GSFC

X-591-73-351
PREPRINT

NASA TM X- 70555

CORRECTION OF LASER RANGE TRACKING DATA FOR ATMOSPHERIC REFRACTION AT ELEVATIONS ABOVE 10 DEGREES

J. W. MARINI
C. W. MURRAY, JR.

NOVEMBER 1973

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

X-591-73-351

CORRECTION OF LASER RANGE TRACKING DATA FOR ATMOSPHERIC REFRACTION AT ELEVATIONS ABOVE 10 DEGREES

J. W. Marini

C. W. Murray, Jr.

November 1973

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

CORRECTION OF LASER RANGE TRACKING DATA FOR ATMOSPHERIC REFRACTION AT ELEVATIONS ABOVE 10 DEGREES

J. W. Marini
C. W. Murray, Jr.

ABSTRACT

A formula for correcting laser measurements of satellite range for the effect of atmospheric refraction is given. The corrections apply above 10° elevation to satellites whose heights exceed 70 km. The meteorological measurements required are the temperature, pressure, and relative humidity of the air at the laser site at the time of satellite pass.

The accuracy of the formula was tested by comparison with corrections obtained by ray-tracing radiosonde profiles. The standard deviation of the difference between the refractive retardation given by the formula and that calculated by ray-tracing was less than about 0.04% of the retardation or about 0.5 cm at 10° elevation, decreasing to 0.04 cm near zenith.

PRECEDING PAGE BLANK NOT FILMED

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

CORRECTION OF LASER RANGE TRACKING DATA FOR ATMOSPHERIC REFRACTION AT ELEVATIONS ABOVE 10 DEGREES

INTRODUCTION

The correction of tracking data for atmospheric refraction has been exhaustively studied, and many correction formulas have been published [1-6]. For certain earth and ocean physics applications, however, position accuracies of better than a few centimeters are desirable [7], and these accuracies are much greater than required for most previous applications. Out of the work cited, only the approach given by Marini [3], and the expansion and integral evaluations of Saastamoinen [5,6] provide the desired accuracy at lower elevation angles (10° - 20°). In this report Saastamoinen's integral evaluations are incorporated into Marini's continued fraction form to provide relatively simple algorithms for correcting laser range-data using surface meteorological measurements.

REFRACTIVITY AT OPTICAL FREQUENCIES

There are a number of formulas [8-11] for the refractive index n of air and for the corresponding refractivity

$$N \equiv 10^6 (n - 1) \tag{1}$$

all of which have sufficient accuracy for use here. The formula employed is [12]

$$N = \left(287.604 + \frac{1.6288}{\lambda^2} + \frac{0.0136}{\lambda^4}\right)\left(\frac{P}{1013.25}\right)\left(\frac{1}{1 + 0.003661\, t}\right) - 0.055\left(\frac{760}{1013.25}\right)\left(\frac{e}{1 + 0.00366\, t}\right) \tag{2}$$

where

$\lambda \equiv$ wavelength of radiation in microns
$P \equiv$ atmospheric pressure in millibars
$e \equiv$ partial water vapor pressure in millibars
$t \equiv$ temperature in degrees Celsius

Because air is dispersive at optical frequencies, the group refractivity N_g is also required

$$N_g = \frac{d}{df}(fN) = N - \lambda \frac{dN}{d\lambda} \tag{3}$$

where f is the frequency. The expression for the group refractivity can be written as

$$N_g = 80.343\, f(\lambda)\frac{P}{T} - 11.3\,\frac{e}{T} \tag{4}$$

where

P = Total air pressure in millibars
e = Partial pressure of water vapor (mb)
T = Temperature (°K)

and

$$f(\lambda) \equiv 0.9650 + \frac{0.0164}{\lambda^2} + \frac{0.000228}{\lambda^4} \tag{5}$$

which, at the 0.6943 micron wavelength of the ruby laser becomes

$$f(0.6943) = 1.0000 \tag{6}$$

GEOMETRY AND NOTATION

The geometry of the satellite-tracking station configuration is shown in Figure 1. Spherical symmetry is assumed, i.e. the refractivity is taken to be a function of height only. The height h is measured from the tracking station upward. The subscript "0" designates quantities evaluated at the tracking station, the subscript "1", quantities evaluated at the satellite. The ray or phase path between tracking station and satellite is shown as a curved line. The true range R is the distance along the straight line connecting the tracking station and the satellite, and the true elevation angle E is the angle between this line and the horizontal at the station. The nominal earth radius used is r_e = 6378 km, and H is the height of the tracking station above sea level. The latitude of the tracking station is φ degrees above the equator.

EXPANSION FORMULA

The apparent range R_e between the ground station and the satellite as measured by a pulsed system is given by the integral of the group index of refraction along the phase path [13, 14]

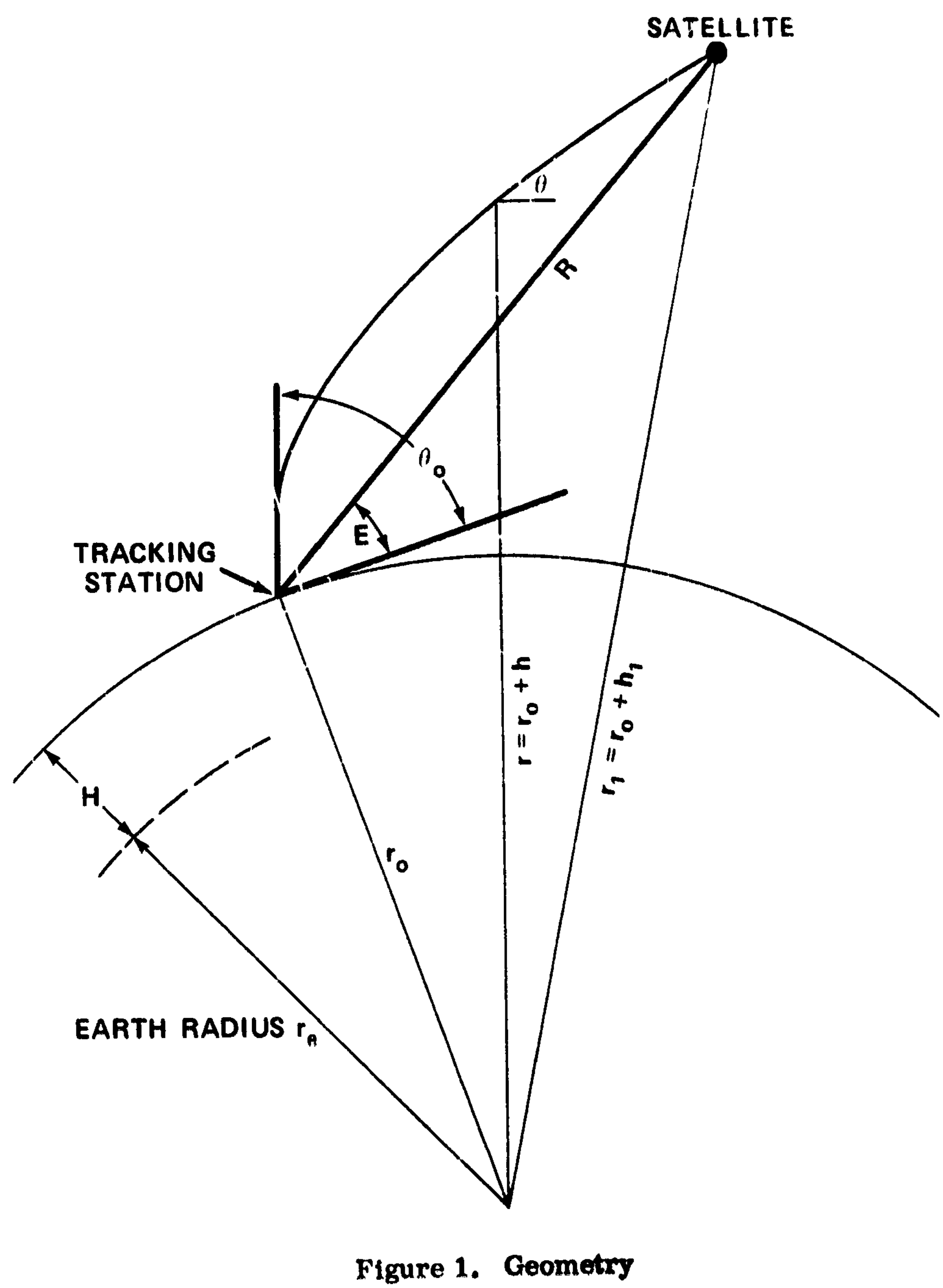

Figure 1. Geometry

$$R_e = \int_{r_0}^{r_1} \frac{n_g}{\sin\theta}\, dr \tag{7}$$

where the angle θ is given by Snell's law for a spherically stratified medium

$$nr\cos\theta = n_0\, r_0 \cos\theta_0 \tag{8}$$

The correction sought is the difference between the measured and the true value of the range

$$\Delta R \equiv R_e - R \tag{9}$$

The expansion of ΔR in inverse powers of $\sin\theta_0$, following Marini [3] gives

$$\begin{aligned} \Delta R \overset{\circ}{=}\ & 10^{-6} \int N_g\, dh \cdot \frac{1}{\sin\theta_0} \\ & - \left[\frac{10^{-6}}{r_0} \int hN_g dh - 10^{-12} N_0 \int N_g dh \right. \\ & \left. + 10^{-12} \int (NN_g - \frac{1}{2} N^2)\, dh \right] \cdot \frac{1}{\sin^3\theta_0} \\ & + \circ\circ\circ \end{aligned} \tag{10}$$

where the range of integration is from the tracking station ($h = 0$) upward to above the atmosphere ($h = \infty$). The terms containing the satellite range R that appear in reference [3] can be neglected, as shown in Appendix 1, because (10) is to be applied only where $E > 10°$ and $h_1 > 70$ km.

The expansion (10) is not the most useful one for many orbit determination programs because the correction is expressed as a function of arrival angle θ_0, which may not even be measured, rather than as a function of elevation angle E, which is computed. To convert (10) to the desired for:. , the first term of the expansion of the angular correction is used

$$\theta_0 - E \overset{\circ}{=} 10^{-6} N_0 \cot E \tag{11}$$

substituting (11) into (10), and making suitable approximations

$$\Delta R = \left[10^{-6} \int N_g \, dh \right] \cdot \frac{1}{\sin E}$$

$$- \left[\frac{10^{-6}}{r_0} \int h N_g dh + 10^{-12} \int (N N_g - \frac{1}{2} N^2) \, dh \right] \frac{1}{\sin^3 E} \quad (12)$$

$$+ \circ \circ \circ$$

Equation (12) above is the expansion that provides the basis for the correction formula that is the subject of this report.

EVALUATION OF INTEGRALS

The evaluation of the integrals, appearing in (12), as functions of the pressure, temperature, and relative humidity of the surface air at the tracking station, has been treated by Saastamoinen [6]. For completeness, and because they differ in detail, our evaluations are given in Appendix 2. The results are

$$10^{-6} \int N_g \, dh \stackrel{\circ}{=} \frac{f(\lambda)}{f(\varphi,H)} [0.002357 P_0 + 0.000141 e_0] \quad (13)$$

$$\frac{10^{-6}}{r_0} \int h N_g dh = f(\lambda) (1.084 \times 10^{-8}) P_0 T_0 K \quad (14)$$

$$10^{-12} \int (N N_g - \frac{1}{2} N^2) \, dh = f(\lambda) (4.734 \times 10^{-8}) \frac{P_0^2}{T_0} \cdot \frac{2}{3 - 1/K} \quad (15)$$

where

$$f(\varphi,H) = 1 - 0.0026 \cos 2\varphi - 0.00031 H \quad (16)$$

and

$$K = 1.163 - 0.00968 \cos 2\varphi - 0.00104 \, T_0 + 0.00001435 P_0 \quad (17)$$

CORRECTION FORMULA

The formula for calculating the range error ΔR from the satellite elevation E is obtained by approximating (12) by a continued fraction form

$$\Delta R = \frac{f(\lambda)}{f(\varphi,H)} \cdot \frac{A + B}{\sin E + \dfrac{B/(A + B)}{\sin E + 0.01}} \qquad (18)$$

where

$$A = 0.002357 P_0 + 0.000141 e_0 \qquad (19)$$

$$B = (1.084 \times 10^{-8})\, P_0\, T_0\, K + (4.734 \times 10^{-8})\, \frac{P_0^{\,2}}{T_0}\, \frac{2}{(3 - 1/K)} \qquad (20)$$

$$K = 1.163 - 0.00968 \cos 2\varphi - 0.00104\, T_0 + 0.00001435 P_0 \qquad (21)$$

Here

ΔR = Range correction (meters)
E = True elevation of satellite
P_0 = Atmospheric pressure at the laser site (millibars)
T_0 = Atmospheric temperature at the laser site (degrees Kelvin)
e_0 = Water vapor pressure at the laser site (millibars)
$f(\lambda)$ = 1 for a ruby laser, and is given by (5) otherwise
$f(\varphi, H)$ = 1 for a laser site at 45° latitude and at sea level, and is given by (16) for sites at different latitudes φ and elevations H (in km)

The water vapor pressure e_0 may be calculated from a relative humidity measurement R_h (%)

$$e_0 = \frac{R_h}{100} \times 6.11 \times 10^{\frac{7.5\,(T_0 - 273.15)}{237.3 + (T_0 - 273.15)}} \qquad (22)$$

In (18) the quantity 0.01 is an empirical constant that serves to compensate for the neglect of higher order terms. The divisor $f(\varphi, H)$ can be factored out of the series (12) and consequently the fraction (18) because the error thereby incurred in the second term of (12) is negligable. The use of the sum A + B where it appears in (18) instead of using A alone is an optional adjustment used to reduce at elevations near 90° a small bias that occurs in the expansion (12) because of approximations made in its derivation.

TEST OF ACCURACY

To test the accuracy of formula (18), which is based on surface measurements, range corrections obtained using the formula were compared with corrections obtained by ray-tracing radiosonde refractivity profiles. The ray-trace corrections are considered to have state-of-the-art accuracy, so that the differences between these corrections and those calculated from the simpler formulas represent the penalty paid for simplicity in calculation and measurement.

The data used in Figures 2-11 was obtained from the National Climatic Center at Asheville, North Carolina. It consists of radiosonde observations taken near Dulles Airport, Virginia, during the year 1967.

Using the procedure described in Appendices 3 and 4, 634 refractivity profiles were calculated up to a height of 1000 kilometers from the radiosonde observations. The calculated profiles were ray-traced [16] at arrival angles of 10°, 15°, 20°, 40°, and 80°, and the tropospheric errors in range and elevation angle were obtained. The histograms of these errors are shown in Figures 2,4,6,8, and 10. The correction formula (18) was applied using only surface data and the known elevation angle to obtain approximate tropospheric corrections. The differences between these algorithm corrections and the ray-trace corrections were calculated. The histograms of these differences is shown in Figures 3,5,7,9, and 11. The maximum bias of the error remaining after correction was -0.1 cm, and the maximum standard deviation was 0.49 cm at 10°, decreasing to 0.04 cm at 80°.

In addition formula (18) was compared with range corrections obtained by ray tracing (at arrived angles of 10°, 15°, 20°, 40°, and 80°) radiosonde refractivity profiles calculated at Jananarive (85 profiles), Fairbanks, Alaska (200 profiles), Athens, Georgia (200 profiles), Greensboro, North Carolina (200 profiles), and Nashville, Tennessee (135 profiles). The maximum standard deviation of the error in the algorithm at 10° was 1 centimeter and the maximum at 80° was 0.06 centimeters. The maximum mean error of the algorithm at 10° was 0.16 cm and the maximum at 80° was 0.07 cm.

CONCLUSIONS

An equation that corrects laser range data for atmospheric refraction using surface meteorological measurements has been derived, and a comparison made between the corrections calculated using this equation (equation 18) and the corrections calculated by ray-tracing through a radiosonde profile. The comparison (Figures 2-11) indicates that the differences between the corrections calculated be the two methods are negligible for practical applications. Hence accurate refraction correction of laser range data can be made without the requirement for radiosonde measurements or lengthy ray-tracing algorithms.

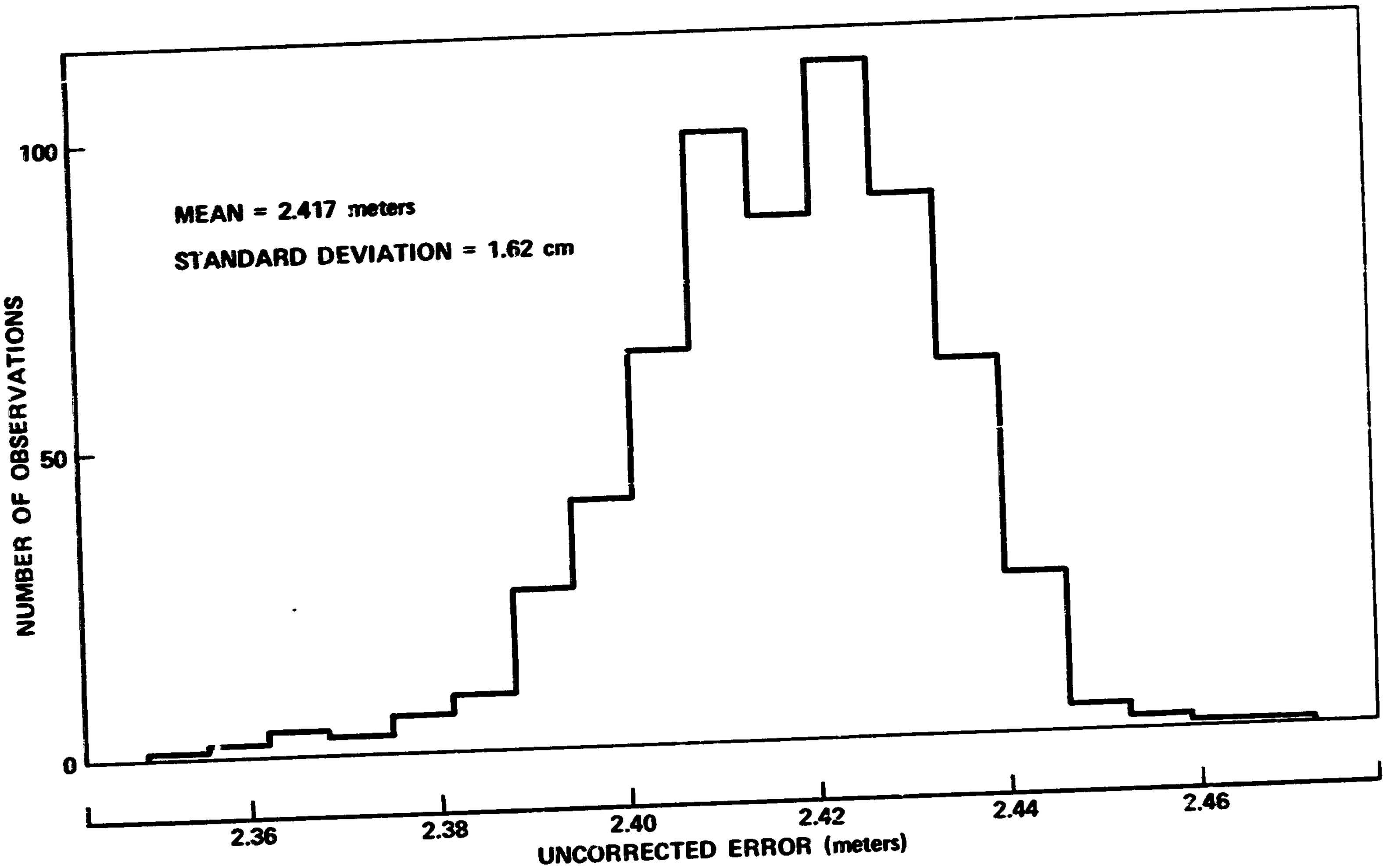

Figure 2. Tropospheric Range Error at About 80 Degrees Elevation for Laser Frequency of 0.6943 Microns

