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# REFRACTIVE EFFECTS IN REMOTE SENSING OF THE ATMOSPHERE WITH INFRARED TRANSMISSION SPECTROSCOPY

Donald E. Snider
Aaron Goldman

June 1975

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A ray tracing technique which includes atmospheric refraction is used to tabulate the air mass and the single layer effective temperature and pressure for a grazing ray from the sun. Summer and winter atmospheric profiles are used with observer altitudes ranging from 10 to 50 km in steps of 1 km. Zenith angles ranging from 80° up to 97° are considered.

Results indicate that neglecting refraction in the computation of air mass and effective pressure can lead to overestimates of these quantities by up to 25%

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for aircraft observers, 60% for high altitude balloons, and 200% for satellite observers.

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# INTRODUCTION

Our ability to predict the performance of Army systems in natural and disturbed environments depends on our understanding of the chemistry and physics of the atmosphere. In order to improve our knowledge in this area, the BRL undertook the Combined Stratospheric Measuring Program (COSMEP) in the summer of 1972. The goal of this program is to make near simultaneous measurements of stratospheric minor constituents, both charged and neutral. This report deals with one of the techniques used to obtain mixing ratio profiles for minor neutral constituents.

The use of infrared remote sensing techniques for studying atmospheric composition has increased greatly within the last decade. One of these techniques is to analyze transmission spectra of the earth's atmosphere which are made using the setting sun as a source. This technique has the advantages that 1) the long optical paths through the atmosphere increase the sensitivity of this technique to minor constituents, 2) the long paths through the atmosphere decrease the sensitivity of this technique to localized contamination, especially water vapor, and 3) the geometry associated with this technique allows the vertical mixing ratio profiles for minor constituents to be established.[1,2]

In order to use this technique to derive mixing ratio profiles, one must know the quantity of gas in the optical path, the so-called *air mass*. Since this quantity is so fundamental, it has been calculated by many investigators for a variety of conditions, under a variety of different assumptions.

One assumption which greatly simplifies the calculation of the air mass is that atmospheric refraction is negligible. In this case, the Chapman function[3] can be used to calculate the air mass, and simple geometry can be used to compute the minimum altitude for a grazing ray.

The subject of atmospheric refraction has been treated by many authors and was originally discussed by Laplace. It has been reviewed recently by Kondratyev,[4] and will not be reviewed here, except to the extent that it contributes to the air mass calculations.

---

[1] Drayson, S. R., Bartman, F. L., Kuhn, W. R. and Tallamraju, R., "Feasibility of Satellite Measurements of Stratospheric Minor Constituents by Solar Occultation," Technical Report 011023-2-T, High Altitude Engineering Laboratory, University of Michigan, Oct. 1973.

[2] Farmer, C. B., "Infrared Measurements of Stratospheric Composition," Can. J. Chem., 52, 1544 (1974).

[3] Chapman, S., "The Absorption and Dissociative or Ionizing Effect of Monochromatic Radiation in an Atmosphere on a Rotating Earth. II. Grazing Incidence,"Proc. Phys. Soc. (London) 43, 483 (1931).

[4] Kondratyev, K. Ya., "Radiation in the Atmosphere,", Academic Press, 1969.

One of the earliest tabulations of air mass which took refraction into account was performed by Bemporad,[5,6] and has been generally accepted by astronomers. This calculation was performed for a ground based observer and for zenith angles less than or equal to 90°. A closed form expression, approximating Bemporad's results to within 1.5% for zenith angles less than or equal to 87.5°, has been given by Nagel.[7]

Since air mass and refraction depend on the meteorological conditions of pressure, temperature, and humidity, as well as on wavelength, one would expect that the computed air mass and refraction would vary depending on the assumed atmospheric profile. Kasten[8,9] has studied the effect of density variations on relative air masses. Link[10,11,12] has published a large number of computations, the most comprehensive of which[12] tabulates the refraction, air mass, and related quantities for a variety of reference atmospheres, observer and source heights, and zenith angles (70 to 90°). The index of refraction used in the above calculations corresponds to light with a wavelength of 500 nm. Formulae for correcting the tabulated refraction are given for wavelengths between 400 and 700 nm.

None of the tables described above gives the refraction and the air mass for an observer above the surface and for zenith angles greater than 90°, the so-called *occultation* geometry. Several investigators have filled this gap by developing computer programs to calculate refraction and air mass under specific conditions.

---

[5] Bemporad, A., "Search for a New Empirical Formula for the Representation of the Variation of the Intensity of Solar Radiation with Zenith Angle," Rend. Acc. Lincei, 16, 66 (1907).

[6] List, R. J., "Smithsonian Meteorological Tables," 6th Revised Edition, 1949, Fifth Reprint, 1971, Smithsonian Publication 4014.

[7] Nagle, M. R., "Improved Approximation of Bemporad's Air Mass Function," Appl. Opt. 13, 1009 (1974).

[8] Kasten, F., "A New Table and Approximation Formula for the Relative Optical Airmass," Arch. Meteorol. Geophys. u. Bioklimatol. B14, 206 (1966).

[9] Kasten, F., "Effect of Variation of the Vertical Air Density Profile on the Relative Optical Air Mass," Arch. Meteorol. Geophys. u. Bioklimatol. B15, 62 (1967).

[10] Link, F. and Sekera, Z., "Dioptrische Tafeln der Erdatmosphare," Publikace Prazske, Hvezdarny Prague (1940)

[11] Link, F., "Extension des Tables Dioptriques De L'Atmosphere Terrestre," Prometheus, Prague, 1947.

[12] Link, F. and Neuzil, L., "Tables of Light Trajectories in the Terrestrial Atmosphere," Hermann, Paris, 1969.

Selby and McClatchey[13] have included refraction in their multi-purpose computer code LOWTRAN 2. This code is flexible enough to include almost any remote sensing geometry. They have defined six reference atmospheres with respect to pressure, temperature, and water vapor content. These reference atmospheres are used to compute the index of refraction as a function of altitude. They also took into account the deviation of the earth's surface from that of a sphere.

Watson and Yin[14] have studied the effects of refraction on solar occultation measurements of atmospheric gases. They have included anomalous dispersion,[15] and have computed the "infinite resolution" and instrumental line shapes for three $H_2O$ lines under a variety of atmospheric models. They formed the absorption coefficient in a line-by-line and layer-by-layer process, and therefore did not use a single layer approximation of the Curtis-Godson type.

Hymus and Lloyd,[16,17] and Miller[18] have computed the refraction and extinction of a near ultraviolet tangential ray. Since different processes govern the extinction of infrared and ultraviolet radiation, their results are not directly applicable to the IR remote sensing problem. Treve[19,20] has described a ray-tracing technique which can be used to compute the atmospheric refraction and air mass for a number of different source-observer geometries, and for a wavelength range of 0.2 to 20 micrometers.

[13] Selby, J. E. A., and McClatchey, R. A., "Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 2," Technical Report AFCRL-72-0745, Environmental Research Paper No. 427, 29 Dec 1972.

[14] Watson, J. K. G. and Yin, P. K. L., "The Effects of Refraction and Dispersion on High Altitude Measurements of Atmospheric Gases," Interim Report R.F. Project 3460, The Ohio State University Research Foundation, October 1973.

[15] Calfee, Robert F., "Anomalous Dispersion Calculated for Atmospheric Water Vapor," Appl. Opt. 7, 1652 (1968).

[16] Hymus, F. C., and Lloyd, K. H., "Extinction of a Tangential Ray, by Ray Tracing Through The Atmosphere," Technical Note HSA-152, Australian Defence Scientific Service, Weapons Research Establishment, May 1969.

[17] Lloyd, K. H., "Absorption of a grazing Ray Calculated by Ray Tracing," Planetary and Space Sciences 17, 1683 (1969).

[18] Miller, D. E., "Stratospheric Attenuation in the Near Ultraviolet," Proc. Roy. Soc. A 301, 57 (1967).

[19] Treve, Y. M., "New Values of the Optical Air Mass and the Refraction and Comparison with Previous Tables," Technical Report ESD-TDR-64-103, Mitre Corp. 1964.

[20] Treve, Y. M., "A New Method for the Calculation of the Atmospheric Refraction and the Optical Air Mass," Unpublished.

This report describes a series of air mass and refraction calculations, performed using a modified and extended version of Treve's ray-tracing technique. In an attempt to assess the accuracy of this technique several checks and comparisons were performed, and are also described in this report. Finally, tables giving the refraction, air mass, and Curtis-Godson effective temperature and pressure for both a summer and winter reference atmosphere are given in Appendix A. Tables in Appendix A cover an observer altitude range of 10 to 50 km in steps of 1 km. For each altitude, the zenith angles go from 80° to 89° in steps of 1.0°, and from 89° to the disc in steps of 0.2°. A statement listing for the computer program used to generate the tables in Appendix A is given in Appendix B.

## THEORY

The technique used for these calculations is basically that of Treve, with several modifications. A brief description of that technique will be given here with a somewhat more detailed description of the modifications. For more details, the reader is referred to the original descriptions.[19,20]

The model assumes a dry atmosphere, which is made up of spherically symmetric concentric shells, of known temperature and pressure. The atmosphere is assumed to be an ideal gas* in hydrostatic equilibrium. Together with the above assumptions, Snell's law can be used to derive the relation (see reference 13):

$$n_i \, r_i \sin z_i = \text{constant} \qquad (1)$$

where: $n_i$ is the phase refractive index of level i.
$r_i$ is the distance from the center of the earth to level i.
and $z_i$ is the angle of incidence with respect to the local normal.

The phase refractive index for dry air is given by reference 22:

$$(n_o - 1.0) \times 10^6 = 64.328 + 29498.1 \, (146 - 1/\lambda^2)^{-1} + 255.4 \, (41 - 1/\lambda^2)^{-1} \qquad (2)$$

for a temperature of 288.16K and a pressure of 101325.0 $N/m^2$. The wavelength $\lambda$ is given in micrometers. This expression for the index of refraction neglects the effects of anomalous dispersion as well as the contribution of water vapor. Anomalous dispersion has been studied by Calfee,[15] and Watson and Yin,[14] and has been shown[14] to be negligible for stratospheric conditions. The correction to the index of refractions for water vapor has been given by Owens[21] and has also been determined to be small for stratospheric conditions.

* Strictly speaking, this is not true (see Ref. 21), but to the degree of accuracy that we are interested in here, this approximation is a good one.

[21] Owens, James C., "Optical Refractive Index of Air: Dependence on Pressure, Temperature, and Composition," Appl. Opt. 6, 51 (1967).

[22] Edlen, B., "The Index of Refraction for Dry Air in the Visible and Infrared," Metrologia 2, 71 (1966).

The index of refraction for each shell was computed from Equation (2) assuming it to be a function of density alone. This dependence is given by the Lorentz-Lorenz relation:

$$\frac{1}{\rho}\left(\frac{n^2 - 1}{n^2 + 2}\right) = \text{constant} \qquad (3)$$

The density $\rho$ in this expression is obtained from the perfect gas law;

$$\rho = \frac{M\,P}{R^*T} \qquad (4)$$

where: M is the mean molecular weight of air = 28.966,

$R^*$ is the universal gas constant = 8314.39 J/K/kg-mole,

P is the pressure in $N/m^2$ ,

and T is the temperature in K.

For the calculations performed in this study, various temperature profiles were used and the corresponding pressure profiles were computed from the following relations derived [assuming an ideal gas - Reference (23)] from the hydrostatic equation:

$$\frac{P}{P_o} = \begin{cases} \left(\dfrac{T_o}{T_o + L(H - H_o)}\right)^{\frac{g_o M}{R^* L}} & L \neq 0 \\ \exp\left[-g_o M \dfrac{(H - H_o)}{R^* T}\right] & L = 0 \end{cases}$$

where: $P_o$ is the pressure at the base level,

H is the geopotential altitude,

$H_o$ is the geopotential altitude of base,

L is the gradient of temperature T with geopotential altitude H,

and $g_o$ is the acceleration of gravity - assumed to be a function of latitude, but not of altitude.

Since the conversion factors between geopotential and geometric altitude as well as the acceleration of gravity $g_o$ are functions of latitude, Treve's model was extended to cover all latitudes by using the appropriate expressions given by Lambert:[6,23]

[23] U.S. Standard Atmospheric Supplements, 1966.

$$Z_\phi(H) \equiv \frac{r_\phi H}{\frac{r_\phi g_\phi}{G} - H} \tag{6}$$

$$H_\phi(Z) \equiv \frac{r_\phi Z}{r_\phi + Z} \cdot \frac{g_\phi}{G} \tag{7}$$

where: $H_\phi$ = altitude in geopotential meters (m'),

$Z_\phi$ = altitude in geometric meters (m),

$G = 9.80665 (m)^2 (sec)^{-1} (m')^{-1}$ ,

$g_\phi$ = sea level acceleration of gravity at latitude $\phi$, $(m)(sec)^{-2}$,

$r_\phi$ = effective earth radius for latitude $\phi$, (m),

$$g_\phi = 9.806160 \left\{1.0 - 0.0026373 \cos 2\phi + 0.0000059 \cos^2 2\phi \right\} \tag{8}$$

and

$$r_\phi = \frac{2\, g_\phi}{3.085462 \times 10^{-6} + 2.27 \times 10^{-9} \cos 2\phi - 2 \times 10^{-12} \cos 4\phi} \tag{9}$$

This expression for the effective earth radius $r_\phi$ is not in general equal to the radius of the earth at the given latitude. It is rather a fictitious quantity, designed to satisfy boundary conditions and to take into account the non-spherical shape of the earth, its density distribution, and centripetal acceleration.[24]

The geocentric radius vector to the surface of the ellipsoid, which approximates the surface of the earth, is computed from the relationship:[24]

$$R(\phi) = \left\{ \frac{a^4 \cos^2\phi + b^4 \sin^2\phi}{a^2 \cos^2\phi + b^2 \sin^2\phi} \right\}^{1/2} \tag{10}$$

where: a = equatorial radius = 6378.160 km

b = polar radius = 6356.775 km

and $\phi$ = latitude

---

[24] Hankey, John R., "The American Ephemeris and Nautical Almanac 1974," U.S. Government Printing Office, 1971.

The earth is here approximated as a sphere, with an effective radius $R(\phi)$, which depends on latitude. Table 1 shows a comparison of $r_\phi$ and $R(\phi)$ as a function of latitude.

TABLE 1. COMPARISON OF $r_\phi$ AND $R(\phi)$

| Latitude | $R(\phi)$ km | $r_\phi$ km |
|---|---|---|
| 0.0 | 6378.160 | 6334.984 |
| 30.0 | 6372.847 | 6337.838 |
| 45.0 | 6367.512 | 6356.360 |
| 60.0 | 6362.155 | 6367.103 |
| 90.0 | 6356.775 | 6377.862 |

For the purposes of ray tracing, it is important to use the geometric radius vector $R(\phi)$ rather than the effective radius $r_\phi$. For altitudes of less than 100 km, the error in geopotential altitude H will be less than 0.01 km.

The relevant geometry for this type of calculation is shown in Figures 1 and 2. $H_{ob}$ is the altitude of the observer in geometric meters above the earth's surface. The astronomical zenith angle (z) is the angle between the local normal and an unrefracted ray from the source. The apparent zenith angle (z') is the angle of arrival of a refracted ray from the source. The refraction is the difference (z - z').

For the case that z' is greater than 90° (Figure 2) the grazing altitude (minimum height) is less than the observer height. As long as the density profile is monotonic decreasing with altitude, the minimum height for a refracted ray will always be greater than that for an unrefracted ray. From Figure 2 and simple geometric consideration, the minimum altitude for an unrefracted ray can be seen to be:

$$H_{min} = (R(\phi) + H_{ob}) \sin(\pi - z) - R(\phi) \qquad (11)$$

Thus the unrefracted minimum height is a function of observer height, zenith angle, and earth radius (which is a function of latitude).

The air mass, or the quantity of atmosphere traversed by the ray, is defined as:

$$\text{air mass} \equiv \frac{1}{2.15335 \times 10^{29}} \int_{\text{Observer}}^{\text{Source}} N \, ds \qquad (12)$$

where ds is the arclength along the refracted ray, and N is the number density (molecule/$m^3$). Since the source is outside the atmosphere, integration is cut off at the height of the highest level of the assumed

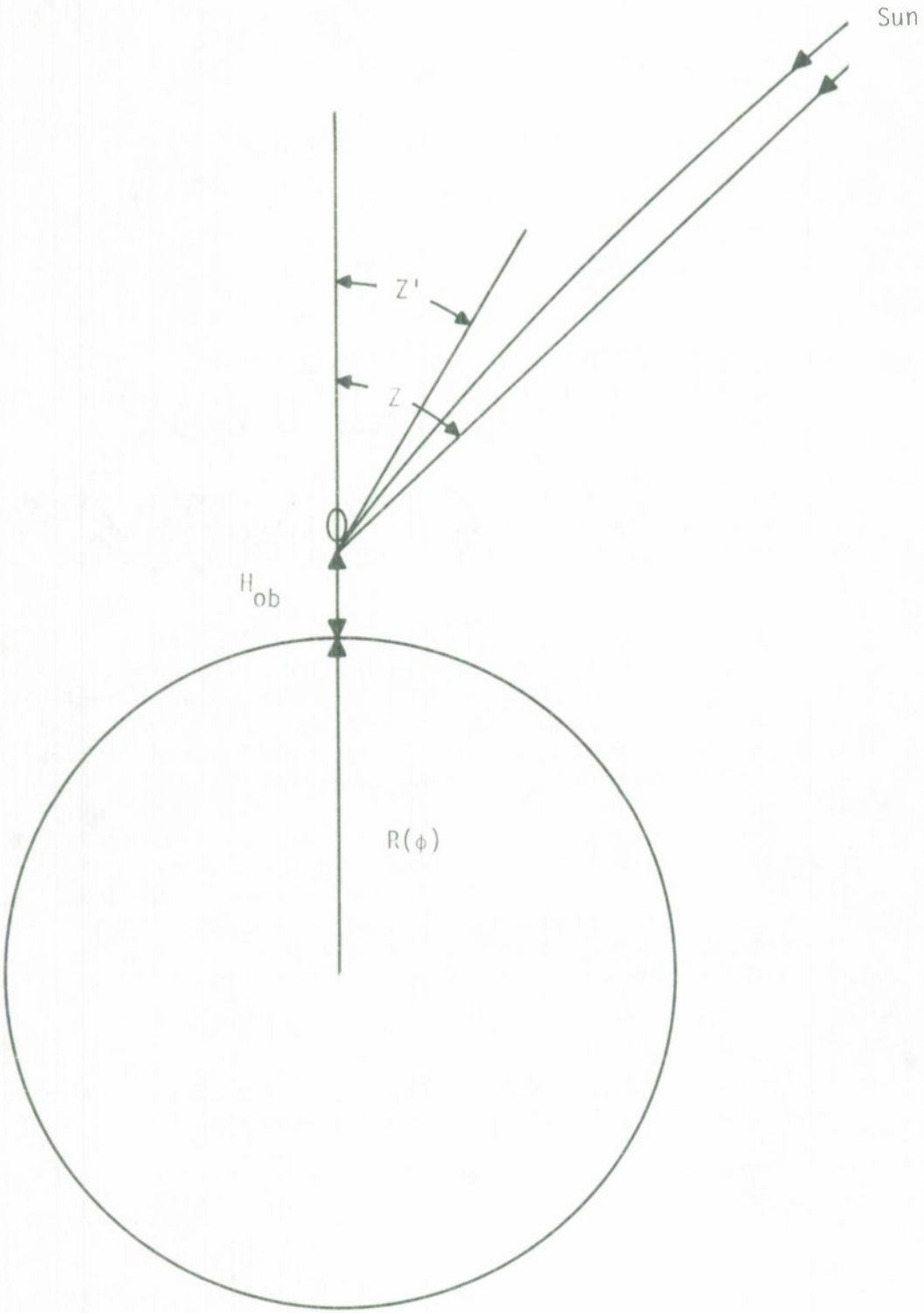


Figure 1. Refracted and unrefracted rays for zenith angles less than 90°.

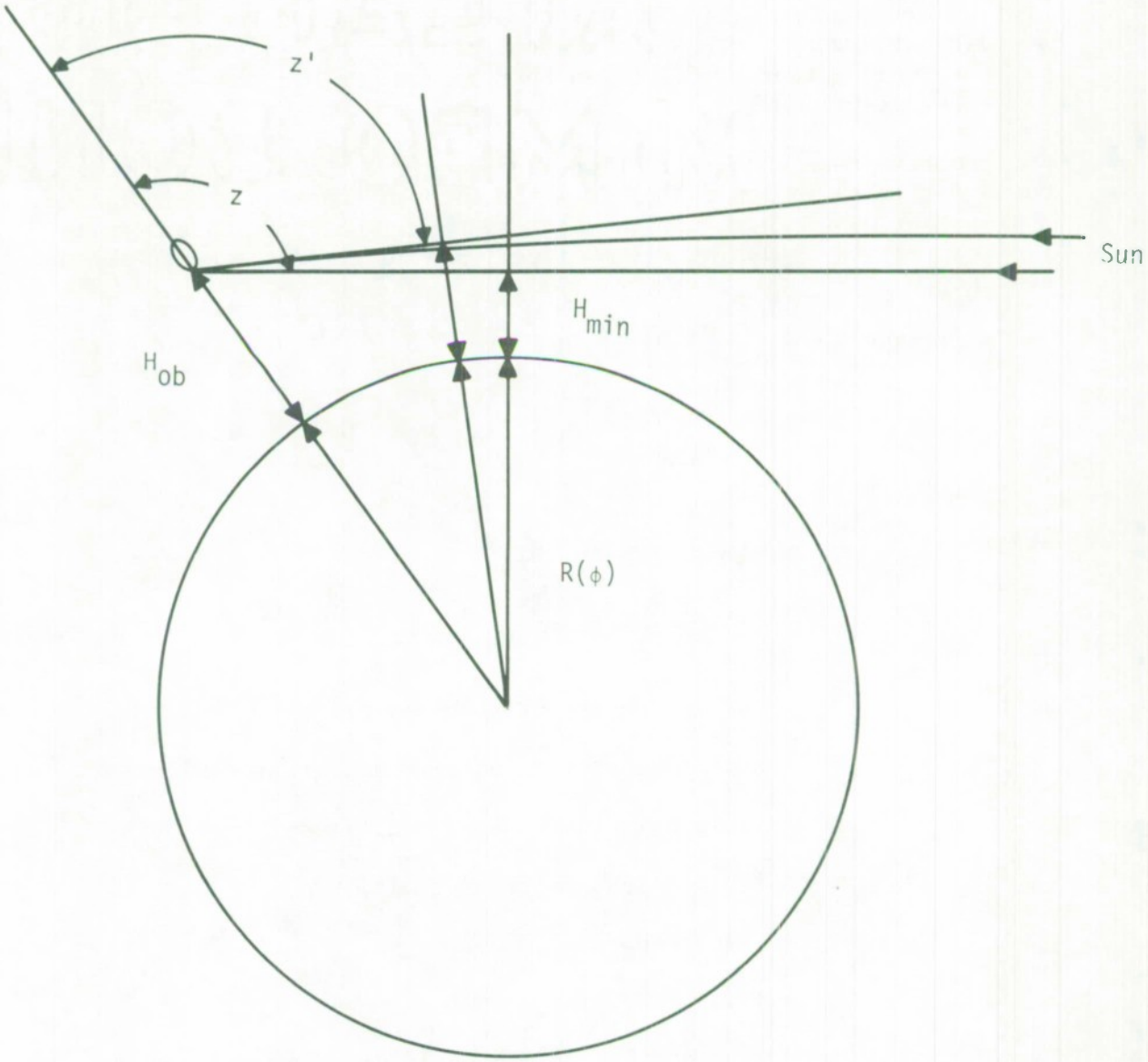


Figure 2. Refracted and unrefracted rays for zenith angles greater than 90°.

profile. For purposes of comparison, one standard air mass is here defined* as $2.15335 \times 10^{29}$ molecules/$m^2$. This corresponds to the numerical integration of Equation (12) with z = 0 between 0 and 100 km for the 1962 U.S. Standard Atmosphere. Thus the present calculation gives an absolute air mass, to which other profiles can be compared, rather than a relative air mass, as originally computed by Treve.

For the case when refraction is neglected, the air mass can be computed for large zenith angles from the Chapman function.[5] Simplified approximations to this function have been derived by Smith and Smith,[25] from expressions given by Fitzmaurice[26] and modified for a non-exponential atmosphere. They are given by:

$$\text{air mass} \equiv \frac{n_p H_p}{2.15335 \times 10^{29}} \, Ch(X_p, \chi_p) \equiv \frac{n_p H_p}{2.15335 \times 10^{29}} \, [(\pi/2) X_p]^{1/2} \, e^{(y^2)} \cdot \operatorname{erfc}(y) \qquad \chi_p \leq 90^\circ \tag{13}$$

$$\text{air mass} \equiv [(\pi/2) X_g]^{1/2} \, \frac{H_g}{2.15335 \times 10^{29}} \, [2 n_g - n_p e^{(y^2)} \cdot \operatorname{erfc}(y)] \qquad \chi_p > 90^\circ \tag{14}$$

Where $n_p$ = number density at observer height,

$n_g$ = number density at unrefracted grazing height $H_{min}$ (Eq. 11)

$H_p$ = scale height at observer altitude,

$H_g$ = scale height at grazing altitude,

$X_p = (R(\phi) + H_{ob})/H_p$,

$X_g = (R(\phi) + H_{min})/H_g$,

$\chi_p$ = astronomical zenith angle at observer,

$y = (X_p/2)^{1/2} \, |\cos \chi_p|$

and $\operatorname{erfc}(y) = 1.0 - \operatorname{erf}(y)$ .

---

* Note: The term air mass does not have a standard definition. Before comparing the values in this report to other work, the definitions must be compatible.

[25] Smith, F. L. III, and Smith, Cody, "Numerical Evaluation of Chapman's Grazing Incidence Integral ch(X,χ)," J. Geophys. Res. 77, 3592 (1972).

[26] Fitzmaurice, John A., "Simplification of the Chapman Function for Atmospheric Attenuation," App. Opt. 3, 640 (1964).

These approximations take into account the fact that the air mass is most sensitive to the scale height and density near the observer for zenith angles less than or equal to 90°.[27] For zenith angles greater than 90°, the air mass is most sensitive to the scale height near the grazing altitude.[27] For X = 800 this approximation is expected to be better than 1%.

In order to compute the infrared absorption for a non-homogeneous ray path, such as used in this study, one must evaluate the absorption coefficient at each wavelength for each layer. This turns out to be a very time consuming computation.

An alternative to this procedure is to define an "equivalent" homogeneous path at an effective pressure P(eff) and effective temperature T(eff), such that the calculated absorption is the same as that for the non-homogeneous case.[28] For a uniformly mixed gas such as $CO_2$, Sasamori has suggested defining these quantities as:

$$P(\text{eff}) \equiv \int_{\text{Observer}}^{\text{Source}} P \, dm \Big/ \int_{\text{Observer}}^{\text{Source}} dm$$

$$T(\text{eff}) \equiv \int_{\text{Observer}}^{\text{Source}} T \, dm \Big/ \int_{\text{Observer}}^{\text{Source}} dm \qquad (15)$$

Where $\int_{\text{Ob}}^{\text{Source}} dm$ gives the total integrated absorber mass, along the ray path.[Ob] Thus the effective temperature* and pressure are essentially mass weighted average values.

For the case that the gas in question is not uniformly distributed, the varying mixing ratios should be included inside the integrals of Equation (15). However, for the case that Z > 90°, the air mass increases rapidly with a small change in zenith angle. Thus for this case, the effective pressure and temperature are most sensitive to the mixing ratio at the tangent height, since most of the air mass is located within a few kilometers of the tangent height.

* Strictly speaking, the effective temperature depends on the intensities of the spectral lines.[29] For stratospheric occultation geometries, the temperature variation along a tangent ray will not be large. In this case, the mass weighted average temperature will be a good approximation to the effective temperature.

[27] Swider, William Jr., "The Determination of the Optical Depth at Large Solar Zenith Distances", Planet. Space Sci. 12, 761 (1964).

[28] Sasamori, T., "The Temperature Effect on the Absorption of the 15μ $CO_2$ Band," Sci. Rept. Tohoku Univ. Fifth Series 11, No. 3.

[29] Plass, G. N., "Spectral Band Absorptance for Atmospheric Slant Paths," Appl. Opt. 2, 515 (1963).

## VERIFICATION OF MODEL

In order to verify the numerical integration of the ray tracing technique and the above approximations to the Chapman function, the following calculation was performed. An isothermal exponential atmosphere ($T = 272.344°K$) was chosen so that $X_p$ would be 800.00 for an observer at 10 km. A ray trace was performed on this atmosphere ignoring the effects of refraction ($n_1 = 1.000000000000$). The Chapman function derived from the numerically integrated ray traced air mass is compared to the value calculated by Wilkes.[30] The value for the Smith and Smith approximation is also compared to the Wilkes value. Table 2 shows the results of these comparisons. It can be seen that the Smith and Smith approximation agrees well with the Wilkes value, which is good to three decimal places.[30] In all cases, the agreement is better than 1/2%. The ray tracing technique gives better results for larger zenith angles, but in all cases, the difference is less than 1/2%. This agreement gives an estimate of the error associated with the numerical techniques used to approximate the ray trace air mass integral.

In an attempt to verify the accuracy of this technique for a non-exponential atmosphere, the air mass for a ground based observer was computed for a series of zenith angles, assuming the 1962 U.S. Standard Atmosphere (58 layers between 0 and 100 km). For comparison, the same calculation was performed for the case of no refraction. The results are tabulated in Table 3. There it can be seen that inclusion of refractive effects can increase the computed air mass by up to about 10% for $z = 90°$. This is probably an upper limit since water vapor, which was neglected in computing the effects of refraction, would be expected to decrease the index of refraction[21] and hence the calculated air mass. For comparison, values obtained by other investigators are also listed in Table 3. The values given by Treve appear to be the same as those given in the Handbook of Geophysics and Space Environments,[31] although no reference is given. The difference between the values calculated in this report and those of Treve[19] are most likely caused by the fact that Treve used the 1959 U.S. Standard Atmosphere, which differs slightly from the 1962 U.S. Standard Atmosphere above 20 km.

The importance of the assumed profile to such refraction and air mass calculations has long been recognized.[9,12] Table 4 shows a comparison of air mass for six different reference atmospheres. The 1962 U.S. Standard Atmosphere (58 layers, 0 to 100 km) was taken from Reference 32, and the other five were taken from Reference 33. The air mass depends on wavelength, but this effect is small[12] compared to the effect of different profiles.

[30] Wilkes, M. V., "A Table of Chapman's Grazing Incidence Integral $ch(X,\chi)$, Proc. Phys. Soc. London, B67, 304 (1954).

[31] Valley, S. L. "Handbook of Geophysics and Space Environment,"

[32] U.S. Standard Atmosphere 1962.

[33] McClatchey, R. A., Fenn, R. W., Selby, J. E. A., Volz, F. E., and Garing, J. S., "Optical Properties of the Atmosphere (Third Edition)," Technical Report AFCRL-72-0497, Environmental Research Paper No. 411, 24 August 1972.

TABLE 2. COMPARISON OF CHAPMAN FUNCTION EVALUATED AT SEVERAL ZENITH ANGLES

| Z(°) | WILKE | SMITH AND SMITH | % DIFFERENCE | RAY TRACE | % DIFFERENCE |
|---|---|---|---|---|---|
| 84 | 8.732 | 8.7001 | .36 | 8.7705 | -.44 |
| 85 | 10.144 | 10.1096 | .34 | 10.186 | -.42 |
| 86 | 12.051 | 12.0096 | .34 | 12.1007 | -.41 |
| 87 | 14.730 | 14.6807 | .33 | 14.7899 | -.37 |
| 88 | 18.686 | 18.6243 | .33 | 18.7505 | -.35 |
| 90 | 35.466 | 35.448 | .15 | 35.5345 | -.19 |
| 91 | 55.211 | 55.0456 | .30 | 55.2560 | -.08 |
| 92 | 96.753 | 96.4727 | .29 | 96.7005 | -.05 |

$$\% \text{ DIFFERENCE} = \frac{\text{WILKE} - \text{CHAPMAN FUNCTION (CALC.)}}{\text{WILKE}}$$

TABLE 3. AIR MASS FOR A GROUND BASED OBSERVER

(WAVELENGTH = 550 nm)

| APPARENT ZENITH ANGLE* | REFRACTION* | NO REFRACTION* | HANDBOOK OF GEOPHYSICS** | TREVE** | BEMPORAD** | LINK** |
|---|---|---|---|---|---|---|
| 81.0 | 6.156 | 6.125 | - | - | 6.18 | - |
| 82.0 | 6.856 | 6.814 | - | - | 6.88 | - |
| 83.0 | 7.729 | 7.673 | - | - | 7.77 | 7.71 |
| 84.0 | 8.847 | 8.765 | - | - | 8.90 | - |
| 85.0 | 10.316 | 10.193 | - | - | 10.39 | 10.27 |
| 86.0 | 12.316 | 12.122 | 12.32 | 12.32 | 12.44 | 12.26 |
| 87.0 | 15.163 | 14.829 | 15.17 | - | 15.36 | 15.09 |
| 88.0 | 19.432 | 18.809 | 19.44 | - | 19.79 | 19.35 |
| 89.0 | 26.265 | 24.982 | 26.27 | 26.27 | 26.96 | 26.35 |
| 90.0 | 38.104 | 35.135 | 38.11 | 38.11 | - | 38.58 |

*Assumes a 1962 U.S. Standard Atmosphere

**Atmospheric profile is not the same or is not given.

TABLE 4. AIR MASS* FOR A GROUND BASED OBSERVER

(WAVELENGTH = 550 nm)

| APPARENT ZENITH ANGLE | 1962 U.S. STANDARD | MIDLATITUDE SUMMER | MIDLATITUDE WINTER | SUBARCTIC SUMMER | SUBARCTIC WINTER | TROPICAL |
|---|---|---|---|---|---|---|
| 81.0 | 6.156 | 6.150 | 6.192 | 6.117 | 6.153 | 6.157 |
| 82.0 | 6.856 | 6.847 | 6.899 | 6.812 | 6.857 | 6.854 |
| 83.0 | 7.729 | 7.717 | 7.781 | 7.680 | 7.739 | 7.723 |
| 84.0 | 8.847 | 8.827 | 8.912 | 8.790 | 8.871 | 8.833 |
| 85.0 | 10.316 | 10.286 | 10.401 | 10.250 | 10.366 | 10.288 |
| 86.0 | 12.316 | 12.269 | 12.437 | 12.239 | 12.417 | 12.264 |
| 87.0 | 15.163 | 15.080 | 15.349 | 15.068 | 15.369 | 15.059 |
| 88.0 | 19.432 | 19.282 | 19.756 | 19.319 | 19.883 | 19.220 |
| 89.0 | 26.265 | 25.986 | 26.935 | 26.147 | 27.387 | 25.809 |
| 90.0 | 38.104 | 37.634 | 39.846 | 38.098 | 41.650 | 37.070 |

*1.0 Air Mass $\equiv 2.15335 \times 10^{29}$ Molecules/$m^2$

## RESULTS

It is a well known fact that the air mass increases rapidly with zenith angle for zenith angles greater than 90°. Fig. 3 shows quantitatively how rapidly the air mass increases for an observer at 45 km. It is seen that the air mass changes by 3 orders of magnitude over the range z = 90 to z = 96 degrees. Since the sun is not a point source, it can make a significant difference in the computed air mass whether a grazing ray comes from the top of the sun or from the bottom. This can be seen from Fig. 3 where the sun's finite angular diameter is shown for comparison. If the field of view of the spectrometer is constrained only to point somewhere on the sun, the resulting uncertainty in air mass can be large. This uncertainty is shown in Table 5 where the air mass and effective pressure are seen to vary by a factor of two over a range of 0.4° (the sun's angular diameter is about 0.5°). This effect has nothing to do with refraction, but is mentioned in passing because it can sometimes (depending on the experiment) be the major source of error, and errors caused by neglecting refractive effects must be compared with it.

As an example of the errors introduced by neglecting refraction, Fig. 4 was computed for the above example. The air mass was computed both including refraction (Fig. 3) and neglecting refraction (n = 1.0000000000). The ordinate of Fig. 4 is proportional to the percentage error, and the upper abscissa is the corresponding minimum height (including refraction). The observer altitude of 45 km was chosen as typical of the state of the art for high altitude balloon packages. It is seen in Fig. 4 that errors introduced by neglecting refraction (for the above geometry) are less than 10% when the minimum altitude is greater than 20 km. For minimum altitudes less than 20 km, the errors become rapidly larger. The result of neglecting refraction is to underestimate the minimum altitude, and therefore to overestimate the air mass. For a realistic atmosphere (where the density is a monotonic decreasing function with altitude), the minimum altitude computed from Equation 11 will always be less than the minimum altitude obtained by ray tracing. This causes the density at the minimum altitude ($n_g$) to be overestimated, and this is the dominant term in the approximation to the Chapman function.

Since Equation 11 shows the minimum height to be a function of observer height (as well as a number of other variables), one might expect that the error in minimum height would be a function of observer altitude. Fig. 5 shows this error for 3 different observer altitudes. Fig. 6 shows the corresponding errors in the computed air masses. It is thus seen that for a given grazing altitude, the above errors are larger for observers at higher altitudes. By extending this concept to an observer in a satellite at 200 km, the errors become quite significant as seen in Fig. 7.

TABLE 5

EXAMPLE OF POINTING ERROR

OBSERVER ALTITUDE = 45 KM

MIDLATITUDE WINTER MODEL

| ZENITH ANGLE | AIR MASS | EFFECTIVE PRESSURE ($N/m^2$) |
|---|---|---|
| 95.8° | 15.98 | 14238.72 |
| 96.0° | 23.49 | 20909.61 |
| 96.2° | 33.54 | 30301.77 |

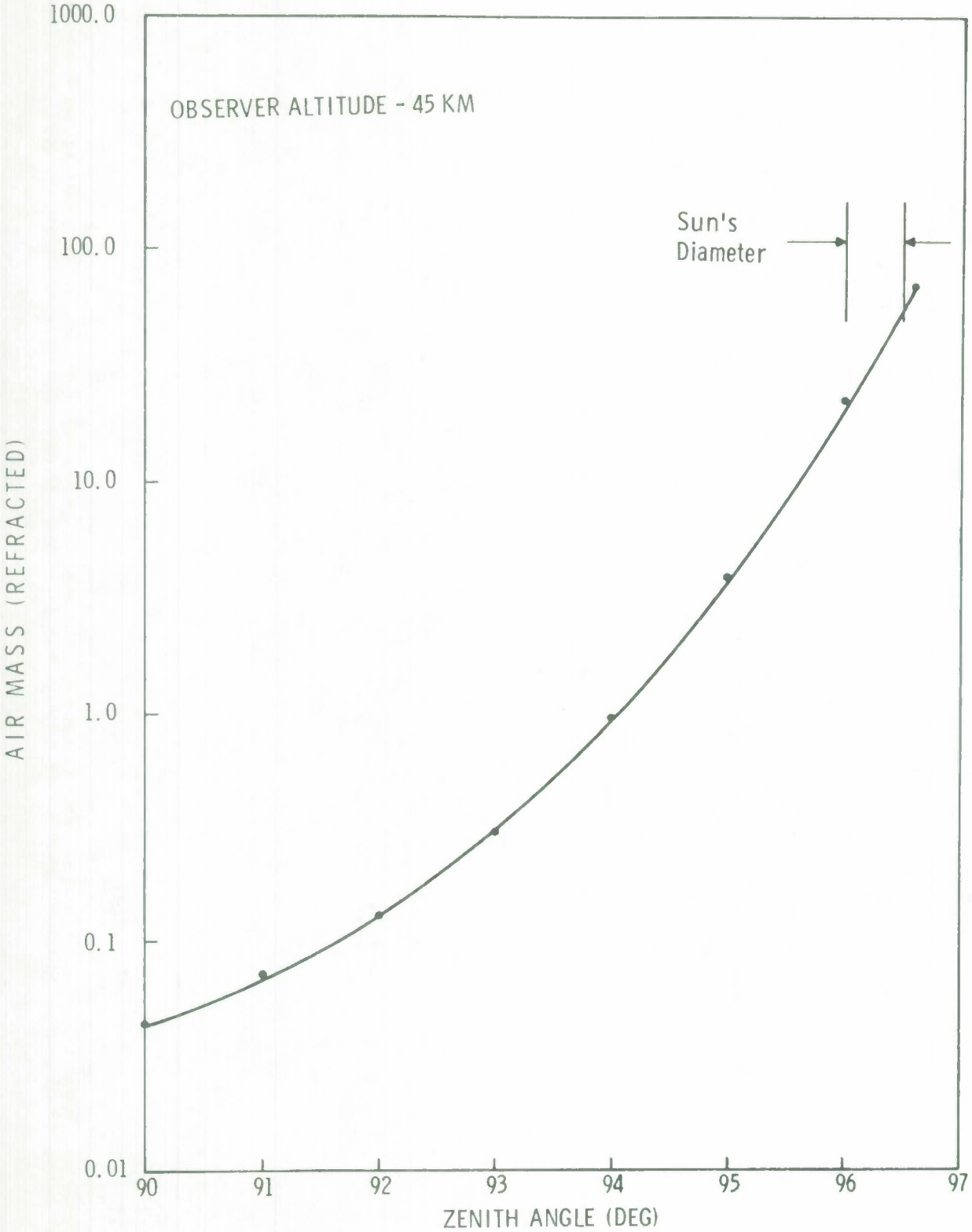


Figure 3. Air mass vs zenith angle for an observer at 45 km.

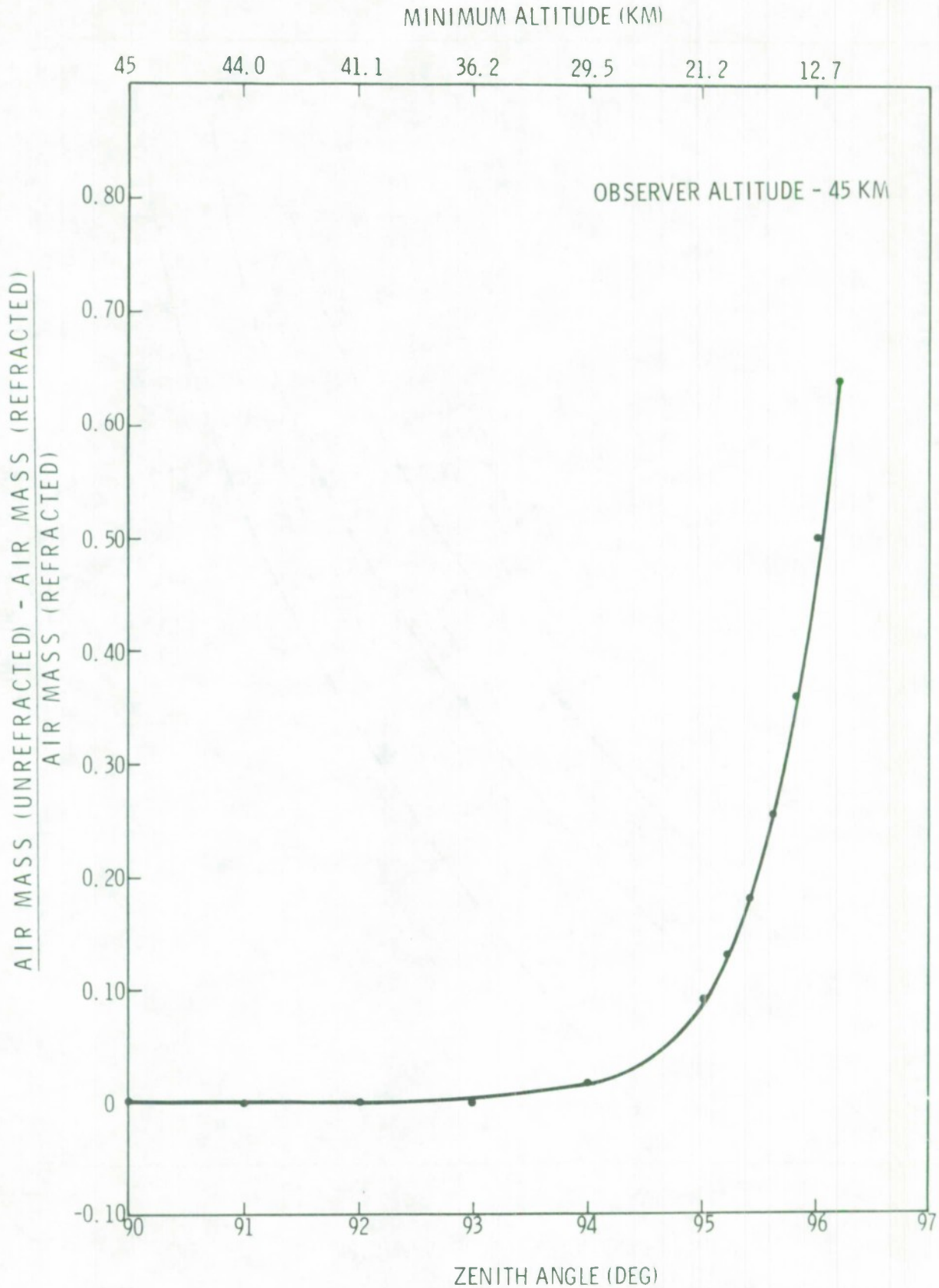


Figure 4. Air mass error due to neglecting refraction for an observer at 45 km.

Figure 5. Error in tangent height due to refraction for observers at 25, 35, and 45 km.

Figure 6. Error in air mass due to refraction for observers at 25, 35, and 45 km.

Figure 7. Error in air mass due to refraction for an observer at 200 km.

Several investigators[9,12] have shown that the computed air mass depends on the atmospheric profile used. Fig. 8 shows the errors that would result for an observer at 45 km, if a winter profile were used to interpret summer measurements. Although the errors are not large (compared with, for example, pointing error), they can be easily reduced by using the atmospheric profile obtained on the day of the measurement.

The sensitivity of the computed air mass with respect to wavelength errors was investigated by computing the air mass for an observer at 45 km, at both 5 and 0.5 micrometers. Even for the minimum altitude of less than 10 km, the difference in computed air mass was less than 0.4%, and the difference in minimum altitude was 19.4 meters. That the air mass is not a sensitive function to small changes in refractive index is consistent with the neglect of the contribution of water vapor and anomalous dispersion to the index of refraction.

Differential refraction,[16,18] which has been studied by several investigators, has not been included here. It is expected to be small for balloon altitudes, but might possibly be significant at satellite altitudes.

## SUMMARY

Effects due to refraction have been investigated for several representative occultation geometries. Errors in the computed air mass and effective pressure, associated with neglecting refraction are shown to be a function of observer altitude. For observers in high-altitude aircraft, the errors introduced by neglecting refraction are probably less than those introduced by uncertainties in solar pointing. For observations from high altitude balloons or satellites, refraction should definitely be taken into account when the minimum altitude is less than 20 km. For all cases, accurate knowledge of the astronomical zenith angle is a necessity.

For interpretation of infrared transmission spectra, where the absorption is pressure dependent, errors in minimum altitude are doubly important. Not only will the air mass be overestimated but also the effective pressure will be overestimated. By neglecting refraction, the mixing ratios for minor constituents in the lower stratosphere would tend to be underestimated.

## ACKNOWLEDGEMENTS

The authors are indebted to Yvon Treve, whose model served as a basis for the computations performed here, and who generously supplied unpublished material. R. Gast and R. Harter of AFCRL who supplied a FORTRAN program based on Treve's model are also gratefully acknowledged.

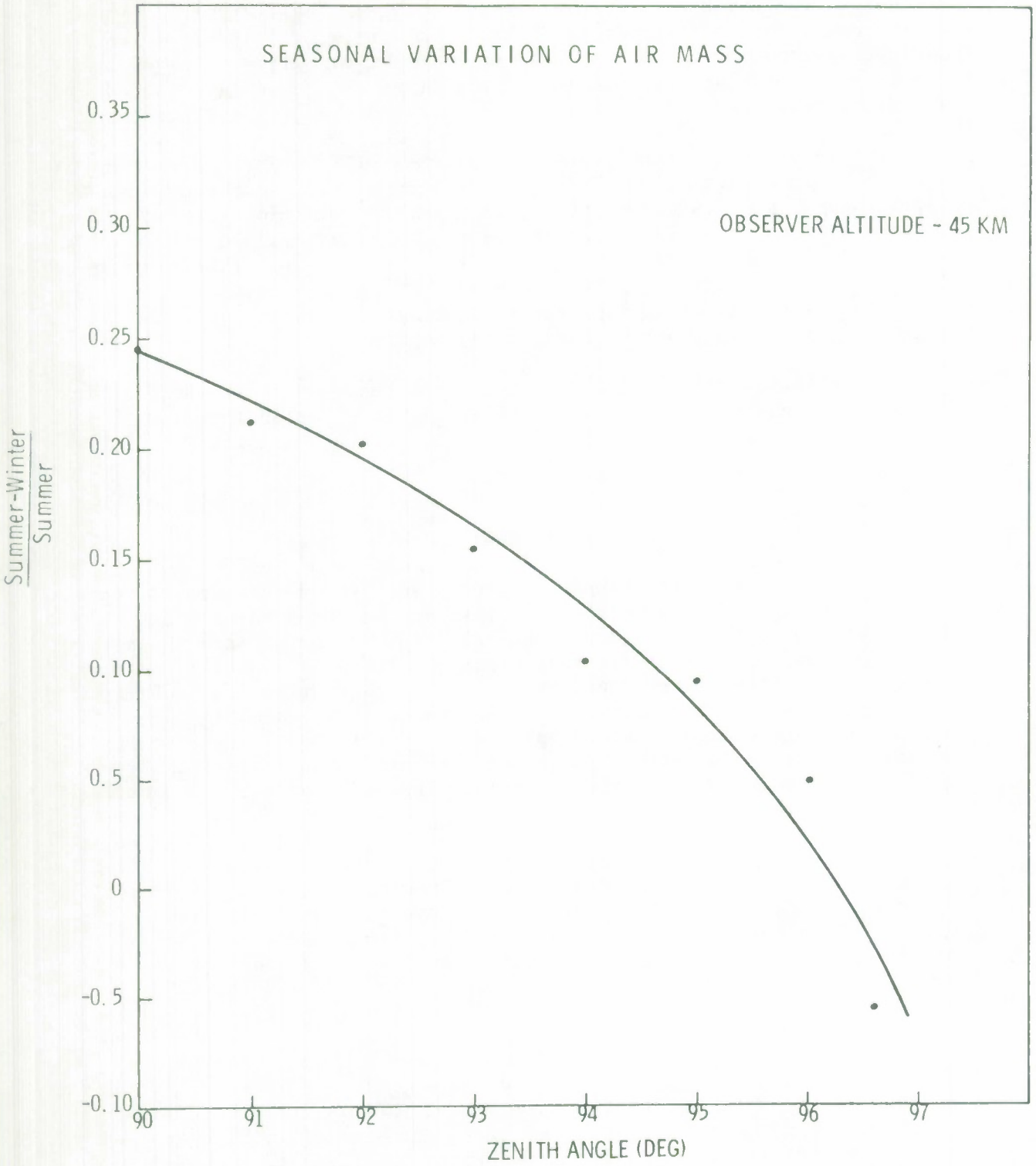


Figure 8. Error in air mass due to use of the wrong atmospheric profile.

## APPENDIX A. AIR MASS TABLES

In order to present the results of this research in a form that would be convenient for other investigators, a series of refraction air mass tables was generated. Two atmospheric models were assumed: a midlatitude summer and a midlatitude winter. Other models could have easily been included, but these two were judged adequate for most applications.

The temperature profiles and the surface pressures are those of McClatchey *et al.*[33] The pressure profile is calculated from the temperature profile and the surface pressure by integrating the hydrostatic equation. These calculated pressures agree to within 2% of those of McClatchey, up to 30 km. The layer thickness is 250 m up to 40 km, 1000 m up to 70 km, and 5000 m up to 100 km. There are thus 197 layers in these model atmospheres.

Tables are given for observer altitudes between 10 and 50 km, in steps of 1 km. For each observer altitude, the zenith angles range from 80° to 89° in steps of 1°, and from 89° to the solid earth in steps of 0.2°. A single wavelength of 5.0 micrometers was chosen, since the air mass is not strongly wavelength dependent.

The first column, labeled APP. Z, represents the angle of arrival (deg) with respect to the local normal. Columns 2 and 3 represent the observer height (m) and the highest level (m) included in the atmospheric profile respectively. The minimum height (m) in column 4 represents the observer altitude for z less than or equal to 90°, and the tangent altitude for a grazing ray, for z greater than 90°. Columns 5 and 6 give the air mass from the Smith and Smith approximation to the Chapman function, and the ray tracing numerical integration, respectively. In these two columns, 1.0 air masses is defined as $2.15335 \times 10^{29}$ molecules/$m^2$. HDIFF (m) represents the difference between the ray traced minimum altitude, and that obtained from Equation (11), neglecting refraction. Columns 8 and 9 give the refraction (deg) and the astronomical zenith angle (deg). Columns 1 and 8 add to give column 9. The single layer effective pressure P ($N/m^2$) and temperature T (°K) for a uniformly mixed gas are given in columns 10 and 11 respectively. Column 12 gives the pressure at the tangent or minimum altitude $P_{tan}$ ($N/m^3$).

AIR MASS TABLES FOR SUMMER PROFILE

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 10000.0 | 99000.0 | 10000.0 | 1.714 | 1.728 | .0 | .03251 | 81.03 | 14609.79 | 222.93 | 28279.63 |
| 82.000 | 10000.0 | 99000.0 | 10000.0 | 1.909 | 1.926 | .0 | .03630 | 82.04 | 14668.30 | 222.93 | 28279.63 |
| 83.000 | 10000.0 | 99000.0 | 10000.0 | 2.154 | 2.173 | .0 | .04102 | 83.04 | 14748.39 | 222.92 | 28279.63 |
| 84.000 | 10000.0 | 99000.0 | 10000.0 | 2.467 | 2.489 | .0 | .04704 | 84.05 | 14861.45 | 222.93 | 28279.63 |
| 85.000 | 10000.0 | 99000.0 | 10000.0 | 2.879 | 2.906 | .0 | .05493 | 85.05 | 15027.01 | 222.95 | 28279.63 |
| 86.000 | 10000.0 | 99000.0 | 10000.0 | 3.445 | 3.477 | .0 | .06565 | 86.07 | 15260.19 | 222.99 | 28279.63 |
| 87.000 | 10000.0 | 99000.0 | 10000.0 | 4.257 | 4.296 | .0 | .08086 | 87.08 | 15688.00 | 223.13 | 28279.63 |
| 88.000 | 10000.0 | 99000.0 | 10000.0 | 5.499 | 5.538 | .0 | .10355 | 88.10 | 16387.00 | 223.48 | 28279.63 |
| 89.200 | 10000.0 | 99000.0 | 10000.0 | 8.138 | 8.120 | .0 | .14958 | 89.35 | 18056.30 | 224.78 | 28279.63 |
| 89.400 | 10000.0 | 99000.0 | 10000.0 | 8.796 | 8.747 | .0 | .16074 | 89.56 | 18493.36 | 225.19 | 28279.63 |
| 89.600 | 10000.0 | 99000.0 | 10000.0 | 9.550 | 9.456 | .0 | .17352 | 89.77 | 18998.53 | 225.69 | 28279.63 |
| 89.800 | 10000.0 | 99000.0 | 10000.0 | 10.421 | 10.261 | .0 | .18837 | 89.99 | 19582.40 | 226.28 | 28279.63 |
| 90.000 | 10000.0 | 99000.0 | 10000.0 | 11.388 | 11.184 | 41.1 | .20579 | 90.21 | 20250.22 | 226.95 | 28379.44 |
| 90.200 | 10000.0 | 99000.0 | 9960.9 | 12.400 | 12.096 | 111.7 | .19455 | 90.39 | 20976.66 | 228.21 | 28823.86 |
| 90.400 | 10000.0 | 99000.0 | 9842.2 | 13.573 | 13.131 | 175.5 | .18584 | 90.59 | 21735.64 | 229.89 | 29577.93 |
| 90.600 | 10000.0 | 99000.0 | 9636.9 | 15.330 | 14.539 | 306.1 | .23003 | 90.83 | 22795.24 | 231.89 | 31017.23 |
| 90.800 | 10000.0 | 99000.0 | 9338.8 | 17.069 | 16.194 | 460.5 | .27464 | 91.07 | 24076.00 | 233.36 | 33071.72 |
| 91.000 | 10000.0 | 99000.0 | 8956.9 | 19.204 | 17.956 | 562.0 | .28550 | 91.29 | 25753.65 | 234.73 | 35355.40 |
| 91.200 | 10000.0 | 99000.0 | 8500.3 | 21.617 | 20.027 | 757.9 | .32457 | 91.52 | 27271.96 | 238.03 | 38669.13 |
| 91.400 | 10000.0 | 99000.0 | 7944.7 | 24.673 | 22.412 | 884.3 | .33970 | 91.74 | 29691.44 | 239.99 | 42378.98 |
| 91.600 | 10000.0 | 99000.0 | 7313.3 | 28.759 | 25.326 | 1215.8 | .40451 | 92.00 | 32098.50 | 244.11 | 48113.31 |
| 91.800 | 10000.0 | 99000.0 | 6593.4 | 32.959 | 28.529 | 1427.4 | .43097 | 92.23 | 35165.07 | 248.03 | 54251.98 |
| 92.000 | 10000.0 | 99000.0 | 5778.5 | 37.412 | 32.168 | 1534.7 | .43452 | 92.43 | 38648.21 | 251.84 | 60949.92 |
| 92.200 | 10000.0 | 99000.0 | 4862.7 | 44.393 | 36.984 | 1991.2 | .50927 | 92.71 | 43286.50 | 256.07 | 72186.35 |
| 92.400 | 10000.0 | 99000.0 | 3857.2 | 53.531 | 42.552 | 2450.4 | .57467 | 92.97 | 48662.43 | 261.13 | 85968.41 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 11000.0 | 99000.0 | 11000.0 | 1.482 | 1.495 | .0 | .02887 | 81.03 | 12629.92 | 220.97 | 24440.97 |
| 82.000 | 11000.0 | 99000.0 | 11000.0 | 1.652 | 1.666 | .0 | .03225 | 82.03 | 12680.62 | 220.95 | 24440.97 |
| 83.000 | 11000.0 | 99000.0 | 11000.0 | 1.863 | 1.880 | .0 | .03645 | 83.04 | 12750.01 | 220.92 | 24440.97 |
| 84.000 | 11000.0 | 99000.0 | 11000.0 | 2.135 | 2.153 | .0 | .04181 | 84.04 | 12847.96 | 220.89 | 24440.97 |
| 85.000 | 11000.0 | 99000.0 | 11000.0 | 2.493 | 2.515 | .0 | .04885 | 85.05 | 12991.37 | 220.85 | 24440.97 |
| 86.000 | 11000.0 | 99000.0 | 11000.0 | 2.984 | 3.010 | .0 | .05844 | 86.06 | 13210.67 | 220.81 | 24440.97 |
| 87.000 | 11000.0 | 99000.0 | 11000.0 | 3.690 | 3.720 | .0 | .07207 | 87.07 | 13563.94 | 220.80 | 24440.97 |
| 88.000 | 11000.0 | 99000.0 | 11000.0 | 4.771 | 4.800 | .0 | .09250 | 88.09 | 14169.65 | 220.89 | 24440.97 |
| 89.200 | 11000.0 | 99000.0 | 11000.0 | 7.074 | 7.056 | .0 | .13408 | 89.33 | 15617.87 | 221.58 | 24440.97 |
| 89.400 | 11000.0 | 99000.0 | 11000.0 | 7.648 | 7.605 | .0 | .14415 | 89.54 | 15997.48 | 221.84 | 24440.97 |
| 89.600 | 11000.0 | 99000.0 | 11000.0 | 8.305 | 8.227 | .0 | .15567 | 89.76 | 16436.51 | 222.18 | 24440.97 |
| 89.800 | 11000.0 | 99000.0 | 11000.0 | 9.065 | 8.935 | .0 | .16905 | 89.97 | 16944.19 | 222.60 | 24440.97 |
| 90.000 | 11000.0 | 99000.0 | 11000.0 | 9.899 | 9.747 | 33.2 | .18478 | 90.18 | 17525.08 | 223.09 | 24489.53 |
| 90.200 | 11000.0 | 99000.0 | 10960.2 | 10.613 | 10.577 | 99.4 | .17848 | 90.38 | 18176.57 | 224.13 | 24869.81 |
| 90.400 | 11000.0 | 99000.0 | 10840.9 | 11.879 | 11.522 | 161.5 | .17450 | 90.57 | 18852.11 | 225.54 | 25537.79 |
| 90.600 | 11000.0 | 99000.0 | 10635.6 | 13.401 | 12.763 | 277.5 | .21288 | 90.81 | 19773.94 | 227.16 | 26762.12 |
| 90.800 | 11000.0 | 99000.0 | 10339.7 | 14.839 | 14.225 | 414.2 | .25169 | 91.05 | 20895.40 | 228.34 | 28513.41 |
| 91.000 | 11000.0 | 99000.0 | 9960.8 | 16.675 | 15.788 | 497.8 | .25785 | 91.26 | 22376.70 | 229.46 | 30443.91 |
| 91.200 | 11000.0 | 99000.0 | 9509.5 | 18.781 | 17.592 | 666.6 | .29013 | 91.49 | 23702.79 | 232.91 | 33233.24 |
| 91.400 | 11000.0 | 99000.0 | 8957.6 | 21.606 | 19.773 | 814.8 | .31517 | 91.72 | 25861.07 | 234.75 | 36610.86 |
| 91.600 | 11000.0 | 99000.0 | 8328.3 | 24.993 | 22.359 | 1096.8 | .36962 | 91.97 | 27992.61 | 238.44 | 41418.38 |
| 91.800 | 11000.0 | 99000.0 | 7616.9 | 28.439 | 25.158 | 1248.1 | .38349 | 92.18 | 30700.40 | 242.39 | 46431.48 |
| 92.000 | 11000.0 | 99000.0 | 6806.7 | 32.554 | 28.484 | 1387.6 | .39697 | 92.40 | 33824.46 | 246.08 | 52520.35 |
| 92.200 | 11000.0 | 99000.0 | 5899.2 | 39.160 | 32.798 | 1822.8 | .46983 | 92.67 | 37954.90 | 250.28 | 62240.28 |
| 92.400 | 11000.0 | 99000.0 | 4902.8 | 46.542 | 37.798 | 2258.1 | .53295 | 92.93 | 42756.22 | 255.24 | 74176.91 |
| 92.600 | 11000.0 | 99000.0 | 3816.3 | 55.890 | 43.570 | 2644.3 | .58102 | 93.18 | 48361.11 | 260.95 | 88380.39 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 12000.0 | 99000.0 | 12000.0 | 1.277 | 1.288 | .0 | .02568 | 81.03 | 10875.41 | 219.63 | 21044.10 |
| 82.000 | 12000.0 | 99000.0 | 12000.0 | 1.423 | 1.436 | .0 | .02869 | 82.03 | 10919.25 | 219.59 | 21044.10 |
| 83.000 | 12000.0 | 99000.0 | 12000.0 | 1.606 | 1.620 | .0 | .03244 | 83.03 | 10979.24 | 219.54 | 21044.10 |
| 84.000 | 12000.0 | 99000.0 | 12000.0 | 1.840 | 1.856 | .0 | .03723 | 84.04 | 11063.92 | 219.47 | 21044.10 |
| 85.000 | 12000.0 | 99000.0 | 12000.0 | 2.149 | 2.167 | .0 | .04353 | 85.04 | 11187.89 | 219.38 | 21044.10 |
| 86.000 | 12000.0 | 99000.0 | 12000.0 | 2.574 | 2.594 | .0 | .05214 | 86.05 | 11377.45 | 219.26 | 21044.10 |
| 87.000 | 12000.0 | 99000.0 | 12000.0 | 3.185 | 3.208 | .0 | .06444 | 87.06 | 11682.84 | 219.11 | 21044.10 |
| 88.000 | 12000.0 | 99000.0 | 12000.0 | 4.122 | 4.143 | .0 | .08301 | 88.08 | 12206.77 | 218.96 | 21044.10 |
| 89.200 | 12000.0 | 99000.0 | 12000.0 | 6.122 | 6.107 | .0 | .12131 | 89.32 | 13461.79 | 218.96 | 21044.10 |
| 89.400 | 12000.0 | 99000.0 | 12000.0 | 6.621 | 6.587 | .0 | .13062 | 89.53 | 13791.35 | 219.03 | 21044.10 |
| 89.600 | 12000.0 | 99000.0 | 12000.0 | 7.193 | 7.133 | .0 | .14125 | 89.74 | 14172.72 | 219.14 | 21044.10 |
| 89.800 | 12000.0 | 99000.0 | 12000.0 | 7.854 | 7.756 | .0 | .15354 | 89.95 | 14614.00 | 219.30 | 21044.10 |
| 90.000 | 12000.0 | 99000.0 | 12000.0 | 8.568 | 8.471 | 27.4 | .16789 | 90.17 | 15119.06 | 219.50 | 21057.34 |
| 90.200 | 12000.0 | 99000.0 | 11960.6 | 9.356 | 9.199 | 85.6 | .15867 | 90.36 | 15683.90 | 220.36 | 21366.21 |
| 90.400 | 12000.0 | 99000.0 | 11842.3 | 10.272 | 10.025 | 138.0 | .15147 | 90.55 | 16267.56 | 221.61 | 21919.67 |
| 90.600 | 12000.0 | 99000.0 | 11639.2 | 11.588 | 11.112 | 241.7 | .18746 | 90.79 | 17069.07 | 223.09 | 22950.04 |
| 90.800 | 12000.0 | 99000.0 | 11345.7 | 13.174 | 12.400 | 364.5 | .22402 | 91.02 | 18049.18 | 224.05 | 24424.00 |
| 91.000 | 12000.0 | 99000.0 | 10968.7 | 14.540 | 13.818 | 454.8 | .23674 | 91.24 | 19362.66 | 224.93 | 26159.54 |
| 91.200 | 12000.0 | 99000.0 | 10517.8 | 16.308 | 15.429 | 601.7 | .26449 | 91.46 | 20531.13 | 227.87 | 28551.02 |
| 91.400 | 12000.0 | 99000.0 | 9969.2 | 18.759 | 17.381 | 733.5 | .28680 | 91.69 | 22442.18 | 229.37 | 31440.34 |
| 91.600 | 12000.0 | 99000.0 | 9347.9 | 21.642 | 19.621 | 967.5 | .33018 | 91.93 | 24308.36 | 233.21 | 35426.35 |
| 91.800 | 12000.0 | 99000.0 | 8638.2 | 24.690 | 22.172 | 1126.0 | .34927 | 92.15 | 26723.30 | 236.79 | 39884.28 |
| 92.000 | 12000.0 | 99000.0 | 7834.1 | 28.165 | 25.139 | 1224.8 | .35558 | 92.36 | 29501.01 | 240.18 | 44989.76 |
| 92.200 | 12000.0 | 99000.0 | 6935.3 | 34.072 | 29.017 | 1671.6 | .43325 | 92.63 | 33177.01 | 244.51 | 53575.04 |
| 92.400 | 12000.0 | 99000.0 | 5947.5 | 40.580 | 33.587 | 2093.8 | .49581 | 92.90 | 37456.72 | 249.43 | 63998.08 |
| 92.600 | 12000.0 | 99000.0 | 4870.4 | 48.503 | 38.670 | 2436.5 | .53809 | 93.14 | 42462.95 | 254.96 | 76077.59 |
| 92.800 | 12000.0 | 99000.0 | 3697.1 | 60.370 | 45.193 | 3116.6 | .62871 | 93.43 | 48924.59 | 261.46 | 94714.15 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 13000.0 | 99000.0 | 13000.3 | 1.095 | 1.105 | .0 | .02265 | 81.02 | 9320.36 | 219.22 | 18032.34 |
| 82.000 | 13000.0 | 99000.0 | 13000.0 | 1.221 | 1.231 | .0 | .02531 | 82.03 | 9358.14 | 219.17 | 18032.34 |
| 83.000 | 13000.0 | 99000.0 | 13000.0 | 1.378 | 1.389 | .0 | .02863 | 83.03 | 9409.83 | 219.10 | 18032.34 |
| 84.000 | 13000.0 | 99000.0 | 13000.0 | 1.579 | 1.591 | .0 | .03287 | 84.03 | 9482.78 | 219.00 | 18032.34 |
| 85.000 | 13000.0 | 99000.0 | 13000.0 | 1.845 | 1.859 | .0 | .03846 | 85.04 | 9589.54 | 218.88 | 18032.34 |
| 86.000 | 13000.0 | 99000.0 | 13000.0 | 2.211 | 2.225 | .0 | .04612 | 86.05 | 9752.75 | 218.71 | 18032.34 |
| 87.000 | 13000.0 | 99000.0 | 13000.0 | 2.738 | 2.751 | .0 | .05711 | 87.06 | 10015.65 | 218.47 | 18032.34 |
| 88.000 | 13000.0 | 99000.0 | 13000.0 | 3.548 | 3.554 | .0 | .07386 | 88.07 | 10466.77 | 218.13 | 18032.34 |
| 89.200 | 13000.0 | 99000.0 | 13000.0 | 5.284 | 5.248 | .0 | .10914 | 89.31 | 11549.19 | 217.59 | 18032.34 |
| 89.400 | 13000.0 | 99000.0 | 13000.0 | 5.718 | 5.665 | .0 | .11782 | 89.52 | 11833.94 | 217.49 | 18032.34 |
| 89.600 | 13000.0 | 99000.0 | 13000.0 | 6.216 | 6.140 | .0 | .12769 | 89.73 | 12163.67 | 217.38 | 18032.34 |
| 89.800 | 13000.0 | 99000.0 | 13000.0 | 6.791 | 6.683 | .0 | .13898 | 89.94 | 12545.33 | 217.27 | 18032.34 |
| 90.000 | 13000.0 | 99000.0 | 13000.0 | 7.674 | 7.308 | 22.4 | .15198 | 90.15 | 12982.13 | 217.17 | 18006.61 |
| 90.200 | 13000.0 | 99000.0 | 12960.4 | 8.108 | 7.963 | 77.2 | .14676 | 90.35 | 13483.46 | 217.63 | 18283.04 |
| 90.400 | 13000.0 | 99000.0 | 12841.5 | 8.931 | 8.710 | 128.2 | .14322 | 90.54 | 13997.86 | 218.42 | 18770.28 |
| 90.600 | 13000.0 | 99000.0 | 12638.1 | 10.068 | 9.668 | 220.2 | .17396 | 90.77 | 14691.71 | 219.36 | 19646.08 |
| 90.800 | 13000.0 | 99000.0 | 12346.5 | 11.437 | 10.803 | 328.8 | .20536 | 91.01 | 15545.19 | 219.86 | 20896.80 |
| 91.000 | 13000.0 | 99000.0 | 11972.0 | 12.562 | 12.060 | 404.6 | .21416 | 91.21 | 16698.81 | 220.34 | 22372.56 |
| 91.200 | 13000.0 | 99000.0 | 11525.6 | 14.386 | 13.459 | 529.0 | .23584 | 91.44 | 17712.85 | 223.31 | 24367.69 |
| 91.400 | 13000.0 | 99000.0 | 10980.1 | 16.328 | 15.222 | 673.6 | .26488 | 91.66 | 19402.19 | 224.61 | 26963.50 |
| 91.600 | 13000.0 | 99000.0 | 10360.7 | 18.732 | 17.215 | 871.9 | .30090 | 91.90 | 21048.87 | 227.92 | 30329.96 |
| 91.800 | 13000.0 | 99000.0 | 9658.0 | 21.306 | 19.444 | 979.6 | .30889 | 92.11 | 23171.60 | 231.45 | 33997.94 |
| 92.000 | 13000.0 | 99000.0 | 8856.7 | 24.611 | 22.190 | 1146.2 | .33318 | 92.33 | 25663.08 | 234.61 | 38838.13 |
| 92.200 | 13000.0 | 99000.0 | 7963.9 | 29.610 | 25.644 | 1531.6 | .39988 | 92.60 | 28922.47 | 238.58 | 46047.06 |
| 92.400 | 13000.0 | 99000.0 | 6986.6 | 35.906 | 29.672 | 1966.7 | .46588 | 92.87 | 32731.28 | 243.69 | 55275.19 |
| 92.600 | 13000.0 | 99000.0 | 5918.3 | 42.177 | 34.261 | 2249.4 | .49906 | 93.10 | 37184.90 | 249.06 | 65465.32 |
| 92.800 | 13000.0 | 99000.0 | 4760.2 | 50.422 | 39.683 | 2543.5 | .53156 | 93.33 | 42430.43 | 255.40 | 78086.20 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 14000.0 | 99000.0 | 14000.0 | .935 | .944 | .0 | .01935 | 81.02 | 7956.89 | 219.78 | 15386.52 |
| 82.000 | 14000.0 | 99000.0 | 14000.0 | 1.042 | 1.052 | .0 | .02162 | 82.02 | 7989.33 | 219.73 | 15386.52 |
| 83.000 | 14000.0 | 99000.0 | 14000.0 | 1.177 | 1.186 | .0 | .02445 | 83.02 | 8033.69 | 219.65 | 15386.52 |
| 84.000 | 14000.0 | 99000.0 | 14000.0 | 1.349 | 1.359 | .0 | .02807 | 84.03 | 8096.27 | 219.55 | 15386.52 |
| 85.000 | 14000.0 | 99000.0 | 14000.0 | 1.577 | 1.587 | .0 | .03284 | 85.03 | 8187.81 | 219.41 | 15386.52 |
| 86.000 | 14000.0 | 99000.0 | 14000.0 | 1.890 | 1.900 | .0 | .03937 | 86.04 | 8327.64 | 219.22 | 15386.52 |
| 87.000 | 14000.0 | 99000.0 | 14000.0 | 2.342 | 2.348 | .0 | .04875 | 87.05 | 8552.66 | 218.95 | 15386.52 |
| 88.000 | 14000.0 | 99000.0 | 14000.0 | 3.038 | 3.032 | .0 | .06302 | 88.06 | 8938.25 | 218.56 | 15386.52 |
| 89.200 | 14000.0 | 99000.0 | 14000.0 | 4.528 | 4.472 | .0 | .09301 | 89.29 | 9861.43 | 217.93 | 15386.52 |
| 89.400 | 14000.0 | 99000.0 | 14000.0 | 4.900 | 4.826 | .0 | .10038 | 89.50 | 10103.89 | 217.80 | 15386.52 |
| 89.600 | 14000.0 | 99000.0 | 14000.0 | 5.328 | 5.228 | .0 | .10875 | 89.71 | 10384.47 | 217.68 | 15386.52 |
| 89.800 | 14000.0 | 99000.0 | 14000.0 | 5.823 | 5.688 | .0 | .11832 | 89.92 | 10709.00 | 217.55 | 15386.52 |
| 90.000 | 14000.0 | 99000.0 | 14000.0 | 6.332 | 6.217 | 16.3 | .12931 | 90.13 | 11080.12 | 217.42 | 15347.01 |
| 90.200 | 14000.0 | 99000.0 | 13958.8 | 7.005 | 6.828 | 72.5 | .14203 | 90.34 | 11541.70 | 217.29 | 15588.09 |
| 90.400 | 14000.0 | 99000.0 | 13835.2 | 7.801 | 7.541 | 136.5 | .15684 | 90.56 | 12013.02 | 217.16 | 16060.46 |
| 90.600 | 14000.0 | 99000.0 | 13628.8 | 8.751 | 8.376 | 211.4 | .17420 | 90.77 | 12604.99 | 217.04 | 16793.69 |
| 90.800 | 14000.0 | 99000.0 | 13339.1 | 9.901 | 9.363 | 300.8 | .19472 | 90.99 | 13339.82 | 216.92 | 17834.43 |
| 91.000 | 14000.0 | 99000.0 | 12967.0 | 10.916 | 10.477 | 368.3 | .20074 | 91.20 | 14350.99 | 216.90 | 19104.06 |
| 91.200 | 14000.0 | 99000.0 | 12520.2 | 12.524 | 11.740 | 484.5 | .22163 | 91.42 | 15240.75 | 219.10 | 20839.16 |
| 91.400 | 14000.0 | 99000.0 | 11978.5 | 14.117 | 13.299 | 606.2 | .24240 | 91.64 | 16727.65 | 219.90 | 23015.77 |
| 91.600 | 14000.0 | 99000.0 | 11364.6 | 16.217 | 15.042 | 773.9 | .27296 | 91.87 | 18166.04 | 223.22 | 25869.10 |
| 91.800 | 14000.0 | 99000.0 | 10663.4 | 18.502 | 17.069 | 893.2 | .28622 | 92.09 | 20050.77 | 226.32 | 29145.48 |
| 92.000 | 14000.0 | 99000.0 | 9868.2 | 21.313 | 19.500 | 1009.7 | .30013 | 92.30 | 22250.98 | 229.13 | 33162.13 |
| 92.200 | 14000.0 | 99000.0 | 8982.9 | 25.818 | 22.614 | 1426.8 | .37506 | 92.58 | 25146.80 | 233.20 | 39649.76 |
| 92.400 | 14000.0 | 99000.0 | 8010.6 | 31.514 | 26.297 | 1879.2 | .44557 | 92.85 | 28276.84 | 237.87 | 47900.12 |
| 92.600 | 14000.0 | 99000.0 | 6952.6 | 36.655 | 30.316 | 2070.5 | .46319 | 93.06 | 32494.90 | 243.30 | 56263.10 |
| 92.800 | 14000.0 | 99000.0 | 5803.5 | 43.724 | 35.165 | 2322.5 | .49019 | 93.29 | 37178.44 | 249.45 | 66990.47 |
| 93.000 | 14000.0 | 99000.0 | 4544.3 | 56.716 | 41.786 | 3271.6 | .61923 | 93.62 | 43415.08 | 256.17 | 87336.74 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 15000.0 | 99000.0 | 15000.0 | .798 | .806 | .0 | .01653 | 81.02 | 6792.88 | 220.45 | 13135.80 |
| 82.000 | 15000.0 | 99000.0 | 15000.0 | .890 | .898 | .0 | .01847 | 82.02 | 6820.73 | 220.39 | 13135.80 |
| 83.000 | 15000.0 | 99000.0 | 15000.0 | 1.004 | 1.013 | .0 | .02088 | 83.02 | 6858.81 | 220.31 | 13135.80 |
| 84.000 | 15000.0 | 99000.0 | 15000.0 | 1.151 | 1.161 | .0 | .02397 | 84.02 | 6912.50 | 220.19 | 13135.80 |
| 85.000 | 15000.0 | 99000.0 | 15000.0 | 1.345 | 1.355 | .0 | .02805 | 85.03 | 6990.98 | 220.04 | 13135.80 |
| 86.000 | 15000.0 | 99000.0 | 15000.0 | 1.612 | 1.622 | .0 | .03362 | 86.03 | 7110.79 | 219.83 | 13135.80 |
| 87.000 | 15000.0 | 99000.0 | 15000.0 | 1.996 | 2.004 | .0 | .04162 | 87.04 | 7303.40 | 219.52 | 13135.80 |
| 88.000 | 15000.0 | 99000.0 | 15000.0 | 2.587 | 2.587 | .0 | .05379 | 88.05 | 7633.04 | 219.09 | 13135.80 |
| 89.200 | 15000.0 | 99000.0 | 15000.0 | 3.846 | 3.811 | .0 | .07932 | 89.28 | 8420.64 | 218.35 | 13135.80 |
| 89.400 | 15000.0 | 99000.0 | 15000.0 | 4.160 | 4.112 | .0 | .08558 | 89.49 | 8627.19 | 218.20 | 13135.80 |
| 89.600 | 15000.0 | 99000.0 | 15000.0 | 4.519 | 4.453 | .0 | .09268 | 89.69 | 8866.07 | 218.05 | 13135.80 |
| 89.800 | 15000.0 | 99000.0 | 15000.0 | 4.932 | 4.844 | .0 | .10080 | 89.90 | 9142.18 | 217.89 | 13135.80 |
| 90.000 | 15000.0 | 99000.0 | 15000.0 | 5.351 | 5.292 | 11.8 | .11012 | 90.11 | 9457.73 | 217.73 | 13083.16 |
| 90.200 | 15000.0 | 99000.0 | 14959.2 | 5.912 | 5.810 | 59.3 | .12088 | 90.32 | 9849.99 | 217.58 | 13269.64 |
| 90.400 | 15000.0 | 99000.0 | 14836.6 | 6.571 | 6.412 | 113.2 | .13340 | 90.53 | 10250.53 | 217.42 | 13645.25 |
| 90.600 | 15000.0 | 99000.0 | 14632.0 | 7.359 | 7.118 | 176.0 | .14805 | 90.75 | 10753.77 | 217.27 | 14239.88 |
| 90.800 | 15000.0 | 99000.0 | 14345.0 | 8.305 | 7.949 | 250.9 | .16534 | 90.97 | 11378.09 | 217.12 | 15081.40 |
| 91.000 | 15000.0 | 99000.0 | 13974.9 | 9.459 | 8.938 | 342.0 | .18589 | 91.19 | 12253.12 | 216.99 | 16228.21 |
| 91.200 | 15000.0 | 99000.0 | 13520.9 | 10.887 | 10.124 | 454.9 | .21055 | 91.41 | 13047.30 | 216.86 | 17756.63 |
| 91.400 | 15000.0 | 99000.0 | 12982.4 | 12.295 | 11.517 | 555.5 | .22699 | 91.63 | 14354.27 | 216.77 | 19618.78 |
| 91.600 | 15000.0 | 99000.0 | 12369.6 | 14.056 | 13.083 | 705.2 | .25245 | 91.85 | 15621.15 | 219.13 | 22051.19 |
| 91.800 | 15000.0 | 99000.0 | 11674.3 | 15.993 | 14.861 | 782.6 | .25588 | 92.06 | 17273.14 | 221.92 | 24758.62 |
| 92.000 | 15000.0 | 99000.0 | 10882.4 | 18.567 | 17.075 | 939.2 | .28091 | 92.28 | 19227.19 | 224.35 | 28442.19 |
| 92.200 | 15000.0 | 99000.0 | 10001.8 | 22.694 | 19.914 | 1374.4 | .36057 | 92.56 | 21567.86 | 227.90 | 34237.84 |
| 92.400 | 15000.0 | 99000.0 | 9040.8 | 27.066 | 23.047 | 1667.7 | .40130 | 92.80 | 24536.87 | 232.64 | 40637.23 |
| 92.600 | 15000.0 | 99000.0 | 7985.3 | 32.373 | 26.785 | 1937.2 | .43500 | 93.03 | 28323.17 | 237.50 | 48427.22 |
| 92.800 | 15000.0 | 99000.0 | 6847.1 | 37.892 | 31.067 | 2120.2 | .45125 | 93.25 | 32479.94 | 243.64 | 57369.22 |
| 93.000 | 15000.0 | 99000.0 | 5604.2 | 48.097 | 36.811 | 2877.4 | .55378 | 93.55 | 37978.95 | 250.41 | 73450.83 |
| 93.200 | 15000.0 | 99000.0 | 4246.3 | 62.786 | 43.998 | 3812.0 | .67160 | 93.87 | 45056.89 | 257.05 | 96338.30 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 16000.0 | 99000.0 | 16001.0 | .681 | .689 | .0 | .01412 | 81.01 | 5799.13 | 221.24 | 11214.32 |
| 82.000 | 16000.0 | 99000.0 | 16000.0 | .759 | .768 | .0 | .01578 | 82.02 | 5823.05 | 221.17 | 11214.32 |
| 83.000 | 16000.0 | 99000.0 | 16000.0 | .857 | .866 | .0 | .01784 | 83.02 | 5855.74 | 221.08 | 11214.32 |
| 84.000 | 16000.0 | 99000.0 | 16000.0 | .982 | .992 | .0 | .02048 | 84.02 | 5901.80 | 220.96 | 11214.32 |
| 85.000 | 16000.0 | 99000.0 | 16000.0 | 1.148 | 1.158 | .0 | .02396 | 85.02 | 5969.11 | 220.79 | 11214.32 |
| 86.000 | 16000.0 | 99000.0 | 16000.0 | 1.375 | 1.385 | .0 | .02872 | 86.03 | 6071.77 | 220.55 | 11214.32 |
| 87.000 | 16000.0 | 99000.0 | 16000.0 | 1.702 | 1.711 | .0 | .03554 | 87.04 | 6236.67 | 220.22 | 11214.32 |
| 88.000 | 16000.0 | 99000.0 | 16000.0 | 2.203 | 2.207 | .0 | .04592 | 88.05 | 6518.53 | 219.73 | 11214.32 |
| 89.200 | 16000.0 | 99000.0 | 16000.0 | 3.270 | 3.249 | .0 | .06768 | 89.27 | 7190.68 | 218.87 | 11214.32 |
| 89.400 | 16000.0 | 99000.0 | 16000.0 | 3.534 | 3.505 | .0 | .07300 | 89.47 | 7366.71 | 218.69 | 11214.32 |
| 89.600 | 16000.0 | 99000.0 | 16000.0 | 3.836 | 3.795 | .0 | .07905 | 89.68 | 7570.18 | 218.51 | 11214.32 |
| 89.800 | 16000.0 | 99000.0 | 16000.0 | 4.184 | 4.126 | .0 | .08594 | 89.89 | 7805.23 | 218.32 | 11214.32 |
| 90.000 | 16000.0 | 99000.0 | 16000.0 | 4.588 | 4.507 | 8.6 | .09384 | 90.09 | 8073.69 | 218.13 | 11154.89 |
| 90.200 | 16000.0 | 99000.0 | 15959.3 | 4.997 | 4.946 | 48.7 | .10297 | 90.30 | 8407.27 | 217.94 | 11300.39 |
| 90.400 | 16000.0 | 99000.0 | 15837.7 | 5.547 | 5.456 | 94.2 | .11357 | 90.51 | 8747.88 | 217.74 | 11603.19 |
| 90.600 | 16000.0 | 99000.0 | 15634.7 | 6.200 | 6.053 | 147.1 | .12596 | 90.73 | 9175.94 | 217.56 | 12084.92 |
| 90.800 | 16000.0 | 99000.0 | 15349.9 | 6.984 | 6.756 | 210.0 | .14055 | 90.94 | 9706.72 | 217.38 | 12772.97 |
| 91.000 | 16000.0 | 99000.0 | 14982.9 | 7.934 | 7.590 | 286.3 | .15787 | 91.16 | 10449.11 | 217.21 | 13705.86 |
| 91.200 | 16000.0 | 99000.0 | 14532.8 | 9.100 | 8.588 | 380.6 | .17861 | 91.38 | 11124.49 | 217.05 | 14943.40 |
| 91.400 | 16000.0 | 99000.0 | 13998.7 | 10.555 | 9.793 | 499.0 | .20368 | 91.60 | 12240.57 | 216.90 | 16573.81 |
| 91.600 | 16000.0 | 99000.0 | 13379.1 | 12.168 | 11.263 | 649.8 | .23421 | 91.83 | 13369.46 | 216.77 | 18721.10 |
| 91.800 | 16000.0 | 99000.0 | 12685.1 | 13.836 | 12.877 | 719.9 | .23725 | 92.04 | 14827.24 | 218.38 | 21080.84 |
| 92.000 | 16000.0 | 99000.0 | 11898.1 | 16.288 | 14.850 | 837.3 | .25403 | 92.25 | 16547.12 | 220.00 | 24135.13 |
| 92.200 | 16000.0 | 99000.0 | 11026.0 | 19.476 | 17.328 | 1220.6 | .32435 | 92.52 | 18596.22 | 223.43 | 29001.07 |
| 92.400 | 16000.0 | 99000.0 | 10068.5 | 23.348 | 20.162 | 1502.0 | .36534 | 92.77 | 21231.74 | 227.46 | 34526.57 |
| 92.600 | 16000.0 | 99000.0 | 9022.2 | 28.250 | 23.553 | 1840.2 | .41192 | 93.01 | 24350.81 | 232.38 | 41694.22 |
| 92.800 | 16000.0 | 99000.0 | 7888.5 | 32.679 | 27.358 | 1911.2 | .41113 | 93.21 | 28287.08 | 237.80 | 48894.63 |
| 93.000 | 16000.0 | 99000.0 | 6661.7 | 41.291 | 32.342 | 2512.6 | .49181 | 93.49 | 33125.84 | 244.76 | 61676.45 |
| 93.200 | 16000.0 | 99000.0 | 5318.5 | 52.918 | 38.713 | 3373.6 | .60280 | 93.80 | 39078.72 | 251.34 | 80684.50 |
| 93.400 | 16000.0 | 99000.0 | 3878.5 | 65.395 | 45.892 | 3742.0 | .64015 | 94.04 | 46509.54 | 258.26 | 99730.48 |

