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

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NOVEMBER 1973

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GODDARD SPACE FLIGHT CENTER
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## 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.

CONTENTS



ILLUSTRATIONS





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## 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

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

where

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

and

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

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

$$f(0.6943) = 1.0000 \qquad (6)$$

## 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 $\varphi$ 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]

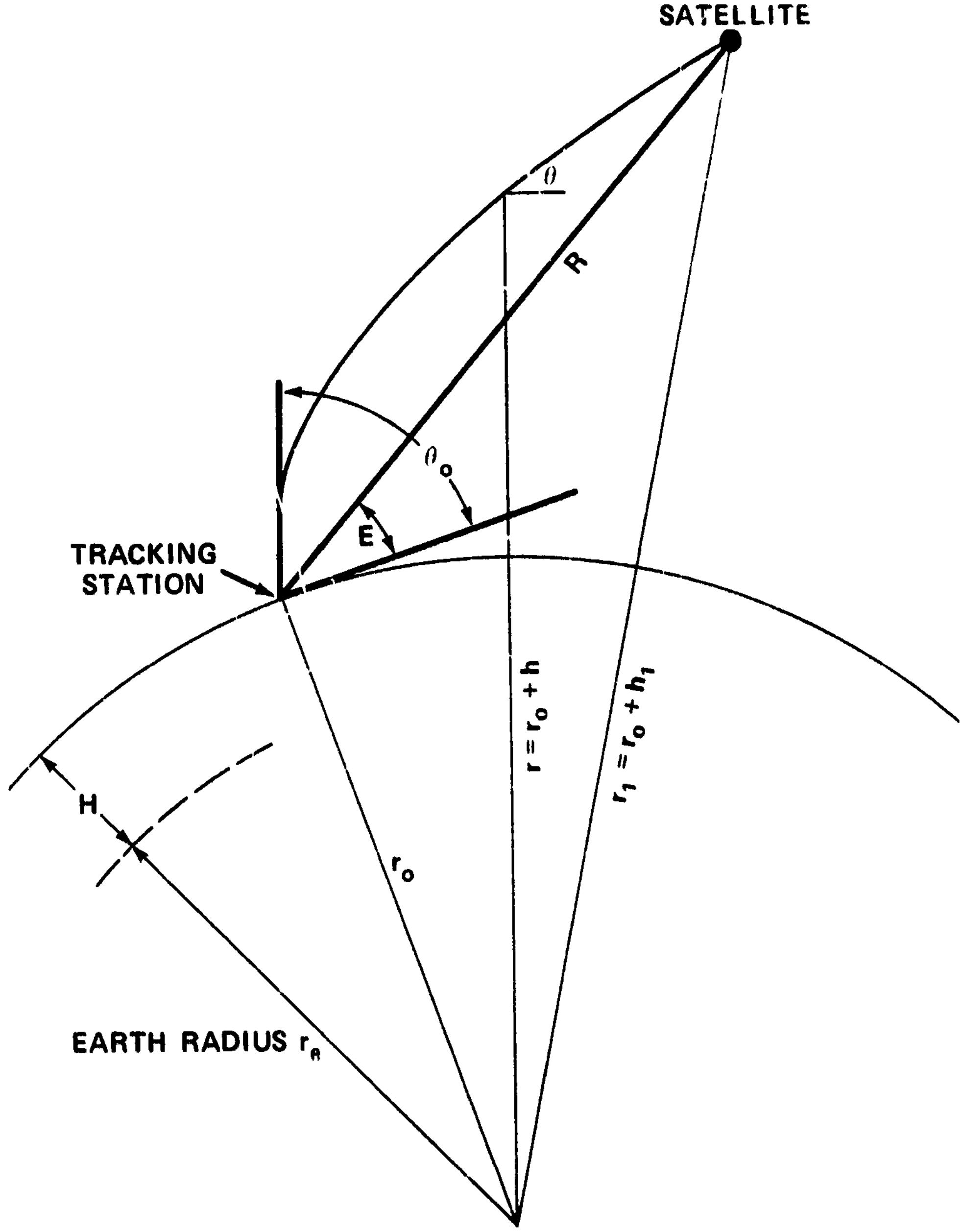


Figure 1. Geometry

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

where the angle $\theta$ 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 $\Delta R$ in inverse powers of $\sin\theta_0$, following Marini [3] gives

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

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 $\theta_0$, 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

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

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

$$+ \circ \circ \circ$$

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

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

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

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

where

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

and

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

## CORRECTION FORMULA

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

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

where

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

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

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

Here

$\Delta R$ = 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 $\varphi$ and elevations H (in km)

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

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

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.

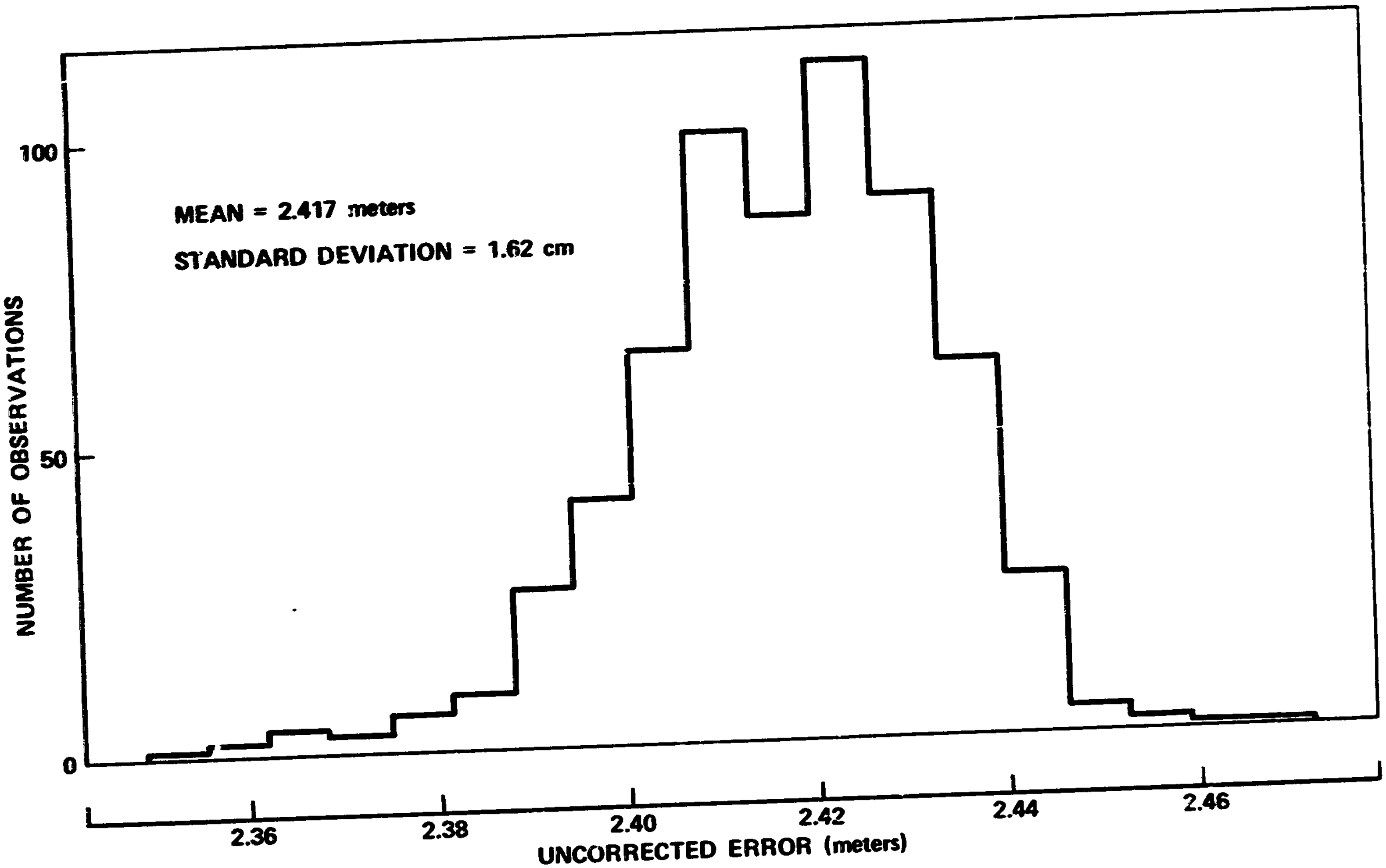


Figure 2. Tropospheric Range Error at About 80 Degrees Elevation for Laser Frequency of 0.6943 Microns