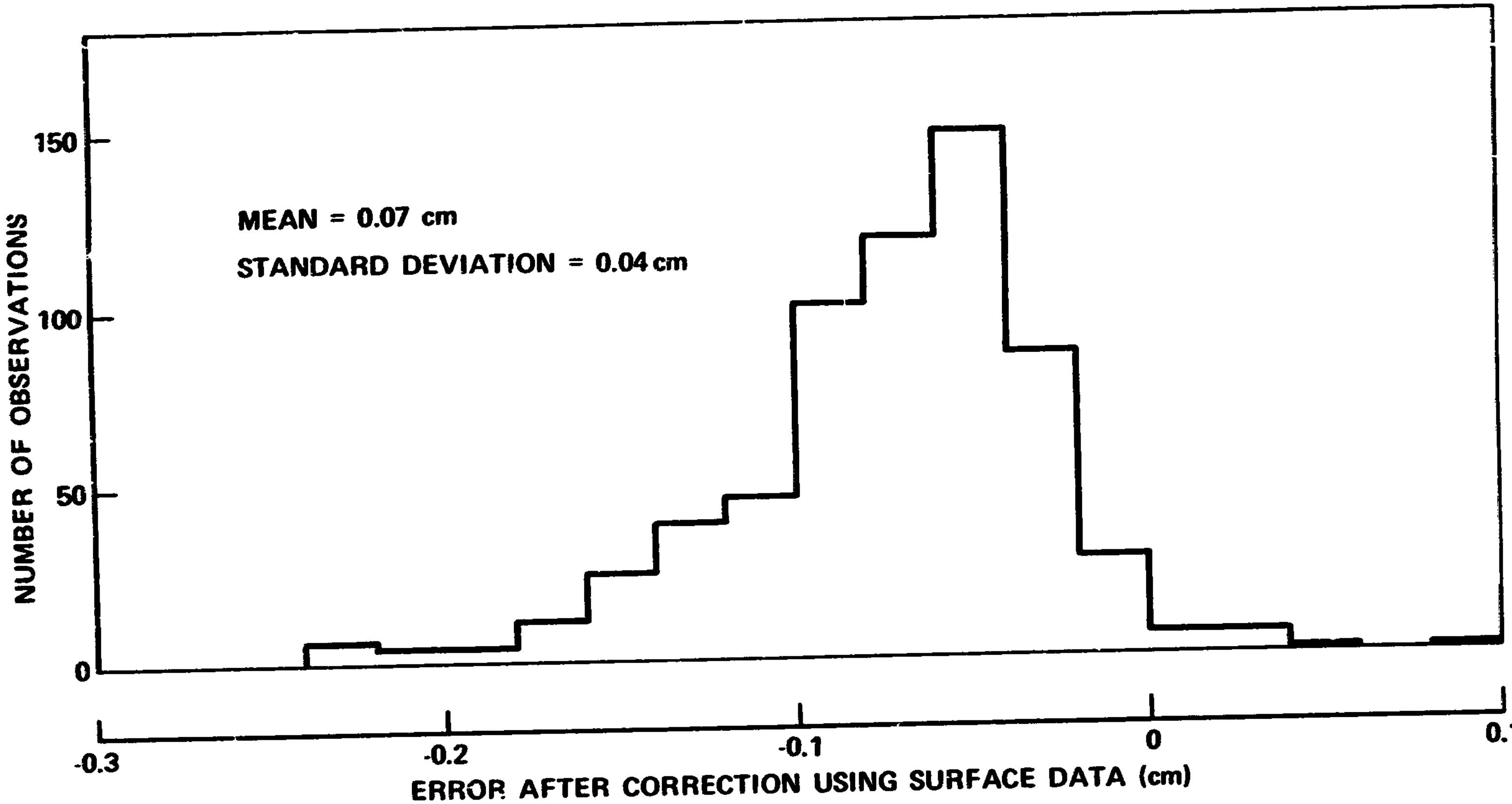

Figure 3. Tropospheric Range Error at About 80 Degrees Elevation for Laser Frequency of 0.6943 Microns

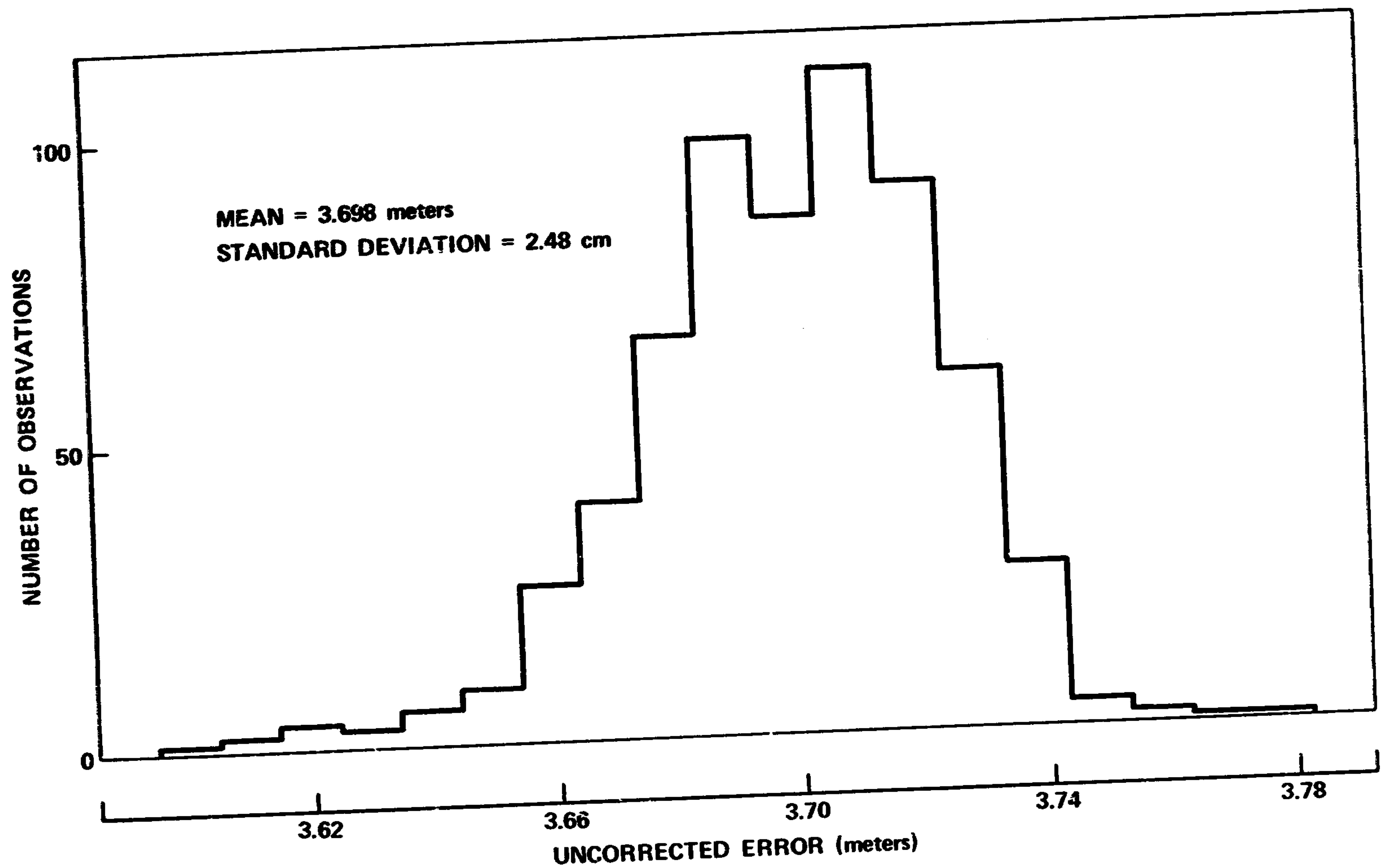

Figure 4. Tropospheric Range Error at About 40 Degrees Elevation for Laser Frequency of 0.6943 Microns

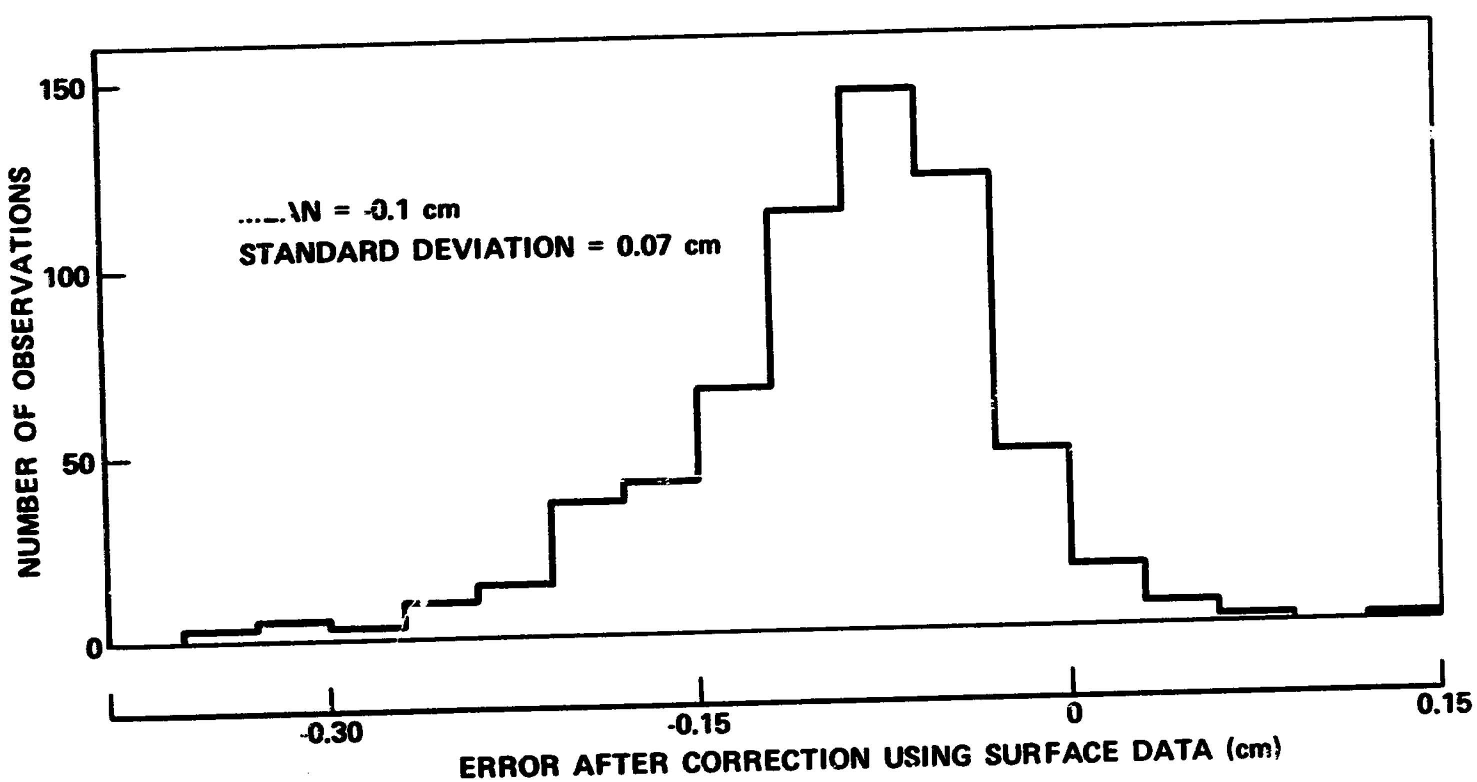

Figure 5. Tropospheric Range Error at About 40 Degrees Elevation for Laser Frequency of 0.6943 Microns

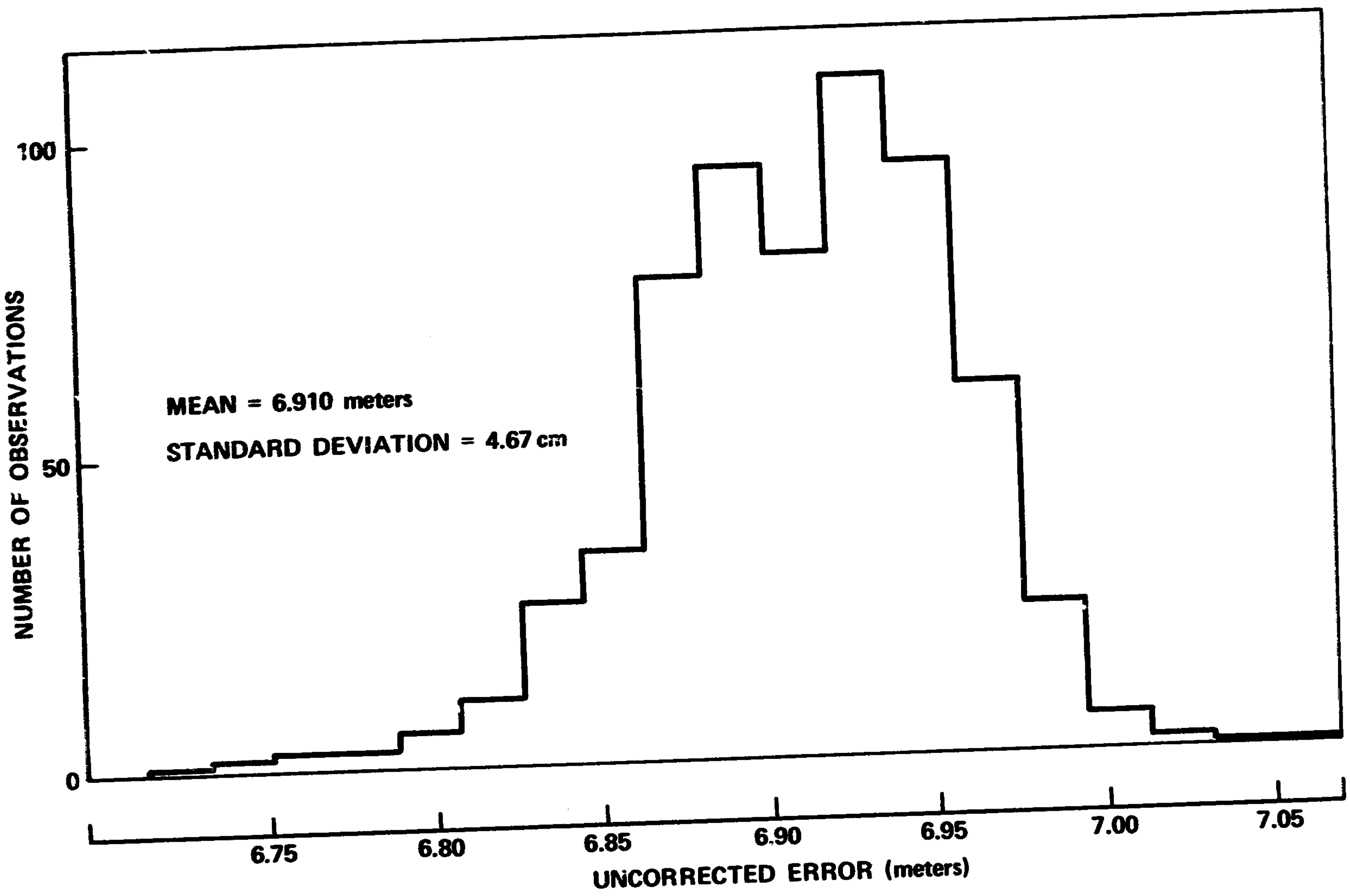

Figure 6. Tropospheric Range Error at About 20 Degrees Elevation for Laser Frequency of 0.6943 Microns

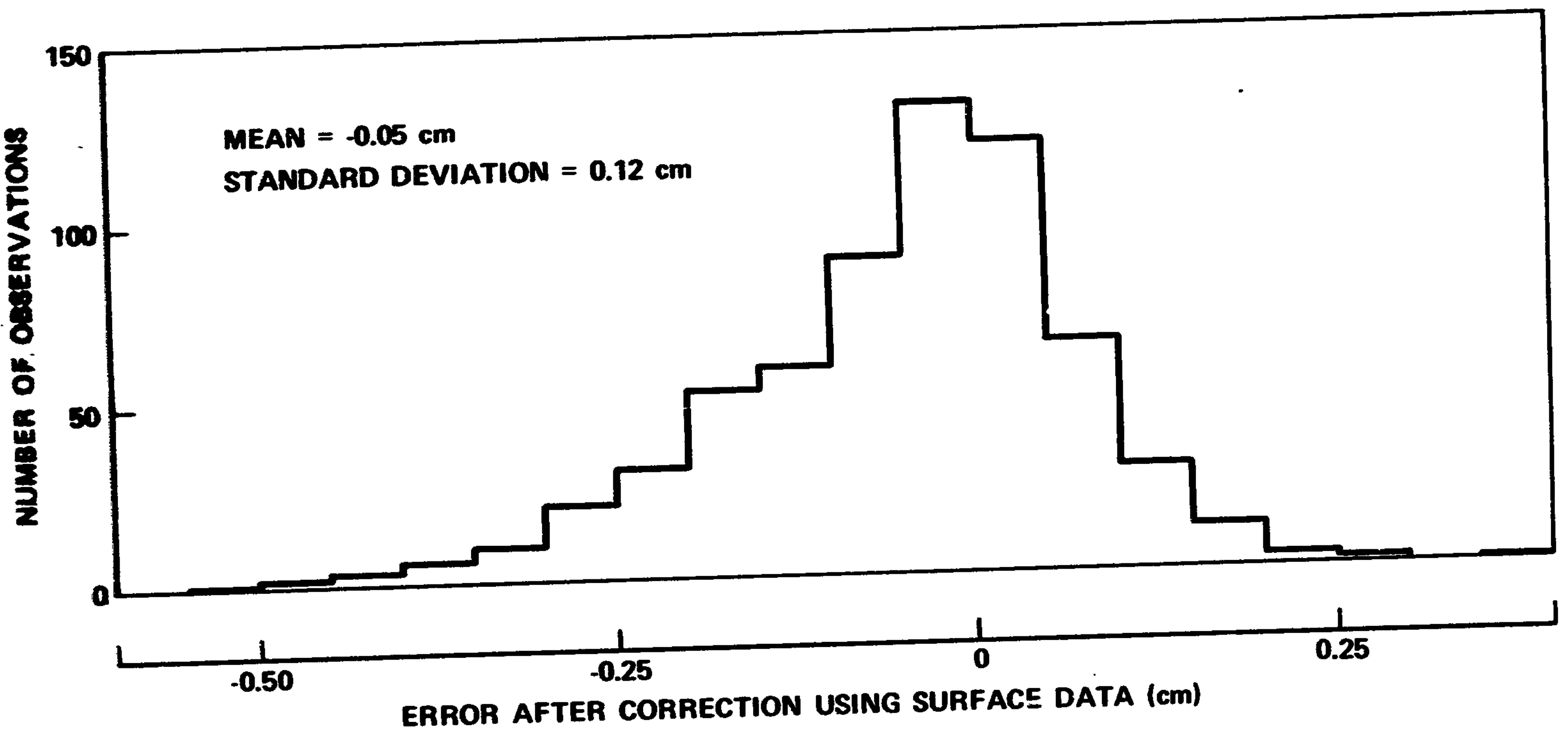

Figure 7. Tropospheric Range Error at About 20 Degrees Elevation for Laser Frequency of 0.6943 Microns

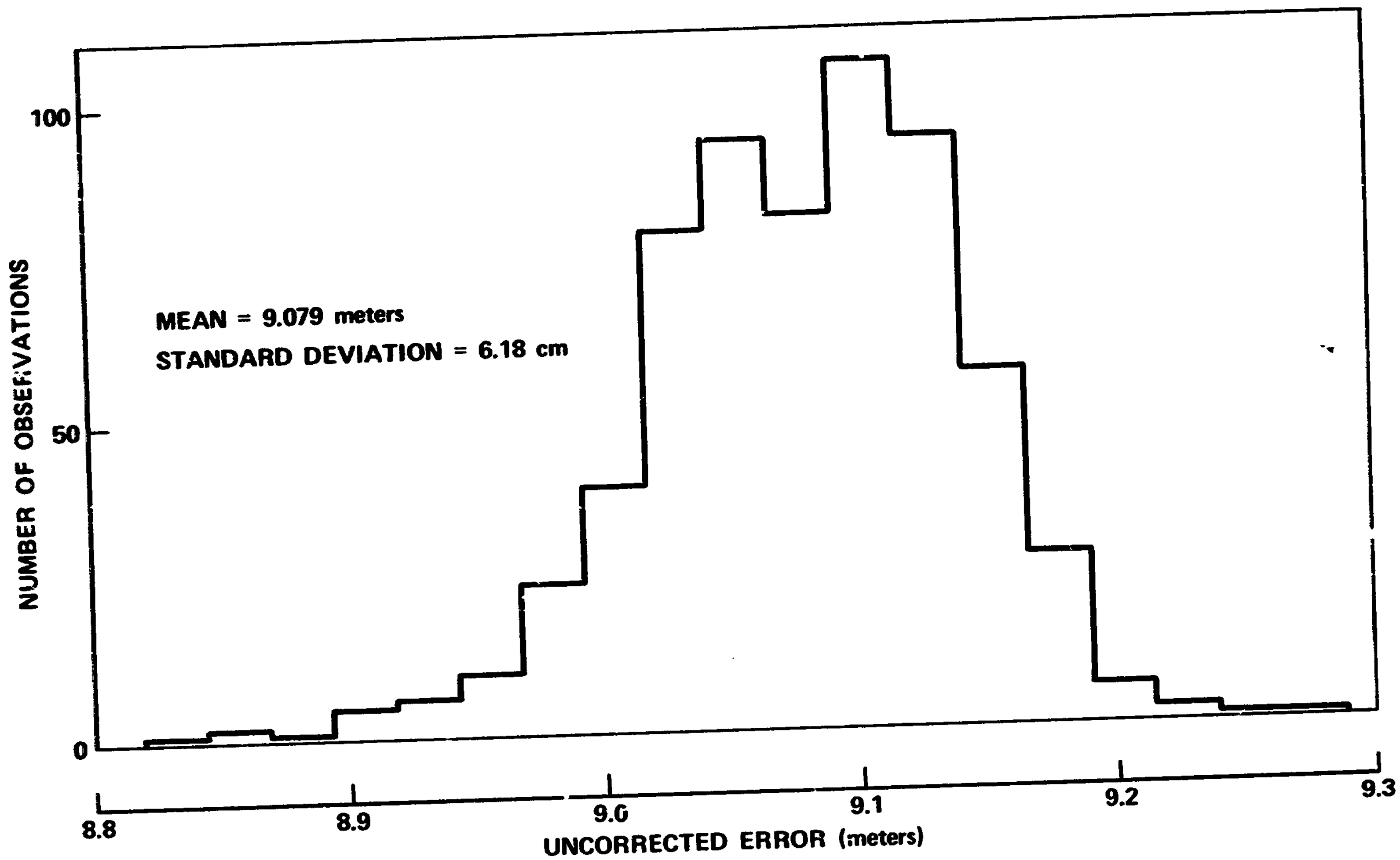

Figure 8. Tropospheric Range Error at About 15 Degrees Elevation for Laser Frequency of 0.6943 Microns