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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 17000.0 | 99000.0 | 17000.[illegible] | .581 | .589 | .0 | .01206 | 81.01 | 4950.73 | 222.16 | 9573.91 |
| 82.000 | 17000.0 | 99000.0 | 17000.[illegible] | .648 | .656 | .0 | .01348 | 82.01 | 4971.27 | 222.09 | 9573.91 |
| 83.000 | 17000.0 | 99000.0 | 17000.[illegible] | .731 | .740 | .0 | .01524 | 83.02 | 4999.33 | 221.99 | 9573.91 |
| 84.000 | 17000.0 | 99000.0 | 17000.[illegible] | .838 | .847 | .0 | .01749 | 84.02 | 5038.86 | 221.86 | 9573.91 |
| 85.000 | 17000.0 | 99000.0 | 17000.[illegible] | .979 | .989 | .0 | .02047 | 85.02 | 5096.58 | 221.68 | 9573.91 |
| 86.000 | 17000.0 | 99000.0 | 17000.[illegible] | 1.173 | 1.183 | .0 | .02453 | 86.02 | 5184.57 | 221.42 | 9573.91 |
| 87.000 | 17000.0 | 99000.0 | 17000.[illegible] | 1.451 | 1.461 | .0 | .03036 | 87.03 | 5325.76 | 221.05 | 9573.91 |
| 88.000 | 17000.0 | 99000.0 | 17000.[illegible] | 1.878 | 1.883 | .0 | .03922 | 88.04 | 5566.81 | 220.51 | 9573.91 |
| 89.200 | 17000.0 | 99000.0 | 17000.[illegible] | 2.781 | 2.770 | .0 | .05779 | 89.26 | 6140.62 | 219.52 | 9573.91 |
| 89.400 | 17000.0 | 99000.0 | 17000.[illegible] | 3.005 | 2.988 | .0 | .06233 | 89.46 | 6290.71 | 219.32 | 9573.91 |
| 89.600 | 17000.0 | 99000.0 | 17000.[illegible] | 3.260 | 3.234 | .0 | .06748 | 89.67 | 6464.11 | 219.10 | 9573.91 |
| 89.800 | 17000.0 | 99000.0 | 17000.[illegible] | 3.553 | 3.516 | .0 | .07334 | 89.87 | 6664.32 | 218.87 | 9573.91 |
| 90.000 | 17000.0 | 99000.0 | 17000.[illegible] | 3.835 | 3.839 | 6.2 | .08006 | 90.08 | 6892.84 | 218.63 | 9511.70 |
| 90.200 | 17000.0 | 99000.0 | 16959.7 | 4.230 | 4.212 | 40.2 | .08780 | 90.29 | 7176.71 | 218.40 | 9626.18 |
| 90.400 | 17000.0 | 99000.0 | 16838.7 | 4.689 | 4.645 | 78.7 | .09678 | 90.50 | 7466.51 | 218.16 | 9872.01 |
| 90.600 | 17000.0 | 99000.0 | 16636.9 | 5.234 | 5.151 | 123.4 | .10727 | 90.71 | 7830.80 | 217.92 | 10266.53 |
| 90.800 | 17000.0 | 99000.0 | 16354.0 | 5.886 | 5.746 | 176.3 | .11961 | 90.92 | 8282.33 | 217.70 | 10831.12 |
| 91.000 | 17000.0 | 99000.0 | 15989.5 | 6.670 | 6.451 | 240.5 | .13423 | 91.13 | 8912.74 | 217.49 | 11593.14 |
| 91.200 | 17000.0 | 99000.0 | 15542.8 | 7.629 | 7.293 | 319.4 | .15171 | 91.35 | 9467.38 | 217.29 | 12603.11 |
| 91.400 | 17000.0 | 99000.0 | 15013.0 | 8.819 | 8.307 | 418.3 | .17277 | 91.57 | 10291.78 | 217.11 | 13928.30 |
| 91.600 | 17000.0 | 99000.0 | 14399.0 | 10.317 | 9.541 | 543.8 | .19841 | 91.80 | 11389.75 | 216.94 | 15664.94 |
| 91.800 | 17000.0 | 99000.0 | 13699.1 | 12.242 | 11.058 | 705.6 | .22993 | 92.03 | 12673.72 | 216.79 | 17961.34 |
| 92.000 | 17000.0 | 99000.0 | 12915.4 | 14.136 | 12.837 | 791.1 | .23935 | 92.24 | 14185.59 | 216.96 | 20557.19 |
| 92.200 | 17000.0 | 99000.0 | 12048.0 | 16.772 | 15.033 | 1104.2 | .29579 | 92.50 | 15984.73 | 219.31 | 24571.66 |
| 92.400 | 17000.0 | 99000.0 | 11098.9 | 19.972 | 17.514 | 1332.5 | .32767 | 92.73 | 18292.82 | 223.11 | 29160.94 |
| 92.600 | 17000.0 | 99000.0 | 10056.9 | 24.289 | 20.574 | 1655.4 | .37396 | 92.97 | 21060.80 | 227.28 | 35323.56 |
| 92.800 | 17000.0 | 99000.0 | 8929.7 | 28.801 | 24.044 | 1803.0 | .38685 | 93.19 | 24564.10 | 232.52 | 42004.26 |
| 93.000 | 17000.0 | 99000.0 | 7716.3 | 34.775 | 28.310 | 2129.0 | .42636 | 93.43 | 28795.49 | 239.14 | 51399.23 |
| 93.200 | 17000.0 | 99000.0 | 6386.5 | 45.223 | 33.989 | 2980.6 | .53961 | 93.74 | 34092.87 | 245.74 | 67610.37 |
| 93.400 | 17000.0 | 99000.0 | 4953.8 | 56.727 | 40.651 | 3538.5 | .60416 | 94.00 | 40782.06 | 252.40 | 85882.20 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 18000.0 | 99000.0 | 18000.0 | .496 | .503 | .0 | .01031 | 81.01 | 4226.39 | 223.25 | 8173.45 |
| 82.000 | 18000.0 | 99000.0 | 18000.0 | .553 | .560 | .0 | .01151 | 82.01 | 4244.03 | 223.17 | 8173.45 |
| 83.000 | 18000.0 | 99000.0 | 18000.0 | .624 | .632 | .0 | .01302 | 83.01 | 4268.12 | 223.07 | 8173.45 |
| 84.000 | 18000.0 | 99000.0 | 18000.0 | .715 | .723 | .0 | .01495 | 84.01 | 4302.04 | 222.93 | 8173.45 |
| 85.000 | 18000.0 | 99000.0 | 18000.0 | .836 | .844 | .0 | .01748 | 85.02 | 4351.55 | 222.73 | 8173.45 |
| 86.000 | 18000.0 | 99000.0 | 18000.0 | 1.001 | 1.010 | .0 | .02096 | 86.02 | 4426.95 | 222.46 | 8173.45 |
| 87.000 | 18000.0 | 99000.0 | 18000.0 | 1.238 | 1.247 | .0 | .02594 | 87.03 | 4547.84 | 222.07 | 8173.45 |
| 88.000 | 18000.0 | 99000.0 | 18000.0 | 1.600 | 1.607 | .0 | .03352 | 88.03 | 4753.99 | 221.48 | 8173.45 |
| 89.200 | 18000.0 | 99000.0 | 18000.0 | 2.367 | 2.362 | .0 | .04942 | 89.25 | 5243.96 | 220.38 | 8173.45 |
| 89.400 | 18000.0 | 99000.0 | 18000.0 | 2.557 | 2.547 | .0 | .05331 | 89.45 | 5371.98 | 220.13 | 8173.45 |
| 89.600 | 18000.0 | 99000.0 | 18000.0 | 2.772 | 2.756 | .0 | .05771 | 89.66 | 5519.84 | 219.87 | 8173.45 |
| 89.800 | 18000.0 | 99000.0 | 18000.0 | 3.020 | 2.996 | .0 | .06271 | 89.86 | 5690.47 | 219.60 | 8173.45 |
| 90.000 | 18000.0 | 99000.0 | 18000.0 | 3.251 | 3.271 | 4.6 | .06843 | 90.07 | 5885.15 | 219.30 | 8111.00 |
| 90.200 | 18000.0 | 99000.0 | 17959.9 | 3.583 | 3.588 | 33.5 | .07500 | 90.28 | 6126.87 | 219.00 | 8201.83 |
| 90.400 | 18000.0 | 99000.0 | 17839.6 | 3.970 | 3.955 | 66.1 | .08261 | 90.48 | 6373.60 | 218.70 | 8402.68 |
| 90.600 | 18000.0 | 99000.0 | 17638.8 | 4.426 | 4.385 | 103.9 | .09148 | 90.69 | 6683.79 | 218.40 | 8727.62 |
| 90.800 | 18000.0 | 99000.0 | 17357.5 | 4.968 | 4.889 | 148.6 | .10191 | 90.90 | 7068.09 | 218.11 | 9191.55 |
| 91.000 | 18000.0 | 99000.0 | 16995.1 | 5.621 | 5.486 | 202.6 | .11427 | 91.11 | 7603.83 | 217.84 | 9821.42 |
| 91.200 | 18000.0 | 99000.0 | 16551.2 | 6.415 | 6.198 | 268.9 | .12901 | 91.33 | 8092.97 | 217.59 | 10651.29 |
| 91.400 | 18000.0 | 99000.0 | 16025.6 | 7.393 | 7.054 | 351.7 | .14677 | 91.55 | 8776.44 | 217.36 | 11735.21 |
| 91.600 | 18000.0 | 99000.0 | 15415.6 | 8.616 | 8.093 | 456.6 | .16833 | 91.77 | 9706.66 | 217.15 | 13146.15 |
| 91.800 | 18000.0 | 99000.0 | 14721.6 | 10.171 | 9.367 | 591.2 | .19478 | 91.99 | 10792.74 | 216.97 | 14995.12 |
| 92.000 | 18000.0 | 99000.0 | 13941.3 | 12.196 | 10.945 | 766.7 | .22757 | 92.23 | 12098.10 | 216.80 | 17453.91 |
| 92.200 | 18000.0 | 99000.0 | 13072.1 | 14.696 | 12.924 | 998.6 | .26872 | 92.47 | 13677.09 | 216.66 | 20718.38 |
| 92.400 | 18000.0 | 99000.0 | 12126.1 | 17.152 | 15.169 | 1205.0 | .29813 | 92.70 | 15713.01 | 219.15 | 24652.98 |
| 92.600 | 18000.0 | 99000.0 | 11093.2 | 20.712 | 17.850 | 1467.4 | .33468 | 92.93 | 18137.54 | 222.99 | 29749.16 |
| 92.800 | 18000.0 | 99000.0 | 9968.3 | 24.933 | 21.040 | 1668.2 | .35848 | 93.16 | 21256.52 | 227.36 | 35819.97 |
| 93.000 | 18000.0 | 99000.0 | 8764.1 | 29.440 | 24.731 | 1815.6 | .37142 | 93.37 | 24718.88 | 233.68 | 43032.87 |
| 93.200 | 18000.0 | 99000.0 | 7450.1 | 38.275 | 29.771 | 2617.9 | .48020 | 93.68 | 29656.13 | 240.23 | 56615.88 |
| 93.400 | 18000.0 | 99000.0 | 6027.6 | 49.918 | 35.993 | 3458.5 | .58404 | 93.98 | 35374.75 | 246.88 | 74853.23 |
| 93.600 | 18000.0 | 99000.0 | 4521.3 | 63.493 | 43.179 | 4073.6 | .64920 | 94.25 | 42589.51 | 255.11 | 96188.96 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 19000.0 | 99000.0 | 19000.0 | .424 | .430 | .0 | .00876 | 81.01 | 3608.28 | 224.52 | 6977.85 |
| 82.000 | 19000.0 | 99000.0 | 19000.0 | .472 | .479 | .0 | .00979 | 82.01 | 3623.42 | 224.44 | 6977.85 |
| 83.000 | 19000.0 | 99000.0 | 19000.0 | .533 | .540 | .0 | .01107 | 83.01 | 3644.11 | 224.34 | 6977.85 |
| 84.000 | 19000.0 | 99000.0 | 19000.0 | .610 | .618 | .0 | .01271 | 84.01 | 3673.21 | 224.19 | 6977.85 |
| 85.000 | 19000.0 | 99000.0 | 19000.0 | .713 | .721 | .0 | .01486 | 85.01 | 3715.66 | 223.99 | 6977.85 |
| 86.000 | 19000.0 | 99000.0 | 19000.0 | .854 | .862 | .0 | .01781 | 86.02 | 3780.27 | 223.71 | 6977.85 |
| 87.000 | 19000.0 | 99000.0 | 19000.0 | 1.056 | 1.064 | .0 | .02204 | 87.02 | 3883.74 | 223.29 | 6977.85 |
| 88.000 | 19000.0 | 99000.0 | 19000.0 | 1.364 | 1.371 | .0 | .02846 | 88.03 | 4059.96 | 222.68 | 6977.85 |
| 89.200 | 19000.0 | 99000.0 | 19000.0 | 2.015 | 2.013 | .0 | .04192 | 89.24 | 4477.91 | 221.54 | 6977.85 |
| 89.400 | 19000.0 | 99000.0 | 19000.0 | 2.176 | 2.169 | .0 | .04520 | 89.45 | 4586.96 | 221.29 | 6977.85 |
| 89.600 | 19000.0 | 99000.0 | 19000.0 | 2.359 | 2.348 | .0 | .04892 | 89.65 | 4712.82 | 221.02 | 6977.85 |
| 89.800 | 19000.0 | 99000.0 | 19000.0 | 2.568 | 2.551 | .0 | .05314 | 89.85 | 4857.99 | 220.73 | 6977.85 |
| 90.000 | 19000.0 | 99000.0 | 19000.0 | 2.740 | 2.783 | 3.3 | .05796 | 90.06 | 5023.50 | 220.43 | 6917.56 |
| 90.200 | 19000.0 | 99000.0 | 18960.0 | 3.039 | 3.053 | 28.1 | .06477 | 90.26 | 5230.04 | 220.02 | 6989.69 |
| 90.400 | 19000.0 | 99000.0 | 18839.8 | 3.367 | 3.368 | 57.0 | .07257 | 90.47 | 5441.31 | 219.55 | 7156.41 |
| 90.600 | 19000.0 | 99000.0 | 18639.7 | 3.749 | 3.734 | 88.6 | .07935 | 90.68 | 5705.81 | 219.07 | 7425.25 |
| 90.800 | 19000.0 | 99000.0 | 18359.6 | 4.203 | 4.162 | 126.0 | .08764 | 90.89 | 6033.12 | 218.68 | 7809.41 |
| 91.000 | 19000.0 | 99000.0 | 17999.6 | 4.747 | 4.669 | 171.5 | .09790 | 91.10 | 6488.90 | 218.31 | 8331.16 |
| 91.200 | 19000.0 | 99000.0 | 17557.5 | 5.407 | 5.272 | 227.3 | .11023 | 91.31 | 6905.35 | 217.99 | 9016.88 |
| 91.400 | 19000.0 | 99000.0 | 17034.3 | 6.214 | 5.996 | 296.8 | .12515 | 91.53 | 7486.51 | 217.69 | 9907.23 |
| 91.600 | 19000.0 | 99000.0 | 16428.8 | 7.219 | 6.874 | 384.7 | .14328 | 91.74 | 8275.58 | 217.43 | 11062.37 |
| 91.800 | 19000.0 | 99000.0 | 15739.7 | 8.487 | 7.946 | 497.2 | .16550 | 91.97 | 9195.50 | 217.19 | 12564.90 |
| 92.000 | 19000.0 | 99000.0 | 14965.7 | 10.121 | 9.271 | 643.1 | .19299 | 92.19 | 10300.85 | 216.99 | 14543.64 |
| 92.200 | 19000.0 | 99000.0 | 14104.6 | 12.273 | 10.927 | 835.2 | .22738 | 92.43 | 11638.41 | 216.81 | 17191.41 |
| 92.400 | 19000.0 | 99000.0 | 13153.7 | 14.901 | 13.024 | 1091.9 | .27095 | 92.67 | 13436.61 | 216.66 | 20755.52 |
| 92.600 | 19000.0 | 99000.0 | 12124.5 | 17.744 | 15.445 | 1326.1 | .30403 | 92.90 | 15574.82 | 219.09 | 25096.57 |
| 92.800 | 19000.0 | 99000.0 | 11007.3 | 21.754 | 18.357 | 1631.8 | .34598 | 93.15 | 18136.17 | 223.07 | 30823.31 |
| 93.000 | 19000.0 | 99000.0 | 9808.6 | 25.539 | 21.595 | 1612.1 | .33311 | 93.33 | 21387.33 | 228.46 | 36338.32 |
| 93.200 | 19000.0 | 99000.0 | 8505.5 | 33.022 | 26.057 | 2345.8 | .43383 | 93.63 | 25483.51 | 234.82 | 47722.54 |
| 93.400 | 19000.0 | 99000.0 | 7099.6 | 42.594 | 31.511 | 3055.6 | .52192 | 93.92 | 30794.24 | 241.41 | 62493.45 |
| 93.600 | 19000.0 | 99000.0 | 5607.3 | 53.411 | 37.864 | 3559.0 | .57550 | 94.18 | 37187.23 | 249.42 | 79678.18 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 20000.0 | 99000.0 | 20000.0 | .362 | .367 | .0 | .00746 | 81.01 | 3082.85 | 225.84 | 5962.02 |
| 82.000 | 20000.0 | 99000.0 | 20000.0 | .403 | .409 | .0 | .00833 | 82.01 | 3095.86 | 225.76 | 5962.02 |
| 83.000 | 20000.0 | 99000.0 | 20000.0 | .455 | .462 | .0 | .00942 | 83.01 | 3113.63 | 225.65 | 5962.02 |
| 84.000 | 20000.0 | 99000.0 | 20000.0 | .521 | .528 | .0 | .01081 | 84.01 | 3138.62 | 225.50 | 5962.02 |
| 85.000 | 20000.0 | 99000.0 | 20000.0 | .609 | .616 | .0 | .01264 | 85.01 | 3175.05 | 225.29 | 5962.02 |
| 86.000 | 20000.0 | 99000.0 | 20000.0 | .729 | .737 | .0 | .01515 | 86.02 | 3230.44 | 224.99 | 5962.02 |
| 87.000 | 20000.0 | 99000.0 | 20000.0 | .901 | .909 | .0 | .01874 | 87.02 | 3319.06 | 224.56 | 5962.02 |
| 88.000 | 20000.0 | 99000.0 | 20000.0 | 1.163 | 1.171 | .0 | .02419 | 88.02 | 3469.80 | 223.92 | 5962.02 |
| 89.200 | 20000.0 | 99000.0 | 20000.0 | 1.715 | 1.717 | .0 | .03559 | 89.24 | 3826.62 | 222.73 | 5962.02 |
| 89.400 | 20000.0 | 99000.0 | 20000.0 | 1.851 | 1.850 | .0 | .03837 | 89.44 | 3919.58 | 222.47 | 5962.02 |
| 89.600 | 20000.0 | 99000.0 | 20000.0 | 2.005 | 2.001 | .0 | .04151 | 89.64 | 4026.83 | 222.19 | 5962.02 |
| 89.800 | 20000.0 | 99000.0 | 20000.0 | 2.182 | 2.173 | .0 | .04508 | 89.85 | 4150.45 | 221.89 | 5962.02 |
| 90.000 | 20000.0 | 99000.0 | 20000.0 | 2.322 | 2.371 | 2.4 | .04915 | 90.05 | 4291.33 | 221.58 | 5904.13 |
| 90.200 | 20000.0 | 99000.0 | 19960.1 | 2.558 | 2.600 | 23.3 | .05489 | 90.25 | 4466.85 | 221.16 | 5960.71 |
| 90.400 | 20000.0 | 99000.0 | 19840.5 | 2.848 | 2.866 | 47.6 | .06146 | 90.46 | 4646.46 | 220.68 | 6098.29 |
| 90.600 | 20000.0 | 99000.0 | 19641.2 | 3.169 | 3.175 | 74.2 | .06718 | 90.67 | 4871.39 | 220.19 | 6320.60 |
| 90.800 | 20000.0 | 99000.0 | 19362.3 | 3.547 | 3.538 | 105.7 | .07414 | 90.87 | 5149.44 | 219.78 | 6638.67 |
| 91.000 | 20000.0 | 99000.0 | 19003.3 | 4.017 | 3.965 | 143.8 | .08273 | 91.08 | 5452.66 | 219.41 | 7070.06 |
| 91.200 | 20000.0 | 99000.0 | 18562.9 | 4.571 | 4.483 | 194.1 | .09488 | 91.29 | 5892.51 | 218.68 | 7644.13 |
| 91.400 | 20000.0 | 99000.0 | 18042.3 | 5.241 | 5.098 | 251.7 | .10700 | 91.51 | 6387.33 | 218.22 | 8379.86 |
| 91.600 | 20000.0 | 99000.0 | 17440.[illegible] | 6.071 | 5.840 | 325.2 | .12216 | 91.72 | 7057.46 | 217.85 | 9331.33 |
| 91.800 | 20000.0 | 99000.0 | 16755.[illegible] | 7.112 | 6.746 | 419.4 | .14082 | 91.94 | 7737.18 | 217.53 | 10561.58 |
| 92.000 | 20000.0 | 99000.0 | 15986.5 | 8.442 | 7.862 | 541.3 | .16391 | 92.16 | 8774.61 | 217.26 | 12168.86 |
| 92.200 | 20000.0 | 99000.0 | 15132.0 | 10.174 | 9.253 | 701.0 | .19273 | 92.39 | 9908.91 | 217.03 | 14296.46 |
| 92.400 | 20000.0 | 99000.0 | 14189.8 | 12.489 | 11.007 | 913.5 | .22913 | 92.63 | 11426.75 | 216.83 | 17172.61 |
| 92.600 | 20000.0 | 99000.0 | 13156.6 | 15.126 | 13.249 | 1200.3 | .27572 | 92.88 | 13313.35 | 216.66 | 21108.88 |
| 92.800 | 20000.0 | 99000.0 | 12043.5 | 18.590 | 15.875 | 1472.2 | .31353 | 93.11 | 15573.25 | 219.16 | 25942.41 |
| 93.000 | 20000.0 | 99000.0 | 10849.9 | 22.096 | 18.821 | 1521.1 | .31237 | 93.31 | 18452.29 | 223.86 | 31025.94 |
| 93.200 | 20000.0 | 99000.0 | 9587.5 | 27.923 | 22.682 | 2049.7 | .38352 | 93.58 | 22038.39 | 229.88 | 39691.13 |
| 93.400 | 20000.0 | 99000.0 | 8263.1 | 36.175 | 27.574 | 2739.0 | .47144 | 93.87 | 26743.48 | 235.93 | 52486.79 |
| 93.600 | 20000.0 | 99000.0 | 6886.7 | 44.634 | 33.124 | 3071.9 | .50479 | 94.10 | 32373.32 | 243.84 | 65900.61 |
| 93.800 | 20000.0 | 99000.0 | 5475.9 | 61.606 | 40.898 | 4327.2 | .64949 | 94.45 | 39642.86 | 251.50 | 92881.35 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 21000.0 | 99000.0 | 21000.0 | .309 | .314 | .0 | .00635 | 81.01 | 2635.87 | 227.21 | 5097.75 |
| 82.000 | 21000.0 | 99000.0 | 21000.0 | .345 | .350 | .0 | .00710 | 82.01 | 2647.06 | 227.13 | 5097.75 |
| 83.000 | 21000.0 | 99000.0 | 21000.0 | .389 | .395 | .0 | .00802 | 83.01 | 2662.34 | 227.01 | 5097.75 |
| 84.000 | 21000.0 | 99000.0 | 21000.0 | .445 | .452 | .0 | .00921 | 84.01 | 2683.81 | 226.85 | 5097.75 |
| 85.000 | 21000.0 | 99000.0 | 21000.0 | .520 | .527 | .0 | .01077 | 85.01 | 2715.08 | 226.63 | 5097.75 |
| 86.000 | 21000.0 | 99000.0 | 21000.0 | .622 | .630 | .0 | .01290 | 86.01 | 2762.61 | 226.32 | 5097.75 |
| 87.000 | 21000.0 | 99000.0 | 21000.0 | .769 | .777 | .0 | .01595 | 87.02 | 2838.57 | 225.87 | 5097.75 |
| 88.000 | 21000.0 | 99000.0 | 21000.0 | .993 | 1.000 | .0 | .02058 | 88.02 | 2967.59 | 225.21 | 5097.75 |
| 89.200 | 21000.0 | 99000.0 | 21000.0 | 1.461 | 1.465 | .0 | .03026 | 89.23 | 3272.44 | 223.97 | 5097.75 |
| 89.400 | 21000.0 | 99000.0 | 21000.0 | 1.576 | 1.579 | .0 | .03261 | 89.43 | 3351.78 | 223.70 | 5097.75 |
| 89.600 | 21000.0 | 99000.0 | 21000.0 | 1.707 | 1.707 | .0 | .03527 | 89.64 | 3443.25 | 223.41 | 5097.75 |
| 89.800 | 21000.0 | 99000.0 | 21000.0 | 1.856 | 1.854 | .0 | .03829 | 89.84 | 3548.63 | 223.10 | 5097.75 |
| 90.000 | 21000.0 | 99000.0 | 21000.0 | 1.970 | 2.022 | 1.7 | .04173 | 90.04 | 3668.67 | 222.77 | 5042.82 |
| 90.200 | 21000.0 | 99000.0 | 20960.3 | 2.169 | 2.216 | 19.4 | .04658 | 90.25 | 3818.01 | 222.33 | 5088.23 |
| 90.400 | 21000.0 | 99000.0 | 20841.0 | 2.414 | 2.441 | 39.9 | .05212 | 90.45 | 3970.87 | 221.84 | 5201.71 |
| 90.600 | 21000.0 | 99000.0 | 20642.5 | 2.683 | 2.704 | 62.4 | .05695 | 90.66 | 4162.35 | 221.33 | 5386.42 |
| 90.800 | 21000.0 | 99000.0 | 20364.5 | 3.000 | 3.010 | 88.9 | .06281 | 90.86 | 4398.80 | 220.91 | 5651.03 |
| 91.000 | 21000.0 | 99000.0 | 20006.9 | 3.392 | 3.372 | 120.9 | .07003 | 91.07 | 4656.59 | 220.52 | 6009.55 |
| 91.200 | 21000.0 | 99000.0 | 19568.4 | 3.853 | 3.809 | 163.1 | .08024 | 91.28 | 5029.76 | 219.78 | 6485.12 |
| 91.400 | 21000.0 | 99000.0 | 19050.0 | 4.423 | 4.327 | 211.2 | .09040 | 91.49 | 5449.40 | 219.31 | 7093.32 |
| 91.600 | 21000.0 | 99000.0 | 18449.6 | 5.117 | 4.963 | 277.1 | .10471 | 91.70 | 6020.05 | 218.52 | 7886.94 |
| 91.800 | 21000.0 | 99000.0 | 17768.2 | 5.976 | 5.730 | 355.1 | .12039 | 91.92 | 6598.89 | 218.04 | 8899.50 |
| 92.000 | 21000.0 | 99000.0 | 17003.8 | 7.065 | 6.673 | 457.0 | .13944 | 92.14 | 7383.66 | 217.65 | 10212.74 |
| 92.200 | 21000.0 | 99000.0 | 16155.1 | 8.472 | 7.845 | 590.3 | .16363 | 92.36 | 8440.51 | 217.33 | 11938.43 |
| 92.400 | 21000.0 | 99000.0 | 15220.1 | 10.332 | 9.317 | 767.0 | .19413 | 92.59 | 9723.50 | 217.07 | 14246.37 |
| 92.600 | 21000.0 | 99000.0 | 14196.3 | 12.856 | 11.191 | 1004.2 | .23302 | 92.83 | 11317.14 | 216.85 | 17405.94 |
| 92.800 | 21000.0 | 99000.0 | 13079.9 | 15.802 | 13.613 | 1328.2 | .28334 | 93.08 | 13311.72 | 216.67 | 21762.91 |
| 93.000 | 21000.0 | 99000.0 | 11889.2 | 18.906 | 16.296 | 1371.9 | .28271 | 93.28 | 15854.80 | 219.74 | 26146.27 |
| 93.200 | 21000.0 | 99000.0 | 10609.3 | 23.818 | 19.708 | 1834.4 | .34519 | 93.55 | 19004.07 | 225.24 | 33547.59 |
| 93.400 | 21000.0 | 99000.0 | 9225.2 | 30.546 | 23.999 | 2415.9 | .41962 | 93.82 | 23130.12 | 231.01 | 43824.16 |
| 93.600 | 21000.0 | 99000.0 | 7758.8 | 36.776 | 28.791 | 2431.5 | .41419 | 94.01 | 27797.34 | 238.18 | 53140.73 |
| 93.800 | 21000.0 | 99000.0 | 6166.1 | 51.804 | 35.795 | 3822.2 | .57981 | 94.38 | 34548.56 | 245.98 | 76903.73 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 22000.0 | 99000.0 | 22000.0 | .265 | .269 | .0 | .00541 | 81.01 | 2255.35 | 228.64 | 4361.89 |
| 82.000 | 22000.0 | 99000.0 | 22000.0 | .295 | .300 | .0 | .00605 | 82.01 | 2264.99 | 228.55 | 4361.89 |
| 83.000 | 22000.0 | 99000.0 | 22000.0 | .333 | .338 | .0 | .00684 | 83.01 | 2278.12 | 228.43 | 4361.89 |
| 84.000 | 22000.0 | 99000.0 | 22000.0 | .381 | .387 | .0 | .00785 | 84.01 | 2296.58 | 228.27 | 4361.89 |
| 85.000 | 22000.0 | 99000.0 | 22000.0 | .445 | .451 | .0 | .00917 | 85.01 | 2323.46 | 228.04 | 4361.89 |
| 86.000 | 22000.0 | 99000.0 | 22000.0 | .532 | .539 | .0 | .01099 | 86.01 | 2364.26 | 227.72 | 4361.89 |
| 87.000 | 22000.0 | 99000.0 | 22000.0 | .657 | .665 | .0 | .01359 | 87.01 | 2429.39 | 227.25 | 4361.89 |
| 88.000 | 22000.0 | 99000.0 | 22000.0 | .848 | .856 | .0 | .01753 | 88.02 | 2539.89 | 226.56 | 4361.89 |
| 89.200 | 22000.0 | 99000.0 | 22000.0 | 1.246 | 1.252 | .0 | .02576 | 89.23 | 2800.50 | 225.28 | 4361.89 |
| 89.400 | 22000.0 | 99000.0 | 22000.0 | 1.344 | 1.348 | .0 | .02776 | 89.43 | 2868.24 | 225.00 | 4361.89 |
| 89.600 | 22000.0 | 99000.0 | 22000.0 | 1.455 | 1.458 | .0 | .03003 | 89.63 | 2946.33 | 224.69 | 4361.89 |
| 89.800 | 22000.0 | 99000.0 | 22000.0 | 1.581 | 1.583 | .0 | .03259 | 89.83 | 3036.26 | 224.37 | 4361.89 |
| 90.000 | 22000.0 | 99000.0 | 22000.0 | 1.674 | 1.725 | 1.2 | .03551 | 90.04 | 3138.65 | 224.02 | 4310.19 |
| 90.200 | 22000.0 | 99000.0 | 21960.4 | 1.842 | 1.890 | 16.3 | .03960 | 90.24 | 3265.87 | 223.56 | 4346.92 |
| 90.400 | 22000.0 | 99000.0 | 21841.5 | 2.048 | 2.082 | 33.6 | .04427 | 90.44 | 3396.13 | 223.04 | 4441.01 |
| 90.600 | 22000.0 | 99000.0 | 21643.5 | 2.275 | 2.304 | 52.6 | .04835 | 90.65 | 3559.29 | 222.51 | 4595.13 |
| 90.800 | 22000.0 | 99000.0 | 21366.4 | 2.541 | 2.565 | 75.0 | .05328 | 90.85 | 3760.59 | 222.07 | 4816.16 |
| 91.000 | 22000.0 | 99000.0 | 21009.8 | 2.870 | 2.871 | 101.9 | .05936 | 91.06 | 3979.97 | 221.66 | 5115.39 |
| 91.200 | 22000.0 | 99000.0 | 20572.9 | 3.254 | 3.240 | 137.4 | .06796 | 91.27 | 4296.95 | 220.90 | 5509.88 |
| 91.400 | 22000.0 | 99000.0 | 20056.4 | 3.730 | 3.678 | 177.8 | .07648 | 91.48 | 4653.27 | 220.41 | 6016.52 |
| 91.600 | 22000.0 | 99000.0 | 19458.5 | 4.303 | 4.213 | 232.9 | .08850 | 91.69 | 5136.46 | 219.62 | 6671.11 |
| 91.800 | 22000.0 | 99000.0 | 18779.4 | 5.039 | 4.867 | 309.1 | .10456 | 91.90 | 5629.53 | 218.89 | 7520.77 |
| 92.000 | 22000.0 | 99000.0 | 18018.6 | 5.932 | 5.667 | 387.6 | .11895 | 92.12 | 6296.81 | 218.23 | 8596.09 |
| 92.200 | 22000.0 | 99000.0 | 17174.8 | 7.084 | 6.656 | 498.7 | .13917 | 92.34 | 7192.88 | 217.77 | 10006.49 |
| 92.400 | 22000.0 | 99000.0 | 16245.6 | 8.590 | 7.896 | 646.1 | .16476 | 92.56 | 8278.74 | 217.40 | 11872.89 |
| 92.600 | 22000.0 | 99000.0 | 15229.6 | 10.609 | 9.469 | 843.2 | .19732 | 92.80 | 9626.70 | 217.11 | 14397.63 |
| 92.800 | 22000.0 | 99000.0 | 14123.5 | 13.397 | 11.491 | 1110.9 | .23930 | 93.04 | 11313.93 | 216.87 | 17907.21 |
| 93.000 | 22000.0 | 99000.0 | 12926.5 | 16.275 | 14.036 | 1307.4 | .26649 | 93.27 | 13572.47 | 216.90 | 22200.83 |
| 93.200 | 22000.0 | 99000.0 | 11656.1 | 20.389 | 17.016 | 1592.4 | .30272 | 93.50 | 16320.34 | 221.30 | 27935.40 |
| 93.400 | 22000.0 | 99000.0 | 10279.7 | 26.299 | 20.860 | 2165.9 | .37811 | 93.78 | 19752.46 | 226.23 | 36754.85 |
| 93.600 | 22000.0 | 99000.0 | 8818.9 | 31.930 | 25.254 | 2311.5 | .39074 | 93.99 | 24133.28 | 232.76 | 45593.49 |
| 93.800 | 22000.0 | 99000.0 | 7248.1 | 43.415 | 31.272 | 3366.3 | .51582 | 94.32 | 30022.36 | 240.57 | 63777.79 |
| 94.000 | 22000.0 | 99000.0 | 5580.5 | 56.823 | 38.405 | 4061.1 | .58871 | 94.59 | 36957.84 | 249.23 | 84833.04 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | PIEFF) (10) | TIEFF) (11) | PITAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 23000.0 | 99000.0 | 23000.0 | .227 | .231 | .0 | .00460 | 81.00 | 1931.35 | 230.13 | 3734.89 |
| 82.000 | 23000.0 | 99000.0 | 23000.0 | .252 | .257 | .0 | .00513 | 82.01 | 1939.65 | 230.04 | 3734.89 |
| 83.000 | 23000.0 | 99000.0 | 23000.0 | .285 | .290 | .0 | .00580 | 83.01 | 1950.96 | 229.92 | 3734.89 |
| 84.000 | 23000.0 | 99000.0 | 23000.0 | .326 | .332 | .0 | .00666 | 84.01 | 1966.84 | 229.75 | 3734.89 |
| 85.000 | 23000.0 | 99000.0 | 23000.0 | .381 | .387 | .0 | .00779 | 85.01 | 1989.95 | 229.51 | 3734.89 |
| 86.000 | 23000.0 | 99000.0 | 23000.0 | .455 | .462 | .0 | .00932 | 86.01 | 2024.99 | 229.17 | 3734.89 |
| 87.000 | 23000.0 | 99000.0 | 23000.0 | .562 | .570 | .0 | .01152 | 87.01 | 2080.88 | 228.69 | 3734.89 |
| 88.000 | 23000.0 | 99000.0 | 23000.0 | .725 | .732 | .0 | .01484 | 88.01 | 2175.54 | 227.98 | 3734.89 |
| 89.200 | 23000.0 | 99000.0 | 23000.0 | 1.064 | 1.070 | .0 | .02175 | 89.22 | 2398.24 | 226.71 | 3734.89 |
| 89.400 | 23000.0 | 99000.0 | 23000.0 | 1.147 | 1.152 | .0 | .02342 | 89.42 | 2456.03 | 226.45 | 3734.89 |
| 89.600 | 23000.0 | 99000.0 | 23000.0 | 1.241 | 1.245 | .0 | .02532 | 89.63 | 2522.60 | 226.16 | 3734.89 |
| 89.800 | 23000.0 | 99000.0 | 23000.0 | 1.348 | 1.351 | .0 | .02746 | 89.83 | 2599.22 | 225.87 | 3734.89 |
| 90.000 | 23000.0 | 99000.0 | 23000.0 | 1.414 | 1.472 | .9 | .02991 | 90.03 | 2686.41 | 225.56 | 3687.07 |
| 90.200 | 23000.0 | 99000.0 | 22960.4 | 1.557 | 1.612 | 13.7 | .03399 | 90.23 | 2794.94 | 225.05 | 3716.94 |
| 90.400 | 23000.0 | 99000.0 | 22841.7 | 1.741 | 1.776 | 28.9 | .03862 | 90.44 | 2906.43 | 224.43 | 3795.30 |
| 90.600 | 23000.0 | 99000.0 | 22644.0 | 1.932 | 1.966 | 44.8 | .04172 | 90.64 | 3045.87 | 223.78 | 3924.36 |
| 90.800 | 23000.0 | 99000.0 | 22367.6 | 2.157 | 2.187 | 63.5 | .04561 | 90.85 | 3217.51 | 223.28 | 4109.54 |
| 91.000 | 23000.0 | 99000.0 | 22011.9 | 2.423 | 2.447 | 86.2 | .05063 | 91.05 | 3404.44 | 222.84 | 4359.42 |
| 91.200 | 23000.0 | 99000.0 | 21576.2 | 2.754 | 2.760 | 116.1 | .05783 | 91.26 | 3674.06 | 222.05 | 4689.85 |
| 91.400 | 23000.0 | 99000.0 | 21061.2 | 3.152 | 3.130 | 150.0 | .06496 | 91.46 | 3976.97 | 221.54 | 5112.70 |
| 91.600 | 23000.0 | 99000.0 | 20465.5 | 3.629 | 3.583 | 196.2 | .07504 | 91.68 | 4386.75 | 220.73 | 5656.69 |
| 91.800 | 23000.0 | 99000.0 | 19789.0 | 4.237 | 4.133 | 259.8 | .08844 | 91.89 | 4865.24 | 220.00 | 6358.24 |
| 92.000 | 23000.0 | 99000.0 | 19031.4 | 4.987 | 4.806 | 325.5 | .10052 | 92.10 | 5370.63 | 219.31 | 7243.89 |
| 92.200 | 23000.0 | 99000.0 | 18190.6 | 5.942 | 5.651 | 423.6 | .11886 | 92.32 | 6132.31 | 218.39 | 8411.32 |
| 92.400 | 23000.0 | 99000.0 | 17266.7 | 7.171 | 6.699 | 546.1 | .14018 | 92.54 | 6968.50 | 217.86 | 9933.76 |
| 92.600 | 23000.0 | 99000.0 | 16257.2 | 8.803 | 8.023 | 710.4 | .16748 | 92.77 | 8095.60 | 217.45 | 11972.42 |
| 92.800 | 23000.0 | 99000.0 | 15159.5 | 11.024 | 9.719 | 932.7 | .20260 | 93.00 | 9623.19 | 217.13 | 14765.58 |
| 93.000 | 23000.0 | 99000.0 | 13970.2 | 13.941 | 11.924 | 1237.9 | .24836 | 93.25 | 11551.77 | 216.87 | 18712.28 |
| 93.200 | 23000.0 | 99000.0 | 12697.0 | 17.314 | 14.640 | 1633.8 | .27304 | 93.47 | 13970.39 | 218.16 | 23414.31 |
| 93.400 | 23000.0 | 99000.0 | 11331.8 | 22.182 | 18.024 | 1911.2 | .33583 | 93.74 | 16978.86 | 222.22 | 30626.60 |
| 93.600 | 23000.0 | 99000.0 | 9875.6 | 27.237 | 22.016 | 2088.2 | .35420 | 93.95 | 20864.42 | 227.62 | 38436.99 |
| 93.800 | 23000.0 | 99000.0 | 8319.6 | 37.079 | 27.311 | 3011.6 | .46441 | 94.26 | 25807.66 | 235.19 | 53272.19 |
| 94.000 | 23000.0 | 99000.0 | 6669.7 | 47.591 | 33.550 | 3511.4 | .51618 | 94.52 | 32156.76 | 243.68 | 69692.86 |
| 94.200 | 23000.0 | 99000.0 | 4890.7 | 63.409 | 41.697 | 4343.9 | .60437 | 94.80 | 40242.64 | 252.05 | 95086.32 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 24000.0 | 99000.0 | 24000.0 | .194 | .198 | .0 | .00393 | 81.00 | 1656.20 | 231.53 | 3202.77 |
| 82.000 | 24000.0 | 99000.0 | 24000.0 | .216 | .221 | .0 | .00439 | 82.00 | 1663.35 | 231.43 | 3202.77 |
| 83.000 | 24000.0 | 99000.0 | 24000.0 | .244 | .249 | .0 | .00496 | 83.00 | 1673.10 | 231.30 | 3202.77 |
| 84.000 | 24000.0 | 99000.0 | 24000.0 | .279 | .285 | .0 | .00569 | 84.01 | 1686.79 | 231.12 | 3202.77 |
| 85.000 | 24000.0 | 99000.0 | 24000.0 | .326 | .332 | .0 | .00665 | 85.01 | 1706.69 | 230.87 | 3202.77 |
| 86.000 | 24000.0 | 99000.0 | 24000.0 | .390 | .396 | .0 | .00796 | 86.01 | 1736.85 | 230.51 | 3202.77 |
| 87.000 | 24000.0 | 99000.0 | 24000.0 | .481 | .488 | .0 | .00983 | 87.01 | 1784.89 | 229.99 | 3202.77 |
| 88.000 | 24000.0 | 99000.0 | 24000.0 | .620 | .628 | .0 | .01266 | 88.01 | 1866.14 | 229.23 | 3202.77 |
| 89.200 | 24000.0 | 99000.0 | 24000.0 | .908 | .917 | .0 | .01853 | 89.22 | 2056.92 | 227.87 | 3202.77 |
| 89.400 | 24000.0 | 99000.0 | 24000.0 | .979 | .987 | .0 | .01996 | 89.42 | 2106.37 | 227.59 | 3202.77 |
| 89.600 | 24000.0 | 99000.0 | 24000.0 | 1.059 | 1.066 | .0 | .02157 | 89.62 | 2163.31 | 227.30 | 3202.77 |
| 89.800 | 24000.0 | 99000.0 | 24000.0 | 1.149 | 1.157 | .0 | .02339 | 89.82 | 2228.81 | 226.99 | 3202.77 |
| 90.000 | 24000.0 | 99000.0 | 24000.0 | 1.210 | 1.260 | .6 | .02546 | 90.03 | 2303.33 | 226.67 | 3157.94 |
| 90.200 | 24000.0 | 99000.0 | 23960.6 | 1.330 | 1.379 | 11.3 | .02838 | 90.23 | 2395.68 | 226.26 | 3182.29 |
| 90.400 | 24000.0 | 99000.0 | 23842.3 | 1.477 | 1.517 | 23.7 | .03171 | 90.43 | 2490.32 | 225.78 | 3247.49 |
| 90.600 | 24000.0 | 99000.0 | 23645.2 | 1.638 | 1.677 | 37.2 | .03461 | 90.63 | 2608.80 | 225.29 | 3355.43 |
| 90.800 | 24000.0 | 99000.0 | 23369.3 | 1.827 | 1.864 | 53.1 | .03812 | 90.84 | 2754.66 | 224.89 | 3510.50 |
| 91.000 | 24000.0 | 99000.0 | 23014.4 | 2.050 | 2.083 | 72.2 | .04242 | 91.04 | 2913.54 | 224.52 | 3719.51 |
| 91.200 | 24000.0 | 99000.0 | 22579.4 | 2.338 | 2.351 | 99.0 | .04942 | 91.25 | 3143.57 | 223.41 | 3997.42 |
| 91.400 | 24000.0 | 99000.0 | 22065.7 | 2.661 | 2.666 | 127.1 | .05520 | 91.46 | 3401.59 | 222.81 | 4350.62 |
| 91.600 | 24000.0 | 99000.0 | 21471.7 | 3.069 | 3.049 | 165.8 | .06364 | 91.66 | 3749.65 | 221.94 | 4805.32 |
| 91.800 | 24000.0 | 99000.0 | 20797.4 | 3.574 | 3.514 | 218.9 | .07483 | 91.87 | 4105.33 | 221.18 | 5387.71 |
| 92.000 | 24000.0 | 99000.0 | 20042.5 | 4.195 | 4.082 | 274.0 | .08600 | 92.09 | 4585.02 | 220.45 | 6121.70 |
| 92.200 | 24000.0 | 99000.0 | 19205.2 | 4.993 | 4.793 | 355.9 | .10036 | 92.30 | 5229.02 | 219.51 | 7081.43 |
| 92.400 | 24000.0 | 99000.0 | 18284.8 | 6.011 | 5.685 | 464.1 | .11965 | 92.52 | 5941.42 | 218.55 | 8340.14 |
| 92.600 | 24000.0 | 99000.0 | 17280.8 | 7.340 | 6.804 | 600.4 | .14235 | 92.74 | 6898.32 | 217.94 | 9999.31 |
| 92.800 | 24000.0 | 99000.0 | 16190.2 | 9.128 | 8.231 | 785.6 | .17178 | 92.97 | 8190.12 | 217.49 | 12246.94 |
| 93.000 | 24000.0 | 99000.0 | 15010.3 | 11.607 | 10.078 | 1038.8 | .21004 | 93.21 | 9701.03 | 217.14 | 15376.73 |
| 93.200 | 24000.0 | 99000.0 | 13736.7 | 14.929 | 12.506 | 1390.3 | .26045 | 93.46 | 11911.33 | 216.87 | 19863.39 |
| 93.400 | 24000.0 | 99000.0 | 12377.7 | 18.846 | 15.526 | 1724.9 | .30346 | 93.70 | 14549.42 | 218.75 | 25636.81 |
| 93.600 | 24000.0 | 99000.0 | 10928.6 | 23.539 | 19.141 | 1978.0 | .33261 | 93.93 | 17981.35 | 223.22 | 32743.78 |
| 93.800 | 24000.0 | 99000.0 | 9388.3 | 31.119 | 23.731 | 2645.7 | .41135 | 94.21 | 22305.90 | 230.32 | 44208.35 |
| 94.000 | 24000.0 | 99000.0 | 7751.1 | 38.684 | 29.097 | 2753.8 | .41928 | 94.42 | 27582.14 | 238.09 | 55436.03 |
| 94.200 | 24000.0 | 99000.0 | 5981.9 | 55.194 | 36.798 | 4193.0 | .57801 | 94.78 | 35171.55 | 246.39 | 82182.23 |

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THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 25000.0 | 99000.0 | 25000.0 | .167 | .170 | .0 | .00336 | 81.00 | 1421.30 | 232.98 | 2748.11 |
| 82.000 | 25000.0 | 99000.0 | 25000.0 | .186 | .189 | .0 | .00375 | 82.00 | 1427.48 | 232.88 | 2748.11 |
| 83.000 | 25000.0 | 99000.0 | 25000.0 | .209 | .214 | .0 | .00424 | 83.00 | 1435.89 | 232.74 | 2748.11 |
| 84.000 | 25000.0 | 99000.0 | 25000.0 | .240 | .244 | .0 | .00486 | 84.00 | 1447.70 | 232.55 | 2748.11 |
| 85.000 | 25000.0 | 99000.0 | 25000.0 | .280 | .285 | .0 | .00568 | 85.01 | 1464.86 | 232.28 | 2748.11 |
| 86.000 | 25000.0 | 99000.0 | 25000.0 | .334 | .340 | .0 | .00680 | 86.01 | 1490.84 | 231.90 | 2748.11 |
| 87.000 | 25000.0 | 99000.0 | 25000.0 | .413 | .419 | .0 | .00840 | 87.01 | 1532.19 | 231.35 | 2748.11 |
| 88.000 | 25000.0 | 99000.0 | 25000.0 | .531 | .539 | .0 | .01081 | 88.01 | 1602.01 | 230.52 | 2748.11 |
| 89.200 | 25000.0 | 99000.0 | 25000.0 | .778 | .786 | .0 | .01580 | 89.22 | 1765.60 | 229.04 | 2748.11 |
| 89.400 | 25000.0 | 99000.0 | 25000.0 | .838 | .846 | .0 | .01700 | 89.42 | 1807.94 | 228.73 | 2748.11 |
| 89.600 | 25000.0 | 99000.0 | 25000.0 | .906 | .914 | .0 | .01837 | 89.62 | 1856.67 | 228.42 | 2748.11 |
| 89.800 | 25000.0 | 99000.0 | 25000.0 | .983 | .991 | .0 | .01991 | 89.82 | 1912.70 | 228.10 | 2748.11 |
| 90.000 | 25000.0 | 99000.0 | 25000.0 | 1.032 | 1.080 | .5 | .02167 | 90.02 | 1976.43 | 227.77 | 2706.53 |
| 90.200 | 25000.0 | 99000.0 | 24960.6 | 1.134 | 1.181 | 9.6 | .02415 | 90.22 | 2055.32 | 227.35 | 2726.61 |
| 90.400 | 25000.0 | 99000.0 | 24842.5 | 1.259 | 1.299 | 20.0 | .02698 | 90.43 | 2136.20 | 226.87 | 2781.36 |
| 90.600 | 25000.0 | 99000.0 | 24645.8 | 1.395 | 1.435 | 31.5 | .02945 | 90.63 | 2237.45 | 226.38 | 2872.38 |
| 90.800 | 25000.0 | 99000.0 | 24370.4 | 1.555 | 1.594 | 45.0 | .03243 | 90.83 | 2362.02 | 225.98 | 3003.24 |
| 91.000 | 25000.0 | 99000.0 | 24016.1 | 1.744 | 1.781 | 61.2 | .03608 | 91.04 | 2497.68 | 225.60 | 3179.54 |
| 91.200 | 25000.0 | 99000.0 | 23582.4 | 1.977 | 2.005 | 82.4 | .04123 | 91.24 | 2692.58 | 224.88 | 3411.62 |
| 91.400 | 25000.0 | 99000.0 | 23069.9 | 2.248 | 2.270 | 106.3 | .04628 | 91.45 | 2911.36 | 224.42 | 3707.33 |
| 91.600 | 25000.0 | 99000.0 | 22476.9 | 2.599 | 2.597 | 141.1 | .05424 | 91.65 | 3207.68 | 223.25 | 4089.30 |
| 91.800 | 25000.0 | 99000.0 | 21804.4 | 3.020 | 2.991 | 185.1 | .06346 | 91.86 | 3510.40 | 222.42 | 4574.78 |
| 92.000 | 25000.0 | 99000.0 | 21051.8 | 3.537 | 3.472 | 231.3 | .07200 | 92.07 | 3917.92 | 221.62 | 5185.97 |
| 92.200 | 25000.0 | 99000.0 | 20217.4 | 4.197 | 4.071 | 299.8 | .08488 | 92.28 | 4463.30 | 220.65 | 5979.64 |
| 92.400 | 25000.0 | 99000.0 | 19300.8 | 5.045 | 4.822 | 390.1 | .10103 | 92.50 | 5067.29 | 219.66 | 7013.01 |
| 92.600 | 25000.0 | 99000.0 | 18300.6 | 6.141 | 5.773 | 510.4 | .12147 | 92.72 | 5880.52 | 218.64 | 8380.48 |
| 92.800 | 25000.0 | 99000.0 | 17216.8 | 7.593 | 6.978 | 663.8 | .14594 | 92.95 | 6974.46 | 217.98 | 10204.16 |
| 93.000 | 25000.0 | 99000.0 | 16043.8 | 9.582 | 8.531 | 874.6 | .17798 | 93.18 | 8256.81 | 217.50 | 12713.94 |
| 93.200 | 25000.0 | 99000.0 | 14780.6 | 12.393 | 10.563 | 1165.8 | .22009 | 93.42 | 10001.90 | 217.13 | 16274.96 |
| 93.400 | 25000.0 | 99000.0 | 13421.4 | 15.981 | 13.267 | 1575.4 | .27625 | 93.68 | 12411.67 | 216.85 | 21458.74 |
| 93.600 | 25000.0 | 99000.0 | 11976.5 | 20.471 | 16.566 | 1854.3 | .30981 | 93.91 | 15441.50 | 219.29 | 27699.07 |
| 93.800 | 25000.0 | 99000.0 | 10448.2 | 26.672 | 20.591 | 2367.7 | .36957 | 94.17 | 19226.50 | 225.68 | 36923.36 |
| 94.000 | 25000.0 | 99000.0 | 8817.5 | 33.530 | 25.501 | 2621.0 | .39570 | 94.40 | 23940.08 | 232.66 | 47493.75 |
| 94.200 | 25000.0 | 99000.0 | 7071.6 | 47.761 | 32.281 | 3918.2 | .53825 | 94.74 | 30356.41 | 241.06 | 69736.07 |
| 94.400 | 25000.0 | 99000.0 | 5222.4 | 65.678 | 40.549 | 4958.3 | .64203 | 95.04 | 38712.78 | 250.61 | 98261.54 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 26000.0 | 99000.0 | 26000.0 | .143 | .146 | .0 | .00289 | 81.00 | 1220.52 | 234.50 | 2359.61 |
| 82.000 | 26000.0 | 99000.0 | 26000.0 | .159 | .163 | .0 | .00322 | 82.00 | 1225.86 | 234.39 | 2359.61 |
| 83.000 | 26000.0 | 99000.0 | 26000.0 | .180 | .184 | .0 | .00364 | 83.00 | 1233.14 | 234.25 | 2359.61 |
| 84.000 | 26000.0 | 99000.0 | 26000.0 | .206 | .210 | .0 | .00418 | 84.00 | 1243.34 | 234.05 | 2359.61 |
| 85.000 | 26000.0 | 99000.0 | 26000.0 | .240 | .245 | .0 | .00489 | 85.00 | 1258.15 | 233.77 | 2359.61 |
| 86.000 | 26000.0 | 99000.0 | 26000.0 | .287 | .292 | .0 | .00585 | 86.01 | 1280.56 | 233.36 | 2359.61 |
| 87.000 | 26000.0 | 99000.0 | 26000.0 | .354 | .360 | .0 | .00722 | 87.01 | 1316.19 | 232.76 | 2359.61 |
| 88.000 | 26000.0 | 99000.0 | 26000.0 | .455 | .462 | .0 | .00930 | 88.01 | 1376.28 | 231.85 | 2359.61 |
| 89.200 | 26000.0 | 99000.0 | 26000.0 | .666 | .675 | .0 | .01360 | 89.21 | 1516.86 | 230.14 | 2359.61 |
| 89.400 | 26000.0 | 99000.0 | 26000.0 | .717 | .726 | .0 | .01463 | 89.41 | 1553.21 | 229.78 | 2359.61 |
| 89.600 | 26000.0 | 99000.0 | 26000.0 | .775 | .785 | .0 | .01580 | 89.62 | 1595.03 | 229.40 | 2359.61 |
| 89.800 | 26000.0 | 99000.0 | 26000.0 | .841 | .851 | .0 | .01713 | 89.82 | 1643.10 | 229.01 | 2359.61 |
| 90.000 | 26000.0 | 99000.0 | 26000.0 | .887 | .927 | .3 | .01864 | 90.02 | 1697.76 | 228.61 | 2320.81 |
| 90.200 | 26000.0 | 99000.0 | 25960.7 | .973 | 1.013 | 8.0 | .02038 | 90.22 | 1765.23 | 228.21 | 2337.49 |
| 90.400 | 26000.0 | 99000.0 | 25842.9 | 1.073 | 1.114 | 16.6 | .02237 | 90.42 | 1834.21 | 227.81 | 2383.73 |
| 90.600 | 26000.0 | 99000.0 | 25646.5 | 1.190 | 1.230 | 26.5 | .02469 | 90.62 | 1920.56 | 227.41 | 2460.68 |
| 90.800 | 26000.0 | 99000.0 | 25371.5 | 1.325 | 1.365 | 38.1 | .02739 | 90.83 | 2026.92 | 227.03 | 2571.40 |
| 91.000 | 26000.0 | 99000.0 | 25017.7 | 1.485 | 1.524 | 51.9 | .03056 | 91.03 | 2142.80 | 226.67 | 2720.49 |
| 91.200 | 26000.0 | 99000.0 | 24584.8 | 1.683 | 1.715 | 69.9 | .03497 | 91.23 | 2309.11 | 225.96 | 2916.42 |
| 91.400 | 26000.0 | 99000.0 | 24073.1 | 1.911 | 1.940 | 90.2 | .03927 | 91.44 | 2495.75 | 225.49 | 3165.91 |
| 91.600 | 26000.0 | 99000.0 | 23481.8 | 2.197 | 2.214 | 117.7 | .04531 | 91.65 | 2746.53 | 224.72 | 3484.72 |
| 91.800 | 26000.0 | 99000.0 | 22810.6 | 2.558 | 2.547 | 159.9 | .05466 | 91.85 | 3003.86 | 223.87 | 3893.09 |
| 92.000 | 26000.0 | 99000.0 | 22059.6 | 2.989 | 2.956 | 195.9 | .06109 | 92.06 | 3350.68 | 222.86 | 4402.53 |
| 92.200 | 26000.0 | 99000.0 | 21227.8 | 3.527 | 3.463 | 253.2 | .07186 | 92.27 | 3813.27 | 221.83 | 5061.50 |
| 92.400 | 26000.0 | 99000.0 | 20314.3 | 4.225 | 4.096 | 328.7 | .08540 | 92.49 | 4325.99 | 220.81 | 5915.24 |
| 92.600 | 26000.0 | 99000.0 | 19318.2 | 5.148 | 4.896 | 429.0 | .10251 | 92.70 | 5014.42 | 219.76 | 7036.96 |
| 92.800 | 26000.0 | 99000.0 | 18237.6 | 6.344 | 5.920 | 563.9 | .12439 | 92.92 | 5941.98 | 218.67 | 8537.93 |
| 93.000 | 26000.0 | 99000.0 | 17072.1 | 7.951 | 7.230 | 738.6 | .15108 | 93.15 | 7031.43 | 217.97 | 10565.43 |
| 93.200 | 26000.0 | 99000.0 | 15817.5 | 10.193 | 8.937 | 980.9 | .18633 | 93.39 | 8508.95 | 217.48 | 13403.18 |
| 93.400 | 26000.0 | 99000.0 | 14470.0 | 13.437 | 11.196 | 1319.6 | .23318 | 93.63 | 10538.18 | 217.10 | 17521.28 |
| 93.600 | 26000.0 | 99000.0 | 13023.4 | 17.649 | 14.243 | 1802.3 | .29648 | 93.90 | 13052.01 | 216.82 | 23564.93 |
| 93.800 | 26000.0 | 99000.0 | 11505.2 | 22.372 | 17.763 | 2077.9 | .32628 | 94.13 | 16323.52 | 221.78 | 30597.64 |
| 94.000 | 26000.0 | 99000.0 | 9880.1 | 28.518 | 22.215 | 2375.6 | .35918 | 94.36 | 20690.15 | 227.54 | 39924.50 |
| 94.200 | 26000.0 | 99000.0 | 8151.2 | 40.118 | 28.171 | 3504.2 | .48401 | 94.68 | 26335.56 | 235.67 | 57945.46 |
| 94.400 | 26000.0 | 99000.0 | 6322.8 | 54.224 | 35.419 | 4366.9 | .57060 | 94.97 | 33402.82 | 245.12 | 80580.99 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 27000.0 | 99000.0 | 27000.0 | .123 | .126 | .0 | .00248 | 81.00 | 1048.14 | 236.29 | 2025.86 |
| 82.000 | 27000.0 | 99000.0 | 27000.0 | .137 | .140 | .0 | .00277 | 82.00 | 1052.76 | 236.18 | 2025.86 |
| 83.000 | 27000.0 | 99000.0 | 27000.0 | .154 | .158 | .0 | .00313 | 83.00 | 1059.05 | 236.03 | 2025.86 |
| 84.000 | 27000.0 | 99000.0 | 27000.0 | .177 | .180 | .0 | .00359 | 84.00 | 1067.86 | 235.82 | 2025.86 |
| 85.000 | 27000.0 | 99000.0 | 27000.0 | .206 | .210 | .0 | .00420 | 85.00 | 1080.65 | 235.53 | 2025.86 |
| 86.000 | 27000.0 | 99000.0 | 27000.0 | .246 | .251 | .0 | .00503 | 86.01 | 1099.99 | 235.10 | 2025.86 |
| 87.000 | 27000.0 | 99000.0 | 27000.0 | .304 | .309 | .0 | .00621 | 87.01 | 1130.70 | 234.46 | 2025.86 |
| 88.000 | 27000.0 | 99000.0 | 27000.0 | .391 | .397 | .0 | .00800 | 88.01 | 1182.44 | 233.47 | 2025.86 |
| 89.200 | 27000.0 | 99000.0 | 27000.0 | .571 | .579 | .0 | .01171 | 89.21 | 1303.30 | 231.54 | 2025.86 |
| 89.400 | 27000.0 | 99000.0 | 27000.0 | .615 | .623 | .0 | .01261 | 89.41 | 1334.52 | 231.11 | 2025.86 |
| 89.600 | 27000.0 | 99000.0 | 27000.0 | .665 | .673 | .0 | .01362 | 89.61 | 1370.42 | 230.66 | 2025.86 |
| 89.800 | 27000.0 | 99000.0 | 27000.0 | .722 | .730 | .0 | .01476 | 89.81 | 1411.68 | 230.19 | 2025.86 |
| 90.000 | 27000.0 | 99000.0 | 27000.0 | .758 | .795 | .3 | .01606 | 90.02 | 1458.58 | 229.70 | 1989.97 |
| 90.200 | 27000.0 | 99000.0 | 26960.8 | .833 | .870 | 6.9 | .01754 | 90.22 | 1516.46 | 229.20 | 2003.93 |
| 90.400 | 27000.0 | 99000.0 | 26843.1 | .918 | .956 | 14.3 | .01926 | 90.42 | 1575.60 | 228.69 | 2043.19 |
| 90.600 | 27000.0 | 99000.0 | 26646.9 | 1.018 | 1.055 | 22.7 | .02124 | 90.62 | 1649.66 | 228.20 | 2108.65 |
| 90.800 | 27000.0 | 99000.0 | 26372.1 | 1.134 | 1.172 | 32.7 | .02355 | 90.82 | 1740.87 | 227.72 | 2202.91 |
| 91.000 | 27000.0 | 99000.0 | 26018.7 | 1.270 | 1.308 | 44.5 | .02627 | 91.03 | 1840.24 | 227.27 | 2329.82 |
| 91.200 | 27000.0 | 99000.0 | 25586.6 | 1.432 | 1.469 | 58.8 | .02947 | 91.23 | 1981.98 | 226.85 | 2495.50 |
| 91.400 | 27000.0 | 99000.0 | 25075.7 | 1.625 | 1.661 | 76.4 | .03329 | 91.43 | 2141.17 | 226.46 | 2706.62 |
| 91.600 | 27000.0 | 99000.0 | 24485.3 | 1.867 | 1.893 | 99.7 | .03846 | 91.64 | 2354.88 | 225.72 | 2975.64 |
| 91.800 | 27000.0 | 99000.0 | 23815.7 | 2.161 | 2.174 | 131.1 | .04511 | 91.85 | 2573.74 | 225.07 | 3315.14 |
| 92.000 | 27000.0 | 99000.0 | 23066.5 | 2.529 | 2.517 | 163.9 | .05122 | 92.05 | 2867.46 | 224.37 | 3742.73 |
| 92.200 | 27000.0 | 99000.0 | 22236.3 | 2.979 | 2.949 | 214.7 | .06103 | 92.26 | 3260.71 | 223.06 | 4294.94 |
| 92.400 | 27000.0 | 99000.0 | 21325.4 | 3.559 | 3.484 | 277.6 | .07232 | 92.47 | 3696.53 | 221.97 | 5004.01 |
| 92.600 | 27000.0 | 99000.0 | 20332.7 | 4.308 | 4.159 | 361.5 | .08667 | 92.69 | 4280.18 | 220.88 | 5928.63 |
| 92.800 | 27000.0 | 99000.0 | 19256.7 | 5.309 | 5.020 | 473.9 | .10497 | 92.90 | 5003.41 | 219.77 | 7156.33 |
| 93.000 | 27000.0 | 99000.0 | 18095.7 | 6.628 | 6.133 | 626.7 | .12865 | 93.13 | 5990.76 | 218.62 | 8819.13 |
| 93.200 | 27000.0 | 99000.0 | 16848.3 | 8.434 | 7.572 | 827.9 | .15807 | 93.36 | 7243.27 | 217.92 | 11103.94 |
| 93.400 | 27000.0 | 99000.0 | 15510.4 | 11.003 | 9.467 | 1109.4 | .19727 | 93.60 | 8849.41 | 217.42 | 14364.29 |
| 93.600 | 27000.0 | 99000.0 | 14077.1 | 14.591 | 12.008 | 1507.8 | .24999 | 93.85 | 11081.68 | 217.05 | 19190.68 |
| 93.800 | 27000.0 | 99000.0 | 12554.5 | 18.947 | 15.277 | 1874.6 | .29438 | 94.09 | 13974.58 | 218.54 | 25535.82 |
| 94.000 | 27000.0 | 99000.0 | 10937.7 | 24.616 | 19.302 | 2255.1 | .33780 | 94.34 | 17825.29 | 223.17 | 33978.41 |
| 94.200 | 27000.0 | 99000.0 | 9226.5 | 33.882 | 24.465 | 3086.7 | .42926 | 94.63 | 22753.41 | 230.82 | 47847.36 |
| 94.400 | 27000.0 | 99000.0 | 7413.1 | 45.375 | 30.888 | 3827.8 | .50469 | 94.90 | 29007.55 | 239.73 | 66139.08 |
| 94.600 | 27000.0 | 99000.0 | 5481.6 | 63.437 | 39.252 | 4907.7 | .61075 | 95.21 | 37355.90 | 249.47 | 94787.34 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 28000.0 | 99000.0 | 28000.0 | .105 | .108 | .0 | .00213 | 81.00 | 900.14 | 238.37 | 1739.32 |
| 82.000 | 28000.0 | 99000.0 | 28000.0 | .117 | .120 | .0 | .00238 | 82.00 | 904.13 | 238.26 | 1739.32 |
| 83.000 | 28000.0 | 99000.0 | 28000.0 | .132 | .135 | .0 | .00269 | 83.00 | 909.56 | 238.11 | 1739.32 |
| 84.000 | 28000.0 | 99000.0 | 28000.0 | .152 | .155 | .0 | .00309 | 84.00 | 917.18 | 237.90 | 1739.32 |
| 85.000 | 28000.0 | 99000.0 | 28000.0 | .177 | .181 | .0 | .00361 | 85.00 | 928.22 | 237.61 | 1739.32 |
| 86.000 | 28000.0 | 99000.0 | 28000.0 | .211 | .216 | .0 | .00433 | 86.00 | 944.90 | 237.17 | 1739.32 |
| 87.000 | 28000.0 | 99000.0 | 28000.0 | .261 | .265 | .0 | .00535 | 87.01 | 971.36 | 236.52 | 1739.32 |
| 88.000 | 28000.0 | 99000.0 | 28000.0 | .335 | .340 | .0 | .00689 | 88.01 | 1015.91 | 235.48 | 1739.32 |
| 89.200 | 28000.0 | 99000.0 | 28000.0 | .490 | .496 | .0 | .01011 | 89.21 | 1119.83 | 233.36 | 1739.32 |
| 89.400 | 28000.0 | 99000.0 | 28000.0 | .528 | .534 | .0 | .01089 | 89.41 | 1146.66 | 232.86 | 1739.32 |
| 89.600 | 28000.0 | 99000.0 | 28000.0 | .571 | .577 | .0 | .01176 | 89.61 | 1177.51 | 232.33 | 1739.32 |
| 89.800 | 28000.0 | 99000.0 | 28000.0 | .619 | .626 | .0 | .01275 | 89.81 | 1212.96 | 231.75 | 1739.32 |
| 90.000 | 28000.0 | 99000.0 | 28000.0 | .649 | .682 | .2 | .01387 | 90.01 | 1253.22 | 231.14 | 1706.22 |
| 90.200 | 28000.0 | 99000.0 | 27960.8 | .712 | .746 | 5.9 | .01514 | 90.22 | 1302.90 | 230.50 | 1717.94 |
| 90.400 | 28000.0 | 99000.0 | 27843.2 | .786 | .820 | 12.3 | .01661 | 90.42 | 1353.64 | 229.86 | 1751.32 |
| 90.600 | 28000.0 | 99000.0 | 27647.2 | .871 | .906 | 19.6 | .01830 | 90.62 | 1417.16 | 229.23 | 1807.07 |
| 90.800 | 28000.0 | 99000.0 | 27372.7 | .970 | 1.006 | 28.1 | .02028 | 90.82 | 1495.39 | 228.62 | 1887.40 |
| 91.000 | 28000.0 | 99000.0 | 27019.6 | 1.086 | 1.123 | 38.2 | .02260 | 91.02 | 1580.60 | 228.04 | 1995.54 |
| 91.200 | 28000.0 | 99000.0 | 26588.0 | 1.224 | 1.261 | 50.5 | .02534 | 91.23 | 1702.16 | 227.50 | 2136.69 |
| 91.400 | 28000.0 | 99000.0 | 26077.6 | 1.389 | 1.426 | 65.5 | .02861 | 91.43 | 1838.66 | 227.01 | 2316.42 |
| 91.600 | 28000.0 | 99000.0 | 25488.3 | 1.588 | 1.622 | 84.2 | .03252 | 91.63 | 2020.73 | 226.57 | 2543.05 |
| 91.800 | 28000.0 | 99000.0 | 24819.6 | 1.837 | 1.861 | 111.0 | .03827 | 91.84 | 2207.43 | 226.01 | 2830.32 |
| 92.000 | 28000.0 | 99000.0 | 24071.7 | 2.134 | 2.152 | 138.9 | .04349 | 92.04 | 2457.80 | 225.35 | 3190.33 |
| 92.200 | 28000.0 | 99000.0 | 23243.6 | 2.514 | 2.513 | 179.5 | .05117 | 92.25 | 2790.28 | 224.48 | 3650.36 |
| 92.400 | 28000.0 | 99000.0 | 22334.6 | 3.006 | 2.968 | 235.6 | .06148 | 92.46 | 3161.30 | 223.18 | 4243.62 |
| 92.600 | 28000.0 | 99000.0 | 21344.7 | 3.626 | 3.538 | 305.4 | .07341 | 92.67 | 3656.89 | 222.02 | 5010.66 |
| 92.800 | 28000.0 | 99000.0 | 20272.4 | 4.450 | 4.264 | 399.3 | .08874 | 92.89 | 4270.26 | 220.88 | 6021.71 |
| 93.000 | 28000.0 | 99000.0 | 19116.2 | 5.540 | 5.199 | 526.5 | .10853 | 93.11 | 5105.07 | 219.71 | 7380.05 |
| 93.200 | 28000.0 | 99000.0 | 17874.0 | 7.015 | 6.421 | 701.5 | .13446 | 93.33 | 6169.13 | 218.52 | 9246.56 |
| 93.400 | 28000.0 | 99000.0 | 16544.1 | 9.072 | 8.017 | 935.5 | .16723 | 93.57 | 7531.18 | 217.83 | 11855.93 |
| 93.600 | 28000.0 | 99000.0 | 15121.7 | 12.069 | 10.145 | 1266.1 | .21129 | 93.81 | 9416.65 | 217.34 | 15663.93 |
| 93.800 | 28000.0 | 99000.0 | 13600.8 | 16.095 | 13.037 | 1740.2 | .27133 | 94.07 | 11911.67 | 216.97 | 21412.39 |
| 94.000 | 28000.0 | 99000.0 | 11989.5 | 21.162 | 16.708 | 2146.4 | .31847 | 94.32 | 15305.78 | 219.29 | 28849.06 |
| 94.200 | 28000.0 | 99000.0 | 10291.7 | 28.506 | 21.224 | 2762.2 | .38543 | 94.59 | 19416.57 | 226.12 | 39791.44 |
| 94.400 | 28000.0 | 99000.0 | 8491.4 | 38.485 | 26.929 | 3414.2 | .45248 | 94.85 | 25128.60 | 234.43 | 54871.74 |
| 94.600 | 28000.0 | 99000.0 | 6580.7 | 52.572 | 34.262 | 4284.5 | .53859 | 95.14 | 32211.81 | 243.96 | 77343.39 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
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IN DECIMAL DEGREES FROM THE ZENITH