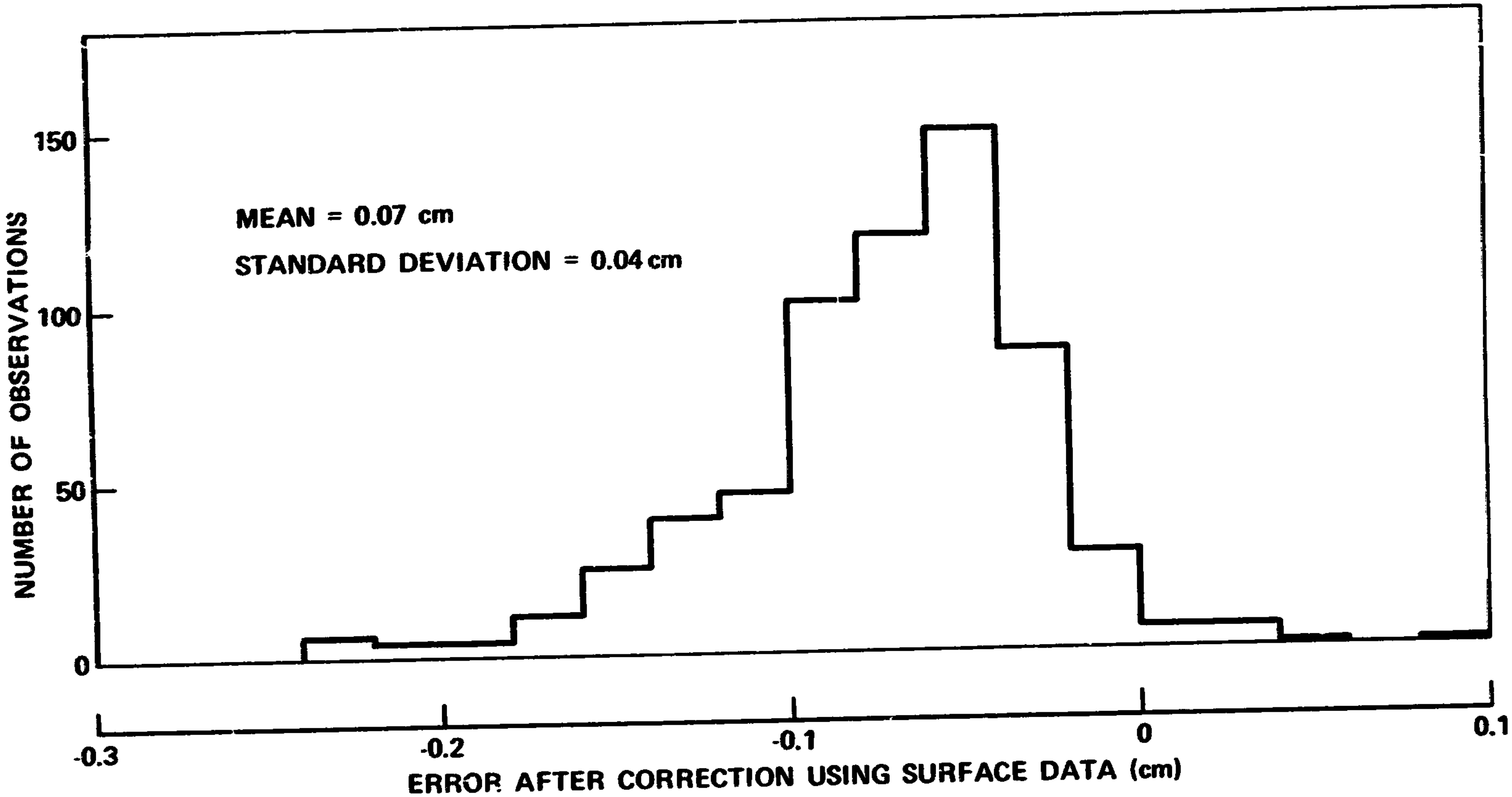


Figure 3. Tropospheric Range Error at About 80 Degrees Elevation for Laser Frequency of 0.6943 Microns

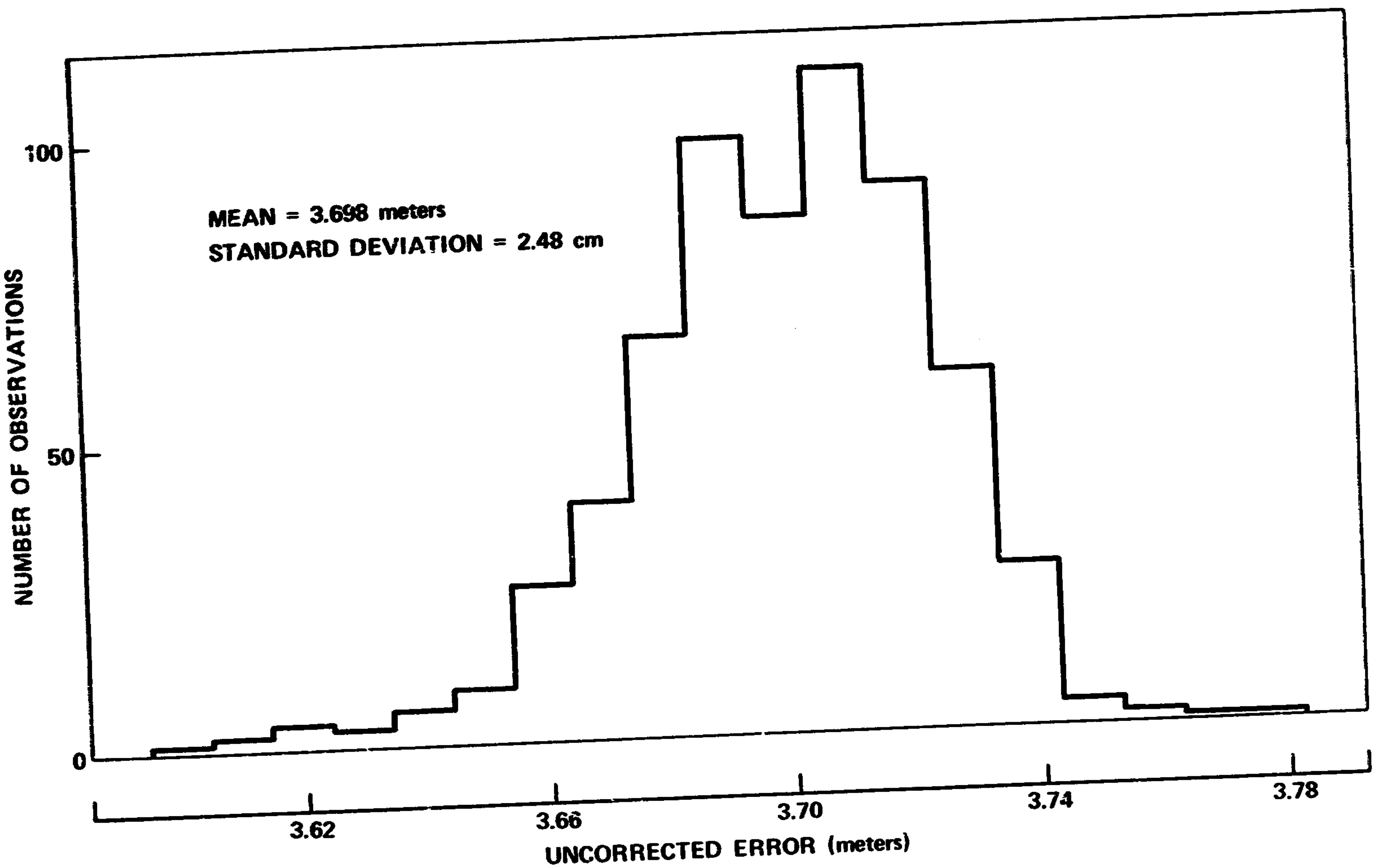


Figure 4. Tropospheric Range Error at About 40 Degrees Elevation for Laser Frequency of 0.6943 Microns

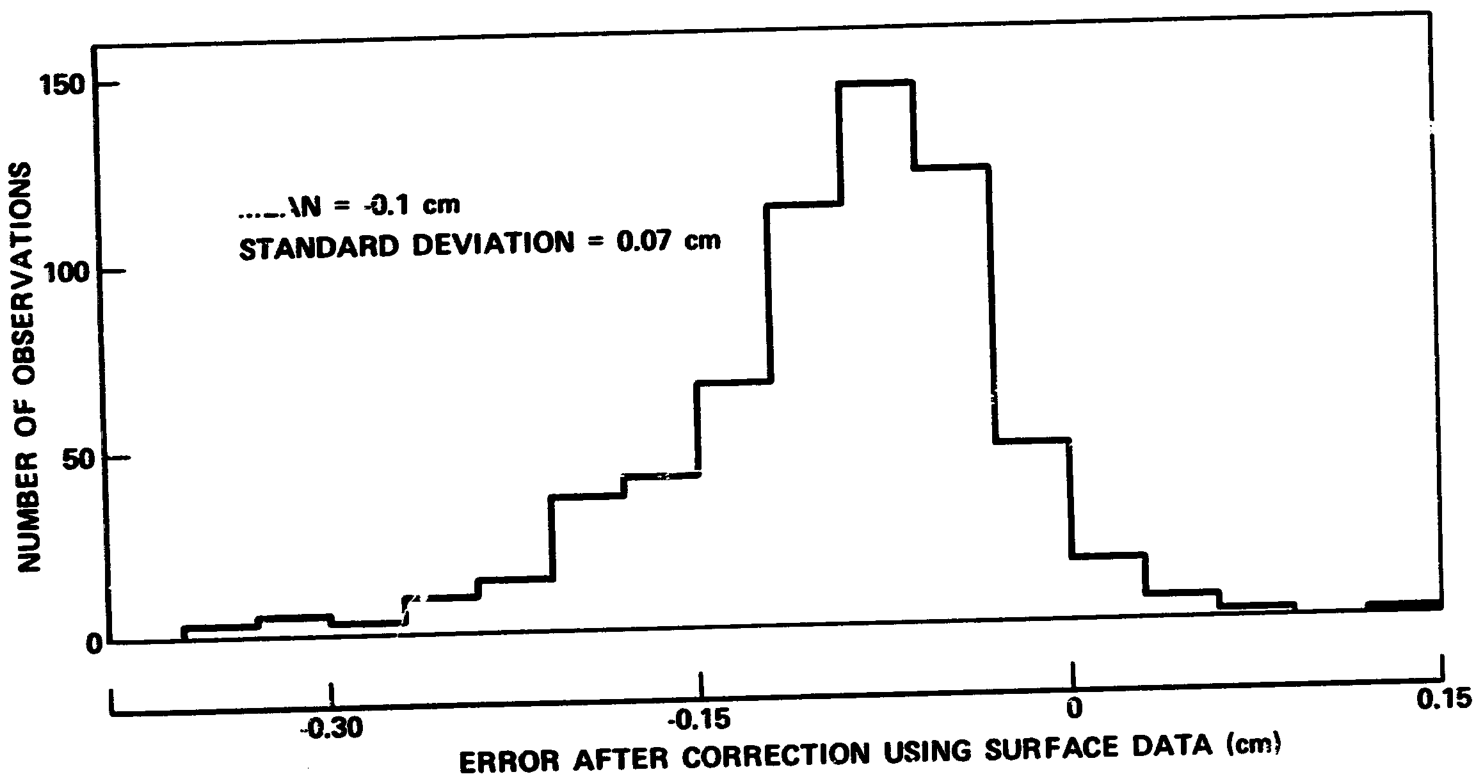


Figure 5. Tropospheric Range Error at About 40 Degrees Elevation for Laser Frequency of 0.6943 Microns