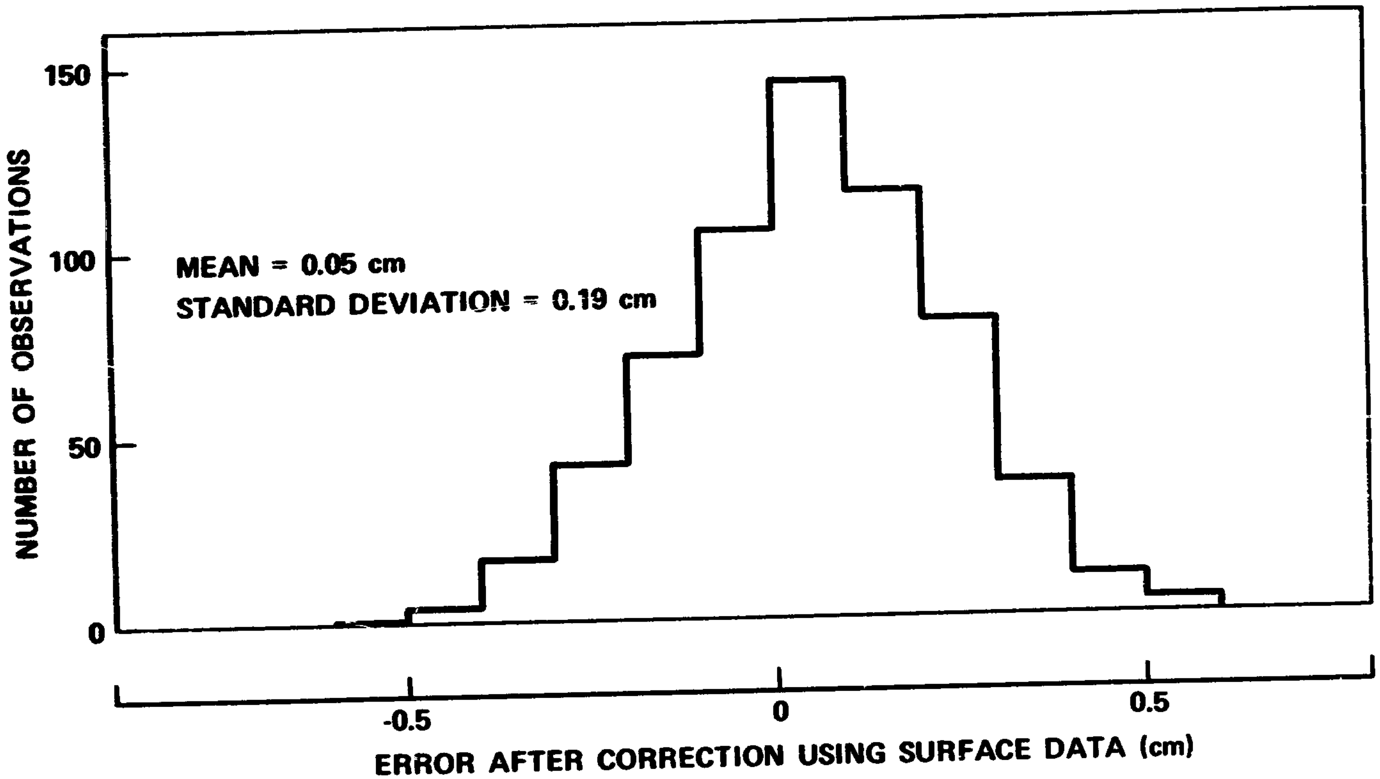

Figure 9. Tropospheric Range Error at About 15 Degrees Elevation for Laser Frequency of 0.6943 Microns

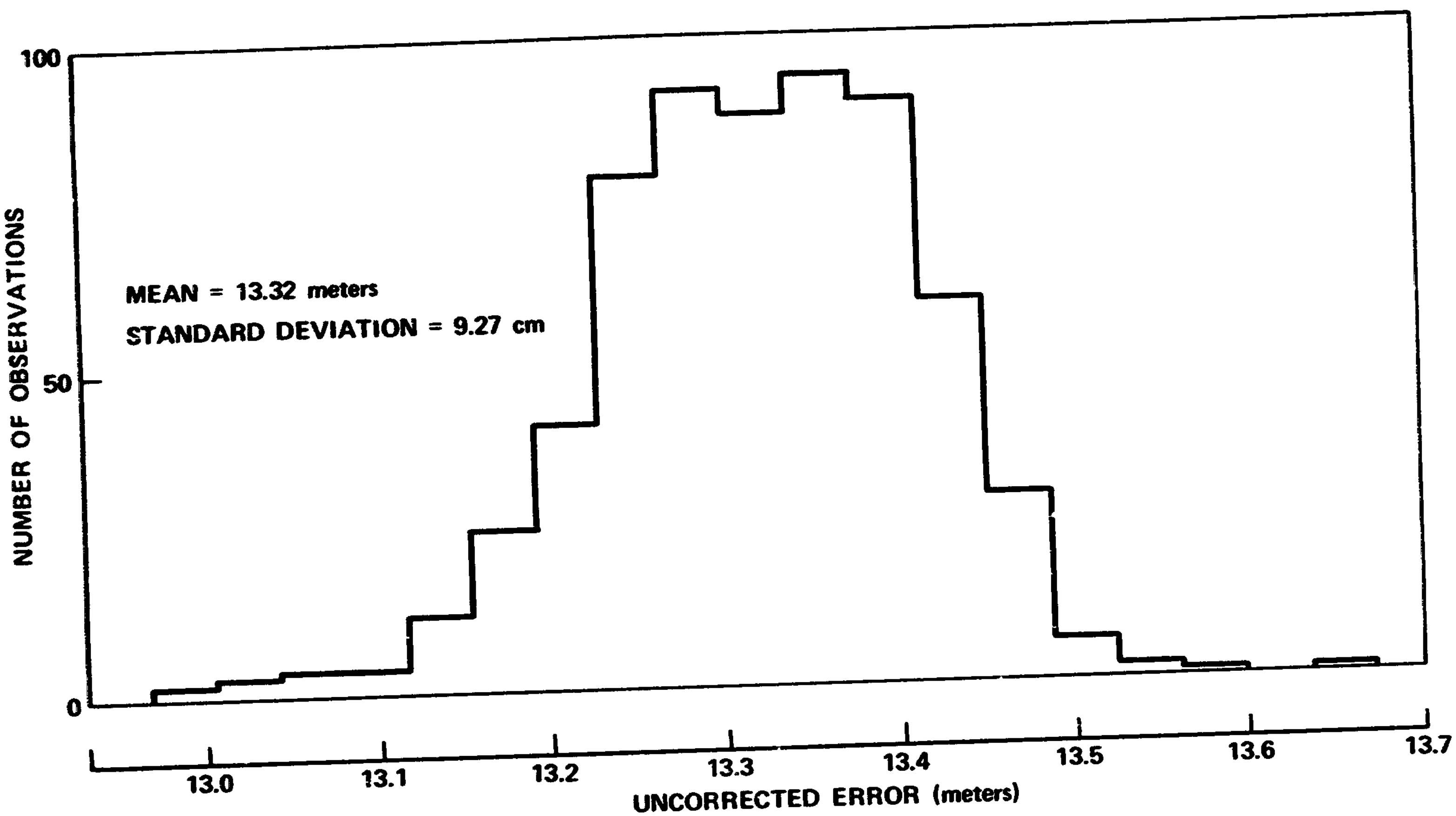

Figure 10. Tropospheric Range Error at About 10 Degrees Elevation for Laser Frequency of 0.6943 Microns

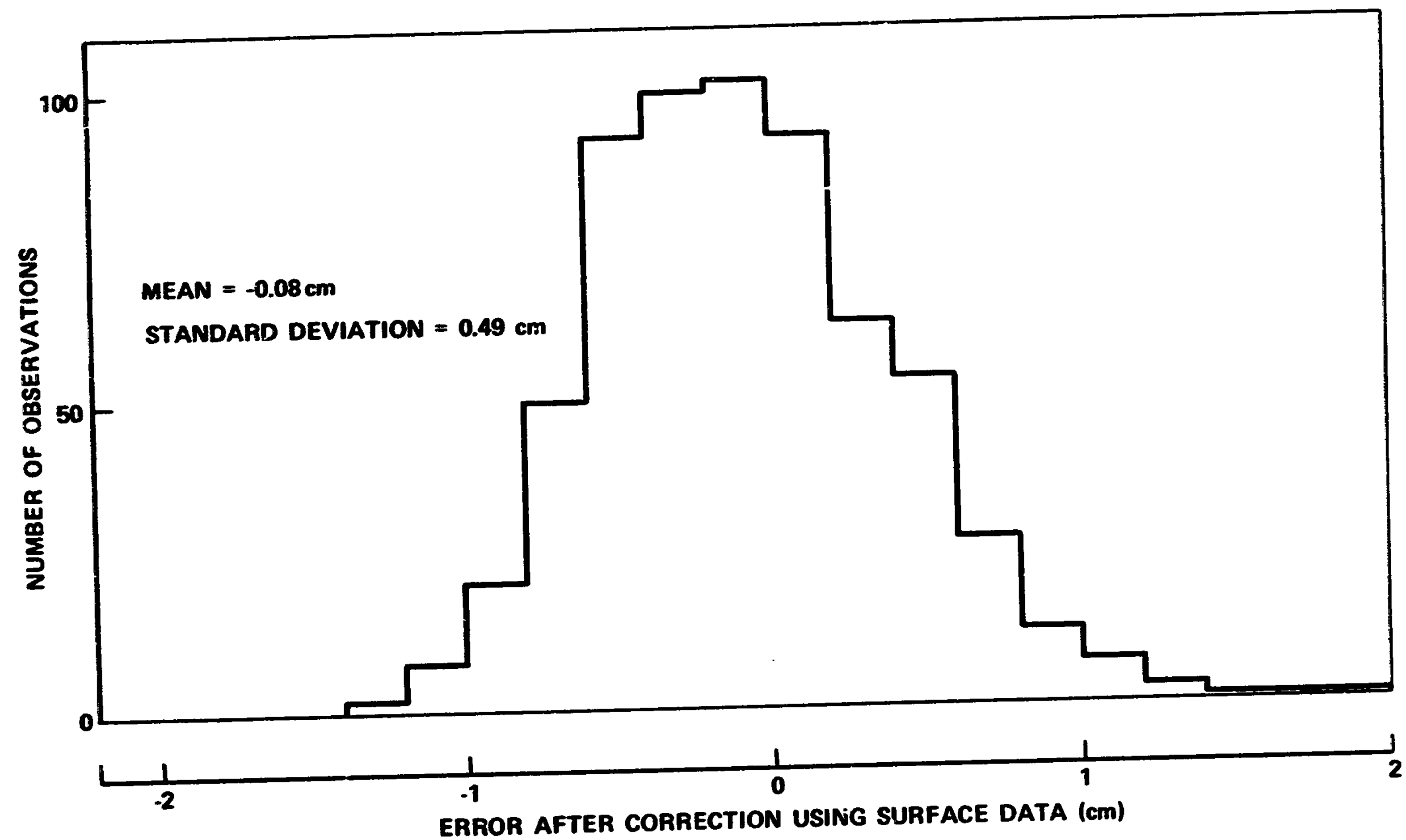

Figure 11. Tropospheric Range Error at About 10 Degrees Elevation for Laser Frequency of 0.6943 Microns

It should be pointed out that only the relative accuracy of the two procedures has been tested, and that errors caused by factors common to both methods are not in evidence. For example, equation (4) for the group refractive index is used both in (18) and in the ray-trace equations, and any error in its magnitude would reflect equally in the corrections. Similarly, the hydrostatic equation used in equation (2-1) and hence (18) is also implicit in the ray-tracing method because the heights that appear in radiosonde profiles are not measured quantities but rather are calculated from the measured pressures, temperatures, and relative humidities using the hydrostatic equation. Also, both methods assume horizontal homogeneity. Saastamoinen [6] has estimated the standard error from such sources to be less than 1 or 2 centimeters at 10° elevation.

REFERENCES

[1] Freeman, J. (1962), Range error compensation for a troposphere with exponentially varying refractivity, J. Res. Nat. Bur. Stand. Sect. D., 66 (6), 695-697.

[2] Hopfield, H. (1969), Two-quartic tropospheric refractivity profile for correcting satellite data, J. Geophys. Res., 74 (18), 4487-4499.

[3] Marini, J. (1972), Correction of satellite tracking data for an arbitrary tropospheric profile, Radio Sci., 7(2), 223-231.

[4] Rowlandson, L. and Moldt (1969), Derivation of closed functions to compensate range and angle errors in an exponential atmosphere, Radio Sci. 4(10), 927-933.

[5] Saastamoinen, J. (1972), Atmospheric correction for the troposphere and stratosphere in radio ranging of satellites, Geophysical Monograph 15, "The Use of Artifical Satellites for Goedesy," American Geophysical Union, Washington D.C.

[6] Saastamoinen, J. (1972), Contributions to the theory of Atmospheric Refraction, Bulletin Geodesique 105-107, pp. 279-298, 383-397, 13-34.

[7] (1970) The Terrestial Environment: Solid-Earth and Ocean Physics, NASA Contractor Report 1579, Prepared under contract NAS 12-2180 by the Massachusetts Institute of Technology.

[8] Peck, E. and Reeder, K. (1972), Dispersion of air, J. Opt. Soc. Am. 62 (8), 958-962.

[9] Barrell, H. and Sears, J. The refraction and dispersion of air for the visible spectrum, (1939) Trans. Roy. Soc. London A238 (1), 1-64.

[10] Edlen, B. (1953), The dispersion of standard air, J. Opt. Soc. Am. 43 (5) 339-344.

[11] Edlen, B. (1966), The refractive index of air, Metrologia 2(2), 71.

[12] International Association of Geodesy, Resolution No. 1 of the 13th General Assembly, Bulletin Geodesique, 70 p. 360, 1963.

[13] Bennett, J. (1967), J. Atm. Terrestial Phys. 29, 893-896.

[14] Titheridge, J. (1965), J. Atm. Terrestial Phys. 27, 1115-1116.

[15] List, R., Smithsonian Meteorological Tables, Smithsonian Institution, Washington D.C., 1963.

[16] Thayer, G. D., "A Rapid and Accurate Ray Tracing Algorithm for a Horizontally Stratified Atmosphere," Radio Science, Vol. 1, No. 2, pp. 249-252, Feb. 1967.

APPENDIX 1

NEGLECT OF SATELLITE RANGE

APPENDIX 1

NEGLECT OF SATELLITE RANGE

The correction

$$\Delta R = \int_{r_0}^{r_1} \frac{n_g}{\sin\theta}\, dr - R \qquad (1\text{-}1)$$

can be written as

$$\Delta R = 10^{-6} \int_{r_0}^{r_1} \frac{N_g\, dr}{\sin\theta} + \left[\int_{r_0}^{r_1} \frac{1}{\sin\theta}\, dr - R \right] \qquad (1\text{-}2)$$

The expansion of the first term in (1-2), using suitable approximations [3], gives

$$\begin{aligned} 10^{-6} \int_{r_0}^{r_1} \frac{N_g\, dr}{\sin\theta} &= \frac{10^{-6}}{\sin\theta_0} \int_0^{\infty} N_g\, dh \\ &- \frac{1}{\sin^3\theta_0} \left[\frac{10^{-6}}{r_0} \int h\, N_g\, dh \right. \\ &\left. - 10^{-12} \int N_g (N_0 - N)\, dh \right] \\ &+ \cdots \end{aligned} \qquad (1\text{-}3)$$

The expansion of the bracketed second term in (1-2), which represents the difference ΔR_g between the geometrical lengths of the phase and the straight-line paths between the satellite and the tracking station, can be obtained by expanding equation (A5) of reference [3] in inverse powers of $\sin\theta_0$ giving

$$\begin{aligned} \Delta R_g &= \frac{1}{\sin^3\theta_0} \cdot \frac{1}{2}\, 10^{-12} \int N^2\, dh \\ &- \frac{1}{2}\, 10^{-12} \frac{(\int N\, dh)^2}{R} \cdot \frac{\cos^2\theta_0}{\sin\theta_0{}^4} \end{aligned} \qquad (1\text{-}4)$$

The relative error incurred in neglecting the last term in (1-4) is estimated by dividing it by the (dominant) first term in (1-3), ignoring the small difference between the magnitudes of N and N_g

$$\text{relative error} = \frac{1}{2} \frac{10^{-6} \int N\, dh}{R} \cdot \frac{\cos^2 \theta_0}{\sin^3 \theta_0} \qquad (1\text{-}5)$$

The satellite height h_1 is roughly approximated by approximated by R $\sin \theta_0$, and the zenith integral is about 2 meters:

$$\text{relative error} \approx \frac{1}{h_1} \tan^2 \theta_0 \qquad (1\text{-}6)$$

where h_1 is the satellite height in meters. Taking $h_1 \geq 70$ km and $\theta_0 > 10°$, the error calculated from (1-6) is less than 0.05% which can be neglected.

APPENDIX 2

EVALUATION OF INTEGRALS

From the perfect-gas law, the law of partial pressures, and the hydrostatic equation

$$-\frac{dP}{dh} = \frac{Mg(P-e)}{RT} + \frac{Mwge}{RT}$$

$$= -\frac{MgP}{RT} - \frac{0.378\,Mge}{RT} \qquad (2\text{-}1)$$

where [15]

M = 28.966 = Molecular weight of dry air
Mw = 18.016 = Molecular weight of water vapor
R = 8314.36 Joules $(^{\circ}K)^{-1}$ (Kg - Mole)$^{-1}$
= Universal gas constant
g = acceleration of gravity (m/s)
h = height (m)

Combining (2-1) and (4)

$$\int N_g\, dh = -80.343\, f(\lambda) \frac{R}{M} \int \frac{1}{g} dP$$

$$+ [30.5\, f(\lambda) - 11.3] \int \frac{e}{T} dh \qquad (2\text{-}2)$$

The first integral on the right side of (2-2) above can be evaluated using the approximation [15].

$$g = 9.806\,[1 - 0.0026 \cos 2\varphi - 0.00031\,(H + h)] \qquad (2\text{-}3)$$

$$\frac{1}{g} \doteq \frac{1}{9.806}[1 + 0.0026 \cos 2\varphi + 0.00031\,(H + h)] \qquad (2\text{-}4)$$

from which, integrating the last term by parts,

$$-\int \frac{1}{g} dP = P_0 \frac{1}{9.806} [1 + 0.0026 \cos 2\varphi + 0.00031 (H + \frac{1}{P_0} \int P dh)] \tag{2-5}$$

$$= P_0/\bar{g}$$

where $\bar{g}$ is the value of g at the height

$$\bar{h} = \frac{1}{P_0} \int P\, dh \tag{2-6}$$

above the tracking station or $H + \bar{h}$ above sea level. Saastamoinen uses a gravitational constant evaluated at*

$$H + \bar{h} = 7.3 + 0.9\, H \text{ km} \tag{2-7}$$

From (2-7) and (2-3)

$$\bar{g} = 9.784 (1 - 0.0026 \cos 2\varphi - 0.00028\, H) \tag{2-8}$$

$$\equiv 9.784\, f(\varphi, H)$$

where H is the station elevation in kilometers. Saastamoinen has also evaluated the integral

$$\int \frac{e}{T} dh \overset{\circ}{=} \frac{R}{4M\bar{g}} e_0 \tag{2-9}$$

where the $\bar{g}$ appearing in (2-9) is set equal to $\bar{g}$ in (2-8) as a convenient approximation. The expression for the zenith integral becomes

$$\int N dh = 80.343\, f(\lambda) \frac{R}{M\bar{g}} P_0$$

$$+ [30.5\, f(\lambda) - 11.3] \frac{R}{4M\bar{g}} e_0 \tag{2-10}$$

*An equivalent result can be obtained by numerically estimating $\bar{h}$ using (2-17) with T_0 set equal to $T_e + \beta H$ where T_e is the sea level temperature.

$$10^{-6} \int N\,dh = \frac{f(\lambda)}{f(\varphi,H)} \left[0.002357\,P_0 + \frac{(30.5 - 11.3/f(\lambda))}{19.2}\ 0.000141\,e_0 \right] \quad (2\text{-}11)$$

Neglecting small errors in the second term of (2-11), equation (13) results.

