate Balance," December 1966.
204. Armendariz, M., and H. Rachele, "Determination of a Representative Wind Profile from Balloon Data," December 1966.
205. Hansen, Frank V., "The Aerodynamic Roughness of the Complex Terrain of White Sands Missile Range," January 1967.
206. Morris, James E., "Wind Measurements in the Subpolar Mesopause Region," January 1967.
207. Hall, James T., "Attenuation of Millimeter Wavelength Radiation by Gaseous Water," January 1967.
208. Thiele, O. W., and N. J. Beyers, "Upper Atmosphere Pressure Measurements With Thermal Conductivity Gauges," January 1967.
209. Armendariz, M., and H. Rachele, "Determination of a Representative Wind Profile from Balloon Data," January 1967.
210. Hansen, F. V., "The Aerodynamic Roughness of the Complex Terrain of White Sands Missile Range, New Mexico," January 1967.
211. D'Arcy, Edward M., "Some Applications of Wind to Unguided Rocket Impact Prediction," March 1967.
212. Kennedy, Bruce, "Operation Manual for Stratosphere Temperature Sonde," March 1967.
213. Hoidale, G. B., S. M. Smith, A. J. Blanco, and T. L. Barber, "A Study of Atmospheric Dust," March 1967.
214. Longyear, J. Q., "An Algorithm for Obtaining Solutions to Laplace's Tidal Equations," March 1967.
215. Rider, L. J., "A Comparison of Pibal with Raob and Rawin Wind Measurements," April 1967.
216. Breeland, A. H., and R. S. Bonner, "Results of Tests Involving Hemispherical Wind Screens in the Reduction of Wind Noise," April 1967.
217. Webb, Willis L., and Max C. Bolen, "The D-region Fair-Weather Electric Field," April 1967.
218. Kubinski, Stanley F., "A Comparative Evaluation of the Automatic Tracking Pilot Balloon Wind Measuring System," April 1967.
219. Miller, Walter B., and Henry Rachele, "On Nonparametric Testing of the Nature of Certain Time Series," April 1967.
220. Hansen, Frank V., "Spacial and Temporal Distribution of the Gradient Richardson Number in the Surface and Planetary Layers," May 1967.
221. Randhawa, Jagir S., "Diurnal Variation of Ozone at High Altitudes," May 1967.
222. Ballard, Harold N., "A Review of Seven Papers Concerning the Measurement of Temperature in the Stratosphere and Mesosphere," May 1967.
223. Williams, Ben H., "Synoptic Analyses of the Upper Stratospheric Circulation During the Late Winter Storm Period of 1966," May 1967.
224. Horn, J. D., and J. A. Hunt, "System Design for the Atmospheric Sciences Office Wind Research Facility," May 1967.
225. Miller, Walter B., and Henry Rachele, "Dynamic Evaluation of Radar and Photo Tracking Systems, " May 1967.
226. Bonner, Robert S., and Ralph H. Rohwer, "Acoustical and Meteorological Data Report - SOTRAN III and IV," May 1967.
227. Rider, L. J., "On Time Variability of Wind at White Sands Missile Range, New Mexico," June 1967.
228. Randhawa, Jagir S., "Mesospheric Ozone Measurements During a Solar Eclipse," June 1967.
229. Beyers, N. J., and B. T. Miers, "A Tidal Experiment in the Equatorial Stratosphere over Ascension Island (8S)", June 1967.
230. Miller, W. B., and H. Rachele, "On the Behavior of Derivative Processes," June 1967
231. Walters, Randall K., "Numerical Integration Methods for Ballistic Rocket Trajectory Simulation Programs," June 1967.
232. Hansen, Frank V., "A Diabatic Surface Boundary Layer Model," July 1967.
233. Butler, Ralph L., and James K. Hall, "Comparison of Two Wind Measuring Systems with the Contraves Photo-Theodolite," July 1967.
234. Webb, Willis L., "The Source of Atmospheric Electrification," June 1967.