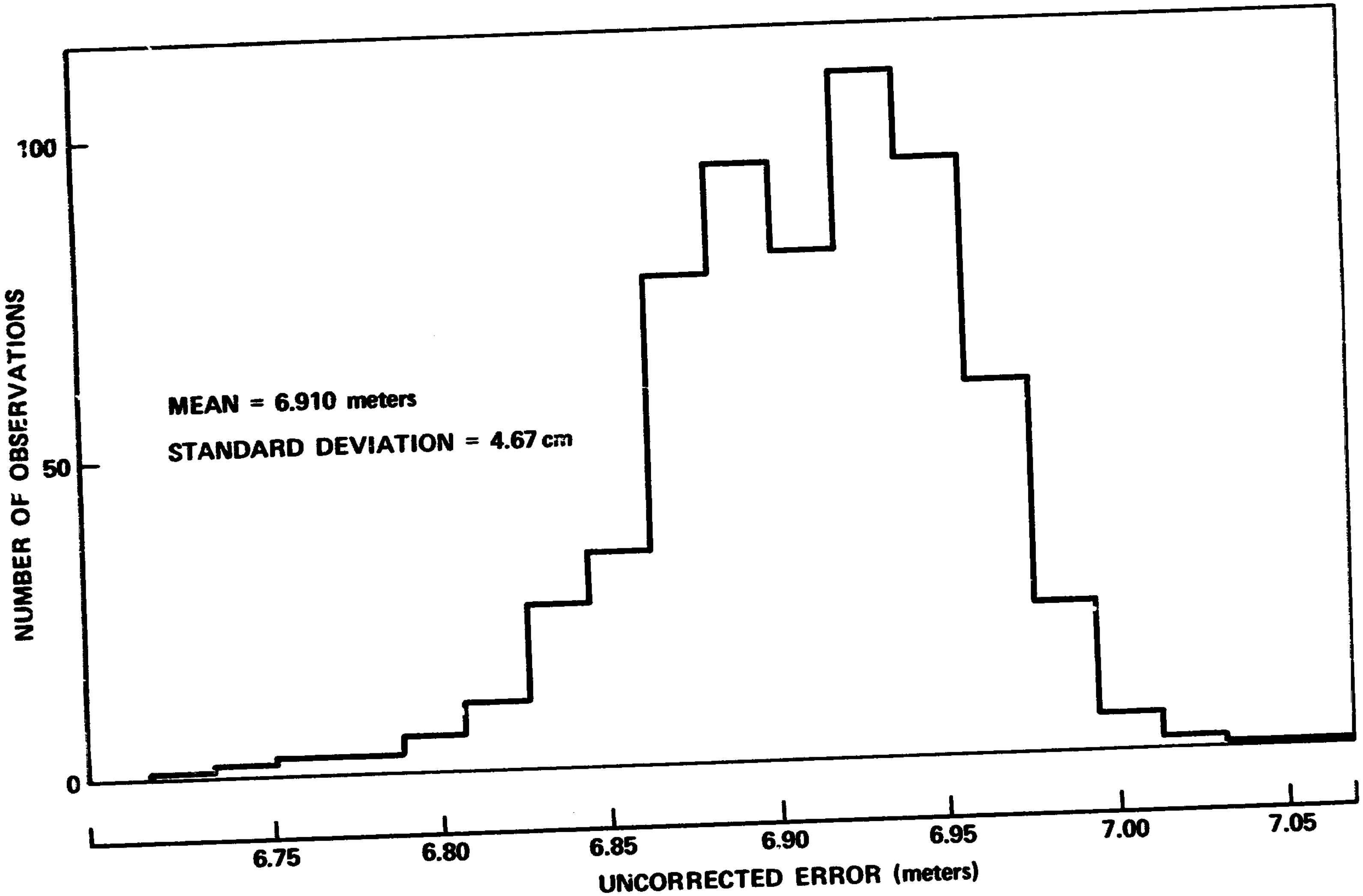


Figure 6. Tropospheric Range Error at About 20 Degrees Elevation for Laser Frequency of 0.6943 Microns

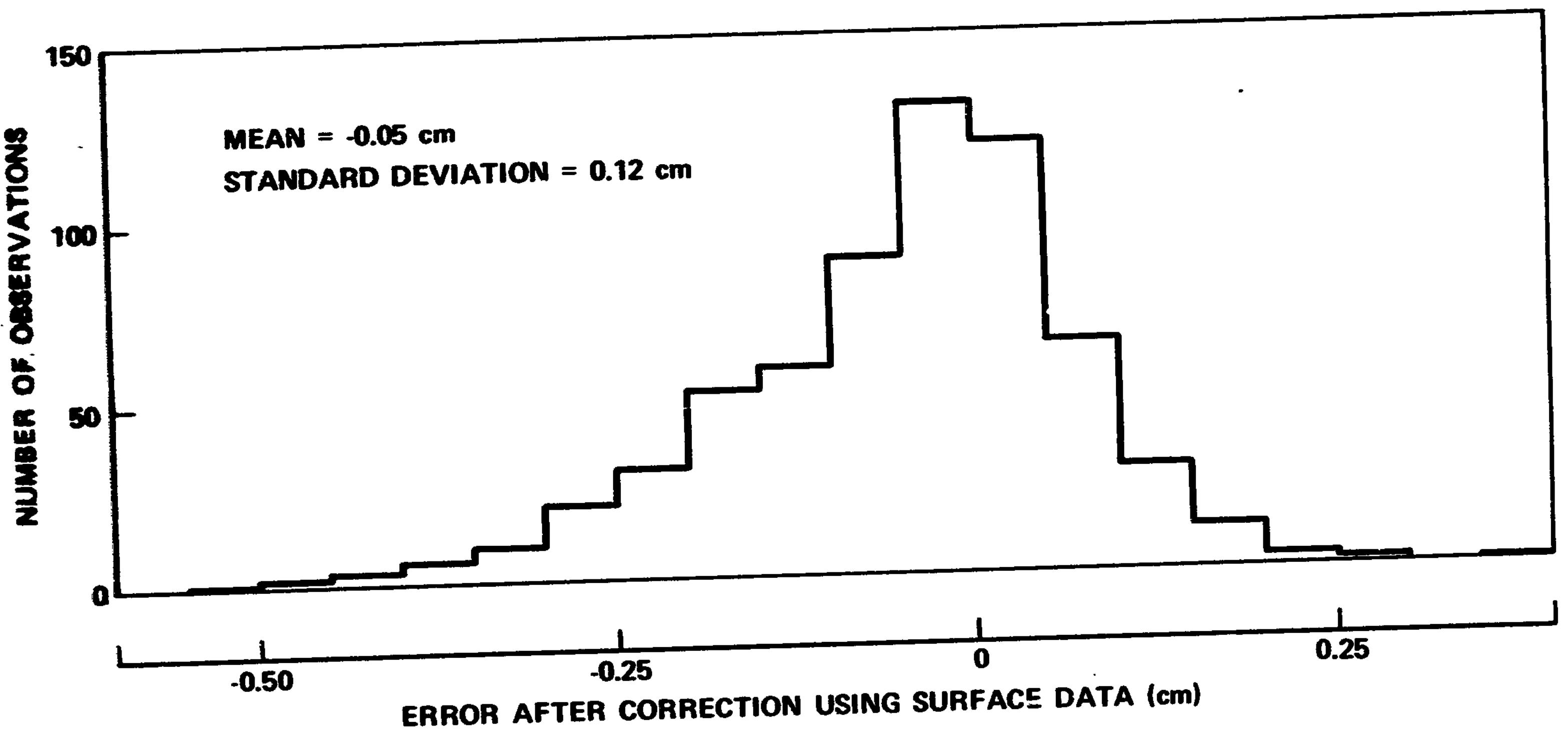


Figure 7. Tropospheric Range Error at About 20 Degrees Elevation for Laser Frequency of 0.6943 Microns