SECOND INTEGRAL

In equation (12), the magnitude of the coefficient of $1/\sin E$ is about 2.4 meters, while the coefficient of $1/\sin^3 E$, is only about ¼ centimeters. At $E = 10^\circ$, the magnitude of the first term is about 12 meters, while the second is about half a meter. Consequently the second term need not be as accurately evaluated as the first, and it is sufficient to use the approximation

$$\frac{10^{-6}}{r_0} \int hN_g\,dh \doteq \frac{10^{-6}}{r_e} \int \frac{80.343\,f(\lambda)\,P}{T} h\,dh \quad (2\text{-}12)$$

where r_e is a nominal earth radius (6378 km) and the air is assumed to be dry. It is also sufficient to treat g as a constant throughout.

From (2-1), and integrating by parts

$$\int \frac{P}{T} h\,dh = \frac{R}{Mg} \int P\,dh \quad (2\text{-}13)$$

The pressure P in (2-13) is obtained by integrating (2-1)

$$P = P_0 \exp\left[\frac{Mg}{R} \int \frac{1}{T}\,dh\right] \quad (2\text{-}14)$$

The temperature T is assumed to have a linear slope

$$T = T_0 + \beta h \quad (2\text{-}15)$$

and the integration in (2-14) is carried out giving

$$P = P_0 \left(\frac{T}{T_0}\right)^{-Mg/R\beta} \quad (2\text{-}16)$$

The integration in (2-13) may now be performed

$$\int P\,dh = P_0 \cdot \frac{R\,T_0}{Mg} \cdot \frac{1}{1 - \frac{R\beta}{Mg}} \qquad (2\text{-}17)$$

From (2-12), (2-13), and (2-17)

$$\frac{10^{-6}}{r_0} \int h\,N_g\,dh \stackrel{\circ}{=} f(\lambda)\,\frac{10^{-6}\,(80.343)R^2}{r_e\,M^2\,g^2}\,P_0\,T_0\,K \qquad (2\text{-}18)$$

$$= f(\lambda)\,(1.084 \times 10^{-8})\,P_0\,T_0\,K$$

where g has been set equal to 9.784 and the factor

$$K \equiv \frac{1}{1 - \frac{R\beta}{Mg}} \qquad (2\text{-}19)$$

is equal to unity in an isothermal atmosphere ($\beta = 0$) and is equal to about 0.8 in an atmosphere in which the temperature lapse rate is a constant 6°/km (β = -6°/km).

Rather than use the theoretical value for K given by (2-19), which is based on a constant lapse rate, the value of K used in the corrections equations is taken to be an empirical constant which was determined by solving (2-18) for k and calculating its value by numerically integrating through the atmospheres of the U.S. Standard Atmosphere Supplements, 1966. Using linear regression on the values so obtained, the formula

$$K = 1.163 - 0.00968\cos 2\varphi - 0.00104\,T_0 + 0.00001435\,P_0 \qquad (2\text{-}20)$$

resulted. Here φ is the latitude of the tracking station.

THIRD INTEGRAL

The contribution from the third integral in (12) is only marginally significant, and the term can be approximated by

$$\frac{1}{2} 10^{-12} \int N_g N\,dh = \frac{1}{2} 10^{-12}\,(80.343)^2\,f(\lambda) \int \frac{P^2}{T^2}\,dh \qquad (2\text{-}21)$$

Assuming a constant temperature gradient, and using (2-16)

$$10^{-12} \int \left(N\,N_g - \frac{1}{2} N^2 \right) dh \overset{\circ}{=} \frac{10^{-12}}{4} (80.343)^2 f(\lambda) \frac{R}{Mg} \frac{P_0^{\,2}}{T_0} \cdot \frac{1}{1 + \frac{RP}{2mg}} \qquad (2\text{-}22)$$

The last factor in (2-22) can be expressed in terms of K using (2-19), giving (15).

APPENDIX 3

PROGRAM FOR CALCULATING REFRACTIVITY PROFILES FROM RADIOSONDE DATA

APPENDIX 3

PROGRAM FOR CALCULATING REFRACTIVITY PROFILES FROM RADIOSONDE DATA*

RADIOSONDE DATA

Radiosonde observations are measurements of pressure, temperature, and humidity taken from the surface up to the point where the balloon that carries the sensors bursts [1]. The values of temperature, pressure and relative humidity measured at certain standard and significant levels during each balloon ascent from numerous weather stations is available from the National Climatic Center. This data can be used to construct continuous refractivity profiles from the surface up to the point of highest measurement. Above the latter point, the refractivity profile can be extended by assuming a suitable temperature profile.

GEOPOTENTIAL ALTITUDE

The equations used to calculate the refractivity profiles employ the geopotential altitude H [2, p. 217], which is given by

$$H = \frac{1}{G}\int_0^Z g\,dZ \tag{1}$$

where Z is the geometric altitude, and the lower limit of integration is from sea level (Z = 0). H is in geopotential meters when G equals 9.8 m/sec^2. The local acceleration of gravity is calculated from the latitude ϕ by [2, p. 488]

$$g_0 = 9.780356\,(1 + 0.0052885 \sin^2\phi - 5.9 \times 10^{-6} \sin^2 2\phi) \tag{2}$$

and [2, p. 217]

$$g = \frac{g_0 r_0^2}{(r_0 + Z)^2} \text{ (m/sec}^2\text{)} \tag{3}$$

Here r_0 is an effective earth radius given by [2, p. 218]

$$r_0 = \frac{2 g_0}{3.085462 \times 10^{-6} + 2.27 \times 10^{-9} \cos 2\phi - 2 \times 10^{-12} \cos 4\phi} \text{ (m)} \tag{4}$$

*This appendix is self-contained. It has separate references, and the notation used differs from that in the rest of the report.

From (1) and (3) the conversion between geopotential and geometric altitude is given by [2, p. 218]

$$H = \frac{g_0}{G}\left(\frac{r_0 Z}{r_0 + Z}\right) \tag{5}$$

and

$$Z = \frac{r_0 H}{\frac{g_0 r_0}{G} - H} \tag{6}$$

VIRTUAL TEMPERATURE

The calculations also make use of the virtual temperature T_v [3] which is related to the ordinary temperature T (°K) by

$$T_v = \frac{T}{1 - 0.379 \frac{e}{P}} \tag{7}$$

where e is the partial pressure of the water vapor in the air, and is given by [4, p. 343]

$$e = \left(\frac{R_h}{100}\right) (6.11)\ 10^{\frac{7.5\,(T - 273.15)}{237.3 + (T - 273.15)}} \text{ (mbar)} \tag{8}$$

R_h being the relative humidity in percent.*

CALCULATION OF GEOPOTENTIAL ALTITUDES

The first step in the calculation of refractivity profiles from the radiosonde measurements of pressure, temperature, and relative humidity is to establish a

*If the dewpoint temperature T_d (°K) is given instead of the relative humidity, e can be calculated from (8) by setting R_h = 100 and T = T_d.

table of pressure, temperature, and virtual temperature versus geopotential altitude. The virtual temperatures at the given points are calculated from the measured values of P, T, and R_h using (8) and (7).

To calculate the geopotential altitudes, it is necessary to assume hydrostatic equilibrium [3]

$$dP = -\rho g \, dZ \tag{9}$$

The density ρ is given with sufficient accuracy by [3]

$$\rho = \frac{MP}{RT_v} \tag{10}$$

The apparent molecular weight of dry air is taken to be [2, p. 289]

$$M = 28.966 \tag{11}$$

and the universal gas constant [2, p. 289]

$$R = 8314.36 \text{ Joules } (^\circ K)^{-1} \text{ (Kg-mole)}^{-1} \tag{12}$$

Using the assumption that the virtual temperature is a linear function of geopotential height between any two adjacent measured points H_1 and H_2, (9) may be integrated with the use of (1) and (10) to give

$$\frac{P_2}{P_1} = \left(\frac{T_{v1}}{T_{v2}}\right)^{\frac{GM(H_2 - H_1)}{R(T_{v2} - T_{v1})}} \tag{13}$$

which may be written as

$$H_2 = H_1 + \left(\frac{RT_{v1}}{GM}\right) \frac{\chi \ln (P_2/P_1)}{\ln (1+\chi)}$$

$$= H_1 + \left(\frac{RT_{v1}}{GM}\right) \ln \left(\frac{P_2}{P_1}\right) \left(1 - \frac{\chi}{2} + \frac{\chi^2}{3} \ldots\right)^{-1} \tag{14}$$

where

$$\chi = (T_{v2} - T_{v1})/T_{v1} \tag{15}$$

Equation (14) can be used stepwise starting at the known geopotential elevation of the radiosonde station to compute the geopotential altitudes.* In this way the required table of pressure, temperature, and virtual temperature versus height is established.

CALCULATION OF REFRACTIVITY PROFILES

The radio refractivity N is given by the formula† [5, p. 7]

$$N = 77.6\frac{P}{T} + 3.73 \times 10^5 \frac{e}{T^2} \tag{16}$$

with P and e expressed in millibars and T in degrees Kelvin.

To calculate N at a given height, i.e., to obtain a point of a refractivity profile, it is necessary to know the values of P, T and e at that height. These are obtained as follows:

The height is converted to a geopotential altitude by adding it to the geometric station elevation to obtain the geometric altitude Z, and applying (5). Using the geopotential altitude so calculated, the temperature and the virtual temperature at the given height are obtained from the table of P, T, and T_v vs. H by linear interpolation. The pressure at the given height is calculated using (13) with P_2, T_{v2} and H_2 replaced by the values associated with the given height. Finally the vapor pressure e is calculated from (7). Substitution into (16) then gives the required refractivity.

---

*The geopotential altitudes are computed at the radio-sonde stations and are included in the data stored at the National Climatic Center. The altitudes are recomputed both as a check of the self-consistency of the data and also to generate geopotential altitudes consistent with the values of the fundamental constants (R and M, for example) adopted.

†At optical frequencies (2) and (4) of the main text are used.

$$N = 77.6\frac{P}{T}\left(1 + \frac{7.52 \times 10^{-3}}{\lambda^2}\right)$$

where the wavelength λ is in microns.

A listing of the FORTRANH program with a sample profile calculated from meteorological data taken at Dulles airport on 1 January 1967 is shown in Appendix 4.

Also shown are the surface measurements of temperature, pressure and relative humidity, the tropospheric range error obtained from ray-trace (RANGE ERROR), the tropospheric elevation angle error, the tropospheric range error approximation (RANGE ERROR APPROX) obtained from using equation (18) of the main text, and the difference between the ray-trace and the approximation (RANGE DIFF) for arrival angles of 10°, 15°, 20°, 40° and 80°.

REFERENCES FOR APPENDIX 3

1. Federal Meteorological Handbook No. 3, "Radiosonde Observations," U.S. Department of Commerce, U.S. Department of Defense, Washington, D.C., January 1, 1969.

2. List, R. J., "Smithsonian Meteorological Tables," Sixth Revised Edition (Second Reprint), Publication 4014, 1963.

3. U.S. Standard Atmosphere Supplements, 1966, Environmental Science Services Administration, National Aeronautics and Space Administration, United States Air Force.