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 29000.0 | 99000.0 | 29000.0 | .090 | .093 | .0 | .00183 | 81.00 | 773.04 | 240.82 | 1493.30 |
| 82.000 | 29000.0 | 99000.0 | 29000.0 | .101 | .103 | .0 | .00205 | 82.00 | 776.49 | 240.71 | 1493.30 |
| 83.000 | 29000.0 | 99000.0 | 29000.0 | .114 | .116 | .0 | .00232 | 83.00 | 781.19 | 240.57 | 1493.30 |
| 84.000 | 29000.0 | 99000.0 | 29000.0 | .130 | .133 | .0 | .00266 | 84.00 | 787.76 | 240.36 | 1493.30 |
| 85.000 | 29000.0 | 99000.0 | 29000.0 | .152 | .155 | .0 | .00311 | 85.00 | 797.28 | 240.07 | 1493.30 |
| 86.000 | 29000.0 | 99000.0 | 29000.0 | .181 | .185 | .0 | .00372 | 86.00 | 811.66 | 239.65 | 1493.30 |
| 87.000 | 29000.0 | 99000.0 | 29000.0 | .224 | .228 | .0 | .00460 | 87.00 | 834.43 | 239.01 | 1493.30 |
| 88.000 | 29000.0 | 99000.0 | 29000.0 | .288 | .292 | .0 | .00594 | 88.01 | 872.71 | 238.00 | 1493.30 |
| 89.200 | 29000.0 | 99000.0 | 29000.0 | .421 | .425 | .0 | .00879 | 89.21 | 961.94 | 235.83 | 1493.30 |
| 89.400 | 29000.0 | 99000.0 | 29000.0 | .453 | .457 | .0 | .00948 | 89.41 | 984.99 | 235.29 | 1493.30 |
| 89.600 | 29000.0 | 99000.0 | 29000.0 | .490 | .494 | .0 | .01026 | 89.61 | 1011.52 | 234.67 | 1493.30 |
| 89.800 | 29000.0 | 99000.0 | 29000.0 | .531 | .536 | .0 | .01113 | 89.81 | 1042.01 | 233.97 | 1493.30 |
| 90.000 | 29000.0 | 99000.0 | 29000.0 | .555 | .584 | .1 | .01210 | 90.01 | 1076.65 | 233.20 | 1462.86 |
| 90.200 | 29000.0 | 99000.0 | 28960.8 | .609 | .639 | 5.1 | .01319 | 90.21 | 1119.38 | 232.36 | 1472.74 |
| 90.400 | 29000.0 | 99000.0 | 28843.3 | .672 | .702 | 10.6 | .01442 | 90.41 | 1162.98 | 231.50 | 1501.16 |
| 90.600 | 29000.0 | 99000.0 | 28647.4 | .745 | .776 | 16.9 | .01585 | 90.62 | 1217.53 | 230.65 | 1548.17 |
| 90.800 | 29000.0 | 99000.0 | 28373.1 | .830 | .862 | 24.2 | .01752 | 90.82 | 1284.66 | 229.83 | 1617.21 |
| 91.000 | 29000.0 | 99000.0 | 28020.4 | .929 | .963 | 32.9 | .01949 | 91.02 | 1357.77 | 229.06 | 1709.44 |
| 91.200 | 29000.0 | 99000.0 | 27589.1 | 1.047 | 1.082 | 43.4 | .02182 | 91.22 | 1462.04 | 228.36 | 1829.80 |
| 91.400 | 29000.0 | 99000.0 | 27079.1 | 1.188 | 1.223 | 56.3 | .02461 | 91.42 | 1579.10 | 227.72 | 1982.97 |
| 91.600 | 29000.0 | 99000.0 | 26490.4 | 1.357 | 1.392 | 72.2 | .02795 | 91.63 | 1735.18 | 227.16 | 2175.93 |
| 91.800 | 29000.0 | 99000.0 | 25822.8 | 1.563 | 1.596 | 92.3 | .03199 | 91.83 | 1894.93 | 226.66 | 2418.80 |
| 92.000 | 29000.0 | 99000.0 | 25075.9 | 1.815 | 1.842 | 117.7 | .03691 | 92.04 | 2108.31 | 226.22 | 2723.62 |
| 92.200 | 29000.0 | 99000.0 | 24249.3 | 2.134 | 2.149 | 152.2 | .04347 | 92.24 | 2391.45 | 225.42 | 3111.01 |
| 92.400 | 29000.0 | 99000.0 | 23342.5 | 2.536 | 2.530 | 196.8 | .05154 | 92.45 | 2705.90 | 224.54 | 3604.87 |
| 92.600 | 29000.0 | 99000.0 | 22354.5 | 3.061 | 3.014 | 259.2 | .06241 | 92.66 | 3127.03 | 223.21 | 4246.03 |
| 92.800 | 29000.0 | 99000.0 | 21285.3 | 3.733 | 3.627 | 337.2 | .07516 | 92.88 | 3648.02 | 222.00 | 5082.51 |
| 93.000 | 29000.0 | 99000.0 | 20133.1 | 4.636 | 4.415 | 443.5 | .09173 | 93.09 | 4355.01 | 220.80 | 6198.18 |
| 93.200 | 29000.0 | 99000.0 | 18896.0 | 5.863 | 5.445 | 602.3 | .11549 | 93.32 | 5255.72 | 219.53 | 7735.60 |
| 93.400 | 29000.0 | 99000.0 | 17572.3 | 7.523 | 6.797 | 791.7 | .14210 | 93.54 | 6412.93 | 218.37 | 9839.95 |
| 93.600 | 29000.0 | 99000.0 | 16158.9 | 9.907 | 8.586 | 1066.6 | .17896 | 93.78 | 8007.72 | 217.71 | 12869.58 |
| 93.800 | 29000.0 | 99000.0 | 14650.5 | 13.474 | 11.004 | 1459.2 | .22907 | 94.03 | 10114.34 | 217.23 | 17408.20 |
| 94.000 | 29000.0 | 99000.0 | 13039.6 | 18.348 | 14.337 | 2030.7 | .29830 | 94.30 | 12929.71 | 216.89 | 24323.05 |
| 94.200 | 29000.0 | 99000.0 | 11352.9 | 23.888 | 18.308 | 2433.8 | .34120 | 94.54 | 16676.02 | 222.18 | 32886.12 |
| 94.400 | 29000.0 | 99000.0 | 9565.1 | 31.990 | 23.364 | 2974.3 | .39740 | 94.80 | 21487.92 | 229.60 | 45098.80 |
| 94.600 | 29000.0 | 99000.0 | 7669.9 | 43.636 | 29.836 | 3669.0 | .46722 | 95.07 | 27943.80 | 238.51 | 62831.06 |
| 94.800 | 29000.0 | 99000.0 | 5654.8 | 61.815 | 38.371 | 4849.8 | .58161 | 95.38 | 36357.27 | 248.59 | 92275.89 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 30000.0 | 99000.0 | 30000.0 | .078 | .080 | .0 | .00151 | 81.00 | 664.48 | 243.67 | 1282.09 |
| 82.000 | 30000.0 | 99000.0 | 30000.0 | .087 | .089 | .0 | .00168 | 82.00 | 667.46 | 243.57 | 1282.09 |
| 83.000 | 30000.0 | 99000.0 | 30000.0 | .098 | .100 | .0 | .00190 | 83.00 | 671.51 | 243.43 | 1282.09 |
| 84.000 | 30000.0 | 99000.0 | 30000.0 | .112 | .114 | .0 | .00218 | 84.00 | 677.18 | 243.25 | 1282.09 |
| 85.000 | 30000.0 | 99000.0 | 30000.0 | .130 | .133 | .0 | .00254 | 85.00 | 685.39 | 242.98 | 1282.09 |
| 86.000 | 30000.0 | 99000.0 | 30000.0 | .156 | .159 | .0 | .00304 | 86.00 | 697.76 | 242.60 | 1282.09 |
| 87.000 | 30000.0 | 99000.0 | 30000.0 | .192 | .195 | .0 | .00374 | 87.00 | 717.32 | 242.03 | 1282.09 |
| 88.000 | 30000.0 | 99000.0 | 30000.0 | .247 | .250 | .0 | .00481 | 88.00 | 750.08 | 241.16 | 1282.09 |
| 89.200 | 30000.0 | 99000.0 | 30000.0 | .361 | .363 | .0 | .00698 | 89.21 | 825.92 | 239.58 | 1282.09 |
| 89.400 | 30000.0 | 99000.0 | 30000.0 | .389 | .390 | .0 | .00750 | 89.41 | 845.39 | 239.25 | 1282.09 |
| 89.600 | 30000.0 | 99000.0 | 30000.0 | .420 | .421 | .0 | .00808 | 89.61 | 867.73 | 238.91 | 1282.09 |
| 89.800 | 30000.0 | 99000.0 | 30000.0 | .456 | .455 | .0 | .00875 | 89.81 | 893.35 | 238.56 | 1282.09 |
| 90.000 | 30000.0 | 99000.0 | 30000.0 | .445 | .495 | .1 | .00950 | 90.01 | 922.42 | 238.21 | 1256.35 |
| 90.200 | 30000.0 | 99000.0 | 29960.7 | .492 | .541 | 4.6 | .01237 | 90.21 | 958.73 | 236.93 | 1264.42 |
| 90.400 | 30000.0 | 99000.0 | 29842.6 | .576 | .596 | 10.9 | .01563 | 90.42 | 997.06 | 235.07 | 1287.21 |
| 90.600 | 30000.0 | 99000.0 | 29646.3 | .638 | .662 | 15.8 | .01580 | 90.62 | 1045.24 | 232.98 | 1327.32 |
| 90.800 | 30000.0 | 99000.0 | 29372.2 | .711 | .737 | 21.5 | .01632 | 90.82 | 1103.45 | 231.66 | 1386.16 |
| 91.000 | 30000.0 | 99000.0 | 29019.7 | .795 | .825 | 28.7 | .01763 | 91.02 | 1166.41 | 230.52 | 1464.85 |
| 91.200 | 30000.0 | 99000.0 | 28588.7 | .896 | .928 | 37.6 | .01944 | 91.22 | 1256.04 | 229.53 | 1567.56 |
| 91.400 | 30000.0 | 99000.0 | 28079.2 | 1.017 | 1.049 | 48.5 | .02170 | 91.42 | 1356.53 | 228.67 | 1698.22 |
| 91.600 | 30000.0 | 99000.0 | 27491.0 | 1.161 | 1.195 | 62.2 | .02448 | 91.62 | 1490.46 | 227.92 | 1862.71 |
| 91.800 | 30000.0 | 99000.0 | 26823.9 | 1.336 | 1.369 | 79.3 | .02788 | 91.83 | 1627.46 | 227.27 | 2069.58 |
| 92.000 | 30000.0 | 99000.0 | 26077.9 | 1.550 | 1.581 | 101.0 | .03205 | 92.03 | 1810.45 | 226.72 | 2328.87 |
| 92.200 | 30000.0 | 99000.0 | 25252.6 | 1.815 | 1.840 | 128.8 | .03717 | 92.24 | 2027.50 | 226.24 | 2655.71 |
| 92.400 | 30000.0 | 99000.0 | 24347.3 | 2.153 | 2.164 | 166.9 | .04406 | 92.44 | 2319.82 | 225.45 | 3070.68 |
| 92.600 | 30000.0 | 99000.0 | 23361.7 | 2.583 | 2.569 | 216.6 | .05260 | 92.65 | 2676.75 | 224.54 | 3605.17 |
| 92.800 | 30000.0 | 99000.0 | 22294.6 | 3.150 | 3.090 | 286.2 | .06413 | 92.86 | 3119.66 | 223.16 | 4303.70 |
| 93.000 | 30000.0 | 99000.0 | 21145.8 | 3.895 | 3.756 | 374.6 | .07791 | 93.08 | 3719.51 | 221.91 | 5226.13 |
| 93.200 | 30000.0 | 99000.0 | 19913.2 | 4.898 | 4.623 | 506.2 | .09763 | 93.30 | 4482.09 | 220.62 | 6483.38 |
| 93.400 | 30000.0 | 99000.0 | 18594.5 | 6.274 | 5.767 | 676.5 | .12185 | 93.52 | 5463.97 | 219.14 | 8212.86 |
| 93.600 | 30000.0 | 99000.0 | 17188.6 | 8.187 | 7.278 | 901.7 | .15212 | 93.75 | 6815.18 | 218.19 | 10643.41 |
| 93.800 | 30000.0 | 99000.0 | 15690.5 | 11.003 | 9.307 | 1228.1 | .19403 | 93.99 | 8596.65 | 217.56 | 14225.50 |
| 94.000 | 30000.0 | 99000.0 | 14094.1 | 15.104 | 12.087 | 1700.1 | .25170 | 94.25 | 10974.78 | 217.12 | 19718.51 |
| 94.200 | 30000.0 | 99000.0 | 12394.3 | 20.409 | 15.754 | 2193.7 | .30775 | 94.51 | 14280.71 | 218.81 | 27344.90 |
| 94.400 | 30000.0 | 99000.0 | 10627.5 | 26.884 | 20.246 | 2648.6 | .35528 | 94.76 | 18508.79 | 225.08 | 37463.20 |
| 94.600 | 30000.0 | 99000.0 | 8745.8 | 35.883 | 25.929 | 3113.0 | .40233 | 95.00 | 24165.70 | 233.24 | 51100.68 |
| 94.800 | 30000.0 | 99000.0 | 6751.7 | 49.251 | 33.311 | 3904.3 | .48070 | 95.28 | 31251.37 | 242.95 | 72394.59 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 31000.0 | 99000.0 | 31000.0 | .067 | .069 | .0 | .00130 | 81.00 | 574.75 | 245.23 | 1108.84 |
| 82.000 | 31000.0 | 99000.0 | 31000.0 | .075 | .077 | .0 | .00145 | 82.00 | 577.34 | 245.13 | 1108.84 |
| 83.000 | 31000.0 | 99000.0 | 31000.0 | .084 | .087 | .0 | .00164 | 83.00 | 580.86 | 244.99 | 1108.84 |
| 84.000 | 31000.0 | 99000.0 | 31000.0 | .096 | .099 | .0 | .00188 | 84.00 | 585.79 | 244.80 | 1108.84 |
| 85.000 | 31000.0 | 99000.0 | 31000.0 | .112 | .115 | .0 | .00220 | 85.00 | 592.91 | 244.53 | 1108.84 |
| 86.000 | 31000.0 | 99000.0 | 31000.0 | .134 | .137 | .0 | .00263 | 86.00 | 603.64 | 244.12 | 1108.84 |
| 87.000 | 31000.0 | 99000.0 | 31000.0 | .165 | .169 | .0 | .00324 | 87.00 | 620.59 | 243.51 | 1108.84 |
| 88.000 | 31000.0 | 99000.0 | 31000.0 | .212 | .216 | .0 | .00416 | 88.00 | 648.95 | 242.57 | 1108.84 |
| 89.200 | 31000.0 | 99000.0 | 31000.0 | .307 | .314 | .0 | .00605 | 89.21 | 714.49 | 240.76 | 1108.84 |
| 89.400 | 31000.0 | 99000.0 | 31000.0 | .330 | .337 | .0 | .00650 | 89.41 | 731.30 | 240.38 | 1108.84 |
| 89.600 | 31000.0 | 99000.0 | 31000.0 | .357 | .363 | .0 | .00701 | 89.61 | 750.59 | 239.97 | 1108.84 |
| 89.800 | 31000.0 | 99000.0 | 31000.0 | .386 | .393 | .0 | .00758 | 89.81 | 772.71 | 239.55 | 1108.84 |
| 90.000 | 31000.0 | 99000.0 | 31000.0 | .401 | .428 | .1 | .00823 | 90.01 | 797.79 | 239.12 | 1084.17 |
| 90.200 | 31000.0 | 99000.0 | 30960.9 | .439 | .467 | 3.4 | .00898 | 90.21 | 828.59 | 238.68 | 1090.92 |
| 90.400 | 31000.0 | 99000.0 | 30843.5 | .484 | .511 | 7.2 | .00983 | 90.41 | 860.12 | 238.24 | 1110.78 |
| 90.600 | 31000.0 | 99000.0 | 30647.9 | .534 | .563 | 11.5 | .01082 | 90.61 | 899.37 | 237.81 | 1143.67 |
| 90.800 | 31000.0 | 99000.0 | 30374.0 | .593 | .623 | 16.5 | .01196 | 90.81 | 947.46 | 237.40 | 1191.62 |
| 91.000 | 31000.0 | 99000.0 | 30021.8 | .663 | .694 | 22.4 | .01330 | 91.01 | 999.77 | 237.00 | 1256.45 |
| 91.200 | 31000.0 | 99000.0 | 29589.8 | .775 | .788 | 35.2 | .01788 | 91.22 | 1078.01 | 232.84 | 1343.25 |
| 91.400 | 31000.0 | 99000.0 | 29080.6 | .877 | .895 | 42.8 | .01902 | 91.42 | 1165.17 | 231.01 | 1454.43 |
| 91.600 | 31000.0 | 99000.0 | 28492.8 | .999 | 1.021 | 54.0 | .02120 | 91.62 | 1280.50 | 229.67 | 1594.65 |
| 91.800 | 31000.0 | 99000.0 | 27826.3 | 1.148 | 1.172 | 68.5 | .02404 | 91.82 | 1398.22 | 228.62 | 1770.95 |
| 92.000 | 31000.0 | 99000.0 | 27080.9 | 1.330 | 1.354 | 86.9 | .02757 | 92.03 | 1555.28 | 227.76 | 1991.71 |
| 92.200 | 31000.0 | 99000.0 | 26256.5 | 1.554 | 1.577 | 110.6 | .03194 | 92.23 | 1741.48 | 227.06 | 2268.92 |
| 92.400 | 31000.0 | 99000.0 | 25352.6 | 1.835 | 1.851 | 141.3 | .03736 | 92.44 | 1990.90 | 226.47 | 2619.71 |
| 92.600 | 31000.0 | 99000.0 | 24368.6 | 2.195 | 2.196 | 183.7 | .04468 | 92.64 | 2295.09 | 225.62 | 3068.55 |
| 92.800 | 31000.0 | 99000.0 | 23304.1 | 2.659 | 2.632 | 239.3 | .05379 | 92.85 | 2670.54 | 224.64 | 3650.01 |
| 93.000 | 31000.0 | 99000.0 | 22157.7 | 3.286 | 3.197 | 317.5 | .06615 | 93.07 | 3179.98 | 223.16 | 4418.72 |
| 93.200 | 31000.0 | 99000.0 | 20928.7 | 4.109 | 3.929 | 426.4 | .08249 | 93.28 | 3826.57 | 221.81 | 5452.41 |
| 93.400 | 31000.0 | 99000.0 | 19615.1 | 5.230 | 4.892 | 569.5 | .10292 | 93.50 | 4658.08 | 220.28 | 6864.61 |
| 93.600 | 31000.0 | 99000.0 | 18214.8 | 6.805 | 6.171 | 765.8 | .12957 | 93.73 | 5803.20 | 218.89 | 8848.93 |
| 93.800 | 31000.0 | 99000.0 | 16725.3 | 9.052 | 7.881 | 1036.5 | .16450 | 93.96 | 7311.46 | 218.02 | 11706.33 |
| 94.000 | 31000.0 | 99000.0 | 15140.9 | 12.443 | 10.209 | 1428.2 | .21269 | 94.21 | 9322.79 | 217.43 | 16024.65 |
| 94.200 | 31000.0 | 99000.0 | 13454.0 | 17.216 | 13.447 | 2002.9 | .27991 | 94.48 | 12172.35 | 217.01 | 22767.02 |
| 94.400 | 31000.0 | 99000.0 | 11667.4 | 22.598 | 17.435 | 2277.4 | .36811 | 94.71 | 15873.55 | 221.25 | 30672.40 |
| 94.600 | 31000.0 | 99000.0 | 9813.8 | 30.281 | 22.525 | 2710.7 | .35341 | 94.95 | 20665.36 | 228.09 | 42137.17 |
| 94.800 | 31000.0 | 99000.0 | 7833.1 | 42.079 | 29.165 | 3534.0 | .43616 | 95.24 | 27164.48 | 237.16 | 60527.29 |
| 95.000 | 31000.0 | 99000.0 | 5740.4 | 60.840 | 37.843 | 4734.9 | .54994 | 95.55 | 35951.49 | 248.06 | 90130.51 |

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REFRACTION AIRMASS TABLES

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 32000.0 | 99000.0 | 32000.0 | .058 | .060 | .0 | .00113 | 81.00 | 497.27 | 247.05 | 958.23 |
| 82.000 | 32000.0 | 99000.0 | 32000.0 | .065 | .066 | .0 | .00126 | 82.00 | 499.52 | 246.95 | 958.23 |
| 83.000 | 32000.0 | 99000.0 | 32000.0 | .073 | .075 | .0 | .00142 | 83.00 | 502.58 | 246.81 | 958.23 |
| 84.000 | 32000.0 | 99000.0 | 32000.0 | .083 | .086 | .0 | .00163 | 84.00 | 506.86 | 246.62 | 958.23 |
| 85.000 | 32000.0 | 99000.0 | 32000.0 | .097 | .100 | .0 | .00190 | 85.00 | 513.05 | 246.34 | 958.23 |
| 86.000 | 32000.0 | 99000.0 | 32000.0 | .116 | .119 | .0 | .00228 | 86.00 | 522.36 | 245.93 | 958.23 |
| 87.000 | 32000.0 | 99000.0 | 32000.0 | .143 | .146 | .0 | .00281 | 87.00 | 537.05 | 245.29 | 958.23 |
| 88.000 | 32000.0 | 99000.0 | 32000.0 | .183 | .187 | .0 | .00361 | 88.00 | 561.60 | 244.28 | 958.23 |
| 89.200 | 32000.0 | 99000.0 | 32000.0 | .266 | .271 | .0 | .00525 | 89.21 | 618.25 | 242.25 | 958.23 |
| 89.400 | 32000.0 | 99000.0 | 32000.0 | .286 | .291 | .0 | .00564 | 89.41 | 632.77 | 241.80 | 958.23 |
| 89.600 | 32000.0 | 99000.0 | 32000.0 | .308 | .314 | .0 | .00608 | 89.61 | 649.43 | 241.32 | 958.23 |
| 89.800 | 32000.0 | 99000.0 | 32000.0 | .334 | .340 | .0 | .00658 | 89.81 | 668.52 | 240.81 | 958.23 |
| 90.000 | 32000.0 | 99000.0 | 32000.0 | .345 | .369 | .0 | .00714 | 90.01 | 690.17 | 240.28 | 935.55 |
| 90.200 | 32000.0 | 99000.0 | 31960.9 | .379 | .403 | 3.0 | .00779 | 90.21 | 716.75 | 239.74 | 941.31 |
| 90.400 | 32000.0 | 99000.0 | 31843.6 | .417 | .442 | 6.2 | .00852 | 90.41 | 743.95 | 239.20 | 958.38 |
| 90.600 | 32000.0 | 99000.0 | 31648.0 | .460 | .487 | 9.9 | .00937 | 90.61 | 777.82 | 238.66 | 986.67 |
| 90.800 | 32000.0 | 99000.0 | 31374.2 | .511 | .539 | 14.3 | .01036 | 90.81 | 819.33 | 238.15 | 1027.93 |
| 91.000 | 32000.0 | 99000.0 | 31022.1 | .571 | .600 | 19.4 | .01152 | 91.01 | 864.47 | 237.65 | 1083.73 |
| 91.200 | 32000.0 | 99000.0 | 30591.7 | .641 | .671 | 25.5 | .01287 | 91.21 | 928.30 | 237.19 | 1155.86 |
| 91.400 | 32000.0 | 99000.0 | 30083.0 | .724 | .755 | 33.0 | .01448 | 91.41 | 999.73 | 236.77 | 1247.21 |
| 91.600 | 32000.0 | 99000.0 | 29494.3 | .854 | .870 | 49.3 | .01910 | 91.62 | 1099.72 | 232.53 | 1365.88 |
| 91.800 | 32000.0 | 99000.0 | 28828.2 | .981 | 1.002 | 59.8 | .02092 | 91.82 | 1201.34 | 230.56 | 1515.94 |
| 92.000 | 32000.0 | 99000.0 | 28083.4 | 1.136 | 1.159 | 75.2 | .02380 | 92.02 | 1336.30 | 229.18 | 1704.02 |
| 92.200 | 32000.0 | 99000.0 | 27259.7 | 1.327 | 1.351 | 95.3 | .02749 | 92.23 | 1496.09 | 228.13 | 1939.98 |
| 92.400 | 32000.0 | 99000.0 | 26356.8 | 1.565 | 1.587 | 121.4 | .03210 | 92.43 | 1709.99 | 227.30 | 2238.15 |
| 92.600 | 32000.0 | 99000.0 | 25374.3 | 1.865 | 1.879 | 155.5 | .03788 | 92.64 | 1969.56 | 226.62 | 2616.73 |
| 92.800 | 32000.0 | 99000.0 | 24311.4 | 2.255 | 2.249 | 203.0 | .04570 | 92.85 | 2289.57 | 225.70 | 3105.59 |
| 93.000 | 32000.0 | 99000.0 | 23167.8 | 2.774 | 2.723 | 265.7 | .05554 | 93.06 | 2720.82 | 224.65 | 3743.03 |
| 93.200 | 32000.0 | 99000.0 | 21941.6 | 3.456 | 3.343 | 360.3 | .06987 | 93.27 | 3270.21 | 223.04 | 4602.08 |
| 93.400 | 32000.0 | 99000.0 | 20632.0 | 4.377 | 4.156 | 480.6 | .08710 | 93.49 | 3975.45 | 221.44 | 5763.56 |
| 93.600 | 32000.0 | 99000.0 | 19237.4 | 5.668 | 5.231 | 643.8 | .10934 | 93.71 | 4943.00 | 220.01 | 7375.50 |
| 93.800 | 32000.0 | 99000.0 | 17754.3 | 7.489 | 6.681 | 877.9 | .13983 | 93.94 | 6148.59 | 218.63 | 9691.92 |
| 94.000 | 32000.0 | 99000.0 | 16179.8 | 10.173 | 8.638 | 1203.5 | .18011 | 94.18 | 7925.78 | 217.83 | 13107.88 |
| 94.200 | 32000.0 | 99000.0 | 14507.0 | 14.159 | 11.343 | 1679.2 | .23618 | 94.44 | 10203.99 | 217.28 | 18439.44 |
| 94.400 | 32000.0 | 99000.0 | 12739.1 | 18.928 | 14.957 | 2001.0 | .27181 | 94.67 | 13566.07 | 218.25 | 25317.56 |
| 94.600 | 32000.0 | 99000.0 | 10874.3 | 26.076 | 19.573 | 2566.0 | .33171 | 94.93 | 17808.79 | 223.59 | 35779.85 |
| 94.800 | 32000.0 | 99000.0 | 8906.6 | 36.372 | 25.523 | 3370.0 | .41239 | 95.21 | 23554.83 | 231.92 | 51733.73 |
| 95.000 | 32000.0 | 99000.0 | 6832.2 | 50.564 | 33.111 | 4196.6 | .49087 | 95.49 | 31017.60 | 242.22 | 74258.74 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 33000.0 | 99000.0 | 33000.0 | .050 | .052 | .0 | .00098 | 81.00 | 430.38 | 249.17 | 828.07 |
| 82.000 | 33000.0 | 99000.0 | 33000.0 | .056 | .057 | .0 | .00109 | 82.00 | 432.34 | 249.07 | 828.07 |
| 83.000 | 33000.0 | 99000.0 | 33000.0 | .063 | .065 | .0 | .00123 | 83.00 | 435.00 | 248.94 | 828.07 |
| 84.000 | 33000.0 | 99000.0 | 33000.0 | .072 | .074 | .0 | .00141 | 84.00 | 438.72 | 248.75 | 828.07 |
| 85.000 | 33000.0 | 99000.0 | 33000.0 | .084 | .086 | .0 | .00165 | 85.00 | 444.09 | 248.47 | 828.07 |
| 86.000 | 33000.0 | 99000.0 | 33000.0 | .100 | .103 | .0 | .00197 | 86.00 | 452.17 | 248.06 | 828.07 |
| 87.000 | 33000.0 | 99000.0 | 33000.0 | .123 | .126 | .0 | .00243 | 87.00 | 464.90 | 247.43 | 828.07 |
| 88.000 | 33000.0 | 99000.0 | 33000.0 | .158 | .161 | .0 | .00313 | 88.00 | 486.14 | 246.39 | 828.07 |
| 89.200 | 33000.0 | 99000.0 | 33000.0 | .229 | .234 | .0 | .00456 | 89.20 | 535.10 | 244.18 | 828.07 |
| 89.400 | 33000.0 | 99000.0 | 33000.0 | .247 | .251 | .0 | .00491 | 89.40 | 547.64 | 243.66 | 828.07 |
| 89.600 | 33000.0 | 99000.0 | 33000.0 | .266 | .271 | .0 | .00529 | 89.61 | 562.03 | 243.09 | 828.07 |
| 89.800 | 33000.0 | 99000.0 | 33000.0 | .288 | .293 | .0 | .00572 | 89.81 | 578.52 | 242.48 | 828.07 |
| 90.000 | 33000.0 | 99000.0 | 33000.0 | .298 | .319 | .0 | .00621 | 90.01 | 597.21 | 241.82 | 807.26 |
| 90.200 | 33000.0 | 99000.0 | 32960.9 | .326 | .348 | 2.6 | .00677 | 90.21 | 620.15 | 241.14 | 812.19 |
| 90.400 | 33000.0 | 99000.0 | 32843.6 | .359 | .382 | 5.4 | .00741 | 90.41 | 643.62 | 240.45 | 826.56 |
| 90.600 | 33000.0 | 99000.0 | 32648.1 | .397 | .421 | 8.6 | .00814 | 90.61 | 672.85 | 239.77 | 851.21 |
| 90.800 | 33000.0 | 99000.0 | 32374.4 | .441 | .466 | 12.4 | .00899 | 90.81 | 708.67 | 239.11 | 886.73 |
| 91.000 | 33000.0 | 99000.0 | 32022.4 | .492 | .518 | 16.8 | .00998 | 91.01 | 747.62 | 238.49 | 934.78 |
| 91.200 | 33000.0 | 99000.0 | 31592.1 | .553 | .580 | 22.1 | .01115 | 91.21 | 802.72 | 237.90 | 996.87 |
| 91.400 | 33000.0 | 99000.0 | 31083.6 | .624 | .653 | 28.5 | .01254 | 91.41 | 864.38 | 237.37 | 1075.49 |
| 91.600 | 33000.0 | 99000.0 | 30496.6 | .709 | .740 | 36.5 | .01418 | 91.61 | 945.94 | 236.88 | 1173.91 |
| 91.800 | 33000.0 | 99000.0 | 29830.2 | .840 | .848 | 61.2 | .02060 | 91.82 | 1030.81 | 234.97 | 1299.57 |
| 92.000 | 33000.0 | 99000.0 | 29085.5 | .971 | .990 | 66.1 | .02083 | 92.02 | 1148.09 | 231.31 | 1458.52 |
| 92.200 | 33000.0 | 99000.0 | 28262.3 | 1.134 | 1.156 | 82.5 | .02375 | 92.22 | 1285.46 | 229.61 | 1659.44 |
| 92.400 | 33000.0 | 99000.0 | 27360.2 | 1.337 | 1.359 | 104.5 | .02764 | 92.43 | 1468.99 | 228.38 | 1913.18 |
| 92.600 | 33000.0 | 99000.0 | 26378.7 | 1.591 | 1.611 | 133.6 | .03256 | 92.63 | 1691.57 | 227.44 | 2234.84 |
| 92.800 | 33000.0 | 99000.0 | 25317.5 | 1.915 | 1.925 | 171.8 | .03877 | 92.84 | 1964.68 | 226.70 | 2646.90 |
| 93.000 | 33000.0 | 99000.0 | 24175.6 | 2.339 | 2.327 | 225.3 | .04719 | 93.05 | 2331.95 | 225.70 | 3181.78 |
| 93.200 | 33000.0 | 99000.0 | 22952.4 | 2.916 | 2.847 | 305.6 | .05932 | 93.26 | 2796.71 | 224.55 | 3895.47 |
| 93.400 | 33000.0 | 99000.0 | 21646.0 | 3.676 | 3.536 | 406.7 | .07386 | 93.47 | 3396.34 | 222.64 | 4855.47 |
| 93.600 | 33000.0 | 99000.0 | 20256.3 | 4.731 | 4.442 | 542.6 | .09244 | 93.69 | 4166.02 | 221.16 | 6175.08 |
| 93.800 | 33000.0 | 99000.0 | 18778.6 | 6.243 | 5.666 | 761.1 | .12110 | 93.92 | 5238.56 | 219.54 | 8082.78 |
| 94.000 | 33000.0 | 99000.0 | 17212.2 | 8.379 | 7.319 | 1017.4 | .15286 | 94.15 | 6742.88 | 218.35 | 10801.86 |
| 94.200 | 33000.0 | 99000.0 | 15551.3 | 11.656 | 9.588 | 1412.7 | .19974 | 94.40 | 8673.04 | 217.63 | 14976.33 |
| 94.400 | 33000.0 | 99000.0 | 13787.1 | 16.393 | 12.773 | 1997.9 | .26583 | 94.67 | 11428.43 | 217.13 | 21641.47 |
| 94.600 | 33000.0 | 99000.0 | 11929.2 | 22.105 | 16.912 | 2353.7 | .30341 | 94.90 | 15285.19 | 219.62 | 29961.12 |
| 94.800 | 33000.0 | 99000.0 | 9973.0 | 31.196 | 22.252 | 3171.2 | .38579 | 95.19 | 20353.18 | 226.94 | 43867.53 |
| 95.000 | 33000.0 | 99000.0 | 7913.0 | 43.491 | 29.011 | 3870.6 | .45224 | 95.45 | 26957.29 | 236.50 | 62505.32 |
| 95.200 | 33000.0 | 99000.0 | 5740.7 | 61.987 | 37.872 | 4948.5 | .55034 | 95.75 | 35920.74 | 248.05 | 92412.79 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 34000.0 | 99000.0 | 34000.0 | .043 | .045 | .0 | .00084 | 81.00 | 372.65 | 251.64 | 715.60 |
| 82.000 | 34000.0 | 99000.0 | 34000.0 | .048 | .050 | .0 | .00094 | 82.00 | 374.35 | 251.54 | 715.60 |
| 83.000 | 34000.0 | 99000.0 | 34000.0 | .054 | .056 | .0 | .00107 | 83.00 | 376.67 | 251.42 | 715.60 |
| 84.000 | 34000.0 | 99000.0 | 34000.0 | .062 | .064 | .0 | .00122 | 84.00 | 379.90 | 251.24 | 715.60 |
| 85.000 | 34000.0 | 99000.0 | 34000.0 | .072 | .074 | .0 | .00143 | 85.00 | 384.56 | 250.99 | 715.60 |
| 86.000 | 34000.0 | 99000.0 | 34000.0 | .086 | .089 | .0 | .00171 | 86.00 | 391.57 | 250.60 | 715.60 |
| 87.000 | 34000.0 | 99000.0 | 34000.0 | .106 | .109 | .0 | .00211 | 87.00 | 402.59 | 250.00 | 715.60 |
| 88.000 | 34000.0 | 99000.0 | 34000.0 | .137 | .139 | .0 | .00272 | 88.00 | 420.93 | 249.02 | 715.60 |
| 89.200 | 34000.0 | 99000.0 | 34000.0 | .198 | .201 | .0 | .00399 | 89.20 | 463.14 | 246.80 | 715.60 |
| 89.400 | 34000.0 | 99000.0 | 34000.0 | .213 | .216 | .0 | .00431 | 89.40 | 473.97 | 246.24 | 715.60 |
| 89.600 | 34000.0 | 99000.0 | 34000.0 | .230 | .233 | .0 | .00465 | 89.60 | 486.40 | 245.59 | 715.60 |
| 89.800 | 34000.0 | 99000.0 | 34000.0 | .249 | .253 | .0 | .00504 | 89.81 | 500.65 | 244.85 | 715.60 |
| 90.000 | 34000.0 | 99000.0 | 34000.0 | .256 | .275 | .0 | .00547 | 90.01 | 516.81 | 244.03 | 696.54 |
| 90.200 | 34000.0 | 99000.0 | 33960.9 | .281 | .300 | 2.3 | .00594 | 90.21 | 536.65 | 243.14 | 700.75 |
| 90.400 | 34000.0 | 99000.0 | 33843.6 | .309 | .329 | 4.7 | .00648 | 90.41 | 556.93 | 242.21 | 713.11 |
| 90.600 | 34000.0 | 99000.0 | 33648.2 | .342 | .363 | 7.5 | .00710 | 90.61 | 582.17 | 241.30 | 734.34 |
| 90.800 | 34000.0 | 99000.0 | 33374.5 | .380 | .402 | 10.8 | .00782 | 90.81 | 613.09 | 240.41 | 764.93 |
| 91.000 | 34000.0 | 99000.0 | 33022.6 | .424 | .448 | 14.6 | .00867 | 91.01 | 646.70 | 239.58 | 806.31 |
| 91.200 | 34000.0 | 99000.0 | 32592.5 | .476 | .501 | 19.1 | .00967 | 91.21 | 694.26 | 238.82 | 859.79 |
| 91.400 | 34000.0 | 99000.0 | 32084.0 | .538 | .564 | 24.7 | .01086 | 91.41 | 747.48 | 238.14 | 927.48 |
| 91.600 | 34000.0 | 99000.0 | 31497.2 | .611 | .639 | 31.6 | .01228 | 91.61 | 817.89 | 237.52 | 1012.18 |
| 91.800 | 34000.0 | 99000.0 | 30832.1 | .700 | .729 | 40.1 | .01399 | 91.81 | 889.92 | 236.97 | 1117.99 |
| 92.000 | 34000.0 | 99000.0 | 30088.4 | .807 | .838 | 50.8 | .01605 | 92.02 | 985.32 | 236.50 | 1249.47 |
| 92.200 | 34000.0 | 99000.0 | 29264.5 | .969 | .987 | 73.1 | .02094 | 92.22 | 1104.28 | 231.88 | 1420.27 |
| 92.400 | 34000.0 | 99000.0 | 28362.9 | 1.142 | 1.164 | 90.5 | .02390 | 92.42 | 1262.13 | 229.88 | 1636.19 |
| 92.600 | 34000.0 | 99000.0 | 27382.3 | 1.359 | 1.380 | 115.0 | .02803 | 92.63 | 1453.10 | 228.51 | 1909.79 |
| 92.800 | 34000.0 | 99000.0 | 26322.1 | 1.633 | 1.650 | 147.6 | .03332 | 92.83 | 1687.29 | 227.49 | 2259.02 |
| 93.000 | 34000.0 | 99000.0 | 25182.1 | 1.985 | 1.991 | 190.9 | .04006 | 93.04 | 2000.45 | 226.70 | 2710.01 |
| 93.200 | 34000.0 | 99000.0 | 23961.0 | 2.460 | 2.431 | 255.1 | .04975 | 93.25 | 2396.02 | 225.62 | 3304.30 |
| 93.400 | 34000.0 | 99000.0 | 22657.5 | 3.099 | 3.011 | 347.5 | .06315 | 93.46 | 2904.19 | 223.94 | 4105.77 |
| 93.600 | 34000.0 | 99000.0 | 21271.3 | 3.966 | 3.778 | 458.5 | .07830 | 93.68 | 3558.14 | 222.33 | 5192.18 |
| 93.800 | 34000.0 | 99000.0 | 19799.3 | 5.192 | 4.808 | 639.7 | .10213 | 93.90 | 4466.16 | 220.69 | 6742.38 |
| 94.000 | 34000.0 | 99000.0 | 18239.2 | 6.942 | 6.207 | 864.4 | .13023 | 94.13 | 5739.95 | 219.06 | 8953.49 |
| 94.200 | 34000.0 | 99000.0 | 16587.6 | 9.541 | 8.117 | 1192.1 | .16929 | 94.37 | 7377.22 | 218.07 | 12264.65 |
| 94.400 | 34000.0 | 99000.0 | 14837.5 | 13.644 | 10.782 | 1677.3 | .22446 | 94.62 | 9705.15 | 217.42 | 17494.01 |
| 94.600 | 34000.0 | 99000.0 | 12979.8 | 19.742 | 14.539 | 2271.4 | .28969 | 94.89 | 13068.64 | 217.01 | 25430.27 |
| 94.800 | 34000.0 | 99000.0 | 11037.4 | 27.237 | 19.307 | 3035.9 | .36555 | 95.17 | 17337.07 | 222.91 | 37327.22 |
| 95.000 | 34000.0 | 99000.0 | 8987.9 | 37.957 | 25.405 | 3777.2 | .43595 | 95.44 | 23370.50 | 231.49 | 53942.69 |
| 95.200 | 34000.0 | 99000.0 | 6832.9 | 51.779 | 33.136 | 4390.5 | .49150 | 95.69 | 30990.69 | 242.21 | 75999.34 |