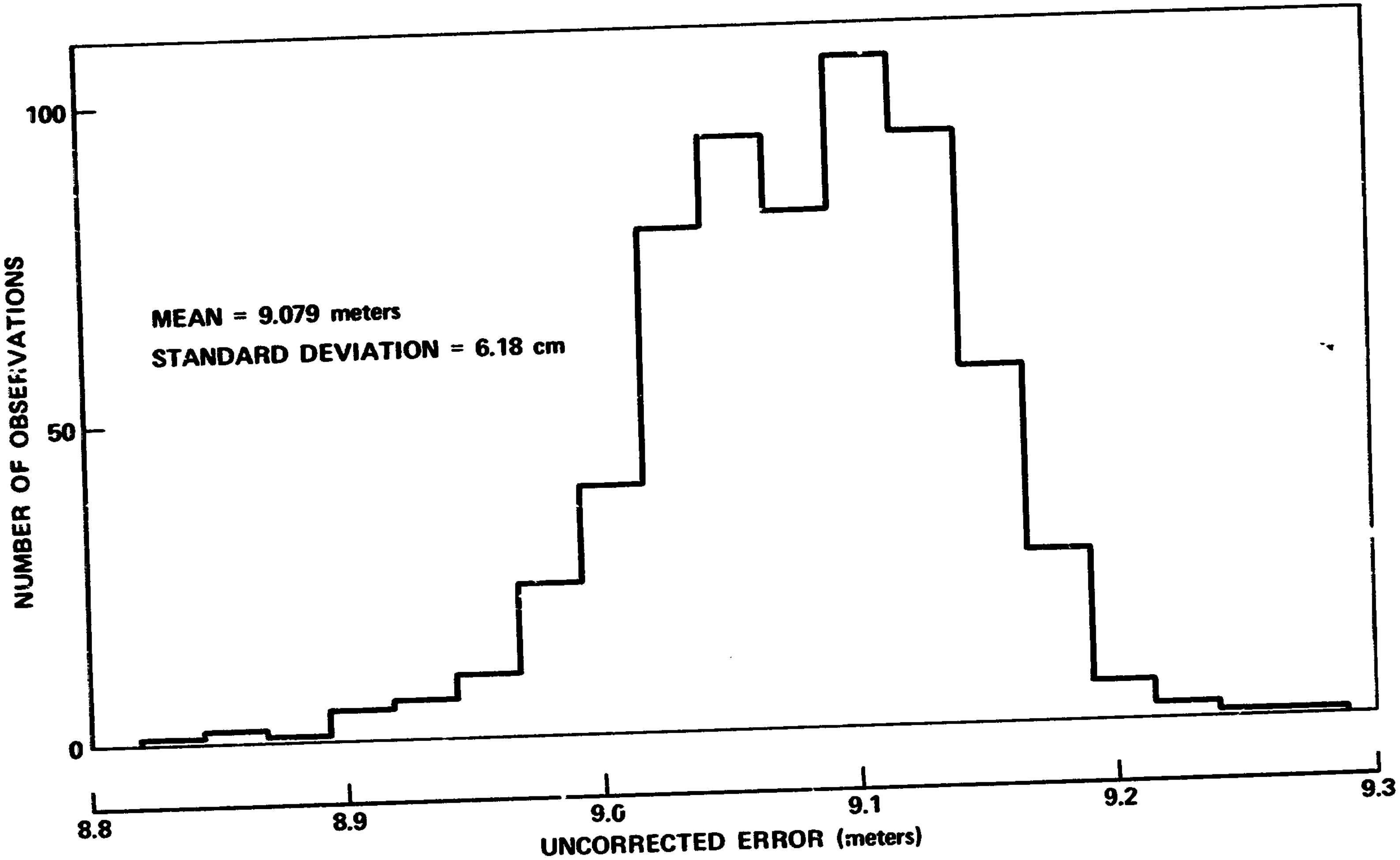


Figure 8. Tropospheric Range Error at About 15 Degrees Elevation for Laser Frequency of 0.6943 Microns

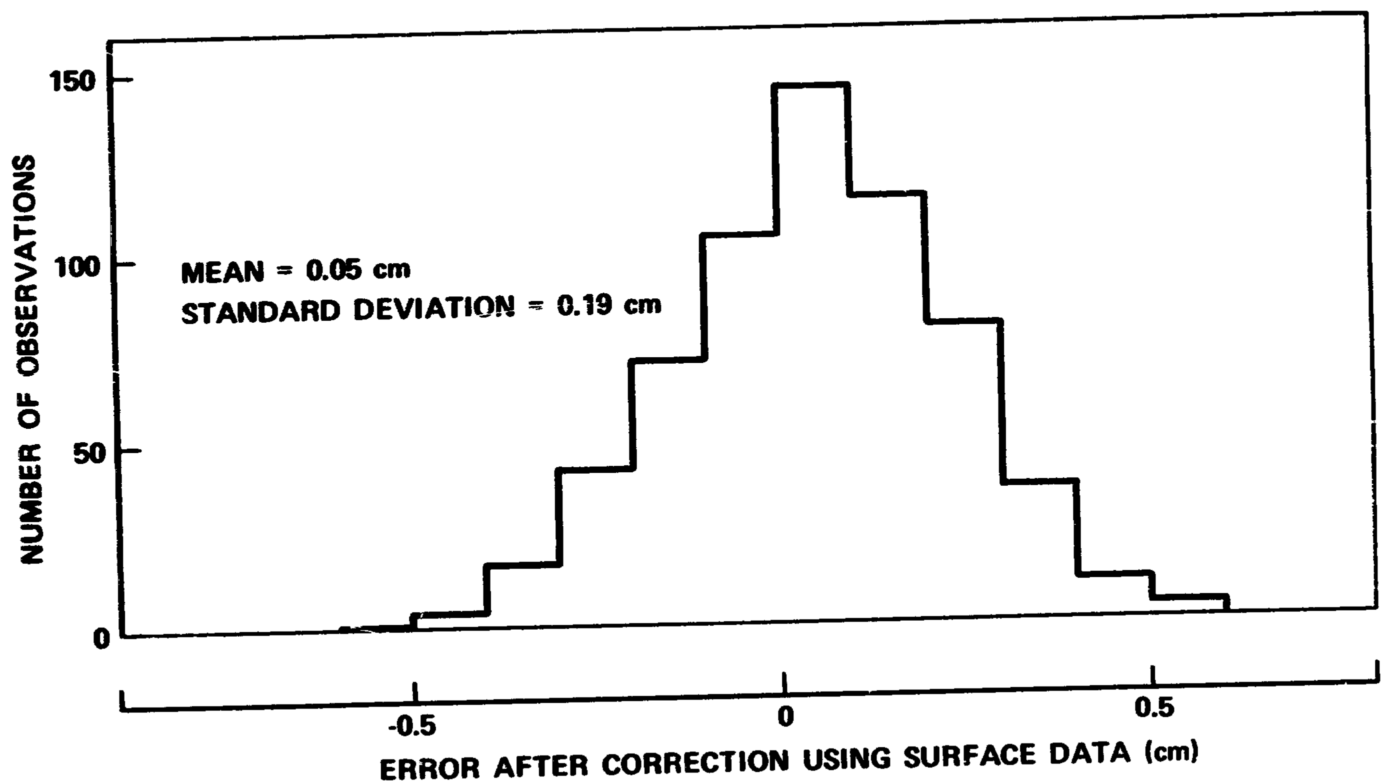


Figure 9. Tropospheric Range Error at About 15 Degrees Elevation for Laser Frequency of 0.6943 Microns

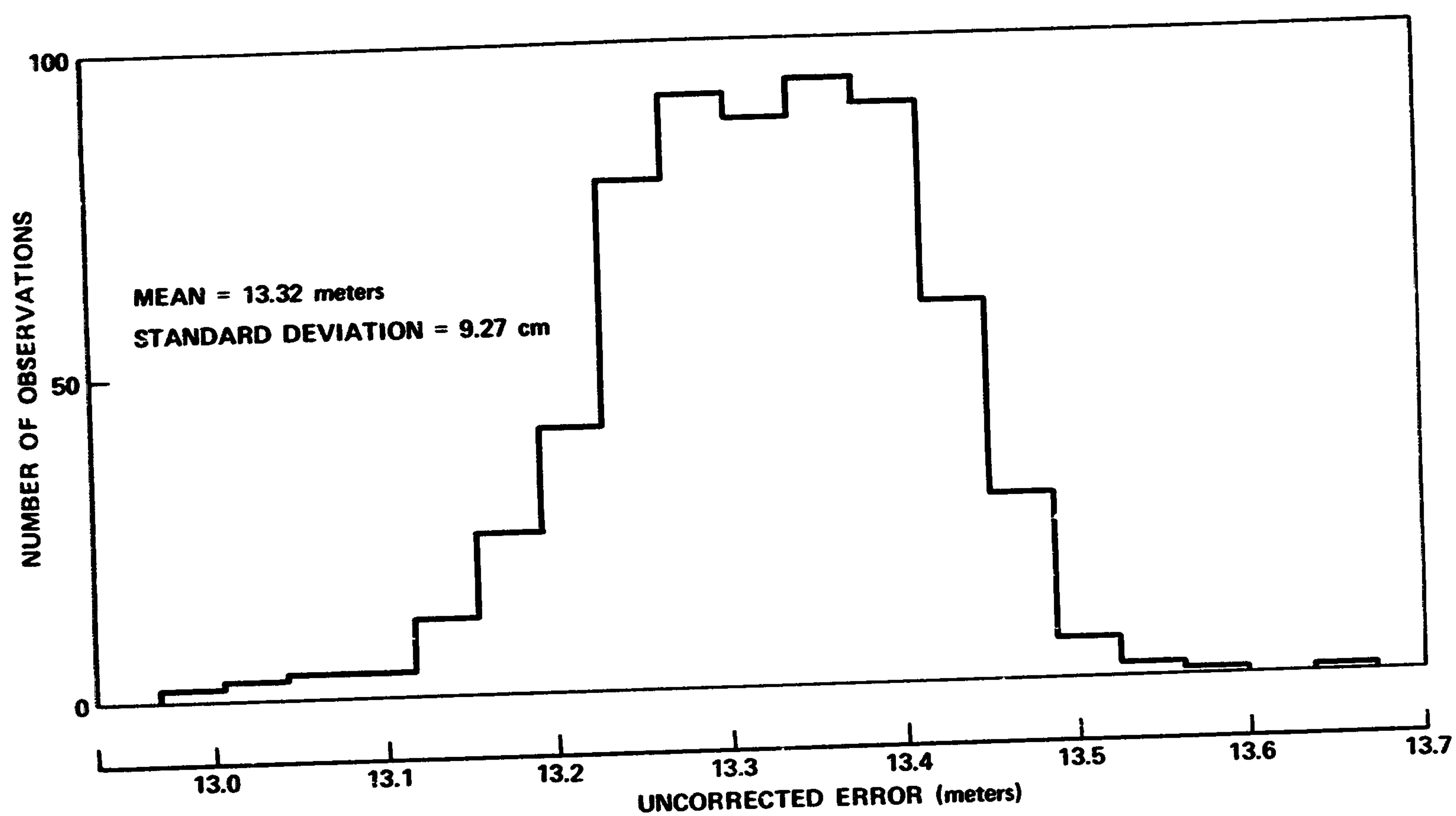


Figure 10. Tropospheric Range Error at About 10 Degrees Elevation for Laser Frequency of 0.6943 Microns