4. Berry, F., Bollay, E., and Beers, N., "Handbook of Meteorology," McGraw-Hill, N.Y., 1945.

5. Bean, B. and Dutton, E., "Radio Meteorology," NBS Monograph 92, March 1, 1966.

APPENDIX 4

PROGRAM LISTING AND EXAMPLE CALCULATION

```
      COMPILER OPTIONS - NAME=  MAIN,OPT=01,LINECNT=60,SIZE=0000K,
                         SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
                 C        PROGRAM FOR ANALYZING AND PROCESSING OF DAILY RAW RADIOSONDE DATA
ISN 0002                  IMPLICIT REAL*8(A-H,O-Z)
ISN 0003                  COMMON X(1500),U(1500),S(1500),REL(1500),Q1,QN,NPTS
ISN 0004                  DIMENSION PRESS(100),TEMPC(100),RELHUM(100),THOUR(100),HGPR(100)
ISN 0005                  DIMENSION TDAY(100),TMONTH(100),TYEAR(100)
ISN 0006                  DIMENSION HGMREF(1200),GMREFP(1200),GPMREF(1200),F(1200),
                         1TEMPK(1500),TEMPKV(1200),SLPK(1200),SLPKV(1200),TK(1200),TKV(1200)
ISN 0007                  DIMENSION GGMREF(1200)
ISN 0008                  DIMENSION             PR(1200),REFDRY(1200),REFWET(1200),
                         1REFRAT(1200),TC(1200),RH(1200)          ,CALCH(1200)
ISN 0009                  DIMENSION THETA(30)
ISN 0010                  DIMENSION HEFHGM(1200),PRGP(100)
ISN 0011                  DIMENSION REFRAG(1201)
ISN 0012                5 FORMAT(1X,10HSTATION = ,I5,1X,7HYEAR = ,I2,9H MONTH = ,I2,7H DAY =
                         * ,I2,8H HOUR = ,I2)
ISN 0013                  READ (5,810) PRINT,WLMICR,FOPT
ISN 0014                  WRITE (6,811) PRINT,WLMICR,FOPT
ISN 0015              810 FORMAT (3D15.8)
ISN 0016              811 FORMAT(1H1,9H PRINT = ,F5.2,3X,24HWAVELENGTH IN MICRONS = ,G16.8,
                         13X,16HOPTICAL FREQS = ,F5.2)
ISN 0017                  READ (5,801) NTH
ISN 0018              801 FORMAT(I3)
ISN 0019                  DO 802 I = 1,NTH
ISN 0020                  READ (5,803) THETA(I)
ISN 0021              802 WRITE (6,1650) THETA(I)
ISN 0022              803 FORMAT(G20.5)
ISN 0023             1650 FORMAT(1X,8HANGLE = ,F15.8, 2X,7HRADIANS)
                 C        READ IN LATITUDE OF STATION IN DEGREES.
ISN 0024                  READ (5,601) GLAT
ISN 0025                  FLAT = GLAT
ISN 0026                  WRITE (6,812) FLAT
ISN 0027              812 FORMAT (1X,11HLATITUDE = ,F6.2,8H DEGREES)
ISN 0028              601 FORMAT(4F10.5)
ISN 0029                  GLAT = 0.017453293D0*GLAT
ISN 0030                  AA = 9.780356D0
ISN 0031                  BB = 0.0052885D0*DSIN(GLAT)**2
ISN 0032                  CC = -0.0000059D0*DSIN(2.0D0*GLAT)**2
ISN 0033                  GO = AA*(1.0D0 + BB + CC)
ISN 0034                  WRITE (6,947) GO
ISN 0035              947 FORMAT(1X,5HGO = ,D15.8)
ISN 0036                  AA = 3.085462D-6
ISN 0037                  BB = (2.27D-9)*DCOS(2.0D0*GLAT)
ISN 0038                  CC = 8.0D0*(DCOS(GLAT)**4 - DCOS(GLAT)**2) + 1.0D0
ISN 0039                  CC = (-2.0D-12)*CC
ISN 0040                  BOT = AA + BB + CC
ISN 0041                  R = (2.0D0*GO)/BOT
ISN 0042                  WRITE (6,948) R
ISN 0043              948 FORMAT(1X,5H R = ,D15.8)
ISN 0044                  FMD = 28.966D0
ISN 0045                  RSTAR = 8.31436D3
ISN 0046                  G = 9.8D0
ISN 0047                  FS = RSTAR/(G*FMD)
ISN 0048                  INDEX = 1
ISN 0049                  I = 1
ISN 0050              101 READ (1,7,END=99)       ISTAT,IYEAR,IMONTH,IDAY,IHOUR,IHEIGT,IPRES
                         *S,ITEMP,IRELH,IDUM
```

```
ISN 0051          7 FORMAT(I5,4I2,2I5,I4,I3,I6)
ISN 0052            HGPR(I) = IHEIGT
ISN 0053            PRESI = IPRESS
ISN 0054            PRESS(I) = 0.1D0*PRESI
ISN 0055            TEMPI = ITEMP
ISN 0056            TEMPC(I) =0.1D0*TEMPI
ISN 0057            RELHUM(I) = IRELH
ISN 0058            THOUR(I) = IHOUR
ISN 0059            TDAY(I) = IDAY
ISN 0060            TMONTH(I) = IMONTH
ISN 0061            TYEAR(I) = IYEAR
ISN 0062        102 I = I + 1
ISN 0063            READ (1,7,END=99      )ISTAT,IYEAR,IMONTH,IDAY,IHOUR,IHEIGT,IPRES
                   *S,ITEMP,IRELH,IDUM
ISN 0064            HGPR(I) = IHEIGT
ISN 0065            PRESI = IPRESS
ISN 0066            PRESS(I) = 0.1D0*PRESI
ISN 0067            TEMPI = ITEMP
ISN 0068            TEMPC(I) =0.1D0*TEMPI
ISN 0069            RELHUM(I) = IRELH
ISN 0070            THOUR(I) = IHOUR
ISN 0071            TDAY(I) = IDAY
ISN 0072            TMONTH(I) = IMONTH
ISN 0073            TYEAR(I) = IYEAR
ISN 0074            IF(THOUR(I)-THOUR(I-1).EQ.0.0D0.AND.TDAY(I)-TDAY(I-1).EQ.0.0D0.AND
                   *.TMONTH(I)-TMONTH(I-1).EQ.0.0D0.AND.TYEAR(I)-TYEAR(I-1).EQ.0.0D0)
                   *GO TO 102
ISN 0076            M = I - 1
ISN 0077            MP1 = I
ISN 0078            IDAY = TDAY(I-1)
ISN 0079            IHOUR = THOUR(I-1)
ISN 0080            IMONTH = TMONTH(I-1)
ISN 0081            IYEAR = TYEAR(I-1)
ISN 0082            DO 1 I = 1,M
ISN 0083            F1 = 0.01D0*RELHUM(I)*6.11D0
ISN 0084            EX = (7.5D0*TEMPC(I))/(237.3D0 + TEMPC(I))
ISN 0085            E(I) = (F1)*(10.0D0**EX)
ISN 0086            TEMPK(I) = TEMPC(I) + 273.15D0
ISN 0087            TOP = TEMPK(I)
ISN 0088            BOT = 1.0D0 - 0.379D0*(E(I)/PRESS(I))
ISN 0089          1 TEMPKV(I) = TOP/BOT
ISN 0090            CALCH(1) = HGPR(1)
ISN 0091            MM1 = M - 1
ISN 0092            DO 2 I = 1, MM1
ISN 0093            W = (TEMPKV(I+1)-TEMPKV(I))/TEMPKV(I)
ISN 0094            BOT = 1.0D0-(W/2.0D0)+((W**2)/3.0D0)-((W**3)/4.0D0)+((W**4)/5.0D0)
ISN 0095            BOT = BOT - ((W**5)/6.0D0) + ((W**6)/7.0D0)
ISN 0096            F3 = DLOG(PRESS(I)/PRESS(I+1))
ISN 0097          2 CALCH(I+1) = CALCH(I) + (1.0D0/BOT)*F5*TEMPKV(I)*F3
ISN 0098            DO 50 I = 1, M
ISN 0099            BRGP(I) = HGPR(I)
ISN 0100         50 HGPR(I) = CALCH(I)
ISN 0101            INDEX = INDEX + 1
ISN 0102            DO 250 I = 1,M
ISN 0103            IF(RELHUM(I).EQ.0.0D0.AND.PRESS(I).34.500.0D0)GO TO 60A
ISN 0105        250 CONTINUE
ISN 0106            GO TO 9191
ISN 0107       9191 IF(PRESS(M).GT. 30.0D0) GO TO 603
```

```
            C     GENERATE REFERENCE GEOMETRIC HEIGHTS (  N) IN METERS.
ISN 0109          HGMREF(1) = 0.0DC
ISN 0110          I = 1
ISN 0111      511 IF((HGMREF(I)/7000.0D0) - 170.0D0) 913,913,912
ISN 0112      912 HGMREF(I+1) = HGMREF(I) + 500000.0D0
ISN 0113          GO TC 914
ISN 0114      913 HGMREF(I+1) = HGMREF(I) + 50.19530*DEXP(HGMREF(I)/21000.0D0)
ISN 0115      914 IF(HGMREF(I+1) .GE. 1000000.0D0) GO TO 510
ISN 0117          I = I + 1
ISN 0118          GO TC 511
ISN 0119      510 N = I + 1
ISN 0120          HGMREF(N) = 1000000.0DC
ISN 0121      513 CONTINUE
ISN 0122      916 FORMAT(2X,DF15.8)
            C     CONVERT STATION HEIGHT FROM GEOPOTENTIAL METERS TO GEOMETRIC METERS
ISN 0123          TOP = R*HGPR(1)
ISN 0124          BOT = ((G0*R)/G) - HGPR(1)
ISN 0125          CONST = TOP/BOT
            C     ADD STATION HEIGHT IN METERS (GEOMETRIC) TO REFERENCE GEOMETRIC
            C     HEIGHTS
ISN 0126          DO 705 I = 1,N
ISN 0127      705 GMREFP(I) = HGMREF(I) + CONST
            C     CONVERT GMREFP(I) IN GEOMETRICAL METERS TO GEOPOTENTIAL HEIGHTS
            C     ABOVE SEA LEVEL GPMREF(I)
ISN 0128          GPMREF(1) = HGPR(1)
ISN 0129          DO 706 I = 2,N
ISN 0130          TOP = G0*R*GMREFP(I)
ISN 0131          BOT = G*(R + GMREFP(I))
ISN 0132      706 GPMREF(I) = TOP/BOT
ISN 0133          DO 861 I = 1,N
ISN 0134          TOP = G0*R*HGMREF(I)
ISN 0135          BOT = G*(R + HGMREF(I))
ISN 0136      861 GGMREF(I) = 1.0E-3*TOP/BOT
            C     ASSUME LINEARITY IN TEMPERATURE TEMPK(I) AND TEMPKV(I) WITH 'READ-
            C     IN' VALUES OF HEIGHT IN GEOPOTENTIAL METERS. COMPUTE SLOPES
            C     SLPK(I) AND SLPKV(I) IN DEGREES KELVIN PER GEOPOTENTIAL METER.
ISN 0137          MM1 = M - 1
ISN 0138          DO 709 I = 1,MM1
ISN 0139          TOP1 = TEMPK(I+1) - TEMPK(I)
ISN 0140          TOP2 = TEMPKV(I+1) - TEMPKV(I)
ISN 0141          BOT = HGPR(I+1) - HGPR(I)
ISN 0142          SLPK(I) = TOP1/BOT
ISN 0143      709 SLPKV(I) = TOP2/BOT
            C     LINEARLY INTERPOLATE BETWEEN 'READ-IN' VALUES OF TEMPK(I) AND
            C     TEMPKV(I) TO OBTAIN VALUES OF TEMPERATURE AT THE 'FIXED' LEVELS.
ISN 0144          NM1 = N - 1
ISN 0145          DO 710 I = 1,NM1
ISN 0146          IF(GPMREF(I).LE.HGPR(M).AND.GPMREF(I+1).GT.HGPR(M)) MT = I
ISN 0148      710 CONTINUE
ISN 0149          IF(GPMREF(  N) .LE. HGPR(M)) MT = N
ISN 0151          DO 712 K = 1,MM1
ISN 0152          DO 712 I = 1, MT
ISN 0153          IF(GPMREF(I).GE.HGPR(K).AND.GPMREF(I).LT.HGPR(K+1))TK(I)=TEMPK(K)
                 *+ SLPK(K)*(GPMREF(I) - HGPR(K))
ISN 0155      712 IF(GPMREF(I).GE.HGPR(K).AND.GPMREF(I).LT.HGPR(K+1))TKV(I)=TEMPKV(K
                 *) + SLPKV(K)*(GPMREF(I) - HGPR(K))
            C     SET TEMPERATURES ABOVE LAST 'READ-IN' TEMPERATURE TEMPKV(M) EQUAL
            C     TO THE LAST 'READ-IN' TEMPERATURE.
```

```
ISN 0157          MTP1 = MT + 1
ISN 0158          IF(MTP1 .GE.   N) GO TO 720
ISN 0160          DO 713 I = MTP1, N
ISN 0161          TK(I) = TEMPKV(M)
ISN 0162      713 TKV(I) = TK(I)
            C     COMPUTE THE PRESSURE PR(I) AT THE VARIOUS 'FIXED' LEVELS.
ISN 0163      720 MTM1 = MT - 1
ISN 0164          PR(1) = PRESS(1)
ISN 0165          DO 789 K = 1, MM1
ISN 0166          DO 789 I = 1,MTM1
ISN 0167          IF(GPMREF(I+1) .GE. HGPR(K) .AND. GPMREF(I+1) .LT. HGPR(K+1))
                 *GO TO 788
ISN 0169          GO TO 789
ISN 0170      788 BB = DABS(SLPKV(K))
ISN 0171          IF(BB.LE.1.0D-10) SLPKV(K) = 1.0D-10
ISN 0173          EXPT = (G*FMD)/(RSTAR*SLPKV(K))
ISN 0174          TOP = TEMPKV(K)
ISN 0175          BOT = TEMPKV(K) + SLPKV(K)*(GPMREF(I+1) - HGPR(K))
ISN 0176          PR(I+1) = PRESS(K)*10.0D0**(EXPT*DLOG10(TOP/BOT))
ISN 0177      789 CONTINUE
ISN 0178      791 FORMAT (4X,4D15.8)
ISN 0179          SLOPE = 1.0D-10
ISN 0180          DO 790 I = MT,NM1
ISN 0181          EXPT = (G*FMD)/(RSTAR*SLOPE)
ISN 0182          TOP = TEMPKV(M)
ISN 0183          BOT = TEMPKV(M)+SLOPE*(GPMREF(I+1)-HGPR(M))
ISN 0184      790 PR(I+1) = PRESS(M)*10.0D0**(EXPT*DLOG10(TOP/BOT))
            C     COMPUTE THE PARTIAL PRESSURE OF THE WATER VAPOR E(I) AT THE 'FIXED'
            C     LEVELS.
ISN 0185          DO 716 I = 1,N
ISN 0186          F1 = 1.0D0 - (TK(I)/TKV(I))
ISN 0187          F2 = 1.0D0/0.379D0
ISN 0188      716 E(I) = F2*PR(I)*F1
            C     CALCULATE TEMPERATURE IN DEGREES CELCIUS TC(I) FROM TEMPERATURE IN
            C     DEGREES KELVIN TK(I) FOR   N 'FIXED' LEVELS.
ISN 0189          DO 717 I = 1, N
ISN 0190      717 TC(I) = TK(I) - 273.15D0
            C     COMPUTE DRY REFRACTIVITY, WET REFRACTIVITY, AND TOTAL REFRACTIVITY
ISN 0191          FCST1 = 287.604D0
ISN 0192          FCST2 = 1.6288D0/WLMICR**2
ISN 0193          FCST3 = 0.0136D0/WLMICR**4
ISN 0194          FSTD = FCST1 + FCST2 + FCST3
ISN 0195          FSTDG = FCST1 + 3.0D0*FCST2 + 5.0D0*FCST3
ISN 0196          FPARP = (0.055D0*760.0D0*273.15D0)/1013.25D0
ISN 0197          FST1 = 273.15D0/1013.25D0
ISN 0198          DO 718 I = 1, N
ISN 0199          REFDRY(I) = (77.624D0*PR(I))/TK(I)
ISN 0200          REFWET(I) = (373000.0D0*E(I))/(TK(I)**2)-12.92D0*(E(I)/TK(I))
ISN 0201          REFFGM(I) = HGMREF(I)
ISN 0202          HGMREF(I) = HGMREF(I)*1.0D-3
ISN 0203          REFRAT(I)=((FST1*PR(I)*FSTD)/TK(I))-((FPARP*E(I))/TK(I))
ISN 0204          REFRAG(I) = ((FST1*PR(I)*FSTDG)/TK(I))-((FPARP*E(I))/TK(I))
ISN 0205          IF(FOPT.EQ. 0.0D0) REFRAT(I)=REFDRY(I)+REFWET(I)
ISN 0207      718 IF(FOPT.EQ. 0.0D0) REFRAG(I) = REFRAT(I)
ISN 0209          SAVE1 = REFRAT(1)
            C     COMPUTE RELATIVE HUMIDITY RH(I) AT EACH OF THE 'FIXED' LEVELS
            C     FROM THE PARTIAL PRESSURE OF THE WATER VAPOR E(I) AND THE TEMP-
            C     ERATURE IN DEGREES CELCIUS TC(I).
```

```
ISN 0210            DO 719 I = 1, N
ISN 0211            TOP = -7.500*TC(I)
ISN 0212            BOT = 237.300 + TC(I)
ISN 0213            EX = TOP/BOT
ISN 0214            RH(I) = (((100.0*(RH(I))/6.1100)*10.)))**-X
ISN 0215       719  IF(RH(I) .GT. 100.000) RH(I) = 100.000
ISN 0217      5555  FORMAT(1H0,17X)
ISN 0218        21  FORMAT(1H1, 17X)
ISN 0219            GMREFR(1) = GMREFR(1)*1.0E-3
ISN 0220            NPTS = N
ISN 0221            DO 930  K = 1,N
ISN 0222            X(K) = HGMREF(K)
ISN 0223       930  U(K) = REFRAG(K)
ISN 0224            CALL FSPINT(SUM)
ISN 0225            SUM7 = SUM
ISN 0226            IF(PRINT)1814,1814,1812
ISN 0227      1812  WRITE (6,104)
ISN 0228            WRITE (6,104)
ISN 0229            WRITE (6,104)
ISN 0230            WRITE (6,1813)
ISN 0231      1813  FORMAT(10H    HGT CMP,10H PRESS(MB),10H TEMP DEGC,10H   RELH PCT,
                   110H    CALHGT)
ISN 0232            WRITE (6,104)
ISN 0233       104  FORMAT(1H0,17X)
ISN 0234            DO 110 I = 1, M
ISN 0235       110  WRITE (6,111) PRGP(I),PRESS(I),TEMPC(I),RELHUM(I),CALCH(I)
ISN 0236       111  FORMAT(4F10.1, F10.3)
ISN 0237            WRITE (6,21)
ISN 0238       815  WRITE (6,817)
ISN 0239       817  FORMAT(9H    H(KM),9H   TEMP(K),9H   PR(MB),9H   WV(MB),9H   RH(PCT)
                   -1,2X,6HREFWET,6X,6HREFDRY,3X,6HREFRAT,6X,9HGR REFRAT)
ISN 0240            WRITE (6,104)
ISN 0241            WRITE (6,104)
ISN 0242            DO 23 I = 1,N
ISN 0243        23  WRITE (6,820)HGMREF(I),TK(I),PR(I),E(I),RH(I),REFWET(I),REFDRY(I),
                   1REFRAT(I),REFRAG(I)
ISN 0244            WRITE (6,104)
ISN 0245            WRITE (6,104)
ISN 0246       820  FORMAT(F9.3,F9.1,F9.2,F9.4,F9.2,4D13.4)
ISN 0247      1814  DO 13 K = 1, NTH
ISN 0248            THETA0 = THETA(K)
ISN 0249            CALL RAYTHR(N,HGMREF,REFRAT,THETA0,EPS,RNGERR,RANGE,REFRAG)
ISN 0250            WRITE (6,5) ISTAT,IYEAR,IMONTH,IDAY,IHOUR
ISN 0251            WRITE (4,5) ISTAT,IYEAR,IMONTH,IDAY,IHOUR
ISN 0252            WRITE (6,10) THETA0
ISN 0253            WRITE (4,10) THETA0
ISN 0254        10  FORMAT(1X,18HELEVATION ANGLE = ,D15.8,1X,7HRADIANS)
ISN 0255            WRITE(6,11) RANGE
ISN 0256            WRITE(4,11) RANGE
ISN 0257        11  FORMAT(1X,8HRANGE = ,D15.8,1X,10HKILOMETERS)
ISN 0258            WRITE (6,19) SUM7
ISN 0259        19  FORMAT(1X,22HSUM OF REFRACTIVITY = ,D15.8)
ISN 0260            WRITE (6,18) GMREFR(1)
ISN 0261            WRITE (4,18) GMREFR(1)
ISN 0262        18  FORMAT(1X,9HHEIGHT = ,D15.8,1X,10HKILOMETERS)
ISN 0263            WRITE (6,12) PR(1)
ISN 0264            WRITE (4,12) PR(1)
ISN 0265        12  FORMAT(1X,11HPRESSURE = ,D15.3,1X,9HMILLIBARS)
```

```
ISN 0266            WRITE (6,14) TC(1)
ISN 0267            WRITE (4,14) TC(1)
ISN 0268         14 FORMAT(1X,14HTEMPERATURE = ,D15.3,1X,15HDEGREES CELCIUS)
ISN 0269            WRITE (6,15) RH(1)
ISN 0270            WRITE (4,15) RH(1)
ISN 0271         15 FORMAT(1X,20HRELATIVE HUMIDITY = ,D13.2,1X,7HPERCENT)
ISN 0272            WRITE (6,16)EPS
ISN 0273            WRITE (4,16)EPS
ISN 0274         16 FORMAT(1X,24HELEVATION ANGLE ERROR = ,D15.3,1X,7HRADIANS)
ISN 0275            IF(ECPT - 1.0D0)) 850,851,850
ISN 0276        851 BETA = THETA0 - EPS
ISN 0277            FACT7 = 0.0100
ISN 0278            DHF = 1.0D0 - 2.00D0*(DSIN(GLAT)**2)
ISN 0279            BCD = 1.0D0 - 0.0026D0)*38D - 0.0)2330*GMRLFP(1)
ISN 0280            FACT1=1.26052D0-0.10360D-1*BDD-0.11231D-2*TK(1)+0.15357D-4*FR(1)
ISN 0281            FACT2 = (FACT1*PR(1)*TK(1)*1.0D-3)/BCD
ISN 0282            FACTK = (FACT1*BCD)/1.094205D0
ISN 0283            FACT3 = 1.0D0/FACTK
ISN 0284            FACT3 = 3.0D0 - FACT3
ISN 0285            FACT3 = 2.0D0/FACT3
ISN 0286            FACT4=47343.46D-12*FACT3*((PR(1)**2)/TK(1))
ISN 0287            FACT4 = FACT4/BCD
ISN 0288            FBB = FACT2 + FACT4
ISN 0289            FAA = (0.002357D0*PR(1)+0.000141D0*E(1))/BCD
ISN 0290            FSIN1 = DSIN(BETA)
ISN 0291            TOP = FAA + FBB
ISN 0292            BOT = FSIN1 + FBB/(TOP*(FSIN1 + FACT7))
ISN 0293            RER = TOP/BOT
ISN 0294            RDIFF = (RER - RNGERR*1.0D3)*100.0D0
ISN 0295            WRITE (6,853) RER
ISN 0296            WRITE (4,853) RER
ISN 0297        853 FORMAT(1X,21HRANGE ERROR APPROX = ,D15.8,7H METERS)
ISN 0298            WRITE (6,854) RDIFF
ISN 0299            WRITE (4,854) RDIFF
ISN 0300        854 FORMAT(1X,14H RANGE DIFF = ,D15.3, 3H CM)
ISN 0301        850 WRITE (6,17) RNGERR
ISN 0302            WRITE (4,17) RNGERR
ISN 0303         17 FORMAT(1X,14HRANGE ERROR = ,D24.16,1X,10HKILOMETERS)
ISN 0304         13 CONTINUE
ISN 0305            GO TO 604
ISN 0306        604 CONTINUE
ISN 0307        605 HGPR(1) = HGPR(MP1)
ISN 0308            PRESS(1) = PRESS(MP1)
ISN 0309            TEMPC(1) = TEMPC(MP1)
ISN 0310            RELHUM(1) = RELHUM(MP1)
ISN 0311            TDAY(1) = TDAY(MP1)
ISN 0312            THOUR(1) = THOUR(MP1)
ISN 0313            TMONTH(1) = TMONTH(MP1)
ISN 0314            TYEAR(1) = TYEAR(MP1)
ISN 0315            I = 2
ISN 0316            IF(INDEX .LT.    3) GO TO 101
ISN 0318         99 STOP
ISN 0319            END

       COMPILER OPTIONS - NAME=  MAIN,OPT=01,LINECNT=60,SIZE=0000K,
                          SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF

ISN 0002            SUBROUTINE ESPINT(SUM)
ISN 0003            IMPLICIT REAL*8(A-H,O-Z)
ISN 0004            COMMON X(1500),U(1500),S(3002),NPTS
ISN 0005            M = NPTS - 1
ISN 0006            SUM = 0.0D0
ISN 0007            DO 1 I = 1,M
ISN 0008            Z = 1.0D0/DLOG(U(I+1)/U(I))
ISN 0009          1 SUM = SUM + Z*(X(I+1)-X(I))*(U(I+1)-U(I))
ISN 0010            RETURN
ISN 0011            END
```

```
COMPILER OPTIONS - NAME=  MAIN,OPT=01,LINECNT=60,SIZE=0000K,
                   SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE RAYTER(N,HGT,REFRAT,THETAO,EPS,RNGERR,RANGE,REFRAG)
      IMPLICIT REAL*8(A-H,O-Z)
C     THAYER METHOD FOR RAY TRACING
C     INPUT-NUMBER OF POINTS N, REFRACTIVITY PROFILE REFRAT(I)
C     (DIMENSIONLESS) VERSUS HEIGHT HGT(I) IN KILOMETERS, THETAO IN
C     RADIANS. OUTPUT-ELEVATION ANGLE CORRECTION EPS IN RADIANS AND
C     RANGE CORRECTION RNGERR IN KILOMETERS.
      DIMENSION HGT(1),REFRAT(1),THETA(1501),REFIND(1501),REFRATD(1501)
      DIMENSION R(1501), A(1501)
      DIMENSION REFRAG(1), REFING(1501)
      THETA(1) = THETAO
  475 DO 5 I = 1,N
      REFIND(I) = 1.0D0 + (1.0D-6)*REFRAT(I)
    5 R(I) = HGT(I) + 6378.0D0
      DO 6 I = 2,N
      DELN2 = (1.0D-6)*(REFRAT(I)-REFRAT(I-1))
      DELR2 = R(I) - R(I-1)
      P = DELN2/REFIND(I-1)
      Q = DELR2/R(I-1)
      TOP = 1.0D0 - (P/2.0D0) + (P**2/3.0D0)
      BOT = 1.0D0 - (Q/2.0D0) + (Q**2/3.0D0)
    6 A(I) = (P*TOP)/(Q*BOT)
      DO 7 I = 2,N
      AA = R(1)/(2.0D0*R(I))
      BB = 2.0D0*(DSIN(THETA(1)*0.5D0)**2)
      CC = (R(I) - R(1))/R(1)
      DD = (REFRAT(1) - REFRAT(I))/REFIND(I)
      EE = (1.0D-6)*DCOS(THETA(1))
      SINSQ = AA*(BB + CC - DD*EE)
      SINA = DSQRT(SINSQ)
      ARGT = DARSIN(SINA)
    7 THETA(I) = 2.0D0*ARGT
      TAU = 0.0D0
      DO 9 I = 2,N
      AA = THETA(I) - THETA(I-1)
      BB = -A(I)/(1.0D0 + A(I))
      CC = AA*BB
    9 TAU = TAU + CC
      PHI = 0.0D0
      DO 11 I = 2,N
      AA = THETA(I) - THETA(I-1)
      BB = 1.0D0/(A(I) + 1.0D0)
      CC = AA*BB
   11 PHI = PHI + CC
      RE = 0.0D0
      DO 14 I = 1, N
   14 REFING(I) = 1.0D0 + (1.0D-6)*REFRAT(I)
      DO 13 I = 2,N
      AA = REFING(I-1)*R(I-1)*DCOS(THETA(I-1))
      BB = DTAN(THETA(I)) - DTAN(THETA(I-1))
      CC = 1.0D0 + A(I)
      DD = (AA*BB)/CC
   13 RE = RE + DD
      RANGSQ = (R(N) - R(1))**2+4.0D0*R(1)*R(N)*DSIN(0.5D0*PHI)**2
      RANGE = DSQRT(RANGSQ)
      RNGERR = RE - RANGE

      TOP = DCOS(TAU) - DSIN(TAU)*DTAN(THETA(N))
      TOP = TOP - (REFIND(N)/REFIND(1))
      BOT = (REFIND(N)/REFIND(1))*DTAN(THETA(1))
      BOT = BOT - DSIN(TAU)
      BOT = BOT - DCOS(TAU)*DTAN(THETA(N))
      EPS = DATAN(TOP/BOT)
      RETURN
      END
```

```
IEF142I - STEP WAS EXECUTED - COND CODE 0000
***** JOB NBR-556  STEP NBR-01   GBCWM001  SOURCE   PGM=IEKAA00  CARDS=00415   INITIATION TIME=19.03.15.90 DATE=11-01-73
*  * CPU=000MIN 04.24SECS  I/O=000MIN 02.02SECS REGION START=2066K NASA-GSFC TERMINATION TIME=19.07.30.83 DATE=11-01-73
*  * I/O TIME BY DEVICE   DISK=*****2.55 DRUM=******.27 TAPE=******.00 CELL=******.00 GRAF=******.00 OTHR=******.00
***** STEP REGION SIZE=0300K  MAXIMUM REGION SIZE USED=0298K  PERCENT OF REGION USED=99
//      EXEC LOADER,PARM='SIZE=450K',REGION=450K
//GO.FT04F001 DD UNIT=2400-9,DISP=(OLD,KEEP),LABEL=(4,BLP),
//    DCB=(RECFM=FB,LRECL=132,BLKSIZE=2300,DEN=3),VOL=SER=35375A
//GO.FT01F001 DD DSN=GBCWM.DULLES,
//      DCB=(RECFM=FB,LRECL=36,BLKSIZE=2160,DEN=3),
//      UNIT=(2400-9,,DEFER),DISP=(OLD,KEEP),LABEL=(1,BLP,,IN),
//      VOL=SER=GBCW10
//GO.DATA5 DD *
```