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REFRACTION AIRMASS TABLES

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 35000.0 | 99000.0 | 35000.0 | .037 | .039 | .0 | .00070 | 81.00 | 323.13 | 254.49 | 618.40 |
| 82.000 | 35000.0 | 99000.0 | 35000.0 | .042 | .043 | .0 | .00078 | 82.00 | 324.61 | 254.41 | 618.40 |
| 83.000 | 35000.0 | 99000.0 | 35000.0 | .047 | .048 | .0 | .00088 | 83.00 | 326.62 | 254.30 | 618.40 |
| 84.000 | 35000.0 | 99000.0 | 35000.0 | .054 | .055 | .0 | .00100 | 84.00 | 329.43 | 254.15 | 618.40 |
| 85.000 | 35000.0 | 99000.0 | 35000.0 | .063 | .064 | .0 | .00117 | 85.00 | 333.48 | 253.94 | 618.40 |
| 86.000 | 35000.0 | 99000.0 | 35000.0 | .075 | .077 | .0 | .00140 | 86.00 | 339.55 | 253.61 | 618.40 |
| 87.000 | 35000.0 | 99000.0 | 35000.0 | .092 | .094 | .0 | .00172 | 87.00 | 349.07 | 253.10 | 618.40 |
| 88.000 | 35000.0 | 99000.0 | 35000.0 | .118 | .120 | .0 | .00220 | 88.00 | 364.86 | 252.31 | 618.40 |
| 89.200 | 35000.0 | 99000.0 | 35000.0 | .171 | .173 | .0 | .00318 | 89.20 | 400.87 | 250.77 | 618.40 |
| 89.400 | 35000.0 | 99000.0 | 35000.0 | .184 | .186 | .0 | .00341 | 89.40 | 410.04 | 250.45 | 618.40 |
| 89.600 | 35000.0 | 99000.0 | 35000.0 | .199 | .200 | .0 | .00367 | 89.60 | 420.53 | 250.11 | 618.40 |
| 89.800 | 35000.0 | 99000.0 | 35000.0 | .215 | .216 | .0 | .00396 | 89.80 | 432.53 | 249.75 | 618.40 |
| 90.000 | 35000.0 | 99000.0 | 35000.0 | .206 | .234 | .0 | .00430 | 90.00 | 446.13 | 249.39 | 602.23 |
| 90.200 | 35000.0 | 99000.0 | 34960.8 | .227 | .256 | 2.1 | .00565 | 90.21 | 462.98 | 248.04 | 605.70 |
| 90.400 | 35000.0 | 99000.0 | 34843.3 | .252 | .281 | 5.0 | .00718 | 90.41 | 480.84 | 246.06 | 615.96 |
| 90.600 | 35000.0 | 99000.0 | 34647.6 | .295 | .312 | 7.2 | .00721 | 90.61 | 503.33 | 243.81 | 633.61 |
| 90.800 | 35000.0 | 99000.0 | 34374.0 | .327 | .346 | 9.7 | .00739 | 90.81 | 530.33 | 242.39 | 659.94 |
| 91.000 | 35000.0 | 99000.0 | 34022.2 | .366 | .386 | 12.8 | .00794 | 91.01 | 559.46 | 241.16 | 695.59 |
| 91.200 | 35000.0 | 99000.0 | 33592.1 | .410 | .433 | 16.7 | .00871 | 91.21 | 600.60 | 240.09 | 741.37 |
| 91.400 | 35000.0 | 99000.0 | 33083.8 | .464 | .487 | 21.5 | .00967 | 91.41 | 646.57 | 239.16 | 799.95 |
| 91.600 | 35000.0 | 99000.0 | 32497.2 | .527 | .553 | 27.4 | .01086 | 91.61 | 707.38 | 238.35 | 872.89 |
| 91.800 | 35000.0 | 99000.0 | 31832.2 | .603 | .630 | 34.7 | .01230 | 91.81 | 769.56 | 237.64 | 963.98 |
| 92.000 | 35000.0 | 99000.0 | 31088.7 | .695 | .724 | 44.0 | .01405 | 92.01 | 851.93 | 237.04 | 1077.10 |
| 92.200 | 35000.0 | 99000.0 | 30266.8 | .807 | .838 | 55.7 | .01620 | 92.22 | 949.15 | 236.52 | 1217.79 |
| 92.400 | 35000.0 | 99000.0 | 29364.6 | .976 | .993 | 80.9 | .02132 | 92.42 | 1084.24 | 232.24 | 1400.40 |
| 92.600 | 35000.0 | 99000.0 | 28384.6 | 1.161 | 1.182 | 99.6 | .02437 | 92.62 | 1248.55 | 230.00 | 1633.06 |
| 92.800 | 35000.0 | 99000.0 | 27325.3 | 1.394 | 1.414 | 127.1 | .02880 | 92.83 | 1449.49 | 228.53 | 1930.00 |
| 93.000 | 35000.0 | 99000.0 | 26186.4 | 1.693 | 1.707 | 164.0 | .03454 | 93.03 | 1717.96 | 227.46 | 2312.76 |
| 93.200 | 35000.0 | 99000.0 | 24967.3 | 2.087 | 2.080 | 216.1 | .04233 | 93.24 | 2054.96 | 226.63 | 2811.90 |
| 93.400 | 35000.0 | 99000.0 | 23666.5 | 2.611 | 2.569 | 289.1 | .05286 | 93.45 | 2486.65 | 225.25 | 3477.58 |
| 93.600 | 35000.0 | 99000.0 | 22283.2 | 3.337 | 3.218 | 389.0 | .06664 | 93.67 | 3042.09 | 223.56 | 4391.64 |
| 93.800 | 35000.0 | 99000.0 | 20815.7 | 4.339 | 4.086 | 539.1 | .08642 | 93.89 | 3812.19 | 221.86 | 5650.20 |
| 94.000 | 35000.0 | 99000.0 | 19261.7 | 5.770 | 5.262 | 727.1 | .11000 | 94.11 | 4831.44 | 220.17 | 7444.59 |
| 94.200 | 35000.0 | 99000.0 | 17617.4 | 7.866 | 6.881 | 1009.5 | .14392 | 94.34 | 6279.55 | 218.65 | 10114.51 |
| 94.400 | 35000.0 | 99000.0 | 15878.7 | 11.086 | 9.119 | 1412.9 | .19006 | 94.59 | 8249.23 | 217.80 | 14218.03 |
| 94.600 | 35000.0 | 99000.0 | 14036.6 | 16.094 | 12.291 | 2016.4 | .25585 | 94.86 | 10966.31 | 217.23 | 20889.03 |
| 94.800 | 35000.0 | 99000.0 | 12093.9 | 22.802 | 16.629 | 2729.2 | .32893 | 95.13 | 14861.28 | 219.27 | 30869.30 |
| 95.000 | 35000.0 | 99000.0 | 10057.1 | 32.397 | 22.116 | 3537.0 | .40621 | 95.41 | 19983.03 | 226.74 | 45517.86 |
| 95.200 | 35000.0 | 99000.0 | 7913.5 | 44.016 | 29.034 | 4049.5 | .45288 | 95.65 | 26934.74 | 236.49 | 63917.09 |
| 95.400 | 35000.0 | 99000.0 | 5652.3 | 67.136 | 38.485 | 5542.8 | .58431 | 95.98 | 36275.18 | 248.56 | 100044.70 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z [1] | LOWER HEIGHT [2] | UPPER HEIGHT [3] | MIN. HEIGHT [4] | CHAPMAN AIR MASS [5] | OPTICAL AIR MASS [6] | HDIFF [7] | REFRACTION [8] | AST. Z [9] | P(EFF) [10] | T(EFF) [11] | P(TAN) [12] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 36000.0 | 99000.0 | 36000.0 | .033 | .034 | .0 | .00061 | 81.00 | 282.12 | 255.95 | 538.35 |
| 82.000 | 36000.0 | 99000.0 | 36000.0 | .036 | .037 | .0 | .00068 | 82.00 | 283.42 | 255.87 | 538.35 |
| 83.000 | 36000.0 | 99000.0 | 36000.0 | .041 | .042 | .0 | .00076 | 83.00 | 285.19 | 255.77 | 538.35 |
| 84.000 | 36000.0 | 99000.0 | 36000.0 | .047 | .048 | .0 | .00088 | 84.00 | 287.65 | 255.62 | 538.35 |
| 85.000 | 36000.0 | 99000.0 | 36000.0 | .054 | .056 | .0 | .00102 | 85.00 | 291.19 | 255.41 | 538.35 |
| 86.000 | 36000.0 | 99000.0 | 36000.0 | .065 | .067 | .0 | .00122 | 86.00 | 296.50 | 255.08 | 538.35 |
| 87.000 | 36000.0 | 99000.0 | 36000.0 | .079 | .082 | .0 | .00150 | 87.00 | 304.82 | 254.55 | 538.35 |
| 88.000 | 36000.0 | 99000.0 | 36000.0 | .102 | .105 | .0 | .00192 | 88.00 | 318.57 | 253.70 | 538.35 |
| 89.200 | 36000.0 | 99000.0 | 36000.0 | .147 | .151 | .0 | .00277 | 89.20 | 349.83 | 251.97 | 538.35 |
| 89.400 | 36000.0 | 99000.0 | 36000.0 | .157 | .162 | .0 | .00298 | 89.40 | 357.77 | 251.59 | 538.35 |
| 89.600 | 36000.0 | 99000.0 | 36000.0 | .170 | .174 | .0 | .00320 | 89.60 | 366.85 | 251.19 | 538.35 |
| 89.800 | 36000.0 | 99000.0 | 36000.0 | .183 | .188 | .0 | .00346 | 89.80 | 377.24 | 250.76 | 538.35 |
| 90.000 | 36000.0 | 99000.0 | 36000.0 | .188 | .204 | .0 | .00375 | 90.00 | 389.01 | 250.33 | 523.04 |
| 90.200 | 36000.0 | 99000.0 | 35960.9 | .205 | .222 | 1.5 | .00408 | 90.20 | 403.39 | 249.88 | 526.01 |
| 90.400 | 36000.0 | 99000.0 | 35843.7 | .225 | .243 | 3.2 | .00446 | 90.40 | 418.14 | 249.43 | 534.80 |
| 90.600 | 36000.0 | 99000.0 | 35648.3 | .249 | .267 | 5.2 | .00489 | 90.60 | 436.42 | 248.99 | 549.94 |
| 90.800 | 36000.0 | 99000.0 | 35374.8 | .275 | .295 | 7.4 | .00539 | 90.81 | 458.75 | 248.56 | 571.72 |
| 91.000 | 36000.0 | 99000.0 | 35023.1 | .307 | .327 | 10.0 | .00598 | 91.01 | 483.01 | 248.16 | 601.14 |
| 91.200 | 36000.0 | 99000.0 | 34592.4 | .358 | .370 | 15.9 | .00812 | 91.21 | 519.12 | 243.68 | 639.55 |
| 91.400 | 36000.0 | 99000.0 | 34084.2 | .403 | .419 | 19.2 | .00855 | 91.41 | 559.29 | 241.69 | 689.68 |
| 91.600 | 36000.0 | 99000.0 | 33497.7 | .457 | .476 | 24.0 | .00948 | 91.61 | 612.01 | 240.25 | 752.75 |
| 91.800 | 36000.0 | 99000.0 | 32832.9 | .523 | .543 | 30.2 | .01069 | 91.81 | 665.78 | 239.11 | 831.17 |
| 92.000 | 36000.0 | 99000.0 | 32089.7 | .602 | .625 | 38.2 | .01218 | 92.01 | 736.96 | 238.18 | 928.54 |
| 92.200 | 36000.0 | 99000.0 | 31268.0 | .698 | .723 | 48.2 | .01402 | 92.21 | 820.94 | 237.41 | 1049.57 |
| 92.400 | 36000.0 | 99000.0 | 30367.7 | .817 | .844 | 61.1 | .01629 | 92.42 | 932.42 | 236.78 | 1200.94 |
| 92.600 | 36000.0 | 99000.0 | 29387.1 | .994 | 1.008 | 89.1 | .02162 | 92.62 | 1072.77 | 232.55 | 1397.35 |
| 92.800 | 36000.0 | 99000.0 | 28328.6 | 1.193 | 1.210 | 110.0 | .02490 | 92.82 | 1245.68 | 230.12 | 1649.68 |
| 93.000 | 36000.0 | 99000.0 | 27190.7 | 1.447 | 1.462 | 141.1 | .02972 | 93.03 | 1475.96 | 228.56 | 1974.92 |
| 93.200 | 36000.0 | 99000.0 | 25972.9 | 1.775 | 1.783 | 183.3 | .03600 | 93.24 | 1764.73 | 227.44 | 2397.13 |
| 93.400 | 36000.0 | 99000.0 | 24674.2 | 2.214 | 2.196 | 245.3 | .04494 | 93.44 | 2132.26 | 226.34 | 2955.10 |
| 93.600 | 36000.0 | 99000.0 | 23294.6 | 2.802 | 2.741 | 325.6 | .05595 | 93.66 | 2603.49 | 225.04 | 3704.53 |
| 93.800 | 36000.0 | 99000.0 | 21829.9 | 3.642 | 3.477 | 455.7 | .07322 | 93.87 | 3257.46 | 223.11 | 4754.43 |
| 94.000 | 36000.0 | 99000.0 | 20280.9 | 4.859 | 4.469 | 613.0 | .09300 | 94.09 | 4121.71 | 221.33 | 6220.95 |
| 94.200 | 36000.0 | 99000.0 | 18642.9 | 6.528 | 5.836 | 864.0 | .12333 | 94.32 | 5347.81 | 219.50 | 8395.45 |
| 94.400 | 36000.0 | 99000.0 | 16913.6 | 9.080 | 7.723 | 1193.7 | .16119 | 94.56 | 7016.68 | 218.29 | 11646.63 |
| 94.600 | 36000.0 | 99000.0 | 15085.2 | 13.173 | 10.380 | 1694.6 | .21615 | 94.82 | 9314.67 | 217.55 | 16864.88 |
| 94.800 | 36000.0 | 99000.0 | 13147.3 | 19.112 | 14.213 | 2456.1 | .29575 | 95.10 | 12678.92 | 217.04 | 25494.04 |
| 95.000 | 36000.0 | 99000.0 | 11123.4 | 27.270 | 19.079 | 3124.9 | .36016 | 95.36 | 17167.99 | 222.76 | 37343.07 |
| 95.200 | 36000.0 | 99000.0 | 8988.9 | 38.847 | 25.425 | 3954.8 | .43697 | 95.64 | 23351.07 | 231.49 | 55175.71 |
| 95.400 | 36000.0 | 99000.0 | 6752.9 | 52.817 | 33.392 | 4472.7 | .48249 | 95.88 | 31171.13 | 242.92 | 77491.63 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HOIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 37000.0 | 99000.0 | 37000.0 | .028 | .029 | .0 | .00053 | 81.00 | 246.61 | 257.64 | 468.29 |
| 82.000 | 37000.0 | 99000.0 | 37000.0 | .031 | .033 | .0 | .00059 | 82.00 | 247.75 | 257.57 | 468.29 |
| 83.000 | 37000.0 | 99000.0 | 37000.0 | .035 | .037 | .0 | .00067 | 83.00 | 249.30 | 257.47 | 468.29 |
| 84.000 | 37000.0 | 99000.0 | 37000.0 | .041 | .042 | .0 | .00076 | 84.00 | 251.46 | 257.33 | 468.29 |
| 85.000 | 37000.0 | 99000.0 | 37000.0 | .047 | .049 | .0 | .00089 | 85.00 | 254.57 | 257.12 | 468.29 |
| 86.000 | 37000.0 | 99000.0 | 37000.0 | .056 | .058 | .0 | .00106 | 86.00 | 259.23 | 256.80 | 468.29 |
| 87.000 | 37000.0 | 99000.0 | 37000.0 | .069 | .071 | .0 | .00131 | 87.00 | 266.51 | 256.28 | 468.29 |
| 88.000 | 37000.0 | 99000.0 | 37000.0 | .088 | .091 | .0 | .00168 | 88.00 | 278.53 | 255.40 | 468.29 |
| 89.200 | 37000.0 | 99000.0 | 37000.0 | .128 | .131 | .0 | .00242 | 89.20 | 305.67 | 253.48 | 468.29 |
| 89.400 | 37000.0 | 99000.0 | 37000.0 | .137 | .141 | .0 | .00260 | 89.40 | 312.54 | 253.04 | 468.29 |
| 89.600 | 37000.0 | 99000.0 | 37000.0 | .147 | .151 | .0 | .00280 | 89.60 | 320.40 | 252.57 | 468.29 |
| 89.800 | 37000.0 | 99000.0 | 37000.0 | .159 | .164 | .0 | .00302 | 89.80 | 329.38 | 252.06 | 468.29 |
| 90.000 | 37000.0 | 99000.0 | 37000.0 | .163 | .177 | .0 | .00328 | 90.00 | 339.54 | 251.52 | 454.24 |
| 90.200 | 37000.0 | 99000.0 | 36960.9 | .178 | .193 | 1.3 | .00356 | 90.20 | 351.97 | 250.97 | 456.80 |
| 90.400 | 37000.0 | 99000.0 | 36843.7 | .195 | .211 | 2.8 | .00389 | 90.40 | 364.70 | 250.42 | 464.43 |
| 90.600 | 37000.0 | 99000.0 | 36648.3 | .216 | .232 | 4.5 | .00427 | 90.60 | 380.52 | 249.87 | 477.56 |
| 90.800 | 37000.0 | 99000.0 | 36374.8 | .239 | .256 | 6.5 | .00471 | 90.80 | 399.84 | 249.33 | 496.46 |
| 91.000 | 37000.0 | 99000.0 | 36023.1 | .266 | .284 | 8.7 | .00521 | 91.01 | 420.85 | 248.83 | 521.99 |
| 91.200 | 37000.0 | 99000.0 | 35593.2 | .298 | .317 | 11.5 | .00581 | 91.21 | 450.38 | 248.35 | 554.66 |
| 91.400 | 37000.0 | 99000.0 | 35085.1 | .335 | .356 | 14.8 | .00650 | 91.41 | 483.36 | 247.91 | 596.12 |
| 91.600 | 37000.0 | 99000.0 | 34498.1 | .394 | .408 | 22.2 | .00864 | 91.61 | 529.35 | 243.34 | 649.27 |
| 91.800 | 37000.0 | 99000.0 | 33633.4 | .450 | .467 | 26.7 | .00938 | 91.81 | 576.07 | 241.21 | 716.74 |
| 92.000 | 37000.0 | 99000.0 | 33090.4 | .518 | .538 | 33.3 | .01060 | 92.01 | 637.65 | 239.73 | 800.56 |
| 92.200 | 37000.0 | 99000.0 | 32268.9 | .601 | .624 | 41.9 | .01216 | 92.21 | 710.19 | 238.59 | 904.71 |
| 92.400 | 37000.0 | 99000.0 | 31368.9 | .703 | .728 | 53.0 | .01411 | 92.41 | 806.48 | 237.68 | 1034.93 |
| 92.600 | 37000.0 | 99000.0 | 30390.2 | .830 | .857 | 67.3 | .01653 | 92.62 | 922.55 | 236.95 | 1198.07 |
| 92.800 | 37000.0 | 99000.0 | 29331.2 | 1.019 | 1.033 | 97.9 | .02200 | 92.82 | 1070.27 | 232.55 | 1411.20 |
| 93.000 | 37000.0 | 99000.0 | 28194.1 | 1.235 | 1.252 | 122.0 | .02567 | 93.03 | 1268.28 | 230.06 | 1687.53 |
| 93.200 | 37000.0 | 99000.0 | 26977.4 | 1.514 | 1.528 | 157.7 | .03097 | 93.23 | 1515.92 | 228.48 | 2046.04 |
| 93.400 | 37000.0 | 99000.0 | 25680.5 | 1.879 | 1.881 | 206.3 | .03792 | 93.44 | 1830.22 | 227.34 | 2516.02 |
| 93.600 | 37000.0 | 99000.0 | 24302.4 | 2.372 | 2.343 | 276.2 | .04755 | 93.65 | 2231.78 | 226.13 | 3144.99 |
| 93.800 | 37000.0 | 99000.0 | 22841.6 | 3.068 | 2.961 | 391.3 | .06282 | 93.86 | 2785.79 | 224.57 | 4016.19 |
| 94.000 | 37000.0 | 99000.0 | 21296.6 | 4.024 | 3.801 | 518.1 | .07879 | 94.08 | 3520.03 | 222.53 | 5220.13 |
| 94.200 | 37000.0 | 99000.0 | 19664.7 | 5.429 | 4.950 | 728.1 | .10424 | 94.30 | 4557.27 | 220.65 | 6984.35 |
| 94.400 | 37000.0 | 99000.0 | 17942.7 | 7.490 | 6.548 | 1012.3 | .13710 | 94.54 | 5972.15 | 218.95 | 9609.64 |
| 94.600 | 37000.0 | 99000.0 | 16125.6 | 10.702 | 8.781 | 1428.6 | .18302 | 94.78 | 7918.30 | 217.95 | 13704.80 |
| 94.800 | 37000.0 | 99000.0 | 14204.3 | 15.803 | 11.980 | 2058.4 | .24934 | 95.05 | 10752.47 | 217.31 | 20488.89 |
| 95.000 | 37000.0 | 99000.0 | 12180.2 | 22.803 | 16.424 | 2810.0 | .32402 | 95.32 | 14707.69 | 219.20 | 30845.35 |
| 95.200 | 37000.0 | 99000.0 | 10059.2 | 33.086 | 22.127 | 3694.8 | .40636 | 95.61 | 19963.91 | 226.75 | 46458.49 |
| 95.400 | 37000.0 | 99000.0 | 7835.7 | 44.474 | 29.232 | 4053.0 | .43801 | 95.84 | 27092.71 | 237.13 | 64556.93 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 38000.0 | 99000.0 | 38000.0 | .025 | .026 | .0 | .00046 | 81.00 | 215.88 | 259.60 | 407.34 |
| 82.000 | 38000.0 | 99000.0 | 38000.0 | .027 | .028 | .0 | .00051 | 82.00 | 216.89 | 259.54 | 407.34 |
| 83.000 | 38000.0 | 99000.0 | 38000.0 | .031 | .032 | .0 | .00058 | 83.00 | 218.26 | 259.45 | 407.34 |
| 84.000 | 38000.0 | 99000.0 | 38000.0 | .035 | .037 | .0 | .00066 | 84.00 | 220.16 | 259.32 | 407.34 |
| 85.000 | 38000.0 | 99000.0 | 38000.0 | .041 | .042 | .0 | .00078 | 85.00 | 222.91 | 259.13 | 407.34 |
| 86.000 | 38000.0 | 99000.0 | 38000.0 | .049 | .051 | .0 | .00093 | 86.00 | 227.01 | 258.84 | 407.34 |
| 87.000 | 38000.0 | 99000.0 | 38000.0 | .060 | .062 | .0 | .00114 | 87.00 | 233.41 | 258.34 | 407.34 |
| 88.000 | 38000.0 | 99000.0 | 38000.0 | .077 | .079 | .0 | .00146 | 88.00 | 243.95 | 257.48 | 407.34 |
| 89.200 | 38000.0 | 99000.0 | 38000.0 | .111 | .114 | .0 | .00212 | 89.20 | 267.59 | 255.45 | 407.34 |
| 89.400 | 38000.0 | 99000.0 | 38000.0 | .119 | .122 | .0 | .00228 | 89.40 | 273.54 | 254.95 | 407.34 |
| 89.600 | 38000.0 | 99000.0 | 38000.0 | .128 | .131 | .0 | .00246 | 89.60 | 280.32 | 254.39 | 407.34 |
| 89.800 | 38000.0 | 99000.0 | 38000.0 | .139 | .142 | .0 | .00265 | 89.80 | 288.07 | 253.78 | 407.34 |
| 90.000 | 38000.0 | 99000.0 | 38000.0 | .141 | .154 | .0 | .00287 | 90.00 | 296.82 | 253.12 | 394.47 |
| 90.200 | 38000.0 | 99000.0 | 37960.9 | .154 | .168 | 1.2 | .00312 | 90.20 | 307.52 | 252.42 | 396.69 |
| 90.400 | 38000.0 | 99000.0 | 37843.7 | .169 | .184 | 2.5 | .00341 | 90.40 | 318.48 | 251.72 | 403.30 |
| 90.600 | 38000.0 | 99000.0 | 37648.3 | .187 | .202 | 3.9 | .00373 | 90.60 | 332.11 | 251.01 | 414.69 |
| 90.800 | 38000.0 | 99000.0 | 37374.8 | .207 | .223 | 5.6 | .00411 | 90.80 | 348.79 | 250.33 | 431.09 |
| 91.000 | 38000.0 | 99000.0 | 37023.1 | .231 | .247 | 7.6 | .00455 | 91.00 | 366.94 | 249.69 | 453.26 |
| 91.200 | 38000.0 | 99000.0 | 36593.3 | .258 | .276 | 10.0 | .00507 | 91.21 | 392.52 | 249.08 | 481.61 |
| 91.400 | 38000.0 | 99000.0 | 36085.2 | .291 | .309 | 12.9 | .00567 | 91.41 | 421.10 | 248.53 | 517.58 |
| 91.600 | 38000.0 | 99000.0 | 35499.0 | .329 | .349 | 16.4 | .00639 | 91.61 | 458.72 | 248.03 | 562.61 |
| 91.800 | 38000.0 | 99000.0 | 34834.6 | .388 | .398 | 27.7 | .00937 | 91.81 | 497.78 | 246.03 | 618.46 |
| 92.000 | 38000.0 | 99000.0 | 34090.9 | .446 | .463 | 29.6 | .00936 | 92.01 | 551.73 | 242.03 | 690.33 |
| 92.200 | 38000.0 | 99000.0 | 33269.6 | .517 | .538 | 36.6 | .01060 | 92.21 | 614.51 | 240.19 | 779.96 |
| 92.400 | 38000.0 | 99000.0 | 32369.8 | .605 | .629 | 46.0 | .01224 | 92.41 | 697.70 | 238.86 | 892.02 |
| 92.600 | 38000.0 | 99000.0 | 31391.5 | .715 | .740 | 58.3 | .01432 | 92.61 | 797.93 | 237.84 | 1032.32 |
| 92.800 | 38000.0 | 99000.0 | 30334.4 | .851 | .878 | 74.4 | .01692 | 92.82 | 920.10 | 237.03 | 1209.12 |
| 93.000 | 38000.0 | 99000.0 | 29196.8 | 1.055 | 1.069 | 107.6 | .02253 | 93.02 | 1089.69 | 232.31 | 1443.07 |
| 93.200 | 38000.0 | 99000.0 | 27981.0 | 1.292 | 1.308 | 136.1 | .02672 | 93.23 | 1302.46 | 229.86 | 1747.61 |
| 93.400 | 38000.0 | 99000.0 | 26685.3 | 1.602 | 1.612 | 177.4 | .03261 | 93.43 | 1571.98 | 228.29 | 2146.34 |
| 93.600 | 38000.0 | 99000.0 | 25309.2 | 2.012 | 2.005 | 234.0 | .04037 | 93.64 | 1914.93 | 227.17 | 2675.47 |
| 93.800 | 38000.0 | 99000.0 | 23851.1 | 2.582 | 2.527 | 323.2 | .05220 | 93.85 | 2386.16 | 225.78 | 3397.04 |
| 94.000 | 38000.0 | 99000.0 | 22309.5 | 3.382 | 3.236 | 439.7 | .06698 | 94.07 | 3009.13 | 223.80 | 4398.35 |
| 94.200 | 38000.0 | 99000.0 | 20682.5 | 4.517 | 4.207 | 615.0 | .08827 | 94.29 | 3888.15 | 221.83 | 5839.79 |
| 94.400 | 38000.0 | 99000.0 | 18967.4 | 6.210 | 5.550 | 861.0 | .11678 | 94.52 | 5084.44 | 220.06 | 7969.82 |
| 94.600 | 38000.0 | 99000.0 | 17159.1 | 8.767 | 7.440 | 1208.0 | .15531 | 94.76 | 6736.17 | 218.48 | 11228.46 |
| 94.800 | 38000.0 | 99000.0 | 15251.6 | 12.916 | 10.120 | 1731.2 | .21073 | 95.01 | 9018.77 | 217.65 | 16519.52 |
| 95.000 | 38000.0 | 99000.0 | 13233.0 | 19.108 | 14.031 | 2535.3 | .29194 | 95.29 | 12540.87 | 217.09 | 25469.82 |
| 95.200 | 38000.0 | 99000.0 | 11125.5 | 27.423 | 19.088 | 3264.7 | .36028 | 95.56 | 17151.07 | 222.77 | 38060.50 |
| 95.400 | 38000.0 | 99000.0 | 8910.3 | 38.796 | 25.577 | 3863.4 | .41427 | 95.81 | 23490.89 | 231.91 | 55084.81 |
| 95.600 | 38000.0 | 99000.0 | 6579.1 | 59.322 | 34.423 | 5348.2 | .54199 | 96.14 | 32076.86 | 243.91 | 87767.54 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | PIEFF) (10) | TIEFF) (11) | PITAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 39000.0 | 99000.0 | 39000.0 | .021 | .022 | .0 | .00040 | 81.00 | 189.36 | 261.86 | 354.33 |
| 82.000 | 39000.0 | 99000.0 | 39000.0 | .024 | .025 | .0 | .00045 | 82.00 | 190.25 | 261.81 | 354.33 |
| 83.000 | 39000.0 | 99000.0 | 39000.0 | .027 | .028 | .0 | .00051 | 83.00 | 191.46 | 261.74 | 354.33 |
| 84.000 | 39000.0 | 99000.0 | 39000.0 | .031 | .032 | .0 | .00058 | 84.00 | 193.15 | 261.64 | 354.33 |
| 85.000 | 39000.0 | 99000.0 | 39000.0 | .036 | .037 | .0 | .00068 | 85.00 | 195.58 | 261.49 | 354.33 |
| 86.000 | 39000.0 | 99000.0 | 39000.0 | .043 | .044 | .0 | .00081 | 86.00 | 199.21 | 261.24 | 354.33 |
| 87.000 | 39000.0 | 99000.0 | 39000.0 | .052 | .054 | .0 | .00100 | 87.00 | 204.89 | 260.82 | 354.33 |
| 88.000 | 39000.0 | 99000.0 | 39000.0 | .067 | .069 | .0 | .00128 | 88.00 | 214.20 | 260.07 | 354.33 |
| 89.200 | 39000.0 | 99000.0 | 39000.0 | .097 | .099 | .0 | .00188 | 89.20 | 234.94 | 258.15 | 354.33 |
| 89.400 | 39000.0 | 99000.0 | 39000.0 | .104 | .106 | .0 | .00202 | 89.40 | 240.11 | 257.61 | 354.33 |
| 89.600 | 39000.0 | 99000.0 | 39000.0 | .112 | .114 | .0 | .00218 | 89.60 | 245.98 | 256.99 | 354.33 |
| 89.800 | 39000.0 | 99000.0 | 39000.0 | .121 | .123 | .0 | .00236 | 89.80 | 252.64 | 256.25 | 354.33 |
| 90.000 | 39000.0 | 99000.0 | 39000.0 | .122 | .134 | .0 | .00255 | 90.00 | 260.15 | 255.42 | 342.55 |
| 90.200 | 39000.0 | 99000.0 | 38960.9 | .134 | .146 | 1.0 | .00277 | 90.20 | 269.32 | 254.51 | 344.47 |
| 90.400 | 39000.0 | 99000.0 | 38843.7 | .147 | .160 | 2.2 | .00301 | 90.40 | 278.68 | 253.56 | 350.21 |
| 90.600 | 39000.0 | 99000.0 | 38648.3 | .162 | .175 | 3.5 | .00329 | 90.60 | 290.35 | 252.61 | 360.09 |
| 90.800 | 39000.0 | 99000.0 | 38374.8 | .180 | .194 | 4.9 | .00361 | 90.80 | 304.68 | 251.69 | 374.33 |
| 91.000 | 39000.0 | 99000.0 | 38023.1 | .200 | .215 | 6.7 | .00398 | 91.00 | 320.29 | 250.83 | 393.57 |
| 91.200 | 39000.0 | 99000.0 | 37593.3 | .224 | .240 | 8.7 | .00443 | 91.20 | 342.38 | 250.04 | 418.17 |
| 91.400 | 39000.0 | 99000.0 | 37085.3 | .252 | .269 | 11.2 | .00495 | 91.40 | 367.10 | 249.32 | 449.39 |
| 91.600 | 39000.0 | 99000.0 | 36499.0 | .286 | .304 | 14.3 | .00557 | 91.61 | 399.70 | 248.68 | 488.46 |
| 91.800 | 39000.0 | 99000.0 | 35834.6 | .325 | .345 | 18.0 | .00632 | 91.81 | 433.03 | 248.12 | 536.59 |
| 92.000 | 39000.0 | 99000.0 | 35091.8 | .373 | .394 | 22.7 | .00721 | 92.01 | 476.96 | 247.62 | 596.22 |
| 92.200 | 39000.0 | 99000.0 | 34270.1 | .446 | .462 | 32.8 | .00943 | 92.21 | 531.66 | 242.66 | 672.55 |
| 92.400 | 39000.0 | 99000.0 | 33370.5 | .521 | .542 | 40.2 | .01067 | 92.41 | 603.70 | 240.49 | 768.67 |
| 92.600 | 39000.0 | 99000.0 | 32392.4 | .615 | .638 | 50.6 | .01242 | 92.61 | 690.29 | 239.01 | 889.35 |
| 92.800 | 39000.0 | 99000.0 | 31335.7 | .733 | .758 | 64.4 | .01465 | 92.81 | 795.78 | 237.90 | 1041.69 |
| 93.000 | 39000.0 | 99000.0 | 30200.1 | .880 | .907 | 82.6 | .01747 | 93.02 | 935.42 | 237.04 | 1234.53 |
| 93.200 | 39000.0 | 99000.0 | 28983.9 | 1.104 | 1.119 | 119.1 | .02330 | 93.22 | 1119.06 | 231.87 | 1493.83 |
| 93.400 | 39000.0 | 99000.0 | 27689.2 | 1.367 | 1.381 | 152.9 | .02810 | 93.43 | 1350.47 | 229.55 | 1832.41 |
| 93.600 | 39000.0 | 99000.0 | 26314.4 | 1.714 | 1.719 | 201.0 | .03470 | 93.63 | 1644.56 | 228.04 | 2280.88 |
| 93.800 | 39000.0 | 99000.0 | 24858.6 | 2.187 | 2.162 | 274.0 | .04434 | 93.84 | 2046.23 | 226.86 | 2885.45 |
| 94.000 | 39000.0 | 99000.0 | 23320.3 | 2.834 | 2.758 | 368.0 | .05624 | 94.06 | 2574.88 | 225.26 | 3713.75 |
| 94.200 | 39000.0 | 99000.0 | 21697.1 | 3.784 | 3.580 | 520.8 | .07490 | 94.27 | 3320.90 | 223.05 | 4904.72 |
| 94.400 | 39000.0 | 99000.0 | 19987.9 | 5.152 | 4.711 | 722.2 | .09831 | 94.50 | 4333.41 | 221.22 | 6629.23 |
| 94.600 | 39000.0 | 99000.0 | 18186.9 | 7.231 | 6.309 | 1026.2 | .13226 | 94.73 | 5734.06 | 219.19 | 9263.75 |
| 94.800 | 39000.0 | 99000.0 | 16290.8 | 10.488 | 8.564 | 1460.4 | .17849 | 94.98 | 7669.45 | 218.07 | 13416.24 |
| 95.000 | 39000.0 | 99000.0 | 14289.2 | 15.773 | 11.830 | 2126.0 | .24618 | 95.25 | 10513.01 | 217.37 | 20434.23 |
| 95.200 | 39000.0 | 99000.0 | 12182.4 | 23.217 | 16.431 | 2935.8 | .32413 | 95.52 | 14692.81 | 219.22 | 31388.35 |
| 95.400 | 39000.0 | 99000.0 | 9977.4 | 33.246 | 22.302 | 3647.3 | .38876 | 95.79 | 20298.13 | 226.95 | 46667.42 |
| 95.600 | 39000.0 | 99000.0 | 7671.5 | 48.449 | 29.960 | 4584.5 | .46953 | 96.07 | 27819.63 | 238.48 | 70304.14 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HOIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 40000.0 | 99000.0 | 40000.0 | .019 | .019 | .0 | .00033 | 81.00 | 166.66 | 264.45 | 308.21 |
| 82.000 | 40000.0 | 99000.0 | 40000.0 | .021 | .022 | .0 | .00037 | 82.00 | 167.45 | 264.42 | 308.21 |
| 83.000 | 40000.0 | 99000.0 | 40000.0 | .023 | .024 | .0 | .00042 | 83.00 | 168.54 | 264.39 | 308.21 |
| 84.000 | 40000.0 | 99000.0 | 40000.0 | .027 | .028 | .0 | .00048 | 84.00 | 170.04 | 264.33 | 308.21 |
| 85.000 | 40000.0 | 99000.0 | 40000.0 | .031 | .032 | .0 | .00056 | 85.00 | 172.22 | 264.23 | 308.21 |
| 86.000 | 40000.0 | 99000.0 | 40000.0 | .037 | .038 | .0 | .00066 | 86.00 | 175.47 | 264.07 | 308.21 |
| 87.000 | 40000.0 | 99000.0 | 40000.0 | .046 | .047 | .0 | .00081 | 87.00 | 180.55 | 263.80 | 308.21 |
| 88.000 | 40000.0 | 99000.0 | 40000.0 | .058 | .060 | .0 | .00104 | 88.00 | 188.92 | 263.32 | 308.21 |
| 89.200 | 40000.0 | 99000.0 | 40000.0 | .084 | .085 | .0 | .00148 | 89.20 | 207.56 | 262.29 | 308.21 |
| 89.400 | 40000.0 | 99000.0 | 40000.0 | .090 | .091 | .0 | .00159 | 89.40 | 212.15 | 262.06 | 308.21 |
| 89.600 | 40000.0 | 99000.0 | 40000.0 | .097 | .098 | .0 | .00171 | 89.60 | 217.29 | 261.82 | 308.21 |
| 89.800 | 40000.0 | 99000.0 | 40000.0 | .105 | .106 | .0 | .00184 | 89.80 | 222.98 | 261.57 | 308.21 |
| 90.000 | 40000.0 | 99000.0 | 40000.0 | .098 | .115 | .0 | .00199 | 90.00 | 229.17 | 261.30 | 298.25 |
| 90.200 | 40000.0 | 99000.0 | 39960.9 | .108 | .125 | 1.0 | .00268 | 90.20 | 236.62 | 259.90 | 299.84 |
| 90.400 | 40000.0 | 99000.0 | 39843.5 | .120 | .137 | 2.4 | .00346 | 90.40 | 244.46 | 257.77 | 304.59 |
| 90.600 | 40000.0 | 99000.0 | 39648.0 | .141 | .151 | 3.4 | .00344 | 90.60 | 254.51 | 255.30 | 312.70 |
| 90.800 | 40000.0 | 99000.0 | 39374.5 | .156 | .168 | 4.5 | .00348 | 90.80 | 266.74 | 253.79 | 325.05 |
| 91.000 | 40000.0 | 99000.0 | 39022.8 | .174 | .187 | 5.9 | .00370 | 91.00 | 280.06 | 252.49 | 341.60 |
| 91.200 | 40000.0 | 99000.0 | 38592.9 | .194 | .209 | 7.7 | .00404 | 91.20 | 299.05 | 251.36 | 363.10 |
| 91.400 | 40000.0 | 99000.0 | 38084.9 | .219 | .234 | 9.8 | .00446 | 91.40 | 320.36 | 250.39 | 390.20 |
| 91.600 | 40000.0 | 99000.0 | 37498.7 | .248 | .264 | 12.5 | .00498 | 91.60 | 348.55 | 249.54 | 424.12 |
| 91.800 | 40000.0 | 99000.0 | 36834.3 | .282 | .300 | 15.7 | .00561 | 91.81 | 377.40 | 248.81 | 465.88 |
| 92.000 | 40000.0 | 99000.0 | 36091.6 | .324 | .343 | 19.8 | .00637 | 92.01 | 415.50 | 248.18 | 517.62 |
| 92.200 | 40000.0 | 99000.0 | 35270.6 | .374 | .395 | 24.9 | .00730 | 92.21 | 460.31 | 247.64 | 581.72 |
| 92.400 | 40000.0 | 99000.0 | 34370.6 | .449 | .466 | 36.3 | .00963 | 92.41 | 522.31 | 243.05 | 662.83 |
| 92.600 | 40000.0 | 99000.0 | 33392.7 | .530 | .550 | 44.2 | .01090 | 92.61 | 597.32 | 240.62 | 766.63 |
| 92.800 | 40000.0 | 99000.0 | 32336.3 | .631 | .654 | 55.9 | .01277 | 92.81 | 688.46 | 239.03 | 897.69 |
| 93.000 | 40000.0 | 99000.0 | 31201.1 | .758 | .784 | 71.5 | .01519 | 93.02 | 809.04 | 237.87 | 1063.46 |
| 93.200 | 40000.0 | 99000.0 | 29987.0 | .921 | .947 | 99.1 | .01937 | 93.22 | 959.19 | 236.95 | 1277.08 |
| 93.400 | 40000.0 | 99000.0 | 28691.9 | 1.167 | 1.182 | 132.9 | .02443 | 93.42 | 1160.36 | 231.32 | 1565.67 |
| 93.600 | 40000.0 | 99000.0 | 27318.8 | 1.462 | 1.473 | 173.0 | .02992 | 93.63 | 1412.75 | 229.16 | 1945.66 |
| 93.800 | 40000.0 | 99000.0 | 25864.2 | 1.856 | 1.852 | 229.6 | .03737 | 93.84 | 1756.79 | 227.72 | 2455.21 |
| 94.000 | 40000.0 | 99000.0 | 24328.4 | 2.398 | 2.358 | 312.3 | .04786 | 94.05 | 2207.05 | 226.35 | 3149.89 |
| 94.200 | 40000.0 | 99000.0 | 22708.7 | 3.183 | 3.049 | 446.8 | .06429 | 94.26 | 2839.20 | 224.38 | 4136.49 |
| 94.400 | 40000.0 | 99000.0 | 21004.2 | 4.297 | 4.005 | 605.8 | .08280 | 94.48 | 3654.89 | 222.40 | 5543.35 |
| 94.600 | 40000.0 | 99000.0 | 19210.3 | 5.987 | 5.349 | 863.4 | .11167 | 94.71 | 4882.83 | 220.33 | 7670.62 |
| 94.800 | 40000.0 | 99000.0 | 17323.3 | 8.588 | 7.258 | 1235.9 | .15158 | 94.95 | 6526.76 | 218.62 | 10987.27 |
| 95.000 | 40000.0 | 99000.0 | 15335.5 | 12.873 | 9.996 | 1789.0 | .20816 | 95.21 | 8931.46 | 217.71 | 16451.55 |
| 95.200 | 40000.0 | 99000.0 | 13234.8 | 19.432 | 14.039 | 2649.0 | .29209 | 95.49 | 12528.39 | 217.12 | 25887.56 |
| 95.400 | 40000.0 | 99000.0 | 11042.4 | 28.491 | 19.339 | 3463.1 | .36618 | 95.77 | 17288.04 | 222.95 | 39527.14 |
| 95.600 | 40000.0 | 99000.0 | 8750.9 | 38.871 | 25.982 | 3801.9 | .39572 | 96.00 | 23803.28 | 233.21 | 55794.58 |
| 95.800 | 40000.0 | 99000.0 | 6315.8 | 65.225 | 35.695 | 5953.3 | .57632 | 96.38 | 33206.34 | 245.04 | 97145.09 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HOIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 41000.0 | 99000.0 | 41000.0 | .016 | .017 | .0 | .00029 | 81.00 | 145.94 | 265.40 | 270.56 |
| 82.000 | 41000.0 | 99000.0 | 41000.0 | .018 | .019 | .0 | .00032 | 82.00 | 146.64 | 265.37 | 270.56 |
| 83.000 | 41000.0 | 99000.0 | 41000.0 | .020 | .021 | .0 | .00037 | 83.00 | 147.59 | 265.34 | 270.56 |
| 84.000 | 41000.0 | 99000.0 | 41000.0 | .023 | .024 | .0 | .00042 | 84.00 | 148.91 | 265.29 | 270.56 |
| 85.000 | 41000.0 | 99000.0 | 41000.0 | .027 | .028 | .0 | .00049 | 85.00 | 150.82 | 265.21 | 270.56 |
| 86.000 | 41000.0 | 99000.0 | 41000.0 | .032 | .034 | .0 | .00058 | 86.00 | 153.68 | 265.06 | 270.56 |
| 87.000 | 41000.0 | 99000.0 | 41000.0 | .040 | .041 | .0 | .00071 | 87.00 | 158.14 | 264.80 | 270.56 |
| 88.000 | 41000.0 | 99000.0 | 41000.0 | .050 | .052 | .0 | .00091 | 88.00 | 165.49 | 264.31 | 270.56 |
| 89.200 | 41000.0 | 99000.0 | 41000.0 | .072 | .075 | .0 | .00130 | 89.20 | 181.86 | 263.18 | 270.56 |
| 89.400 | 41000.0 | 99000.0 | 41000.0 | .078 | .080 | .0 | .00140 | 89.40 | 185.88 | 262.91 | 270.56 |
| 89.600 | 41000.0 | 99000.0 | 41000.0 | .083 | .086 | .0 | .00150 | 89.60 | 190.39 | 262.63 | 270.56 |
| 89.800 | 41000.0 | 99000.0 | 41000.0 | .090 | .093 | .0 | .00162 | 89.80 | 195.38 | 262.32 | 270.56 |
| 90.000 | 41000.0 | 99000.0 | 41000.0 | .090 | .101 | .0 | .00175 | 90.00 | 200.80 | 262.00 | 260.82 |
| 90.200 | 41000.0 | 99000.0 | 40960.9 | .099 | .109 | .7 | .00190 | 90.20 | 209.42 | 261.67 | 262.20 |
| 90.400 | 41000.0 | 99000.0 | 40843.7 | .108 | .119 | 1.5 | .00207 | 90.40 | 217.78 | 261.34 | 266.33 |
| 90.600 | 41000.0 | 99000.0 | 40648.3 | .119 | .130 | 2.4 | .00227 | 90.60 | 225.79 | 261.02 | 273.80 |
| 90.800 | 41000.0 | 99000.0 | 40374.8 | .132 | .144 | 3.4 | .00249 | 90.80 | 233.32 | 260.70 | 283.93 |
| 91.000 | 41000.0 | 99000.0 | 40023.2 | .146 | .159 | 4.6 | .00275 | 91.00 | 240.31 | 260.39 | 297.52 |
| 91.200 | 41000.0 | 99000.0 | 39593.0 | .171 | .179 | 7.5 | .00383 | 91.20 | 263.39 | 255.35 | 315.29 |
| 91.400 | 41000.0 | 99000.0 | 39084.9 | .192 | .202 | 8.9 | .00399 | 91.40 | 281.27 | 253.18 | 338.79 |
| 91.600 | 41000.0 | 99000.0 | 38498.7 | .217 | .229 | 11.0 | .00439 | 91.60 | 305.31 | 251.63 | 368.23 |
| 91.800 | 41000.0 | 99000.0 | 37834.3 | .247 | .260 | 13.8 | .00491 | 91.80 | 330.02 | 250.41 | 404.47 |
| 92.000 | 41000.0 | 99000.0 | 37091.6 | .282 | .298 | 17.3 | .00557 | 92.01 | 362.87 | 249.43 | 449.37 |
| 92.200 | 41000.0 | 99000.0 | 36270.7 | .326 | .343 | 21.7 | .00637 | 92.21 | 401.62 | 248.62 | 504.99 |
| 92.400 | 41000.0 | 99000.0 | 35371.5 | .379 | .398 | 27.4 | .00735 | 92.41 | 452.86 | 247.95 | 573.57 |
| 92.600 | 41000.0 | 99000.0 | 34393.2 | .458 | .473 | 40.0 | .00977 | 92.61 | 517.20 | 243.41 | 661.01 |
| 92.800 | 41000.0 | 99000.0 | 33337.0 | .544 | .564 | 48.8 | .01113 | 92.81 | 596.10 | 240.77 | 773.71 |
| 93.000 | 41000.0 | 99000.0 | 32202.1 | .654 | .676 | 62.0 | .01317 | 93.01 | 700.22 | 239.09 | 916.27 |
| 93.200 | 41000.0 | 99000.0 | 30988.5 | .793 | .817 | 79.8 | .01581 | 93.22 | 829.74 | 237.87 | 1098.72 |
| 93.400 | 41000.0 | 99000.0 | 29694.4 | 1.000 | 1.006 | 127.1 | .02294 | 93.42 | 996.30 | 234.42 | 1340.66 |
| 93.600 | 41000.0 | 99000.0 | 28321.7 | 1.248 | 1.261 | 149.7 | .02587 | 93.63 | 1214.04 | 230.75 | 1661.45 |
| 93.800 | 41000.0 | 99000.0 | 26868.8 | 1.582 | 1.588 | 197.4 | .03214 | 93.83 | 1509.11 | 228.76 | 2092.83 |
| 94.000 | 41000.0 | 99000.0 | 25335.1 | 2.034 | 2.018 | 264.6 | .04063 | 94.04 | 1893.75 | 227.42 | 2677.37 |
| 94.200 | 41000.0 | 99000.0 | 23718.7 | 2.676 | 2.602 | 371.0 | .05363 | 94.25 | 2430.74 | 225.74 | 3493.53 |
| 94.400 | 41000.0 | 99000.0 | 22017.9 | 3.602 | 3.410 | 513.3 | .07029 | 94.47 | 3123.62 | 223.66 | 4657.44 |
| 94.600 | 41000.0 | 99000.0 | 20229.8 | 4.972 | 4.542 | 728.1 | .09442 | 94.69 | 4163.12 | 221.49 | 6385.82 |
| 94.800 | 41000.0 | 99000.0 | 18350.3 | 7.083 | 6.155 | 1051.5 | .12924 | 94.93 | 5557.43 | 219.38 | 9062.10 |
| 95.000 | 41000.0 | 99000.0 | 16374.1 | 10.441 | 8.460 | 1509.8 | .17634 | 95.18 | 7593.81 | 218.15 | 13344.42 |
| 95.200 | 41000.0 | 99000.0 | 14291.. | 16.112 | 11.836 | 2221.9 | .24632 | 95.45 | 10502.80 | 217.39 | 20732.18 |
| 95.400 | 41000.0 | 99000.0 | 12099.9 | 24.096 | 16.654 | 3112.9 | .32933 | 95.73 | 14817.34 | 219.33 | 32563.38 |
| 95.600 | 41000.0 | 99000.0 | 9619.9 | 32.929 | 22.609 | 3414.7 | .35607 | 95.96 | 20568.56 | 228.08 | 46210.88 |
| 95.800 | 41000.0 | 99000.0 | 7411.3 | 53.446 | 31.104 | 5224.7 | .50913 | 96.31 | 28826.83 | 239.68 | 78368.25 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 42000.0 | 99000.0 | 42000.0 | .014 | .015 | .0 | .00025 | 81.00 | 127.78 | 266.48 | 237.02 |
| 82.000 | 42000.0 | 99000.0 | 42000.0 | .016 | .017 | .0 | .00028 | 82.00 | 128.39 | 266.47 | 237.02 |
| 83.000 | 42000.0 | 99000.0 | 42000.0 | .018 | .019 | .0 | .00032 | 83.00 | 129.23 | 266.45 | 237.02 |
| 84.000 | 42000.0 | 99000.0 | 42000.0 | .020 | .021 | .0 | .00037 | 84.00 | 130.39 | 266.41 | 237.02 |
| 85.000 | 42000.0 | 99000.0 | 42000.0 | .024 | .025 | .0 | .00043 | 85.00 | 132.07 | 266.35 | 237.02 |
| 86.000 | 42000.0 | 99000.0 | 42000.0 | .028 | .029 | .0 | .00051 | 86.00 | 134.57 | 266.22 | 237.02 |
| 87.000 | 42000.0 | 99000.0 | 42000.0 | .035 | .036 | .0 | .00063 | 87.00 | 138.49 | 265.99 | 237.02 |
| 88.000 | 42000.0 | 99000.0 | 42000.0 | .044 | .046 | .0 | .00080 | 88.00 | 144.95 | 265.52 | 237.02 |
| 89.200 | 42000.0 | 99000.0 | 42000.0 | .063 | .065 | .0 | .00115 | 89.20 | 159.31 | 264.30 | 237.02 |
| 89.400 | 42000.0 | 99000.0 | 42000.0 | .068 | .070 | .0 | .00123 | 89.40 | 162.85 | 264.00 | 237.02 |
| 89.600 | 42000.0 | 99000.0 | 42000.0 | .073 | .075 | .0 | .00132 | 89.60 | 166.80 | 263.66 | 237.02 |
| 89.800 | 42000.0 | 99000.0 | 42000.0 | .079 | .081 | .0 | .00143 | 89.80 | 171.18 | 263.30 | 237.02 |
| 90.000 | 42000.0 | 99000.0 | 42000.0 | .079 | .088 | .0 | .00154 | 90.00 | 175.94 | 262.91 | 228.08 |
| 90.200 | 42000.0 | 99000.0 | 41960.9 | .086 | .096 | .6 | .00167 | 90.20 | 183.49 | 262.50 | 229.28 |
| 90.400 | 42000.0 | 99000.0 | 41843.7 | .095 | .104 | 1.3 | .00182 | 90.40 | 190.83 | 262.09 | 232.89 |
| 90.600 | 42000.0 | 99000.0 | 41648.3 | .104 | .114 | 2.1 | .00199 | 90.60 | 197.84 | 261.68 | 239.43 |
| 90.800 | 42000.0 | 99000.0 | 41374.8 | .115 | .126 | 3.0 | .00219 | 90.80 | 204.44 | 261.28 | 248.29 |
| 91.000 | 42000.0 | 99000.0 | 41023.1 | .128 | .139 | 4.0 | .00242 | 91.00 | 210.55 | 260.90 | 260.16 |
| 91.200 | 42000.0 | 99000.0 | 40593.3 | .143 | .155 | 5.3 | .00268 | 91.20 | 226.67 | 260.54 | 275.91 |
| 91.400 | 42000.0 | 99000.0 | 40085.3 | .160 | .173 | 6.8 | .00299 | 91.40 | 232.73 | 260.20 | 295.16 |
| 91.600 | 42000.0 | 99000.0 | 39498.7 | .188 | .197 | 10.4 | .00406 | 91.60 | 268.64 | 255.07 | 319.73 |
| 91.800 | 42000.0 | 99000.0 | 38834.3 | .214 | .226 | 12.3 | .00435 | 91.80 | 289.40 | 252.73 | 351.16 |
| 92.000 | 42000.0 | 99000.0 | 38091.8 | .245 | .259 | 15.2 | .00488 | 92.00 | 317.49 | 251.13 | 390.13 |
| 92.200 | 42000.0 | 99000.0 | 37270.7 | .283 | .298 | 19.0 | .00556 | 92.21 | 350.84 | 249.90 | 438.39 |
| 92.400 | 42000.0 | 99000.0 | 36371.6 | .328 | .346 | 23.9 | .00641 | 92.41 | 395.16 | 248.94 | 497.89 |
| 92.600 | 42000.0 | 99000.0 | 35394.1 | .385 | .404 | 30.1 | .00746 | 92.61 | 448.45 | 248.16 | 571.99 |
| 92.800 | 42000.0 | 99000.0 | 34337.4 | .469 | .484 | 43.9 | .00993 | 92.81 | 516.13 | 243.43 | 667.05 |
| 93.000 | 42000.0 | 99000.0 | 33202.8 | .563 | .583 | 54.1 | .01147 | 93.01 | 606.23 | 240.73 | 789.62 |
| 93.200 | 42000.0 | 99000.0 | 31989.5 | .683 | .705 | 69.2 | .01370 | 93.21 | 718.05 | 239.01 | 946.49 |
| 93.400 | 42000.0 | 99000.0 | 30697.2 | .836 | .861 | 89.6 | .01662 | 93.42 | 858.83 | 237.77 | 1148.49 |
| 93.600 | 42000.0 | 99000.0 | 29324.3 | 1.067 | 1.077 | 132.8 | .02283 | 93.62 | 1043.02 | 233.17 | 1420.24 |
| 93.800 | 42000.0 | 99000.0 | 27872.5 | 1.350 | 1.360 | 170.3 | .02772 | 93.83 | 1296.64 | 230.13 | 1786.04 |
| 94.000 | 42000.0 | 99000.0 | 26340.3 | 1.732 | 1.730 | 227.3 | .03492 | 94.03 | 1626.45 | 228.32 | 2281.02 |
| 94.200 | 42000.0 | 99000.0 | 24726.4 | 2.263 | 2.225 | 315.1 | .04562 | 94.25 | 2083.99 | 226.84 | 2963.09 |
| 94.400 | 42000.0 | 99000.0 | 23029.4 | 3.027 | 2.904 | 430.2 | .05908 | 94.46 | 2671.63 | 225.20 | 3924.40 |
| 94.600 | 42000.0 | 99000.0 | 21245.7 | 4.151 | 3.863 | 615.5 | .08000 | 94.68 | 3553.62 | 222.70 | 5344.23 |
| 94.800 | 42000.0 | 99000.0 | 19373.1 | 5.861 | 5.220 | 885.1 | .10912 | 94.91 | 4734.21 | 220.53 | 7499.80 |
| 95.000 | 42000.0 | 99000.0 | 17406.2 | 8.541 | 7.170 | 1278.1 | .14974 | 95.15 | 6461.12 | 218.72 | 10916.41 |
| 95.200 | 42000.0 | 99000.0 | 15337.6 | 13.045 | 10.001 | 1869.9 | .20823 | 95.41 | 8922.37 | 217.74 | 16660.71 |
| 95.400 | 42000.0 | 99000.0 | 13153.3 | 20.115 | 14.234 | 2801.5 | .29611 | 95.70 | 12640.54 | 217.12 | 26786.58 |
| 95.600 | 42000.0 | 99000.0 | 10881.5 | 28.217 | 19.642 | 3228.3 | .33420 | 95.93 | 17723.48 | 223.62 | 39136.98 |
| 95.800 | 42000.0 | 99000.0 | 8493.6 | 44.230 | 27.099 | 4661.1 | .45587 | 96.26 | 24964.34 | 234.42 | 64164.88 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 43000.0 | 99000.0 | 43000.0 | .013 | .013 | .0 | .00022 | 81.00 | 111.86 | 267.72 | 207.63 |
| 82.000 | 43000.0 | 99000.0 | 43000.0 | .014 | .015 | .0 | .00025 | 82.00 | 112.39 | 267.72 | 207.63 |
| 83.000 | 43000.0 | 99000.0 | 43000.0 | .016 | .016 | .0 | .00028 | 83.00 | 113.13 | 267.72 | 207.63 |
| 84.000 | 43000.0 | 99000.0 | 43000.0 | .018 | .019 | .0 | .00032 | 84.00 | 114.14 | 267.70 | 207.63 |
| 85.000 | 43000.0 | 99000.0 | 43000.0 | .021 | .022 | .0 | .00038 | 85.00 | 115.61 | 267.67 | 207.63 |
| 86.000 | 43000.0 | 99000.0 | 43000.0 | .025 | .026 | .0 | .00045 | 86.00 | 117.81 | 267.59 | 207.63 |
| 87.000 | 43000.0 | 99000.0 | 43000.0 | .030 | .032 | .0 | .00055 | 87.00 | 121.25 | 267.41 | 207.63 |
| 88.000 | 43000.0 | 99000.0 | 43000.0 | .039 | .040 | .0 | .00070 | 88.00 | 126.91 | 267.00 | 207.63 |
| 89.200 | 43000.0 | 99000.0 | 43000.0 | .055 | .057 | .0 | .00102 | 89.20 | 139.51 | 265.78 | 207.63 |
| 89.400 | 43000.0 | 99000.0 | 43000.0 | .059 | .061 | .0 | .00109 | 89.40 | 142.62 | 265.44 | 207.63 |
| 89.600 | 43000.0 | 99000.0 | 43000.0 | .064 | .066 | .0 | .00117 | 89.60 | 146.09 | 265.05 | 207.63 |
| 89.800 | 43000.0 | 99000.0 | 43000.0 | .069 | .071 | .0 | .00126 | 89.80 | 149.94 | 264.61 | 207.63 |
| 90.000 | 43000.0 | 99000.0 | 43000.0 | .069 | .077 | .0 | .00137 | 90.00 | 154.12 | 264.13 | 199.44 |
| 90.200 | 43000.0 | 99000.0 | 42960.9 | .075 | .084 | .6 | .00148 | 90.20 | 160.76 | 263.62 | 200.49 |
| 90.400 | 43000.0 | 99000.0 | 42843.7 | .083 | .091 | 1.2 | .00161 | 90.40 | 167.19 | 263.09 | 203.65 |
| 90.600 | 43000.0 | 99000.0 | 42648.3 | .091 | .100 | 1.9 | .00176 | 90.60 | 173.34 | 262.56 | 209.37 |
| 90.800 | 43000.0 | 99000.0 | 42374.7 | .101 | .110 | 2.6 | .00193 | 90.80 | 179.12 | 262.04 | 217.12 |
| 91.000 | 43000.0 | 99000.0 | 42023.0 | .112 | .122 | 3.5 | .00213 | 91.00 | 184.48 | 261.55 | 227.49 |
| 91.200 | 43000.0 | 99000.0 | 41593.2 | .125 | .136 | 4.6 | .00236 | 91.20 | 198.61 | 261.09 | 241.27 |
| 91.400 | 43000.0 | 99000.0 | 41085.1 | .140 | .151 | 5.9 | .00263 | 91.40 | 203.90 | 260.67 | 258.10 |
| 91.600 | 43000.0 | 99000.0 | 40498.9 | .158 | .170 | 7.5 | .00295 | 91.60 | 228.54 | 260.29 | 279.46 |
| 91.800 | 43000.0 | 99000.0 | 39834.3 | .179 | .193 | 13.2 | .00447 | 91.80 | 255.18 | 258.17 | 305.40 |
| 92.000 | 43000.0 | 99000.0 | 39091.5 | .212 | .224 | 13.7 | .00436 | 92.00 | 278.67 | 253.67 | 338.71 |
| 92.200 | 43000.0 | 99000.0 | 38270.6 | .245 | .259 | 16.7 | .00489 | 92.20 | 307.08 | 251.67 | 380.59 |
| 92.400 | 43000.0 | 99000.0 | 37371.5 | .285 | .301 | 20.9 | .00560 | 92.41 | 345.24 | 250.23 | 432.21 |
| 92.600 | 43000.0 | 99000.0 | 36394.3 | .334 | .352 | 26.3 | .00651 | 92.61 | 391.30 | 249.14 | 496.50 |
| 92.800 | 43000.0 | 99000.0 | 35338.2 | .394 | .414 | 33.3 | .00763 | 92.81 | 447.36 | 248.28 | 576.72 |
| 93.000 | 43000.0 | 99000.0 | 34203.2 | .485 | .501 | 48.2 | .01016 | 93.01 | 524.91 | 243.19 | 680.68 |
| 93.200 | 43000.0 | 99000.0 | 32990.1 | .588 | .609 | 60.2 | .01192 | 93.21 | 621.59 | 240.53 | 815.56 |
| 93.400 | 43000.0 | 99000.0 | 31698.8 | .720 | .743 | 77.6 | .01440 | 93.41 | 743.13 | 238.82 | 989.18 |
| 93.600 | 43000.0 | 99000.0 | 30327.4 | .891 | .916 | 101.3 | .01764 | 93.62 | 896.54 | 237.60 | 1215.13 |
| 93.800 | 43000.0 | 99000.0 | 28875.4 | 1.152 | 1.163 | 148.5 | .02412 | 93.82 | 1114.14 | 232.09 | 1525.57 |
| 94.000 | 43000.0 | 99000.0 | 27344.4 | 1.476 | 1.483 | 195.7 | .03007 | 94.03 | 1397.22 | 229.49 | 1944.63 |
| 94.200 | 43000.0 | 99000.0 | 25732.5 | 1.919 | 1.906 | 264.0 | .03839 | 94.24 | 1788.64 | 227.86 | 2518.21 |
| 94.400 | 43000.0 | 99000.0 | 24038.1 | 2.550 | 2.481 | 365.1 | .05022 | 94.45 | 2289.36 | 226.31 | 3321.02 |
| 94.600 | 43000.0 | 99000.0 | 22258.6 | 3.479 | 3.290 | 522.3 | .06799 | 94.67 | 3001.81 | 223.98 | 4490.86 |
| 94.800 | 43000.0 | 99000.0 | 20391.8 | 4.867 | 4.434 | 746.9 | .09231 | 94.89 | 4037.81 | 221.71 | 6243.46 |
| 95.000 | 43000.0 | 99000.0 | 18432.6 | 7.039 | 6.081 | 1088.6 | .12779 | 95.13 | 5500.62 | 219.51 | 8997.21 |
| 95.200 | 43000.0 | 99000.0 | 16376.1 | 10.559 | 8.465 | 1578.4 | .17641 | 95.38 | 7585.94 | 218.18 | 13485.83 |
| 95.400 | 43000.0 | 99000.0 | 14216.2 | 16.289 | 11.999 | 2349.7 | .24967 | 95.65 | 10719.07 | 217.39 | 21412.48 |
| 95.600 | 43000.0 | 99000.0 | 11937.0 | 23.879 | 16.972 | 2968.0 | .30637 | 95.91 | 15211.15 | 219.68 | 32660.98 |
| 95.800 | 43000.0 | 99000.0 | 9570.2 | 36.598 | 23.499 | 4064.1 | .39988 | 96.20 | 21343.41 | 229.62 | 51936.06 |
| 96.000 | 43000.0 | 99000.0 | 7062.0 | 59.455 | 32.633 | 5846.8 | .54541 | 96.55 | 30110.58 | 240.99 | 87931.55 |

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | PIEFF) (10) | TIEFF) (11) | PITAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | PIEFF) (10) | TIEFF) (11) | PITAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 44000.0 | 99000.0 | 44000.0 | .011 | .011 | .0 | .00020 | 81.00 | 97.89 | 269.15 | 181.89 |
| 82.000 | 44000.0 | 99000.0 | 44000.0 | .012 | .013 | .0 | .00022 | 82.00 | 98.36 | 269.16 | 181.89 |
| 83.000 | 44000.0 | 99000.0 | 44000.0 | .014 | .014 | .0 | .00025 | 83.00 | 99.00 | 269.18 | 181.89 |
| 84.000 | 44000.0 | 99000.0 | 44000.0 | .016 | .016 | .0 | .00028 | 84.00 | 99.89 | 269.20 | 181.89 |
| 85.000 | 44000.0 | 99000.0 | 44000.0 | .018 | .019 | .0 | .00033 | 85.00 | 101.18 | 269.21 | 181.89 |
| 86.000 | 44000.0 | 99000.0 | 44000.0 | .022 | .023 | .0 | .00039 | 86.00 | 103.10 | 269.19 | 181.89 |
| 87.000 | 44000.0 | 99000.0 | 44000.0 | .027 | .028 | .0 | .00048 | 87.00 | 106.11 | 269.11 | 181.89 |
| 88.000 | 44000.0 | 99000.0 | 44000.0 | .034 | .035 | .0 | .00062 | 88.00 | 111.05 | 268.85 | 181.89 |
| 89.200 | 44000.0 | 99000.0 | 44000.0 | .049 | .050 | .0 | .00091 | 89.20 | 122.04 | 267.83 | 181.89 |
| 89.400 | 44000.0 | 99000.0 | 44000.0 | .052 | .054 | .0 | .00098 | 89.40 | 124.75 | 267.49 | 181.89 |
| 89.600 | 44000.0 | 99000.0 | 44000.0 | .056 | .058 | .0 | .00107 | 89.60 | 127.79 | 267.07 | 181.89 |
| 89.800 | 44000.0 | 99000.0 | 44000.0 | .060 | .062 | .0 | .00117 | 89.80 | 131.16 | 266.56 | 181.89 |
| 90.000 | 44000.0 | 99000.0 | 44000.0 | .060 | .067 | .0 | .00129 | 90.00 | 134.85 | 265.95 | 174.39 |
| 90.200 | 44000.0 | 99000.0 | 43960.9 | .066 | .073 | .5 | .00136 | 90.20 | 140.72 | 265.26 | 175.31 |
| 90.400 | 44000.0 | 99000.0 | 43843.7 | .072 | .080 | 1.1 | .00145 | 90.40 | 146.41 | 264.54 | 178.07 |
| 90.600 | 44000.0 | 99000.0 | 43648.3 | .080 | .088 | 1.7 | .00157 | 90.60 | 151.83 | 263.80 | 183.08 |
| 90.800 | 44000.0 | 99000.0 | 43374.7 | .088 | .096 | 2.3 | .00171 | 90.80 | 156.91 | 263.10 | 189.85 |
| 91.000 | 44000.0 | 99000.0 | 43023.0 | .098 | .107 | 3.1 | .00188 | 91.00 | 161.62 | 262.43 | 198.92 |
| 91.200 | 44000.0 | 99000.0 | 42593.0 | .109 | .119 | 4.1 | .00208 | 91.20 | 174.01 | 261.83 | 210.97 |
| 91.400 | 44000.0 | 99000.0 | 42085.0 | .122 | .133 | 5.2 | .00231 | 91.40 | 178.65 | 261.28 | 225.69 |
| 91.600 | 44000.0 | 99000.0 | 41498.7 | .138 | .149 | 6.6 | .00259 | 91.60 | 200.24 | 260.79 | 244.37 |
| 91.800 | 44000.0 | 99000.0 | 40834.3 | .156 | .168 | 8.3 | .00292 | 91.80 | 223.33 | 260.36 | 266.90 |
| 92.000 | 44000.0 | 99000.0 | 40091.7 | .178 | .192 | 10.4 | .00332 | 92.00 | 231.81 | 259.99 | 295.05 |
| 92.200 | 44000.0 | 99000.0 | 39270.4 | .212 | .224 | 15.2 | .00440 | 92.20 | 269.72 | 254.39 | 330.29 |
| 92.400 | 44000.0 | 99000.0 | 38371.3 | .247 | .261 | 18.4 | .00493 | 92.40 | 302.23 | 252.02 | 375.22 |
| 92.600 | 44000.0 | 99000.0 | 37393.9 | .290 | .306 | 23.0 | .00569 | 92.61 | 341.87 | 250.41 | 430.99 |
| 92.800 | 44000.0 | 99000.0 | 36338.1 | .342 | .360 | 29.0 | .00666 | 92.81 | 390.33 | 249.22 | 500.58 |
| 93.000 | 44000.0 | 99000.0 | 35203.9 | .408 | .428 | 36.9 | .00788 | 93.01 | 454.29 | 248.30 | 588.14 |
| 93.200 | 44000.0 | 99000.0 | 33990.5 | .506 | .524 | 53.1 | .01048 | 93.21 | 538.19 | 242.73 | 702.94 |
| 93.400 | 44000.0 | 99000.0 | 32698.9 | .620 | .641 | 67.5 | .01251 | 93.41 | 643.20 | 240.21 | 852.20 |
| 93.600 | 44000.0 | 99000.0 | 31328.5 | .767 | .791 | 87.7 | .01528 | 93.62 | 775.64 | 238.55 | 1046.35 |
| 93.800 | 44000.0 | 99000.0 | 29878.2 | .986 | .987 | 142.0 | .02258 | 93.82 | 955.41 | 236.60 | 1306.11 |
| 94.000 | 44000.0 | 99000.0 | 28347.5 | 1.259 | 1.270 | 169.3 | .02600 | 94.03 | 1200.51 | 231.09 | 1659.86 |
| 94.200 | 44000.0 | 99000.0 | 26737.1 | 1.634 | 1.634 | 227.0 | .03302 | 94.23 | 1536.17 | 228.85 | 2145.64 |
| 94.400 | 44000.0 | 99000.0 | 25045.1 | 2.159 | 2.123 | 309.7 | .04269 | 94.44 | 1963.68 | 227.39 | 2818.70 |
| 94.600 | 44000.0 | 99000.0 | 23269.4 | 2.924 | 2.804 | 437.5 | .05713 | 94.66 | 2568.43 | 225.47 | 3784.03 |
| 94.800 | 44000.0 | 99000.0 | 21407.1 | 4.062 | 3.772 | 631.7 | .07824 | 94.88 | 3447.73 | 222.92 | 5222.74 |
| 95.000 | 44000.0 | 99000.0 | 19455.1 | 5.820 | 5.158 | 916.8 | .10793 | 95.11 | 4685.28 | 220.66 | 7440.23 |
| 95.200 | 44000.0 | 99000.0 | 17407.9 | 8.623 | 7.174 | 1336.4 | .14981 | 95.35 | 6454.34 | 218.75 | 11014.42 |
| 95.400 | 44000.0 | 99000.0 | 15257.2 | 13.444 | 10.137 | 1977.4 | .21103 | 95.61 | 8991.36 | 217.74 | 17163.16 |
| 95.600 | 44000.0 | 99000.0 | 12988.0 | 20.828 | 14.592 | 2873.0 | .29322 | 95.89 | 13005.17 | 217.12 | 27728.00 |
| 95.800 | 44000.0 | 99000.0 | 10636.1 | 30.723 | 20.359 | 3615.4 | .35667 | 96.16 | 18377.93 | 225.14 | 42604.78 |
| 96.000 | 44000.0 | 99000.0 | 8147.7 | 48.973 | 28.459 | 5231.1 | .48967 | 96.49 | 26112.01 | 235.64 | 71796.81 |

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 45000.0 | 99000.0 | 45000.0 | .010 | .010 | .0 | .00016 | 81.00 | 85.94 | 270.74 | 159.34 |
| 82.000 | 45000.0 | 99000.0 | 45000.0 | .011 | .011 | .0 | .00018 | 82.00 | 86.36 | 270.78 | 159.34 |
| 83.000 | 45000.0 | 99000.0 | 45000.0 | .012 | .013 | .0 | .00021 | 83.00 | 86.92 | 270.83 | 159.34 |
| 84.000 | 45000.0 | 99000.0 | 45000.0 | .014 | .014 | .0 | .00024 | 84.00 | 87.70 | 270.89 | 159.34 |
| 85.000 | 45000.0 | 99000.0 | 45000.0 | .016 | .017 | .0 | .00027 | 85.00 | 88.83 | 270.96 | 159.34 |
| 86.000 | 45000.0 | 99000.0 | 45000.0 | .019 | .020 | .0 | .00033 | 86.00 | 90.52 | 271.03 | 159.34 |
| 87.000 | 45000.0 | 99000.0 | 45000.0 | .023 | .024 | .0 | .00040 | 87.00 | 93.15 | 271.10 | 159.34 |
| 88.000 | 45000.0 | 99000.0 | 45000.0 | .030 | .031 | .0 | .00051 | 88.00 | 97.47 | 271.13 | 159.34 |
| 89.200 | 45000.0 | 99000.0 | 45000.0 | .043 | .044 | .0 | .00072 | 89.20 | 107.05 | 271.01 | 159.34 |
| 89.400 | 45000.0 | 99000.0 | 45000.0 | .046 | .047 | .0 | .00077 | 89.40 | 109.40 | 270.97 | 159.34 |
| 89.600 | 45000.0 | 99000.0 | 45000.0 | .049 | .050 | .0 | .00083 | 89.60 | 112.02 | 270.92 | 159.34 |
| 89.800 | 45000.0 | 99000.0 | 45000.0 | .053 | .054 | .0 | .00089 | 89.80 | 114.92 | 270.87 | 159.34 |
| 90.000 | 45000.0 | 99000.0 | 45000.0 | .057 | .058 | .0 | .00096 | 90.00 | 118.08 | 270.80 | 153.23 |
| 90.200 | 45000.0 | 99000.0 | 44960.9 | .054 | .063 | .4 | .00110 | 90.20 | 123.05 | 269.83 | 154.00 |
| 90.400 | 45000.0 | 99000.0 | 44843.6 | .060 | .069 | .9 | .00126 | 90.40 | 127.93 | 268.78 | 156.31 |
| 90.600 | 45000.0 | 99000.0 | 44648.2 | .070 | .076 | 1.5 | .00143 | 90.60 | 132.69 | 267.51 | 160.08 |
| 90.800 | 45000.0 | 99000.0 | 44374.5 | .077 | .084 | 2.2 | .00164 | 90.80 | 137.25 | 265.89 | 166.00 |
| 91.000 | 45000.0 | 99000.0 | 44022.7 | .085 | .093 | 3.1 | .00189 | 91.00 | 141.54 | 263.85 | 173.94 |
| 91.200 | 45000.0 | 99000.0 | 43592.8 | .095 | .104 | 3.7 | .00193 | 91.20 | 152.34 | 262.87 | 184.48 |
| 91.400 | 45000.0 | 99000.0 | 43084.7 | .107 | .116 | 4.6 | .00211 | 91.40 | 156.45 | 262.11 | 197.34 |
| 91.600 | 45000.0 | 99000.0 | 42498.4 | .121 | .130 | 5.8 | .00234 | 91.60 | 175.43 | 261.45 | 213.68 |
| 91.800 | 45000.0 | 99000.0 | 41833.9 | .136 | .148 | 7.3 | .00262 | 91.80 | 195.70 | 260.89 | 233.38 |
| 92.000 | 45000.0 | 99000.0 | 41091.2 | .156 | .168 | 9.1 | .00296 | 92.00 | 203.12 | 260.41 | 258.00 |
| 92.200 | 45000.0 | 99000.0 | 40270.3 | .179 | .192 | 11.4 | .00337 | 92.20 | 228.45 | 260.00 | 288.19 |
| 92.400 | 45000.0 | 99000.0 | 39370.9 | .214 | .225 | 16.8 | .00450 | 92.40 | 265.61 | 254.85 | 325.77 |
| 92.600 | 45000.0 | 99000.0 | 38393.4 | .251 | .265 | 20.2 | .00503 | 92.61 | 299.34 | 252.18 | 374.16 |
| 92.800 | 45000.0 | 99000.0 | 37337.7 | .297 | .313 | 25.4 | .00585 | 92.81 | 341.03 | 250.46 | 434.53 |
| 93.000 | 45000.0 | 99000.0 | 36203.6 | .354 | .372 | 32.2 | .00690 | 93.01 | 396.37 | 249.20 | 510.48 |
| 93.200 | 45000.0 | 99000.0 | 34991.3 | .426 | .446 | 43.9 | .00867 | 93.21 | 465.06 | 248.23 | 606.69 |
| 93.400 | 45000.0 | 99000.0 | 33699.1 | .534 | .553 | 59.1 | .01097 | 93.41 | 556.93 | 242.14 | 734.41 |
| 93.600 | 45000.0 | 99000.0 | 32329.0 | .660 | .683 | 76.1 | .01328 | 93.61 | 671.30 | 239.79 | 901.31 |
| 93.800 | 45000.0 | 99000.0 | 30879.8 | .826 | .850 | 99.9 | .01641 | 93.82 | 825.59 | 238.22 | 1119.96 |
| 94.000 | 45000.0 | 99000.0 | 29349.7 | 1.076 | 1.084 | 150.4 | .02301 | 94.02 | 1031.28 | 233.52 | 1418.54 |
| 94.200 | 45000.0 | 99000.0 | 27740.5 | 1.394 | 1.400 | 195.7 | .02848 | 94.23 | 1319.74 | 230.17 | 1830.04 |
| 94.400 | 45000.0 | 99000.0 | 26050.2 | 1.833 | 1.821 | 265.9 | .03670 | 94.44 | 1686.33 | 228.23 | 2399.05 |
| 94.600 | 45000.0 | 99000.0 | 24277.4 | 2.464 | 2.397 | 371.3 | .04859 | 94.65 | 2201.45 | 226.57 | 3204.05 |
| 94.800 | 45000.0 | 99000.0 | 22419.2 | 3.406 | 3.213 | 536.9 | .06661 | 94.87 | 2946.98 | 224.22 | 4389.76 |
| 95.000 | 45000.0 | 99000.0 | 20473.3 | 4.830 | 4.382 | 773.9 | .09134 | 95.09 | 3995.83 | 221.83 | 6188.67 |
| 95.200 | 45000.0 | 99000.0 | 18434.1 | 7.098 | 6.085 | 1138.5 | .12768 | 95.33 | 5494.93 | 219.54 | 9066.33 |
| 95.400 | 45000.0 | 99000.0 | 16296.4 | 10.855 | 8.580 | 1669.1 | .17879 | 95.58 | 7646.05 | 218.17 | 13857.75 |
| 95.600 | 45000.0 | 99000.0 | 14045.7 | 17.118 | 12.327 | 2515.1 | .25648 | 95.86 | 10910.18 | 217.37 | 22495.82 |
| 95.800 | 45000.0 | 99000.0 | 11697.1 | 28.161 | 17.520 | 3105.4 | .30643 | 96.11 | 15757.83 | 221.34 | 34407.00 |
| 96.000 | 45000.0 | 99000.0 | 9227.5 | 40.554 | 24.689 | 4613.3 | .43378 | 96.43 | 22552.25 | 230.83 | 58184.23 |

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 45000.0 | 99000.0 | 6644.7 | 61.976 | 34.126 | 5840.6 | .53076 | 96.73 | 31844.78 | 243.60 | 92284.78 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 46000.0 | 99000.0 | 46000.0 | .008 | .009 | .0 | .00014 | 81.00 | 75.72 | 270.85 | 140.81 |
| 82.000 | 46000.0 | 99000.0 | 46000.0 | .009 | .010 | .0 | .00016 | 82.00 | 76.09 | 270.89 | 140.81 |
| 83.000 | 46000.0 | 99000.0 | 46000.0 | .011 | .011 | .0 | .00018 | 83.00 | 76.58 | 270.95 | 140.81 |
| 84.000 | 46000.0 | 99000.0 | 46000.0 | .012 | .013 | .0 | .00021 | 84.00 | 77.27 | 271.02 | 140.81 |
| 85.000 | 46000.0 | 99000.0 | 46000.0 | .014 | .015 | .0 | .00024 | 85.00 | 78.26 | 271.11 | 140.81 |
| 86.000 | 46000.0 | 99000.0 | 46000.0 | .017 | .018 | .0 | .00029 | 86.00 | 79.75 | 271.21 | 140.81 |
| 87.000 | 46000.0 | 99000.0 | 46000.0 | .020 | .021 | .0 | .00035 | 87.00 | 82.07 | 271.31 | 140.81 |
| 88.000 | 46000.0 | 99000.0 | 46000.0 | .026 | .027 | .0 | .00045 | 88.00 | 85.88 | 271.37 | 140.81 |
| 89.200 | 46000.0 | 99000.0 | 46000.0 | .037 | .039 | .0 | .00064 | 89.20 | 94.33 | 271.26 | 140.81 |
| 89.400 | 46000.0 | 99000.0 | 46000.0 | .040 | .041 | .0 | .00068 | 89.40 | 96.40 | 271.21 | 140.81 |
| 89.600 | 46000.0 | 99000.0 | 46000.0 | .043 | .044 | .0 | .00073 | 89.60 | 98.71 | 271.15 | 140.81 |
| 89.800 | 46000.0 | 99000.0 | 46000.0 | .046 | .048 | .0 | .00079 | 89.80 | 101.27 | 271.08 | 140.81 |
| 90.000 | 46000.0 | 99000.0 | 46000.0 | .045 | .052 | .0 | .00085 | 90.00 | 104.05 | 271.01 | 134.77 |
| 90.200 | 46000.0 | 99000.0 | 45960.9 | .049 | .056 | .3 | .00092 | 90.20 | 108.39 | 270.92 | 135.45 |
| 90.400 | 46000.0 | 99000.0 | 45843.6 | .054 | .061 | .7 | .00100 | 90.40 | 112.61 | 270.84 | 137.48 |
| 90.600 | 46000.0 | 99000.0 | 45648.2 | .060 | .067 | 1.1 | .00110 | 90.60 | 116.68 | 270.75 | 141.18 |
| 90.800 | 46000.0 | 99000.0 | 45374.6 | .066 | .073 | 1.6 | .00120 | 90.80 | 120.52 | 270.67 | 146.16 |
| 91.000 | 46000.0 | 99000.0 | 45022.8 | .073 | .080 | 2.2 | .00133 | 91.00 | 124.10 | 270.59 | 152.83 |
| 91.200 | 46000.0 | 99000.0 | 44592.8 | .084 | .089 | 3.3 | .00167 | 91.20 | 133.39 | 268.80 | 161.30 |
| 91.400 | 46000.0 | 99000.0 | 44084.5 | .094 | .101 | 4.5 | .00200 | 91.40 | 137.17 | 265.00 | 172.56 |
| 91.600 | 46000.0 | 99000.0 | 43498.2 | .106 | .114 | 5.2 | .00209 | 91.60 | 153.63 | 263.21 | 186.84 |
| 91.800 | 46000.0 | 99000.0 | 42833.6 | .120 | .129 | 6.4 | .00231 | 91.80 | 171.48 | 262.23 | 204.06 |
| 92.000 | 46000.0 | 99000.0 | 42090.9 | .137 | .147 | 8.0 | .00260 | 92.00 | 177.99 | 261.45 | 225.59 |
| 92.200 | 46000.0 | 99000.0 | 41270.0 | .157 | .168 | 10.0 | .00296 | 92.20 | 200.21 | 260.82 | 251.99 |
| 92.400 | 46000.0 | 99000.0 | 40370.8 | .182 | .194 | 12.5 | .00339 | 92.40 | 225.67 | 260.30 | 284.43 |
| 92.600 | 46000.0 | 99000.0 | 39393.1 | .218 | .229 | 18.6 | .00457 | 92.60 | 263.10 | 255.23 | 324.84 |
| 92.800 | 46000.0 | 99000.0 | 38337.3 | .258 | .272 | 22.3 | .00514 | 92.81 | 298.59 | 252.34 | 377.20 |
| 93.000 | 46000.0 | 99000.0 | 37203.6 | .307 | .323 | 28.1 | .00603 | 93.01 | 346.28 | 250.51 | 443.10 |
| 93.200 | 46000.0 | 99000.0 | 35990.8 | .370 | .388 | 35.8 | .00717 | 93.21 | 405.70 | 249.20 | 526.33 |
| 93.400 | 46000.0 | 99000.0 | 34699.2 | .461 | .473 | 57.7 | .01047 | 93.41 | 481.88 | 245.51 | 633.51 |
| 93.600 | 46000.0 | 99000.0 | 33329.3 | .569 | .589 | 66.4 | .01158 | 93.61 | 581.21 | 241.53 | 776.57 |
| 93.800 | 46000.0 | 99000.0 | 31880.5 | .712 | .734 | 86.6 | .01423 | 93.81 | 714.44 | 239.35 | 964.47 |
| 94.000 | 46000.0 | 99000.0 | 30352.6 | .900 | .922 | 114.7 | .01778 | 94.02 | 886.46 | 237.88 | 1213.03 |
| 94.200 | 46000.0 | 99000.0 | 28743.2 | 1.190 | 1.198 | 170.1 | .02473 | 94.22 | 1133.95 | 232.03 | 1562.33 |
| 94.400 | 46000.0 | 99000.0 | 27054.3 | 1.562 | 1.561 | 228.8 | .03159 | 94.43 | 1448.55 | 229.33 | 2044.20 |
| 94.600 | 46000.0 | 99000.0 | 25283.9 | 2.082 | 2.052 | 314.7 | .04127 | 94.64 | 1868.78 | 227.66 | 2719.11 |
| 94.800 | 46000.0 | 99000.0 | 23429.9 | 2.849 | 2.740 | 449.3 | .05591 | 94.86 | 2521.63 | 225.68 | 3697.87 |
| 95.000 | 46000.0 | 99000.0 | 21488.1 | 4.029 | 3.729 | 654.8 | .07744 | 95.08 | 3411.72 | 223.06 | 5175.52 |
| 95.200 | 46000.0 | 99000.0 | 19456.4 | 5.862 | 5.162 | 958.9 | .10800 | 95.31 | 4680.47 | 220.70 | 7488.43 |
| 95.400 | 46000.0 | 99000.0 | 17328.1 | 8.846 | 7.271 | 1413.0 | .15180 | 95.55 | 6506.52 | 218.73 | 11292.66 |
| 95.600 | 46000.0 | 99000.0 | 15094.4 | 14.109 | 10.411 | 2116.0 | .21672 | 95.82 | 9266.05 | 217.70 | 18005.40 |
| 95.800 | 46000.0 | 99000.0 | 12749.4 | 20.932 | 15.011 | 2667.5 | .26666 | 96.07 | 13459.07 | 218.38 | 27861.80 |
| 96.000 | 46000.0 | 99000.0 | 10296.1 | 33.988 | 21.405 | 4129.0 | .38934 | 96.39 | 19240.58 | 226.19 | 47676.37 |

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 46000.0 | 99000.0 | 7735.8 | 49.122 | 29.641 | 4844.1 | .44682 | 96.65 | 27583.30 | 238.12 | 72011.37 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 47000.0 | 99000.0 | 47000.0 | .007 | .008 | .0 | .00013 | 81.00 | 66.72 | 270.97 | 124.08 |
| 82.000 | 47000.0 | 99000.0 | 47000.0 | .008 | .009 | .0 | .00014 | 82.00 | 67.04 | 271.02 | 124.08 |
| 83.000 | 47000.0 | 99000.0 | 47000.0 | .009 | .010 | .0 | .00016 | 83.00 | 67.47 | 271.09 | 124.08 |
| 84.000 | 47000.0 | 99000.0 | 47000.0 | .011 | .011 | .0 | .00018 | 84.00 | 68.08 | 271.18 | 124.08 |
| 85.000 | 47000.0 | 99000.0 | 47000.0 | .012 | .013 | .0 | .00021 | 85.00 | 68.95 | 271.29 | 124.08 |
| 86.000 | 47000.0 | 99000.0 | 47000.0 | .015 | .015 | .0 | .00025 | 86.00 | 70.26 | 271.42 | 124.08 |
| 87.000 | 47000.0 | 99000.0 | 47000.0 | .018 | .019 | .0 | .00031 | 87.00 | 72.31 | 271.56 | 124.08 |
| 88.000 | 47000.0 | 99000.0 | 47000.0 | .023 | .024 | .0 | .00040 | 88.00 | 75.67 | 271.67 | 124.08 |
| 89.200 | 47000.0 | 99000.0 | 47000.0 | .033 | .034 | .0 | .00056 | 89.20 | 83.11 | 271.59 | 124.08 |
| 89.400 | 47000.0 | 99000.0 | 47000.0 | .035 | .036 | .0 | .00060 | 89.40 | 84.94 | 271.53 | 124.08 |
| 89.600 | 47000.0 | 99000.0 | 47000.0 | .037 | .039 | .0 | .00065 | 89.60 | 86.98 | 271.46 | 124.08 |
| 89.800 | 47000.0 | 99000.0 | 47000.0 | .040 | .042 | .0 | .00070 | 89.80 | 89.23 | 271.38 | 124.08 |
| 90.000 | 47000.0 | 99000.0 | 47000.0 | .043 | .046 | .0 | .00075 | 90.00 | 91.68 | 271.28 | 118.54 |
| 90.200 | 47000.0 | 99000.0 | 46960.9 | .043 | .049 | .3 | .00082 | 90.20 | 95.51 | 271.18 | 119.13 |
| 90.400 | 47000.0 | 99000.0 | 46843.6 | .048 | .054 | .6 | .00089 | 90.40 | 99.24 | 271.07 | 120.92 |
| 90.600 | 47000.0 | 99000.0 | 46648.2 | .052 | .059 | 1.0 | .00097 | 90.60 | 102.82 | 270.95 | 124.18 |
| 90.800 | 47000.0 | 99000.0 | 46374.5 | .058 | .064 | 1.4 | .00106 | 90.80 | 106.20 | 270.84 | 128.56 |
| 91.000 | 47000.0 | 99000.0 | 46022.7 | .064 | .071 | 1.9 | .00117 | 91.00 | 109.36 | 270.73 | 134.42 |
| 91.200 | 47000.0 | 99000.0 | 45592.7 | .071 | .079 | 2.5 | .00130 | 91.20 | 117.42 | 270.63 | 142.20 |
| 91.400 | 47000.0 | 99000.0 | 45084.5 | .080 | .087 | 3.2 | .00144 | 91.40 | 120.55 | 270.54 | 151.66 |
| 91.600 | 47000.0 | 99000.0 | 44498.2 | .093 | .098 | 4.7 | .00185 | 91.60 | 134.61 | 268.31 | 163.37 |
| 91.800 | 47000.0 | 99000.0 | 43833.3 | .105 | .112 | 5.9 | .00211 | 91.80 | 150.16 | 264.20 | 178.43 |
| 92.000 | 47000.0 | 99000.0 | 43090.5 | .119 | .128 | 7.1 | .00231 | 92.00 | 155.93 | 262.88 | 197.25 |
| 92.200 | 47000.0 | 99000.0 | 42269.5 | .137 | .147 | 8.8 | .00261 | 92.20 | 175.46 | 261.89 | 220.34 |
| 92.400 | 47000.0 | 99000.0 | 41370.4 | .159 | .170 | 11.0 | .00298 | 92.40 | 197.79 | 261.12 | 248.70 |
| 92.600 | 47000.0 | 99000.0 | 40392.9 | .185 | .197 | 13.7 | .00345 | 92.60 | 223.73 | 260.50 | 283.64 |
| 92.800 | 47000.0 | 99000.0 | 39336.9 | .224 | .235 | 20.3 | .00464 | 92.80 | 262.34 | 255.25 | 327.48 |
| 93.000 | 47000.0 | 99000.0 | 38202.8 | .267 | .281 | 24.7 | .00529 | 93.01 | 303.06 | 252.29 | 384.63 |
| 93.200 | 47000.0 | 99000.0 | 36990.4 | .321 | .337 | 31.3 | .00626 | 93.21 | 354.30 | 250.43 | 456.84 |
| 93.400 | 47000.0 | 99000.0 | 35699.5 | .389 | .408 | 40.2 | .00753 | 93.41 | 418.89 | 249.10 | 548.70 |
| 93.600 | 47000.0 | 99000.0 | 34329.3 | .490 | .506 | 59.6 | .01032 | 93.61 | 503.18 | 244.15 | 669.37 |
| 93.800 | 47000.0 | 99000.0 | 32880.9 | .613 | .633 | 75.3 | .01237 | 93.81 | 618.45 | 240.86 | 830.81 |
| 94.000 | 47000.0 | 99000.0 | 31353.4 | .774 | .797 | 99.3 | .01540 | 94.02 | 766.95 | 238.88 | 1044.31 |
| 94.200 | 47000.0 | 99000.0 | 29745.1 | 1.020 | 1.020 | 172.2 | .02443 | 94.22 | 973.15 | 235.25 | 1339.52 |
| 94.400 | 47000.0 | 99000.0 | 28057.4 | 1.332 | 1.337 | 197.5 | .02727 | 94.43 | 1244.56 | 230.80 | 1743.60 |
| 94.600 | 47000.0 | 99000.0 | 26288.7 | 1.772 | 1.759 | 270.4 | .03548 | 94.64 | 1622.09 | 228.56 | 2314.22 |
| 94.800 | 47000.0 | 99000.0 | 24437.2 | 2.407 | 2.343 | 381.4 | .04755 | 94.85 | 2161.30 | 226.79 | 3130.78 |
| 95.000 | 47000.0 | 99000.0 | 22500.0 | 3.369 | 3.177 | 557.2 | .06598 | 95.07 | 2882.05 | 224.38 | 4347.78 |
| 95.200 | 47000.0 | 99000.0 | 20474.5 | 4.861 | 4.386 | 809.5 | .09139 | 95.29 | 3991.66 | 221.88 | 6223.78 |
| 95.400 | 47000.0 | 99000.0 | 18354.6 | 7.266 | 6.168 | 1202.7 | .12946 | 95.53 | 5540.06 | 219.50 | 9276.73 |
| 95.600 | 47000.0 | 99000.0 | 16133.9 | 11.350 | 8.810 | 1785.6 | .18353 | 95.78 | 7876.40 | 218.12 | 14484.60 |
| 95.800 | 47000.0 | 99000.0 | 13797.6 | 18.339 | 12.835 | 2725.6 | .26702 | 96.07 | 11344.88 | 217.32 | 24095.11 |
| 96.000 | 47000.0 | 99000.0 | 11359.4 | 27.980 | 18.456 | 3640.7 | .34407 | 96.34 | 16521.04 | 222.31 | 38792.95 |