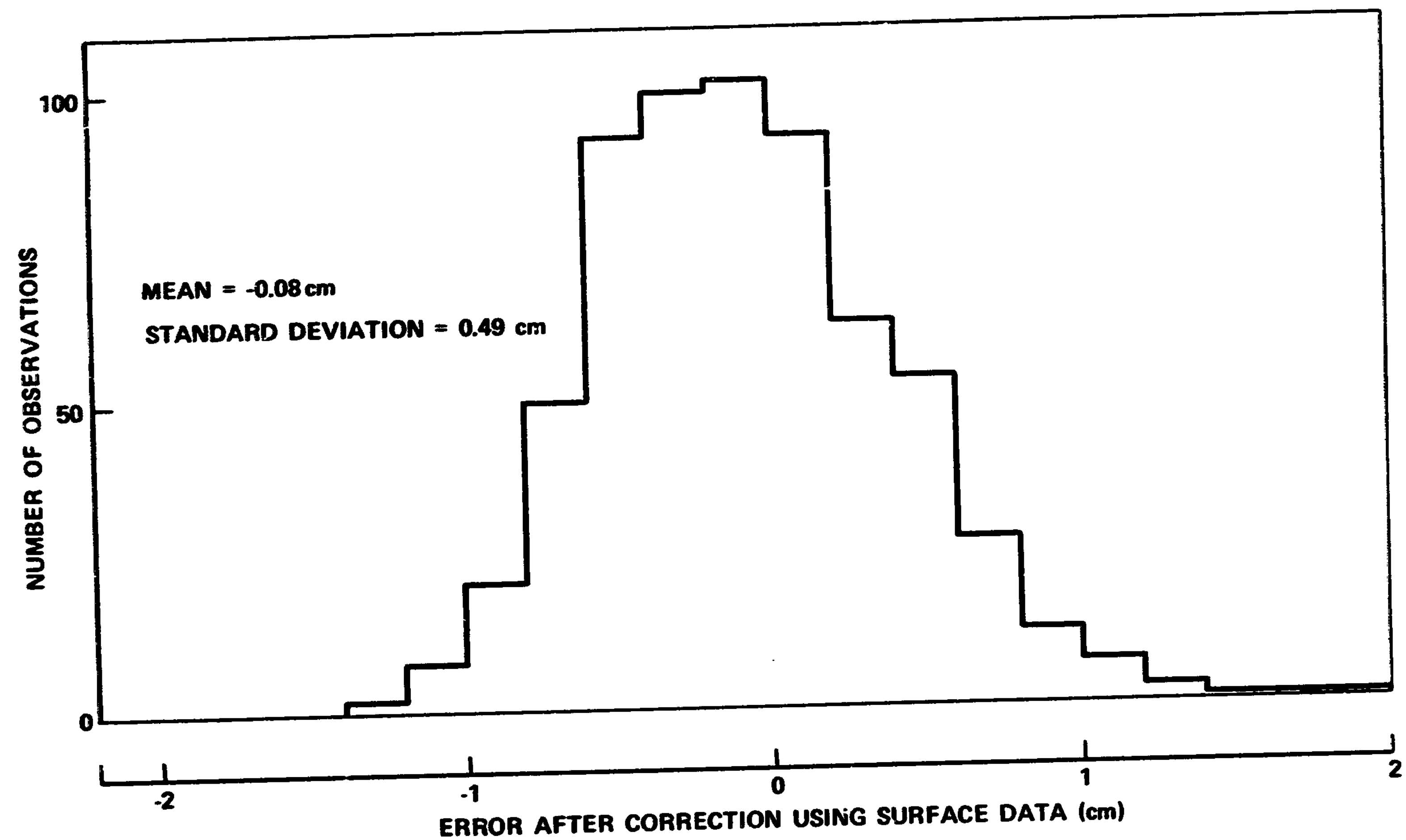


Figure 11. Tropospheric Range Error at About 10 Degrees Elevation for Laser Frequency of 0.6943 Microns

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.

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# APPENDIX 1

## NEGLECT OF SATELLITE RANGE

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## 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

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

The expansion of the bracketed second term in (1-2), which represents the difference $\Delta R_g$ 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 $N_g$

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

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

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

where $h_1$ is the satellite height in meters. Taking $h_1 \geq 70$ km and $\theta_0 > 10^\circ$, 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,

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

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

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

$$\bar{h} = \frac{1}{P_0} \int P\, dh \quad (2\text{-}6)$$

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

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

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

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

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

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

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

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

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

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

*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 $E = 10°$, 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

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

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 ($\beta = -6°$/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 $\varphi$ 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 $\phi$ 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]

$$dP = -\rho g \, dZ \qquad (9)$$

The density $\rho$ is given with sufficient accuracy by [3]

$$\rho = \frac{MP}{RT_v} \qquad (10)$$

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

$$M = 28.966 \qquad (11)$$

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

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

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

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

which may be written as

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

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

where

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

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 $\lambda$ 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


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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),QI,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),E(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 HEFHGH(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 = ,G15.8,
                      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 = 1
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).GE.500.0D0)GO TO 604
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) = 0.0D0
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 TO 914
ISN 0114         913 HGMREF(I+1) = HGMREF(I) + 50.19500*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 TO 511
ISN 0119         510 N = I + 1
ISN 0120             HGMREF(N) = 1000000.0D0
ISN 0121         513 CONTINUE
ISN 0122         916 FORMAT(2X,D15.8)
               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 0165         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,PD15.8)
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          TCP = -7.5D0*TC(I)
ISN 0212          BCT = 237.3D0 + TC(I)
ISN 0213          EX = TCP/BCT
ISN 0214          RH(I) = ((100.0D0*E(I))/(6.1100)*10.))**EX
ISN 0215      719 IF(RH(I) .GT. 100.D0) RH(I) = 100.D0
ISN 0217     5555 FORMAT(1H0,17X)
ISN 0218       21 FORMAT(1H1, 17X)
ISN 0219          GMREFR(1) = GMREFR(1)*1.0D-3
ISN 0220          NPTS = N
ISN 0221          DO 830  K = 1,N
ISN 0222          X(K) = HGMREF(K)
ISN 0223      830 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)
                 1,3X,6HREFWET,6X,6HREFDRY,9X,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,F9.2,4D15.8)
ISN 0247     1814 DO 13 K = 1, NTH
ISN 0248          THETAO = THETA(K)
ISN 0249          CALL RAYTHR(N,HGMREF,REFRAT,THETAO,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) THETAO
ISN 0253          WRITE (4,10) THETAO
ISN 0254       10 FORMAT(1X,19HELEVATION 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 = ,D15.8,1X,9HMILLIBARS)
```