PRINT = 1.00 WAVELENGTH IN MICRONS = 0.69430000D 00 OPTICAL FREQS = 1.00
ANGLE = 0.17453293 RADIANS
ANGLE = 0.26179940 RADIANS
ANGLE = 0.34906586 RADIANS
ANGLE = 0.69813172 RADIANS
ANGLE = 1.39626344 RADIANS
LATITUDE = 39.52 DEGREES
GO = 0.98015995D 01
R = 0.63826400D 07

HGT GMP	PRESS(MB)	TEMP DEGC	RELH PCT	CALHGT
85.0	1003.0	-4.2	96.0	85.000
109.0	1000.0	-3.3	96.0	108.676
170.0	993.0	-1.3	96.0	164.508
440.0	960.0	-2.5	100.0	433.566
520.0	950.0	-1.1	100.0	516.966
610.0	940.0	3.8	94.0	602.270
760.0	921.0	4.4	77.0	768.564
957.0	900.0	3.0	80.0	956.084
1400.0	862.0	-0.4	85.0	1397.716
1418.0	850.0	0.2	78.0	1416.553
1550.0	835.0	3.4	39.0	1560.190
1908.0	800.0	2.2	40.0	1906.755
2420.0	780.0	-0.2	41.0	2426.045
2690.0	725.0	-0.7	43.0	2697.377
2979.0	700.0	-3.1	44.0	2976.813
3550.0	650.0	-8.3	46.0	3557.612
4040.0	611.0	-12.9	55.0	4033.814
4160.0	601.0	-12.9	99.0	4159.741
4175.0	600.0	-13.0	99.0	4172.450
4820.0	550.0	-16.5	99.0	4831.822
5544.0	500.0	-21.4	79.0	5542.068
6300.0	450.0	-27.4	91.0	6310.109
6520.0	436.0	-29.3	98.0	6536.829
7154.0	400.0	-31.3	47.0	7150.008
8089.0	350.0	-36.7	44.0	8085.455
9142.0	300.0	-42.4	0.0	9140.177
9730.0	275.0	-45.3	0.0	9724.547
10355.0	250.0	-50.4	0.0	10353.468
11775.0	200.0	-60.9	0.0	11774.728
11940.0	195.0	-61.9	0.0	11931.751
12600.0	175.0	-62.9	0.0	12695.730
13550.0	150.0	-62.1	0.0	13550.818
14680.0	125.0	-60.7	0.0	14681.587
15270.0	114.0	-60.0	0.0	15255.727
16045.0	100.0	-63.2	0.0	16067.592
16440.0	94.0	-64.8	0.0	16446.634
17433.0	80.0	-63.5	0.0	17433.840
18254.0	70.0	-62.4	0.0	18255.949
19211.0	60.0	-61.3	0.0	19203.971
20346.0	50.0	-59.9	0.0	20345.012
21742.0	40.0	-59.4	0.0	21740.404
23543.0	30.0	-59.3	0.0	23541.906
24686.0	25.0	-59.2	0.0	24684.161
26084.0	20.0	-59.1	0.0	26082.822
27389.0	15.0	-56.8	0.0	27887.058
30439.0	10.0	-58.2	0.0	30436.861
32697.0	7.0	-56.3	0.0	32692.329
33677.0	6.0	-55.6	0.0	33672.990

H(KM)	TEMP(K)	PR(MB)	WV(MB)	RH(PCT)	REFWET	FEFDRY	REFRAT	GR REFRAT
0.0	268.9	1003.00	4.2524	95.00	0.21723540D 02	0.28940456D 03	0.29241809D 03	0.29944732D 03
0.050	270.8	996.67	4.9490	96.29	0.24937197D 02	0.28569498D 03	0.28856001D 03	0.29549722D 03
0.100	271.0	990.41	5.3136	96.30	0.26564702D 02	0.28209697D 03	0.28571752D 03	0.29258679D 03
0.151	271.5	984.17	5.2663	97.04	0.26351853D 02	0.28134786D 03	0.28415355D 03	0.29098520D 03
0.201	271.3	977.95	5.2192	97.73	0.26199543D 02	0.27980229D 03	0.28259313D 03	0.28938726D 03
0.252	271.1	971.75	5.1724	99.54	0.25007789D 02	0.27826025D 03	0.28103629D 03	0.28779297D 03
0.303	270.9	965.57	5.1258	99.30	0.25816577D 02	0.27672176D 03	0.27948362D 03	0.28620234D 03
0.353	270.7	959.41	5.1167	100.00	0.25794371D 02	0.27508160D 03	0.27782552D 03	0.28450501D 03
0.404	271.6	953.29	5.4569	100.00	0.27245477D 02	0.27246414D 03	0.27516547D 03	0.28178241D 03
0.455	273.4	947.21	6.1744	99.21	0.30518489D 02	0.26893016D 03	0.27156644D 03	0.27809656D 03
0.507	276.3	941.22	7.2113	95.13	0.35369156D 02	0.26430384D 03	0.26692760D 03	0.27334733D 03
0.558	277.1	935.30	7.2665	89.65	0.34960808D 02	0.26200726D 03	0.26452820D 03	0.27089023D 03
0.610	277.3	929.40	6.9254	84.34	0.33274955D 02	0.26018109D 03	0.26265717D 03	0.26901487D 03
0.661	277.5	923.54	6.5879	79.18	0.31610483D 02	0.25836575D 03	0.26087541D 03	0.26714901D 03
0.713	277.3	917.69	6.3827	77.47	0.30656791D 02	0.25686874D 03	0.25936040D 03	0.26559741D 03
0.765	276.9	911.86	6.2774	78.29	0.30235765D 02	0.25558426D 03	0.25807614D 03	0.26428221D 03
0.817	276.6	906.05	6.1727	79.12	0.29815279D 02	0.25431118D 03	0.25679328D 03	0.26296843D 03
0.869	276.2	900.25	6.0686	79.96	0.29395331D 02	0.25303950D 03	0.25551183D 03	0.26165610D 03
0.921	275.8	894.47	5.9450	80.60	0.28861056D 02	0.25177982D 03	0.25424330D 03	0.26035698D 03
0.973	275.4	888.70	5.8212	81.23	0.28363083D 02	0.25052190D 03	0.25297657D 03	0.25905971D 03
1.026	275.0	882.94	5.6982	81.84	0.27845721D 02	0.24926652D 03	0.25171113D 03	0.25776376D 03
1.079	274.6	877.20	5.5759	82.45	0.27328987D 02	0.24800996D 03	0.25044699D 03	0.25646914D 03
1.131	274.1	871.47	5.4544	83.06	0.26812084D 02	0.24675655D 03	0.24918416D 03	0.25517586D 03
1.184	273.7	865.76	5.3336	83.63	0.26297417D 02	0.24550326D 03	0.24792264D 03	0.25388392D 03
1.237	273.3	860.07	5.2146	84.21	0.25782594D 02	0.24425189D 03	0.24666245D 03	0.25259334D 03
1.290	272.9	854.38	5.0942	84.77	0.25268422D 02	0.24300186D 03	0.24540359D 03	0.25130413D 03
1.344	273.6	848.72	4.6808	74.04	0.23059162D 02	0.24077686D 03	0.24317223D 03	0.24901874D 03
1.397	274.8	843.11	4.0048	58.14	0.19591624D 02	0.23814791D 03	0.24054357D 03	0.24632625D 03
1.451	276.0	837.54	3.3411	44.54	0.16203314D 02	0.23586188D 03	0.23794744D 03	0.24366798D 03
1.504	276.4	832.01	3.0260	39.08	0.14627432D 02	0.23361888D 03	0.23600673D 03	0.24167543D 03
1.558	276.3	826.50	2.9980	39.24	0.14511914D 02	0.23222912D 03	0.23460309D 03	0.24024204D 03
1.612	276.1	821.01	2.9702	39.39	0.14396311D 02	0.23084317D 03	0.23320330D 03	0.23880860D 03
1.666	275.9	815.54	2.9426	39.55	0.14282124D 02	0.22946106D 03	0.23180736D 03	0.23737911D 03
1.721	275.7	810.09	2.9150	39.70	0.14167855D 02	0.22808275D 03	0.23041529D 03	0.23595357D 03
1.776	275.5	804.66	2.8876	39.86	0.14054000D 02	0.22670828D 03	0.22902708D 03	0.23453199D 03
1.830	275.3	799.25	2.8592	40.01	0.13935371D 02	0.22534006D 03	0.22764523D 03	0.23311691D 03
1.884	275.1	793.85	2.8241	40.12	0.13765160D 02	0.22399047D 03	0.22626249D 03	0.23172140D 03
1.939	274.9	788.48	2.7891	40.23	0.13635557D 02	0.22264446D 03	0.22492336D 03	0.23032958D 03
1.994	274.7	783.12	2.7544	40.34	0.13486590D 02	0.22130203D 03	0.22356784D 03	0.22894147D 03
2.049	274.5	777.78	2.7199	40.44	0.13338263D 02	0.21936320D 03	0.22221594D 03	0.22755706D 03
2.105	274.3	772.46	2.6855	40.55	0.13190563D 02	0.21862795D 03	0.22086767D 03	0.22617637D 03
2.160	274.0	767.16	2.6515	40.66	0.13043495D 02	0.21729631D 03	0.21952303D 03	0.22479939D 03
2.215	273.8	761.87	2.6176	40.76	0.12897063D 02	0.21596828D 03	0.21818203D 03	0.22342614D 03
2.271	273.6	756.61	2.5839	40.87	0.12751263D 02	0.21464385D 03	0.21684466D 03	0.22205662D 03
2.327	273.4	751.36	2.5505	40.97	0.12606394D 02	0.21332304D 03	0.21551065D 03	0.22069083D 03
2.383	273.2	746.14	2.5349	41.30	0.12546783D 02	0.21193873D 03	0.21416286D 03	0.21931035D 03

2.439	273.0	740.53	2.5255	41.71	0.12517433D 02	0.21065234D 03	0.21281243D 03	0.21792746D 03
2.495	272.6	735.74	2.5161	42.12	0.12487955D 02	0.20931995D 03	0.21146604D 03	0.21654872D 03
2.552	272.7	730.67	2.5066	42.54	0.12453343D 02	0.20799157D 03	0.21012370D 03	0.21517412D 03
2.609	272.5	725.42	2.4572	42.97	0.12428583D 02	0.20666721D 03	0.20878542D 03	0.21380368D 03
2.665	272.0	720.28	2.4284	43.23	0.12127677D 02	0.20555404D 03	0.20766296D 03	0.21265419D 03
2.722	271.5	715.16	2.3549	43.45	0.11803107D 02	0.20446007D 03	0.20656010D 03	0.21152478D 03
2.779	271.0	710.05	2.2819	43.66	0.11478691D 02	0.20336700D 03	0.20545814D 03	0.21039627D 03
2.836	270.5	704.96	2.2093	43.95	0.11154434D 02	0.20227482D 03	0.20435707D 03	0.20926868D 03
2.894	270.0	699.88	2.1374	44.01	0.10831106D 02	0.20119391D 03	0.20325727D 03	0.20814239D 03
2.951	269.5	694.81	2.0718	44.33	0.10538533D 02	0.20010846D 03	0.20217283D 03	0.20703184D 03
3.009	269.0	689.75	2.0065	44.63	0.10246093D 02	0.19903377D 03	0.20108915D 03	0.20592207D 03
3.067	268.5	684.71	1.9417	44.91	0.99536402D 01	0.19795964D 03	0.20000624D 03	0.20481307D 03
3.125	268.0	679.69	1.8774	45.17	0.96612160D 01	0.19688668D 03	0.19892409D 03	0.20370487D 03
3.183	267.5	674.67	1.8135	45.40	0.93688291D 01	0.19581431D 03	0.19784273D 03	0.20259747D 03
3.241	266.9	669.67	1.7500	45.59	0.90764827D 01	0.19474272D 03	0.19676215D 03	0.20149087D 03
3.300	266.4	664.69	1.6870	45.75	0.87841801D 01	0.19367194D 03	0.19568238D 03	0.20038510D 03
3.358	265.9	659.71	1.6244	45.88	0.84919244D 01	0.19260196D 03	0.19460341D 03	0.19928015D 03
3.417	265.4	654.75	1.5623	45.96	0.81997191D 01	0.19153280D 03	0.19352526D 03	0.19817604D 03
3.476	264.8	649.81	1.5017	46.04	0.79135184D 01	0.19046565D 03	0.19244908D 03	0.19707395D 03
3.536	264.3	644.87	1.4687	47.09	0.77731613D 01	0.18942816D 03	0.19140171D 03	0.19600138D 03
3.596	263.7	639.96	1.4359	48.16	0.76326365D 01	0.18839119D 03	0.19035486D 03	0.19492935D 03
3.654	263.1	635.05	1.4033	49.25	0.74921234D 01	0.18735473D 03	0.18930853D 03	0.19385785D 03
3.714	262.5	630.16	1.3709	50.37	0.73514423D 01	0.18631882D 03	0.18826273D 03	0.19278691D 03
3.774	262.0	625.28	1.3387	51.51	0.72106553D 01	0.18528344D 03	0.18721748D 03	0.19171651D 03
3.834	261.4	620.41	1.3067	52.68	0.70697623D 01	0.18424861D 03	0.18617279D 03	0.19064669D 03
3.894	260.8	615.56	1.2750	53.86	0.69287643D 01	0.18321435D 03	0.18512865D 03	0.18957744D 03
3.954	260.2	610.72	1.2737	56.26	0.69511073D 01	0.18215676D 03	0.18405563D 03	0.18848274D 03
4.015	260.2	605.90	1.7557	77.55	0.95817105D 01	0.18071942D 03	0.18258598D 03	0.18697418D 03
4.075	260.2	601.10	2.2311	98.54	0.12176103D 02	0.17928980D 03	0.18112040D 03	0.18547390D 03
4.136	259.9	596.33	2.1813	99.12	0.11936593D 02	0.17810490D 03	0.17992479D 03	0.18424951D 03
4.197	259.6	591.58	2.1271	99.25	0.11666362D 02	0.17690554D 03	0.17871477D 03	0.18301037D 03
4.259	259.3	586.85	2.0734	99.35	0.11403343D 02	0.17570930D 03	0.17750790D 03	0.18177445D 03
4.320	258.9	582.13	2.0202	99.42	0.11138555D 02	0.17451620D 03	0.17630417D 03	0.18054175D 03
4.382	258.6	577.43	1.9674	99.47	0.10874983D 02	0.17332623D 03	0.17510361D 03	0.17931229D 03
4.443	258.3	572.75	1.9151	99.48	0.10612652D 02	0.17213942D 03	0.17390621D 03	0.17808608D 03
4.505	257.9	568.09	1.8632	99.46	0.10351550D 02	0.17095577D 03	0.17271199D 03	0.17686312D 03
4.567	257.6	563.45	1.8117	99.40	0.10091664D 02	0.16977528D 03	0.17152097D 03	0.17564343D 03
4.630	257.3	558.82	1.7608	99.30	0.98330690D 01	0.16859798D 03	0.17033314D 03	0.17442701D 03
4.692	257.0	554.22	1.7102	99.16	0.95756981D 01	0.16742386D 03	0.16914852D 03	0.17321388D 03
4.755	256.6	549.63	1.6582	98.93	0.93087633D 01	0.16625819D 03	0.16797250D 03	0.17200956D 03
4.818	256.2	545.06	1.5836	98.03	0.85207264D 01	0.16515448D 03	0.16686008D 03	0.17087034D 03
4.881	255.7	540.59	1.5098	96.92	0.85332974D 01	0.16405293D 03	0.16574983D 03	0.16973334D 03
4.944	255.3	535.97	1.4367	95.70	0.81422353D 01	0.16295355D 03	0.16464174D 03	0.16859856D 03
5.007	254.9	531.45	1.3642	94.33	0.77639000D 01	0.16185635D 03	0.16353584D 03	0.16746602D 03
5.071	254.4	526.94	1.2924	92.78	0.73807514D 01	0.16076134D 03	0.16243214D 03	0.16633573D 03
5.135	254.0	522.46	1.2213	91.05	0.69988475D 01	0.15966853D 03	0.16133064D 03	0.16520770D 03
5.199	253.6	517.99	1.1508	89.12	0.66181584D 01	0.15857795D 03	0.16023137D 03	0.16408194D 03
5.263	253.1	513.54	1.0811	86.99	0.62388139D 01	0.15748559D 03	0.15913433D 03	0.16295847D 03
5.327	252.7	509.10	1.0120	84.63	0.58607036D 01	0.15640347D 03	0.15803953D 03	0.16183730D 03
5.392	252.2	504.68	0.9436	82.04	0.54838772D 01	0.15531960D 03	0.15694699D 03	0.16071844D 03
5.457	251.8	500.28	0.8758	79.19	0.51083443D 01	0.15423800D 03	0.15585672D 03	0.15960191D 03

5.522	251.3	495.90	0.8472	80.08	0.49615192D 01	0.15319236D 03	0.15430105D 03	0.15852085D 03
5.587	250.8	491.53	0.8215	81.22	0.46305334D 01	0.15215081D 03	0.15374638D 03	0.15744389D 03
5.652	250.3	487.18	0.7960	82.36	0.46957395D 01	0.15111103D 03	0.15269950D 03	0.15636876D 03
5.718	249.7	482.84	0.7707	83.47	0.45653132D 01	0.15007304D 03	0.15165142D 03	0.15529547D 03
5.784	249.2	478.52	0.7457	84.57	0.44390353D 01	0.14903686D 03	0.15060515D 03	0.15422405D 03
5.850	248.7	474.22	0.7209	85.64	0.43021324D 01	0.14800248D 03	0.14956072D 03	0.15315449D 03
5.916	248.2	469.93	0.6962	86.68	0.41794319D 01	0.14696994D 03	0.14851812D 03	0.15208683D 03
5.983	247.7	465.66	0.6719	87.69	0.40499275D 01	0.14593923D 03	0.14747738D 03	0.15102105D 03
6.049	247.2	461.41	0.6477	88.65	0.39208323D 01	0.14491037D 03	0.14643850D 03	0.14995719D 03
6.116	246.6	457.17	0.6237	89.57	0.37919394D 01	0.14388338D 03	0.14540150D 03	0.14889526D 03
6.183	246.1	452.95	0.6000	90.43	0.36633221D 01	0.14285827D 03	0.14436640D 03	0.14783527D 03
6.250	245.6	448.75	0.5763	91.61	0.35462207D 01	0.14184162D 03	0.14333976D 03	0.14678394D 03
6.318	245.0	444.56	0.5610	93.67	0.34557871D 01	0.14084213D 03	0.14233025D 03	0.14575017D 03
6.386	244.5	440.39	0.5438	95.77	0.33654662D 01	0.13984421D 03	0.14132234D 03	0.14471802D 03
6.454	243.9	436.24	0.5267	97.88	0.32752690D 01	0.13884787D 03	0.14031603D 03	0.14368751D 03
6.522	243.6	432.10	0.4903	93.23	0.30550013D 01	0.13766828D 03	0.13912581D 03	0.14246825D 03
6.590	243.4	427.99	0.4532	88.01	0.28289063D 01	0.13648258D 03	0.13792866D 03	0.14124271D 03
6.659	243.2	423.90	0.4166	82.63	0.26049943D 01	0.13530216D 03	0.13673726D 03	0.14002265D 03
6.728	243.0	419.83	0.3804	77.09	0.23832641D 01	0.13412709D 03	0.13555120D 03	0.13880806D 03
6.797	242.7	415.78	0.3447	71.38	0.21637133D 01	0.13295732D 03	0.13437049D 03	0.13759894D 03
6.866	242.5	411.76	0.3095	65.49	0.19463405D 01	0.13179286D 03	0.13319513D 03	0.13639531D 03
6.935	242.3	407.76	0.2748	59.42	0.17311443D 01	0.13063371D 03	0.13202512D 03	0.13519715D 03
7.005	242.1	403.78	0.2405	53.15	0.15181226D 01	0.12947987D 03	0.13086047D 03	0.13400448D 03
7.075	241.8	399.82	0.2079	47.30	0.13148237D 01	0.12833561D 03	0.12970542D 03	0.13282165D 03
7.145	241.4	395.88	0.2002	47.07	0.12704074D 01	0.12728458D 03	0.12864343D 03	0.13173414D 03
7.216	241.0	391.96	0.1926	47.10	0.12262343D 01	0.12623694D 03	0.12758487D 03	0.13065014D 03
7.286	240.6	388.06	0.1851	47.09	0.11823069D 01	0.12519271D 03	0.12652976D 03	0.12956967D 03
7.357	240.2	384.19	0.1776	47.04	0.11386249D 01	0.12415191D 03	0.12547810D 03	0.12849274D 03
7.429	239.8	380.33	0.1702	46.95	0.10951839D 01	0.12311454D 03	0.12442991D 03	0.12741936D 03
7.500	239.4	376.49	0.1630	46.80	0.10520033D 01	0.12208061D 03	0.12338520D 03	0.12634955D 03
7.572	239.0	372.66	0.1558	46.61	0.10090654D 01	0.12105015D 03	0.12234398D 03	0.12528331D 03
7.643	238.6	368.86	0.1487	46.35	0.96637622D 00	0.12002315D 03	0.12130627D 03	0.12422066D 03
7.716	238.1	365.08	0.1416	46.03	0.92394261D 00	0.11899964D 03	0.12027207D 03	0.12316161D 03
7.788	237.7	361.32	0.1347	45.65	0.88176974D 00	0.11797962D 03	0.11924140D 03	0.12210617D 03
7.861	237.3	357.57	0.1278	45.19	0.83983075D 00	0.11696310D 03	0.11821428D 03	0.12105436D 03
7.933	236.9	353.85	0.1211	44.65	0.79815683D 00	0.11595011D 03	0.11719071D 03	0.12000619D 03
8.007	236.5	350.14	0.1144	44.03	0.75673913D 00	0.11494064D 03	0.11617070D 03	0.11896167D 03
8.080	236.1	346.46	0.1056	42.33	0.70101645D 00	0.11392227D 03	0.11514180D 03	0.11790804D 03
8.154	235.7	342.80	0.0968	40.43	0.64509807D 00	0.11290723D 03	0.11411625D 03	0.11685784D 03
8.228	235.3	339.15	0.0882	38.36	0.58950063D 00	0.11189602D 03	0.11309457D 03	0.11581162D 03
8.302	234.9	335.53	0.0797	36.12	0.53446579D 00	0.11088866D 03	0.11207679D 03	0.11476938D 03
8.376	234.5	331.92	0.0713	33.68	0.47975481D 00	0.10988517D 03	0.11106291D 03	0.11373113D 03
8.451	234.1	328.34	0.0630	31.04	0.42544924D 00	0.10888556D 03	0.11005294D 03	0.11269689D 03
8.526	233.7	324.77	0.0548	28.10	0.37155055D 00	0.10788383D 03	0.10904690D 03	0.11166667D 03
8.601	233.3	321.23	0.0468	25.09	0.31806022D 00	0.10689800D 03	0.10804479D 03	0.11064048D 03
8.676	232.9	317.71	0.0388	21.74	0.26497573D 00	0.10591008D 03	0.10704663D 03	0.10961833D 03
8.752	232.4	314.20	0.0310	18.12	0.21231055D 00	0.10492608D 03	0.10605243D 03	0.10860023D 03
8.828	232.0	310.72	0.0233	14.22	0.16005423D 00	0.10394601D 03	0.10506220D 03	0.10758621D 03
8.905	231.6	307.25	0.0157	10.01	0.10821215D 00	0.10296988D 03	0.10407595D 03	0.10657626D 03
8.981	231.2	303.81	0.0082	5.47	0.56785285D-01	0.10199771D 03	0.10309370D 03	0.10557039D 03
9.058	230.8	300.39	0.0008	0.58	0.57769236D-02	0.10102951D 03	0.10211545D 03	0.10456863D 03