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
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THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | PITAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 47000.0 | 99000.0 | 8910.2 | 41.299 | 25.849 | 4340.7 | .40156 | 96.60 | 23669.20 | 232.70 | 59249.98 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 48000.0 | 99000.0 | 48000.0 | .007 | .007 | .0 | .00011 | 81.00 | 58.78 | 271.11 | 109.34 |
| 82.000 | 48000.0 | 99000.0 | 48000.0 | .007 | .008 | .0 | .00013 | 82.00 | 59.06 | 271.17 | 109.34 |
| 83.000 | 48000.0 | 99000.0 | 48000.0 | .008 | .009 | .0 | .00014 | 83.00 | 59.44 | 271.26 | 109.34 |
| 84.000 | 48000.0 | 99000.0 | 48000.0 | .009 | .010 | .0 | .00016 | 84.00 | 59.98 | 271.36 | 109.34 |
| 85.000 | 48000.0 | 99000.0 | 48000.0 | .011 | .012 | .0 | .00019 | 85.00 | 60.74 | 271.50 | 109.34 |
| 86.000 | 48000.0 | 99000.0 | 48000.0 | .013 | .014 | .0 | .00022 | 86.00 | 61.90 | 271.67 | 109.34 |
| 87.000 | 48000.0 | 99000.0 | 48000.0 | .016 | .017 | .0 | .00028 | 87.00 | 63.70 | 271.87 | 109.34 |
| 88.000 | 48000.0 | 99000.0 | 48000.0 | .021 | .021 | .0 | .00035 | 88.00 | 66.66 | 272.05 | 109.34 |
| 89.200 | 48000.0 | 99000.0 | 48000.0 | .029 | .030 | .0 | .00050 | 89.20 | 73.22 | 272.04 | 109.34 |
| 89.400 | 48000.0 | 99000.0 | 48000.0 | .031 | .032 | .0 | .00054 | 89.40 | 74.83 | 271.99 | 109.34 |
| 89.600 | 48000.0 | 99000.0 | 48000.0 | .033 | .035 | .0 | .00058 | 89.60 | 76.63 | 271.91 | 109.34 |
| 89.800 | 48000.0 | 99000.0 | 48000.0 | .036 | .037 | .0 | .00062 | 89.80 | 78.62 | 271.80 | 109.34 |
| 90.000 | 48000.0 | 99000.0 | 48000.0 | .035 | .040 | .0 | .00067 | 90.00 | 80.78 | 271.68 | 104.25 |
| 90.200 | 48000.0 | 99000.0 | 47960.9 | .038 | .044 | .3 | .00072 | 90.20 | 84.15 | 271.54 | 104.77 |
| 90.400 | 48000.0 | 99000.0 | 47843.6 | .042 | .047 | .6 | .00079 | 90.40 | 87.44 | 271.39 | 106.35 |
| 90.600 | 48000.0 | 99000.0 | 47648.1 | .046 | .052 | .9 | .00086 | 90.60 | 90.60 | 271.23 | 109.01 |
| 90.800 | 48000.0 | 99000.0 | 47374.4 | .051 | .057 | 1.3 | .00094 | 90.80 | 93.58 | 271.08 | 113.07 |
| 91.000 | 48000.0 | 99000.0 | 47022.6 | .056 | .063 | 1.7 | .00104 | 91.00 | 96.36 | 270.94 | 118.23 |
| 91.200 | 48000.0 | 99000.0 | 46592.5 | .063 | .069 | 2.2 | .00115 | 91.20 | 103.47 | 270.80 | 125.07 |
| 91.400 | 48000.0 | 99000.0 | 46084.2 | .070 | .077 | 2.8 | .00127 | 91.40 | 106.23 | 270.68 | 133.39 |
| 91.600 | 48000.0 | 99000.0 | 45497.8 | .079 | .086 | 3.6 | .00142 | 91.60 | 118.48 | 270.57 | 143.94 |
| 91.800 | 48000.0 | 99000.0 | 44833.1 | .089 | .097 | 4.9 | .00172 | 91.80 | 131.56 | 270.08 | 156.59 |
| 92.000 | 48000.0 | 99000.0 | 44090.2 | .104 | .111 | 6.8 | .00217 | 92.00 | 136.77 | 265.53 | 172.48 |
| 92.200 | 48000.0 | 99000.0 | 43269.1 | .120 | .128 | 7.8 | .00232 | 92.20 | 153.71 | 263.37 | 192.66 |
| 92.400 | 48000.0 | 99000.0 | 42369.8 | .139 | .148 | 9.7 | .00263 | 92.40 | 173.34 | 262.19 | 217.46 |
| 92.600 | 48000.0 | 99000.0 | 41392.3 | .161 | .173 | 12.1 | .00303 | 92.60 | 196.09 | 261.31 | 248.01 |
| 92.800 | 48000.0 | 99000.0 | 40336.6 | .189 | .202 | 15.2 | .00353 | 92.80 | 222.78 | 260.62 | 285.82 |
| 93.000 | 48000.0 | 99000.0 | 39202.2 | .231 | .243 | 22.2 | .00474 | 93.00 | 266.07 | 254.96 | 333.92 |
| 93.200 | 48000.0 | 99000.0 | 37989.8 | .278 | .293 | 27.4 | .00549 | 93.21 | 309.92 | 252.07 | 396.55 |
| 93.400 | 48000.0 | 99000.0 | 36699.0 | .337 | .355 | 35.0 | .00657 | 93.41 | 365.67 | 250.23 | 476.22 |
| 93.600 | 48000.0 | 99000.0 | 35329.6 | .413 | .433 | 45.3 | .00797 | 93.61 | 436.03 | 248.92 | 578.60 |
| 93.800 | 48000.0 | 99000.0 | 33880.9 | .528 | .545 | 66.2 | .01085 | 93.81 | 535.46 | 242.98 | 715.92 |
| 94.000 | 48000.0 | 99000.0 | 32353.7 | .666 | .688 | 86.1 | .01337 | 94.01 | 663.76 | 240.16 | 899.37 |
| 94.200 | 48000.0 | 99000.0 | 30747.3 | .852 | .874 | 114.8 | .01685 | 94.22 | 839.06 | 238.37 | 1144.33 |
| 94.400 | 48000.0 | 99000.0 | 29059.6 | 1.136 | 1.144 | 172.9 | .02382 | 94.42 | 1069.23 | 232.93 | 1488.33 |
| 94.600 | 48000.0 | 99000.0 | 27292.3 | 1.509 | 1.508 | 232.7 | .03055 | 94.63 | 1393.40 | 229.74 | 1971.89 |
| 94.800 | 48000.0 | 99000.0 | 25443.2 | 2.038 | 2.006 | 322.9 | .04035 | 94.84 | 1854.35 | 227.86 | 2657.16 |
| 95.000 | 48000.0 | 99000.0 | 23509.9 | 2.824 | 2.709 | 465.9 | .05535 | 95.06 | 2467.02 | 225.81 | 3661.75 |
| 95.200 | 48000.0 | 99000.0 | 21489.1 | 4.051 | 3.732 | 685.0 | .07749 | 95.28 | 3408.14 | 223.11 | 5199.28 |
| 95.400 | 48000.0 | 99000.0 | 19377.1 | 5.992 | 5.231 | 1012.9 | .10932 | 95.51 | 4719.34 | 220.65 | 7649.81 |
| 95.600 | 48000.0 | 99000.0 | 17166.8 | 9.221 | 7.465 | 1511.1 | .15578 | 95.76 | 6700.22 | 218.66 | 11768.01 |
| 95.800 | 48000.0 | 99000.0 | 14847.9 | 14.866 | 10.836 | 2291.8 | .22551 | 96.03 | 9632.78 | 217.63 | 19230.05 |
| 96.000 | 48000.0 | 99000.0 | 12414.4 | 23.611 | 15.872 | 3278.8 | .30983 | 96.31 | 14143.01 | 218.99 | 31887.20 |

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 48000.0 | 99000.0 | 9877.9 | 34.636 | 22.502 | 3939.5 | .36451 | 96.56 | 20450.84 | 227.61 | 49138.50 |
| 96.400 | 48000.0 | 99000.0 | 7211.5 | 60.140 | 31.983 | 6092.1 | .53080 | 96.93 | 29659.42 | 240.47 | 88929.41 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

ALL HEIGHTS ARE IN GEOMETRIC METERS
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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 49000.0 | 99000.0 | 49000.0 | .006 | .006 | .0 | .00010 | 81.00 | 51.78 | 271.26 | 96.35 |
| 82.000 | 49000.0 | 99000.0 | 49000.0 | .006 | .007 | .0 | .00011 | 82.00 | 52.03 | 271.34 | 96.35 |
| 83.000 | 49000.0 | 99000.0 | 49000.0 | .007 | .008 | .0 | .00013 | 83.00 | 52.37 | 271.44 | 96.35 |
| 84.000 | 49000.0 | 99000.0 | 49000.0 | .008 | .009 | .0 | .00014 | 84.00 | 52.83 | 271.58 | 96.35 |
| 85.000 | 49000.0 | 99000.0 | 49000.0 | .010 | .010 | .0 | .00017 | 85.00 | 53.51 | 271.75 | 96.35 |
| 86.000 | 49000.0 | 99000.0 | 49000.0 | .011 | .012 | .0 | .00020 | 86.00 | 54.52 | 271.97 | 96.35 |
| 87.000 | 49000.0 | 99000.0 | 49000.0 | .014 | .015 | .0 | .00024 | 87.00 | 56.10 | 272.24 | 96.35 |
| 88.000 | 49000.0 | 99000.0 | 49000.0 | .018 | .019 | .0 | .00031 | 88.00 | 58.70 | 272.54 | 96.35 |
| 89.200 | 49000.0 | 99000.0 | 49000.0 | .025 | .026 | .0 | .00045 | 89.20 | 64.47 | 272.72 | 96.35 |
| 89.400 | 49000.0 | 99000.0 | 49000.0 | .027 | .028 | .0 | .00048 | 89.40 | 65.88 | 272.68 | 96.35 |
| 89.600 | 49000.0 | 99000.0 | 49000.0 | .029 | .030 | .0 | .00052 | 89.60 | 67.47 | 272.60 | 96.35 |
| 89.800 | 49000.0 | 99000.0 | 49000.0 | .031 | .033 | .0 | .00056 | 89.80 | 69.22 | 272.48 | 96.35 |
| 90.000 | 49000.0 | 99000.0 | 49000.0 | .031 | .035 | .0 | .00061 | 90.00 | 71.14 | 272.32 | 91.69 |
| 90.200 | 49000.0 | 99000.0 | 48960.9 | .033 | .038 | .2 | .00065 | 90.20 | 74.12 | 272.12 | 92.15 |
| 90.400 | 49000.0 | 99000.0 | 48843.6 | .037 | .042 | .5 | .00070 | 90.40 | 77.03 | 271.90 | 93.53 |
| 90.600 | 49000.0 | 99000.0 | 48648.1 | .040 | .046 | .8 | .00076 | 90.60 | 79.82 | 271.66 | 95.87 |
| 90.800 | 49000.0 | 99000.0 | 48374.4 | .045 | .050 | 1.1 | .00083 | 90.80 | 82.46 | 271.44 | 99.45 |
| 91.000 | 49000.0 | 99000.0 | 48022.4 | .049 | .055 | 1.5 | .00092 | 91.00 | 84.91 | 271.23 | 103.98 |
| 91.200 | 49000.0 | 99000.0 | 47592.3 | .055 | .061 | 2.0 | .00101 | 91.20 | 91.17 | 271.04 | 110.01 |
| 91.400 | 49000.0 | 99000.0 | 47084.0 | .062 | .068 | 2.5 | .00113 | 91.40 | 93.61 | 270.87 | 117.32 |
| 91.600 | 49000.0 | 99000.0 | 46497.5 | .069 | .076 | 3.1 | .00126 | 91.60 | 104.40 | 270.72 | 126.60 |
| 91.800 | 49000.0 | 99000.0 | 45832.8 | .078 | .086 | 3.9 | .00141 | 91.80 | 115.90 | 270.60 | 137.72 |
| 92.000 | 49000.0 | 99000.0 | 45089.9 | .089 | .097 | 4.9 | .00160 | 92.00 | 120.23 | 270.49 | 151.59 |
| 92.200 | 49000.0 | 99000.0 | 44268.6 | .105 | .112 | 7.3 | .00213 | 92.20 | 134.78 | 266.97 | 168.46 |
| 92.400 | 49000.0 | 99000.0 | 43369.3 | .121 | .130 | 8.6 | .00234 | 92.40 | 151.86 | 263.70 | 190.14 |
| 92.600 | 49000.0 | 99000.0 | 42391.7 | .141 | .151 | 10.6 | .00267 | 92.60 | 171.86 | 262.38 | 216.86 |
| 92.800 | 49000.0 | 99000.0 | 41335.9 | .165 | .177 | 13.3 | .00310 | 92.80 | 195.25 | 261.41 | 249.91 |
| 93.000 | 49000.0 | 99000.0 | 40201.8 | .196 | .209 | 16.8 | .00364 | 93.00 | 222.82 | 260.67 | 291.03 |
| 93.200 | 49000.0 | 99000.0 | 38989.4 | .241 | .254 | 24.4 | .00488 | 93.20 | 271.83 | 254.46 | 344.25 |
| 93.400 | 49000.0 | 99000.0 | 37698.8 | .293 | .308 | 30.7 | .00575 | 93.41 | 319.67 | 251.72 | 413.36 |
| 93.600 | 49000.0 | 99000.0 | 36329.8 | .359 | .377 | 39.5 | .00696 | 93.61 | 380.48 | 249.95 | 502.15 |
| 93.800 | 49000.0 | 99000.0 | 34880.9 | .444 | .465 | 64.2 | .01028 | 93.81 | 462.74 | 247.88 | 617.82 |
| 94.000 | 49000.0 | 99000.0 | 33353.7 | .574 | .593 | 75.1 | .01165 | 94.01 | 574.61 | 241.90 | 774.80 |
| 94.200 | 49000.0 | 99000.0 | 31747.8 | .733 | .755 | 99.5 | .01461 | 94.21 | 725.99 | 239.47 | 985.20 |
| 94.400 | 49000.0 | 99000.0 | 30062.4 | .948 | .969 | 134.0 | .01865 | 94.42 | 917.10 | 237.87 | 1269.54 |
| 94.600 | 49000.0 | 99000.0 | 28295.3 | 1.287 | 1.292 | 201.3 | .02642 | 94.63 | 1197.16 | 231.32 | 1681.96 |
| 94.800 | 49000.0 | 99000.0 | 26447.6 | 1.733 | 1.720 | 277.5 | .03470 | 94.83 | 1592.46 | 228.80 | 2260.56 |
| 95.000 | 49000.0 | 99000.0 | 24517.2 | 2.285 | 2.317 | 395.6 | .04707 | 95.05 | 2114.95 | 226.93 | 3099.34 |
| 95.200 | 49000.0 | 99000.0 | 22500.8 | 3.394 | 3.179 | 582.9 | .06602 | 95.27 | 2879.06 | 224.43 | 4365.50 |
| 95.400 | 49000.0 | 99000.0 | 20395.2 | 4.960 | 4.445 | 855.0 | .09249 | 95.49 | 4025.10 | 221.83 | 6347.29 |
| 95.600 | 49000.0 | 99000.0 | 18193.8 | 7.555 | 6.332 | 1284.5 | .13270 | 95.73 | 5703.34 | 219.39 | 9641.66 |
| 95.800 | 49000.0 | 99000.0 | 15889.2 | 12.083 | 9.166 | 1933.0 | .19089 | 95.99 | 8186.28 | 218.03 | 15416.54 |
| 96.000 | 49000.0 | 99000.0 | 13464.7 | 19.775 | 13.547 | 2991.1 | .28181 | 96.28 | 12052.12 | 217.24 | 26316.35 |

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 49000.0 | 99000.0 | 10939.3 | 29.974 | 19.541 | 3732.3 | .34299 | 96.54 | 17615.58 | 223.30 | 41554.90 |
| 96.400 | 49000.0 | 99000.0 | 8295.0 | 49.399 | 27.879 | 5449.3 | .47630 | 96.88 | 25464.03 | 235.16 | 72409.25 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE SUMMER

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 50000.0 | 99000.0 | 50000.0 | .005 | .005 | .0 | .00009 | 81.00 | 45.70 | 271.44 | 84.90 |
| 82.000 | 50000.0 | 99000.0 | 50000.0 | .006 | .006 | .0 | .00010 | 82.00 | 45.91 | 271.54 | 84.90 |
| 83.000 | 50000.0 | 99000.0 | 50000.0 | .006 | .007 | .0 | .00011 | 83.00 | 46.21 | 271.66 | 84.90 |
| 84.000 | 50000.0 | 99000.0 | 50000.0 | .007 | .008 | .0 | .00012 | 84.00 | 46.62 | 271.82 | 84.90 |
| 85.000 | 50000.0 | 99000.0 | 50000.0 | .008 | .009 | .0 | .00014 | 85.00 | 47.21 | 272.03 | 84.90 |
| 86.000 | 50000.0 | 99000.0 | 50000.0 | .010 | .011 | .0 | .00017 | 86.00 | 48.10 | 272.32 | 84.90 |
| 87.000 | 50000.0 | 99000.0 | 50000.0 | .012 | .013 | .0 | .00021 | 87.00 | 49.49 | 272.70 | 84.90 |
| 88.000 | 50000.0 | 99000.0 | 50000.0 | .016 | .017 | .0 | .00026 | 88.00 | 51.78 | 273.18 | 84.90 |
| 89.200 | 50000.0 | 99000.0 | 50000.0 | .022 | .023 | .0 | .00037 | 89.20 | 56.84 | 273.89 | 84.90 |
| 89.400 | 50000.0 | 99000.0 | 50000.0 | .024 | .025 | .0 | .00040 | 89.40 | 58.08 | 274.01 | 84.90 |
| 89.600 | 50000.0 | 99000.0 | 50000.0 | .026 | .027 | .0 | .00043 | 89.60 | 59.47 | 274.14 | 84.90 |
| 89.800 | 50000.0 | 99000.0 | 50000.0 | .028 | .029 | .0 | .00046 | 89.80 | 61.00 | 274.26 | 84.90 |
| 90.000 | 50000.0 | 99000.0 | 50000.0 | .026 | .031 | .0 | .00050 | 90.00 | 62.66 | 274.39 | 80.83 |
| 90.200 | 50000.0 | 99000.0 | 49960.9 | .029 | .034 | .2 | .00056 | 90.20 | 65.25 | 274.07 | 81.23 |
| 90.400 | 50000.0 | 99000.0 | 49843.6 | .031 | .037 | .4 | .00062 | 90.40 | 67.79 | 273.71 | 82.42 |
| 90.600 | 50000.0 | 99000.0 | 49648.0 | .035 | .040 | .7 | .00069 | 90.60 | 70.25 | 273.24 | 84.44 |
| 90.800 | 50000.0 | 99000.0 | 49374.3 | .039 | .044 | 1.0 | .00077 | 90.80 | 72.60 | 272.59 | 87.46 |
| 91.000 | 50000.0 | 99000.0 | 49022.3 | .043 | .049 | 1.4 | .00087 | 91.00 | 74.80 | 271.74 | 91.45 |
| 91.200 | 50000.0 | 99000.0 | 48592.1 | .048 | .054 | 1.7 | .00092 | 91.20 | 80.31 | 271.39 | 96.75 |
| 91.400 | 50000.0 | 99000.0 | 48083.7 | .054 | .060 | 2.2 | .00101 | 91.40 | 82.46 | 271.14 | 103.18 |
| 91.600 | 50000.0 | 99000.0 | 47497.1 | .061 | .067 | 2.8 | .00113 | 91.60 | 91.99 | 270.93 | 111.35 |
| 91.800 | 50000.0 | 99000.0 | 46832.4 | .069 | .076 | 3.5 | .00126 | 91.80 | 102.13 | 270.76 | 121.13 |
| 92.000 | 50000.0 | 99000.0 | 46089.4 | .078 | .086 | 4.3 | .00142 | 92.00 | 105.95 | 270.61 | 133.33 |
| 92.200 | 50000.0 | 99000.0 | 45268.2 | .089 | .097 | 5.4 | .00162 | 92.20 | 118.55 | 270.49 | 148.22 |
| 92.400 | 50000.0 | 99000.0 | 44368.7 | .106 | .113 | 7.9 | .00212 | 92.40 | 133.13 | 267.70 | 166.26 |
| 92.600 | 50000.0 | 99000.0 | 43391.0 | .123 | .132 | 9.5 | .00239 | 92.60 | 150.57 | 263.86 | 189.62 |
| 92.800 | 50000.0 | 99000.0 | 42335.1 | .145 | .155 | 11.7 | .00274 | 92.80 | 171.13 | 262.44 | 218.52 |
| 93.000 | 50000.0 | 99000.0 | 41200.9 | .171 | .183 | 14.7 | .00321 | 93.00 | 195.30 | 261.41 | 254.47 |
| 93.200 | 50000.0 | 99000.0 | 39988.5 | .204 | .217 | 20.4 | .00406 | 93.20 | 239.75 | 260.62 | 299.51 |
| 93.400 | 50000.0 | 99000.0 | 38697.4 | .254 | .267 | 27.1 | .00508 | 93.41 | 280.11 | 253.81 | 358.82 |
| 93.600 | 50000.0 | 99000.0 | 37328.1 | .311 | .327 | 34.5 | .00609 | 93.61 | 332.41 | 251.27 | 435.66 |
| 93.800 | 50000.0 | 99000.0 | 35880.4 | .385 | .404 | 44.8 | .00745 | 93.81 | 403.25 | 249.59 | 535.17 |
| 94.000 | 50000.0 | 99000.0 | 34353.3 | .495 | .510 | 67.4 | .01041 | 94.01 | 497.39 | 244.54 | 667.80 |
| 94.200 | 50000.0 | 99000.0 | 32747.7 | .631 | .652 | 86.4 | .01270 | 94.21 | 628.37 | 240.90 | 848.50 |
| 94.400 | 50000.0 | 99000.0 | 31062.9 | .816 | .837 | 116.0 | .01616 | 94.42 | 793.35 | 238.79 | 1092.60 |
| 94.600 | 50000.0 | 99000.0 | 29296.7 | 1.099 | 1.104 | 178.0 | .02328 | 94.62 | 1028.32 | 233.70 | 1436.08 |
| 94.800 | 50000.0 | 99000.0 | 27450.8 | 1.477 | 1.475 | 239.0 | .02990 | 94.83 | 1367.93 | 230.03 | 1926.01 |
| 95.000 | 50000.0 | 99000.0 | 25522.8 | 2.018 | 1.984 | 334.6 | .03992 | 95.04 | 1814.99 | 227.99 | 2628.98 |
| 95.200 | 50000.0 | 99000.0 | 23510.3 | 2.836 | 2.712 | 487.6 | .05540 | 95.26 | 2464.46 | 225.86 | 3673.69 |
| 95.400 | 50000.0 | 99000.0 | 21409.7 | 4.129 | 3.782 | 723.4 | .07842 | 95.48 | 3436.92 | 223.06 | 5296.13 |
| 95.600 | 50000.0 | 99000.0 | 19216.6 | 6.217 | 5.369 | 1081.5 | .11202 | 95.71 | 4856.47 | 220.53 | 7933.73 |
| 95.800 | 50000.0 | 99000.0 | 16923.3 | 9.777 | 7.765 | 1635.0 | .16194 | 95.96 | 6962.50 | 218.54 | 12474.23 |
| 96.000 | 50000.0 | 99000.0 | 14517.6 | 16.189 | 11.430 | 2513.1 | .23783 | 96.24 | 10103.07 | 217.54 | 20938.88 |

REFRACTION AIRMASS TABLES

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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 50000.0 | 99000.0 | 11993.4 | 25.759 | 16.915 | 3569.4 | .32545 | 96.53 | 15125.21 | 219.48 | 35214.07 |
| 96.400 | 50000.0 | 99000.0 | 9372.8 | 40.747 | 24.189 | 4795.3 | .42097 | 96.82 | 21996.64 | 230.37 | 58451.92 |
| 96.600 | 50000.0 | 99000.0 | 6616.5 | 65.825 | 34.273 | 6329.8 | .53627 | 97.14 | 31930.11 | 243.75 | 98004.61 |

UNREFRACTED RAY STRIKES DISC

AIR MASS TABLES FOR WINTER PROFILE

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 10000.0 | 99000.0 | 10000.0 | 1.575 | 1.585 | .0 | .03195 | 81.03 | 13388.98 | 217.97 | 25913.58 |
| 82.000 | 10000.0 | 99000.0 | 10000.0 | 1.755 | 1.767 | .0 | .03570 | 82.04 | 13442.16 | 217.97 | 25913.58 |
| 83.000 | 10000.0 | 99000.0 | 10000.0 | 1.981 | 1.994 | .0 | .04038 | 83.04 | 13515.07 | 217.97 | 25913.58 |
| 84.000 | 10000.0 | 99000.0 | 10000.0 | 2.271 | 2.285 | .0 | .04635 | 84.05 | 13618.18 | 217.97 | 25913.58 |
| 85.000 | 10000.0 | 99000.0 | 10000.0 | 2.655 | 2.669 | .0 | .05423 | 85.05 | 13769.50 | 217.98 | 25913.58 |
| 86.000 | 10000.0 | 99000.0 | 10000.0 | 3.183 | 3.196 | .0 | .06501 | 86.07 | 14001.55 | 217.99 | 25913.58 |
| 87.000 | 10000.0 | 99000.0 | 10000.0 | 3.946 | 3.954 | .0 | .08048 | 87.08 | 14376.68 | 218.03 | 25913.58 |
| 88.000 | 10000.0 | 99000.0 | 10000.0 | 5.123 | 5.110 | .0 | .10404 | 88.10 | 15022.79 | 218.11 | 25913.58 |
| 89.200 | 10000.0 | 99000.0 | 10000.0 | 7.670 | 7.552 | .0 | .15368 | 89.35 | 16579.43 | 218.35 | 25913.58 |
| 89.400 | 10000.0 | 99000.0 | 10000.0 | 8.314 | 8.154 | .0 | .16593 | 89.57 | 16989.86 | 218.42 | 25913.58 |
| 89.600 | 10000.0 | 99000.0 | 10000.0 | 9.056 | 8.840 | .0 | .17989 | 89.78 | 17465.54 | 218.49 | 25913.58 |
| 89.800 | 10000.0 | 99000.0 | 10000.0 | 9.918 | 9.625 | .0 | .19590 | 90.00 | 18016.76 | 218.58 | 25913.58 |
| 90.000 | 10000.0 | 99000.0 | 10000.0 | 10.880 | 10.530 | 44.7 | .21440 | 90.21 | 18648.49 | 218.67 | 26025.50 |
| 90.200 | 10000.0 | 99000.0 | 9960.1 | 11.908 | 11.445 | 120.8 | .20681 | 90.41 | 19350.38 | 219.31 | 26486.90 |
| 90.400 | 10000.0 | 99000.0 | 9840.3 | 13.110 | 12.493 | 191.9 | .20166 | 90.60 | 20079.02 | 220.28 | 27266.43 |
| 90.600 | 10000.0 | 99000.0 | 9633.2 | 14.893 | 13.908 | 328.7 | .24618 | 90.85 | 21093.68 | 221.43 | 28726.52 |
| 90.800 | 10000.0 | 99000.0 | 9333.4 | 16.671 | 15.582 | 489.9 | .29121 | 91.09 | 22330.36 | 222.14 | 30807.30 |
| 91.000 | 10000.0 | 99000.0 | 8949.7 | 18.833 | 17.360 | 589.2 | .29918 | 91.30 | 23972.55 | 222.87 | 33087.25 |
| 91.200 | 10000.0 | 99000.0 | 8490.5 | 21.471 | 19.498 | 805.0 | .34368 | 91.54 | 25797.67 | 225.61 | 36535.68 |
| 91.400 | 10000.0 | 99000.0 | 7931.2 | 24.301 | 21.969 | 945.8 | .36173 | 91.76 | 27872.31 | 227.07 | 40429.30 |
| 91.600 | 10000.0 | 99000.0 | 7291.4 | 28.832 | 25.084 | 1324.2 | .43769 | 92.04 | 30294.33 | 230.36 | 46661.06 |
| 91.800 | 10000.0 | 99000.0 | 6565.5 | 33.942 | 28.474 | 1562.4 | .46824 | 92.27 | 33404.66 | 233.84 | 53249.41 |
| 92.000 | 10000.0 | 99000.0 | 5745.4 | 38.977 | 32.357 | 1705.8 | .47734 | 92.48 | 37344.04 | 237.47 | 60602.91 |
| 92.200 | 10000.0 | 99000.0 | 4819.9 | 46.645 | 37.405 | 2125.4 | .54270 | 92.74 | 41713.97 | 241.37 | 72265.07 |
| 92.400 | 10000.0 | 99000.0 | 3802.3 | 57.433 | 43.417 | 2623.4 | .61386 | 93.01 | 47302.41 | 246.27 | 87753.18 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 11000.0 | 99000.0 | 11000.0 | 1.348 | 1.358 | .0 | .02742 | 81.03 | 11459.93 | 217.67 | 22170.70 |
| 82.000 | 11000.0 | 99000.0 | 11000.0 | 1.502 | 1.513 | .0 | .03064 | 82.03 | 11505.59 | 217.67 | 22170.70 |
| 83.000 | 11000.0 | 99000.0 | 11000.0 | 1.696 | 1.708 | .0 | .03465 | 83.03 | 11568.16 | 217.66 | 22170.70 |
| 84.000 | 11000.0 | 99000.0 | 11000.0 | 1.945 | 1.956 | .0 | .03977 | 84.04 | 11656.64 | 217.66 | 22170.70 |
| 85.000 | 11000.0 | 99000.0 | 11000.0 | 2.274 | 2.285 | .0 | .04653 | 85.05 | 11786.45 | 217.66 | 22170.70 |
| 86.000 | 11000.0 | 99000.0 | 11000.0 | 2.727 | 2.736 | .0 | .05577 | 86.06 | 11985.44 | 217.66 | 22170.70 |
| 87.000 | 11000.0 | 99000.0 | 11000.0 | 3.382 | 3.384 | .0 | .06902 | 87.07 | 12306.91 | 217.68 | 22170.70 |
| 88.000 | 11000.0 | 99000.0 | 11000.0 | 4.392 | 4.371 | .0 | .08918 | 88.09 | 12860.14 | 217.74 | 22170.70 |
| 89.200 | 11000.0 | 99000.0 | 11000.0 | 6.576 | 6.452 | .0 | .13156 | 89.33 | 14190.69 | 217.95 | 22170.70 |
| 89.400 | 11000.0 | 99000.0 | 11000.0 | 7.126 | 6.964 | .0 | .14199 | 89.54 | 14540.98 | 218.01 | 22170.70 |
| 89.600 | 11000.0 | 99000.0 | 11000.0 | 7.760 | 7.546 | .0 | .15387 | 89.75 | 14946.67 | 218.08 | 22170.70 |
| 89.800 | 11000.0 | 99000.0 | 11000.0 | 8.495 | 8.212 | .0 | .16749 | 89.97 | 15416.39 | 218.16 | 22170.70 |
| 90.000 | 11000.0 | 99000.0 | 11000.0 | 9.303 | 8.979 | 32.6 | .18320 | 90.18 | 15954.22 | 218.24 | 22215.86 |
| 90.200 | 11000.0 | 99000.0 | 10958.1 | 10.306 | 9.858 | 112.9 | .19925 | 90.40 | 16617.16 | 218.38 | 22642.22 |
| 90.400 | 11000.0 | 99000.0 | 10832.1 | 11.504 | 10.883 | 203.4 | .21820 | 90.62 | 17295.22 | 218.55 | 23420.26 |
| 90.600 | 11000.0 | 99000.0 | 10621.1 | 12.975 | 12.099 | 314.1 | .24460 | 90.84 | 18151.23 | 218.73 | 24624.88 |
| 90.800 | 11000.0 | 99000.0 | 10324.1 | 14.428 | 13.541 | 446.7 | .27498 | 91.07 | 19211.37 | 218.87 | 26334.45 |
| 91.000 | 11000.0 | 99000.0 | 9944.2 | 16.260 | 15.100 | 526.6 | .27624 | 91.28 | 20647.32 | 219.18 | 28238.55 |
| 91.200 | 11000.0 | 99000.0 | 9487.8 | 18.508 | 16.983 | 719.6 | .31572 | 91.52 | 22242.95 | 221.54 | 31150.84 |
| 91.400 | 11000.0 | 99000.0 | 8933.8 | 21.317 | 19.174 | 844.9 | .33113 | 91.73 | 24062.80 | 222.67 | 34443.11 |
| 91.600 | 11000.0 | 99000.0 | 8299.8 | 25.137 | 21.897 | 1175.3 | .39740 | 92.00 | 26179.14 | 225.69 | 39610.14 |
| 91.800 | 11000.0 | 99000.0 | 7580.4 | 29.072 | 24.892 | 1381.8 | .42326 | 92.22 | 28916.77 | 228.93 | 45154.01 |
| 92.000 | 11000.0 | 99000.0 | 6766.9 | 33.215 | 28.309 | 1472.3 | .42357 | 92.42 | 32047.00 | 232.26 | 51165.21 |
| 92.200 | 11000.0 | 99000.0 | 5850.7 | 39.908 | 32.883 | 1923.5 | .49845 | 92.70 | 36276.00 | 235.96 | 61532.55 |
| 92.400 | 11000.0 | 99000.0 | 4843.9 | 49.001 | 38.236 | 2386.0 | .56557 | 92.97 | 41229.66 | 240.65 | 74503.35 |
| 92.600 | 11000.0 | 99000.0 | 3744.2 | 60.770 | 44.671 | 2946.2 | .64099 | 93.24 | 47550.55 | 246.33 | 92096.61 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
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THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 12000.0 | 99000.0 | 12000.0 | 1.153 | 1.163 | .0 | .02353 | 81.02 | 9805.29 | 217.41 | 18970.52 |
| 82.000 | 12000.0 | 99000.0 | 12000.0 | 1.285 | 1.296 | .0 | .02629 | 82.03 | 9844.47 | 217.40 | 18970.52 |
| 83.000 | 12000.0 | 99000.0 | 12000.0 | 1.451 | 1.462 | .0 | .02973 | 83.03 | 9898.14 | 217.39 | 18970.52 |
| 84.000 | 12000.0 | 99000.0 | 12000.0 | 1.663 | 1.675 | .0 | .03412 | 84.03 | 9974.02 | 217.38 | 18970.52 |
| 85.000 | 12000.0 | 99000.0 | 12000.0 | 1.944 | 1.956 | .0 | .03991 | 85.04 | 10085.31 | 217.37 | 18970.52 |
| 86.000 | 12000.0 | 99000.0 | 12000.0 | 2.330 | 2.342 | .0 | .04783 | 86.05 | 10255.83 | 217.36 | 18970.52 |
| 87.000 | 12000.0 | 99000.0 | 12000.0 | 2.888 | 2.895 | .0 | .05918 | 87.06 | 10531.19 | 217.36 | 18970.52 |
| 88.000 | 12000.0 | 99000.0 | 12000.0 | 3.747 | 3.739 | .0 | .07644 | 88.08 | 11004.68 | 217.40 | 18970.52 |
| 89.200 | 12000.0 | 99000.0 | 12000.0 | 5.592 | 5.513 | .0 | .11265 | 89.31 | 12141.85 | 217.57 | 18970.52 |
| 89.400 | 12000.0 | 99000.0 | 12000.0 | 6.055 | 5.948 | .0 | .12155 | 89.52 | 12440.86 | 217.62 | 18970.52 |
| 89.600 | 12000.0 | 99000.0 | 12000.0 | 6.587 | 6.444 | .0 | .13167 | 89.73 | 12786.96 | 217.68 | 18970.52 |
| 89.800 | 12000.0 | 99000.0 | 12000.0 | 7.202 | 7.010 | .0 | .14326 | 89.94 | 13187.40 | 217.75 | 18970.52 |
| 90.000 | 12000.0 | 99000.0 | 12000.0 | 7.865 | 7.660 | 23.8 | .15662 | 90.16 | 13645.56 | 217.83 | 18972.48 |
| 90.200 | 12000.0 | 99000.0 | 11958.5 | 8.699 | 8.407 | 91.7 | .17027 | 90.37 | 14210.75 | 217.96 | 19298.68 |
| 90.400 | 12000.0 | 99000.0 | 11833.9 | 9.691 | 9.275 | 168.0 | .18636 | 90.59 | 14788.61 | 218.12 | 19915.24 |
| 90.600 | 12000.0 | 99000.0 | 11625.4 | 10.897 | 10.302 | 260.8 | .20866 | 90.81 | 15517.59 | 218.29 | 20875.71 |
| 90.800 | 12000.0 | 99000.0 | 11332.2 | 12.341 | 11.516 | 371.7 | .23433 | 91.03 | 16420.38 | 218.42 | 22239.66 |
| 91.000 | 12000.0 | 99000.0 | 10953.8 | 14.130 | 12.955 | 501.5 | .26211 | 91.26 | 17684.50 | 218.55 | 24074.78 |
| 91.200 | 12000.0 | 99000.0 | 10489.6 | 16.058 | 14.684 | 668.8 | .29764 | 91.50 | 19097.33 | 218.85 | 26561.11 |
| 91.400 | 12000.0 | 99000.0 | 9940.1 | 18.429 | 16.628 | 767.9 | .30603 | 91.71 | 20691.84 | 219.20 | 29311.03 |
| 91.600 | 12000.0 | 99000.0 | 9311.7 | 21.588 | 19.005 | 1047.3 | .36086 | 91.96 | 22537.30 | 221.71 | 33559.83 |
| 91.800 | 12000.0 | 99000.0 | 8598.3 | 24.911 | 21.653 | 1222.7 | .38171 | 92.18 | 24941.07 | 224.55 | 38202.82 |
| 92.000 | 12000.0 | 99000.0 | 7790.3 | 28.609 | 24.736 | 1325.4 | .38693 | 92.39 | 27713.63 | 227.44 | 43496.72 |
| 92.200 | 12000.0 | 99000.0 | 6883.2 | 34.810 | 28.793 | 1745.7 | .45781 | 92.66 | 31441.07 | 230.87 | 52279.27 |
| 92.400 | 12000.0 | 99000.0 | 5886.5 | 41.905 | 33.555 | 2177.4 | .52141 | 92.92 | 35820.37 | 235.29 | 63311.94 |
| 92.600 | 12000.0 | 99000.0 | 4798.6 | 51.286 | 39.126 | 2574.7 | .57235 | 93.17 | 40989.19 | 240.64 | 76784.87 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HOIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 13000.0 | 99000.0 | 13000.0 | .986 | .995 | .0 | .02018 | 81.02 | 8386.56 | 217.18 | 16226.48 |
| 82.000 | 13000.0 | 99000.0 | 13000.0 | 1.099 | 1.109 | .0 | .02255 | 82.02 | 8420.15 | 217.17 | 16226.48 |
| 83.000 | 13000.0 | 99000.0 | 13000.0 | 1.240 | 1.251 | .0 | .02550 | 83.03 | 8466.17 | 217.15 | 16226.48 |
| 84.000 | 13000.0 | 99000.0 | 13000.0 | 1.422 | 1.434 | .0 | .02927 | 84.03 | 8531.20 | 217.14 | 16226.48 |
| 85.000 | 13000.0 | 99000.0 | 13000.0 | 1.661 | 1.674 | .0 | .03423 | 85.03 | 8626.55 | 217.12 | 16226.48 |
| 86.000 | 13000.0 | 99000.0 | 13000.0 | 1.991 | 2.004 | .0 | .04102 | 86.04 | 8772.61 | 217.09 | 16226.48 |
| 87.000 | 13000.0 | 99000.0 | 13000.0 | 2.466 | 2.477 | .0 | .05074 | 87.05 | 9008.35 | 217.08 | 16226.48 |
| 88.000 | 13000.0 | 99000.0 | 13000.0 | 3.196 | 3.198 | .0 | .06552 | 88.07 | 9413.45 | 217.09 | 16226.48 |
| 89.200 | 13000.0 | 99000.0 | 13000.0 | 4.759 | 4.711 | .0 | .09647 | 89.30 | 10385.21 | 217.21 | 16226.48 |
| 89.400 | 13000.0 | 99000.0 | 13000.0 | 5.149 | 5.082 | .0 | .10406 | 89.50 | 10640.46 | 217.26 | 16226.48 |
| 89.600 | 13000.0 | 99000.0 | 13000.0 | 5.596 | 5.503 | .0 | .11270 | 89.71 | 10935.77 | 217.31 | 16226.48 |
| 89.800 | 13000.0 | 99000.0 | 13000.0 | 6.112 | 5.985 | .0 | .12258 | 89.92 | 11277.26 | 217.36 | 16226.48 |
| 90.000 | 13000.0 | 99000.0 | 13000.0 | 6.677 | 6.538 | 17.4 | .13396 | 90.13 | 11667.72 | 217.43 | 16198.56 |
| 90.200 | 13000.0 | 99000.0 | 12958.9 | 7.355 | 7.172 | 74.9 | .14558 | 90.35 | 12149.75 | 217.55 | 16453.45 |
| 90.400 | 13000.0 | 99000.0 | 12835.5 | 8.180 | 7.909 | 139.4 | .15926 | 90.56 | 12642.41 | 217.70 | 16946.19 |
| 90.600 | 13000.0 | 99000.0 | 12629.1 | 9.176 | 8.778 | 217.5 | .17815 | 90.78 | 13263.58 | 217.86 | 17718.94 |
| 90.800 | 13000.0 | 99000.0 | 12338.9 | 10.380 | 9.804 | 310.5 | .19989 | 91.00 | 14032.85 | 217.99 | 18814.62 |
| 91.000 | 13000.0 | 99000.0 | 11964.8 | 11.821 | 11.019 | 419.7 | .22361 | 91.22 | 15108.34 | 218.10 | 20294.02 |
| 91.200 | 13000.0 | 99000.0 | 11506.1 | 13.627 | 12.472 | 558.5 | .25327 | 91.45 | 16080.67 | 218.40 | 22284.12 |
| 91.400 | 13000.0 | 99000.0 | 10960.0 | 15.933 | 14.235 | 729.5 | .28822 | 91.69 | 17702.85 | 218.56 | 24922.82 |
| 91.600 | 13000.0 | 99000.0 | 10325.9 | 18.563 | 16.389 | 955.7 | .33272 | 91.93 | 19328.57 | 218.89 | 28442.14 |
| 91.800 | 13000.0 | 99000.0 | 9617.9 | 21.320 | 18.730 | 1088.5 | .34495 | 92.14 | 21433.49 | 220.94 | 32270.41 |
| 92.000 | 13000.0 | 99000.0 | 8815.1 | 24.594 | 21.508 | 1198.1 | .35370 | 92.35 | 23881.85 | 223.17 | 36896.85 |
| 92.200 | 13000.0 | 99000.0 | 7916.4 | 29.914 | 25.107 | 1591.2 | .42100 | 92.62 | 27157.94 | 226.20 | 44356.59 |
| 92.400 | 13000.0 | 99000.0 | 6929.1 | 36.038 | 29.341 | 1998.4 | .48186 | 92.88 | 31019.22 | 230.28 | 53792.71 |
| 92.600 | 13000.0 | 99000.0 | 5851.6 | 43.736 | 34.288 | 2352.4 | .52712 | 93.13 | 35590.64 | 235.26 | 65070.72 |
| 92.800 | 13000.0 | 99000.0 | 4674.4 | 56.314 | 40.685 | 3119.4 | .63229 | 93.43 | 41607.34 | 241.26 | 83653.72 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 14000.0 | 99000.0 | 14000.0 | .843 | .852 | .0 | .01731 | 81.02 | 7170.55 | 217.00 | 13874.39 |
| 82.000 | 14000.0 | 99000.0 | 14000.0 | .939 | .949 | .0 | .01933 | 82.02 | 7199.33 | 216.99 | 13874.39 |
| 83.000 | 14000.0 | 99000.0 | 14000.0 | 1.060 | 1.071 | .0 | .02186 | 83.02 | 7238.76 | 216.97 | 13874.39 |
| 84.000 | 14000.0 | 99000.0 | 14000.0 | 1.215 | 1.227 | .0 | .02509 | 84.03 | 7294.47 | 216.94 | 13874.39 |
| 85.000 | 14000.0 | 99000.0 | 14000.0 | 1.420 | 1.432 | .0 | .02935 | 85.03 | 7376.13 | 216.91 | 13874.39 |
| 86.000 | 14000.0 | 99000.0 | 14000.0 | 1.701 | 1.714 | .0 | .03517 | 86.04 | 7501.18 | 216.87 | 13874.39 |
| 87.000 | 14000.0 | 99000.0 | 14000.0 | 2.106 | 2.119 | .0 | .04350 | 87.04 | 7702.91 | 216.84 | 13874.39 |
| 88.000 | 14000.0 | 99000.0 | 14000.0 | 2.727 | 2.735 | .0 | .05615 | 88.06 | 8049.38 | 216.82 | 13874.39 |
| 89.200 | 14000.0 | 99000.0 | 14000.0 | 4.052 | 4.026 | .0 | .08262 | 89.28 | 8879.64 | 216.89 | 13874.39 |
| 89.400 | 14000.0 | 99000.0 | 14000.0 | 4.382 | 4.342 | .0 | .08911 | 89.49 | 9097.54 | 216.92 | 13874.39 |
| 89.600 | 14000.0 | 99000.0 | 14000.0 | 4.759 | 4.701 | .0 | .09648 | 89.70 | 9349.54 | 216.96 | 13874.39 |
| 89.800 | 14000.0 | 99000.0 | 14000.0 | 5.193 | 5.111 | .0 | .10491 | 89.90 | 9640.82 | 217.00 | 13874.39 |
| 90.000 | 14000.0 | 99000.0 | 14000.0 | 5.659 | 5.581 | 12.8 | .11461 | 90.11 | 9973.69 | 217.06 | 13830.85 |
| 90.200 | 14000.0 | 99000.0 | 13959.2 | 6.227 | 6.121 | 61.6 | .12451 | 90.32 | 10384.89 | 217.17 | 14029.36 |
| 90.400 | 14000.0 | 99000.0 | 13836.8 | 6.914 | 6.747 | 116.2 | .13617 | 90.54 | 10805.04 | 217.31 | 14423.71 |
| 90.600 | 14000.0 | 99000.0 | 13632.1 | 7.743 | 7.484 | 182.1 | .15219 | 90.75 | 11334.58 | 217.46 | 15052.75 |
| 90.800 | 14000.0 | 99000.0 | 13344.7 | 8.737 | 8.353 | 260.4 | .17065 | 90.97 | 11990.37 | 217.57 | 15942.61 |
| 91.000 | 14000.0 | 99000.0 | 12974.0 | 9.923 | 9.381 | 352.5 | .19094 | 91.19 | 12905.96 | 217.67 | 17144.74 |
| 91.200 | 14000.0 | 99000.0 | 12520.0 | 11.411 | 10.606 | 468.2 | .21577 | 91.42 | 13735.31 | 217.95 | 18745.80 |
| 91.400 | 14000.0 | 99000.0 | 11979.9 | 13.258 | 12.091 | 612.4 | .24578 | 91.65 | 15111.21 | 218.10 | 20866.18 |
| 91.600 | 14000.0 | 99000.0 | 11353.7 | 15.630 | 13.895 | 798.2 | .28260 | 91.88 | 16493.66 | 218.43 | 23688.42 |
| 91.800 | 14000.0 | 99000.0 | 10638.3 | 18.403 | 16.114 | 1030.7 | .32593 | 92.13 | 18356.27 | 218.75 | 27435.08 |
| 92.000 | 14000.0 | 99000.0 | 9840.5 | 21.125 | 18.598 | 1095.9 | .32547 | 92.33 | 20505.91 | 219.73 | 31259.59 |
| 92.200 | 14000.0 | 99000.0 | 8949.6 | 25.692 | 21.793 | 1462.9 | .38889 | 92.59 | 23377.67 | 222.11 | 37597.56 |
| 92.400 | 14000.0 | 99000.0 | 7970.9 | 31.437 | 25.567 | 1857.6 | .44884 | 92.85 | 26775.15 | 225.73 | 45697.25 |
| 92.600 | 14000.0 | 99000.0 | 6903.0 | 37.516 | 29.944 | 2159.3 | .48637 | 93.09 | 30803.20 | 230.23 | 55156.55 |
| 92.800 | 14000.0 | 99000.0 | 5743.9 | 46.213 | 35.266 | 2568.9 | .53772 | 93.34 | 35981.97 | 235.98 | 67887.94 |
| 93.000 | 14000.0 | 99000.0 | 4462.8 | 62.428 | 42.581 | 3683.7 | .68876 | 93.69 | 42565.73 | 241.95 | 92314.65 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 15000.0 | 99000.0 | 15000.0 | .720 | .729 | .0 | .01484 | 81.01 | 6128.66 | 216.88 | 11858.97 |
| 82.000 | 15000.0 | 99000.0 | 15000.0 | .803 | .812 | .0 | .01657 | 82.02 | 6153.32 | 216.86 | 11858.97 |
| 83.000 | 15000.0 | 99000.0 | 15000.0 | .906 | .916 | .0 | .01874 | 83.02 | 6187.09 | 216.83 | 11858.97 |
| 84.000 | 15000.0 | 99000.0 | 15000.0 | 1.038 | 1.049 | .0 | .02151 | 84.02 | 6234.79 | 216.80 | 11858.97 |
| 85.000 | 15000.0 | 99000.0 | 15000.0 | 1.213 | 1.225 | .0 | .02516 | 85.03 | 6304.70 | 216.75 | 11858.97 |
| 86.000 | 15000.0 | 99000.0 | 15000.0 | 1.453 | 1.466 | .0 | .03014 | 86.03 | 6411.71 | 216.70 | 11858.97 |
| 87.000 | 15000.0 | 99000.0 | 15000.0 | 1.798 | 1.812 | .0 | .03728 | 87.04 | 6584.28 | 216.64 | 11858.97 |
| 88.000 | 15000.0 | 99000.0 | 15000.0 | 2.327 | 2.338 | .0 | .04812 | 88.05 | 6880.51 | 216.59 | 11858.97 |
| 89.200 | 15000.0 | 99000.0 | 15000.0 | 3.451 | 3.440 | .0 | .07076 | 89.27 | 7589.75 | 216.60 | 11858.97 |
| 89.400 | 15000.0 | 99000.0 | 15000.0 | 3.730 | 3.710 | .0 | .07631 | 89.48 | 7775.76 | 216.62 | 11858.97 |
| 89.600 | 15000.0 | 99000.0 | 15000.0 | 4.049 | 4.016 | .0 | .08261 | 89.68 | 7990.81 | 216.64 | 11858.97 |
| 89.800 | 15000.0 | 99000.0 | 15000.0 | 4.415 | 4.365 | .0 | .08980 | 89.89 | 8239.28 | 216.67 | 11858.97 |
| 90.000 | 15000.0 | 99000.0 | 15000.0 | 4.800 | 4.766 | 9.4 | .09808 | 90.10 | 8523.11 | 216.71 | 11806.66 |
| 90.200 | 15000.0 | 99000.0 | 14959.5 | 5.277 | 5.225 | 50.8 | .10653 | 90.31 | 8873.95 | 216.81 | 11962.41 |
| 90.400 | 15000.0 | 99000.0 | 14837.9 | 5.853 | 5.758 | 97.2 | .11646 | 90.52 | 9232.32 | 216.93 | 12281.89 |
| 90.600 | 15000.0 | 99000.0 | 14634.7 | 6.543 | 6.384 | 152.9 | .13008 | 90.73 | 9683.88 | 217.07 | 12793.38 |
| 90.800 | 15000.0 | 99000.0 | 14349.5 | 7.370 | 7.120 | 219.0 | .14577 | 90.95 | 10243.11 | 217.17 | 13523.41 |
| 91.000 | 15000.0 | 99000.0 | 13981.8 | 8.351 | 7.992 | 297.0 | .16317 | 91.16 | 11022.98 | 217.26 | 14507.16 |
| 91.200 | 15000.0 | 99000.0 | 13531.7 | 9.572 | 9.027 | 393.7 | .18401 | 91.38 | 11730.63 | 217.53 | 15809.03 |
| 91.400 | 15000.0 | 99000.0 | 12996.7 | 11.080 | 10.282 | 516.4 | .21003 | 91.61 | 12898.89 | 217.66 | 17527.14 |
| 91.600 | 15000.0 | 99000.0 | 12377.0 | 12.989 | 11.798 | 669.3 | .24040 | 91.84 | 14075.34 | 217.98 | 19786.08 |
| 91.800 | 15000.0 | 99000.0 | 11669.9 | 15.444 | 13.659 | 861.5 | .27660 | 92.08 | 15654.16 | 218.29 | 22771.80 |
| 92.000 | 15000.0 | 99000.0 | 10872.2 | 18.419 | 15.975 | 1113.4 | .32214 | 92.32 | 17546.73 | 218.56 | 26811.49 |
| 92.200 | 15000.0 | 99000.0 | 9982.1 | 22.116 | 18.825 | 1377.9 | .36523 | 92.57 | 20054.87 | 218.94 | 31916.59 |
| 92.400 | 15000.0 | 99000.0 | 9012.2 | 27.264 | 22.222 | 1794.4 | .42967 | 92.83 | 22786.36 | 221.83 | 39081.95 |
| 92.600 | 15000.0 | 99000.0 | 7952.4 | 32.204 | 26.058 | 2001.7 | .45141 | 93.05 | 26573.34 | 225.67 | 46766.28 |
| 92.800 | 15000.0 | 99000.0 | 6803.8 | 38.926 | 30.666 | 2248.5 | .47830 | 93.28 | 30799.74 | 230.83 | 56562.42 |
| 93.000 | 15000.0 | 99000.0 | 5544.0 | 51.772 | 36.998 | 3204.0 | .60936 | 93.61 | 36501.92 | 236.74 | 75643.19 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIOLATITUOE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 16000.0 | 99000.0 | 16000.0 | .615 | .623 | .0 | .01271 | 81.01 | 5236.29 | 216.82 | 10132.66 |
| 82.000 | 16000.0 | 99000.0 | 16000.0 | .686 | .694 | .0 | .01420 | 82.01 | 5257.41 | 216.80 | 10132.66 |
| 83.000 | 16000.0 | 99000.0 | 16000.0 | .774 | .783 | .0 | .01606 | 83.02 | 5286.32 | 216.76 | 10132.66 |
| 84.000 | 16000.0 | 99000.0 | 16000.0 | .887 | .897 | .0 | .01844 | 84.02 | 5327.16 | 216.72 | 10132.66 |
| 85.000 | 16000.0 | 99000.0 | 16000.0 | 1.036 | 1.048 | .0 | .02156 | 85.02 | 5386.98 | 216.67 | 10132.66 |
| 86.000 | 16000.0 | 99000.0 | 16000.0 | 1.241 | 1.254 | .0 | .02583 | 86.03 | 5478.53 | 216.60 | 10132.66 |
| 87.000 | 16000.0 | 99000.0 | 16000.0 | 1.535 | 1.549 | .0 | .03195 | 87.03 | 5626.10 | 216.51 | 10132.66 |
| 88.000 | 16000.0 | 99000.0 | 16000.0 | 1.986 | 1.999 | .0 | .04123 | 88.04 | 5879.30 | 216.42 | 10132.66 |
| 89.200 | 16000.0 | 99000.0 | 16000.0 | 2.941 | 2.939 | .0 | .06061 | 89.26 | 6485.04 | 216.35 | 10132.66 |
| 89.400 | 16000.0 | 99000.0 | 16000.0 | 3.177 | 3.169 | .0 | .06535 | 89.47 | 6643.81 | 216.36 | 10132.66 |
| 89.600 | 16000.0 | 99000.0 | 16000.0 | 3.446 | 3.430 | .0 | .07073 | 89.67 | 6827.33 | 216.37 | 10132.66 |
| 89.800 | 16000.0 | 99000.0 | 16000.0 | 3.756 | 3.728 | .0 | .07688 | 89.88 | 7039.29 | 216.38 | 10132.66 |
| 90.000 | 16000.0 | 99000.0 | 16000.0 | 4.074 | 4.069 | 6.9 | .08394 | 90.08 | 7281.34 | 216.41 | 10075.97 |
| 90.200 | 16000.0 | 99000.0 | 15959.7 | 4.476 | 4.461 | 42.1 | .09116 | 90.29 | 7580.70 | 216.48 | 10199.06 |
| 90.400 | 16000.0 | 99000.0 | 15838.8 | 4.960 | 4.915 | 81.5 | .09964 | 90.50 | 7886.40 | 216.59 | 10459.46 |
| 90.600 | 16000.0 | 99000.0 | 15636.9 | 5.537 | 5.447 | 128.7 | .11123 | 90.71 | 8271.54 | 216.71 | 10879.50 |
| 90.800 | 16000.0 | 99000.0 | 15353.5 | 6.228 | 6.072 | 184.7 | .12458 | 90.92 | 8748.53 | 216.79 | 11480.28 |
| 91.000 | 16000.0 | 99000.0 | 14988.4 | 7.041 | 6.812 | 250.9 | .13952 | 91.14 | 9413.07 | 216.86 | 12287.97 |
| 91.200 | 16000.0 | 99000.0 | 14541.6 | 8.052 | 7.689 | 332.0 | .15705 | 91.36 | 10017.00 | 217.12 | 13356.57 |
| 91.400 | 16000.0 | 99000.0 | 14010.9 | 9.291 | 8.751 | 436.2 | .17946 | 91.58 | 10862.85 | 217.24 | 14759.56 |
| 91.600 | 16000.0 | 99000.0 | 13396.6 | 10.841 | 10.029 | 563.1 | .20475 | 91.80 | 12011.58 | 217.54 | 16583.68 |
| 91.800 | 16000.0 | 99000.0 | 12696.4 | 12.819 | 11.595 | 722.6 | .23507 | 92.04 | 13351.27 | 217.84 | 18979.58 |
| 92.000 | 16000.0 | 99000.0 | 11907.5 | 15.423 | 13.540 | 934.6 | .27401 | 92.27 | 14958.10 | 218.09 | 22196.61 |
| 92.200 | 16000.0 | 99000.0 | 11027.9 | 18.698 | 15.986 | 1229.2 | .32572 | 92.53 | 16895.45 | 218.45 | 26650.05 |
| 92.400 | 16000.0 | 99000.0 | 10053.5 | 23.083 | 19.085 | 1609.7 | .38806 | 92.79 | 19512.62 | 218.86 | 32683.49 |
| 92.600 | 16000.0 | 99000.0 | 8999.3 | 28.342 | 22.644 | 1951.3 | .43472 | 93.03 | 22866.80 | 221.77 | 40047.79 |
| 92.800 | 16000.0 | 99000.0 | 7859.9 | 33.244 | 26.656 | 2058.2 | .43913 | 93.24 | 26565.57 | 226.14 | 47729.33 |
| 93.000 | 16000.0 | 99000.0 | 6618.8 | 42.811 | 32.062 | 2776.6 | .53675 | 93.54 | 31522.19 | 231.82 | 62218.78 |
| 93.200 | 16000.0 | 99000.0 | 5260.1 | 57.563 | 38.966 | 3732.2 | .65883 | 93.86 | 37652.50 | 237.62 | 83942.11 |

UNREFRACTEO RAY STRIKES DISC

REFRACTION AIRMASS TABLES

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 17000.0 | 99000.0 | 17000.0 | .525 | .533 | .0 | .01089 | 81.01 | 4472.26 | 216.84 | 8654.50 |
| 82.000 | 17000.0 | 99000.0 | 17000.0 | .586 | .594 | .0 | .01217 | 82.01 | 4490.34 | 216.81 | 8654.50 |
| 83.000 | 17000.0 | 99000.0 | 17000.0 | .661 | .670 | .0 | .01376 | 83.01 | 4515.08 | 216.77 | 8654.50 |
| 84.000 | 17000.0 | 99000.0 | 17000.0 | .757 | .767 | .0 | .01579 | 84.02 | 4550.03 | 216.72 | 8654.50 |
| 85.000 | 17000.0 | 99000.0 | 17000.0 | .885 | .896 | .0 | .01847 | 85.02 | 4601.21 | 216.65 | 8654.50 |
| 86.000 | 17000.0 | 99000.0 | 17000.0 | 1.059 | 1.072 | .0 | .02213 | 86.02 | 4679.50 | 216.56 | 8654.50 |
| 87.000 | 17000.0 | 99000.0 | 17000.0 | 1.310 | 1.324 | .0 | .02737 | 87.03 | 4805.66 | 216.45 | 8654.50 |
| 88.000 | 17000.0 | 99000.0 | 17000.0 | 1.694 | 1.708 | .0 | .03532 | 88.04 | 5022.01 | 216.32 | 8654.50 |
| 89.200 | 17000.0 | 99000.0 | 17000.0 | 2.506 | 2.511 | .0 | .05192 | 89.25 | 5539.28 | 216.17 | 8654.50 |
| 89.400 | 17000.0 | 99000.0 | 17000.0 | 2.706 | 2.707 | .0 | .05597 | 89.46 | 5674.79 | 216.16 | 8654.50 |
| 89.600 | 17000.0 | 99000.0 | 17000.0 | 2.935 | 2.930 | .0 | .06057 | 89.66 | 5831.38 | 216.15 | 8654.50 |
| 89.800 | 17000.0 | 99000.0 | 17000.0 | 3.197 | 3.184 | .0 | .06583 | 89.87 | 6012.20 | 216.14 | 8654.50 |
| 90.000 | 17000.0 | 99000.0 | 17000.0 | 3.459 | 3.475 | 5.0 | .07186 | 90.07 | 6218.63 | 216.15 | 8596.29 |
| 90.200 | 17000.0 | 99000.0 | 16959.9 | 3.799 | 3.809 | 35.1 | .07803 | 90.28 | 6474.06 | 216.20 | 8694.24 |
| 90.400 | 17000.0 | 99000.0 | 16839.6 | 4.206 | 4.196 | 68.6 | .08526 | 90.49 | 6734.84 | 216.29 | 8907.64 |
| 90.600 | 17000.0 | 99000.0 | 16638.8 | 4.691 | 4.648 | 108.6 | .09514 | 90.70 | 7063.36 | 216.38 | 9254.35 |
| 90.800 | 17000.0 | 99000.0 | 16357.0 | 5.269 | 5.180 | 156.1 | .10652 | 90.91 | 7470.26 | 216.44 | 9751.29 |
| 91.000 | 17000.0 | 99000.0 | 15994.0 | 5.948 | 5.809 | 212.4 | .11937 | 91.12 | 8036.70 | 216.50 | 10419.53 |
| 91.200 | 17000.0 | 99000.0 | 15549.9 | 6.786 | 6.553 | 280.6 | .13412 | 91.33 | 8552.17 | 216.73 | 11298.23 |
| 91.400 | 17000.0 | 99000.0 | 15022.9 | 7.810 | 7.452 | 368.5 | .15315 | 91.55 | 9273.10 | 216.84 | 12451.61 |
| 91.600 | 17000.0 | 99000.0 | 14413.1 | 9.082 | 8.534 | 475.1 | .17456 | 91.77 | 10249.91 | 217.12 | 13940.92 |
| 91.800 | 17000.0 | 99000.0 | 13718.7 | 10.703 | 9.855 | 607.9 | .19999 | 92.00 | 11387.69 | 217.40 | 15876.64 |
| 92.000 | 17000.0 | 99000.0 | 12937.2 | 12.804 | 11.494 | 787.2 | .23343 | 92.23 | 12753.03 | 217.63 | 18460.66 |
| 92.200 | 17000.0 | 99000.0 | 12067.3 | 15.613 | 13.541 | 1029.8 | .27641 | 92.48 | 14398.86 | 217.98 | 21970.62 |
| 92.400 | 17000.0 | 99000.0 | 11105.4 | 19.135 | 16.124 | 1343.1 | .32844 | 92.73 | 16611.90 | 218.39 | 26797.20 |
| 92.600 | 17000.0 | 99000.0 | 10046.6 | 24.006 | 19.446 | 1769.6 | .39542 | 93.00 | 19353.36 | 218.83 | 33497.61 |
| 92.800 | 17000.0 | 99000.0 | 8912.6 | 28.764 | 23.074 | 1897.6 | .40483 | 93.20 | 22836.22 | 222.06 | 40238.40 |
| 93.000 | 17000.0 | 99000.0 | 7687.5 | 36.002 | 27.694 | 2386.2 | .46903 | 93.47 | 27131.58 | 227.27 | 51117.79 |
| 93.200 | 17000.0 | 99000.0 | 6345.2 | 47.717 | 33.750 | 3263.6 | .58397 | 93.78 | 32522.89 | 232.69 | 68721.24 |
| 93.400 | 17000.0 | 99000.0 | 4901.3 | 60.437 | 40.766 | 3716.4 | .63366 | 94.03 | 39388.86 | 238.74 | 87686.34 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 18000.0 | 99000.0 | 18000.0 | .449 | .455 | .0 | .00933 | 81.01 | 3818.34 | 216.95 | 7389.28 |
| 82.000 | 18000.0 | 99000.0 | 18000.0 | .500 | .507 | .0 | .01042 | 82.01 | 3833.81 | 216.92 | 7389.28 |
| 83.000 | 18000.0 | 99000.0 | 18000.0 | .564 | .572 | .0 | .01179 | 83.01 | 3854.99 | 216.87 | 7389.28 |
| 84.000 | 18000.0 | 99000.0 | 18000.0 | .646 | .656 | .0 | .01353 | 84.01 | 3884.88 | 216.81 | 7389.28 |
| 85.000 | 18000.0 | 99000.0 | 18000.0 | .755 | .765 | .0 | .01582 | 85.02 | 3928.66 | 216.73 | 7389.28 |
| 86.000 | 18000.0 | 99000.0 | 18000.0 | .904 | .916 | .0 | .01896 | 86.02 | 3995.59 | 216.62 | 7389.28 |
| 87.000 | 18000.0 | 99000.0 | 18000.0 | 1.118 | 1.131 | .0 | .02345 | 87.02 | 4103.41 | 216.48 | 7389.28 |
| 88.000 | 18000.0 | 99000.0 | 18000.0 | 1.445 | 1.459 | .0 | .03026 | 88.03 | 4288.24 | 216.30 | 7389.28 |
| 89.200 | 18000.0 | 99000.0 | 18000.0 | 2.135 | 2.145 | .0 | .04447 | 89.24 | 4729.85 | 216.07 | 7389.28 |
| 89.400 | 18000.0 | 99000.0 | 18000.0 | 2.306 | 2.312 | .0 | .04794 | 89.45 | 4845.50 | 216.03 | 7389.28 |
| 89.600 | 18000.0 | 99000.0 | 18000.0 | 2.499 | 2.502 | .0 | .05188 | 89.65 | 4979.11 | 216.00 | 7389.28 |
| 89.800 | 18000.0 | 99000.0 | 18000.0 | 2.721 | 2.719 | .0 | .05638 | 89.86 | 5133.37 | 215.97 | 7389.28 |
| 90.000 | 18000.0 | 99000.0 | 18000.0 | 2.938 | 2.967 | 3.7 | .06154 | 90.06 | 5309.41 | 215.95 | 7331.41 |
| 90.200 | 18000.0 | 99000.0 | 17960.1 | 3.225 | 3.252 | 29.3 | .06681 | 90.27 | 5527.37 | 215.97 | 7409.86 |
| 90.400 | 18000.0 | 99000.0 | 17840.3 | 3.569 | 3.582 | 57.9 | .07298 | 90.47 | 5749.82 | 216.03 | 7585.60 |
| 90.600 | 18000.0 | 99000.0 | 17640.3 | 3.977 | 3.967 | 91.9 | .08140 | 90.68 | 6030.05 | 216.10 | 7873.05 |
| 90.800 | 18000.0 | 99000.0 | 17359.9 | 4.461 | 4.420 | 132.2 | .09110 | 90.89 | 6377.17 | 216.14 | 8284.11 |
| 91.000 | 18000.0 | 99000.0 | 16998.8 | 5.032 | 4.955 | 180.3 | .10224 | 91.10 | 6860.12 | 216.16 | 8841.30 |
| 91.200 | 18000.0 | 99000.0 | 16557.0 | 5.730 | 5.587 | 237.7 | .11459 | 91.31 | 7300.08 | 216.38 | 9569.02 |
| 91.400 | 18000.0 | 99000.0 | 16033.0 | 6.579 | 6.350 | 311.9 | .13078 | 91.53 | 7914.71 | 216.46 | 10519.12 |
| 91.600 | 18000.0 | 99000.0 | 15427.1 | 7.640 | 7.267 | 401.7 | .14894 | 91.75 | 8745.83 | 216.72 | 11742.43 |
| 91.800 | 18000.0 | 99000.0 | 14737.5 | 8.956 | 8.384 | 512.5 | .17024 | 91.97 | 9712.83 | 216.98 | 13321.94 |
| 92.000 | 18000.0 | 99000.0 | 13962.2 | 10.665 | 9.768 | 665.1 | .19912 | 92.20 | 10873.78 | 217.19 | 15417.58 |
| 92.200 | 18000.0 | 99000.0 | 13100.3 | 12.911 | 11.488 | 865.8 | .23495 | 92.43 | 12273.23 | 217.54 | 18215.78 |
| 92.400 | 18000.0 | 99000.0 | 12148.7 | 15.929 | 13.652 | 1125.5 | .27859 | 92.68 | 14146.95 | 217.92 | 22019.47 |
| 92.600 | 18000.0 | 99000.0 | 11103.4 | 19.825 | 16.418 | 1476.4 | .33445 | 92.93 | 16467.16 | 218.35 | 27354.69 |
| 92.800 | 18000.0 | 99000.0 | 9961.7 | 24.631 | 19.881 | 1786.0 | .37868 | 93.18 | 19563.32 | 218.89 | 34004.73 |
| 93.000 | 18000.0 | 99000.0 | 8750.3 | 29.400 | 23.746 | 1918.3 | .38915 | 93.39 | 22992.84 | 223.20 | 41308.36 |
| 93.200 | 18000.0 | 99000.0 | 7422.7 | 39.641 | 29.158 | 2855.1 | .51701 | 93.72 | 28004.43 | 228.11 | 56469.94 |
| 93.400 | 18000.0 | 99000.0 | 5987.0 | 52.126 | 35.682 | 3592.5 | .60651 | 94.01 | 34136.01 | 233.61 | 75114.11 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 19000.0 | 99000.0 | 19000.0 | .383 | .389 | .0 | .00799 | 81.01 | 3258.86 | 217.17 | 6306.72 |
| 82.000 | 19000.0 | 99000.0 | 19000.0 | .427 | .433 | .0 | .00893 | 82.01 | 3272.10 | 217.13 | 6306.72 |
| 83.000 | 19000.0 | 99000.0 | 19000.0 | .481 | .489 | .0 | .01009 | 83.01 | 3290.21 | 217.08 | 6306.72 |
| 84.000 | 19000.0 | 99000.0 | 19000.0 | .552 | .560 | .0 | .01158 | 84.01 | 3315.78 | 217.01 | 6306.72 |
| 85.000 | 19000.0 | 99000.0 | 19000.0 | .644 | .654 | .0 | .01355 | 85.01 | 3353.21 | 216.91 | 6306.72 |
| 86.000 | 19000.0 | 99000.0 | 19000.0 | .771 | .782 | .0 | .01623 | 86.02 | 3410.42 | 216.78 | 6306.72 |
| 87.000 | 19000.0 | 99000.0 | 19000.0 | .954 | .966 | .0 | .02008 | 87.02 | 3502.54 | 216.62 | 6306.72 |
| 88.000 | 19000.0 | 99000.0 | 19000.0 | 1.233 | 1.246 | .0 | .02592 | 88.03 | 3660.36 | 216.40 | 6306.72 |
| 89.200 | 19000.0 | 99000.0 | 19000.0 | 1.820 | 1.831 | .0 | .03811 | 89.24 | 4037.30 | 216.07 | 6306.72 |
| 89.400 | 19000.0 | 99000.0 | 19000.0 | 1.965 | 1.974 | .0 | .04109 | 89.44 | 4135.98 | 216.01 | 6306.72 |
| 89.600 | 19000.0 | 99000.0 | 19000.0 | 2.129 | 2.136 | .0 | .04447 | 89.64 | 4249.98 | 215.96 | 6306.72 |
| 89.800 | 19000.0 | 99000.0 | 19000.0 | 2.317 | 2.321 | .0 | .04832 | 89.85 | 4381.57 | 215.90 | 6306.72 |
| 90.000 | 19000.0 | 99000.0 | 19000.0 | 2.496 | 2.533 | 2.7 | .05273 | 90.05 | 4531.72 | 215.84 | 6250.36 |
| 90.200 | 19000.0 | 99000.0 | 18960.2 | 2.739 | 2.776 | 24.6 | .05723 | 90.26 | 4717.69 | 215.83 | 6313.61 |
| 90.400 | 19000.0 | 99000.0 | 18840.9 | 3.030 | 3.057 | 48.9 | .06251 | 90.46 | 4907.44 | 215.85 | 6458.96 |
| 90.600 | 19000.0 | 99000.0 | 18641.7 | 3.374 | 3.385 | 77.9 | .06968 | 90.67 | 5146.48 | 215.88 | 6698.19 |
| 90.800 | 19000.0 | 99000.0 | 18362.4 | 3.782 | 3.771 | 112.1 | .07795 | 90.88 | 5442.62 | 215.88 | 7040.82 |
| 91.000 | 19000.0 | 99000.0 | 18002.8 | 4.261 | 4.227 | 153.2 | .08754 | 91.09 | 5765.85 | 215.87 | 7505.57 |
| 91.200 | 19000.0 | 99000.0 | 17563.0 | 4.845 | 4.765 | 201.6 | .09796 | 91.30 | 6229.94 | 216.06 | 8111.05 |
| 91.400 | 19000.0 | 99000.0 | 17041.6 | 5.552 | 5.413 | 264.5 | .11174 | 91.51 | 6754.04 | 216.12 | 8899.08 |
| 91.600 | 19000.0 | 99000.0 | 16438.8 | 6.433 | 6.191 | 340.4 | .12717 | 91.73 | 7461.55 | 216.35 | 9910.03 |
| 91.800 | 19000.0 | 99000.0 | 15753.4 | 7.517 | 7.138 | 432.1 | .14480 | 91.94 | 8178.24 | 216.58 | 11206.23 |
| 92.000 | 19000.0 | 99000.0 | 14983.3 | 8.920 | 8.309 | 563.5 | .17006 | 92.17 | 9271.62 | 216.77 | 12920.82 |
| 92.200 | 19000.0 | 99000.0 | 14128.2 | 10.735 | 9.758 | 730.1 | .19997 | 92.40 | 10462.44 | 217.10 | 15175.83 |
| 92.400 | 19000.0 | 99000.0 | 13185.1 | 13.143 | 11.577 | 946.5 | .23671 | 92.64 | 12050.62 | 217.47 | 18204.19 |
| 92.600 | 19000.0 | 99000.0 | 12151.0 | 16.430 | 13.893 | 1237.2 | .28353 | 92.88 | 14016.70 | 217.88 | 22401.80 |
| 92.800 | 19000.0 | 99000.0 | 11021.3 | 20.818 | 16.884 | 1634.5 | .34408 | 93.14 | 16465.95 | 218.33 | 28370.69 |
| 93.000 | 19000.0 | 99000.0 | 9803.9 | 25.356 | 20.454 | 1765.8 | .35747 | 93.36 | 19703.42 | 219.74 | 34701.98 |
| 93.200 | 19000.0 | 99000.0 | 8493.0 | 33.014 | 25.113 | 2501.0 | .45749 | 93.66 | 24035.09 | 224.01 | 46502.43 |
| 93.400 | 19000.0 | 99000.0 | 7072.6 | 43.980 | 30.972 | 3322.2 | .56024 | 93.96 | 29164.24 | 229.00 | 62968.91 |
| 93.600 | 19000.0 | 99000.0 | 5566.3 | 57.285 | 37.832 | 3921.7 | .62494 | 94.22 | 35735.31 | 236.14 | 82705.14 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 20000.0 | 99000.0 | 20000.0 | .327 | .332 | .0 | .00682 | 81.01 | 2780.48 | 217.52 | 5380.77 |
| 82.000 | 20000.0 | 99000.0 | 20000.0 | .364 | .370 | .0 | .00762 | 82.01 | 2791.80 | 217.47 | 5380.77 |
| 83.000 | 20000.0 | 99000.0 | 20000.0 | .411 | .418 | .0 | .00862 | 83.01 | 2807.30 | 217.41 | 5380.77 |
| 84.000 | 20000.0 | 99000.0 | 20000.0 | .471 | .478 | .0 | .00989 | 84.01 | 2829.16 | 217.33 | 5380.77 |
| 85.000 | 20000.0 | 99000.0 | 20000.0 | .550 | .558 | .0 | .01157 | 85.01 | 2861.15 | 217.23 | 5380.77 |
| 86.000 | 20000.0 | 99000.0 | 20000.0 | .658 | .668 | .0 | .01386 | 86.01 | 2910.03 | 217.08 | 5380.77 |
| 87.000 | 20000.0 | 99000.0 | 20000.0 | .814 | .825 | .0 | .01714 | 87.02 | 2988.69 | 216.88 | 5380.77 |
| 88.000 | 20000.0 | 99000.0 | 20000.0 | 1.051 | 1.064 | .0 | .02212 | 88.02 | 3123.39 | 216.63 | 5380.77 |
| 89.200 | 20000.0 | 99000.0 | 20000.0 | 1.551 | 1.563 | .0 | .03252 | 89.23 | 3444.85 | 216.25 | 5380.77 |
| 89.400 | 20000.0 | 99000.0 | 20000.0 | 1.674 | 1.684 | .0 | .03506 | 89.44 | 3528.96 | 216.18 | 5380.77 |
| 89.600 | 20000.0 | 99000.0 | 20000.0 | 1.814 | 1.823 | .0 | .03793 | 89.64 | 3626.11 | 216.11 | 5380.77 |
| 89.800 | 20000.0 | 99000.0 | 20000.0 | 1.973 | 1.980 | .0 | .04121 | 89.84 | 3738.23 | 216.04 | 5380.77 |
| 90.000 | 20000.0 | 99000.0 | 20000.0 | 2.114 | 2.160 | 2.0 | .04497 | 90.04 | 3866.13 | 215.97 | 5327.04 |
| 90.200 | 20000.0 | 99000.0 | 19960.3 | 2.326 | 2.368 | 20.8 | .04929 | 90.25 | 4024.93 | 215.90 | 5376.74 |
| 90.400 | 20000.0 | 99000.0 | 19841.2 | 2.574 | 2.608 | 42.0 | .05430 | 90.45 | 4187.13 | 215.83 | 5499.23 |
| 90.600 | 20000.0 | 99000.0 | 19642.5 | 2.865 | 2.889 | 66.5 | .06014 | 90.66 | 4391.19 | 215.77 | 5698.95 |
| 90.800 | 20000.0 | 99000.0 | 19364.2 | 3.208 | 3.218 | 95.4 | .06700 | 90.87 | 4643.86 | 215.71 | 5985.33 |
| 91.000 | 20000.0 | 99000.0 | 19005.9 | 3.611 | 3.606 | 130.3 | .07509 | 91.08 | 4919.65 | 215.65 | 6373.96 |
| 91.200 | 20000.0 | 99000.0 | 18567.7 | 4.102 | 4.064 | 171.4 | .08392 | 91.28 | 5315.58 | 215.79 | 6879.76 |
| 91.400 | 20000.0 | 99000.0 | 18048.5 | 4.693 | 4.616 | 224.7 | .09563 | 91.50 | 5762.54 | 215.81 | 7536.06 |
| 91.600 | 20000.0 | 99000.0 | 17448.5 | 5.428 | 5.277 | 288.9 | .10874 | 91.71 | 6365.10 | 216.01 | 8375.53 |
| 91.800 | 20000.0 | 99000.0 | 16766.5 | 6.327 | 6.081 | 366.6 | .12378 | 91.92 | 6976.84 | 216.20 | 9448.35 |
| 92.000 | 20000.0 | 99000.0 | 16000.9 | 7.483 | 7.074 | 479.7 | .14574 | 92.15 | 7806.44 | 216.37 | 10857.26 |
| 92.200 | 20000.0 | 99000.0 | 15151.3 | 8.961 | 8.298 | 617.2 | .17046 | 92.37 | 8919.47 | 216.69 | 12688.92 |
| 92.400 | 20000.0 | 99000.0 | 14215.4 | 10.907 | 9.832 | 798.4 | .20148 | 92.60 | 10266.97 | 217.04 | 15130.84 |
| 92.600 | 20000.0 | 99000.0 | 13190.6 | 13.537 | 11.777 | 1040.6 | .24086 | 92.84 | 11934.76 | 217.43 | 18460.62 |
| 92.800 | 20000.0 | 99000.0 | 12073.1 | 17.194 | 14.278 | 1369.4 | .29157 | 93.09 | 14013.28 | 217.87 | 23148.62 |
| 93.000 | 20000.0 | 99000.0 | 10858.6 | 22.094 | 17.527 | 1797.8 | .35373 | 93.35 | 16831.00 | 218.39 | 29809.48 |
| 93.200 | 20000.0 | 99000.0 | 9556.4 | 27.887 | 21.549 | 2202.0 | .40589 | 93.61 | 20352.51 | 220.62 | 38319.29 |
| 93.400 | 20000.0 | 99000.0 | 8150.8 | 36.898 | 26.675 | 2918.6 | .49685 | 93.90 | 25051.89 | 224.79 | 51606.53 |
| 93.600 | 20000.0 | 99000.0 | 6660.0 | 46.876 | 32.666 | 3364.6 | .54462 | 94.14 | 30796.39 | 231.25 | 66827.91 |
| 93.800 | 20000.0 | 99000.0 | 5030.0 | 68.057 | 41.107 | 4764.4 | .70502 | 94.51 | 38290.80 | 237.93 | 98463.20 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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THE APPARENT AND ASTRONOMICAL ANGLES ARE
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THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 21000.0 | 99000.0 | 21000.0 | .279 | .284 | .0 | .00583 | 81.01 | 2372.37 | 217.93 | 4590.98 |
| 82.000 | 21000.0 | 99000.0 | 21000.0 | .311 | .316 | .0 | .00651 | 82.01 | 2382.07 | 217.88 | 4590.98 |
| 83.000 | 21000.0 | 99000.0 | 21000.0 | .350 | .357 | .0 | .00736 | 83.01 | 2395.32 | 217.81 | 4590.98 |
| 84.000 | 21000.0 | 99000.0 | 21000.0 | .401 | .409 | .0 | .00845 | 84.01 | 2414.02 | 217.72 | 4590.98 |
| 85.000 | 21000.0 | 99000.0 | 21000.0 | .469 | .477 | .0 | .00988 | 85.01 | 2441.37 | 217.60 | 4590.98 |
| 86.000 | 21000.0 | 99000.0 | 21000.0 | .561 | .571 | .0 | .01184 | 86.01 | 2483.13 | 217.43 | 4590.98 |
| 87.000 | 21000.0 | 99000.0 | 21000.0 | .694 | .705 | .0 | .01464 | 87.01 | 2550.30 | 217.21 | 4590.98 |
| 88.000 | 21000.0 | 99000.0 | 21000.0 | .896 | .908 | .0 | .01889 | 88.02 | 2665.26 | 216.91 | 4590.98 |
| 89.200 | 21000.0 | 99000.0 | 21000.0 | 1.321 | 1.334 | .0 | .02775 | 89.23 | 2939.42 | 216.46 | 4590.98 |
| 89.400 | 21000.0 | 99000.0 | 21000.0 | 1.425 | 1.438 | .0 | .02992 | 89.43 | 3011.12 | 216.37 | 4590.98 |
| 89.600 | 21000.0 | 99000.0 | 21000.0 | 1.544 | 1.555 | .0 | .03237 | 89.63 | 3093.93 | 216.29 | 4590.98 |
| 89.800 | 21000.0 | 99000.0 | 21000.0 | 1.680 | 1.689 | .0 | .03516 | 89.84 | 3189.47 | 216.21 | 4590.98 |
| 90.000 | 21000.0 | 99000.0 | 21000.0 | 1.795 | 1.843 | 1.4 | .03836 | 90.04 | 3298.43 | 216.12 | 4540.04 |
| 90.200 | 21000.0 | 99000.0 | 20960.4 | 1.974 | 2.020 | 17.4 | .04204 | 90.24 | 3433.72 | 216.04 | 4580.27 |
| 90.400 | 21000.0 | 99000.0 | 20841.6 | 2.184 | 2.225 | 35.4 | .04631 | 90.45 | 3571.89 | 215.96 | 4682.06 |
| 90.600 | 21000.0 | 99000.0 | 20643.5 | 2.429 | 2.463 | 56.2 | .05127 | 90.65 | 3745.74 | 215.88 | 4848.87 |
| 90.800 | 21000.0 | 99000.0 | 20366.0 | 2.718 | 2.743 | 80.8 | .05710 | 90.86 | 3960.97 | 215.81 | 5088.35 |
| 91.000 | 21000.0 | 99000.0 | 20008.9 | 3.063 | 3.073 | 110.4 | .06397 | 91.06 | 4195.89 | 215.74 | 5413.20 |
| 91.200 | 21000.0 | 99000.0 | 19571.9 | 3.478 | 3.465 | 146.5 | .07215 | 91.27 | 4534.08 | 215.67 | 5838.33 |
| 91.400 | 21000.0 | 99000.0 | 19054.5 | 3.973 | 3.935 | 191.3 | .08194 | 91.48 | 4915.45 | 215.61 | 6386.45 |
| 91.600 | 21000.0 | 99000.0 | 18456.8 | 4.586 | 4.498 | 245.7 | .09304 | 91.69 | 5428.85 | 215.75 | 7084.57 |
| 91.800 | 21000.0 | 99000.0 | 17777.6 | 5.336 | 5.182 | 311.6 | .10586 | 91.91 | 5951.03 | 215.89 | 7976.28 |
| 92.000 | 21000.0 | 99000.0 | 17015.8 | 6.293 | 6.024 | 407.0 | .12447 | 92.12 | 6657.85 | 216.03 | 9140.17 |
| 92.200 | 21000.0 | 99000.0 | 16171.0 | 7.508 | 7.061 | 522.9 | .14543 | 92.35 | 7604.10 | 216.31 | 10642.74 |
| 92.400 | 21000.0 | 99000.0 | 15241.1 | 9.092 | 8.358 | 675.1 | .17167 | 92.57 | 8748.29 | 216.64 | 12625.64 |
| 92.600 | 21000.0 | 99000.0 | 14224.0 | 11.208 | 9.997 | 877.8 | .20491 | 92.80 | 10164.29 | 217.00 | 15299.54 |
| 92.800 | 21000.0 | 99000.0 | 13116.7 | 14.102 | 12.097 | 1151.5 | .24754 | 93.05 | 11929.91 | 217.42 | 19005.04 |
| 93.000 | 21000.0 | 99000.0 | 11915.2 | 18.201 | 14.816 | 1510.6 | .30032 | 93.30 | 14312.70 | 217.90 | 24253.97 |
| 93.200 | 21000.0 | 99000.0 | 10613.7 | 23.606 | 18.412 | 2032.4 | .37311 | 93.57 | 17369.37 | 218.51 | 32024.49 |
| 93.400 | 21000.0 | 99000.0 | 9221.4 | 30.675 | 22.896 | 2575.1 | .44151 | 93.84 | 21448.19 | 221.19 | 42401.48 |
| 93.600 | 21000.0 | 99000.0 | 7744.4 | 37.890 | 28.061 | 2764.0 | .45841 | 94.06 | 26428.55 | 226.72 | 53437.37 |
| 93.800 | 21000.0 | 99000.0 | 6135.2 | 55.175 | 35.511 | 4165.2 | .62349 | 94.42 | 33034.60 | 233.01 | 79352.11 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