```
ISN 0266            WRITE (6,14) TC(1)
ISN 0267            WRITE (4,14) TC(1)
ISN 0268         14 FORMAT(1X,14HTEMPERATURE = ,F15.3,1X,15HDEGREES CELCIUS)
ISN 0269            WRITE (6,15) RH(1)
ISN 0270            WRITE (4,15) RH(1)
ISN 0271         15 FORMAT(1X,20HRELATIVE HUMIDITY = ,F13.2,1X,7HPERCENT)
ISN 0272            WRITE (6,16)EPS
ISN 0273            WRITE (4,16)EPS
ISN 0274         16 FORMAT(1X,24HELEVATION ANGLE ERROR = ,F15.3,1X,7HRADIANS)
ISN 0275            IF(ECPT - 1.0D0) 850,851,850
ISN 0276        851 BETA = THETA0 - EPS
ISN 0277            FACT7 = 0.0100
ISN 0278            DHP = 1.0D0 - 2.0D0*(DSIN(GLAT)**2)
ISN 0279            BCP = 1.0D0 - 0.00026D0*DHP - 0.0031D0*GMRLFP(1)
ISN 0280            FACT1=1.26052D0-0.10D0-1.0D0-0.11221D-2*TK(1)+0.15357D-4*TK(1)
ISN 0281            FACT2 = (FACT1*PR(1)*TK(1)*1.0D-3)/BCD
ISN 0282            FACTK = (FACT1*BCD)/1.694205D0
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 = ,D15.4, 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=00,SIZE=0000K,
                     SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
ISN 0002            SUBROUTINE SPINT(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 RAYTHR(N,HGT,REFRAT,THETA0,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, THETA0 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) = THETA0
  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)*REFRAG(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)/REFING(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.FT03F001 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 | 432.566 |
| 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 |
| 1560.0 | 836.0 | 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 | 12699.730 |
| 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 | 19209.971 |
| 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 | [illegible] |
| 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 | 0.28948456D 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 | 0.27986229D 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 | 0.27568160D 03 | 0.27782552D 03 | 0.28450501D 03 |
| 0.404 | 271.6 | 953.26 | 5.4569 | 100.00 | 0.27254477D 02 | 0.27246414D 03 | 0.27516647D 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 | 0.26438384D 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 | 0.26018189D 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 | 0.25558476D 03 | 0.25807614D 03 | 0.26428221D 03 |
| 0.817 | 276.6 | 906.05 | 6.1727 | 79.12 | 0.29815274D 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 | 0.24675665D 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 | 0.25260334D 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 | 0.23556188D 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 | 0.14054003D 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 | 0.13486593D 02 | 0.22130203D 03 | 0.22356784D 03 | 0.22894147D 03 |
| 2.049 | 274.5 | 777.78 | 2.7199 | 40.44 | 0.13338263D 02 | 0.21996320D 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 | 0.21551095D 03 | 0.22069083D 03 |
| 2.383 | 273.2 | 746.14 | 2.5349 | 41.30 | 0.12546783D 02 | 0.21153873D 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 | 730.57 | 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 | 43.85 | 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 | 649.61 | 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 |
| 3.595 | 263.7 | 639.96 | 1.4359 | 48.16 | 0.76326365D 01 | 0.18839115D 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 | 68.54 | 0.12176103D 02 | 0.17928980D 03 | 0.18112040D 03 | 0.18547390D 03 |
| 4.136 | 259.9 | 596.33 | 2.1813 | 59.12 | 0.11936593D 02 | 0.17610490D 03 | 0.17992479D 03 | 0.18424951D 03 |
| 4.197 | 259.6 | 591.58 | 2.1271 | 59.25 | 0.11666362D 02 | 0.17690554D 03 | 0.17871477D 03 | 0.18301037D 03 |
| 4.259 | 259.3 | 586.85 | 2.0734 | 59.35 | 0.11403343D 02 | 0.17570930D 03 | 0.17750790D 03 | 0.18177445D 03 |
| 4.320 | 258.9 | 582.13 | 2.0202 | 59.42 | 0.11138555D 02 | 0.17451620D 03 | 0.17630417D 03 | 0.18054175D 03 |
| 4.382 | 258.6 | 577.43 | 1.9674 | 59.47 | 0.10874983D 02 | 0.17332623D 03 | 0.17510361D 03 | 0.17931229D 03 |
| 4.443 | 258.3 | 572.75 | 1.9151 | 59.48 | 0.10612652D 02 | 0.17213942D 03 | 0.17390621D 03 | 0.17808608D 03 |
| 4.505 | 257.9 | 568.09 | 1.8632 | 59.46 | 0.10351550D 02 | 0.17095577D 03 | 0.17271199D 03 | 0.17686312D 03 |
| 4.567 | 257.6 | 563.45 | 1.8117 | 59.40 | 0.10091664D 02 | 0.16977528D 03 | 0.17152097D 03 | 0.17564343D 03 |
| 4.630 | 257.3 | 558.82 | 1.7608 | 59.30 | 0.98330690D 01 | 0.16859798D 03 | 0.17033314D 03 | 0.17442701D 03 |
| 4.692 | 257.0 | 554.22 | 1.7102 | 59.16 | 0.95756981D 01 | 0.16742386D 03 | 0.16914852D 03 | 0.17321388D 03 |
| 4.755 | 256.6 | 549.63 | 1.6582 | 58.93 | 0.93087633D 01 | 0.16625819D 03 | 0.16797250D 03 | 0.17200956D 03 |
| 4.818 | 256.2 | 545.06 | 1.5836 | 58.33 | 0.85207264D 01 | 0.16515448D 03 | 0.16686008D 03 | 0.17087034D 03 |
| 4.881 | 255.7 | 540.50 | 1.5098 | 56.92 | 0.85332974D 01 | 0.16405293D 03 | 0.16574983D 03 | 0.16973334D 03 |
| 4.944 | 255.3 | 535.97 | 1.4367 | 55.20 | 0.81422353D 01 | 0.16295355D 03 | 0.16464174D 03 | 0.16859856D 03 |
| 5.007 | 254.9 | 531.45 | 1.3642 | 54.33 | 0.77639003D 01 | 0.16185635D 03 | 0.16353584D 03 | 0.16746602D 03 |
| 5.071 | 254.4 | 526.94 | 1.2924 | 52.78 | 0.73807514D 01 | 0.16076134D 03 | 0.16243214D 03 | 0.16633573D 03 |
| 5.135 | 254.0 | 522.46 | 1.2213 | 51.05 | 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 | 0.15748959D 03 | 0.15913433D 03 | 0.16295847D 03 |
| 5.327 | 252.7 | 509.10 | 1.0120 | 84.63 | 0.58607036D 01 | 0.15640347D 03 | 0.15803955D 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 |