9.135	230.4	296.59	0.0	0.0	0.0	0.100605228D 03	0.101127750 03	0.10355721D 03
9.213	230.0	293.66	0.0	0.0	0.0	0.99077699D 02	0.10014269D 03	0.10254849D 03
9.290	229.6	290.24	0.0	0.0	0.0	0.99107479D 02	0.99162046D 02	0.10154428D 03
9.368	229.3	286.50	0.0	0.0	0.0	0.97141627D 02	0.98185812D 02	0.10054459D 03
9.447	228.9	283.58	0.0	0.0	0.0	0.96180153D 02	0.97214002D 02	0.99549437D 02
9.525	228.5	280.28	0.0	0.0	0.0	0.95223065D 02	0.96246627D 02	0.98558822D 02
9.604	228.1	277.66	0.0	0.0	0.0	0.94270375D 02	0.95283656D 02	0.97572757D 02
9.683	227.6	273.75	0.0	0.0	0.0	0.93361311D 02	0.94364861D 02	0.96631849D 02
9.763	227.0	270.51	0.0	0.0	0.0	0.92517595D 02	0.93512075D 02	0.95758576D 02
9.843	226.3	267.28	0.0	0.0	0.0	0.91675994D 02	0.92661428D 02	0.94887493D 02
9.923	225.7	264.98	0.0	0.0	0.0	0.90836526D 02	0.91812937D 02	0.94018618D 02
10.003	225.0	260.89	0.0	0.0	0.0	0.89999210D 02	0.90966620D 02	0.93151970D 02
10.084	224.4	257.72	0.0	0.0	0.0	0.89164663D 02	0.90122496D 02	0.92287567D 02
10.165	223.7	254.57	0.0	0.0	0.0	0.98331103D 02	0.89280583D 02	0.91425428D 02
10.246	223.1	251.45	0.0	0.0	0.0	0.87500249D 02	0.88440899D 02	0.90565571D 02
10.328	222.4	248.31	0.0	0.0	0.0	0.86659464D 02	0.87590575D 02	0.89695229D 02
10.416	221.8	245.22	0.0	0.0	0.0	0.85810748D 02	0.86733136D 02	0.88816782D 02
10.492	221.2	242.13	0.0	0.0	0.0	0.84964804D 02	0.85878099D 02	0.87941204D 02
10.575	220.6	239.07	0.0	0.0	0.0	0.84121649D 02	0.85025880D 02	0.87068512D 02
10.658	220.0	236.03	0.0	0.0	0.0	0.83281301D 02	0.84176800D 02	0.86198726D 02
10.741	219.4	233.00	0.0	0.0	0.0	0.82443775D 02	0.83329975D 02	0.85331865D 02
10.825	218.8	230.00	0.0	0.0	0.0	0.31609102D 02	0.82486326D 02	0.84467949D 02
10.909	218.1	227.01	0.0	0.0	0.0	0.80777289D 02	0.81645572D 02	0.83606956D 02
10.993	217.5	224.04	0.0	0.0	0.0	0.79948357D 02	0.80807730D 02	0.82749026D 02
11.077	216.9	221.09	0.0	0.0	0.0	0.79122327D 02	0.79972821D 02	0.81894059D 02
11.162	216.3	218.16	0.0	0.0	0.0	0.78299217D 02	0.79140863D 02	0.81042115D 02
11.248	215.7	215.25	0.0	0.0	0.0	0.77479047D 02	0.78311877D 02	0.80193213D 02
11.333	215.0	212.36	0.0	0.0	0.0	0.76661835D 02	0.77485881D 02	0.79347374D 02
11.419	214.4	209.48	0.0	0.0	0.0	0.75847603D 02	0.76662896D 02	0.78504618D 02
11.506	213.8	206.63	0.0	0.0	0.0	0.75036368D 02	0.75842941D 02	0.77664965D 02
11.592	213.1	203.79	0.0	0.0	0.0	0.74228151D 02	0.75026036D 02	0.76828435D 02
11.679	212.5	200.97	0.0	0.0	0.0	0.73422972D 02	0.74212203D 02	0.75995050D 02
11.767	211.9	198.16	0.0	0.0	0.0	0.72620170D 02	0.73381466D 02	0.75144356D 02
11.855	211.3	195.40	0.0	0.0	0.0	0.71772364D 02	0.72543872D 02	0.74286640D 02
11.943	211.1	192.65	0.0	0.0	0.0	0.70825323D 02	0.71586631D 02	0.73306402D 02
12.031	211.0	189.92	0.0	0.0	0.0	0.69865762D 02	0.70616756D 02	0.72313228D 02
12.120	210.9	187.21	0.0	0.0	0.0	0.68914665D 02	0.69655436D 02	0.71328813D 02
12.209	210.7	184.54	0.0	0.0	0.0	0.67972000D 02	0.68702638D 02	0.70353125D 02
12.299	210.6	181.86	0.0	0.0	0.0	0.67037735D 02	0.67758330D 02	0.69386132D 02
12.389	210.5	179.26	0.0	0.0	0.0	0.66111837D 02	0.66822479D 02	0.68427799D 02
12.479	210.3	176.66	0.0	0.0	0.0	0.65194275D 02	0.65895054D 02	0.67478054D 02
12.570	210.3	174.08	0.0	0.0	0.0	0.64261882D 02	0.64952640D 02	0.66513039D 02
12.661	210.4	171.53	0.0	0.0	0.0	0.63298024D 02	0.63978421D 02	0.65515416D 02
12.753	210.4	169.01	0.0	0.0	0.0	0.62344894D 02	0.63015045D 02	0.64529896D 02
12.846	210.5	166.52	0.0	0.0	0.0	0.61402412D 02	0.62062432D 02	0.63553398D 02
12.938	210.6	164.05	0.0	0.0	0.0	0.60470499D 02	0.61120502D 02	0.62588839D 02
13.030	210.7	161.61	0.0	0.0	0.0	0.59549077D 02	0.60189176D 02	0.61635130D 02
13.124	210.7	159.20	0.0	0.0	0.0	0.58638068D 02	0.59268375D 02	0.60692217D 02
13.217	210.8	156.81	0.0	0.0	0.0	0.57737394D 02	0.58358019D 02	0.59759991D 02
13.311	210.9	154.45	0.0	0.0	0.0	0.56846973D 02	0.57458031D 02	0.58838383D 02
13.406	211.0	152.11	0.0	0.0	0.0	0.55966741D 02	0.56568333D 02	0.57927311D 02

13.501	211.1	149.81	0.0	0.0	0.0	0.55095778D 02	0.55688007D 02	0.57025836D 02
13.556	211.2	147.52	0.0	0.0	0.0	0.54226091D 02	0.54808573D 02	0.56125684D 02
13.692	211.3	145.27	0.0	0.0	0.0	0.53366771D 02	0.53940415D 02	0.55236261D 02
13.788	211.4	143.04	0.0	0.0	0.0	0.52517731D 02	0.53082249D 02	0.54357478D 02
13.885	211.5	140.83	0.0	0.0	0.0	0.51678886D 02	0.52234387D 02	0.53489247D 02
13.982	211.7	138.66	0.0	0.0	0.0	0.50850151D 02	0.51396745D 02	0.52631482D 02
14.075	211.8	136.50	0.0	0.0	0.0	0.50031444D 02	0.50569237D 02	0.51784094D 02
14.177	211.9	134.37	0.0	0.0	0.0	0.49222679D 02	0.49751779D 02	0.50946998D 02
14.276	212.0	132.26	0.0	0.0	0.0	0.48423775D 02	0.48944286D 02	0.50120197D 02
14.376	212.1	130.18	0.0	0.0	0.0	0.47634647D 02	0.48146676D 02	0.49303335D 02
14.474	212.3	128.12	0.0	0.0	0.0	0.46855213D 02	0.47358864D 02	0.48496597D 02
14.574	212.4	126.09	0.0	0.0	0.0	0.46085392D 02	0.46580768D 02	0.47699808D 02
14.674	212.5	124.08	0.0	0.0	0.0	0.45325285D 02	0.45812491D 02	0.46913074D 02
14.775	212.6	122.10	0.0	0.0	0.0	0.44574832D 02	0.45053371D 02	0.46136332D 02
14.876	212.8	120.14	0.0	0.0	0.0	0.43833730D 02	0.44304903D 02	0.45369268D 02
14.978	212.9	118.20	0.0	0.0	0.0	0.43101899D 02	0.43565265D 02	0.44611800D 02
15.080	213.0	116.29	0.0	0.0	0.0	0.42379259D 02	0.42834797D 02	0.43863845D 02
15.183	213.1	114.40	0.0	0.0	0.0	0.41665731D 02	0.42113600D 02	0.43125322D 02
15.286	212.8	112.53	0.0	0.0	0.0	0.41041274D 02	0.41482430D 02	0.42478989D 02
15.390	212.4	110.68	0.0	0.0	0.0	0.40443435D 02	0.40878165D 02	0.41860208D 02
15.495	212.0	108.84	0.0	0.0	0.0	0.39850296D 02	0.40278651D 02	0.41246291D 02
15.599	211.6	107.03	0.0	0.0	0.0	0.39261858D 02	0.39683887D 02	0.40637239D 02
15.705	211.2	105.23	0.0	0.0	0.0	0.38678120D 02	0.39093874D 02	0.40033052D 02
15.811	210.8	103.45	0.0	0.0	0.0	0.38099083D 02	0.38508613D 02	0.39433731D 02
15.917	210.4	101.69	0.0	0.0	0.0	0.37524747D 02	0.37928104D 02	0.38839275D 02
16.024	209.9	99.95	0.0	0.0	0.0	0.36955275D 02	0.37352510D 02	0.38249854D 02
16.132	209.5	98.22	0.0	0.0	0.0	0.36395488D 02	0.36786706D 02	0.37670457D 02
16.240	209.0	96.51	0.0	0.0	0.0	0.35840202D 02	0.36225451D 02	0.37095719D 02
16.348	208.6	94.82	0.0	0.0	0.0	0.35289418D 02	0.35668748D 02	0.36525641D 02
16.457	208.4	93.15	0.0	0.0	0.0	0.34692167D 02	0.35065077D 02	0.35907468D 02
16.567	208.6	91.50	0.0	0.0	0.0	0.34038845D 02	0.34415893D 02	0.35246784D 02
16.677	208.7	89.87	0.0	0.0	0.0	0.33424468D 02	0.33783753D 02	0.34595359D 02
16.788	208.9	88.26	0.0	0.0	0.0	0.32803947D 02	0.33156560D 02	0.33953101D 02
16.900	209.0	86.68	0.0	0.0	0.0	0.32192196D 02	0.32538233D 02	0.33319920D 02
17.012	209.1	85.11	0.0	0.0	0.0	0.31589127D 02	0.31928682D 02	0.32695725D 02
17.125	209.3	83.57	0.0	0.0	0.0	0.30994654D 02	[illegible] 02	0.32080427D 02
17.238	209.4	82.05	0.0	0.0	0.0	0.30409[illegible]D 02	0.30735558D 02	0.31473938D 02
17.352	209.6	80.55	0.0	0.0	0.0	0.29831154D 02	0.30151812D 02	0.30876168D 02
17.466	209.7	79.07	0.0	0.0	0.0	0.29261744D 02	0.29576281D 02	0.30286811D 02
17.582	209.9	77.61	0.0	0.0	0.0	0.28703481D 02	0.29008985D 02	0.29705886D 02
17.697	210.1	76.17	0.0	0.0	0.0	0.28147406D 02	0.28445966D 02	0.29133437D 02
17.814	210.2	74.75	0.0	0.0	0.0	0.27602437D 02	0.27895139D 02	0.28565378D 02
17.931	210.4	73.35	0.0	0.0	0.0	0.27065490D 02	0.27356420D 02	0.28013621D 02
18.045	210.5	71.97	0.0	0.0	0.0	0.26536482D 02	0.26821725D 02	0.27466081D 02
18.167	210.7	70.61	0.0	0.0	0.0	0.26015331D 02	0.26294973D 02	0.26926674D 02
18.286	210.8	69.27	0.0	0.0	0.0	0.25503403D 02	0.25777542D 02	0.26396812D 02
18.405	211.0	67.94	0.0	0.0	0.0	0.25000250D 02	0.25268980D 02	0.25876033D 02
18.526	211.1	66.64	0.0	0.0	0.0	0.24504569D 02	0.24767971D 02	0.25362988D 02
18.647	211.2	65.36	0.0	0.0	0.0	0.24016287D 02	0.24274440D 02	0.24857601D 02
18.769	211.4	64.09	0.0	0.0	0.0	0.23535326D 02	0.23788309D 02	0.24359791D 02
18.892	211.5	62.84	0.0	0.0	0.0	0.23061611D 02	0.23309503D 02	0.23869482D 02

19.015	211.7	61.61	0.0	0.0	0.0	0.22595069D 02	0.22837945D 02	0.23386596D 02
19.139	211.8	60.40	0.0	0.0	0.0	0.22135624D 02	0.22373562D 02	0.22911056D 02
19.262	212.0	59.26	0.0	0.0	0.0	0.21682525D 02	0.21915553D 02	0.22442085D 02
19.389	212.1	58.03	0.0	0.0	0.0	0.21236088D 02	0.21464357D 02	0.21980009D 02
19.515	212.3	56.87	0.0	0.0	0.0	0.20796584D 02	0.21020125D 02	0.21525109D 02
19.642	212.4	55.73	0.0	0.0	0.0	0.20363940D 02	0.20582834D 02	0.21077308D 02
19.770	212.6	54.60	0.0	0.0	0.0	0.19938081D 02	0.20152397D 02	0.20636531D 02
19.898	212.7	53.49	0.0	0.0	0.0	0.19518934D 02	0.19728745D 02	0.20202701D 02
20.028	212.9	52.40	0.0	0.0	0.0	0.19106427D 02	0.19311803D 02	0.19775743D 02
20.158	213.0	51.33	0.0	0.0	0.0	0.18700486D 02	0.18901500D 02	0.19355583D 02
20.289	213.2	50.27	0.0	0.0	0.0	0.18301842D 02	0.18497761D 02	0.18942145D 02
20.420	213.3	49.22	0.0	0.0	0.0	0.17915136D 02	0.18107708D 02	0.18542721D 02
20.553	213.3	48.20	0.0	0.0	0.0	0.17537532D 02	0.17726446D 02	0.18151089D 02
20.686	213.4	47.19	0.0	0.0	0.0	0.17165669D 02	0.17350185D 02	0.17766999D 02
20.820	213.4	46.19	0.0	0.0	0.0	0.16799492D 02	0.16980072D 02	0.17387995D 02
20.956	213.5	45.21	0.0	0.0	0.0	0.16439549D 02	0.16615653D 02	0.17014822D 02
21.091	213.5	44.24	0.0	0.0	0.0	0.16083966D 02	0.16256874D 02	0.16647423D 02
21.228	213.6	43.29	0.0	0.0	0.0	0.15734549D 02	0.15903681D 02	0.16285746D 02
21.366	213.6	42.35	0.0	0.0	0.0	0.15390587D 02	0.15556022D 02	0.15929734D 02
21.505	213.7	41.43	0.0	0.0	0.0	0.15052045D 02	0.15213841D 02	0.15579333D 02
21.644	213.7	40.53	0.0	0.0	0.0	0.14719873D 02	0.14877087D 02	0.15234429D 02
21.785	213.8	39.63	0.0	0.0	0.0	0.14392192D 02	0.14546895D 02	0.14896364D 02
21.926	213.8	38.75	0.0	0.0	0.0	0.14072316D 02	0.14223681D 02	0.14565283D 02
22.069	213.8	37.89	0.0	0.0	0.0	0.13757485D 02	0.13905366D 02	0.14239423D 02
22.212	213.8	37.03	0.0	0.0	0.0	0.13447653D 02	0.13592203D 02	0.13918737D 02
22.356	213.8	36.20	0.0	0.0	0.0	0.13142771D 02	0.13284044D 02	0.13603176D 02
22.502	213.8	35.37	0.0	0.0	0.0	0.12842795D 02	0.12980844D 02	0.13292691D 02
22.642	213.8	34.56	0.0	0.0	0.0	0.12547678D 02	0.12682555D 02	0.12987236D 02
22.795	213.8	33.76	0.0	0.0	0.0	0.12257374D 02	0.12389130D 02	0.12686762D 02
22.944	213.8	32.98	0.0	0.0	0.0	0.11971836D 02	0.12100522D 02	0.12391221D 02
23.093	213.8	32.20	0.0	0.0	0.0	0.11691019D 02	0.11816687D 02	0.12100567D 02
23.244	213.8	31.44	0.0	0.0	0.0	0.11414877D 02	0.11537576D 02	0.11814751D 02
23.395	213.8	30.70	0.0	0.0	0.0	0.11143363D 02	0.11263146D 02	0.11533726D 02
23.548	213.9	29.96	0.0	0.0	0.0	0.10876422D 02	0.10993334D 02	0.11257433D 02
23.702	213.9	29.24	0.0	0.0	0.0	0.10613791D 02	0.10727880D 02	0.10985603D 02
23.857	213.9	28.53	0.0	0.0	0.0	0.10355679D 02	0.10466984D 02	0.10718439D 02
24.013	213.9	27.84	0.0	0.0	0.0	0.10102013D 02	0.10210599D 02	0.10455856D 02
24.170	213.9	27.15	0.0	0.0	0.0	0.98527709D 01	0.99586793D 01	0.10197923D 02
24.329	213.9	26.48	0.0	0.0	0.0	0.96079026D 01	0.97111788D 01	0.99444767D 01
24.488	213.9	25.82	0.0	0.0	0.0	0.93673613D 01	0.94680520D 01	0.96955091D 01
24.645	213.9	25.17	0.0	0.0	0.0	0.91311021D 01	0.92292532D 01	0.94509773D 01
24.811	214.0	24.53	0.0	0.0	0.0	0.88991587D 01	0.89948166D 01	0.92109049D 01
24.975	214.0	23.90	0.0	0.0	0.0	0.86714289D 01	0.87646389D 01	0.89751978D 01
25.139	214.0	23.29	0.0	0.0	0.0	0.84478395D 01	0.85386462D 01	0.87437756D 01
25.305	214.0	22.68	0.0	0.0	0.0	0.82283464D 01	0.83167537D 01	0.85165934D 01
25.473	214.0	22.09	0.0	0.0	0.0	0.80129054D 01	0.80990369D 01	0.82936053D 01
25.641	214.0	21.51	0.0	0.0	0.0	0.78014725D 01	0.78853313D 01	0.80747657D 01
25.811	214.0	20.94	0.0	0.0	0.0	0.75940039D 01	0.76756325D 01	0.78600292D 01
25.983	214.0	20.38	0.0	0.0	0.0	0.73904558D 01	0.74698565D 01	0.76493506D 01
26.155	214.1	19.83	0.0	0.0	0.0	0.71906143D 01	0.72679069D 01	0.74425085D 01
26.329	214.1	19.26	0.0	0.0	0.0	0.69942588D 01	0.70694408D 01	0.72392745D 01