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ALL HEIGHTS ARE IN GEOMETRIC METERS
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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HOIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 22000.0 | 99000.0 | 22000.0 | .238 | .242 | .0 | .00498 | 81.00 | 2024.23 | 218.41 | 3917.12 |
| 82.000 | 22000.0 | 99000.0 | 22000.0 | .265 | .270 | .0 | .00556 | 82.01 | 2032.52 | 218.35 | 3917.12 |
| 83.000 | 22000.0 | 99000.0 | 22000.0 | .299 | .305 | .0 | .00629 | 83.01 | 2043.86 | 218.28 | 3917.12 |
| 84.000 | 22000.0 | 99000.0 | 22000.0 | .342 | .349 | .0 | .00722 | 84.01 | 2059.86 | 218.17 | 3917.12 |
| 85.000 | 22000.0 | 99000.0 | 22000.0 | .400 | .407 | .0 | .00844 | 85.01 | 2083.24 | 218.04 | 3917.12 |
| 86.000 | 22000.0 | 99000.0 | 22000.0 | .479 | .487 | .0 | .01011 | 86.01 | 2118.93 | 217.85 | 3917.12 |
| 87.000 | 22000.0 | 99000.0 | 22000.0 | .592 | .602 | .0 | .01250 | 87.01 | 2176.30 | 217.59 | 3917.12 |
| 88.000 | 22000.0 | 99000.0 | 22000.0 | .764 | .776 | .0 | .01613 | 88.02 | 2274.42 | 217.24 | 3917.12 |
| 89.200 | 22000.0 | 99000.0 | 22000.0 | 1.126 | 1.138 | .0 | .02369 | 89.22 | 2508.24 | 216.71 | 3917.12 |
| 89.400 | 22000.0 | 99000.0 | 22000.0 | 1.214 | 1.227 | .0 | .02554 | 89.43 | 2569.37 | 216.61 | 3917.12 |
| 89.600 | 22000.0 | 99000.0 | 22000.0 | 1.315 | 1.327 | .0 | .02763 | 89.63 | 2639.96 | 216.51 | 3917.12 |
| 89.800 | 22000.0 | 99000.0 | 22000.0 | 1.430 | 1.442 | .0 | .03001 | 89.83 | 2721.38 | 216.41 | 3917.12 |
| 90.000 | 22000.0 | 99000.0 | 22000.0 | 1.524 | 1.573 | 1.0 | .03273 | 90.03 | 2814.23 | 216.31 | 3869.21 |
| 90.200 | 22000.0 | 99000.0 | 21960.5 | 1.676 | 1.723 | 14.6 | .03587 | 90.24 | 2929.50 | 216.21 | 3901.96 |
| 90.400 | 22000.0 | 99000.0 | 21842.0 | 1.854 | 1.898 | 30.0 | .03950 | 90.44 | 3047.23 | 216.12 | 3986.84 |
| 90.600 | 22000.0 | 99000.0 | 21644.4 | 2.061 | 2.101 | 47.6 | .04372 | 90.64 | 3195.37 | 216.02 | 4126.56 |
| 90.800 | 22000.0 | 99000.0 | 21367.6 | 2.305 | 2.339 | 68.5 | .04868 | 90.85 | 3378.74 | 215.93 | 4327.40 |
| 91.000 | 22000.0 | 99000.0 | 21011.4 | 2.596 | 2.619 | 93.6 | .05452 | 91.05 | 3578.89 | 215.85 | 4599.80 |
| 91.200 | 22000.0 | 99000.0 | 20575.6 | 2.943 | 2.953 | 124.2 | .06147 | 91.26 | 3866.86 | 215.77 | 4954.57 |
| 91.400 | 22000.0 | 99000.0 | 20059.9 | 3.365 | 3.352 | 162.1 | .06978 | 91.47 | 4191.51 | 215.70 | 5413.83 |
| 91.600 | 22000.0 | 99000.0 | 19463.9 | 3.881 | 3.833 | 209.8 | .07982 | 91.68 | 4629.38 | 215.63 | 5999.24 |
| 91.800 | 22000.0 | 99000.0 | 18787.1 | 4.508 | 4.416 | 265.4 | .09062 | 91.89 | 5075.18 | 215.67 | 6742.92 |
| 92.000 | 22000.0 | 99000.0 | 18028.5 | 5.303 | 5.132 | 345.9 | .10638 | 92.11 | 5677.58 | 215.75 | 7707.83 |
| 92.200 | 22000.0 | 99000.0 | 17187.6 | 6.306 | 6.012 | 443.8 | .12417 | 92.32 | 6482.51 | 215.98 | 8945.88 |
| 92.400 | 22000.0 | 99000.0 | 16262.8 | 7.607 | 7.110 | 572.0 | .14641 | 92.55 | 7365.79 | 216.27 | 10571.56 |
| 92.600 | 22000.0 | 99000.0 | 15252.2 | 9.324 | 8.495 | 742.2 | .17453 | 92.77 | 8553.72 | 216.61 | 12737.14 |
| 92.800 | 22000.0 | 99000.0 | 14153.3 | 11.656 | 10.264 | 971.2 | .21048 | 93.01 | 10158.85 | 217.00 | 15700.25 |
| 93.000 | 22000.0 | 99000.0 | 12962.8 | 14.885 | 12.548 | 1274.5 | .25558 | 93.26 | 12176.00 | 217.44 | 19845.97 |
| 93.200 | 22000.0 | 99000.0 | 11676.3 | 19.352 | 15.544 | 1697.9 | .31523 | 93.52 | 14759.52 | 218.04 | 25934.94 |
| 93.400 | 22000.0 | 99000.0 | 10284.9 | 25.687 | 19.568 | 2315.9 | .39776 | 93.80 | 18098.91 | 218.61 | 35073.48 |
| 93.600 | 22000.0 | 99000.0 | 8815.3 | 32.015 | 24.178 | 2444.3 | .40828 | 94.01 | 22442.62 | 222.48 | 44072.75 |
| 93.800 | 22000.0 | 99000.0 | 7229.7 | 45.327 | 30.615 | 3645.6 | .55115 | 94.35 | 28410.43 | 228.43 | 64353.31 |
| 94.000 | 22000.0 | 99000.0 | 5546.2 | 61.845 | 38.310 | 4452.0 | .63613 | 94.64 | 35516.82 | 236.02 | 88702.82 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER

ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HOIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 23000.0 | 99000.0 | 23000.0 | .203 | .207 | .0 | .00425 | 81.00 | 1727.23 | 218.98 | 3342.16 |
| 82.000 | 23000.0 | 99000.0 | 23000.0 | .226 | .231 | .0 | .00475 | 82.00 | 1734.33 | 218.91 | 3342.16 |
| 83.000 | 23000.0 | 99000.0 | 23000.0 | .255 | .260 | .0 | .00537 | 83.01 | 1744.04 | 218.83 | 3342.16 |
| 84.000 | 23000.0 | 99000.0 | 23000.0 | .292 | .298 | .0 | .00616 | 84.01 | 1757.72 | 218.71 | 3342.16 |
| 85.000 | 23000.0 | 99000.0 | 23000.0 | .341 | .348 | .0 | .00721 | 85.01 | 1777.72 | 218.56 | 3342.16 |
| 86.000 | 23000.0 | 99000.0 | 23000.0 | .408 | .416 | .0 | .00863 | 86.01 | 1808.22 | 218.35 | 3342.16 |
| 87.000 | 23000.0 | 99000.0 | 23000.0 | .505 | .514 | .0 | .01068 | 87.01 | 1857.22 | 218.05 | 3342.16 |
| 88.000 | 23000.0 | 99000.0 | 23000.0 | .651 | .662 | .0 | .01377 | 88.01 | 1940.98 | 217.65 | 3342.16 |
| 89.200 | 23000.0 | 99000.0 | 23000.0 | .959 | .972 | .0 | .02023 | 89.22 | 2140.41 | 217.02 | 3342.16 |
| 89.400 | 23000.0 | 99000.0 | 23000.0 | 1.035 | 1.047 | .0 | .02180 | 89.42 | 2192.53 | 216.90 | 3342.16 |
| 89.600 | 23000.0 | 99000.0 | 23000.0 | 1.120 | 1.133 | .0 | .02358 | 89.62 | 2252.70 | 216.78 | 3342.16 |
| 89.800 | 23000.0 | 99000.0 | 23000.0 | 1.218 | 1.231 | .0 | .02561 | 89.83 | 2322.11 | 216.66 | 3342.16 |
| 90.000 | 23000.0 | 99000.0 | 23000.0 | 1.295 | 1.342 | .8 | .02793 | 90.03 | 2401.24 | 216.54 | 3297.39 |
| 90.200 | 23000.0 | 99000.0 | 22960.6 | 1.424 | 1.471 | 12.3 | .03061 | 90.23 | 2499.46 | 216.42 | 3324.19 |
| 90.400 | 23000.0 | 99000.0 | 22842.3 | 1.574 | 1.619 | 25.4 | .03370 | 90.43 | 2599.78 | 216.31 | 3395.19 |
| 90.600 | 23000.0 | 99000.0 | 22645.1 | 1.750 | 1.792 | 40.4 | .03730 | 90.64 | 2726.04 | 216.19 | 3512.52 |
| 90.800 | 23000.0 | 99000.0 | 22368.9 | 1.956 | 1.995 | 58.1 | .04152 | 90.84 | 2882.29 | 216.09 | 3681.34 |
| 91.000 | 23000.0 | 99000.0 | 22013.5 | 2.201 | 2.234 | 79.4 | .04649 | 91.05 | 3052.85 | 215.98 | 3909.25 |
| 91.200 | 23000.0 | 99000.0 | 21578.8 | 2.494 | 2.517 | 105.4 | .05239 | 91.25 | 3298.12 | 215.89 | 4208.16 |
| 91.400 | 23000.0 | 99000.0 | 21064.5 | 2.849 | 2.856 | 137.6 | .05946 | 91.46 | 3574.57 | 215.80 | 4593.18 |
| 91.600 | 23000.0 | 99000.0 | 20470.1 | 3.281 | 3.265 | 177.9 | .06797 | 91.67 | 3946.96 | 215.71 | 5082.67 |
| 91.800 | 23000.0 | 99000.0 | 19795.3 | 3.814 | 3.762 | 229.0 | .07833 | 91.88 | 4327.32 | 215.64 | 5707.78 |
| 92.000 | 23000.0 | 99000.0 | 19039.3 | 4.475 | 4.372 | 294.6 | .09103 | 92.09 | 4840.94 | 215.57 | 6507.47 |
| 92.200 | 23000.0 | 99000.0 | 18201.7 | 5.309 | 5.120 | 377.3 | .10609 | 92.31 | 5526.00 | 215.73 | 7535.39 |
| 92.400 | 23000.0 | 99000.0 | 17281.2 | 6.382 | 6.052 | 485.6 | .12496 | 92.52 | 6279.31 | 215.95 | 8873.21 |
| 92.600 | 23000.0 | 99000.0 | 16276.0 | 7.789 | 7.225 | 628.9 | .14879 | 92.75 | 7290.47 | 216.25 | 10644.44 |
| 92.800 | 23000.0 | 99000.0 | 15184.2 | 9.675 | 8.718 | 821.1 | .17919 | 92.98 | 8652.32 | 216.60 | 13036.42 |
| 93.000 | 23000.0 | 99000.0 | 14002.8 | 12.266 | 10.644 | 1082.2 | .21843 | 93.22 | 10239.15 | 217.01 | 16359.49 |
| 93.200 | 23000.0 | 99000.0 | 12728.7 | 15.938 | 13.150 | 1422.4 | .26667 | 93.47 | 12547.75 | 217.58 | 21066.44 |
| 93.400 | 23000.0 | 99000.0 | 11354.1 | 21.211 | 16.499 | 1934.5 | .33596 | 93.74 | 15375.38 | 218.14 | 28230.16 |
| 93.600 | 23000.0 | 99000.0 | 9879.6 | 27.175 | 20.790 | 2271.2 | .37739 | 93.98 | 19209.24 | 219.14 | 36942.50 |
| 93.800 | 23000.0 | 99000.0 | 8314.3 | 37.798 | 26.325 | 3196.6 | .48729 | 94.29 | 24122.69 | 224.30 | 52421.19 |
| 94.000 | 23000.0 | 99000.0 | 6648.8 | 49.830 | 33.035 | 3821.0 | .55366 | 94.55 | 30588.21 | 231.15 | 71032.60 |
| 94.200 | 23000.0 | 99000.0 | 4853.6 | 68.726 | 41.725 | 4633.3 | .63920 | 94.84 | 38889.30 | 238.63 | 99024.75 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HOIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 24000.0 | 99000.0 | 24000.0 | .173 | .177 | .0 | .00363 | 81.00 | 1473.86 | 219.64 | 2851.60 |
| 82.000 | 24000.0 | 99000.0 | 24000.0 | .193 | .197 | .0 | .00406 | 82.00 | 1479.95 | 219.57 | 2851.60 |
| 83.000 | 24000.0 | 99000.0 | 24000.0 | .218 | .222 | .0 | .00459 | 83.00 | 1488.26 | 219.48 | 2851.60 |
| 84.000 | 24000.0 | 99000.0 | 24000.0 | .249 | .255 | .0 | .00526 | 84.01 | 1499.97 | 219.35 | 2851.60 |
| 85.000 | 24000.0 | 99000.0 | 24000.0 | .291 | .297 | .0 | .00616 | 85.01 | 1517.08 | 219.18 | 2851.60 |
| 86.000 | 24000.0 | 99000.0 | 24000.0 | .348 | .355 | .0 | .00738 | 86.01 | 1543.16 | 218.94 | 2851.60 |
| 87.000 | 24000.0 | 99000.0 | 24000.0 | .431 | .439 | .0 | .00912 | 87.01 | 1585.02 | 218.60 | 2851.60 |
| 88.000 | 24000.0 | 99000.0 | 24000.0 | .556 | .565 | .0 | .01176 | 88.01 | 1656.52 | 218.14 | 2851.60 |
| 89.200 | 24000.0 | 99000.0 | 24000.0 | .818 | .830 | .0 | .01727 | 89.22 | 1826.64 | 217.39 | 2851.60 |
| 89.400 | 24000.0 | 99000.0 | 24000.0 | .882 | .894 | .0 | .01862 | 89.42 | 1871.07 | 217.25 | 2851.60 |
| 89.600 | 24000.0 | 99000.0 | 24000.0 | .955 | .967 | .0 | .02014 | 89.62 | 1922.37 | 217.11 | 2851.60 |
| 89.800 | 24000.0 | 99000.0 | 24000.0 | 1.038 | 1.050 | .0 | .02187 | 89.82 | 1981.53 | 216.97 | 2851.60 |
| 90.000 | 24000.0 | 99000.0 | 24000.0 | 1.100 | 1.146 | .6 | .02385 | 90.02 | 2048.97 | 216.82 | 2809.97 |
| 90.200 | 24000.0 | 99000.0 | 23960.6 | 1.210 | 1.255 | 10.4 | .02612 | 90.23 | 2132.69 | 216.68 | 2832.01 |
| 90.400 | 24000.0 | 99000.0 | 23842.6 | 1.337 | 1.382 | 21.5 | .02876 | 90.43 | 2218.18 | 216.54 | 2891.55 |
| 90.600 | 24000.0 | 99000.0 | 23645.7 | 1.486 | 1.529 | 34.3 | .03183 | 90.63 | 2325.79 | 216.40 | 2990.29 |
| 90.800 | 24000.0 | 99000.0 | 23370.0 | 1.661 | 1.702 | 49.4 | .03542 | 90.84 | 2458.96 | 216.27 | 3132.48 |
| 91.000 | 24000.0 | 99000.0 | 23015.3 | 1.867 | 1.905 | 67.5 | .03965 | 91.04 | 2604.31 | 216.15 | 3324.41 |
| 91.200 | 24000.0 | 99000.0 | 22581.5 | 2.115 | 2.147 | 89.6 | .04467 | 91.24 | 2813.26 | 216.03 | 3575.96 |
| 91.400 | 24000.0 | 99000.0 | 22068.3 | 2.413 | 2.435 | 116.8 | .05068 | 91.45 | 3048.74 | 215.92 | 3898.50 |
| 91.600 | 24000.0 | 99000.0 | 21475.4 | 2.777 | 2.783 | 151.0 | .05792 | 91.66 | 3365.58 | 215.82 | 4310.05 |
| 91.800 | 24000.0 | 99000.0 | 20802.4 | 3.224 | 3.205 | 194.3 | .06671 | 91.87 | 3689.58 | 215.73 | 4832.87 |
| 92.000 | 24000.0 | 99000.0 | 20048.8 | 3.781 | 3.722 | 249.8 | .07748 | 92.08 | 4126.54 | 215.65 | 5499.42 |
| 92.200 | 24000.0 | 99000.0 | 19213.7 | 4.478 | 4.361 | 321.6 | .09079 | 92.29 | 4710.15 | 215.57 | 6357.30 |
| 92.400 | 24000.0 | 99000.0 | 18296.7 | 5.368 | 5.153 | 412.9 | .10675 | 92.51 | 5352.74 | 215.71 | 7465.05 |
| 92.600 | 24000.0 | 99000.0 | 17296.1 | 6.525 | 6.148 | 533.9 | .12696 | 92.73 | 6213.80 | 215.94 | 8919.94 |
| 92.800 | 24000.0 | 99000.0 | 16210.3 | 8.064 | 7.412 | 695.7 | .15271 | 92.95 | 7370.15 | 216.25 | 10868.60 |
| 93.000 | 24000.0 | 99000.0 | 15036.7 | 10.164 | 9.037 | 914.8 | .18587 | 93.19 | 8721.39 | 216.62 | 13541.61 |
| 93.200 | 24000.0 | 99000.0 | 13772.6 | 13.057 | 11.144 | 1194.5 | .22585 | 93.43 | 10550.68 | 217.14 | 17261.08 |
| 93.400 | 24000.0 | 99000.0 | 12412.1 | 17.382 | 13.946 | 1622.8 | .28446 | 93.68 | 13068.85 | 217.68 | 22839.78 |
| 93.600 | 24000.0 | 99000.0 | 10948.3 | 23.288 | 17.713 | 2201.1 | .35910 | 93.96 | 16364.21 | 218.25 | 31247.37 |
| 93.800 | 24000.0 | 99000.0 | 9390.1 | 31.257 | 22.560 | 2816.5 | .43193 | 94.23 | 20637.66 | 220.84 | 42835.68 |
| 94.000 | 24000.0 | 99000.0 | 7740.5 | 40.250 | 28.356 | 3158.3 | .46730 | 94.47 | 26235.90 | 226.63 | 56359.11 |
| 94.200 | 24000.0 | 99000.0 | 5956.4 | 58.464 | 36.396 | 4404.8 | .60348 | 94.80 | 33654.25 | 233.38 | 83689.61 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 25000.0 | 99000.0 | 25000.0 | .148 | .151 | .0 | .00310 | 81.00 | 1257.73 | 220.43 | 2433.04 |
| 82.000 | 25000.0 | 99000.0 | 25000.0 | .165 | .168 | .0 | .00347 | 82.00 | 1262.94 | 220.35 | 2433.04 |
| 83.000 | 25000.0 | 99000.0 | 25000.0 | .186 | .190 | .0 | .00392 | 83.00 | 1270.06 | 220.25 | 2433.04 |
| 84.000 | 25000.0 | 99000.0 | 25000.0 | .213 | .217 | .0 | .00450 | 84.00 | 1280.09 | 220.11 | 2433.04 |
| 85.000 | 25000.0 | 99000.0 | 25000.0 | .248 | .254 | .0 | .00526 | 85.01 | 1294.73 | 219.91 | 2433.04 |
| 86.000 | 25000.0 | 99000.0 | 25000.0 | .297 | .304 | .0 | .00630 | 86.01 | 1317.03 | 219.64 | 2433.04 |
| 87.000 | 25000.0 | 99000.0 | 25000.0 | .367 | .375 | .0 | .00779 | 87.01 | 1352.81 | 219.26 | 2433.04 |
| 88.000 | 25000.0 | 99000.0 | 25000.0 | .474 | .483 | .0 | .01005 | 88.01 | 1413.86 | 218.73 | 2433.04 |
| 89.200 | 25000.0 | 99000.0 | 25000.0 | .697 | .708 | .0 | .01475 | 89.21 | 1558.97 | 217.86 | 2433.04 |
| 89.400 | 25000.0 | 99000.0 | 25000.0 | .752 | .763 | .0 | .01590 | 89.42 | 1596.86 | 217.69 | 2433.04 |
| 89.600 | 25000.0 | 99000.0 | 25000.0 | .814 | .826 | .0 | .01720 | 89.62 | 1640.60 | 217.52 | 2433.04 |
| 89.800 | 25000.0 | 99000.0 | 25000.0 | .884 | .897 | .0 | .01867 | 89.82 | 1691.03 | 217.34 | 2433.04 |
| 90.000 | 25000.0 | 99000.0 | 25000.0 | .935 | .978 | .4 | .02036 | 90.02 | 1748.51 | 217.17 | 2394.51 |
| 90.200 | 25000.0 | 99000.0 | 24960.7 | 1.028 | 1.071 | 8.8 | .02230 | 90.22 | 1819.86 | 216.99 | 2412.71 |
| 90.400 | 25000.0 | 99000.0 | 24842.8 | 1.136 | 1.179 | 18.3 | .02455 | 90.42 | 1892.73 | 216.82 | 2462.76 |
| 90.600 | 25000.0 | 99000.0 | 24646.2 | 1.262 | 1.305 | 29.2 | .02716 | 90.63 | 1984.45 | 216.66 | 2546.00 |
| 90.800 | 25000.0 | 99000.0 | 24370.9 | 1.410 | 1.452 | 42.0 | .03022 | 90.83 | 2097.95 | 216.50 | 2665.97 |
| 91.000 | 25000.0 | 99000.0 | 24016.8 | 1.585 | 1.625 | 57.4 | .03383 | 91.03 | 2221.84 | 216.34 | 2827.89 |
| 91.200 | 25000.0 | 99000.0 | 23583.7 | 1.795 | 1.831 | 76.2 | .03811 | 91.24 | 2399.88 | 216.20 | 3039.98 |
| 91.400 | 25000.0 | 99000.0 | 23071.5 | 2.046 | 2.077 | 99.3 | .04322 | 91.44 | 2600.50 | 216.07 | 3311.60 |
| 91.600 | 25000.0 | 99000.0 | 22479.8 | 2.352 | 2.372 | 128.3 | .04937 | 91.65 | 2870.19 | 215.95 | 3657.61 |
| 91.800 | 25000.0 | 99000.0 | 21808.4 | 2.728 | 2.731 | 165.0 | .05684 | 91.86 | 3146.22 | 215.84 | 4096.15 |
| 92.000 | 25000.0 | 99000.0 | 21056.7 | 3.194 | 3.170 | 212.0 | .06598 | 92.07 | 3518.13 | 215.74 | 4653.52 |
| 92.200 | 25000.0 | 99000.0 | 20224.1 | 3.780 | 3.712 | 272.7 | .07728 | 92.28 | 4014.00 | 215.65 | 5366.62 |
| 92.400 | 25000.0 | 99000.0 | 19309.9 | 4.529 | 4.388 | 352.1 | .09136 | 92.49 | 4562.40 | 215.57 | 6289.74 |
| 92.600 | 25000.0 | 99000.0 | 18313.2 | 5.482 | 5.234 | 454.0 | .10842 | 92.71 | 5295.95 | 215.70 | 7494.16 |
| 92.800 | 25000.0 | 99000.0 | 17232.3 | 6.747 | 6.306 | 590.5 | .13026 | 92.93 | 6278.47 | 215.94 | 9092.87 |
| 93.000 | 25000.0 | 99000.0 | 16065.2 | 8.452 | 7.680 | 774.9 | .15834 | 93.16 | 7429.60 | 216.26 | 11260.91 |
| 93.200 | 25000.0 | 99000.0 | 14809.6 | 10.779 | 9.459 | 1010.9 | .19234 | 93.39 | 8984.35 | 216.72 | 14248.40 |
| 93.400 | 25000.0 | 99000.0 | 13460.6 | 14.189 | 11.810 | 1366.0 | .24133 | 93.64 | 11113.29 | 217.25 | 18621.07 |
| 93.600 | 25000.0 | 99000.0 | 12012.4 | 19.304 | 14.962 | 1859.6 | .30578 | 93.91 | 13735.37 | 217.79 | 25225.54 |
| 93.800 | 25000.0 | 99000.0 | 10457.7 | 26.147 | 19.253 | 2551.7 | .39103 | 94.19 | 17596.27 | 218.51 | 35392.65 |
| 94.000 | 25000.0 | 99000.0 | 8817.3 | 33.745 | 24.397 | 2770.5 | .41317 | 94.41 | 22262.23 | 222.40 | 46125.27 |
| 94.200 | 25000.0 | 99000.0 | 7054.9 | 50.012 | 31.647 | 4236.1 | .57440 | 94.77 | 28751.62 | 228.79 | 71114.38 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 26000.0 | 99000.0 | 26000.0 | .126 | .129 | .0 | .00265 | 81.00 | 1073.35 | 221.35 | 2075.92 |
| 82.000 | 26000.0 | 99000.0 | 26000.0 | .140 | .144 | .0 | .00296 | 82.00 | 1077.82 | 221.27 | 2075.92 |
| 83.000 | 26000.0 | 99000.0 | 26000.0 | .158 | .162 | .0 | .00335 | 83.00 | 1083.93 | 221.15 | 2075.92 |
| 84.000 | 26000.0 | 99000.0 | 26000.0 | .181 | .186 | .0 | .00384 | 84.00 | 1092.52 | 221.00 | 2075.92 |
| 85.000 | 26000.0 | 99000.0 | 26000.0 | .212 | .217 | .0 | .00449 | 85.00 | 1105.05 | 220.79 | 2075.92 |
| 86.000 | 26000.0 | 99000.0 | 26000.0 | .253 | .259 | .0 | .00538 | 86.01 | 1124.13 | 220.49 | 2075.92 |
| 87.000 | 26000.0 | 99000.0 | 26000.0 | .313 | .320 | .0 | .00666 | 87.01 | 1154.71 | 220.06 | 2075.92 |
| 88.000 | 26000.0 | 99000.0 | 26000.0 | .404 | .412 | .0 | .00859 | 88.01 | 1206.85 | 219.45 | 2075.92 |
| 89.200 | 26000.0 | 99000.0 | 26000.0 | .594 | .605 | .0 | .01261 | 89.21 | 1330.65 | 218.42 | 2075.92 |
| 89.400 | 26000.0 | 99000.0 | 26000.0 | .641 | .652 | .0 | .01358 | 89.41 | 1362.96 | 218.22 | 2075.92 |
| 89.600 | 26000.0 | 99000.0 | 26000.0 | .693 | .705 | .0 | .01469 | 89.61 | 1400.25 | 218.02 | 2075.92 |
| 89.800 | 26000.0 | 99000.0 | 26000.0 | .754 | .765 | .0 | .01595 | 89.82 | 1443.24 | 217.81 | 2075.92 |
| 90.000 | 26000.0 | 99000.0 | 26000.0 | .794 | .835 | .3 | .01739 | 90.02 | 1492.24 | 217.59 | 2040.38 |
| 90.200 | 26000.0 | 99000.0 | 25960.7 | .874 | .914 | 7.5 | .01905 | 90.22 | 1553.05 | 217.38 | 2055.48 |
| 90.400 | 26000.0 | 99000.0 | 25843.0 | .966 | 1.007 | 15.5 | .02096 | 90.42 | 1615.16 | 217.17 | 2097.63 |
| 90.600 | 26000.0 | 99000.0 | 25646.6 | 1.073 | 1.114 | 24.8 | .02319 | 90.62 | 1693.34 | 216.97 | 2167.92 |
| 90.800 | 26000.0 | 99000.0 | 25371.7 | 1.198 | 1.239 | 35.8 | .02580 | 90.83 | 1790.09 | 216.77 | 2269.29 |
| 91.000 | 26000.0 | 99000.0 | 25018.1 | 1.347 | 1.387 | 48.9 | .02887 | 91.03 | 1895.69 | 216.59 | 2406.09 |
| 91.200 | 26000.0 | 99000.0 | 24585.6 | 1.524 | 1.562 | 64.8 | .03251 | 91.23 | 2047.41 | 216.41 | 2585.21 |
| 91.400 | 26000.0 | 99000.0 | 24074.2 | 1.736 | 1.771 | 84.5 | .03686 | 91.44 | 2218.36 | 216.25 | 2814.34 |
| 91.600 | 26000.0 | 99000.0 | 23483.5 | 1.994 | 2.023 | 109.1 | .04210 | 91.64 | 2447.98 | 216.10 | 3105.86 |
| 91.800 | 26000.0 | 99000.0 | 22813.4 | 2.310 | 2.328 | 140.3 | .04845 | 91.85 | 2683.21 | 215.97 | 3473.61 |
| 92.000 | 26000.0 | 99000.0 | 22063.3 | 2.702 | 2.702 | 180.1 | .05622 | 92.06 | 2999.84 | 215.85 | 3942.03 |
| 92.200 | 26000.0 | 99000.0 | 21232.8 | 3.192 | 3.162 | 231.5 | .06581 | 92.27 | 3421.41 | 215.74 | 4538.04 |
| 92.400 | 26000.0 | 99000.0 | 20321.3 | 3.816 | 3.735 | 298.6 | .07775 | 92.48 | 3888.25 | 215.65 | 5306.29 |
| 92.600 | 26000.0 | 99000.0 | 19327.6 | 4.616 | 4.456 | 387.2 | .09277 | 92.69 | 4513.29 | 215.57 | 6308.89 |
| 92.800 | 26000.0 | 99000.0 | 18250.9 | 5.659 | 5.367 | 502.1 | .11121 | 92.91 | 5283.99 | 215.70 | 7626.03 |
| 93.000 | 26000.0 | 99000.0 | 17089.3 | 7.057 | 6.532 | 657.6 | .13501 | 93.14 | 6329.65 | 215.95 | 9400.98 |
| 93.200 | 26000.0 | 99000.0 | 15840.7 | 8.955 | 8.037 | 857.3 | .16398 | 93.36 | 7651.86 | 216.34 | 11820.04 |
| 93.400 | 26000.0 | 99000.0 | 14501.4 | 11.657 | 10.016 | 1153.1 | .20507 | 93.61 | 9342.07 | 216.85 | 15294.46 |
| 93.600 | 26000.0 | 99000.0 | 13066.3 | 15.638 | 12.658 | 1563.9 | .25921 | 93.86 | 11681.44 | 217.35 | 20429.40 |
| 93.800 | 26000.0 | 99000.0 | 11529.5 | 21.475 | 16.232 | 2133.2 | .33013 | 94.13 | 14760.11 | 218.04 | 28329.89 |
| 94.000 | 26000.0 | 99000.0 | 9886.3 | 28.580 | 20.966 | 2578.8 | .38236 | 94.38 | 19047.30 | 219.07 | 38578.84 |
| 94.200 | 26000.0 | 99000.0 | 8147.0 | 41.190 | 27.196 | 3716.5 | .50772 | 94.71 | 24667.76 | 224.62 | 57516.32 |
| 94.400 | 26000.0 | 99000.0 | 6300.0 | 58.464 | 35.007 | 4734.9 | .61084 | 95.01 | 31870.60 | 232.33 | 83545.17 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 27000.0 | 99000.0 | 27000.0 | .107 | .110 | .0 | .00226 | 81.00 | 916.07 | 222.44 | 1771.21 |
| 82.000 | 27000.0 | 99000.0 | 27000.0 | .120 | .123 | .0 | .00253 | 82.00 | 919.91 | 222.34 | 1771.21 |
| 83.000 | 27000.0 | 99000.0 | 27000.0 | .135 | .139 | .0 | .00286 | 83.00 | 925.14 | 222.22 | 1771.21 |
| 84.000 | 27000.0 | 99000.0 | 27000.0 | .155 | .159 | .0 | .00328 | 84.00 | 932.50 | 222.05 | 1771.21 |
| 85.000 | 27000.0 | 99000.0 | 27000.0 | .181 | .185 | .0 | .00384 | 85.00 | 943.24 | 221.82 | 1771.21 |
| 86.000 | 27000.0 | 99000.0 | 27000.0 | .216 | .221 | .0 | .00460 | 86.00 | 959.57 | 221.49 | 1771.21 |
| 87.000 | 27000.0 | 99000.0 | 27000.0 | .267 | .273 | .0 | .00569 | 87.01 | 985.72 | 221.01 | 1771.21 |
| 88.000 | 27000.0 | 99000.0 | 27000.0 | .345 | .352 | .0 | .00734 | 88.01 | 1030.25 | 220.33 | 1771.21 |
| 89.200 | 27000.0 | 99000.0 | 27000.0 | .507 | .516 | .0 | .01077 | 89.21 | 1135.88 | 219.13 | 1771.21 |
| 89.400 | 27000.0 | 99000.0 | 27000.0 | .546 | .556 | .0 | .01161 | 89.41 | 1163.44 | 218.89 | 1771.21 |
| 89.600 | 27000.0 | 99000.0 | 27000.0 | .591 | .602 | .0 | .01256 | 89.61 | 1195.23 | 218.64 | 1771.21 |
| 89.800 | 27000.0 | 99000.0 | 27000.0 | .642 | .653 | .0 | .01363 | 89.81 | 1231.88 | 218.39 | 1771.21 |
| 90.000 | 27000.0 | 99000.0 | 27000.0 | .675 | .712 | .2 | .01486 | 90.01 | 1273.65 | 218.13 | 1738.55 |
| 90.200 | 27000.0 | 99000.0 | 26960.8 | .743 | .780 | 6.3 | .01627 | 90.22 | 1325.49 | 217.87 | 1751.11 |
| 90.400 | 27000.0 | 99000.0 | 26843.1 | .821 | .859 | 13.2 | .01791 | 90.42 | 1378.42 | 217.61 | 1786.68 |
| 90.600 | 27000.0 | 99000.0 | 26647.0 | .912 | .951 | 21.1 | .01981 | 90.62 | 1445.06 | 217.36 | 1846.11 |
| 90.800 | 27000.0 | 99000.0 | 26372.3 | 1.018 | 1.058 | 30.5 | .02203 | 90.82 | 1527.53 | 217.12 | 1931.87 |
| 91.000 | 27000.0 | 99000.0 | 26019.1 | 1.144 | 1.184 | 41.6 | .02465 | 91.02 | 1617.54 | 216.89 | 2047.59 |
| 91.200 | 27000.0 | 99000.0 | 25587.2 | 1.294 | 1.333 | 55.2 | .02775 | 91.23 | 1746.86 | 216.67 | 2199.07 |
| 91.400 | 27000.0 | 99000.0 | 25076.4 | 1.474 | 1.511 | 72.0 | .03146 | 91.43 | 1892.54 | 216.48 | 2392.67 |
| 91.600 | 27000.0 | 99000.0 | 24486.6 | 1.692 | 1.726 | 92.9 | .03591 | 91.64 | 2088.11 | 216.29 | 2638.69 |
| 91.800 | 27000.0 | 99000.0 | 23817.5 | 1.958 | 1.986 | 119.3 | .04132 | 91.84 | 2288.58 | 216.13 | 2948.50 |
| 92.000 | 27000.0 | 99000.0 | 23068.9 | 2.288 | 2.303 | 153.1 | .04793 | 92.05 | 2558.24 | 215.98 | 3342.34 |
| 92.200 | 27000.0 | 99000.0 | 22240.1 | 2.699 | 2.695 | 196.7 | .05607 | 92.26 | 2916.82 | 215.85 | 3841.99 |
| 92.400 | 27000.0 | 99000.0 | 21330.8 | 3.221 | 3.181 | 253.5 | .06621 | 92.47 | 3314.36 | 215.74 | 4483.69 |
| 92.600 | 27000.0 | 99000.0 | 20340.0 | 3.890 | 3.793 | 328.4 | .07894 | 92.68 | 3845.88 | 215.64 | 5315.61 |
| 92.800 | 27000.0 | 99000.0 | 19266.6 | 4.759 | 4.569 | 428.1 | .09511 | 92.90 | 4502.79 | 215.56 | 6411.50 |
| 93.000 | 27000.0 | 99000.0 | 18109.6 | 5.910 | 5.558 | 559.0 | .11523 | 93.12 | 5392.72 | 215.70 | 7870.39 |
| 93.200 | 27000.0 | 99000.0 | 16867.0 | 7.463 | 6.834 | 728.3 | .13992 | 93.34 | 6517.72 | 216.01 | 9847.37 |
| 93.400 | 27000.0 | 99000.0 | 15535.7 | 9.635 | 8.505 | 975.6 | .17448 | 93.57 | 7955.24 | 216.47 | 12637.24 |
| 93.600 | 27000.0 | 99000.0 | 14111.5 | 12.781 | 10.727 | 1319.2 | .22012 | 93.82 | 9938.51 | 216.94 | 16690.87 |
| 93.800 | 27000.0 | 99000.0 | 12589.5 | 17.514 | 13.717 | 1790.3 | .27938 | 94.08 | 12545.59 | 217.59 | 22804.76 |
| 94.000 | 27000.0 | 99000.0 | 10959.5 | 24.409 | 17.845 | 2482.6 | .36211 | 94.36 | 16215.72 | 218.22 | 32524.79 |
| 94.200 | 27000.0 | 99000.0 | 9228.9 | 33.871 | 23.300 | 3274.6 | .44981 | 94.65 | 21094.02 | 221.07 | 46743.68 |
| 94.400 | 27000.0 | 99000.0 | 7400.9 | 47.550 | 30.133 | 4132.7 | .53781 | 94.94 | 27391.40 | 227.81 | 67065.73 |
| 94.600 | 27000.0 | 99000.0 | 5450.6 | 70.040 | 39.150 | 5357.5 | .65798 | 95.26 | 35969.03 | 236.24 | 100618.43 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 28000.0 | 99000.0 | 28000.0 | .092 | .094 | .0 | .00193 | 81.00 | 781.91 | 223.72 | 1511.24 |
| 82.000 | 28000.0 | 99000.0 | 28000.0 | .102 | .105 | .0 | .00216 | 82.00 | 785.20 | 223.62 | 1511.24 |
| 83.000 | 28000.0 | 99000.0 | 28000.0 | .115 | .118 | .0 | .00244 | 83.00 | 789.69 | 223.49 | 1511.24 |
| 84.000 | 28000.0 | 99000.0 | 28000.0 | .132 | .135 | .0 | .00280 | 84.00 | 796.00 | 223.31 | 1511.24 |
| 85.000 | 28000.0 | 99000.0 | 28000.0 | .154 | .158 | .0 | .00328 | 85.00 | 805.20 | 223.05 | 1511.24 |
| 86.000 | 28000.0 | 99000.0 | 28000.0 | .184 | .189 | .0 | .00393 | 86.00 | 819.19 | 222.69 | 1511.24 |
| 87.000 | 28000.0 | 99000.0 | 28000.0 | .228 | .233 | .0 | .00486 | 87.00 | 841.55 | 222.17 | 1511.24 |
| 88.000 | 28000.0 | 99000.0 | 28000.0 | .294 | .300 | .0 | .00627 | 88.01 | 879.60 | 221.40 | 1511.24 |
| 89.200 | 28000.0 | 99000.0 | 28000.0 | .432 | .441 | .0 | .00922 | 89.21 | 969.73 | 220.02 | 1511.24 |
| 89.400 | 28000.0 | 99000.0 | 28000.0 | .466 | .475 | .0 | .00993 | 89.41 | 993.23 | 219.74 | 1511.24 |
| 89.600 | 28000.0 | 99000.0 | 28000.0 | .504 | .513 | .0 | .01074 | 89.61 | 1020.34 | 219.44 | 1511.24 |
| 89.800 | 28000.0 | 99000.0 | 28000.0 | .548 | .558 | .0 | .01166 | 89.81 | 1051.60 | 219.13 | 1511.24 |
| 90.000 | 28000.0 | 99000.0 | 28000.0 | .574 | .608 | .2 | .01271 | 90.01 | 1087.20 | 218.81 | 1481.31 |
| 90.200 | 28000.0 | 99000.0 | 27960.8 | .631 | .666 | 5.4 | .01391 | 90.21 | 1131.40 | 218.49 | 1491.79 |
| 90.400 | 28000.0 | 99000.0 | 27843.3 | .698 | .733 | 11.3 | .01531 | 90.42 | 1176.51 | 218.17 | 1521.84 |
| 90.600 | 28000.0 | 99000.0 | 27647.3 | .775 | .811 | 18.0 | .01693 | 90.62 | 1233.32 | 217.86 | 1571.61 |
| 90.800 | 28000.0 | 99000.0 | 27372.9 | .866 | .903 | 26.0 | .01882 | 90.82 | 1303.62 | 217.55 | 1644.78 |
| 91.000 | 28000.0 | 99000.0 | 27020.0 | .972 | 1.010 | 35.5 | .02105 | 91.02 | 1380.34 | 217.27 | 1742.78 |
| 91.200 | 28000.0 | 99000.0 | 26588.5 | 1.100 | 1.138 | 47.0 | .02369 | 91.22 | 1490.56 | 217.00 | 1871.02 |
| 91.400 | 28000.0 | 99000.0 | 26078.2 | 1.252 | 1.290 | 61.3 | .02685 | 91.43 | 1614.73 | 216.75 | 2034.81 |
| 91.600 | 28000.0 | 99000.0 | 25489.2 | 1.436 | 1.472 | 79.1 | .03065 | 91.63 | 1781.33 | 216.53 | 2242.04 |
| 91.800 | 28000.0 | 99000.0 | 24821.0 | 1.661 | 1.694 | 101.6 | .03525 | 91.84 | 1952.19 | 216.33 | 2504.19 |
| 92.000 | 28000.0 | 99000.0 | 24073.5 | 1.939 | 1.964 | 130.3 | .04087 | 92.04 | 2181.90 | 216.15 | 2835.18 |
| 92.200 | 28000.0 | 99000.0 | 23246.2 | 2.285 | 2.297 | 167.3 | .04780 | 92.25 | 2487.04 | 215.99 | 3255.93 |
| 92.400 | 28000.0 | 99000.0 | 22338.7 | 2.722 | 2.711 | 215.5 | .05641 | 92.46 | 2825.65 | 215.85 | 3793.59 |
| 92.600 | 28000.0 | 99000.0 | 21350.3 | 3.281 | 3.230 | 278.8 | .06722 | 92.67 | 3277.86 | 215.73 | 4487.77 |
| 92.800 | 28000.0 | 99000.0 | 20280.1 | 4.008 | 3.888 | 363.1 | .08092 | 92.88 | 3836.66 | 215.63 | 5397.34 |
| 93.000 | 28000.0 | 99000.0 | 19126.7 | 4.964 | 4.731 | 476.4 | .09849 | 93.10 | 4594.39 | 215.54 | 6606.95 |
| 93.200 | 28000.0 | 99000.0 | 17889.1 | 6.240 | 5.815 | 619.6 | .11949 | 93.32 | 5552.04 | 215.74 | 8229.66 |
| 93.400 | 28000.0 | 99000.0 | 16564.6 | 8.003 | 7.229 | 827.1 | .14861 | 93.55 | 6775.32 | 216.14 | 10492.05 |
| 93.600 | 28000.0 | 99000.0 | 15149.4 | 10.532 | 9.103 | 1115.6 | .18720 | 93.79 | 8458.22 | 216.56 | 13730.19 |
| 93.800 | 28000.0 | 99000.0 | 13639.7 | 14.241 | 11.615 | 1507.4 | .23688 | 94.04 | 10668.31 | 217.17 | 18511.69 |
| 94.000 | 28000.0 | 99000.0 | 12026.9 | 19.857 | 15.066 | 2096.0 | .30795 | 94.31 | 13607.38 | 217.76 | 26121.90 |
| 94.200 | 28000.0 | 99000.0 | 10301.7 | 28.434 | 19.882 | 2940.7 | .40427 | 94.60 | 17785.90 | 218.54 | 38282.76 |
| 94.400 | 28000.0 | 99000.0 | 8490.5 | 38.844 | 25.872 | 3610.7 | .47333 | 94.87 | 23465.36 | 223.77 | 54159.44 |
| 94.600 | 28000.0 | 99000.0 | 6561.9 | 55.907 | 33.738 | 4636.8 | .57558 | 95.18 | 30656.51 | 231.38 | 79806.73 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 29000.0 | 99000.0 | 29000.0 | .078 | .080 | .0 | .00165 | 81.00 | 667.47 | 225.22 | 1289.42 |
| 82.000 | 29000.0 | 99000.0 | 29000.0 | .087 | .090 | .0 | .00185 | 82.00 | 670.30 | 225.12 | 1289.42 |
| 83.000 | 29000.0 | 99000.0 | 29000.0 | .098 | .101 | .0 | .00209 | 83.00 | 674.15 | 224.98 | 1289.42 |
| 84.000 | 29000.0 | 99000.0 | 29000.0 | .113 | .116 | .0 | .00240 | 84.00 | 679.56 | 224.79 | 1289.42 |
| 85.000 | 29000.0 | 99000.0 | 29000.0 | .132 | .135 | .0 | .00280 | 85.00 | 687.45 | 224.52 | 1289.42 |
| 86.000 | 29000.0 | 99000.0 | 29000.0 | .157 | .161 | .0 | .00336 | 86.00 | 699.42 | 224.13 | 1289.42 |
| 87.000 | 29000.0 | 99000.0 | 29000.0 | .194 | .199 | .0 | .00415 | 87.00 | 718.55 | 223.57 | 1289.42 |
| 88.000 | 29000.0 | 99000.0 | 29000.0 | .251 | .256 | .0 | .00536 | 88.01 | 751.05 | 222.72 | 1289.42 |
| 89.200 | 29000.0 | 99000.0 | 29000.0 | .369 | .376 | .0 | .00789 | 89.21 | 827.94 | 221.18 | 1289.42 |
| 89.400 | 29000.0 | 99000.0 | 29000.0 | .397 | .405 | .0 | .00851 | 89.41 | 847.98 | 220.85 | 1289.42 |
| 89.600 | 29000.0 | 99000.0 | 29000.0 | .430 | .438 | .0 | .00921 | 89.61 | 871.11 | 220.49 | 1289.42 |
| 89.800 | 29000.0 | 99000.0 | 29000.0 | .467 | .476 | .0 | .01000 | 89.81 | 897.76 | 220.12 | 1289.42 |
| 90.000 | 29000.0 | 99000.0 | 29000.0 | .488 | .519 | .1 | .01090 | 90.01 | 928.13 | 219.72 | 1262.06 |
| 90.200 | 29000.0 | 99000.0 | 28960.8 | .537 | .568 | 4.6 | .01192 | 90.21 | 965.82 | 219.31 | 1270.84 |
| 90.400 | 29000.0 | 99000.0 | 28843.4 | .593 | .626 | 9.6 | .01311 | 90.41 | 1004.28 | 218.90 | 1296.26 |
| 90.600 | 29000.0 | 99000.0 | 28647.5 | .659 | .692 | 15.4 | .01448 | 90.61 | 1052.72 | 218.50 | 1338.41 |
| 90.800 | 29000.0 | 99000.0 | 28373.3 | .736 | .770 | 22.2 | .01609 | 90.82 | 1112.65 | 218.12 | 1400.46 |
| 91.000 | 29000.0 | 99000.0 | 28020.7 | .827 | .862 | 30.3 | .01799 | 91.02 | 1178.05 | 217.75 | 1483.52 |
| 91.200 | 29000.0 | 99000.0 | 27589.5 | .935 | .971 | 40.1 | .02024 | 91.22 | 1272.00 | 217.41 | 1592.20 |
| 91.400 | 29000.0 | 99000.0 | 27079.8 | 1.064 | 1.101 | 52.3 | .02293 | 91.42 | 1377.84 | 217.10 | 1730.91 |
| 91.600 | 29000.0 | 99000.0 | 26491.3 | 1.220 | 1.256 | 67.4 | .02616 | 91.63 | 1519.78 | 216.82 | 1906.26 |
| 91.800 | 29000.0 | 99000.0 | 25823.9 | 1.410 | 1.445 | 86.5 | .03008 | 91.83 | 1665.43 | 216.57 | 2127.84 |
| 92.000 | 29000.0 | 99000.0 | 25077.3 | 1.645 | 1.676 | 110.9 | .03487 | 92.03 | 1861.14 | 216.35 | 2407.16 |
| 92.200 | 29000.0 | 99000.0 | 24251.3 | 1.937 | 1.959 | 142.4 | .04076 | 92.24 | 2094.45 | 216.16 | 2761.55 |
| 92.400 | 29000.0 | 99000.0 | 23345.4 | 2.304 | 2.311 | 183.2 | .04808 | 92.45 | 2409.38 | 215.99 | 3213.21 |
| 92.600 | 29000.0 | 99000.0 | 22359.0 | 2.772 | 2.752 | 237.0 | .05727 | 92.66 | 2794.27 | 215.84 | 3794.34 |
| 92.800 | 29000.0 | 99000.0 | 21291.4 | 3.377 | 3.311 | 308.3 | .06890 | 92.87 | 3269.81 | 215.72 | 4551.20 |
| 93.000 | 29000.0 | 99000.0 | 20141.4 | 4.174 | 4.025 | 403.9 | .08378 | 93.08 | 3913.64 | 215.61 | 5553.41 |
| 93.200 | 29000.0 | 99000.0 | 18907.7 | 5.233 | 4.949 | 528.2 | .10216 | 93.30 | 4729.49 | 215.55 | 6898.13 |
| 93.400 | 29000.0 | 99000.0 | 17588.9 | 6.676 | 6.148 | 702.4 | .12671 | 93.53 | 5770.97 | 215.86 | 8746.92 |
| 93.600 | 29000.0 | 99000.0 | 16181.3 | 8.717 | 7.733 | 945.4 | .15939 | 93.76 | 7200.09 | 216.21 | 11357.75 |
| 93.800 | 29000.0 | 99000.0 | 14681.9 | 11.661 | 9.850 | 1272.3 | .20113 | 94.00 | 9075.35 | 216.77 | 15148.51 |
| 94.000 | 29000.0 | 99000.0 | 13083.4 | 16.210 | 12.742 | 1763.3 | .26095 | 94.26 | 11567.89 | 217.33 | 21021.15 |
| 94.200 | 29000.0 | 99000.0 | 11378.5 | 22.910 | 16.748 | 2458.5 | .34110 | 94.54 | 15093.03 | 218.07 | 30461.12 |
| 94.400 | 29000.0 | 99000.0 | 9570.2 | 32.235 | 22.138 | 3167.4 | .41750 | 94.82 | 19839.11 | 220.43 | 43876.99 |
| 94.600 | 29000.0 | 99000.0 | 7660.9 | 45.122 | 29.004 | 3983.1 | .49989 | 95.10 | 26321.00 | 226.90 | 63571.39 |
| 94.800 | 29000.0 | 99000.0 | 5626.9 | 68.074 | 38.182 | 5300.9 | .62716 | 95.43 | 34934.60 | 235.49 | 97718.80 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 30000.0 | 99000.0 | 30000.0 | .067 | .069 | .0 | .00140 | 81.00 | 569.98 | 226.99 | 1100.16 |
| 82.000 | 30000.0 | 99000.0 | 30000.0 | .074 | .077 | .0 | .00156 | 82.00 | 572.40 | 226.89 | 1100.16 |
| 83.000 | 30000.0 | 99000.0 | 30000.0 | .084 | .086 | .0 | .00176 | 83.00 | 575.71 | 226.74 | 1100.16 |
| 84.000 | 30000.0 | 99000.0 | 30000.0 | .096 | .099 | .0 | .00203 | 84.00 | 580.36 | 226.54 | 1100.16 |
| 85.000 | 30000.0 | 99000.0 | 30000.0 | .112 | .115 | .0 | .00237 | 85.00 | 587.12 | 226.26 | 1100.16 |
| 86.000 | 30000.0 | 99000.0 | 30000.0 | .134 | .138 | .0 | .00284 | 86.00 | 597.37 | 225.86 | 1100.16 |
| 87.000 | 30000.0 | 99000.0 | 30000.0 | .166 | .170 | .0 | .00351 | 87.00 | 613.73 | 225.26 | 1100.16 |
| 88.000 | 30000.0 | 99000.0 | 30000.0 | .214 | .219 | .0 | .00452 | 88.00 | 641.48 | 224.37 | 1100.16 |
| 89.200 | 30000.0 | 99000.0 | 30000.0 | .314 | .320 | .0 | .00663 | 89.21 | 706.93 | 222.76 | 1100.16 |
| 89.400 | 30000.0 | 99000.0 | 30000.0 | .339 | .345 | .0 | .00714 | 89.41 | 723.95 | 222.44 | 1100.16 |
| 89.600 | 30000.0 | 99000.0 | 30000.0 | .367 | .373 | .0 | .00772 | 89.61 | 743.58 | 222.10 | 1100.16 |
| 89.800 | 30000.0 | 99000.0 | 30000.0 | .398 | .405 | .0 | .00837 | 89.81 | 766.19 | 221.75 | 1100.16 |
| 90.000 | 30000.0 | 99000.0 | 30000.0 | .409 | .441 | .1 | .00912 | 90.01 | 791.94 | 221.40 | 1075.68 |
| 90.200 | 30000.0 | 99000.0 | 29960.8 | .450 | .483 | 4.0 | .01041 | 90.21 | 823.99 | 220.84 | 1082.98 |
| 90.400 | 30000.0 | 99000.0 | 29843.3 | .505 | .533 | 8.6 | .01188 | 90.41 | 856.94 | 220.16 | 1104.20 |
| 90.600 | 30000.0 | 99000.0 | 29647.5 | .560 | .590 | 13.4 | .01283 | 90.61 | 898.50 | 219.43 | 1139.94 |
| 90.800 | 30000.0 | 99000.0 | 29373.4 | .626 | .657 | 19.1 | .01401 | 90.81 | 949.70 | 218.89 | 1192.57 |
| 91.000 | 30000.0 | 99000.0 | 29021.0 | .703 | .736 | 25.9 | .01555 | 91.02 | 1005.50 | 218.39 | 1263.02 |
| 91.200 | 30000.0 | 99000.0 | 28590.2 | .795 | .828 | 34.3 | .01743 | 91.22 | 1085.63 | 217.95 | 1355.20 |
| 91.400 | 30000.0 | 99000.0 | 28080.8 | .904 | .939 | 44.6 | .01969 | 91.42 | 1175.86 | 217.55 | 1472.79 |
| 91.600 | 30000.0 | 99000.0 | 27492.8 | 1.037 | 1.072 | 57.5 | .02243 | 91.62 | 1296.83 | 217.19 | 1621.32 |
| 91.800 | 30000.0 | 99000.0 | 26826.0 | 1.198 | 1.233 | 73.8 | .02576 | 91.83 | 1420.99 | 216.88 | 1808.84 |
| 92.000 | 30000.0 | 99000.0 | 26080.3 | 1.396 | 1.430 | 94.5 | .02982 | 92.03 | 1587.78 | 216.60 | 2044.92 |
| 92.200 | 30000.0 | 99000.0 | 25255.3 | 1.643 | 1.671 | 121.3 | .03484 | 92.23 | 1786.59 | 216.36 | 2343.96 |
| 92.400 | 30000.0 | 99000.0 | 24350.6 | 1.951 | 1.971 | 156.0 | .04106 | 92.44 | 2054.81 | 216.15 | 2723.40 |
| 92.600 | 30000.0 | 99000.0 | 23365.9 | 2.344 | 2.346 | 201.6 | .04886 | 92.65 | 2382.52 | 215.98 | 3211.14 |
| 92.800 | 30000.0 | 99000.0 | 22300.5 | 2.851 | 2.821 | 262.0 | .05874 | 92.86 | 2787.37 | 215.83 | 3845.00 |
| 93.000 | 30000.0 | 99000.0 | 21153.4 | 3.515 | 3.427 | 343.0 | .07137 | 93.07 | 3334.77 | 215.70 | 4678.90 |
| 93.200 | 30000.0 | 99000.0 | 19923.4 | 4.399 | 4.211 | 452.6 | .08769 | 93.29 | 4028.37 | 215.59 | 5795.02 |
| 93.400 | 30000.0 | 99000.0 | 18609.1 | 5.593 | 5.232 | 597.6 | .10819 | 93.51 | 4915.88 | 215.65 | 7313.85 |
| 93.600 | 30000.0 | 99000.0 | 17207.9 | 7.250 | 6.575 | 802.7 | .13590 | 93.74 | 6130.36 | 215.91 | 9440.33 |
| 93.800 | 30000.0 | 99000.0 | 15717.0 | 9.611 | 8.364 | 1075.9 | .17099 | 93.97 | 7722.80 | 216.40 | 12477.62 |
| 94.000 | 30000.0 | 99000.0 | 14130.5 | 13.187 | 10.796 | 1488.0 | .22158 | 94.22 | 9838.71 | 216.92 | 17088.72 |
| 94.200 | 30000.0 | 99000.0 | 12442.3 | 18.809 | 14.146 | 2064.0 | .28860 | 94.49 | 12816.74 | 217.63 | 24353.31 |
| 94.400 | 30000.0 | 99000.0 | 10640.6 | 27.025 | 18.876 | 2915.4 | .38262 | 94.78 | 16906.33 | 218.41 | 36327.92 |
| 94.600 | 30000.0 | 99000.0 | 8748.4 | 36.141 | 24.789 | 3248.1 | .41592 | 95.02 | 22496.86 | 222.90 | 49741.93 |
| 94.800 | 30000.0 | 99000.0 | 6736.8 | 53.294 | 32.793 | 4384.1 | .52862 | 95.33 | 30009.78 | 230.59 | 75519.96 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 31000.0 | 99000.0 | 31000.0 | .057 | .059 | .0 | .00120 | 81.00 | 487.55 | 228.67 | 940.37 |
| 82.000 | 31000.0 | 99000.0 | 31000.0 | .064 | .066 | .0 | .00134 | 82.00 | 489.63 | 228.56 | 940.37 |
| 83.000 | 31000.0 | 99000.0 | 31000.0 | .072 | .074 | .0 | .00151 | 83.00 | 492.48 | 228.41 | 940.37 |
| 84.000 | 31000.0 | 99000.0 | 31000.0 | .082 | .085 | .0 | .00173 | 84.00 | 496.48 | 228.20 | 940.37 |
| 85.000 | 31000.0 | 99000.0 | 31000.0 | .096 | .099 | .0 | .00203 | 85.00 | 502.29 | 227.90 | 940.37 |
| 86.000 | 31000.0 | 99000.0 | 31000.0 | .115 | .118 | .0 | .00243 | 86.00 | 511.09 | 227.46 | 940.37 |
| 87.000 | 31000.0 | 99000.0 | 31000.0 | .142 | .145 | .0 | .00300 | 87.00 | 525.12 | 226.81 | 940.37 |
| 88.000 | 31000.0 | 99000.0 | 31000.0 | .182 | .187 | .0 | .00387 | 88.00 | 548.87 | 225.82 | 940.37 |
| 89.200 | 31000.0 | 99000.0 | 31000.0 | .268 | .274 | .0 | .00568 | 89.21 | 604.81 | 223.97 | 940.37 |
| 89.400 | 31000.0 | 99000.0 | 31000.0 | .288 | .295 | .0 | .00612 | 89.41 | 619.35 | 223.58 | 940.37 |
| 89.600 | 31000.0 | 99000.0 | 31000.0 | .312 | .319 | .0 | .00661 | 89.61 | 636.11 | 223.17 | 940.37 |
| 89.800 | 31000.0 | 99000.0 | 31000.0 | .339 | .346 | .0 | .00718 | 89.81 | 655.41 | 222.75 | 940.37 |
| 90.000 | 31000.0 | 99000.0 | 31000.0 | .352 | .377 | .1 | .00782 | 90.01 | 677.38 | 222.32 | 917.87 |
| 90.200 | 31000.0 | 99000.0 | 30960.9 | .387 | .413 | 3.3 | .00855 | 90.21 | 704.63 | 221.88 | 924.00 |
| 90.400 | 31000.0 | 99000.0 | 30843.5 | .427 | .455 | 6.9 | .00940 | 90.41 | 732.44 | 221.45 | 942.09 |
| 90.600 | 31000.0 | 99000.0 | 30647.9 | .474 | .503 | 11.0 | .01039 | 90.61 | 767.44 | 221.03 | 972.13 |
| 90.800 | 31000.0 | 99000.0 | 30374.0 | .529 | .559 | 15.8 | .01154 | 90.81 | 810.71 | 220.62 | 1016.04 |
| 91.000 | 31000.0 | 99000.0 | 30021.8 | .594 | .625 | 21.6 | .01289 | 91.01 | 857.91 | 220.23 | 1075.63 |
| 91.200 | 31000.0 | 99000.0 | 29590.9 | .677 | .705 | 29.9 | .01513 | 91.22 | 926.46 | 219.03 | 1153.65 |
| 91.400 | 31000.0 | 99000.0 | 29081.9 | .770 | .801 | 38.3 | .01689 | 91.42 | 1003.56 | 218.36 | 1253.33 |
| 91.600 | 31000.0 | 99000.0 | 28494.3 | .882 | .914 | 49.2 | .01919 | 91.62 | 1106.75 | 217.83 | 1379.24 |
| 91.800 | 31000.0 | 99000.0 | 27828.1 | 1.019 | 1.052 | 63.0 | .02201 | 91.82 | 1212.63 | 217.39 | 1538.09 |
| 92.000 | 31000.0 | 99000.0 | 27083.0 | 1.187 | 1.219 | 80.6 | .02546 | 92.03 | 1354.80 | 217.01 | 1737.85 |
| 92.200 | 31000.0 | 99000.0 | 26258.8 | 1.394 | 1.425 | 103.3 | .02973 | 92.23 | 1524.26 | 216.69 | 1989.90 |
| 92.400 | 31000.0 | 99000.0 | 25355.3 | 1.655 | 1.681 | 132.9 | .03503 | 92.44 | 1752.75 | 216.41 | 2310.56 |
| 92.600 | 31000.0 | 99000.0 | 24372.0 | 1.986 | 2.000 | 171.6 | .04166 | 92.64 | 2031.86 | 216.18 | 2720.91 |
| 92.800 | 31000.0 | 99000.0 | 23308.4 | 2.411 | 2.404 | 222.8 | .05006 | 92.85 | 2376.62 | 215.99 | 3252.53 |
| 93.000 | 31000.0 | 99000.0 | 22163.7 | 2.965 | 2.919 | 291.4 | .06078 | 93.06 | 2842.26 | 215.83 | 3948.92 |
| 93.200 | 31000.0 | 99000.0 | 20936.8 | 3.700 | 3.584 | 384.2 | .07462 | 93.27 | 3431.94 | 215.69 | 4875.65 |
| 93.400 | 31000.0 | 99000.0 | 19626.3 | 4.695 | 4.452 | 511.1 | .09270 | 93.49 | 4187.36 | 215.58 | 6134.47 |
| 93.600 | 31000.0 | 99000.0 | 18230.5 | 6.052 | 5.593 | 682.6 | .11595 | 93.72 | 5220.11 | 215.69 | 7873.73 |
| 93.800 | 31000.0 | 99000.0 | 16746.8 | 7.963 | 7.108 | 910.0 | .14529 | 93.95 | 6573.15 | 216.08 | 10329.42 |
| 94.000 | 31000.0 | 99000.0 | 15170.2 | 10.812 | 9.159 | 1258.7 | .18839 | 94.19 | 8370.79 | 216.55 | 13998.95 |
| 94.200 | 31000.0 | 99000.0 | 13495.9 | 15.174 | 11.971 | 1738.5 | .24466 | 94.44 | 10889.41 | 217.21 | 19630.52 |
| 94.400 | 31000.0 | 99000.0 | 11714.0 | 22.019 | 15.912 | 2436.3 | .32251 | 94.72 | 14342.00 | 217.94 | 28842.92 |
| 94.600 | 31000.0 | 99000.0 | 9821.6 | 30.210 | 21.272 | 2949.1 | .37727 | 94.98 | 19033.46 | 219.44 | 41074.84 |
| 94.800 | 31000.0 | 99000.0 | 7828.1 | 43.329 | 28.265 | 3833.6 | .46595 | 95.27 | 25526.41 | 225.81 | 60993.98 |
| 95.000 | 31000.0 | 99000.0 | 5715.3 | 67.040 | 37.648 | 5262.8 | .60091 | 95.60 | 34545.26 | 235.04 | 96179.51 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 32000.0 | 99000.0 | 32000.0 | .049 | .050 | .0 | .00102 | 81.00 | 417.15 | 230.65 | 803.63 |
| 82.000 | 32000.0 | 99000.0 | 32000.0 | .054 | .056 | .0 | .00114 | 82.00 | 418.95 | 230.53 | 803.63 |
| 83.000 | 32000.0 | 99000.0 | 32000.0 | .061 | .063 | .0 | .00129 | 83.00 | 421.40 | 230.37 | 803.63 |
| 84.000 | 32000.0 | 99000.0 | 32000.0 | .070 | .072 | .0 | .00148 | 84.00 | 424.84 | 230.15 | 803.63 |
| 85.000 | 32000.0 | 99000.0 | 32000.0 | .082 | .084 | .0 | .00174 | 85.00 | 429.83 | 229.84 | 803.63 |
| 86.000 | 32000.0 | 99000.0 | 32000.0 | .098 | .101 | .0 | .00208 | 86.00 | 437.39 | 229.39 | 803.63 |
| 87.000 | 32000.0 | 99000.0 | 32000.0 | .121 | .124 | .0 | .00257 | 87.00 | 449.43 | 228.70 | 803.63 |
| 88.000 | 32000.0 | 99000.0 | 32000.0 | .156 | .160 | .0 | .00332 | 88.00 | 469.77 | 227.62 | 803.63 |
| 89.200 | 32000.0 | 99000.0 | 32000.0 | .229 | .234 | .0 | .00487 | 89.20 | 517.59 | 225.50 | 803.63 |
| 89.400 | 32000.0 | 99000.0 | 32000.0 | .246 | .252 | .0 | .00525 | 89.41 | 530.01 | 225.04 | 803.63 |
| 89.600 | 32000.0 | 99000.0 | 32000.0 | .266 | .272 | .0 | .00568 | 89.61 | 544.32 | 224.55 | 803.63 |
| 89.800 | 32000.0 | 99000.0 | 32000.0 | .289 | .296 | .0 | .00616 | 89.81 | 560.79 | 224.03 | 803.63 |
| 90.000 | 32000.0 | 99000.0 | 32000.0 | .299 | .322 | .0 | .00671 | 90.01 | 579.54 | 223.50 | 783.18 |
| 90.200 | 32000.0 | 99000.0 | 31960.9 | .329 | .353 | 2.8 | .00734 | 90.21 | 602.80 | 222.96 | 788.35 |
| 90.400 | 32000.0 | 99000.0 | 31843.6 | .364 | .388 | 5.9 | .00806 | 90.41 | 626.53 | 222.41 | 803.72 |
| 90.600 | 32000.0 | 99000.0 | 31648.0 | .404 | .430 | 9.4 | .00890 | 90.61 | 656.39 | 221.88 | 829.26 |
| 90.800 | 32000.0 | 99000.0 | 31374.2 | .451 | .478 | 13.6 | .00989 | 90.81 | 693.31 | 221.37 | 866.62 |
| 91.000 | 32000.0 | 99000.0 | 31022.2 | .506 | .534 | 18.5 | .01104 | 91.01 | 733.60 | 220.88 | 917.33 |
| 91.200 | 32000.0 | 99000.0 | 30591.8 | .572 | .601 | 24.5 | .01241 | 91.21 | 791.38 | 220.42 | 983.19 |
| 91.400 | 32000.0 | 99000.0 | 30083.1 | .650 | .681 | 31.9 | .01404 | 91.41 | 856.41 | 220.01 | 1067.05 |
| 91.600 | 32000.0 | 99000.0 | 29495.5 | .750 | .779 | 42.6 | .01657 | 91.62 | 944.55 | 218.78 | 1173.62 |
| 91.800 | 32000.0 | 99000.0 | 28829.7 | .866 | .897 | 53.9 | .01885 | 91.82 | 1034.94 | 218.08 | 1308.24 |
| 92.000 | 32000.0 | 99000.0 | 28085.2 | 1.008 | 1.040 | 68.9 | .02176 | 92.02 | 1156.16 | 217.54 | 1477.44 |
| 92.200 | 32000.0 | 99000.0 | 27261.7 | 1.184 | 1.216 | 88.2 | .02539 | 92.23 | 1300.61 | 217.10 | 1690.68 |
| 92.400 | 32000.0 | 99000.0 | 26359.1 | 1.404 | 1.434 | 113.2 | .02989 | 92.43 | 1495.31 | 216.74 | 1961.55 |
| 92.600 | 32000.0 | 99000.0 | 25377.0 | 1.683 | 1.706 | 146.1 | .03554 | 92.64 | 1733.07 | 216.44 | 2307.47 |
| 92.800 | 32000.0 | 99000.0 | 24314.9 | 2.041 | 2.050 | 189.7 | .04268 | 92.84 | 2026.75 | 216.19 | 2754.42 |
| 93.000 | 32000.0 | 99000.0 | 23172.2 | 2.504 | 2.488 | 247.9 | .05179 | 93.05 | 2423.00 | 215.98 | 3336.84 |
| 93.200 | 32000.0 | 99000.0 | 21948.0 | 3.118 | 3.053 | 326.4 | .06355 | 93.26 | 2924.59 | 215.81 | 4110.36 |
| 93.400 | 32000.0 | 99000.0 | 20641.0 | 3.941 | 3.789 | 433.7 | .07887 | 93.48 | 3566.98 | 215.68 | 5151.72 |
| 93.600 | 32000.0 | 99000.0 | 19249.5 | 5.069 | 4.759 | 582.2 | .09912 | 93.70 | 4445.24 | 215.57 | 6589.27 |
| 93.800 | 32000.0 | 99000.0 | 17771.8 | 6.636 | 6.045 | 772.6 | .12380 | 93.92 | 5531.67 | 215.81 | 8590.58 |
| 94.000 | 32000.0 | 99000.0 | 16203.6 | 8.929 | 7.780 | 1067.0 | .16037 | 94.16 | 7123.84 | 216.21 | 11538.63 |
| 94.200 | 32000.0 | 99000.0 | 14540.8 | 12.370 | 10.148 | 1468.3 | .20776 | 94.41 | 9155.35 | 216.81 | 15972.02 |
| 94.400 | 32000.0 | 99000.0 | 12775.2 | 17.819 | 13.446 | 2040.1 | .27214 | 94.67 | 12038.10 | 217.49 | 23032.83 |
| 94.600 | 32000.0 | 99000.0 | 10894.9 | 26.142 | 18.159 | 2930.6 | .36740 | 94.97 | 16223.44 | 218.24 | 35097.53 |
| 94.800 | 32000.0 | 99000.0 | 8909.5 | 36.953 | 24.382 | 3563.4 | .43113 | 95.23 | 21897.88 | 221.73 | 50805.92 |
| 95.000 | 32000.0 | 99000.0 | 6818.7 | 53.362 | 32.436 | 4470.8 | .51771 | 95.52 | 29428.34 | 229.88 | 75565.93 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HOIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 33000.0 | 99000.0 | 33000.0 | .042 | .043 | .0 | .00088 | 81.00 | 357.04 | 232.97 | 686.78 |
| 82.000 | 33000.0 | 99000.0 | 33000.0 | .046 | .048 | .0 | .00098 | 82.00 | 358.59 | 232.85 | 686.78 |
| 83.000 | 33000.0 | 99000.0 | 33000.0 | .052 | .054 | .0 | .00111 | 83.00 | 360.70 | 232.69 | 686.78 |
| 84.000 | 33000.0 | 99000.0 | 33000.0 | .060 | .062 | .0 | .00127 | 84.00 | 363.66 | 232.47 | 686.78 |
| 85.000 | 33000.0 | 99000.0 | 33000.0 | .070 | .072 | .0 | .00149 | 85.00 | 367.96 | 232.16 | 686.78 |
| 86.000 | 33000.0 | 99000.0 | 33000.0 | .084 | .086 | .0 | .00178 | 86.00 | 374.45 | 231.69 | 686.78 |
| 87.000 | 33000.0 | 99000.0 | 33000.0 | .103 | .106 | .0 | .00220 | 87.00 | 384.77 | 230.98 | 686.78 |
| 88.000 | 33000.0 | 99000.0 | 33000.0 | .133 | .136 | .0 | .00285 | 88.00 | 402.19 | 229.85 | 686.78 |
| 89.200 | 33000.0 | 99000.0 | 33000.0 | .195 | .200 | .0 | .00419 | 89.20 | 443.07 | 227.50 | 686.78 |
| 89.400 | 33000.0 | 99000.0 | 33000.0 | .210 | .215 | .0 | .00452 | 89.40 | 453.68 | 226.96 | 686.78 |
| 89.600 | 33000.0 | 99000.0 | 33000.0 | .228 | .232 | .0 | .00488 | 89.60 | 465.90 | 226.37 | 686.78 |
| 89.800 | 33000.0 | 99000.0 | 33000.0 | .247 | .252 | .0 | .00530 | 89.81 | 479.97 | 225.74 | 686.78 |
| 90.000 | 33000.0 | 99000.0 | 33000.0 | .255 | .275 | .0 | .00577 | 90.01 | 495.98 | 225.07 | 668.22 |
| 90.200 | 33000.0 | 99000.0 | 32960.9 | .281 | .301 | 2.4 | .00631 | 90.21 | 515.82 | 224.38 | 672.59 |
| 90.400 | 33000.0 | 99000.0 | 32843.6 | .310 | .332 | 5.0 | .00692 | 90.41 | 536.07 | 223.69 | 685.38 |
| 90.600 | 33000.0 | 99000.0 | 32648.1 | .344 | .367 | 8.1 | .00764 | 90.61 | 561.55 | 223.00 | 707.39 |
| 90.800 | 33000.0 | 99000.0 | 32374.4 | .384 | .408 | 11.6 | .00848 | 90.81 | 593.06 | 222.34 | 739.18 |
| 91.000 | 33000.0 | 99000.0 | 32022.5 | .431 | .457 | 15.8 | .00946 | 91.01 | 627.43 | 221.71 | 782.36 |
| 91.200 | 33000.0 | 99000.0 | 31592.3 | .487 | .514 | 21.0 | .01063 | 91.21 | 676.76 | 221.13 | 838.41 |
| 91.400 | 33000.0 | 99000.0 | 31083.7 | .554 | .582 | 27.3 | .01202 | 91.41 | 732.27 | 220.60 | 909.76 |
| 91.600 | 33000.0 | 99000.0 | 30496.8 | .633 | .664 | 35.1 | .01369 | 91.61 | 806.55 | 220.13 | 999.65 |
| 91.800 | 33000.0 | 99000.0 | 29831.1 | .736 | .763 | 48.1 | .01665 | 91.82 | 883.11 | 219.37 | 1113.29 |
| 92.000 | 33000.0 | 99000.0 | 29087.0 | .857 | .887 | 59.1 | .01866 | 92.02 | 986.73 | 218.27 | 1256.47 |
| 92.200 | 33000.0 | 99000.0 | 28264.1 | 1.006 | 1.037 | 75.3 | .02170 | 92.22 | 1109.92 | 217.64 | 1437.03 |
| 92.400 | 33000.0 | 99000.0 | 27362.2 | 1.192 | 1.223 | 96.6 | .02553 | 92.43 | 1275.85 | 217.15 | 1666.15 |
| 92.600 | 33000.0 | 99000.0 | 26381.1 | 1.428 | 1.455 | 124.6 | .03033 | 92.63 | 1478.45 | 216.76 | 1958.23 |
| 92.800 | 33000.0 | 99000.0 | 25320.3 | 1.728 | 1.748 | 161.6 | .03641 | 92.84 | 1728.66 | 216.44 | 2334.05 |
| 93.000 | 33000.0 | 99000.0 | 24179.2 | 2.118 | 2.121 | 211.0 | .04416 | 93.04 | 2066.00 | 216.17 | 2823.92 |
| 93.200 | 33000.0 | 99000.0 | 22957.2 | 2.631 | 2.601 | 277.6 | .05414 | 93.25 | 2492.83 | 215.96 | 3470.01 |
| 93.400 | 33000.0 | 99000.0 | 21653.2 | 3.317 | 3.226 | 368.4 | .06715 | 93.47 | 3039.37 | 215.79 | 4337.26 |
| 93.600 | 33000.0 | 99000.0 | 20265.6 | 4.252 | 4.049 | 493.7 | .08429 | 93.68 | 3740.96 | 215.65 | 5523.10 |
| 93.800 | 33000.0 | 99000.0 | 18792.7 | 5.546 | 5.143 | 658.4 | .10577 | 93.91 | 4711.87 | 215.63 | 7172.90 |
| 94.000 | 33000.0 | 99000.0 | 17231.6 | 7.404 | 6.613 | 906.0 | .13666 | 94.14 | 6063.91 | 215.92 | 9559.58 |
| 94.200 | 33000.0 | 99000.0 | 15578.4 | 10.150 | 8.613 | 1242.8 | .17667 | 94.38 | 7792.19 | 216.45 | 13092.88 |
| 94.400 | 33000.0 | 99000.0 | 13826.3 | 14.420 | 11.387 | 1724.6 | .23131 | 94.63 | 10237.78 | 217.05 | 18600.49 |
| 94.600 | 33000.0 | 99000.0 | 11965.6 | 21.329 | 15.322 | 2469.9 | .31176 | 94.91 | 13767.12 | 217.77 | 27903.85 |
| 94.800 | 33000.0 | 99000.0 | 9982.8 | 31.596 | 20.962 | 3421.9 | .40958 | 95.21 | 18725.39 | 218.65 | 42911.58 |
| 95.000 | 33000.0 | 99000.0 | 7909.3 | 44.786 | 28.078 | 4162.1 | .47999 | 95.48 | 25318.28 | 225.24 | 62997.64 |
| 95.200 | 33000.0 | 99000.0 | 5715.7 | 69.064 | 37.673 | 5496.6 | .60131 | 95.80 | 34517.58 | 235.02 | 99038.40 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUOE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 34000.0 | 99000.0 | 34000.0 | .036 | .037 | .0 | .00075 | 81.00 | 305.73 | 235.70 | 586.91 |
| 82.000 | 34000.0 | 99000.0 | 34000.0 | .040 | .041 | .0 | .00084 | 82.00 | 307.07 | 235.59 | 586.91 |
| 83.000 | 34000.0 | 99000.0 | 34000.0 | .045 | .046 | .0 | .00095 | 83.00 | 308.89 | 235.44 | 586.91 |
| 84.000 | 34000.0 | 99000.0 | 34000.0 | .051 | .053 | .0 | .00109 | 84.00 | 311.43 | 235.22 | 586.91 |
| 85.000 | 34000.0 | 99000.0 | 34000.0 | .060 | .062 | .0 | .00127 | 85.00 | 315.13 | 234.92 | 586.91 |
| 86.000 | 34000.0 | 99000.0 | 34000.0 | .072 | .074 | .0 | .00153 | 86.00 | 320.70 | 234.47 | 586.91 |
| 87.000 | 34000.0 | 99000.0 | 34000.0 | .088 | .091 | .0 | .00189 | 87.00 | 329.54 | 233.77 | 586.91 |
| 88.000 | 34000.0 | 99000.0 | 34000.0 | .114 | .116 | .0 | .00245 | 88.00 | 344.43 | 232.65 | 586.91 |
| 89.200 | 34000.0 | 99000.0 | 34000.0 | .167 | .170 | .0 | .00363 | 89.20 | 379.30 | 230.23 | 586.91 |
| 89.400 | 34000.0 | 99000.0 | 34000.0 | .180 | .183 | .0 | .00392 | 89.40 | 388.36 | 229.63 | 586.91 |
| 89.600 | 34000.0 | 99000.0 | 34000.0 | .194 | .198 | .0 | .00425 | 89.60 | 398.80 | 228.94 | 586.91 |
| 89.800 | 34000.0 | 99000.0 | 34000.0 | .211 | .215 | .0 | .00461 | 89.80 | 410.82 | 228.18 | 586.91 |
| 90.000 | 34000.0 | 99000.0 | 34000.0 | .217 | .234 | .0 | .00502 | 90.01 | 424.51 | 227.33 | 570.11 |
| 90.200 | 34000.0 | 99000.0 | 33960.9 | .239 | .257 | 2.1 | .00547 | 90.21 | 441.48 | 226.41 | 573.80 |
| 90.400 | 34000.0 | 99000.0 | 33843.7 | .264 | .283 | 4.4 | .00599 | 90.41 | 458.77 | 225.48 | 584.68 |
| 90.600 | 34000.0 | 99000.0 | 33648.2 | .293 | .313 | 7.0 | .00659 | 90.61 | 480.53 | 224.55 | 603.42 |
| 90.800 | 34000.0 | 99000.0 | 33374.6 | .327 | .349 | 10.0 | .00730 | 90.81 | 507.43 | 223.66 | 630.49 |
| 91.000 | 34000.0 | 99000.0 | 33022.7 | .367 | .390 | 13.6 | .00813 | 91.01 | 536.75 | 222.82 | 667.26 |
| 91.200 | 34000.0 | 99000.0 | 32592.6 | .415 | .439 | 18.0 | .00912 | 91.21 | 578.86 | 222.06 | 714.98 |
| 91.400 | 34000.0 | 99000.0 | 32084.2 | .472 | .497 | 23.4 | .01030 | 91.41 | 626.24 | 221.37 | 775.72 |
| 91.600 | 34000.0 | 99000.0 | 31497.5 | .540 | .567 | 30.0 | .01173 | 91.61 | 689.65 | 220.76 | 852.20 |
| 91.800 | 34000.0 | 99000.0 | 30832.3 | .622 | .652 | 38.5 | .01345 | 91.81 | 754.76 | 220.22 | 948.44 |
| 92.000 | 34000.0 | 99000.0 | 30088.6 | .723 | .754 | 49.1 | .01555 | 92.02 | 842.03 | 219.75 | 1069.01 |
| 92.200 | 34000.0 | 99000.0 | 29266.0 | .854 | .884 | 64.7 | .01864 | 92.22 | 947.24 | 218.42 | 1221.91 |
| 92.400 | 34000.0 | 99000.0 | 28364.8 | 1.012 | 1.043 | 82.6 | .02183 | 92.42 | 1088.75 | 217.70 | 1415.88 |
| 92.600 | 34000.0 | 99000.0 | 27384.4 | 1.212 | 1.241 | 106.3 | .02590 | 92.63 | 1261.42 | 217.17 | 1662.83 |
| 92.800 | 34000.0 | 99000.0 | 26324.7 | 1.466 | 1.491 | 137.7 | .03107 | 92.83 | 1474.63 | 216.75 | 1979.98 |
| 93.000 | 34000.0 | 99000.0 | 25185.0 | 1.794 | 1.809 | 179.7 | .03766 | 93.04 | 1761.91 | 216.41 | 2392.32 |
| 93.200 | 34000.0 | 99000.0 | 23964.8 | 2.224 | 2.217 | 236.2 | .04615 | 93.25 | 2125.28 | 216.14 | 2934.30 |
| 93.400 | 34000.0 | 99000.0 | 22663.3 | 2.797 | 2.748 | 313.2 | .05720 | 93.46 | 2590.46 | 215.93 | 3658.46 |
| 93.600 | 34000.0 | 99000.0 | 21279.0 | 3.573 | 3.447 | 419.2 | .07174 | 93.67 | 3187.51 | 215.76 | 4642.39 |
| 93.800 | 34000.0 | 99000.0 | 19810.3 | 4.650 | 4.376 | 566.9 | .09111 | 93.89 | 4013.34 | 215.62 | 6009.44 |
| 94.000 | 34000.0 | 99000.0 | 18255.0 | 6.166 | 5.625 | 770.6 | .11658 | 94.12 | 5101.28 | 215.70 | 7953.11 |
| 94.200 | 34000.0 | 99000.0 | 16609.9 | 8.379 | 7.318 | 1054.0 | .15040 | 94.35 | 6633.54 | 216.13 | 10798.21 |
| 94.400 | 34000.0 | 99000.0 | 14869.1 | 11.758 | 9.658 | 1461.4 | .19690 | 94.60 | 8709.93 | 216.65 | 15152.94 |
| 94.600 | 34000.0 | 99000.0 | 13024.8 | 17.303 | 12.958 | 2092.1 | .26547 | 94.87 | 11558.49 | 217.34 | 22335.90 |
| 94.800 | 34000.0 | 99000.0 | 11065.2 | 26.178 | 17.708 | 3019.9 | .36121 | 95.16 | 15718.33 | 218.16 | 34664.87 |
| 95.000 | 34000.0 | 99000.0 | 8991.1 | 38.466 | 24.265 | 4016.5 | .45820 | 95.46 | 21722.72 | 221.37 | 53478.21 |
| 95.200 | 34000.0 | 99000.0 | 6819.7 | 54.809 | 32.458 | 4675.5 | .51835 | 95.72 | 29404.20 | 229.86 | 77577.60 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 35000.0 | 99000.0 | 35000.0 | .030 | .032 | .0 | .00061 | 81.00 | 262.20 | 238.90 | 501.57 |
| 82.000 | 35000.0 | 99000.0 | 35000.0 | .034 | .035 | .0 | .00068 | 82.00 | 263.36 | 238.80 | 501.57 |
| 83.000 | 35000.0 | 99000.0 | 35000.0 | .038 | .040 | .0 | .00077 | 83.00 | 264.92 | 238.66 | 501.57 |
| 84.000 | 35000.0 | 99000.0 | 35000.0 | .044 | .045 | .0 | .00088 | 84.00 | 267.11 | 238.47 | 501.57 |
| 85.000 | 35000.0 | 99000.0 | 35000.0 | .051 | .053 | .0 | .00103 | 85.00 | 270.29 | 238.19 | 501.57 |
| 86.000 | 35000.0 | 99000.0 | 35000.0 | .061 | .063 | .0 | .00124 | 86.00 | 275.07 | 237.78 | 501.57 |
| 87.000 | 35000.0 | 99000.0 | 35000.0 | .075 | .077 | .0 | .00153 | 87.00 | 282.63 | 237.16 | 501.57 |
| 88.000 | 35000.0 | 99000.0 | 35000.0 | .097 | .099 | .0 | .00196 | 88.00 | 295.31 | 236.19 | 501.57 |
| 89.200 | 35000.0 | 99000.0 | 35000.0 | .143 | .144 | .0 | .00286 | 89.20 | 324.73 | 234.36 | 501.57 |
| 89.400 | 35000.0 | 99000.0 | 35000.0 | .154 | .155 | .0 | .00307 | 89.40 | 332.31 | 233.98 | 501.57 |
| 89.600 | 35000.0 | 99000.0 | 35000.0 | .166 | .168 | .0 | .00332 | 89.60 | 341.03 | 233.58 | 501.57 |
| 89.800 | 35000.0 | 99000.0 | 35000.0 | .180 | .182 | .0 | .00359 | 89.80 | 351.04 | 233.16 | 501.57 |
| 90.000 | 35000.0 | 99000.0 | 35000.0 | .172 | .198 | .0 | .00390 | 90.00 | 362.43 | 232.74 | 487.49 |
| 90.200 | 35000.0 | 99000.0 | 34960.8 | .191 | .216 | 1.9 | .00512 | 90.21 | 376.67 | 231.35 | 490.50 |
| 90.400 | 35000.0 | 99000.0 | 34843.3 | .213 | .239 | 4.5 | .00652 | 90.41 | 391.74 | 229.34 | 499.42 |
| 90.600 | 35000.0 | 99000.0 | 34647.7 | .250 | .266 | 6.5 | .00659 | 90.61 | 410.90 | 227.09 | 514.81 |
| 90.800 | 35000.0 | 99000.0 | 34374.1 | .279 | .297 | 8.9 | .00679 | 90.81 | 434.11 | 225.66 | 537.85 |
| 91.000 | 35000.0 | 99000.0 | 34022.3 | .313 | .332 | 11.8 | .00734 | 91.01 | 459.24 | 224.42 | 569.16 |
| 91.200 | 35000.0 | 99000.0 | 33592.3 | .354 | .375 | 15.5 | .00810 | 91.21 | 495.25 | 223.34 | 609.56 |
| 91.400 | 35000.0 | 99000.0 | 33084.0 | .402 | .425 | 20.1 | .00906 | 91.41 | 535.72 | 222.40 | 661.53 |
| 91.600 | 35000.0 | 99000.0 | 32497.5 | .460 | .485 | 25.8 | .01024 | 91.61 | 589.88 | 221.59 | 726.64 |
| 91.800 | 35000.0 | 99000.0 | 31832.5 | .530 | .557 | 32.9 | .01168 | 91.81 | 645.46 | 220.89 | 808.55 |
| 92.000 | 35000.0 | 99000.0 | 31089.1 | .616 | .645 | 42.1 | .01346 | 92.01 | 719.98 | 220.29 | 911.10 |
| 92.200 | 35000.0 | 99000.0 | 30267.2 | .722 | .753 | 53.8 | .01565 | 92.22 | 808.70 | 219.78 | 1039.80 |
| 92.400 | 35000.0 | 99000.0 | 29366.2 | .860 | .889 | 71.1 | .01889 | 92.42 | 929.23 | 218.49 | 1203.83 |
| 92.600 | 35000.0 | 99000.0 | 28386.6 | 1.029 | 1.059 | 90.8 | .02226 | 92.62 | 1076.50 | 217.71 | 1412.84 |
| 92.800 | 35000.0 | 99000.0 | 27327.7 | 1.244 | 1.272 | 117.5 | .02664 | 92.83 | 1258.25 | 217.15 | 1680.87 |
| 93.000 | 35000.0 | 99000.0 | 26189.2 | 1.521 | 1.543 | 153.2 | .03224 | 93.03 | 1502.98 | 216.71 | 2028.65 |
| 93.200 | 35000.0 | 99000.0 | 24970.6 | 1.882 | 1.891 | 201.2 | .03946 | 93.24 | 1812.44 | 216.37 | 2484.42 |
| 93.400 | 35000.0 | 99000.0 | 23671.0 | 2.362 | 2.343 | 266.6 | .04884 | 93.45 | 2208.53 | 216.10 | 3091.06 |
| 93.600 | 35000.0 | 99000.0 | 22289.5 | 3.008 | 2.936 | 356.4 | .06119 | 93.66 | 2716.83 | 215.88 | 3909.84 |
| 93.800 | 35000.0 | 99000.0 | 20824.6 | 3.900 | 3.725 | 481.3 | .07760 | 93.88 | 3419.06 | 215.72 | 5041.64 |
| 94.000 | 35000.0 | 99000.0 | 19274.1 | 5.154 | 4.786 | 657.2 | .09972 | 94.10 | 4345.32 | 215.58 | 6642.13 |
| 94.200 | 35000.0 | 99000.0 | 17635.7 | 6.952 | 6.223 | 895.5 | .12826 | 94.33 | 5648.50 | 215.86 | 8950.95 |
| 94.400 | 35000.0 | 99000.0 | 15904.4 | 9.658 | 8.202 | 1240.9 | .16789 | 94.57 | 7412.79 | 216.29 | 12433.92 |
| 94.600 | 35000.0 | 99000.0 | 14073.8 | 13.981 | 10.976 | 1766.3 | .22538 | 94.83 | 9830.46 | 216.94 | 18009.23 |
| 94.800 | 35000.0 | 99000.0 | 12134.1 | 21.018 | 14.942 | 2535.0 | .30541 | 95.11 | 13345.17 | 217.72 | 27470.59 |
| 95.000 | 35000.0 | 99000.0 | 10068.5 | 32.602 | 20.777 | 3725.4 | .42299 | 95.42 | 18348.29 | 218.60 | 44245.15 |
| 95.200 | 35000.0 | 99000.0 | 7910.1 | 45.929 | 28.097 | 4352.4 | .48064 | 95.68 | 25297.99 | 225.23 | 64575.09 |