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|---|---|---|---|---|---|---|---|
| 5.522 | 251.3 | 495.90 | 0.8472 | 89.08 | 0.496151920 01 | 0.153192360 03 | 0.154301050 03 0.158520850 03 |
| 5.587 | 250.8 | 491.53 | 0.8215 | 81.22 | 0.483053340 01 | 0.152150810 03 | 0.153746380 03 0.157443890 03 |
| 5.652 | 250.3 | 487.18 | 0.7960 | 82.36 | 0.469973960 01 | 0.151111030 03 | 0.152699500 03 0.156368760 03 |
| 5.718 | 249.7 | 482.84 | 0.7707 | 83.47 | 0.456531320 01 | 0.150073040 03 | 0.151651420 03 0.155295470 03 |
| 5.784 | 249.2 | 478.52 | 0.7457 | 84.57 | 0.443903530 01 | 0.149036860 03 | 0.150605150 03 0.154224050 03 |
| 5.850 | 248.7 | 474.22 | 0.7209 | 85.64 | 0.430213240 01 | 0.148002480 03 | 0.149560720 03 0.153154490 03 |
| 5.916 | 248.2 | 469.93 | 0.6962 | 86.68 | 0.417943190 01 | 0.146569940 03 | 0.148518120 03 0.152086830 03 |
| 5.983 | 247.7 | 465.66 | 0.6719 | 87.69 | 0.404992750 01 | 0.145939230 03 | 0.147477380 03 0.151021050 03 |
| 6.049 | 247.2 | 461.41 | 0.6477 | 88.65 | 0.392083230 01 | 0.144910370 03 | 0.146438500 03 0.149957190 03 |
| 6.116 | 246.6 | 457.17 | 0.6237 | 89.57 | 0.379193940 01 | 0.143883380 03 | 0.145401500 03 0.148895260 03 |
| 6.183 | 246.1 | 452.95 | 0.6000 | 90.43 | 0.366332210 01 | 0.142858270 03 | 0.144366400 03 0.147835270 03 |
| 6.250 | 245.6 | 448.75 | 0.5763 | 91.61 | 0.354622070 01 | 0.141841620 03 | 0.143339760 03 0.146783940 03 |
| 6.318 | 245.0 | 444.56 | 0.5610 | 93.67 | 0.345578710 01 | 0.140842130 03 | 0.142320250 03 0.145750170 03 |
| 6.386 | 244.5 | 440.39 | 0.5438 | 95.77 | 0.336546620 01 | 0.139844210 03 | 0.141322340 03 0.144718020 03 |
| 6.454 | 243.9 | 436.24 | 0.5267 | 97.88 | 0.327526900 01 | 0.138847870 03 | 0.140316030 03 0.143687510 03 |
| 6.522 | 243.6 | 432.10 | 0.4903 | 93.23 | 0.305500130 01 | 0.137668280 03 | 0.139125410 03 0.142468250 03 |
| 6.590 | 243.4 | 427.99 | 0.4532 | 88.01 | 0.282890630 01 | 0.136482580 03 | 0.137928660 03 0.141242710 03 |
| 6.659 | 243.2 | 423.90 | 0.4166 | 82.63 | 0.260499450 01 | 0.135302160 03 | 0.136737260 03 0.140022650 03 |
| 6.728 | 243.0 | 419.83 | 0.3804 | 77.09 | 0.238326410 01 | 0.134127090 03 | 0.135551200 03 0.138808060 03 |
| 6.797 | 242.7 | 415.78 | 0.3447 | 71.38 | 0.216371330 01 | 0.132957320 03 | 0.134370490 03 0.137598540 03 |
| 6.866 | 242.5 | 411.76 | 0.3095 | 65.49 | 0.194634050 01 | 0.131792860 03 | 0.133195130 03 0.136395310 03 |
| 6.935 | 242.3 | 407.76 | 0.2748 | 59.42 | 0.173114430 01 | 0.130633710 03 | 0.132025120 03 0.135197150 03 |
| 7.005 | 242.1 | 403.78 | 0.2405 | 53.15 | 0.151812250 01 | 0.129479870 03 | 0.130860470 03 0.134004480 03 |
| 7.075 | 241.8 | 399.82 | 0.2079 | 47.30 | 0.131482370 01 | 0.128335610 03 | 0.129705420 03 0.132821650 03 |
| 7.145 | 241.4 | 395.88 | 0.2002 | 47.07 | 0.127040740 01 | 0.127284580 03 | 0.128643430 03 0.131734140 03 |
| 7.216 | 241.0 | 391.96 | 0.1926 | 47.10 | 0.122623430 01 | 0.126236940 03 | 0.127584870 03 0.130650140 03 |
| 7.286 | 240.6 | 388.06 | 0.1851 | 47.09 | 0.118230690 01 | 0.125192710 03 | 0.126525760 03 0.129569670 03 |
| 7.357 | 240.2 | 384.19 | 0.1776 | 47.04 | 0.113862490 01 | 0.124151910 03 | 0.125478100 03 0.128492740 03 |
| 7.429 | 239.8 | 380.33 | 0.1702 | 46.95 | 0.109518390 01 | 0.123114540 03 | 0.124429910 03 0.127419360 03 |
| 7.500 | 239.4 | 376.49 | 0.1630 | 46.80 | 0.105200300 01 | 0.122080610 03 | 0.123385200 03 0.126349550 03 |
| 7.572 | 239.0 | 372.66 | 0.1558 | 46.61 | 0.100906540 01 | 0.121050150 03 | 0.122343980 03 0.125283310 03 |
| 7.643 | 238.6 | 368.86 | 0.1487 | 46.35 | 0.966376220 00 | 0.120023150 03 | 0.121306270 03 0.124220660 03 |
| 7.716 | 238.1 | 365.08 | 0.1416 | 46.03 | 0.923942610 00 | 0.118999640 03 | 0.120272070 03 0.123161610 03 |
| 7.788 | 237.7 | 361.32 | 0.1347 | 45.65 | 0.881769740 00 | 0.117979620 03 | 0.119241400 03 0.122106170 03 |
| 7.861 | 237.3 | 357.57 | 0.1278 | 45.19 | 0.839830750 00 | 0.116963100 03 | 0.118214280 03 0.121054360 03 |
| 7.933 | 236.9 | 353.85 | 0.1211 | 44.65 | 0.798156830 00 | 0.115950110 03 | 0.117190710 03 0.120006190 03 |
| 8.007 | 236.5 | 350.14 | 0.1144 | 44.03 | 0.756739130 00 | 0.114940640 03 | 0.116170700 03 0.118961670 03 |
| 8.080 | 236.1 | 346.46 | 0.1056 | 42.33 | 0.701016450 00 | 0.113922270 03 | 0.115141800 03 0.117908040 03 |
| 8.154 | 235.7 | 342.80 | 0.0968 | 40.43 | 0.645098070 00 | 0.112907230 03 | 0.114116250 03 0.116857840 03 |
| 8.228 | 235.3 | 339.15 | 0.0882 | 38.36 | 0.589500630 00 | 0.111896020 03 | 0.113094570 03 0.115811620 03 |
| 8.302 | 234.9 | 335.53 | 0.0797 | 36.12 | 0.534465730 00 | 0.110888660 03 | 0.112076790 03 0.114769380 03 |
| 8.376 | 234.5 | 331.92 | 0.0713 | 33.68 | 0.479754810 00 | 0.109885170 03 | 0.111062910 03 0.113731130 03 |
| 8.451 | 234.1 | 328.34 | 0.0630 | 31.04 | 0.425449240 00 | 0.108885560 03 | 0.110052940 03 0.112696890 03 |
| 8.526 | 233.7 | 324.77 | 0.0548 | 28.18 | 0.371550550 00 | 0.107889830 03 | 0.109046900 03 0.111666670 03 |
| 8.601 | 233.3 | 321.23 | 0.0468 | 25.09 | 0.318060220 00 | 0.106898000 03 | 0.108044790 03 0.110640480 03 |
| 8.676 | 232.9 | 317.71 | 0.0388 | 21.74 | 0.264975730 00 | 0.105910080 03 | 0.107046630 03 0.109618330 03 |
| 8.752 | 232.4 | 314.20 | 0.0310 | 18.12 | 0.212310530 00 | 0.104926080 03 | 0.106052430 03 0.108600230 03 |
| 8.828 | 232.0 | 310.72 | 0.0233 | 14.22 | 0.160064230 00 | 0.103946010 03 | 0.105062200 03 0.107586210 03 |
| 8.905 | 231.6 | 307.25 | 0.0157 | 10.01 | 0.108212150 00 | 0.102969880 03 | 0.104075950 03 0.106576260 03 |
| 8.981 | 231.2 | 303.81 | 0.0082 | 5.47 | 0.567852050-01 | 0.101997710 03 | 0.103093700 03 0.105570390 03 |
| 9.058 | 230.8 | 300.39 | 0.0008 | 0.58 | 0.577692360-02 | 0.101029510 03 | 0.102115450 03 0.104568630 03 |

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|---|---|---|---|---|---|---|---|---|
| 9.135 | 230.4 | 296.59 | 0.0 | 0.0 | 0.0 | 0.100605228D 03 | 0.101127752D 03 | 0.103557218D 03 |
| 9.213 | 230.0 | 293.60 | 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 | 0.99167479D 02 | 0.99162046D 02 | 0.10154428D 03 |
| 9.368 | 229.3 | 286.90 | 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 | 0.88331103D 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 |
| 10.410 | 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 | 233.06 | 0.0 | 0.0 | 0.0 | 0.82443774D 02 | 0.83325975D 02 | 0.85331868D 02 |
| 10.825 | 218.8 | 230.00 | 0.0 | 0.0 | 0.0 | 0.81609102D 02 | 0.82486326D 02 | 0.84467949D 02 |
| 10.909 | 218.1 | 227.61 | 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 | 216.5 | 221.69 | 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 | 0.77474047D 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 | 0.77664565D 02 |
| 11.592 | 213.1 | 203.75 | 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 | 198.18 | 0.0 | 0.0 | 0.0 | 0.72601670D 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 | 0.65895654D 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 | 0.63299024D 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 | 0.64528896D 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 | 0.60185176D 02 | 0.61635139D 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 | 156.61 | 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 | 0.52617731D 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 | 138.65 | 0.0 | 0.0 | 0.0 | 0.50850151D 02 | 0.51396745D 02 | 0.52631482D 02 |
| 14.079 | 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 | 0.49222579D 02 | 0.49751779D 02 | 0.50946998D 02 |
| 14.276 | 212.0 | 132.25 | 0.0 | 0.0 | 0.0 | 0.48423775D 02 | 0.48944286D 02 | 0.50120197D 02 |
| 14.375 | 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 | 0.47358264D 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 | 0.45053271D 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 | 0.34053845D 02 | 0.34419893D 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] | 0.32080427D 02 |
| 17.238 | 209.4 | 82.05 | 0.0 | 0.0 | 0.0 | [illegible] | 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 | 0.29009985D 02 | 0.29705886D 02 |
| 17.697 | 210.1 | 76.17 | 0.0 | 0.0 | 0.0 | 0.28147406D 02 | 0.28449966D 02 | 0.29133437D 02 |
| 17.814 | 210.2 | 74.75 | 0.0 | 0.0 | 0.0 | 0.27602437D 02 | 0.27899139D 02 | 0.28569378D 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 | 0.24594569D 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 | 0.24359751D 02 |
| 18.892 | 211.5 | 62.84 | 0.0 | 0.0 | 0.0 | 0.23061611D 02 | 0.23309503D 02 | 0.23869482D 02 |

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|---|---|---|---|---|---|---|---|---|
| 19.315 | 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 | 59.20 | 0.0 | 0.0 | 0.0 | 0.21682525D 02 | 0.21915593D 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 | 0.20532834D 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 | 0.19355523D 02 |
| 20.289 | 213.2 | 50.27 | 0.0 | 0.0 | 0.0 | 0.18301042D 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 | 0.17726448D 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 | 0.16083986D 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 | 0.14877687D 02 | 0.15234429D 02 |
| 21.785 | 213.6 | 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 | 0.14566283D 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 | 0.10455895D 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 | 26.46 | 0.0 | 0.0 | 0.0 | 0.96079026D 01 | 0.97111788D 01 | 0.99444787D 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 | 0.92292533D 01 | 0.94509734D 01 |
| 24.811 | 214.0 | 24.53 | 0.0 | 0.0 | 0.0 | 0.88991587D 01 | 0.89948166D 01 | 0.92109049D 01 |
| 24.978 | 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 | 0.85166934D 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 |
| 26.325 | 214.1 | 19.29 | 0.0 | 0.0 | 0.0 | 0.69942688D 01 | 0.70694408D 01 | 0.72392745D 01 |