235. Hinds, B. D., "Radar Tracking Anomalies over an Arid Interior Basin," August 1967.
236. Christian, Larry O., "Radar Cross Sections for Totally Reflecting Spheres," August 1967.
237. D'Arcy, Edward M., "Theoretical Dispersion Analysis of the Aerobee 350," August 1967.
238. Anon., "Technical Data Package for Rocket-Borne Temperature Sensor," August 1967.
239. Glass, Roy I., Roy L. Lamberth, and Ralph D. Reynolds, "A High Resolution Continuous Pressure Sensor Modification for Radiosondes," August 1967.
240. Low, Richard D. H., "Acoustic Measurement of Supersaturation in a Warm Cloud," August 1967.
241. Rubio, Roberto, and Harold N. Ballard, "Time Response and Aerodynamic Heating of Atmospheric Temperature Sensing Elements," August 1967.
242. Seagraves, Mary Ann B., "Theoretical Performance Characteristics and Wind Effects for the Aerobee 150," August 1967.
243. Duncan, Louis Dean, "Channel Capacity and Coding," August 1967.
244. Dunaway, G. L., and Mary Ann B. Seagraves, "Launcher Settings Versus Jack Settings for Aerobee 150 Launchers - Launch Complex 35, White Sands Missile Range, New Mexico," August 1967.
245. Duncan, Louis D., and Bernard F. Engebos, "A Six-Degree-of-Freedom Digital Computer Program for Trajectory Simulation," October 1967.
246. Rider, Laurence J., and Manuel Armendariz, "A Comparison of Simultaneous Wind Profiles Derived from Smooth and Roughened Spheres," September 1967.
247. Reynolds, Ralph D., Roy L. Lamberth, and Morton G. Wurtele, "Mountain Wave Theory vs Field Test Measurements," September 1967.
248. Lee, Robert P., "Probabilistic Model for Acoustic Sound Ranging," October 1967.
249. Williamson, L. Edwin, and Bruce Kennedy, "Meteorological Shell for Standard Artillery Pieces - A Feasibility Study," October 1967.
250. Rohwer, Ralph H., "Acoustical, Meteorological and Seismic Data Report - SOTRAN V and VI," October 1967.
251. Nordquist, Walter S., Jr., "A Study in Acoustic Direction Finding," November 1967.
252. Nordquist, Walter S., Jr., "A Study of Acoustic Monitoring of the Gun Probe System," November 1967.
253. Avara, E. P., and B. T. Miers, "A Data Reduction Technique for Meteorological Wind Data above 30 Kilometers," December 1967.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Electronics Command, Fort Monmouth, New Jersey	2a. REPORT SECURITY CLASSIFICATION: Unclassified
	2b. GROUP

3. REPORT TITLE

A DATA REDUCTION TECHNIQUE FOR METEOROLOGICAL WIND DATA ABOVE 30 KILOMETERS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

E. P. Avara
B. T. Miers

6. REPORT DATE: December 1967	7a. TOTAL NO. OF PAGES: 14	7b. NO. OF REFS: 2

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S): ECOM-5168
b. PROJECT NO.	
c. DA TASK 1T014501B53A-03	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Distribution of this report is unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY: U. S. Army Electronics Command, Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico

13. ABSTRACT

The FPS-16 tracking systems superimpose undesired oscillations on the real position data resulting in rapidly fluctuating successive position points which are physically unrealistic. A linear digital filter of the form

$$\overline{Q}_K = \sum_{M=-58}^{M=58} W_M Q_{K+M}$$

is applied separately to each component to smooth the data. The frequency response is given and the data are corrected by a method derived by Eddy et al. ~~(1965)~~. Undesired high frequency oscillations are effectively eliminated and successive wind profiles show good continuity.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. FPS-16 Radar Tracks						
2. Wind Reduction Technique						
3. Linear Digital Filter						
4. Ballistic Rockets						
5. Coefficients						

UNCLASSIFIED
Security Classification