UNREFRACTED RAY STRIKES DISC

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 36000.0 | 99000.0 | 36000.0 | .026 | .027 | .0 | .00053 | 81.00 | 226.58 | 240.75 | 432.11 |
| 82.000 | 36000.0 | 99000.0 | 36000.0 | .029 | .030 | .0 | .00059 | 82.00 | 227.58 | 240.65 | 432.11 |
| 83.000 | 36000.0 | 99000.0 | 36000.0 | .033 | .034 | .0 | .00066 | 83.00 | 228.94 | 240.51 | 432.11 |
| 84.000 | 36000.0 | 99000.0 | 36000.0 | .038 | .039 | .0 | .00076 | 84.00 | 230.84 | 240.31 | 432.11 |
| 85.000 | 36000.0 | 99000.0 | 36000.0 | .044 | .045 | .0 | .00089 | 85.00 | 233.60 | 240.03 | 432.11 |
| 86.000 | 36000.0 | 99000.0 | 36000.0 | .052 | .054 | .0 | .00107 | 86.00 | 237.74 | 239.60 | 432.11 |
| 87.000 | 36000.0 | 99000.0 | 36000.0 | .065 | .067 | .0 | .00132 | 87.00 | 244.29 | 238.95 | 432.11 |
| 88.000 | 36000.0 | 99000.0 | 36000.0 | .083 | .085 | .0 | .00169 | 88.00 | 255.22 | 237.90 | 432.11 |
| 89.200 | 36000.0 | 99000.0 | 36000.0 | .121 | .124 | .0 | .00247 | 89.20 | 280.49 | 235.81 | 432.11 |
| 89.400 | 36000.0 | 99000.0 | 36000.0 | .130 | .134 | .0 | .00265 | 89.40 | 286.98 | 235.35 | 432.11 |
| 89.600 | 36000.0 | 99000.0 | 36000.0 | .140 | .144 | .0 | .00286 | 89.60 | 294.45 | 234.87 | 432.11 |
| 89.800 | 36000.0 | 99000.0 | 36000.0 | .152 | .156 | .0 | .00310 | 89.80 | 303.03 | 234.37 | 432.11 |
| 90.000 | 36000.0 | 99000.0 | 36000.0 | .155 | .170 | .0 | .00337 | 90.00 | 312.78 | 233.85 | 418.90 |
| 90.200 | 36000.0 | 99000.0 | 35960.9 | .171 | .186 | 1.4 | .00368 | 90.20 | 324.81 | 233.33 | 421.45 |
| 90.400 | 36000.0 | 99000.0 | 35843.7 | .188 | .204 | 2.9 | .00403 | 90.40 | 337.11 | 232.80 | 429.02 |
| 90.600 | 36000.0 | 99000.0 | 35648.4 | .208 | .225 | 4.7 | .00444 | 90.60 | 352.53 | 232.29 | 442.08 |
| 90.800 | 36000.0 | 99000.0 | 35374.8 | .232 | .249 | 6.7 | .00492 | 90.80 | 371.51 | 231.79 | 460.93 |
| 91.000 | 36000.0 | 99000.0 | 35023.2 | .260 | .278 | 9.2 | .00548 | 91.01 | 392.20 | 231.31 | 486.47 |
| 91.200 | 36000.0 | 99000.0 | 34592.7 | .304 | .317 | 14.5 | .00745 | 91.21 | 423.39 | 226.89 | 519.93 |
| 91.400 | 36000.0 | 99000.0 | 34084.5 | .345 | .361 | 17.7 | .00791 | 91.41 | 458.34 | 224.91 | 563.91 |
| 91.600 | 36000.0 | 99000.0 | 33498.0 | .394 | .413 | 22.3 | .00884 | 91.61 | 504.77 | 223.47 | 619.58 |
| 91.800 | 36000.0 | 99000.0 | 32833.3 | .454 | .475 | 28.3 | .01004 | 91.81 | 552.29 | 222.33 | 689.30 |
| 92.000 | 36000.0 | 99000.0 | 32090.1 | .527 | .550 | 36.1 | .01154 | 92.01 | 615.96 | 221.41 | 776.55 |
| 92.200 | 36000.0 | 99000.0 | 31268.5 | .617 | .642 | 46.0 | .01340 | 92.21 | 691.74 | 220.65 | 886.00 |
| 92.400 | 36000.0 | 99000.0 | 30368.2 | .729 | .756 | 59.0 | .01571 | 92.42 | 793.62 | 220.02 | 1024.26 |
| 92.600 | 36000.0 | 99000.0 | 29388.9 | .876 | .902 | 78.3 | .01915 | 92.62 | 919.02 | 218.68 | 1200.88 |
| 92.800 | 36000.0 | 99000.0 | 28330.7 | 1.057 | 1.084 | 100.4 | .02277 | 92.82 | 1074.04 | 217.81 | 1427.59 |
| 93.000 | 36000.0 | 99000.0 | 27193.2 | 1.291 | 1.315 | 130.7 | .02752 | 93.03 | 1282.58 | 217.20 | 1721.33 |
| 93.200 | 36000.0 | 99000.0 | 25975.8 | 1.596 | 1.612 | 171.5 | .03366 | 93.23 | 1546.18 | 216.73 | 2105.34 |
| 93.400 | 36000.0 | 99000.0 | 24678.0 | 1.998 | 1.997 | 227.0 | .04164 | 93.44 | 1883.51 | 216.37 | 2614.00 |
| 93.600 | 36000.0 | 99000.0 | 23298.8 | 2.539 | 2.502 | 303.2 | .05213 | 93.65 | 2316.37 | 216.09 | 3299.27 |
| 93.800 | 36000.0 | 99000.0 | 21837.1 | 3.280 | 3.171 | 409.0 | .06607 | 93.87 | 2913.74 | 215.87 | 4238.54 |
| 94.000 | 36000.0 | 99000.0 | 20290.9 | 4.318 | 4.071 | 557.6 | .08481 | 94.08 | 3701.28 | 215.70 | 5557.15 |
| 94.200 | 36000.0 | 99000.0 | 18658.0 | 5.794 | 5.294 | 762.0 | .10942 | 94.31 | 4810.20 | 215.70 | 7450.76 |
| 94.400 | 36000.0 | 99000.0 | 16934.6 | 7.979 | 6.970 | 1055.4 | .14324 | 94.54 | 6310.07 | 215.99 | 10260.91 |
| 94.600 | 36000.0 | 99000.0 | 15115.4 | 11.389 | 9.310 | 1494.6 | .19157 | 94.79 | 8363.64 | 216.57 | 14653.33 |
| 94.800 | 36000.0 | 99000.0 | 13192.1 | 17.006 | 12.635 | 2135.1 | .25875 | 95.06 | 11336.65 | 217.30 | 21903.65 |
| 95.000 | 36000.0 | 99000.0 | 11151.3 | 26.233 | 17.483 | 3115.3 | .35656 | 95.36 | 15558.37 | 218.14 | 34712.29 |
| 95.200 | 36000.0 | 99000.0 | 8992.3 | 39.472 | 24.283 | 4207.3 | .45961 | 95.66 | 21705.82 | 221.37 | 54850.00 |
| 95.400 | 36000.0 | 99000.0 | 6738.8 | 57.308 | 32.853 | 4990.3 | .52874 | 95.93 | 29932.25 | 230.55 | 81620.46 |

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 37000.0 | 99000.0 | 37000.0 | .023 | .023 | .0 | .00045 | 81.00 | 196.04 | 242.91 | 371.94 |
| 82.000 | 37000.0 | 99000.0 | 37000.0 | .025 | .026 | .0 | .00051 | 82.00 | 196.91 | 242.81 | 371.94 |
| 83.000 | 37000.0 | 99000.0 | 37000.0 | .028 | .029 | .0 | .00057 | 83.00 | 198.10 | 242.67 | 371.94 |
| 84.000 | 37000.0 | 99000.0 | 37000.0 | .032 | .034 | .0 | .00066 | 84.00 | 199.76 | 242.48 | 371.94 |
| 85.000 | 37000.0 | 99000.0 | 37000.0 | .038 | .039 | .0 | .00077 | 85.00 | 202.15 | 242.20 | 371.94 |
| 86.000 | 37000.0 | 99000.0 | 37000.0 | .045 | .047 | .0 | .00092 | 86.00 | 205.76 | 241.77 | 371.94 |
| 87.000 | 37000.0 | 99000.0 | 37000.0 | .056 | .057 | .0 | .00114 | 87.00 | 211.44 | 241.10 | 371.94 |
| 88.000 | 37000.0 | 99000.0 | 37000.0 | .071 | .073 | .0 | .00146 | 88.00 | 220.89 | 240.00 | 371.94 |
| 89.200 | 37000.0 | 99000.0 | 37000.0 | .104 | .107 | .0 | .00214 | 89.20 | 242.61 | 237.66 | 371.94 |
| 89.400 | 37000.0 | 99000.0 | 37000.0 | .112 | .115 | .0 | .00230 | 89.40 | 248.17 | 237.12 | 371.94 |
| 89.600 | 37000.0 | 99000.0 | 37000.0 | .121 | .124 | .0 | .00248 | 89.60 | 254.56 | 236.55 | 371.94 |
| 89.800 | 37000.0 | 99000.0 | 37000.0 | .131 | .135 | .0 | .00268 | 89.80 | 261.89 | 235.93 | 371.94 |
| 90.000 | 37000.0 | 99000.0 | 37000.0 | .133 | .146 | .0 | .00292 | 90.00 | 270.22 | 235.30 | 359.95 |
| 90.200 | 37000.0 | 99000.0 | 36960.9 | .146 | .160 | 1.2 | .00318 | 90.20 | 280.51 | 234.64 | 362.13 |
| 90.400 | 37000.0 | 99000.0 | 36843.7 | .161 | .176 | 2.5 | .00349 | 90.40 | 291.02 | 233.98 | 368.62 |
| 90.600 | 37000.0 | 99000.0 | 36648.4 | .179 | .194 | 4.0 | .00384 | 90.60 | 304.21 | 233.33 | 379.83 |
| 90.800 | 37000.0 | 99000.0 | 36374.9 | .199 | .215 | 5.8 | .00425 | 90.80 | 320.46 | 232.70 | 396.01 |
| 91.000 | 37000.0 | 99000.0 | 36023.2 | .223 | .239 | 7.9 | .00473 | 91.00 | 338.19 | 232.11 | 417.94 |
| 91.200 | 37000.0 | 99000.0 | 35593.4 | .251 | .268 | 10.4 | .00529 | 91.21 | 363.46 | 231.55 | 446.13 |
| 91.400 | 37000.0 | 99000.0 | 35085.3 | .284 | .303 | 13.5 | .00596 | 91.41 | 391.83 | 231.04 | 482.07 |
| 91.600 | 37000.0 | 99000.0 | 34498.5 | .336 | .350 | 20.3 | .00795 | 91.61 | 431.83 | 226.53 | 528.39 |
| 91.800 | 37000.0 | 99000.0 | 33833.8 | .387 | .404 | 24.7 | .00870 | 91.81 | 472.64 | 224.41 | 587.71 |
| 92.000 | 37000.0 | 99000.0 | 33090.8 | .449 | .469 | 31.1 | .00992 | 92.01 | 527.10 | 222.93 | 661.97 |
| 92.200 | 37000.0 | 99000.0 | 32269.4 | .525 | .548 | 39.5 | .01149 | 92.21 | 591.83 | 221.80 | 755.08 |
| 92.400 | 37000.0 | 99000.0 | 31369.5 | .621 | .646 | 50.5 | .01346 | 92.41 | 678.85 | 220.90 | 872.65 |
| 92.600 | 37000.0 | 99000.0 | 30390.9 | .740 | .767 | 64.9 | .01593 | 92.62 | 784.88 | 220.18 | 1021.57 |
| 92.800 | 37000.0 | 99000.0 | 29333.1 | .898 | .924 | 86.4 | .01956 | 92.82 | 916.88 | 218.75 | 1213.13 |
| 93.000 | 37000.0 | 99000.0 | 28196.3 | 1.096 | 1.121 | 111.6 | .02352 | 93.02 | 1094.70 | 217.84 | 1461.48 |
| 93.200 | 37000.0 | 99000.0 | 26980.0 | 1.353 | 1.375 | 146.3 | .02873 | 93.23 | 1319.29 | 217.19 | 1785.58 |
| 93.400 | 37000.0 | 99000.0 | 25683.7 | 1.692 | 1.703 | 193.4 | .03552 | 93.44 | 1606.66 | 216.71 | 2213.68 |
| 93.600 | 37000.0 | 99000.0 | 24306.4 | 2.145 | 2.132 | 258.1 | .04444 | 93.64 | 1975.36 | 216.34 | 2788.26 |
| 93.800 | 37000.0 | 99000.0 | 22847.3 | 2.763 | 2.702 | 347.8 | .05628 | 93.86 | 2483.76 | 216.05 | 3571.68 |
| 94.000 | 37000.0 | 99000.0 | 21304.7 | 3.623 | 3.465 | 473.6 | .07218 | 94.07 | 3153.70 | 215.83 | 4663.59 |
| 94.200 | 37000.0 | 99000.0 | 19676.5 | 4.850 | 4.504 | 652.4 | .09380 | 94.29 | 4096.38 | 215.67 | 6223.87 |
| 94.400 | 37000.0 | 99000.0 | 17959.8 | 6.630 | 5.928 | 899.2 | .12234 | 94.52 | 5372.31 | 215.76 | 8507.57 |
| 94.600 | 37000.0 | 99000.0 | 16150.2 | 9.344 | 7.905 | 1267.3 | .16304 | 94.76 | 7117.86 | 216.25 | 12010.90 |
| 94.800 | 37000.0 | 99000.0 | 14240.6 | 13.716 | 10.704 | 1803.4 | .21963 | 95.02 | 9635.35 | 216.91 | 17647.98 |
| 95.000 | 37000.0 | 99000.0 | 12220.1 | 21.018 | 14.753 | 2616.1 | .30143 | 95.30 | 13202.50 | 217.70 | 27450.31 |
| 95.200 | 37000.0 | 99000.0 | 10070.8 | 33.369 | 20.784 | 3889.7 | .42312 | 95.62 | 18331.10 | 218.61 | 45264.71 |
| 95.400 | 37000.0 | 99000.0 | 7831.3 | 46.637 | 28.322 | 4387.9 | .46777 | 95.87 | 25461.87 | 225.77 | 65548.48 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 38000.0 | 99000.0 | 38000.0 | .019 | .020 | .0 | .00039 | 81.00 | 169.90 | 245.43 | 320.14 |
| 82.000 | 38000.0 | 99000.0 | 38000.0 | .022 | .022 | .0 | .00044 | 82.00 | 170.67 | 245.34 | 320.14 |
| 83.000 | 38000.0 | 99000.0 | 38000.0 | .024 | .025 | .0 | .00049 | 83.00 | 171.71 | 245.21 | 320.14 |
| 84.000 | 38000.0 | 99000.0 | 38000.0 | .028 | .029 | .0 | .00057 | 84.00 | 173.16 | 245.03 | 320.14 |
| 85.000 | 38000.0 | 99000.0 | 38000.0 | .032 | .034 | .0 | .00066 | 85.00 | 175.25 | 244.77 | 320.14 |
| 86.000 | 38000.0 | 99000.0 | 38000.0 | .039 | .040 | .0 | .00079 | 86.00 | 178.40 | 244.36 | 320.14 |
| 87.000 | 38000.0 | 99000.0 | 38000.0 | .048 | .049 | .0 | .00098 | 87.00 | 183.35 | 243.71 | 320.14 |
| 88.000 | 38000.0 | 99000.0 | 38000.0 | .061 | .063 | .0 | .00126 | 88.00 | 191.56 | 242.61 | 320.14 |
| 89.200 | 38000.0 | 99000.0 | 38000.0 | .090 | .092 | .0 | .00185 | 89.20 | 210.28 | 240.08 | 320.14 |
| 89.400 | 38000.0 | 99000.0 | 38000.0 | .096 | .099 | .0 | .00200 | 89.40 | 215.05 | 239.47 | 320.14 |
| 89.600 | 38000.0 | 99000.0 | 38000.0 | .104 | .107 | .0 | .00216 | 89.60 | 220.50 | 238.78 | 320.14 |
| 89.800 | 38000.0 | 99000.0 | 38000.0 | .113 | .116 | .0 | .00233 | 89.80 | 226.76 | 238.03 | 320.14 |
| 90.000 | 38000.0 | 99000.0 | 38000.0 | .114 | .126 | .0 | .00253 | 90.00 | 233.85 | 237.23 | 309.27 |
| 90.200 | 38000.0 | 99000.0 | 37960.9 | .126 | .138 | 1.0 | .00276 | 90.20 | 242.62 | 236.40 | 311.14 |
| 90.400 | 38000.0 | 99000.0 | 37843.7 | .139 | .151 | 2.2 | .00302 | 90.40 | 251.56 | 235.55 | 316.71 |
| 90.600 | 38000.0 | 99000.0 | 37648.4 | .154 | .167 | 3.5 | .00333 | 90.60 | 262.81 | 234.71 | 326.34 |
| 90.800 | 38000.0 | 99000.0 | 37374.9 | .171 | .185 | 5.0 | .00368 | 90.80 | 276.69 | 233.90 | 340.23 |
| 91.000 | 38000.0 | 99000.0 | 37023.2 | .191 | .206 | 6.8 | .00409 | 91.00 | 291.84 | 233.13 | 359.06 |
| 91.200 | 38000.0 | 99000.0 | 36593.4 | .215 | .231 | 9.0 | .00457 | 91.20 | 313.50 | 232.42 | 383.26 |
| 91.400 | 38000.0 | 99000.0 | 36085.4 | .244 | .261 | 11.6 | .00515 | 91.41 | 337.83 | 231.77 | 414.12 |
| 91.600 | 38000.0 | 99000.0 | 35499.2 | .278 | .296 | 14.9 | .00583 | 91.61 | 370.22 | 231.18 | 452.96 |
| 91.800 | 38000.0 | 99000.0 | 34834.4 | .319 | .340 | 25.3 | .00856 | 91.81 | 403.94 | 229.17 | 501.65 |
| 92.000 | 38000.0 | 99000.0 | 34091.4 | .382 | .399 | 27.3 | .00866 | 92.01 | 451.09 | 225.21 | 564.39 |
| 92.200 | 38000.0 | 99000.0 | 33270.1 | .447 | .467 | 34.1 | .00989 | 92.21 | 506.47 | 223.38 | 643.62 |
| 92.400 | 38000.0 | 99000.0 | 32370.5 | .528 | .551 | 43.3 | .01154 | 92.41 | 580.81 | 222.06 | 743.64 |
| 92.600 | 38000.0 | 99000.0 | 31392.2 | .630 | .655 | 55.6 | .01364 | 92.61 | 671.36 | 221.04 | 870.24 |
| 92.800 | 38000.0 | 99000.0 | 30335.2 | .759 | .786 | 71.7 | .01630 | 92.82 | 782.97 | 220.25 | 1031.66 |
| 93.000 | 38000.0 | 99000.0 | 29198.8 | .930 | .956 | 95.8 | .02018 | 93.02 | 934.45 | 218.72 | 1241.57 |
| 93.200 | 38000.0 | 99000.0 | 27983.4 | 1.148 | 1.172 | 124.9 | .02455 | 93.22 | 1125.92 | 217.79 | 1515.44 |
| 93.400 | 38000.0 | 99000.0 | 26688.2 | 1.433 | 1.452 | 164.9 | .03032 | 93.43 | 1370.78 | 217.14 | 1876.42 |
| 93.600 | 38000.0 | 99000.0 | 25312.6 | 1.815 | 1.818 | 219.9 | .03790 | 93.64 | 1684.90 | 216.65 | 2359.37 |
| 93.800 | 38000.0 | 99000.0 | 23855.7 | 2.332 | 2.302 | 296.0 | .04797 | 93.85 | 2117.74 | 216.28 | 3014.96 |
| 94.000 | 38000.0 | 99000.0 | 22316.1 | 3.047 | 2.951 | 402.7 | .06147 | 94.06 | 2687.89 | 216.00 | 3923.15 |
| 94.200 | 38000.0 | 99000.0 | 20692.1 | 4.059 | 3.832 | 553.8 | .07980 | 94.28 | 3488.88 | 215.79 | 5209.77 |
| 94.400 | 38000.0 | 99000.0 | 18980.9 | 5.525 | 5.043 | 767.7 | .10465 | 94.50 | 4574.40 | 215.63 | 7082.31 |
| 94.600 | 38000.0 | 99000.0 | 17179.3 | 7.722 | 6.719 | 1076.5 | .13891 | 94.74 | 6059.05 | 215.98 | 9903.25 |
| 94.800 | 38000.0 | 99000.0 | 15281.1 | 11.163 | 9.081 | 1526.8 | .18672 | 94.99 | 8101.55 | 216.56 | 14347.64 |
| 95.000 | 38000.0 | 99000.0 | 13277.4 | 16.976 | 12.478 | 2204.4 | .25542 | 95.26 | 11085.21 | 217.29 | 21849.45 |
| 95.200 | 38000.0 | 99000.0 | 11153.7 | 26.442 | 17.489 | 3253.8 | .35667 | 95.56 | 15543.19 | 218.15 | 35423.75 |
| 95.400 | 38000.0 | 99000.0 | 8913.9 | 39.233 | 24.427 | 4081.1 | .43315 | 95.83 | 21840.59 | 221.70 | 54501.58 |
| 95.600 | 38000.0 | 99000.0 | 6563.1 | 64.281 | 33.871 | 5767.5 | .57828 | 96.18 | 30531.20 | 231.32 | 92123.65 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
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IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HOIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 39000.0 | 99000.0 | 39000.0 | .017 | .017 | .0 | .00034 | 81.00 | 147.58 | 248.38 | 275.56 |
| 82.000 | 39000.0 | 99000.0 | 39000.0 | .019 | .019 | .0 | .00038 | 82.00 | 148.25 | 248.31 | 275.56 |
| 83.000 | 39000.0 | 99000.0 | 39000.0 | .021 | .022 | .0 | .00043 | 83.00 | 149.17 | 248.20 | 275.56 |
| 84.000 | 39000.0 | 99000.0 | 39000.0 | .024 | .025 | .0 | .00049 | 84.00 | 150.44 | 248.04 | 275.56 |
| 85.000 | 39000.0 | 99000.0 | 39000.0 | .028 | .029 | .0 | .00057 | 85.00 | 152.28 | 247.81 | 275.56 |
| 86.000 | 39000.0 | 99000.0 | 39000.0 | .033 | .035 | .0 | .00068 | 86.00 | 155.05 | 247.46 | 275.56 |
| 87.000 | 39000.0 | 99000.0 | 39000.0 | .041 | .042 | .0 | .00085 | 87.00 | 159.40 | 246.88 | 275.56 |
| 88.000 | 39000.0 | 99000.0 | 39000.0 | .053 | .054 | .0 | .00110 | 88.00 | 166.59 | 245.89 | 275.56 |
| 89.200 | 39000.0 | 99000.0 | 39000.0 | .077 | .079 | .0 | .00163 | 89.20 | 182.85 | 243.44 | 275.56 |
| 89.400 | 39000.0 | 99000.0 | 39000.0 | .083 | .085 | .0 | .00176 | 89.40 | 186.94 | 242.77 | 275.56 |
| 89.600 | 39000.0 | 99000.0 | 39000.0 | .089 | .091 | .0 | .00190 | 89.60 | 191.61 | 241.99 | 275.56 |
| 89.800 | 39000.0 | 99000.0 | 39000.0 | .097 | .099 | .0 | .00206 | 89.80 | 196.94 | 241.09 | 275.56 |
| 90.000 | 39000.0 | 99000.0 | 39000.0 | .098 | .108 | .0 | .00224 | 90.00 | 202.95 | 240.07 | 265.72 |
| 90.200 | 39000.0 | 99000.0 | 38960.9 | .108 | .118 | .9 | .00243 | 90.20 | 210.38 | 238.96 | 267.32 |
| 90.400 | 39000.0 | 99000.0 | 38843.7 | .119 | .130 | 1.9 | .00265 | 90.40 | 217.94 | 237.80 | 272.10 |
| 90.600 | 39000.0 | 99000.0 | 38648.4 | .132 | .143 | 3.1 | .00290 | 90.60 | 227.46 | 236.65 | 280.37 |
| 90.800 | 39000.0 | 99000.0 | 38374.9 | .147 | .159 | 4.4 | .00320 | 90.80 | 239.26 | 235.54 | 292.30 |
| 91.000 | 39000.0 | 99000.0 | 38023.2 | .164 | .177 | 5.9 | .00354 | 91.00 | 252.14 | 234.51 | 308.47 |
| 91.200 | 39000.0 | 99000.0 | 37593.4 | .185 | .199 | 7.8 | .00396 | 91.20 | 270.66 | 233.56 | 329.25 |
| 91.400 | 39000.0 | 99000.0 | 37085.5 | .209 | .225 | 10.0 | .00445 | 91.40 | 291.48 | 232.72 | 355.74 |
| 91.600 | 39000.0 | 99000.0 | 36499.3 | .238 | .255 | 12.8 | .00504 | 91.61 | 319.25 | 231.96 | 389.10 |
| 91.800 | 39000.0 | 99000.0 | 35834.9 | .273 | .292 | 16.3 | .00575 | 91.81 | 347.74 | 231.30 | 430.46 |
| 92.000 | 39000.0 | 99000.0 | 35092.3 | .316 | .336 | 20.7 | .00661 | 92.01 | 385.72 | 230.72 | 482.09 |
| 92.200 | 39000.0 | 99000.0 | 34270.6 | .381 | .397 | 30.2 | .00870 | 92.21 | 433.39 | 225.82 | 548.73 |
| 92.400 | 39000.0 | 99000.0 | 33371.1 | .450 | .470 | 37.4 | .00995 | 92.41 | 497.04 | 223.67 | 633.56 |
| 92.600 | 39000.0 | 99000.0 | 32393.1 | .536 | .559 | 47.7 | .01170 | 92.61 | 574.39 | 222.19 | 741.20 |
| 92.800 | 39000.0 | 99000.0 | 31336.5 | .646 | .671 | 61.4 | .01396 | 92.81 | 669.69 | 221.09 | 878.70 |
| 93.000 | 39000.0 | 99000.0 | 30201.0 | .786 | .813 | 79.7 | .01684 | 93.02 | 797.63 | 220.25 | 1054.97 |
| 93.200 | 39000.0 | 99000.0 | 28986.1 | .974 | .999 | 107.0 | .02103 | 93.22 | 961.02 | 218.60 | 1286.51 |
| 93.400 | 39000.0 | 99000.0 | 27691.8 | 1.215 | 1.238 | 140.8 | .02590 | 93.43 | 1169.75 | 217.69 | 1591.79 |
| 93.600 | 39000.0 | 99000.0 | 26317.6 | 1.537 | 1.550 | 187.4 | .03235 | 93.63 | 1437.43 | 217.04 | 1998.58 |
| 93.800 | 39000.0 | 99000.0 | 24862.5 | 1.970 | 1.963 | 252.1 | .04091 | 93.84 | 1806.05 | 216.56 | 2548.72 |
| 94.000 | 39000.0 | 99000.0 | 23325.4 | 2.567 | 2.515 | 342.6 | .05238 | 94.05 | 2291.46 | 216.20 | 3305.98 |
| 94.200 | 39000.0 | 99000.0 | 21704.9 | 3.406 | 3.263 | 470.6 | .06794 | 94.27 | 2972.48 | 215.93 | 4372.11 |
| 94.400 | 39000.0 | 99000.0 | 19998.6 | 4.618 | 4.289 | 654.3 | .08933 | 94.49 | 3894.54 | 215.73 | 5913.91 |
| 94.600 | 39000.0 | 99000.0 | 18203.5 | 6.405 | 5.714 | 915.8 | .11848 | 94.72 | 5158.60 | 215.77 | 8205.99 |
| 94.800 | 39000.0 | 99000.0 | 16315.0 | 9.164 | 7.712 | 1295.1 | .15893 | 94.96 | 6896.54 | 216.24 | 11752.57 |
| 95.000 | 39000.0 | 99000.0 | 14325.2 | 13.672 | 10.572 | 1862.7 | .21683 | 95.22 | 9428.31 | 216.90 | 17578.40 |
| 95.200 | 39000.0 | 99000.0 | 12222.5 | 21.397 | 14.759 | 2733.2 | .30153 | 95.50 | 13189.19 | 217.71 | 27931.05 |
| 95.400 | 39000.0 | 99000.0 | 9988.0 | 33.986 | 21.005 | 3935.4 | .41331 | 95.81 | 18676.92 | 218.65 | 46087.65 |
| 95.600 | 39000.0 | 99000.0 | 7665.0 | 50.994 | 29.102 | 4956.2 | .50144 | 96.10 | 26205.18 | 226.85 | 72131.73 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 40000.0 | 99000.0 | 40000.0 | .014 | .015 | .0 | .00027 | 81.00 | 128.72 | 251.80 | 237.19 |
| 82.000 | 40000.0 | 99000.0 | 40000.0 | .016 | .017 | .0 | .00030 | 82.00 | 129.32 | 251.75 | 237.19 |
| 83.000 | 40000.0 | 99000.0 | 40000.0 | .018 | .019 | .0 | .00034 | 83.00 | 130.13 | 251.67 | 237.19 |
| 84.000 | 40000.0 | 99000.0 | 40000.0 | .021 | .021 | .0 | .00039 | 84.00 | 131.26 | 251.56 | 237.19 |
| 85.000 | 40000.0 | 99000.0 | 40000.0 | .024 | .025 | .0 | .00046 | 85.00 | 132.90 | 251.39 | 237.19 |
| 86.000 | 40000.0 | 99000.0 | 40000.0 | .029 | .030 | .0 | .00055 | 86.00 | 135.35 | 251.13 | 237.19 |
| 87.000 | 40000.0 | 99000.0 | 40000.0 | .035 | .036 | .0 | .00067 | 87.00 | 139.22 | 250.72 | 237.19 |
| 88.000 | 40000.0 | 99000.0 | 40000.0 | .046 | .047 | .0 | .00086 | 88.00 | 145.63 | 250.04 | 237.19 |
| 89.200 | 40000.0 | 99000.0 | 40000.0 | .066 | .067 | .0 | .00124 | 89.20 | 160.10 | 248.65 | 237.19 |
| 89.400 | 40000.0 | 99000.0 | 40000.0 | .071 | .072 | .0 | .00133 | 89.40 | 163.69 | 248.35 | 237.19 |
| 89.600 | 40000.0 | 99000.0 | 40000.0 | .077 | .078 | .0 | .00144 | 89.60 | 167.71 | 248.03 | 237.19 |
| 89.800 | 40000.0 | 99000.0 | 40000.0 | .083 | .084 | .0 | .00155 | 89.80 | 172.18 | 247.70 | 237.19 |
| 90.000 | 40000.0 | 99000.0 | 40000.0 | .076 | .091 | .0 | .00168 | 90.00 | 177.04 | 247.36 | 229.12 |
| 90.200 | 40000.0 | 99000.0 | 39960.9 | .085 | .099 | .8 | .00237 | 90.20 | 182.96 | 245.62 | 230.41 |
| 90.400 | 40000.0 | 99000.0 | 39843.5 | .094 | .109 | 2.1 | .00316 | 90.40 | 189.23 | 242.99 | 234.28 |
| 90.600 | 40000.0 | 99000.0 | 39648.0 | .113 | .122 | 3.0 | .00311 | 90.60 | 197.40 | 239.95 | 240.89 |
| 90.800 | 40000.0 | 99000.0 | 39374.5 | .126 | .136 | 4.0 | .00310 | 90.80 | 207.38 | 238.10 | 251.13 |
| 91.000 | 40000.0 | 99000.0 | 39022.9 | .141 | .152 | 5.2 | .00330 | 91.00 | 218.26 | 236.52 | 264.90 |
| 91.200 | 40000.0 | 99000.0 | 38593.1 | .159 | .171 | 6.8 | .00360 | 91.20 | 234.02 | 235.17 | 282.86 |
| 91.400 | 40000.0 | 99000.0 | 38085.1 | .180 | .193 | 8.7 | .00399 | 91.40 | 251.78 | 234.00 | 305.62 |
| 91.600 | 40000.0 | 99000.0 | 37498.9 | .205 | .219 | 11.1 | .00447 | 91.60 | 275.55 | 232.99 | 334.26 |
| 91.800 | 40000.0 | 99000.0 | 36834.6 | .235 | .251 | 14.1 | .00507 | 91.81 | 299.95 | 232.12 | 369.77 |
| 92.000 | 40000.0 | 99000.0 | 36092.0 | .271 | .289 | 17.9 | .00579 | 92.01 | 332.54 | 231.38 | 414.10 |
| 92.200 | 40000.0 | 99000.0 | 35271.1 | .316 | .335 | 22.7 | .00669 | 92.21 | 371.20 | 230.75 | 469.47 |
| 92.400 | 40000.0 | 99000.0 | 34371.2 | .383 | .399 | 33.4 | .00888 | 92.41 | 425.32 | 226.20 | 540.17 |
| 92.600 | 40000.0 | 99000.0 | 33393.5 | .457 | .477 | 41.2 | .01016 | 92.61 | 491.58 | 223.78 | 631.71 |
| 92.800 | 40000.0 | 99000.0 | 32337.1 | .550 | .573 | 52.7 | .01204 | 92.81 | 572.99 | 222.20 | 748.65 |
| 93.000 | 40000.0 | 99000.0 | 31202.0 | .669 | .695 | 68.3 | .01448 | 93.01 | 682.24 | 221.05 | 898.43 |
| 93.200 | 40000.0 | 99000.0 | 29988.0 | .823 | .850 | 90.7 | .01787 | 93.22 | 820.01 | 220.18 | 1093.17 |
| 93.400 | 40000.0 | 99000.0 | 28694.3 | 1.031 | 1.056 | 120.4 | .02221 | 93.42 | 998.44 | 218.41 | 1351.33 |
| 93.600 | 40000.0 | 99000.0 | 27321.1 | 1.302 | 1.322 | 159.9 | .02767 | 93.63 | 1226.62 | 217.54 | 1694.00 |
| 93.800 | 40000.0 | 99000.0 | 25867.6 | 1.667 | 1.674 | 214.9 | .03495 | 93.83 | 1540.65 | 216.91 | 2156.64 |
| 94.000 | 40000.0 | 99000.0 | 24332.7 | 2.167 | 2.144 | 291.7 | .04470 | 94.04 | 1954.05 | 216.45 | 2791.52 |
| 94.200 | 40000.0 | 99000.0 | 22715.1 | 2.865 | 2.780 | 400.3 | .05792 | 94.26 | 2533.41 | 216.11 | 3678.96 |
| 94.400 | 40000.0 | 99000.0 | 21013.0 | 3.865 | 3.651 | 555.6 | .07605 | 94.48 | 3278.25 | 215.86 | 4949.95 |
| 94.600 | 40000.0 | 99000.0 | 19223.3 | 5.337 | 4.862 | 781.1 | .10128 | 94.70 | 4392.62 | 215.67 | 6829.92 |
| 94.800 | 40000.0 | 99000.0 | 17342.8 | 7.561 | 6.556 | 1100.5 | .13548 | 94.94 | 5872.21 | 215.98 | 9685.97 |
| 95.000 | 40000.0 | 99000.0 | 15364.7 | 11.114 | 8.971 | 1577.6 | .18440 | 95.18 | 8022.43 | 216.55 | 14274.17 |
| 95.200 | 40000.0 | 99000.0 | 13279.4 | 17.228 | 12.483 | 2303.8 | .25555 | 95.46 | 11074.81 | 217.30 | 22187.63 |
| 95.400 | 40000.0 | 99000.0 | 11070.8 | 27.505 | 17.732 | 3442.0 | .36176 | 95.76 | 15674.42 | 218.18 | 36834.36 |
| 95.600 | 40000.0 | 99000.0 | 8754.3 | 39.665 | 24.844 | 4002.1 | .41254 | 96.01 | 22146.34 | 222.84 | 55091.03 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 41000.0 | 99000.0 | 41000.0 | .012 | .013 | .0 | .00024 | 81.00 | 111.81 | 253.14 | 206.62 |
| 82.000 | 41000.0 | 99000.0 | 41000.0 | .014 | .014 | .0 | .00026 | 82.00 | 112.33 | 253.09 | 206.62 |
| 83.000 | 41000.0 | 99000.0 | 41000.0 | .016 | .016 | .0 | .00030 | 83.00 | 113.03 | 253.02 | 206.62 |
| 84.000 | 41000.0 | 99000.0 | 41000.0 | .018 | .019 | .0 | .00034 | 84.00 | 114.02 | 252.91 | 206.62 |
| 85.000 | 41000.0 | 99000.0 | 41000.0 | .021 | .022 | .0 | .00040 | 85.00 | 115.45 | 252.75 | 206.62 |
| 86.000 | 41000.0 | 99000.0 | 41000.0 | .025 | .026 | .0 | .00048 | 86.00 | 117.60 | 252.50 | 206.62 |
| 87.000 | 41000.0 | 99000.0 | 41000.0 | .031 | .032 | .0 | .00059 | 87.00 | 120.97 | 252.09 | 206.62 |
| 88.000 | 41000.0 | 99000.0 | 41000.0 | .039 | .040 | .0 | .00075 | 88.00 | 126.56 | 251.37 | 206.62 |
| 89.200 | 41000.0 | 99000.0 | 41000.0 | .056 | .058 | .0 | .00108 | 89.20 | 139.16 | 249.82 | 206.62 |
| 89.400 | 41000.0 | 99000.0 | 41000.0 | .061 | .063 | .0 | .00116 | 89.40 | 142.29 | 249.47 | 206.62 |
| 89.600 | 41000.0 | 99000.0 | 41000.0 | .065 | .067 | .0 | .00125 | 89.60 | 145.79 | 249.09 | 206.62 |
| 89.800 | 41000.0 | 99000.0 | 41000.0 | .071 | .073 | .0 | .00135 | 89.80 | 149.67 | 248.69 | 206.62 |
| 90.000 | 41000.0 | 99000.0 | 41000.0 | .071 | .079 | .0 | .00147 | 90.00 | 153.90 | 248.27 | 198.74 |
| 90.200 | 41000.0 | 99000.0 | 40960.9 | .078 | .086 | .6 | .00160 | 90.20 | 160.78 | 247.84 | 199.85 |
| 90.400 | 41000.0 | 99000.0 | 40843.7 | .085 | .094 | 1.3 | .00175 | 90.40 | 167.43 | 247.41 | 203.18 |
| 90.600 | 41000.0 | 99000.0 | 40648.4 | .094 | .104 | 2.0 | .00192 | 90.60 | 173.75 | 246.99 | 209.23 |
| 90.800 | 41000.0 | 99000.0 | 40374.9 | .105 | .114 | 2.9 | .00211 | 90.80 | 179.67 | 246.58 | 217.45 |
| 91.000 | 41000.0 | 99000.0 | 40023.3 | .117 | .127 | 3.9 | .00234 | 91.00 | 185.13 | 246.18 | 228.49 |
| 91.200 | 41000.0 | 99000.0 | 39593.1 | .138 | .145 | 6.7 | .00343 | 91.20 | 204.13 | 240.01 | 243.01 |
| 91.400 | 41000.0 | 99000.0 | 39085.1 | .156 | .165 | 7.8 | .00354 | 91.40 | 218.90 | 237.37 | 262.54 |
| 91.600 | 41000.0 | 99000.0 | 38499.0 | .177 | .188 | 9.8 | .00391 | 91.60 | 238.98 | 235.49 | 287.14 |
| 91.800 | 41000.0 | 99000.0 | 37834.6 | .203 | .215 | 12.3 | .00439 | 91.80 | 259.67 | 234.03 | 317.63 |
| 92.000 | 41000.0 | 99000.0 | 37092.0 | .234 | .248 | 15.5 | .00501 | 92.01 | 287.49 | 232.85 | 355.68 |
| 92.200 | 41000.0 | 99000.0 | 36271.2 | .273 | .288 | 19.6 | .00577 | 92.21 | 320.57 | 231.90 | 403.22 |
| 92.400 | 41000.0 | 99000.0 | 35372.1 | .320 | .337 | 24.9 | .00672 | 92.41 | 364.86 | 231.11 | 462.38 |
| 92.600 | 41000.0 | 99000.0 | 34394.0 | .390 | .405 | 36.8 | .00899 | 92.61 | 421.01 | 226.58 | 538.53 |
| 92.800 | 41000.0 | 99000.0 | 33337.8 | .469 | .488 | 45.5 | .01037 | 92.81 | 490.70 | 223.95 | 637.95 |
| 93.000 | 41000.0 | 99000.0 | 32203.1 | .570 | .593 | 58.6 | .01242 | 93.01 | 584.00 | 222.27 | 765.29 |
| 93.200 | 41000.0 | 99000.0 | 30989.5 | .701 | .726 | 76.4 | .01510 | 93.22 | 701.58 | 221.06 | 930.48 |
| 93.400 | 41000.0 | 99000.0 | 29696.5 | .877 | .899 | 105.5 | .01938 | 93.42 | 852.41 | 219.60 | 1148.18 |
| 93.600 | 41000.0 | 99000.0 | 28324.3 | 1.105 | 1.127 | 136.7 | .02365 | 93.62 | 1047.13 | 218.25 | 1437.30 |
| 93.800 | 41000.0 | 99000.0 | 26872.0 | 1.413 | 1.427 | 183.3 | .02983 | 93.83 | 1314.71 | 217.41 | 1827.18 |
| 94.000 | 41000.0 | 99000.0 | 25338.8 | 1.833 | 1.828 | 248.5 | .03813 | 94.04 | 1666.85 | 216.80 | 2360.28 |
| 94.200 | 41000.0 | 99000.0 | 23723.7 | 2.416 | 2.369 | 340.7 | .04936 | 94.25 | 2159.90 | 216.36 | 3101.58 |
| 94.400 | 41000.0 | 99000.0 | 22025.1 | 3.245 | 3.109 | 472.3 | .06476 | 94.46 | 2793.98 | 216.04 | 4155.49 |
| 94.600 | 41000.0 | 99000.0 | 20240.4 | 4.457 | 4.135 | 662.8 | .08614 | 94.69 | 3740.22 | 215.80 | 5697.62 |
| 94.800 | 41000.0 | 99000.0 | 18366.4 | 6.271 | 5.576 | 936.6 | .11558 | 94.92 | 5000.67 | 215.80 | 8023.86 |
| 95.000 | 41000.0 | 99000.0 | 16398.1 | 9.115 | 7.619 | 1338.6 | .15697 | 95.16 | 6828.05 | 216.24 | 11679.42 |
| 95.200 | 41000.0 | 99000.0 | 14327.2 | 13.858 | 10.577 | 1947.0 | .21694 | 95.42 | 9419.47 | 216.92 | 17806.05 |
| 95.400 | 41000.0 | 99000.0 | 12140.6 | 22.199 | 14.961 | 2891.3 | .30578 | 95.71 | 13305.99 | 217.74 | 28967.32 |
| 95.600 | 41000.0 | 99000.0 | 9828.9 | 33.635 | 21.340 | 3700.7 | .37989 | 95.98 | 18946.83 | 219.40 | 45601.93 |
| 95.800 | 41000.0 | 99000.0 | 7402.4 | 57.051 | 30.312 | 5615.1 | .54153 | 96.34 | 27224.97 | 227.74 | 81217.10 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HOIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 42000.0 | 99000.0 | 42000.0 | .011 | .011 | .0 | .00021 | 81.00 | 97.09 | 254.69 | 179.55 |
| 82.000 | 42000.0 | 99000.0 | 42000.0 | .012 | .013 | .0 | .00023 | 82.00 | 97.55 | 254.65 | 179.55 |
| 83.000 | 42000.0 | 99000.0 | 42000.0 | .014 | .014 | .0 | .00026 | 83.00 | 98.16 | 254.58 | 179.55 |
| 84.000 | 42000.0 | 99000.0 | 42000.0 | .016 | .016 | .0 | .00030 | 84.00 | 99.03 | 254.49 | 179.55 |
| 85.000 | 42000.0 | 99000.0 | 42000.0 | .018 | .019 | .0 | .00035 | 85.00 | 100.27 | 254.35 | 179.55 |
| 86.000 | 42000.0 | 99000.0 | 42000.0 | .022 | .022 | .0 | .00041 | 86.00 | 102.14 | 254.12 | 179.55 |
| 87.000 | 42000.0 | 99000.0 | 42000.0 | .027 | .028 | .0 | .00051 | 87.00 | 105.08 | 253.72 | 179.55 |
| 88.000 | 42000.0 | 99000.0 | 42000.0 | .034 | .035 | .0 | .00065 | 88.00 | 109.96 | 253.01 | 179.55 |
| 89.200 | 42000.0 | 99000.0 | 42000.0 | .049 | .051 | .0 | .00095 | 89.20 | 120.95 | 251.32 | 179.55 |
| 89.400 | 42000.0 | 99000.0 | 42000.0 | .053 | .054 | .0 | .00102 | 89.40 | 123.67 | 250.91 | 179.55 |
| 89.600 | 42000.0 | 99000.0 | 42000.0 | .057 | .059 | .0 | .00110 | 89.60 | 126.72 | 250.46 | 179.55 |
| 89.800 | 42000.0 | 99000.0 | 42000.0 | .061 | .063 | .0 | .00119 | 89.80 | 130.10 | 249.97 | 179.55 |
| 90.000 | 42000.0 | 99000.0 | 42000.0 | .061 | .069 | .0 | .00128 | 90.00 | 133.78 | 249.46 | 172.38 |
| 90.200 | 42000.0 | 99000.0 | 41960.9 | .067 | .075 | .5 | .00140 | 90.20 | 139.77 | 248.93 | 173.34 |
| 90.400 | 42000.0 | 99000.0 | 41843.7 | .074 | .082 | 1.1 | .00152 | 90.40 | 145.55 | 248.39 | 176.23 |
| 90.600 | 42000.0 | 99000.0 | 41648.4 | .082 | .090 | 1.8 | .00167 | 90.60 | 151.04 | 247.85 | 181.48 |
| 90.800 | 42000.0 | 99000.0 | 41374.9 | .091 | .099 | 2.5 | .00184 | 90.80 | 156.18 | 247.33 | 188.61 |
| 91.000 | 42000.0 | 99000.0 | 41023.2 | .101 | .110 | 3.4 | .00204 | 91.00 | 160.92 | 246.84 | 198.19 |
| 91.200 | 42000.0 | 99000.0 | 40593.4 | .113 | .123 | 4.4 | .00227 | 91.20 | 173.89 | 246.38 | 210.93 |
| 91.400 | 42000.0 | 99000.0 | 40085.4 | .127 | .138 | 5.7 | .00255 | 91.40 | 178.57 | 245.95 | 226.57 |
| 91.600 | 42000.0 | 99000.0 | 39498.9 | .152 | .160 | 9.2 | .00361 | 91.60 | 208.27 | 239.66 | 246.68 |
| 91.800 | 42000.0 | 99000.0 | 38834.6 | .174 | .184 | 10.9 | .00386 | 91.80 | 225.48 | 236.82 | 272.84 |
| 92.000 | 42000.0 | 99000.0 | 38092.0 | .201 | .213 | 13.5 | .00435 | 92.00 | 249.03 | 234.88 | 305.52 |
| 92.200 | 42000.0 | 99000.0 | 37271.2 | .234 | .248 | 17.0 | .00499 | 92.20 | 277.22 | 233.42 | 346.33 |
| 92.400 | 42000.0 | 99000.0 | 36372.1 | .274 | .290 | 21.5 | .00580 | 92.41 | 315.12 | 232.27 | 397.11 |
| 92.600 | 42000.0 | 99000.0 | 35394.7 | .324 | .342 | 27.4 | .00681 | 92.61 | 361.17 | 231.35 | 460.99 |
| 92.800 | 42000.0 | 99000.0 | 34338.3 | .400 | .415 | 40.4 | .00914 | 92.81 | 420.25 | 226.63 | 543.80 |
| 93.000 | 42000.0 | 99000.0 | 33203.7 | .485 | .505 | 50.5 | .01069 | 93.01 | 500.08 | 223.92 | 652.04 |
| 93.200 | 42000.0 | 99000.0 | 31990.5 | .596 | .619 | 65.5 | .01294 | 93.21 | 600.47 | 222.20 | 792.45 |
| 93.400 | 42000.0 | 99000.0 | 30698.4 | .741 | .766 | 86.0 | .01591 | 93.42 | 728.62 | 220.97 | 975.89 |
| 93.600 | 42000.0 | 99000.0 | 29326.6 | .938 | .960 | 117.5 | .02032 | 93.62 | 894.02 | 219.24 | 1220.39 |
| 93.800 | 42000.0 | 99000.0 | 27875.4 | 1.198 | 1.217 | 156.5 | .02549 | 93.83 | 1122.15 | 218.04 | 1549.40 |
| 94.000 | 42000.0 | 99000.0 | 26343.7 | 1.551 | 1.558 | 211.9 | .03254 | 94.03 | 1422.18 | 217.24 | 1998.04 |
| 94.200 | 42000.0 | 99000.0 | 24730.7 | 2.039 | 2.019 | 290.2 | .04209 | 94.24 | 1841.94 | 216.67 | 2618.36 |
| 94.400 | 42000.0 | 99000.0 | 23034.9 | 2.730 | 2.649 | 401.8 | .05518 | 94.46 | 2381.90 | 216.25 | 3496.72 |
| 94.600 | 42000.0 | 99000.0 | 21254.3 | 3.730 | 3.520 | 563.1 | .07331 | 94.67 | 3148.07 | 215.95 | 4768.29 |
| 94.800 | 42000.0 | 99000.0 | 19385.9 | 5.222 | 4.744 | 799.4 | .09881 | 94.90 | 4258.76 | 215.73 | 6674.15 |
| 95.000 | 42000.0 | 99000.0 | 17425.9 | 7.513 | 6.477 | 1137.6 | .13377 | 95.13 | 5812.83 | 215.99 | 9616.01 |
| 95.200 | 42000.0 | 99000.0 | 15367.0 | 11.245 | 8.974 | 1649.2 | .18445 | 95.38 | 8014.63 | 216.57 | 14432.33 |
| 95.400 | 42000.0 | 99000.0 | 13198.7 | 17.817 | 12.651 | 2436.9 | .25907 | 95.66 | 11302.67 | 217.33 | 22937.67 |
| 95.600 | 42000.0 | 99000.0 | 10903.6 | 29.034 | 18.207 | 3649.0 | .36857 | 95.97 | 16144.98 | 218.26 | 38872.79 |
| 95.800 | 42000.0 | 99000.0 | 8495.8 | 45.796 | 26.009 | 4909.6 | .47605 | 96.28 | 23313.46 | 223.73 | 64336.57 |