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|---|---|---|---|---|---|---|---|---|
| 26.505 | 214.1 | 18.76 | 0.0 | 0.0 | 0.0 | 0.680017327D 01 | 0.697484520D 01 | 0.704000040D 01 |
| 26.682 | 214.1 | 18.24 | 0.0 | 0.0 | 0.0 | 0.661299160D 01 | 0.668407510D 01 | 0.684465100D 01 |
| 26.861 | 214.2 | 17.74 | 0.0 | 0.0 | 0.0 | 0.642799060D 01 | 0.649708570D 01 | 0.665316940D 01 |
| 27.041 | 214.2 | 17.24 | 0.0 | 0.0 | 0.0 | 0.624608610D 01 | 0.631383230D 01 | 0.646551350D 01 |
| 27.223 | 214.2 | 16.75 | 0.0 | 0.0 | 0.0 | 0.606903370D 01 | 0.613427030D 01 | 0.628163780D 01 |
| 27.406 | 214.3 | 16.27 | 0.0 | 0.0 | 0.0 | 0.589498960D 01 | 0.595835540D 01 | 0.610149680D 01 |
| 27.591 | 214.3 | 15.80 | 0.0 | 0.0 | 0.0 | 0.572451020D 01 | 0.578604350D 01 | 0.592504540D 01 |
| 27.777 | 214.3 | 15.34 | 0.0 | 0.0 | 0.0 | 0.555755190D 01 | 0.561729050D 01 | 0.575223830D 01 |
| 27.965 | 214.4 | 14.90 | 0.0 | 0.0 | 0.0 | 0.539399530D 01 | 0.545197590D 01 | 0.558295220D 01 |
| 28.155 | 214.4 | 14.46 | 0.0 | 0.0 | 0.0 | 0.523364080D 01 | 0.528969770D 01 | 0.541698630D 01 |
| 28.347 | 214.4 | 14.03 | 0.0 | 0.0 | 0.0 | 0.507670320D 01 | 0.513127320D 01 | 0.525454510D 01 |
| 28.540 | 214.5 | 13.60 | 0.0 | 0.0 | 0.0 | 0.492313870D 01 | 0.497605800D 01 | 0.509560190D 01 |
| 28.735 | 214.5 | 13.19 | 0.0 | 0.0 | 0.0 | 0.477290350D 01 | 0.482420790D 01 | 0.494010300D 01 |
| 28.932 | 214.6 | 12.79 | 0.0 | 0.0 | 0.0 | 0.462595430D 01 | 0.467567910D 01 | 0.478800590D 01 |
| 29.131 | 214.6 | 12.39 | 0.0 | 0.0 | 0.0 | 0.448224770D 01 | 0.453042780D 01 | 0.463926520D 01 |
| 29.332 | 214.7 | 12.01 | 0.0 | 0.0 | 0.0 | 0.434174070D 01 | 0.438841050D 01 | 0.449383610D 01 |
| 29.534 | 214.7 | 11.63 | 0.0 | 0.0 | 0.0 | 0.420439050D 01 | 0.424958390D 01 | 0.435167440D 01 |
| 29.739 | 214.8 | 11.26 | 0.0 | 0.0 | 0.0 | 0.407015440D 01 | 0.411390480D 01 | 0.421273580D 01 |
| 29.945 | 214.8 | 10.90 | 0.0 | 0.0 | 0.0 | 0.393898980D 01 | 0.398123040D 01 | 0.407697650D 01 |
| 30.154 | 214.9 | 10.55 | 0.0 | 0.0 | 0.0 | 0.381085460D 01 | 0.385181780D 01 | 0.394435250D 01 |
| 30.365 | 214.9 | 10.20 | 0.0 | 0.0 | 0.0 | 0.368570660D 01 | 0.372532460D 01 | 0.381482050D 01 |
| 30.577 | 215.0 | 9.87 | 0.0 | 0.0 | 0.0 | 0.356267220D 01 | 0.360056770D 01 | 0.368747600D 01 |
| 30.792 | 215.2 | 9.54 | 0.0 | 0.0 | 0.0 | 0.344139520D 01 | 0.347838710D 01 | 0.356195060D 01 |
| 31.010 | 215.4 | 9.22 | 0.0 | 0.0 | 0.0 | 0.332316730D 01 | 0.335888840D 01 | 0.343958110D 01 |
| 31.229 | 215.6 | 8.91 | 0.0 | 0.0 | 0.0 | 0.320793860D 01 | 0.324242100D 01 | 0.332031580D 01 |
| 31.451 | 215.7 | 8.60 | 0.0 | 0.0 | 0.0 | 0.309565630D 01 | 0.312893490D 01 | 0.320410330D 01 |
| 31.675 | 215.9 | 8.31 | 0.0 | 0.0 | 0.0 | 0.298628040D 01 | 0.301838020D 01 | 0.309089270D 01 |
| 31.901 | 216.1 | 8.02 | 0.0 | 0.0 | 0.0 | 0.287575290D 01 | 0.291070770D 01 | 0.298063350D 01 |
| 32.130 | 216.3 | 7.74 | 0.0 | 0.0 | 0.0 | 0.277692860D 01 | 0.280586840D 01 | 0.287327560D 01 |
| 32.362 | 216.5 | 7.46 | 0.0 | 0.0 | 0.0 | 0.267505540D 01 | 0.270381390D 01 | 0.276876930D 01 |
| 32.596 | 216.7 | 7.19 | 0.0 | 0.0 | 0.0 | 0.257679780D 01 | 0.260445610D 01 | 0.266706550D 01 |
| 32.833 | 216.9 | 6.93 | 0.0 | 0.0 | 0.0 | 0.248128590D 01 | 0.250756750D 01 | 0.256820780D 01 |
| 33.072 | 217.1 | 6.68 | 0.0 | 0.0 | 0.0 | 0.238862070D 01 | 0.241425620D 01 | 0.247229640D 01 |
| 33.314 | 217.2 | 6.43 | 0.0 | 0.0 | 0.0 | 0.229848910D 01 | 0.232316570D 01 | 0.237900740D 01 |
| 33.555 | 217.4 | 6.19 | 0.0 | 0.0 | 0.0 | 0.221084690D 01 | 0.223461140D 01 | 0.228829490D 01 |
| 33.807 | 217.6 | 5.96 | 0.0 | 0.0 | 0.0 | 0.212595950D 01 | 0.214881160D 01 | 0.220043390D 01 |
| 34.058 | 217.6 | 5.73 | 0.0 | 0.0 | 0.0 | 0.204477190D 01 | 0.206675130D 01 | 0.211640220D 01 |
| 34.311 | 217.6 | 5.51 | 0.0 | 0.0 | 0.0 | 0.196577130D 01 | 0.198690150D 01 | 0.203463410D 01 |
| 34.568 | 217.6 | 5.29 | 0.0 | 0.0 | 0.0 | 0.188692400D 01 | 0.190922820D 01 | 0.195509480D 01 |
| 34.828 | 217.6 | 5.08 | 0.0 | 0.0 | 0.0 | 0.181419630D 01 | 0.183369730D 01 | 0.187774940D 01 |
| 35.091 | 217.6 | 4.88 | 0.0 | 0.0 | 0.0 | 0.174155490D 01 | 0.176027510D 01 | 0.180256330D 01 |
| 35.358 | 217.6 | 4.68 | 0.0 | 0.0 | 0.0 | 0.167096640D 01 | 0.168892770D 01 | 0.172950190D 01 |
| 35.628 | 217.6 | 4.49 | 0.0 | 0.0 | 0.0 | 0.160239740D 01 | 0.161962170D 01 | 0.165853090D 01 |
| 35.901 | 217.6 | 4.30 | 0.0 | 0.0 | 0.0 | 0.153581490D 01 | 0.155232360D 01 | 0.158961600D 01 |
| 36.178 | 217.6 | 4.12 | 0.0 | 0.0 | 0.0 | 0.147118600D 01 | 0.148700000D 01 | 0.152272310D 01 |
| 36.459 | 217.6 | 3.95 | 0.0 | 0.0 | 0.0 | 0.140847780D 01 | 0.142361770D 01 | 0.145781820D 01 |
| 36.744 | 217.6 | 3.78 | 0.0 | 0.0 | 0.0 | 0.134765760D 01 | 0.136214370D 01 | 0.139486740D 01 |
| 37.032 | 217.6 | 3.61 | 0.0 | 0.0 | 0.0 | 0.128869280D 01 | 0.130254510D 01 | 0.133383690D 01 |
| 37.324 | 217.6 | 3.45 | 0.0 | 0.0 | 0.0 | 0.123155090D 01 | 0.124478900D 01 | 0.127469330D 01 |
| 37.621 | 217.6 | 3.30 | 0.0 | 0.0 | 0.0 | 0.117619970D 01 | 0.118884280D 01 | 0.121740310D 01 |
| 37.921 | 217.6 | 3.15 | 0.0 | 0.0 | 0.0 | 0.112260690D 01 | 0.113467400D 01 | 0.116193300D 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 | 0.10205698D 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 | 0.64696257D 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 | 1.60 | 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 | 0.11552997D 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 | 0.62506087D-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 | 0.38956970D-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 | 0.29393444D-01 | 0.29705401D-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 | 0.21003230D-01 | 0.22112455D-01 | 0.22643021D-01 |
| 64.437 | 217.6 | 0.05 | 0.0 | 0.0 | 0.0 | 0.18685965D-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 | 0.92003062D-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 |
| 85.595 | 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 | 0.25491380D-03 | 0.25765389D-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 |

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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 =  0.24179640D 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 = 0.90328892D 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 = 0.687 [illegible] 23376092361D-02 KILOMETERS
STATION = 93734 YEAR = 67 MONTH =  1 DAY =  1 HOUR = 12
ELEVATION ANGLE = 0.69813172D 00 RADIANS
RANGE =  0.14291655D 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 = 0.24033816742537840D-02 KILOMETERS
```

```
IEF142I - STEP WAS EXECUTED - COND CODE 0000
***** JOB NBR-556  STEP NBR-02   GBCWM001  GO        PGM=LOADER   CARDS=00006   INITIATION TIME=19.07.41.40 DATE=11-01-73
***** JOB NBR-556 ... REGION START=1966K NASA-GSFC TERMINATION TIME=19.12.32.28 DATE=11-01-73
*   * CPU=000MIN 0?.?2SECS  I/O=000MIN 06.26SECS  ... TAPE=******.67 CELL=******.00 GRAF=******.00 OTHR=******.00
*   * I/O TIME BY DEVICE   DISK=*****4.45 DRUM=*****1.14
***** STEP REGION SIZE=0450K  MAXIMUM REGION SIZE USED=0450K   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
```

NASA-GSFC