26.505	214.1	18.76	0.0	0.0	0.0	0.68017327D 01	0.69748452D 01	0.70400004D 01
26.682	214.1	18.24	0.0	0.0	0.0	0.66129916D 01	0.66840751D 01	0.68446510D 01
26.861	214.2	17.74	0.0	0.0	0.0	0.64279906D 01	0.64970857D 01	0.66531694D 01
27.041	214.2	17.24	0.0	0.0	0.0	0.62460861D 01	0.63138323D 01	0.64665135D 01
27.223	214.2	16.75	0.0	0.0	0.0	0.60690337D 01	0.61342703D 01	0.62816378D 01
27.406	214.3	16.27	0.0	0.0	0.0	0.58949896D 01	0.59583554D 01	0.61014968D 01
27.591	214.3	15.80	0.0	0.0	0.0	0.57245102D 01	0.57860435D 01	0.59250454D 01
27.777	214.3	15.34	0.0	0.0	0.0	0.55575519D 01	0.56172905D 01	0.57522383D 01
27.965	214.4	14.90	0.0	0.0	0.0	0.53939953D 01	0.54519759D 01	0.55829522D 01
28.155	214.4	14.46	0.0	0.0	0.0	0.52336408D 01	0.52896977D 01	0.54169863D 01
28.347	214.4	14.03	0.0	0.0	0.0	0.50767032D 01	0.51312732D 01	0.52545451D 01
28.540	214.5	13.60	0.0	0.0	0.0	0.49231387D 01	0.49760580D 01	0.50956019D 01
28.735	214.5	13.19	0.0	0.0	0.0	0.47729035D 01	0.48242079D 01	0.49401030D 01
28.932	214.6	12.78	0.0	0.0	0.0	0.46259543D 01	0.46756791D 01	0.47880059D 01
29.131	214.6	12.39	0.0	0.0	0.0	0.44822477D 01	0.45304278D 01	0.46392652D 01
29.332	214.7	12.01	0.0	0.0	0.0	0.43417407D 01	0.43884108D 01	0.44938361D 01
29.534	214.7	11.63	0.0	0.0	0.0	0.42043905D 01	0.42495539D 01	0.43516744D 01
29.739	214.8	11.26	0.0	0.0	0.0	0.40701544D 01	0.41139048D 01	0.42127358D 01
29.945	214.8	10.90	0.0	0.0	0.0	0.39389698D 01	0.39812330D 01	0.40769765D 01
30.154	214.9	10.55	0.0	0.0	0.0	0.38108546D 01	0.38518178D 01	0.39443525D 01
30.365	214.9	10.20	0.0	0.0	0.0	0.36857066D 01	0.37253246D 01	0.38148205D 01
30.577	215.0	9.87	0.0	0.0	0.0	0.35626722D 01	0.36005677D 01	0.36874760D 01
30.792	215.2	9.54	0.0	0.0	0.0	0.34413552D 01	0.34785871D 01	0.35619506D 01
31.010	215.4	9.22	0.0	0.0	0.0	0.33231673D 01	0.33588884D 01	0.34398811D 01
31.229	215.6	8.91	0.0	0.0	0.0	0.32079386D 01	0.32424210D 01	0.33203158D 01
31.451	215.7	8.60	0.0	0.0	0.0	0.30956563D 01	0.31285349D 01	0.32041033D 01
31.675	215.9	8.31	0.0	0.0	0.0	0.29862804D 01	0.30183802D 01	0.30908927D 01
31.901	216.1	8.02	0.0	0.0	0.0	0.28757529D 01	0.29107077D 01	0.29806335D 01
32.130	216.3	7.74	0.0	0.0	0.0	0.27769286D 01	0.28058668D 01	0.28732756D 01
32.362	216.5	7.46	0.0	0.0	0.0	0.26750554D 01	0.27038139D 01	0.27687693D 01
32.596	216.7	7.19	0.0	0.0	0.0	0.25767978D 01	0.26044561D 01	0.26670655D 01
32.833	216.9	6.93	0.0	0.0	0.0	0.24812859D 01	0.25075675D 01	0.25682078D 01
33.072	217.1	6.68	0.0	0.0	0.0	0.23886207D 01	0.24142562D 01	0.24722964D 01
33.314	217.2	6.43	0.0	0.0	0.0	0.22984891D 01	0.23231657D 01	0.23790074D 01
33.555	217.4	6.19	0.0	0.0	0.0	0.22108469D 01	0.22346114D 01	0.22882949D 01
33.807	217.6	5.96	0.0	0.0	0.0	0.21269595D 01	0.21488116D 01	0.22004339D 01
34.058	217.6	5.73	0.0	0.0	0.0	0.20447719D 01	0.20667513D 01	0.21164022D 01
34.311	217.6	5.51	0.0	0.0	0.0	0.19657713D 01	0.19865015D 01	0.20346341D 01
34.568	217.6	5.29	0.0	0.0	0.0	0.18869240D 01	0.19092282D 01	0.19550948D 01
34.828	217.6	5.08	0.0	0.0	0.0	0.18141963D 01	0.18336573D 01	0.18777494D 01
35.091	217.6	4.88	0.0	0.0	0.0	0.17415549D 01	0.17602751D 01	0.18025633D 01
35.358	217.6	4.68	0.0	0.0	0.0	0.16709664D 01	0.16885277D 01	0.17296019D 01
35.628	217.6	4.49	0.0	0.0	0.0	0.16023974D 01	0.16196217D 01	0.16585309D 01
35.901	217.6	4.30	0.0	0.0	0.0	0.15358149D 01	0.15523236D 01	0.15896160D 01
36.178	217.6	4.12	0.0	0.0	0.0	0.14711860D 01	0.14870000D 01	0.15227231D 01
36.459	217.6	3.94	0.0	0.0	0.0	0.14084778D 01	0.14236177D 01	0.14578182D 01
36.744	217.6	3.78	0.0	0.0	0.0	0.13476576D 01	0.13621437D 01	0.13948674D 01
37.032	217.6	3.61	0.0	0.0	0.0	0.12886928D 01	0.13025451D 01	0.13338369D 01
37.324	217.6	3.45	0.0	0.0	0.0	0.12315509D 01	0.12447890D 01	0.12746933D 01
37.621	217.6	3.30	0.0	0.0	0.0	0.11761997D 01	0.11888428D 01	0.12174031D 01
37.921	217.6	3.15	0.0	0.0	0.0	0.11226069D 01	0.11346740D 01	0.11619330D 01

38.226	217.6	3.00	0.0	0.0	0.0	0.10707406D 01	0.10822501D 01	0.11082497D 01
38.536	217.6	2.86	0.0	0.0	0.0	0.10205688D 01	0.10315390D 01	0.10563203D 01
38.850	217.6	2.72	0.0	0.0	0.0	0.97205976D 00	0.98250852D 00	0.10061120D 01
39.169	217.6	2.59	0.0	0.0	0.0	0.92519185D 00	0.93512672D 00	0.95759187D 00
39.452	217.6	2.47	0.0	0.0	0.0	0.87990359D 00	0.88936174D 00	0.91072747D 00
39.821	217.6	2.34	0.0	0.0	0.0	0.83619366D 00	0.84518198D 00	0.86548634D 00
40.155	217.6	2.23	0.0	0.0	0.0	0.79402086D 00	0.80255586D 00	0.82183618D 00
40.404	217.6	2.11	0.0	0.0	0.0	0.75335414D 00	0.76145201D 00	0.77974486D 00
40.839	217.6	2.00	0.0	0.0	0.0	0.71416260D 00	0.72183921D 00	0.73918041D 00
41.189	217.6	1.90	0.0	0.0	0.0	0.67641551D 00	0.68368636D 00	0.70011100D 00
41.546	217.6	1.79	0.0	0.0	0.0	0.64003226D 00	0.64656257D 00	0.66250496D 00
41.908	217.6	1.70	0.0	0.0	0.0	0.60513241D 00	0.61163704D 00	0.62633079D 00
42.277	217.6	1.61	0.0	0.0	0.0	0.57153567D 00	0.57767917D 00	0.59155712D 00
42.652	217.6	1.51	0.0	0.0	0.0	0.53926192D 00	0.54505850D 00	0.55815279D 00
43.034	217.6	1.42	0.0	0.0	0.0	0.50828118D 00	0.51374474D 00	0.52608676D 00
43.423	217.6	1.34	0.0	0.0	0.0	0.47656362D 00	0.48370775D 00	0.49532817D 00
43.820	217.6	1.26	0.0	0.0	0.0	0.45007962D 00	0.45491757D 00	0.46584634D 00
44.223	217.6	1.18	0.0	0.0	0.0	0.42279967D 00	0.42734438D 00	0.43761075D 00
44.635	217.6	1.11	0.0	0.0	0.0	0.39669445D 00	0.40095856D 00	0.41059105D 00
45.055	217.6	1.04	0.0	0.0	0.0	0.37173482D 00	0.37573064D 00	0.38475705D 00
45.483	217.6	0.98	0.0	0.0	0.0	0.34789179D 00	0.35163131D 00	0.36007878D 00
45.921	217.6	0.91	0.0	0.0	0.0	0.32513656D 00	0.32863148D 00	0.33652641D 00
46.367	217.6	0.85	0.0	0.0	0.0	0.30344048D 00	0.30670219D 00	0.31407029D 00
46.823	217.6	0.79	0.0	0.0	0.0	0.28277510D 00	0.28581468D 00	0.29268099D 00
47.285	217.6	0.74	0.0	0.0	0.0	0.26311216D 00	0.26594038D 00	0.27232923D 00
47.766	217.6	0.69	0.0	0.0	0.0	0.24442354D 00	0.24705088D 00	0.25298594D 00
48.253	217.6	0.64	0.0	0.0	0.0	0.22668136D 00	0.22911798D 00	0.23462223D 00
48.752	217.6	0.59	0.0	0.0	0.0	0.20985788D 00	0.21211366D 00	0.21720941D 00
49.263	217.6	0.54	0.0	0.0	0.0	0.19392558D 00	0.19601031D 00	0.20071899D 00
49.786	217.6	0.50	0.0	0.0	0.0	0.17385713D 00	0.18077969D 00	0.18512267D 00
50.323	217.6	0.46	0.0	0.0	0.0	0.16462539D 00	0.16639457D 00	0.17039238D 00
50.873	217.6	0.42	0.0	0.0	0.0	0.15120343D 00	0.15282873D 00	0.15650024D 00
51.438	217.6	0.39	0.0	0.0	0.0	0.13856452D 00	0.14005396D 00	0.14341857D 00
52.019	217.6	0.36	0.0	0.0	0.0	0.12668213D 00	0.12804385D 00	0.13111997D 00
52.616	217.6	0.32	0.0	0.0	0.0	0.11552987D 00	0.11677181D 00	0.11957709D 00
53.230	217.6	0.29	0.0	0.0	0.0	0.10508192D 00	0.10621146D 00	0.10876304D 00
53.862	217.6	0.27	0.0	0.0	0.0	0.95312131D-01	0.96336650D-01	0.98651097D-01
54.513	217.6	0.24	0.0	0.0	0.0	0.86194943D-01	0.87121461D-01	0.89214436D-01
55.186	217.6	0.22	0.0	0.0	0.0	0.77704943D-01	0.78540201D-01	0.80427023D-01
55.879	217.6	0.20	0.0	0.0	0.0	0.69816946D-01	0.70567415D-01	0.72262701D-01
56.597	217.6	0.18	0.0	0.0	0.0	0.62506007D-01	0.63177890D-01	0.64695653D-01
57.339	217.6	0.16	0.0	0.0	0.0	0.55747429D-01	0.56346663D-01	0.57700315D-01
58.108	217.6	0.14	0.0	0.0	0.0	0.49516764D-01	0.50049028D-01	0.51251385D-01
58.905	217.6	0.12	0.0	0.0	0.0	0.43789823D-01	0.44260524D-01	0.45323823D-01
59.734	217.6	0.11	0.0	0.0	0.0	0.38542679D-01	0.38956978D-01	0.39892867D-01
60.596	217.6	0.09	0.0	0.0	0.0	0.33751680D-01	0.34114480D-01	0.34933034D-01
61.493	217.6	0.08	0.0	0.0	0.0	0.29393448D-01	0.29709401D-01	0.30423129D-01
62.431	217.6	0.07	0.0	0.0	0.0	0.25444895D-01	0.25718405D-01	0.26336255D-01
63.410	217.6	0.06	0.0	0.0	0.0	0.21803230D-01	0.22118455D-01	0.22649021D-01
64.437	217.6	0.05	0.0	0.0	0.0	0.18685365D-01	0.18986822D-01	0.19340552D-01
65.515	217.6	0.04	0.0	0.0	0.0	0.15630920D-01	0.16001096D-01	0.16385501D-01

66.650	217.6	0.04	0.0	0.0	0.0	0.13296276D-01	0.13439199D-01	0.13762058D-01
67.846	217.6	0.03	0.0	0.0	0.0	0.11060505D-01	0.11175396D-01	0.11447965D-01
69.116	217.6	0.03	0.0	0.0	0.0	0.91024629D-02	0.92033062D-02	0.94213311D-02
70.463	217.6	0.02	0.0	0.0	0.0	0.74013667D-02	0.74809248D-02	0.76606438D-02
71.900	217.6	0.02	0.0	0.0	0.0	0.59368183D-02	0.60006337D-02	0.61447908D-02
73.438	217.6	0.01	0.0	0.0	0.0	0.46888232D-02	0.47392238D-02	0.48530772D-02
75.093	217.6	0.01	0.0	0.0	0.0	0.36378119D-02	0.36769150D-02	0.37652479D-02
76.884	217.6	0.01	0.0	0.0	0.0	0.27646640D-02	0.27942816D-02	0.28615129D-02
78.834	217.6	0.01	0.0	0.0	0.0	0.20507361D-02	0.20727796D-02	0.21225754D-02
80.974	217.6	0.00	0.0	0.0	0.0	0.14778941D-02	0.14937801D-02	0.15296661D-02
83.343	217.6	0.00	0.0	0.0	0.0	0.10285515D-02	0.10396075D-02	0.10645827D-02
85.995	217.6	0.00	0.0	0.0	0.0	0.68571573D-03	0.69308652D-03	0.70973699D-03
89.005	217.6	0.00	0.0	0.0	0.0	0.43304384D-03	0.43769867D-03	0.44821378D-03
92.478	217.6	0.00	0.0	0.0	0.0	0.26491380D-03	0.26765389D-03	0.26384368D-03
96.576	217.6	0.00	0.0	0.0	0.0	0.13651535D-03	0.13798276D-03	0.14129761D-03
101.557	217.6	0.00	0.0	0.0	0.0	0.63972298D-04	0.64655542D-04	0.66213309D-04
107.872	217.6	0.00	0.0	0.0	0.0	0.24513977D-04	0.24777480D-04	0.25372725D-04
116.401	217.6	0.00	0.0	0.0	0.0	0.67297593D-05	0.68020581D-05	0.69655093D-05
129.203	217.6	0.00	0.0	0.0	0.0	0.97290427D-06	0.98336212D-06	0.10069861D-05
152.758	217.6	0.00	0.0	0.0	0.0	0.28275438D-07	0.28579373D-07	0.29265954D-07
225.067	217.6	0.00	0.0	0.0	0.0	0.63504285D-12	0.64186899D-12	0.65728902D-12
1000.000	217.6	0.00	0.0	0.0	0.0	0.53021092D-56	0.53591021D-56	0.54878473D-56

```
STATION = 93734 YEAR = 67 MONTH =  1 DAY =  1 HOUR = 12
ELEVATION ANGLE =  0.17453293D 00 RADIANS
RANGE =  0.27703016D 04 KILOMETERS
SUM OF REFRACTIVITY =  0.23666038D 04
HEIGHT =  0.84987263D-01 KILOMETERS
PRESSURE =  0.10030000D 04 MILLIBARS
TEMPERATURE = -0.42000000D 01 DEGREES CELCIUS
RELATIVE HUMIDITY =  0.95000000D 02 PERCENT
ELEVATION ANGLE ERROR =  0.15786025D-02 RADIANS
RANGE ERROR APPROX =  0.13261796D 02 METERS
 RANGE DIFF =  0.44837180D 00 CM
RANGE ERROR =  0.13267311288156460D-01 KILOMETERS
STATION = 93734 YEAR = 67 MONTH =  1 DAY =  1 HOUR = 12
ELEVATION ANGLE =  0.26179540D 00 RADIANS
RANGE =  0.24128112D 04 KILOMETERS
SUM OF REFRACTIVITY =  0.23666038D 04
HEIGHT =  0.84987263D-01 KILOMETERS
PRESSURE =  0.10030000D 04 MILLIBARS
TEMPERATURE = -0.42000000D 01 DEGREES CELCIUS
RELATIVE HUMIDITY =  0.95000000D 02 PERCENT
ELEVATION ANGLE ERROR =  0.10608963D-02 RADIANS
RANGE ERROR APPROX =  0.90320892D 01 METERS
 RANGE DIFF =  0.12548156D 00 CM
RANGE ERROR =  0.90316343495260290D-02 KILOMETERS
STATION = 93734 YEAR = 67 MONTH =  1 DAY =  1 HOUR = 12
ELEVATION ANGLE =  0.34906586D 00 RADIANS
RANGE =  0.21237755D 04 KILOMETERS
SUM OF REFRACTIVITY =  0.23666038D 04
HEIGHT =  0.84987263D-01 KILOMETERS
PRESSURE =  0.10030000D 04 MILLIBARS
TEMPERATURE = -0.42000000D 01 DEGREES CELCIUS
RELATIVE HUMIDITY =  0.95000000D 02 PERCENT
ELEVATION ANGLE ERROR =  0.78744938D-03 RADIANS
RANGE ERROR APPROX =  0.68724301D 01 METERS
 RANGE DIFF = -0.65328914D-01 CM
RANGE ERROR =  0.68723760923610D-02 KILOMETERS
STATION = 93734 YEAR = 67 MONTH =  1 DAY =  1 HOUR = 12
ELEVATION ANGLE =  0.69813172D 00 RADIANS
RANGE =  0.14291685D 04 KILOMETERS
SUM OF REFRACTIVITY =  0.23666038D 04
HEIGHT =  0.84987263D-01 KILOMETERS
PRESSURE =  0.10030000D 04 MILLIBARS
TEMPERATURE = -0.42000000D 01 DEGREES CELCIUS
RELATIVE HUMIDITY =  0.95000000D 02 PERCENT
ELEVATION ANGLE ERROR =  0.34454493D-03 RADIANS
RANGE ERROR APPROX =  0.36760370D 01 METERS
 RANGE DIFF = -0.14033405D 00 CM
RANGE ERROR =  0.36774403195867860D-02 KILOMETERS
STATION = 93734 YEAR = 67 MONTH =  1 DAY =  1 HOUR = 12
ELEVATION ANGLE =  0.13962634D 01 RADIANS
RANGE =  0.10133036D 04 KILOMETERS
SUM OF REFRACTIVITY =  0.23666038D 04
HEIGHT =  0.84987263D-01 KILOMETERS
PRESSURE =  0.10030000D 04 MILLIBARS
TEMPERATURE = -0.42000000D 01 DEGREES CELCIUS
RELATIVE HUMIDITY =  0.95000000D 02 PERCENT
ELEVATION ANGLE ERROR =  0.51068237D-04 RADIANS
RANGE ERROR APPROX =  0.24022744D 01 METERS
 RANGE DIFF = -0.10773084D 00 CM
RANGE ERROR =  0.24033816742637840D-02 KILOMETERS
```

```
IEF142I - STEP WAS EXECUTED - COND CODE 0000
**** JOB NBR-556  STEP NBR-02   GBCWM001  GO        PGM=LOADER   CARDS=00008   INITIATION TIME=19.07.41.40 DATE=11-01-73
                                                                              TERMINATION TIME=19.12.32.28 DATE=11-01-73
* - * CPU=000MIN 01.42SECS  I/O=000MIN 06.26SECS REGION START=1966K NASA-GSFC
*   * I/O TIME BY DEVICE   DISK=*****4.45 DRUM=*****1.14 TAPE=******.67 CELL=******.00 GRAF=******.00 OTHR=******.00
***** STEP REGION SIZE=0450K  MAXIMUM REGION SIZE USED=0460K   PERCENT OF REGION USED=99

*   * CPU=000MIN 06.66SECS  I/O=000MIN 09.09SECS  JOB NBR-556 GBCWM001 SYSTEM=MVT-21.6 360/95 G1 CLASS=I PRTY=10 RDR=8
* - * I/O TIME BY DEVICE   DISK=*****7.00 DRUM=*****1.41 TAPE=******.67 CELL=******.00 GRAF=******.00 OTHR=******.00
```