UNREFRACTED RAY STRIKES DISC

REGRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 43000.0 | 99000.0 | 43000.0 | .009 | .010 | .0 | .00018 | 81.00 | 84.29 | 256.48 | 156.03 |
| 82.000 | 43000.0 | 99000.0 | 43000.0 | .010 | .011 | .0 | .00020 | 82.00 | 84.68 | 256.45 | 156.03 |
| 83.000 | 43000.0 | 99000.0 | 43000.0 | .012 | .012 | .0 | .00023 | 83.00 | 85.22 | 256.40 | 156.03 |
| 84.000 | 43000.0 | 99000.0 | 43000.0 | .014 | .014 | .0 | .00026 | 84.00 | 85.97 | 256.33 | 156.03 |
| 85.000 | 43000.0 | 99000.0 | 43000.0 | .016 | .016 | .0 | .00030 | 85.00 | 87.06 | 256.22 | 156.03 |
| 86.000 | 43000.0 | 99000.0 | 43000.0 | .019 | .020 | .0 | .00036 | 86.00 | 88.68 | 256.03 | 156.03 |
| 87.000 | 43000.0 | 99000.0 | 43000.0 | .023 | .024 | .0 | .00044 | 87.00 | 91.25 | 255.68 | 156.03 |
| 88.000 | 43000.0 | 99000.0 | 43000.0 | .029 | .031 | .0 | .00057 | 88.00 | 95.49 | 255.03 | 156.03 |
| 89.200 | 43000.0 | 99000.0 | 43000.0 | .043 | .044 | .0 | .00083 | 89.20 | 105.06 | 253.29 | 156.03 |
| 89.400 | 43000.0 | 99000.0 | 43000.0 | .046 | .047 | .0 | .00090 | 89.40 | 107.44 | 252.83 | 156.03 |
| 89.600 | 43000.0 | 99000.0 | 43000.0 | .049 | .051 | .0 | .00097 | 89.60 | 110.10 | 252.30 | 156.03 |
| 89.800 | 43000.0 | 99000.0 | 43000.0 | .053 | .055 | .0 | .00104 | 89.80 | 113.05 | 251.71 | 156.03 |
| 90.000 | 43000.0 | 99000.0 | 43000.0 | .053 | .060 | .0 | .00113 | 90.00 | 116.26 | 251.07 | 149.51 |
| 90.200 | 43000.0 | 99000.0 | 42960.9 | .058 | .065 | .5 | .00123 | 90.20 | 121.48 | 250.39 | 150.34 |
| 90.400 | 43000.0 | 99000.0 | 42843.7 | .064 | .071 | 1.0 | .00134 | 90.40 | 126.51 | 249.70 | 152.85 |
| 90.600 | 43000.0 | 99000.0 | 42648.3 | .071 | .078 | 1.5 | .00147 | 90.60 | 131.29 | 249.00 | 157.41 |
| 90.800 | 43000.0 | 99000.0 | 42374.8 | .079 | .086 | 2.2 | .00161 | 90.80 | 135.76 | 248.33 | 163.59 |
| 91.000 | 43000.0 | 99000.0 | 42023.1 | .088 | .096 | 3.0 | .00178 | 91.00 | 139.88 | 247.69 | 171.89 |
| 91.200 | 43000.0 | 99000.0 | 41593.3 | .098 | .107 | 3.9 | .00198 | 91.20 | 151.15 | 247.10 | 182.95 |
| 91.400 | 43000.0 | 99000.0 | 41085.3 | .111 | .120 | 5.0 | .00222 | 91.40 | 155.21 | 246.56 | 196.51 |
| 91.600 | 43000.0 | 99000.0 | 40499.1 | .125 | .136 | 6.3 | .00250 | 91.60 | 175.17 | 246.07 | 213.79 |
| 91.800 | 43000.0 | 99000.0 | 39834.6 | .143 | .155 | 11.9 | .00403 | 91.80 | 196.94 | 243.46 | 234.90 |
| 92.000 | 43000.0 | 99000.0 | 39091.9 | .172 | .182 | 12.1 | .00386 | 92.00 | 216.47 | 237.95 | 262.44 |
| 92.200 | 43000.0 | 99000.0 | 38271.1 | .201 | .212 | 14.8 | .00435 | 92.20 | 240.24 | 235.53 | 297.48 |
| 92.400 | 43000.0 | 99000.0 | 37372.0 | .235 | .249 | 18.7 | .00502 | 92.41 | 272.54 | 233.80 | 341.07 |
| 92.600 | 43000.0 | 99000.0 | 36394.7 | .278 | .294 | 23.7 | .00588 | 92.61 | 311.94 | 232.50 | 395.90 |
| 92.800 | 43000.0 | 99000.0 | 35339.0 | .332 | .351 | 30.3 | .00696 | 92.81 | 360.37 | 231.48 | 465.06 |
| 93.000 | 43000.0 | 99000.0 | 34204.1 | .413 | .430 | 44.4 | .00936 | 93.01 | 428.27 | 226.39 | 555.74 |
| 93.200 | 43000.0 | 99000.0 | 32991.2 | .508 | .528 | 56.3 | .01113 | 93.21 | 514.11 | 223.72 | 675.09 |
| 93.400 | 43000.0 | 99000.0 | 31699.4 | .630 | .654 | 73.7 | .01363 | 93.41 | 623.51 | 222.01 | 830.94 |
| 93.600 | 43000.0 | 99000.0 | 30328.6 | .792 | .817 | 97.7 | .01695 | 93.62 | 763.57 | 220.80 | 1036.94 |
| 93.800 | 43000.0 | 99000.0 | 28878.0 | 1.016 | 1.037 | 134.0 | .02182 | 93.82 | 957.97 | 218.88 | 1314.86 |
| 94.000 | 43000.0 | 99000.0 | 27347.5 | 1.313 | 1.329 | 180.8 | .02779 | 94.03 | 1213.69 | 217.79 | 1692.52 |
| 94.200 | 43000.0 | 99000.0 | 25736.2 | 1.724 | 1.722 | 247.3 | .03591 | 94.24 | 1571.18 | 217.05 | 2214.15 |
| 94.400 | 43000.0 | 99000.0 | 24042.9 | 2.301 | 2.257 | 342.1 | .04704 | 94.45 | 2031.11 | 216.52 | 2947.31 |
| 94.600 | 43000.0 | 99000.0 | 22265.7 | 3.131 | 2.998 | 478.8 | .06244 | 94.66 | 2683.18 | 216.14 | 4002.76 |
| 94.800 | 43000.0 | 99000.0 | 20402.3 | 4.359 | 4.036 | 678.6 | .08405 | 94.88 | 3626.99 | 215.86 | 5565.59 |
| 95.000 | 43000.0 | 99000.0 | 18448.9 | 6.225 | 5.509 | 968.4 | .11413 | 95.11 | 4949.35 | 215.82 | 7958.02 |
| 95.200 | 43000.0 | 99000.0 | 16400.2 | 9.205 | 7.623 | 1399.5 | .15702 | 95.36 | 6821.38 | 216.26 | 11788.04 |
| 95.400 | 43000.0 | 99000.0 | 14247.1 | 14.289 | 10.718 | 2059.8 | .21992 | 95.62 | 9606.10 | 216.95 | 18353.46 |
| 95.600 | 43000.0 | 99000.0 | 11975.0 | 23.132 | 15.362 | 3080.5 | .31284 | 95.91 | 13698.35 | 217.80 | 30576.07 |
| 95.800 | 43000.0 | 99000.0 | 9578.1 | 37.412 | 22.245 | 4307.8 | .41937 | 96.22 | 19706.89 | 220.42 | 51335.40 |
| 96.000 | 43000.0 | 99000.0 | 7049.8 | 64.563 | 31.950 | 6286.6 | .58076 | 96.58 | 28527.65 | 228.70 | 92500.58 |

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UNREFRACTED RAY STRIKES DISC | | | | | | | | | | | |

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 44000.0 | 99000.0 | 44000.0 | .008 | .009 | .0 | .00016 | 81.00 | 73.14 | 258.56 | 135.59 |
| 82.000 | 44000.0 | 99000.0 | 44000.0 | .009 | .010 | .0 | .00017 | 82.00 | 73.48 | 258.54 | 135.59 |
| 83.000 | 44000.0 | 99000.0 | 44000.0 | .010 | .011 | .0 | .00020 | 83.00 | 73.95 | 258.52 | 135.59 |
| 84.000 | 44000.0 | 99000.0 | 44000.0 | .012 | .012 | .0 | .00023 | 84.00 | 74.60 | 258.48 | 135.59 |
| 85.000 | 44000.0 | 99000.0 | 44000.0 | .014 | .014 | .0 | .00026 | 85.00 | 75.54 | 258.41 | 135.59 |
| 86.000 | 44000.0 | 99000.0 | 44000.0 | .016 | .017 | .0 | .00031 | 86.00 | 76.95 | 258.29 | 135.59 |
| 87.000 | 44000.0 | 99000.0 | 44000.0 | .020 | .021 | .0 | .00039 | 87.00 | 79.17 | 258.06 | 135.59 |
| 88.000 | 44000.0 | 99000.0 | 44000.0 | .026 | .026 | .0 | .00050 | 88.00 | 82.85 | 257.57 | 135.59 |
| 89.200 | 44000.0 | 99000.0 | 44000.0 | .037 | .038 | .0 | .00075 | 89.20 | 91.12 | 256.06 | 135.59 |
| 89.400 | 44000.0 | 99000.0 | 44000.0 | .040 | .041 | .0 | .00081 | 89.40 | 93.17 | 255.59 | 135.59 |
| 89.600 | 44000.0 | 99000.0 | 44000.0 | .043 | .044 | .0 | .00089 | 89.60 | 95.48 | 255.01 | 135.59 |
| 89.800 | 44000.0 | 99000.0 | 44000.0 | .046 | .047 | .0 | .00097 | 89.80 | 98.05 | 254.31 | 135.59 |
| 90.000 | 44000.0 | 99000.0 | 44000.0 | .046 | .051 | .0 | .00108 | 90.00 | 100.87 | 253.49 | 129.67 |
| 90.200 | 44000.0 | 99000.0 | 43960.9 | .050 | .056 | .4 | .00113 | 90.20 | 105.46 | 252.58 | 130.39 |
| 90.400 | 44000.0 | 99000.0 | 43843.7 | .055 | .062 | .9 | .00121 | 90.40 | 109.89 | 251.61 | 132.56 |
| 90.600 | 44000.0 | 99000.0 | 43648.3 | .061 | .068 | 1.4 | .00130 | 90.60 | 114.08 | 250.64 | 136.52 |
| 90.800 | 44000.0 | 99000.0 | 43374.7 | .068 | .075 | 1.9 | .00142 | 90.80 | 117.98 | 249.71 | 141.88 |
| 91.000 | 44000.0 | 99000.0 | 43023.0 | .076 | .083 | 2.6 | .00157 | 91.00 | 121.57 | 248.84 | 149.08 |
| 91.200 | 44000.0 | 99000.0 | 42593.2 | .085 | .093 | 3.4 | .00174 | 91.20 | 131.38 | 248.05 | 158.67 |
| 91.400 | 44000.0 | 99000.0 | 42085.1 | .096 | .104 | 4.3 | .00194 | 91.40 | 134.91 | 247.34 | 170.43 |
| 91.600 | 44000.0 | 99000.0 | 41498.9 | .109 | .118 | 5.5 | .00218 | 91.60 | 152.26 | 246.71 | 185.43 |
| 91.800 | 44000.0 | 99000.0 | 40834.6 | .124 | .134 | 7.0 | .00247 | 91.80 | 170.94 | 246.16 | 203.61 |
| 92.000 | 44000.0 | 99000.0 | 40092.0 | .142 | .153 | 8.8 | .00282 | 92.00 | 177.60 | 245.68 | 226.45 |
| 92.200 | 44000.0 | 99000.0 | 39270.8 | .172 | .181 | 13.4 | .00390 | 92.20 | 208.99 | 238.83 | 255.42 |
| 92.400 | 44000.0 | 99000.0 | 38371.8 | .202 | .214 | 16.3 | .00437 | 92.40 | 236.24 | 235.95 | 292.95 |
| 92.600 | 44000.0 | 99000.0 | 37394.5 | .239 | .253 | 20.5 | .00509 | 92.61 | 269.79 | 234.02 | 340.02 |
| 92.800 | 44000.0 | 99000.0 | 36338.8 | .285 | .302 | 26.2 | .00601 | 92.81 | 311.22 | 232.59 | 399.38 |
| 93.000 | 44000.0 | 99000.0 | 35204.8 | .344 | .363 | 33.7 | .00719 | 93.01 | 366.65 | 231.51 | 474.95 |
| 93.200 | 44000.0 | 99000.0 | 33991.5 | .432 | .450 | 49.1 | .00968 | 93.21 | 440.27 | 225.94 | 575.29 |
| 93.400 | 44000.0 | 99000.0 | 32700.1 | .537 | .558 | 63.3 | .01171 | 93.41 | 533.74 | 223.40 | 707.75 |
| 93.600 | 44000.0 | 99000.0 | 31329.7 | .674 | .698 | 83.6 | .01452 | 93.61 | 653.30 | 221.74 | 882.70 |
| 93.800 | 44000.0 | 99000.0 | 29880.0 | .863 | .883 | 117.4 | .01903 | 93.82 | 817.59 | 220.40 | 1116.92 |
| 94.000 | 44000.0 | 99000.0 | 28350.4 | 1.114 | 1.133 | 154.5 | .02376 | 94.02 | 1035.98 | 218.51 | 1435.41 |
| 94.200 | 44000.0 | 99000.0 | 26740.5 | 1.459 | 1.468 | 210.9 | .03066 | 94.23 | 1340.54 | 217.53 | 1874.54 |
| 94.400 | 44000.0 | 99000.0 | 25049.2 | 1.943 | 1.925 | 291.5 | .04012 | 94.44 | 1732.39 | 216.85 | 2489.01 |
| 94.600 | 44000.0 | 99000.0 | 23275.0 | 2.634 | 2.555 | 407.5 | .05321 | 94.65 | 2287.56 | 216.36 | 3368.05 |
| 94.800 | 44000.0 | 99000.0 | 21415.7 | 3.648 | 3.436 | 576.7 | .07155 | 94.87 | 3090.05 | 216.02 | 4657.74 |
| 95.000 | 44000.0 | 99000.0 | 19468.0 | 5.182 | 4.688 | 827.1 | .09762 | 95.10 | 4214.48 | 215.77 | 6616.86 |
| 95.200 | 44000.0 | 99000.0 | 17427.8 | 7.577 | 6.480 | 1189.6 | .13382 | 95.33 | 5807.13 | 216.02 | 9692.21 |
| 95.400 | 44000.0 | 99000.0 | 15287.3 | 11.562 | 9.093 | 1744.7 | .18697 | 95.59 | 8077.99 | 216.60 | 14833.88 |
| 95.600 | 44000.0 | 99000.0 | 13034.5 | 18.785 | 12.991 | 2609.5 | .26618 | 95.87 | 11501.71 | 217.38 | 24177.19 |
| 95.800 | 44000.0 | 99000.0 | 10650.7 | 31.098 | 18.960 | 3962.5 | .38431 | 96.18 | 16788.94 | 218.43 | 42153.06 |
| 96.000 | 44000.0 | 99000.0 | 8147.5 | 51.558 | 27.431 | 5521.6 | .51262 | 96.51 | 24463.15 | 224.56 | 72906.69 |

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER

ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIOLATITUOE WINTER
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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 45000.0 | 99000.0 | 45000.0 | .007 | .007 | .0 | .00013 | 81.00 | 63.76 | 260.88 | 117.82 |
| 82.000 | 45000.0 | 99000.0 | 45000.0 | .008 | .008 | .0 | .00014 | 82.00 | 64.06 | 260.89 | 117.82 |
| 83.000 | 45000.0 | 99000.0 | 45000.0 | .009 | .009 | .0 | .00016 | 83.00 | 64.46 | 260.90 | 117.82 |
| 84.000 | 45000.0 | 99000.0 | 45000.0 | .010 | .011 | .0 | .00018 | 84.00 | 65.03 | 260.90 | 117.82 |
| 85.000 | 45000.0 | 99000.0 | 45000.0 | .012 | .012 | .0 | .00021 | 85.00 | 65.85 | 260.90 | 117.82 |
| 86.000 | 45000.0 | 99000.0 | 45000.0 | .014 | .015 | .0 | .00025 | 86.00 | 67.08 | 260.89 | 117.82 |
| 87.000 | 45000.0 | 99000.0 | 45000.0 | .017 | .018 | .0 | .00031 | 87.00 | 69.01 | 260.84 | 117.82 |
| 88.000 | 45000.0 | 99000.0 | 45000.0 | .022 | .023 | .0 | .00040 | 88.00 | 72.20 | 260.70 | 117.82 |
| 89.200 | 45000.0 | 99000.0 | 45000.0 | .032 | .033 | .0 | .00057 | 89.20 | 79.33 | 260.33 | 117.82 |
| 89.400 | 45000.0 | 99000.0 | 45000.0 | .035 | .035 | .0 | .00061 | 89.40 | 81.09 | 260.24 | 117.82 |
| 89.600 | 45000.0 | 99000.0 | 45000.0 | .037 | .038 | .0 | .00065 | 89.60 | 83.06 | 260.14 | 117.82 |
| 89.800 | 45000.0 | 99000.0 | 45000.0 | .040 | .041 | .0 | .00071 | 89.80 | 85.24 | 260.03 | 117.82 |
| 90.000 | 45000.0 | 99000.0 | 45000.0 | .036 | .044 | .0 | .00076 | 90.00 | 87.61 | 259.92 | 113.23 |
| 90.200 | 45000.0 | 99000.0 | 44960.9 | .040 | .048 | .3 | .00089 | 90.20 | 91.43 | 258.62 | 113.82 |
| 90.400 | 45000.0 | 99000.0 | 44843.6 | .045 | .053 | .7 | .00103 | 90.40 | 95.18 | 257.23 | 115.61 |
| 90.600 | 45000.0 | 99000.0 | 44648.2 | .053 | .058 | 1.2 | .00119 | 90.60 | 98.83 | 255.54 | 118.40 |
| 90.800 | 45000.0 | 99000.0 | 44374.6 | .059 | .064 | 1.8 | .00138 | 90.80 | 102.33 | 253.41 | 123.05 |
| 91.000 | 45000.0 | 99000.0 | 44022.8 | .066 | .072 | 2.6 | .00162 | 91.00 | 105.62 | 250.71 | 129.30 |
| 91.200 | 45000.0 | 99000.0 | 43592.9 | .074 | .080 | 3.0 | .00162 | 91.20 | 114.08 | 249.43 | 137.62 |
| 91.400 | 45000.0 | 99000.0 | 43084.8 | .083 | .090 | 3.8 | .00177 | 91.40 | 117.19 | 248.43 | 147.82 |
| 91.600 | 45000.0 | 99000.0 | 42498.5 | .094 | .102 | 4.8 | .00196 | 91.60 | 132.34 | 247.58 | 160.83 |
| 91.800 | 45000.0 | 99000.0 | 41834.1 | .107 | .116 | 6.1 | .00221 | 91.80 | 148.61 | 246.85 | 176.59 |
| 92.000 | 45000.0 | 99000.0 | 41091.5 | .123 | .133 | 7.6 | .00250 | 92.00 | 154.39 | 246.23 | 196.41 |
| 92.200 | 45000.0 | 99000.0 | 40270.7 | .142 | .153 | 9.6 | .00287 | 92.20 | 174.89 | 245.70 | 220.87 |
| 92.400 | 45000.0 | 99000.0 | 39371.3 | .173 | .182 | 14.9 | .00399 | 92.40 | 205.64 | 239.38 | 251.66 |
| 92.600 | 45000.0 | 99000.0 | 38394.0 | .205 | .217 | 17.9 | .00447 | 92.60 | 233.90 | 236.14 | 292.05 |
| 92.800 | 45000.0 | 99000.0 | 37338.4 | .245 | .259 | 22.7 | .00523 | 92.81 | 269.19 | 234.06 | 343.00 |
| 93.000 | 45000.0 | 99000.0 | 36204.4 | .295 | .312 | 29.1 | .00623 | 93.01 | 316.65 | 232.56 | 407.86 |
| 93.200 | 45000.0 | 99000.0 | 34992.0 | .359 | .379 | 39.9 | .00789 | 93.21 | 376.28 | 231.43 | 491.01 |
| 93.400 | 45000.0 | 99000.0 | 33700.2 | .457 | .475 | 54.8 | .01015 | 93.41 | 457.10 | 225.34 | 603.03 |
| 93.600 | 45000.0 | 99000.0 | 32330.2 | .574 | .596 | 71.7 | .01248 | 93.61 | 559.21 | 222.98 | 751.70 |
| 93.800 | 45000.0 | 99000.0 | 30881.2 | .729 | .753 | 95.7 | .01566 | 93.82 | 699.29 | 221.41 | 949.69 |
| 94.000 | 45000.0 | 99000.0 | 29352.3 | .945 | .966 | 132.9 | .02044 | 94.02 | 884.47 | 219.51 | 1218.39 |
| 94.200 | 45000.0 | 99000.0 | 27743.6 | 1.237 | 1.252 | 180.0 | .02621 | 94.23 | 1144.10 | 218.14 | 1588.64 |
| 94.400 | 45000.0 | 99000.0 | 26053.9 | 1.643 | 1.641 | 248.5 | .03425 | 94.43 | 1478.01 | 217.26 | 2104.95 |
| 94.600 | 45000.0 | 99000.0 | 24282.1 | 2.220 | 2.178 | 347.0 | .04538 | 94.65 | 1950.84 | 216.64 | 2838.80 |
| 94.800 | 45000.0 | 99000.0 | 22426.3 | 3.061 | 2.927 | 490.5 | .06096 | 94.86 | 2633.56 | 216.21 | 3908.15 |
| 95.000 | 45000.0 | 99000.0 | 20483.8 | 4.323 | 3.988 | 702.3 | .08306 | 95.08 | 3589.04 | 215.90 | 5514.72 |
| 95.200 | 45000.0 | 99000.0 | 18450.5 | 6.272 | 5.512 | 1012.8 | .11419 | 95.31 | 4944.66 | 215.84 | 8013.82 |
| 95.400 | 45000.0 | 99000.0 | 16320.6 | 9.436 | 7.724 | 1480.7 | .15918 | 95.56 | 6876.71 | 216.29 | 12092.30 |
| 95.600 | 45000.0 | 99000.0 | 14083.9 | 14.984 | 11.004 | 2205.2 | .22592 | 95.83 | 9781.26 | 217.00 | 19263.12 |
| 95.800 | 45000.0 | 99000.0 | 11725.0 | 24.860 | 15.982 | 3316.8 | .32381 | 96.12 | 14238.72 | 217.98 | 32855.22 |
| 96.000 | 45000.0 | 99000.0 | 9233.6 | 41.792 | 23.486 | 4868.9 | .45364 | 96.45 | 20909.61 | 221.05 | 58024.09 |

REFRACTION AIRMASS TABLES

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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 45000.0 | 99000.0 | 6630.0 | 68.108 | 33.542 | 6292.4 | .56623 | 96.77 | 30301.77 | 231.06 | 97576.47 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 46000.0 | 99000.0 | 46000.0 | .006 | .007 | .0 | .00011 | 81.00 | 55.86 | 261.23 | 103.67 |
| 82.000 | 46000.0 | 99000.0 | 46000.0 | .007 | .007 | .0 | .00012 | 82.00 | 56.12 | 261.24 | 103.67 |
| 83.000 | 46000.0 | 99000.0 | 46000.0 | .008 | .008 | .0 | .00014 | 83.00 | 56.47 | 261.25 | 103.67 |
| 84.000 | 46000.0 | 99000.0 | 46000.0 | .009 | .009 | .0 | .00016 | 84.00 | 56.97 | 261.27 | 103.67 |
| 85.000 | 46000.0 | 99000.0 | 46000.0 | .010 | .011 | .0 | .00019 | 85.00 | 57.69 | 261.28 | 103.67 |
| 86.000 | 46000.0 | 99000.0 | 46000.0 | .012 | .013 | .0 | .00022 | 86.00 | 58.77 | 261.28 | 103.67 |
| 87.000 | 46000.0 | 99000.0 | 46000.0 | .015 | .016 | .0 | .00027 | 87.00 | 60.46 | 261.25 | 103.67 |
| 88.000 | 46000.0 | 99000.0 | 46000.0 | .019 | .020 | .0 | .00035 | 88.00 | 63.26 | 261.13 | 103.67 |
| 89.200 | 46000.0 | 99000.0 | 46000.0 | .028 | .029 | .0 | .00050 | 89.20 | 69.52 | 260.73 | 103.67 |
| 89.400 | 46000.0 | 99000.0 | 46000.0 | .030 | .031 | .0 | .00054 | 89.40 | 71.06 | 260.62 | 103.67 |
| 89.600 | 46000.0 | 99000.0 | 46000.0 | .032 | .033 | .0 | .00058 | 89.60 | 72.78 | 260.50 | 103.67 |
| 89.800 | 46000.0 | 99000.0 | 46000.0 | .034 | .036 | .0 | .00062 | 89.80 | 74.69 | 260.37 | 103.67 |
| 90.000 | 46000.0 | 99000.0 | 46000.0 | .034 | .039 | .0 | .00067 | 90.00 | 76.77 | 260.24 | 99.03 |
| 90.200 | 46000.0 | 99000.0 | 45960.9 | .037 | .042 | .3 | .00073 | 90.20 | 80.07 | 260.09 | 99.54 |
| 90.400 | 46000.0 | 99000.0 | 45843.7 | .041 | .046 | .6 | .00079 | 90.40 | 83.28 | 259.95 | 101.10 |
| 90.600 | 46000.0 | 99000.0 | 45648.2 | .045 | .050 | .9 | .00087 | 90.60 | 86.34 | 259.80 | 103.95 |
| 90.800 | 46000.0 | 99000.0 | 45374.6 | .050 | .055 | 1.3 | .00096 | 90.80 | 89.24 | 259.66 | 107.78 |
| 91.000 | 46000.0 | 99000.0 | 45022.9 | .055 | .061 | 1.7 | .00106 | 91.00 | 91.92 | 259.53 | 112.92 |
| 91.200 | 46000.0 | 99000.0 | 44592.9 | .065 | .068 | 2.7 | .00139 | 91.20 | 99.09 | 257.18 | 119.35 |
| 91.400 | 46000.0 | 99000.0 | 44084.6 | .073 | .078 | 3.8 | .00170 | 91.40 | 101.98 | 252.20 | 128.20 |
| 91.600 | 46000.0 | 99000.0 | 43498.3 | .082 | .088 | 4.3 | .00175 | 91.60 | 114.96 | 249.85 | 139.49 |
| 91.800 | 46000.0 | 99000.0 | 42833.8 | .094 | .101 | 5.3 | .00194 | 91.80 | 129.20 | 248.58 | 153.15 |
| 92.000 | 46000.0 | 99000.0 | 42091.2 | .107 | .115 | 6.7 | .00219 | 92.00 | 134.23 | 247.56 | 170.34 |
| 92.200 | 46000.0 | 99000.0 | 41270.3 | .124 | .133 | 8.4 | .00250 | 92.20 | 152.08 | 246.74 | 191.56 |
| 92.400 | 46000.0 | 99000.0 | 40371.3 | .144 | .155 | 10.5 | .00288 | 92.40 | 172.69 | 246.07 | 217.80 |
| 92.600 | 46000.0 | 99000.0 | 39393.6 | .176 | .185 | 16.4 | .00405 | 92.60 | 203.65 | 239.84 | 250.88 |
| 92.800 | 46000.0 | 99000.0 | 38338.0 | .210 | .222 | 19.8 | .00456 | 92.80 | 233.38 | 236.32 | 294.60 |
| 93.000 | 46000.0 | 99000.0 | 37204.0 | .254 | .268 | 25.1 | .00539 | 93.01 | 273.86 | 234.12 | 350.27 |
| 93.200 | 46000.0 | 99000.0 | 35991.7 | .309 | .326 | 32.4 | .00649 | 93.21 | 324.92 | 232.56 | 421.47 |
| 93.400 | 46000.0 | 99000.0 | 34700.3 | .390 | .403 | 52.7 | .00956 | 93.41 | 391.20 | 228.75 | 514.29 |
| 93.600 | 46000.0 | 99000.0 | 33330.5 | .489 | .508 | 61.8 | .01075 | 93.61 | 478.88 | 224.74 | 640.33 |
| 93.800 | 46000.0 | 99000.0 | 31881.9 | .621 | .643 | 82.0 | .01342 | 93.81 | 598.49 | 222.55 | 808.50 |
| 94.000 | 46000.0 | 99000.0 | 30354.0 | .799 | .822 | 110.4 | .01705 | 94.02 | 755.45 | 221.08 | 1034.88 |
| 94.200 | 46000.0 | 99000.0 | 28746.0 | 1.049 | 1.068 | 154.1 | .02243 | 94.22 | 976.69 | 218.97 | 1347.46 |
| 94.400 | 46000.0 | 99000.0 | 27057.8 | 1.391 | 1.400 | 212.0 | .02925 | 94.43 | 1261.29 | 217.79 | 1782.17 |
| 94.600 | 46000.0 | 99000.0 | 25288.0 | 1.875 | 1.857 | 295.7 | .03871 | 94.64 | 1664.09 | 217.00 | 2397.28 |
| 94.800 | 46000.0 | 99000.0 | 23435.1 | 2.575 | 2.494 | 417.5 | .05196 | 94.85 | 2245.16 | 216.45 | 3287.78 |
| 95.000 | 46000.0 | 99000.0 | 21496.7 | 3.617 | 3.396 | 596.9 | .07072 | 95.07 | 3057.55 | 216.07 | 4612.94 |
| 95.200 | 46000.0 | 99000.0 | 19469.4 | 5.215 | 4.690 | 865.1 | .09768 | 95.30 | 4210.58 | 215.79 | 6655.35 |
| 95.400 | 46000.0 | 99000.0 | 17348.4 | 7.762 | 6.566 | 1258.7 | .13566 | 95.54 | 5855.28 | 216.04 | 9923.79 |
| 95.600 | 46000.0 | 99000.0 | 15125.1 | 12.096 | 9.334 | 1867.8 | .19205 | 95.79 | 8321.52 | 216.65 | 15514.13 |
| 95.800 | 46000.0 | 99000.0 | 12786.8 | 20.071 | 13.505 | 2785.8 | .27349 | 96.07 | 11952.51 | 217.53 | 25828.30 |
| 96.000 | 46000.0 | 99000.0 | 10309.6 | 34.145 | 20.030 | 4371.0 | .40736 | 96.41 | 17625.95 | 218.56 | 46843.95 |

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
ALL TEMPERATURES ARE IN DEGREES KELVIN
ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 46000.0 | 99000.0 | 7730.5 | 52.742 | 28.772 | 5280.4 | .48081 | 96.68 | 25977.81 | 226.58 | 74578.41 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HOIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 47000.0 | 99000.0 | 47000.0 | .005 | .006 | .0 | .00010 | 81.00 | 48.93 | 261.62 | 90.84 |
| 82.000 | 47000.0 | 99000.0 | 47000.0 | .006 | .006 | .0 | .00011 | 82.00 | 49.16 | 261.64 | 90.84 |
| 83.000 | 47000.0 | 99000.0 | 47000.0 | .007 | .007 | .0 | .00012 | 83.00 | 49.47 | 261.67 | 90.84 |
| 84.000 | 47000.0 | 99000.0 | 47000.0 | .008 | .008 | .0 | .00014 | 84.00 | 49.91 | 261.70 | 90.84 |
| 85.000 | 47000.0 | 99000.0 | 47000.0 | .009 | .010 | .0 | .00016 | 85.00 | 50.54 | 261.72 | 90.84 |
| 86.000 | 47000.0 | 99000.0 | 47000.0 | .011 | .011 | .0 | .00020 | 86.00 | 51.49 | 261.75 | 90.84 |
| 87.000 | 47000.0 | 99000.0 | 47000.0 | .013 | .014 | .0 | .00024 | 87.00 | 52.97 | 261.74 | 90.84 |
| 88.000 | 47000.0 | 99000.0 | 47000.0 | .017 | .018 | .0 | .00031 | 88.00 | 55.42 | 261.65 | 90.84 |
| 89.200 | 47000.0 | 99000.0 | 47000.0 | .024 | .025 | .0 | .00044 | 89.20 | 60.91 | 261.24 | 90.84 |
| 89.400 | 47000.0 | 99000.0 | 47000.0 | .026 | .027 | .0 | .00047 | 89.40 | 62.26 | 261.12 | 90.84 |
| 89.600 | 47000.0 | 99000.0 | 47000.0 | .028 | .029 | .0 | .00051 | 89.60 | 63.77 | 260.98 | 90.84 |
| 89.800 | 47000.0 | 99000.0 | 47000.0 | .030 | .031 | .0 | .00055 | 89.80 | 65.45 | 260.83 | 90.84 |
| 90.000 | 47000.0 | 99000.0 | 47000.0 | .030 | .034 | .0 | .00059 | 90.00 | 67.28 | 260.66 | 86.60 |
| 90.200 | 47000.0 | 99000.0 | 46960.9 | .032 | .037 | .2 | .00064 | 90.20 | 70.17 | 260.48 | 87.05 |
| 90.400 | 47000.0 | 99000.0 | 46843.6 | .036 | .040 | .5 | .00070 | 90.40 | 72.98 | 260.30 | 88.42 |
| 90.600 | 47000.0 | 99000.0 | 46648.2 | .039 | .044 | .8 | .00076 | 90.60 | 75.66 | 260.11 | 90.91 |
| 90.800 | 47000.0 | 99000.0 | 46374.6 | .043 | .049 | 1.1 | .00084 | 90.80 | 78.20 | 259.93 | 94.26 |
| 91.000 | 47000.0 | 99000.0 | 46022.7 | .048 | .054 | 1.5 | .00093 | 91.00 | 80.55 | 259.76 | 98.75 |
| 91.200 | 47000.0 | 99000.0 | 45592.8 | .054 | .060 | 2.0 | .00103 | 91.20 | 86.71 | 259.60 | 104.73 |
| 91.400 | 47000.0 | 99000.0 | 45084.6 | .060 | .067 | 2.5 | .00115 | 91.40 | 89.04 | 259.45 | 112.01 |
| 91.600 | 47000.0 | 99000.0 | 44498.2 | .071 | .075 | 3.9 | .00153 | 91.60 | 99.95 | 256.52 | 120.97 |
| 91.800 | 47000.0 | 99000.0 | 43833.5 | .081 | .087 | 4.9 | .00177 | 91.80 | 112.22 | 251.14 | 132.83 |
| 92.000 | 47000.0 | 99000.0 | 43090.8 | .093 | .100 | 5.9 | .00193 | 92.00 | 116.65 | 249.40 | 147.74 |
| 92.200 | 47000.0 | 99000.0 | 42269.9 | .107 | .115 | 7.3 | .00219 | 92.20 | 132.24 | 248.11 | 166.14 |
| 92.400 | 47000.0 | 99000.0 | 41370.8 | .125 | .134 | 9.2 | .00252 | 92.40 | 150.17 | 247.12 | 188.90 |
| 92.600 | 47000.0 | 99000.0 | 40393.4 | .147 | .157 | 11.6 | .00293 | 92.60 | 171.17 | 246.32 | 217.15 |
| 92.800 | 47000.0 | 99000.0 | 39337.5 | .181 | .190 | 18.0 | .00410 | 92.80 | 203.10 | 239.86 | 253.06 |
| 93.000 | 47000.0 | 99000.0 | 38203.5 | .218 | .230 | 21.9 | .00469 | 93.00 | 237.33 | 236.26 | 300.83 |
| 93.200 | 47000.0 | 99000.0 | 36991.2 | .265 | .280 | 28.0 | .00561 | 93.21 | 280.90 | 234.02 | 361.94 |
| 93.400 | 47000.0 | 99000.0 | 35700.5 | .326 | .343 | 36.5 | .00682 | 93.41 | 336.53 | 232.43 | 440.74 |
| 93.600 | 47000.0 | 99000.0 | 34330.5 | .416 | .432 | 54.8 | .00947 | 93.61 | 410.08 | 227.40 | 545.70 |
| 93.800 | 47000.0 | 99000.0 | 32882.2 | .529 | .549 | 70.5 | .01154 | 93.81 | 512.40 | 224.06 | 688.56 |
| 94.000 | 47000.0 | 99000.0 | 31354.8 | .679 | .702 | 94.5 | .01461 | 94.01 | 646.40 | 222.07 | 880.74 |
| 94.200 | 47000.0 | 99000.0 | 29747.7 | .890 | .909 | 137.2 | .01986 | 94.22 | 833.71 | 220.21 | 1144.22 |
| 94.400 | 47000.0 | 99000.0 | 28060.6 | 1.178 | 1.194 | 181.0 | .02500 | 94.42 | 1076.59 | 218.48 | 1509.87 |
| 94.600 | 47000.0 | 99000.0 | 26292.4 | 1.585 | 1.584 | 252.1 | .03304 | 94.63 | 1419.81 | 217.45 | 2027.26 |
| 94.800 | 47000.0 | 99000.0 | 24442.0 | 2.170 | 2.126 | 355.5 | .04431 | 94.84 | 1914.56 | 216.76 | 2771.43 |
| 95.000 | 47000.0 | 99000.0 | 22507.2 | 3.033 | 2.893 | 507.7 | .06024 | 95.06 | 2574.86 | 216.27 | 3868.86 |
| 95.200 | 47000.0 | 99000.0 | 20485.1 | 4.348 | 3.991 | 734.6 | .08310 | 95.28 | 3585.70 | 215.93 | 5541.91 |
| 95.400 | 47000.0 | 99000.0 | 18371.4 | 6.414 | 5.585 | 1071.6 | .11574 | 95.52 | 4986.33 | 215.87 | 8190.39 |
| 95.600 | 47000.0 | 99000.0 | 16159.3 | 9.843 | 7.927 | 1585.1 | .16347 | 95.76 | 7081.99 | 216.34 | 12609.21 |
| 95.800 | 47000.0 | 99000.0 | 13838.1 | 15.951 | 11.438 | 2358.5 | .23247 | 96.03 | 10163.97 | 217.11 | 20502.10 |
| 96.000 | 47000.0 | 99000.0 | 11388.5 | 27.143 | 16.868 | 3663.8 | .34362 | 96.34 | 14951.61 | 218.11 | 36329.88 |

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER

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THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 47000.0 | 99000.0 | 8814.3 | 42.470 | 24.700 | 4569.5 | .41899 | 96.62 | 22017.86 | 222.37 | 58963.43 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
ALL HEIGHTS ARE IN GEOMETRIC METERS
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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 48000.0 | 99000.0 | 48000.0 | .005 | .005 | .0 | .00009 | 81.00 | 42.86 | 262.08 | 79.59 |
| 82.000 | 48000.0 | 99000.0 | 48000.0 | .005 | .006 | .0 | .00010 | 82.00 | 43.07 | 262.11 | 79.59 |
| 83.000 | 48000.0 | 99000.0 | 48000.0 | .006 | .006 | .0 | .00011 | 83.00 | 43.34 | 262.14 | 79.59 |
| 84.000 | 48000.0 | 99000.0 | 48000.0 | .007 | .007 | .0 | .00012 | 84.00 | 43.72 | 262.19 | 79.59 |
| 85.000 | 48000.0 | 99000.0 | 48000.0 | .008 | .008 | .0 | .00014 | 85.00 | 44.27 | 262.24 | 79.59 |
| 86.000 | 48000.0 | 99000.0 | 48000.0 | .010 | .010 | .0 | .00017 | 86.00 | 45.10 | 262.29 | 79.59 |
| 87.000 | 48000.0 | 99000.0 | 48000.0 | .012 | .012 | .0 | .00021 | 87.00 | 46.40 | 262.33 | 79.59 |
| 88.000 | 48000.0 | 99000.0 | 48000.0 | .015 | .016 | .0 | .00027 | 88.00 | 48.55 | 262.30 | 79.59 |
| 89.200 | 48000.0 | 99000.0 | 48000.0 | .021 | .022 | .0 | .00039 | 89.20 | 53.36 | 261.94 | 79.59 |
| 89.400 | 48000.0 | 99000.0 | 48000.0 | .023 | .024 | .0 | .00042 | 89.40 | 54.54 | 261.80 | 79.59 |
| 89.600 | 48000.0 | 99000.0 | 48000.0 | .024 | .026 | .0 | .00045 | 89.60 | 55.87 | 261.64 | 79.59 |
| 89.800 | 48000.0 | 99000.0 | 48000.0 | .026 | .028 | .0 | .00048 | 89.80 | 57.34 | 261.46 | 79.59 |
| 90.000 | 48000.0 | 99000.0 | 48000.0 | .026 | .030 | .0 | .00052 | 90.00 | 58.94 | 261.25 | 75.73 |
| 90.200 | 48000.0 | 99000.0 | 47960.9 | .028 | .032 | .2 | .00057 | 90.20 | 61.48 | 261.02 | 76.13 |
| 90.400 | 48000.0 | 99000.0 | 47843.6 | .031 | .035 | .4 | .00062 | 90.40 | 63.94 | 260.77 | 77.32 |
| 90.600 | 48000.0 | 99000.0 | 47648.1 | .034 | .039 | .7 | .00067 | 90.60 | 66.30 | 260.53 | 79.35 |
| 90.800 | 48000.0 | 99000.0 | 47374.5 | .038 | .043 | 1.0 | .00074 | 90.80 | 68.52 | 260.29 | 82.43 |
| 91.000 | 48000.0 | 99000.0 | 47022.6 | .042 | .047 | 1.3 | .00081 | 91.00 | 70.58 | 260.07 | 86.36 |
| 91.200 | 48000.0 | 99000.0 | 46592.6 | .047 | .052 | 1.7 | .00090 | 91.20 | 75.99 | 259.85 | 91.59 |
| 91.400 | 48000.0 | 99000.0 | 46084.4 | .053 | .058 | 2.2 | .00101 | 91.40 | 78.03 | 259.66 | 97.96 |
| 91.600 | 48000.0 | 99000.0 | 45497.9 | .060 | .066 | 2.8 | .00113 | 91.60 | 87.44 | 259.49 | 106.06 |
| 91.800 | 48000.0 | 99000.0 | 44833.3 | .068 | .074 | 3.9 | .00140 | 91.80 | 97.55 | 258.82 | 115.81 |
| 92.000 | 48000.0 | 99000.0 | 44090.4 | .081 | .086 | 5.8 | .00184 | 92.00 | 101.57 | 252.87 | 128.13 |
| 92.200 | 48000.0 | 99000.0 | 43269.4 | .093 | .100 | 6.5 | .00194 | 92.20 | 114.93 | 250.03 | 144.09 |
| 92.400 | 48000.0 | 99000.0 | 42370.2 | .108 | .116 | 8.0 | .00220 | 92.40 | 130.58 | 248.50 | 163.83 |
| 92.600 | 48000.0 | 99000.0 | 41392.8 | .127 | .136 | 10.1 | .00255 | 92.60 | 148.86 | 247.36 | 188.34 |
| 92.800 | 48000.0 | 99000.0 | 40337.2 | .150 | .161 | 12.8 | .00299 | 92.80 | 170.44 | 246.47 | 218.91 |
| 93.000 | 48000.0 | 99000.0 | 39202.9 | .187 | .196 | 19.6 | .00418 | 93.00 | 206.37 | 239.50 | 258.40 |
| 93.200 | 48000.0 | 99000.0 | 37990.6 | .227 | .240 | 24.4 | .00487 | 93.20 | 243.28 | 235.99 | 310.84 |
| 93.400 | 48000.0 | 99000.0 | 36699.9 | .279 | .295 | 31.5 | .00590 | 93.41 | 290.81 | 233.77 | 378.46 |
| 93.600 | 48000.0 | 99000.0 | 35330.7 | .347 | .365 | 41.3 | .00725 | 93.61 | 351.56 | 232.21 | 466.59 |
| 93.800 | 48000.0 | 99000.0 | 33882.1 | .450 | .468 | 61.2 | .01001 | 93.81 | 438.80 | 226.22 | 586.37 |
| 94.000 | 48000.0 | 99000.0 | 32355.2 | .578 | .600 | 81.1 | .01254 | 94.01 | 553.28 | 223.37 | 749.86 |
| 94.200 | 48000.0 | 99000.0 | 30748.9 | .752 | .775 | 110.1 | .01609 | 94.22 | 712.66 | 221.57 | 971.84 |
| 94.400 | 48000.0 | 99000.0 | 29062.5 | .999 | 1.018 | 155.2 | .02143 | 94.42 | 919.09 | 219.40 | 1280.74 |
| 94.600 | 48000.0 | 99000.0 | 27295.8 | 1.342 | 1.351 | 215.1 | .02822 | 94.63 | 1211.66 | 218.02 | 1716.38 |
| 94.800 | 48000.0 | 99000.0 | 25447.3 | 1.833 | 1.813 | 303.0 | .03780 | 94.84 | 1633.06 | 217.13 | 2340.11 |
| 95.000 | 48000.0 | 99000.0 | 23515.6 | 2.551 | 2.465 | 432.2 | .05135 | 95.05 | 2195.42 | 216.52 | 3253.63 |
| 95.200 | 48000.0 | 99000.0 | 21497.8 | 3.634 | 3.398 | 624.4 | .07075 | 95.27 | 3054.73 | 216.10 | 4632.36 |
| 95.400 | 48000.0 | 99000.0 | 19390.3 | 5.325 | 4.753 | 914.9 | .09897 | 95.50 | 4246.66 | 215.81 | 6792.66 |
| 95.600 | 48000.0 | 99000.0 | 17187.7 | 8.068 | 6.738 | 1347.3 | .13930 | 95.74 | 6028.68 | 216.08 | 10323.62 |
| 95.800 | 48000.0 | 99000.0 | 14880.7 | 12.825 | 9.702 | 2001.1 | .19791 | 96.00 | 8646.73 | 216.74 | 16464.61 |
| 96.000 | 48000.0 | 99000.0 | 12453.9 | 21.805 | 14.245 | 3082.6 | .29065 | 96.29 | 12692.51 | 217.68 | 28437.56 |

REFRACTION AIRMASS TABLES

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 48000.0 | 99000.0 | 9888.0 | 35.579 | 21.214 | 4249.4 | .38789 | 96.59 | 18831.54 | 219.06 | 48809.56 |
| 96.400 | 48000.0 | 99000.0 | 7201.2 | 65.408 | 31.246 | 6540.6 | .56468 | 96.96 | 28077.37 | 228.32 | 93699.72 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 49000.0 | 99000.0 | 49000.0 | .004 | .004 | .0 | .00008 | 81.00 | 37.55 | 262.60 | 69.74 |
| 82.000 | 49000.0 | 99000.0 | 49000.0 | .005 | .005 | .0 | .00008 | 82.00 | 37.72 | 262.64 | 69.74 |
| 83.000 | 49000.0 | 99000.0 | 49000.0 | .005 | .006 | .0 | .00010 | 83.00 | 37.96 | 262.69 | 69.74 |
| 84.000 | 49000.0 | 99000.0 | 49000.0 | .006 | .006 | .0 | .00011 | 84.00 | 38.29 | 262.76 | 69.74 |
| 85.000 | 49000.0 | 99000.0 | 49000.0 | .007 | .007 | .0 | .00013 | 85.00 | 38.77 | 262.84 | 69.74 |
| 86.000 | 49000.0 | 99000.0 | 49000.0 | .008 | .009 | .0 | .00015 | 86.00 | 39.50 | 262.94 | 69.74 |
| 87.000 | 49000.0 | 99000.0 | 49000.0 | .010 | .011 | .0 | .00019 | 87.00 | 40.63 | 263.05 | 69.74 |
| 88.000 | 49000.0 | 99000.0 | 49000.0 | .013 | .014 | .0 | .00024 | 88.00 | 42.51 | 263.12 | 69.74 |
| 89.200 | 49000.0 | 99000.0 | 49000.0 | .019 | .019 | .0 | .00034 | 89.20 | 46.71 | 262.93 | 69.74 |
| 89.400 | 49000.0 | 99000.0 | 49000.0 | .020 | .021 | .0 | .00037 | 89.40 | 47.75 | 262.81 | 69.74 |
| 89.600 | 49000.0 | 99000.0 | 49000.0 | .021 | .022 | .0 | .00040 | 89.60 | 48.91 | 262.64 | 69.74 |
| 89.800 | 49000.0 | 99000.0 | 49000.0 | .023 | .024 | .0 | .00044 | 89.80 | 50.20 | 262.42 | 69.74 |
| 90.000 | 49000.0 | 99000.0 | 49000.0 | .023 | .026 | .0 | .00048 | 90.00 | 51.61 | 262.15 | 66.23 |
| 90.200 | 49000.0 | 99000.0 | 48960.9 | .025 | .028 | .2 | .00051 | 90.20 | 53.84 | 261.84 | 66.57 |
| 90.400 | 49000.0 | 99000.0 | 48843.6 | .027 | .031 | .4 | .00055 | 90.40 | 56.01 | 261.49 | 67.61 |
| 90.600 | 49000.0 | 99000.0 | 48648.1 | .030 | .034 | .6 | .00060 | 90.60 | 58.09 | 261.14 | 69.38 |
| 90.800 | 49000.0 | 99000.0 | 48374.4 | .033 | .037 | .9 | .00065 | 90.80 | 60.04 | 260.81 | 72.09 |
| 91.000 | 49000.0 | 99000.0 | 48022.5 | .037 | .041 | 1.2 | .00072 | 91.00 | 61.85 | 260.49 | 75.52 |
| 91.200 | 49000.0 | 99000.0 | 47592.4 | .041 | .046 | 1.5 | .00080 | 91.20 | 66.58 | 260.20 | 80.10 |
| 91.400 | 49000.0 | 99000.0 | 47084.1 | .046 | .051 | 1.9 | .00089 | 91.40 | 68.37 | 259.95 | 85.67 |
| 91.600 | 49000.0 | 99000.0 | 46497.6 | .052 | .058 | 2.4 | .00099 | 91.60 | 76.63 | 259.72 | 92.75 |
| 91.800 | 49000.0 | 99000.0 | 45833.0 | .059 | .065 | 3.1 | .00112 | 91.80 | 85.45 | 259.52 | 101.28 |
| 92.000 | 49000.0 | 99000.0 | 45090.1 | .067 | .074 | 3.9 | .00127 | 92.00 | 88.71 | 259.35 | 111.95 |
| 92.200 | 49000.0 | 99000.0 | 44268.9 | .081 | .086 | 6.1 | .00178 | 92.20 | 100.01 | 254.74 | 124.97 |
| 92.400 | 49000.0 | 99000.0 | 43369.6 | .094 | .101 | 7.1 | .00196 | 92.40 | 113.49 | 250.45 | 142.09 |
| 92.600 | 49000.0 | 99000.0 | 42392.1 | .110 | .118 | 8.8 | .00224 | 92.60 | 129.44 | 248.73 | 163.34 |
| 92.800 | 49000.0 | 99000.0 | 41336.4 | .130 | .140 | 11.1 | .00261 | 92.80 | 148.22 | 247.47 | 189.86 |
| 93.000 | 49000.0 | 99000.0 | 40202.5 | .155 | .166 | 14.2 | .00309 | 93.00 | 170.51 | 246.52 | 223.14 |
| 93.200 | 49000.0 | 99000.0 | 38989.8 | .195 | .206 | 21.6 | .00430 | 93.20 | 211.33 | 238.88 | 266.99 |
| 93.400 | 49000.0 | 99000.0 | 37699.1 | .240 | .253 | 27.3 | .00511 | 93.41 | 251.68 | 235.55 | 325.02 |
| 93.600 | 49000.0 | 99000.0 | 36330.0 | .298 | .314 | 35.6 | .00626 | 93.61 | 303.65 | 233.42 | 400.47 |
| 93.800 | 49000.0 | 99000.0 | 34882.1 | .375 | .394 | 58.4 | .00934 | 93.81 | 375.06 | 231.15 | 500.55 |
| 94.000 | 49000.0 | 99000.0 | 33355.1 | .492 | .511 | 69.9 | .01081 | 94.01 | 473.73 | 225.13 | 638.67 |
| 94.200 | 49000.0 | 99000.0 | 31749.3 | .640 | .662 | 94.3 | .01379 | 94.21 | 609.83 | 222.67 | 827.13 |
| 94.400 | 49000.0 | 99000.0 | 30064.0 | .843 | .866 | 129.4 | .01793 | 94.42 | 784.51 | 221.06 | 1086.77 |
| 94.600 | 49000.0 | 99000.0 | 28298.1 | 1.137 | 1.152 | 183.8 | .02413 | 94.62 | 1034.25 | 218.75 | 1454.63 |
| 94.800 | 49000.0 | 99000.0 | 26451.4 | 1.549 | 1.547 | 258.4 | .03227 | 94.83 | 1393.29 | 217.60 | 1978.08 |
| 95.000 | 49000.0 | 99000.0 | 24522.1 | 2.149 | 2.102 | 368.1 | .04379 | 95.04 | 1872.35 | 216.83 | 2741.88 |
| 95.200 | 49000.0 | 99000.0 | 22508.1 | 3.046 | 2.895 | 531.2 | .06027 | 95.26 | 2572.55 | 216.31 | 3882.78 |
| 95.400 | 49000.0 | 99000.0 | 20406.0 | 4.436 | 4.044 | 776.9 | .08419 | 95.48 | 3616.80 | 215.95 | 5651.18 |
| 95.600 | 49000.0 | 99000.0 | 18211.1 | 6.661 | 5.732 | 1147.0 | .11884 | 95.72 | 5133.01 | 215.89 | 8502.83 |
| 95.800 | 49000.0 | 99000.0 | 15916.1 | 10.419 | 8.239 | 1701.0 | .16870 | 95.97 | 7358.50 | 216.40 | 13345.05 |
| 96.000 | 49000.0 | 99000.0 | 13508.1 | 17.431 | 12.055 | 2601.6 | .24638 | 96.25 | 10656.56 | 217.27 | 22427.00 |

REFRACTION AIRMASS TABLES

MIDLATITUDE WINTER
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ALL PRESSURES ARE IN N/SQ M
THE APPARENT AND ASTRONOMICAL ANGLES ARE
IN DECIMAL DEGREES FROM THE ZENITH

THE WAVELENGTH FOR THIS TABLE IS 5.00 MICROMETERS.

| APP. Z (1) | LOWER HEIGHT (2) | UPPER HEIGHT (3) | MIN. HEIGHT (4) | CHAPMAN AIR MASS (5) | OPTICAL AIR MASS (6) | HDIFF (7) | REFRACTION (8) | AST. Z (9) | P(EFF) (10) | T(EFF) (11) | P(TAN) (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 49000.0 | 99000.0 | 10965.0 | 30.161 | 18.045 | 4057.6 | .36642 | 96.57 | 16024.00 | 218.24 | 40874.20 |
| 96.400 | 49000.0 | 99000.0 | 8296.3 | 52.043 | 26.825 | 5742.1 | .49801 | 96.90 | 23810.27 | 224.24 | 73583.39 |

UNREFRACTED RAY STRIKES DISC

REFRACTION AIRMASS TABLES

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 81.000 | 50000.0 | 99000.0 | 50000.0 | .004 | .004 | .0 | .00006 | 81.00 | 32.95 | 263.20 | 61.11 |
| 82.000 | 50000.0 | 99000.0 | 50000.0 | .004 | .004 | .0 | .00007 | 82.00 | 33.11 | 263.25 | 61.11 |
| 83.000 | 50000.0 | 99000.0 | 50000.0 | .005 | .005 | .0 | .00008 | 83.00 | 33.32 | 263.32 | 61.11 |
| 84.000 | 50000.0 | 99000.0 | 50000.0 | .005 | .006 | .0 | .00009 | 84.00 | 33.61 | 263.41 | 61.11 |
| 85.000 | 50000.0 | 99000.0 | 50000.0 | .006 | .007 | .0 | .00011 | 85.00 | 34.03 | 263.53 | 61.11 |
| 86.000 | 50000.0 | 99000.0 | 50000.0 | .007 | .008 | .0 | .00013 | 86.00 | 34.66 | 263.69 | 61.11 |
| 87.000 | 50000.0 | 99000.0 | 50000.0 | .009 | .009 | .0 | .00016 | 87.00 | 35.66 | 263.90 | 61.11 |
| 88.000 | 50000.0 | 99000.0 | 50000.0 | .011 | .012 | .0 | .00020 | 88.00 | 37.30 | 264.17 | 61.11 |
| 89.200 | 50000.0 | 99000.0 | 50000.0 | .016 | .017 | .0 | .00028 | 89.20 | 40.96 | 264.56 | 61.11 |
| 89.400 | 50000.0 | 99000.0 | 50000.0 | .017 | .018 | .0 | .00030 | 89.40 | 41.86 | 264.63 | 61.11 |
| 89.600 | 50000.0 | 99000.0 | 50000.0 | .019 | .020 | .0 | .00033 | 89.60 | 42.87 | 264.70 | 61.11 |
| 89.800 | 50000.0 | 99000.0 | 50000.0 | .020 | .021 | .0 | .00035 | 89.80 | 43.99 | 264.77 | 61.11 |
| 90.000 | 50000.0 | 99000.0 | 50000.0 | .019 | .023 | .0 | .00038 | 90.00 | 45.21 | 264.83 | 58.09 |
| 90.200 | 50000.0 | 99000.0 | 49960.9 | .021 | .025 | .2 | .00043 | 90.20 | 47.13 | 264.35 | 58.39 |
| 90.400 | 50000.0 | 99000.0 | 49843.6 | .023 | .027 | .3 | .00048 | 90.40 | 49.01 | 263.83 | 59.28 |
| 90.600 | 50000.0 | 99000.0 | 49648.0 | .025 | .030 | .5 | .00054 | 90.60 | 50.82 | 263.18 | 60.79 |
| 90.800 | 50000.0 | 99000.0 | 49374.3 | .029 | .033 | .8 | .00061 | 90.80 | 52.56 | 262.32 | 63.04 |
| 91.000 | 50000.0 | 99000.0 | 49022.3 | .032 | .036 | 1.1 | .00069 | 91.00 | 54.18 | 261.20 | 66.04 |
| 91.200 | 50000.0 | 99000.0 | 48592.2 | .036 | .040 | 1.3 | .00072 | 91.20 | 58.32 | 260.72 | 70.04 |
| 91.400 | 50000.0 | 99000.0 | 48083.8 | .040 | .045 | 1.7 | .00080 | 91.40 | 59.89 | 260.35 | 74.92 |
| 91.600 | 50000.0 | 99000.0 | 47497.3 | .046 | .050 | 2.1 | .00089 | 91.60 | 67.14 | 260.03 | 81.12 |
| 91.800 | 50000.0 | 99000.0 | 46832.5 | .052 | .057 | 2.7 | .00100 | 91.80 | 74.89 | 259.77 | 88.57 |
| 92.000 | 50000.0 | 99000.0 | 46089.6 | .059 | .065 | 3.4 | .00113 | 92.00 | 77.74 | 259.55 | 97.91 |
| 92.200 | 50000.0 | 99000.0 | 45268.4 | .068 | .074 | 4.2 | .00129 | 92.20 | 87.42 | 259.36 | 109.35 |
| 92.400 | 50000.0 | 99000.0 | 44369.0 | .081 | .086 | 6.5 | .00177 | 92.40 | 98.74 | 255.70 | 123.23 |
| 92.600 | 50000.0 | 99000.0 | 43391.3 | .095 | .102 | 7.9 | .00199 | 92.60 | 112.50 | 250.66 | 141.67 |
| 92.800 | 50000.0 | 99000.0 | 42335.6 | .113 | .121 | 9.7 | .00229 | 92.80 | 128.89 | 248.80 | 164.67 |
| 93.000 | 50000.0 | 99000.0 | 41201.5 | .135 | .144 | 12.3 | .00270 | 93.00 | 148.29 | 247.48 | 193.53 |
| 93.200 | 50000.0 | 99000.0 | 39989.2 | .162 | .173 | 17.5 | .00349 | 93.20 | 184.61 | 246.45 | 230.03 |
| 93.400 | 50000.0 | 99000.0 | 38698.2 | .206 | .217 | 23.9 | .00448 | 93.40 | 218.39 | 238.08 | 279.15 |
| 93.600 | 50000.0 | 99000.0 | 37329.1 | .256 | .270 | 30.8 | .00543 | 93.61 | 262.63 | 235.01 | 343.90 |
| 93.800 | 50000.0 | 99000.0 | 35881.5 | .321 | .338 | 40.6 | .00673 | 93.81 | 323.49 | 232.99 | 429.02 |
| 94.000 | 50000.0 | 99000.0 | 34354.6 | .419 | .435 | 62.0 | .00954 | 94.01 | 405.61 | 227.81 | 544.25 |
| 94.200 | 50000.0 | 99000.0 | 32749.2 | .545 | .565 | 81.0 | .01186 | 94.21 | 522.04 | 224.12 | 704.26 |
| 94.400 | 50000.0 | 99000.0 | 31064.5 | .717 | .740 | 110.7 | .01536 | 94.42 | 671.17 | 221.99 | 924.55 |
| 94.600 | 50000.0 | 99000.0 | 29299.6 | .964 | .982 | 157.9 | .02074 | 94.62 | 882.95 | 219.76 | 1233.52 |
| 94.800 | 50000.0 | 99000.0 | 27454.3 | 1.311 | 1.319 | 220.5 | .02757 | 94.83 | 1189.02 | 218.19 | 1674.60 |
| 95.000 | 50000.0 | 99000.0 | 25527.0 | 1.814 | 1.793 | 313.7 | .03737 | 95.04 | 1597.22 | 217.21 | 2313.91 |
| 95.200 | 50000.0 | 99000.0 | 23516.1 | 2.560 | 2.467 | 452.2 | .05138 | 95.25 | 2193.47 | 216.56 | 3263.71 |
| 95.400 | 50000.0 | 99000.0 | 21418.7 | 3.703 | 3.443 | 660.4 | .07168 | 95.47 | 3081.53 | 216.11 | 4717.83 |
| 95.600 | 50000.0 | 99000.0 | 19230.3 | 5.521 | 4.877 | 978.6 | .10156 | 95.70 | 4370.96 | 215.81 | 7039.21 |
| 95.800 | 50000.0 | 99000.0 | 16945.3 | 8.519 | 7.003 | 1448.2 | .14397 | 95.94 | 6263.92 | 216.12 | 10898.48 |
| 96.000 | 50000.0 | 99000.0 | 14553.1 | 13.933 | 10.219 | 2201.1 | .20923 | 96.21 | 9066.20 | 216.90 | 17884.52 |

REFRACTION AIRMASS TABLES

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 96.200 | 50000.0 | 99000.0 | 12035.0 | 24.160 | 15.230 | 3432.0 | .31137 | 96.51 | 13442.62 | 217.80 | 31922.39 |
| 96.400 | 50000.0 | 99000.0 | 9380.1 | 42.060 | 22.960 | 5062.2 | .44046 | 96.84 | 20356.64 | 220.81 | 58388.44 |

UNREFRACTED RAY STRIKES DISC

## APPENDIX B. SOURCE STATEMENTS FOR THE RAY TRACING PROGRAM

The following listing is for the FORTRAN IV program used to calculate the values in Table 5. The calculations were performed on the BRLESC II computer, at the Ballistic Research Laboratories, which has a single precision accuracy of 16 significant digits. For use on other computers which carry fewer significant digits, the use of double precisions should be investigated.

The data deck consists of the following cards:

Card 1. Title (13A6)

Card 2. LEVELS (I5): the number of levels in the atmospheric profile to be read in.

ALTORH (F5.0): variable defining input altitudes as geometric ($\neq 0$) or geopotential ($=0$) meters.

ALAT (F10.8): latitude of the observer in degrees.

NOPT (I10): format variable for the input profile.

Card 3 to LEVELS + 2 input profile, altitude, temperature, and pressure (units depend on NOPT)

Card LEVELS + 3: data card for specific geometry

DD1 (F10.7) = zenith angle (degrees)

DD2 (F9.6) = observer height (meters)

DD3 (F10.6) = source height = highest level of profile (meters)

DD4 (F11.3) = wavelength (micrometers)

STOP (I4): program option parameter

- 0 = Apparent zenith angle given - compute astronomical
- 1 = Astronomical zenith angle given - compute apparent
- 2 = calculate preceding case with new wavelength
- 3 = call exit

ALTORH (F8.1): parameter for geometric ($\neq 0$) or geopotential ($=0$) meters for observer height.

Any number of cards for specific geometries can be used (within time limit). To end the computation, the last data card should have a "3" in column 44.

```
$     MAXT ( 8  ) MINS.
$     MAXO ( 8000) LINES
C
C     *************   RAY TRACING PROGRAM *********************************
C
C
      DIMENSION  VARCOM(200)                                          REFR0040
      DIMENSION PTORR ( 200 )
      DIMENSION P(200)
      DIMENSION H(200),T(200),GRAD(200),GAMMA(200)
      DIMENSION Z(200)
      DIMENSION THETAS(200)
      DIMENSION DELTH ( 200 )
      DIMENSION OMSTRA(200)
      DIMENSION RHON(200),AIRS(200)
      DIMENSION ESTRAT(200),ESTR(200)
      DIMENSION RHO(200) , ZRHON( 200 )                               REFR0060
      DIMENSION XPTS(6),WGHTS(6)                                      REFR0140
      DIMENSION T(TLE(13)
      COMMON  VARCOM                                                  REFR0150
      EQU(VALENCE (VARCOM(1),G),   (VARCOM(2),A(RWT),   (VARCOM(3),   REFR0280
     1  RSTAR),   (VARCOM(4),RADIUS),   (VARCOM(5),CONST1),  (VARCOM(6) REFR0290
     2,XPTS),(VARCOM(12),WGHT),(VARCOM(18),FAKE)                      REFR0300
      EQU(VALENCE (VARCOM(20),REFAM)
      EQUIVALENCE (WGHT,WGHTS)                                        REFR0310
      EQU(VALENCE(RHO,RHON)                                           REFR0320
      EQUIVALENCE(ESTRAT,ESTR)                                        REFR0330
      REAL IP
      FCNA(Q000FL)=(1.0+Q000FL/2.0)*(1.0+2.0*Q000FL*(1.0+Q000FL/2.0)/3.0REFR0340
     1)/(1.0+Q000FL)**2                                               REFR0350
      FCNB(Q001FL)=2.0*Q001FL*(1.0+Q001FL/2.0)/3.0                    REFR0360
      FCNU(Q002FL,Q003FL,Q004FL,Q005FL)=2.0*Q004FL*Q005FL*Q002FL/(1.0+QOREFR0370
     103FL*Q005FL)                                                    REFR0380
      FCNE(Q006FL,Q007FL)=Q006FL*(1.0-Q007FL)*(1.0-Q007FL*Q006FL/6.0)  REFR0390
C     FHC(X)=X*RADIUS/(X+RADIUS)
C     THIS FUNCTION CONVERTS GEOMETRIC METERS INTO GEOPOTENTIAL METERS
      FHC(X) = GPHI * X/(RADIUS + X)
C     THIS FUNCTION CONVERTS GEOPOTENTIAL METERS INTO GEOMETRIC METERS
      FZC(Y) = RADIUS * Y /(GPHI - Y )
      NTAPA2=5                                                        REFR0400
      NERROR=6                                                        REFR0410
      NTAPA3=6                                                        REFR0420
      RADSEC=.206264806E+06                                           REFR0500
      RADCON=.174532925E-01                                           REFR0510
      FAKE=-10000000.0                                                REFR0440
      XPTS(1)=-.466234757E+00                                         REFR0520
      XPTS(2)=-.330604693E+00                                         REFR0530
      XPTS(3)=-.119309593E+00                                         REFR0540
      XPTS(4)= .119309593E+00                                         REFR0550
      XPTS(5)=.330604693E+00                                          REFR0560
      XPTS(6)=.466234757E+00                                          REFR0570
      WGHTS(1)=.856622491E-01                                         REFR0580
      WGHTS(2)=.180380786E+00                                         REFR0590
      WGHTS(3)=.233956967E+00                                         REFR0600
      WGHTS(4)=.233956967E+00                                         REFR0610
      WGHTS(5)=.180380786E+00                                         REFR0620
      WGHTS(6)=.856622491E-01                                         REFR0630
      AVNMB = 6.02257 E26
```

```
C                                                                       REFR0640
C                                                                       REFR0660
C           READ ATMOSPHERE INFO                                        REFR0650
 1000 READ (NTAPA2,1021) (TITLE(I),I=1,13)
 1021 FORMAT(13A6)
      READ (NTAPA2,1025) LEVELS,ALTCRH,ALAT, NOPT
 1025 FORMAT(I5,F5.0,F10.8, (10 )
      PHI = ALAT * RADCON
      A = 6378160.0          $  B = 6356775.0
      R = SQRT((A**4*(COS(PHI))**2  + B**4*(SIN(PHI))**2)/
     1 ( A**2*(COS(PHI))**2  + B**2*(SIN(PHI))**2))
      WRITE(6, 10) ALAT, R
   10 FORMAT (  *1FOR A LATITUDE OF PHI = *, F6.2,3X*THE RADIUS OF THE
     1 SPHEROID IS R =*,F12.2,*   METERS.*)
      X = COS(2.0 * PHI)
      Y = COS(4.0 * PHI)
C     G*9.80665                                                         REFR0460
C
C     THE FOLLOWING GEOPOTENTIAL FORMULAE WERE TAKEN FROM THE SMITHSON-
C     IAN METEOROLOGICAL HANDBOOK.
      G = 980.6160 * ( 1.0 -( 0.0026373 * X ) + ( 0.0000059 *X**2))
      G = G/100.0
      PARTGZ = 3.085462 E-06  + 2.27 E-09 * X  - 2.0 E-12 * Y
C     RADIUS=6356766.0                                                  REFR0490
      RADIUS = 2.0 * G / PARTGZ
      RADIUS =R
      RSTAR=8314.39                                                     REFR0450
      AIRWT=28.966                                                      REFR0470
      CONST1=G*AIRWT/RSTAR                                              REFR0480
      GEE = 9.80665
C     GEE = 9.8
      GPHI = RADIUS * G / GEE
      WRITE ( 6,12 ) G, RADIUS, PARTGZ, GEE,  GPHI
   12 FORMAT ( * FOR THE GIVEN LATITUDE, THE FOLLOWING GEOPOTENTIAL INFO
     1MATION IS CALCULATED-* ///* G(PHI)=*,  F15.8,/ * R(PHI)= *, F15.5,
     2 / * PARTGZ =*, E15.8,/* GEE = *, F15.8,/* GPHI =*, F15.6 )
      GO TO ( 1050, 1060, 1050,1050 ), NOPT
 1050 READ(NTAPA2,1075) (H(I),T(I),P(I),I=1,LEVELS)
 1075 FORMAT(3F10.2)
      GO TO 1080
 1060 READ(NTAPA2,1085) (H(I),T(I),P(I),I=1,LEVELS)
 1085 FORMAT ( F10.4, F10.6,  E9.3 )
 1080 CONTINUE
      GO TO  ( 1, 2, 3,4     ), NOPT
C     NOPT = 1   MCCLATCHEY'S PROFILES
C     NOPT = 2   MET ROCKET NETWORK'S PROFILES
C     NOPT = 3   MURCRAY'S RAWINDSONDE PROFILES
C     NOPT = 4 1962 STANDARD ATMOSPHERE
    1 DO 6  I = 1, LEVELS
      IF ( I.EQ.1) GO TO 5
      J = I - 1
      IF (H(J).LT.39.75 ) IF ( H(I) - 0.0) 101,102,101
  101 IF (H(J).LT.69.0  ) IF ( H(I) - 0.0) 103,104,103
  103 IF (H(J).LT.95.0  ) IF ( H(I) - 0.0) 105,106,105
  105 CONTINUE
      GO TO 5
  102 H(I) = H(J) + 0.25
      GO TO 5
  104 H(I) = H(J) + 1.0
      GO TO 5
```

```
  106 H(I) = H(J) + 5.0
    5 CONTINUE
      IF ( T(I).EQ.0.0000 )   T(I) = T(I-1)
C     T(I) = 272.344
    6 CONTINUE
      DO 107 I= 1,LEVELS
      H(I) = H(I) * 1000.
  107 CONTINUE
      GO TO 1051
    2 DO 7  I = 1, LEVELS
      H(I) = H(I) * 10.0
      T(I) = T(I) + 273.15
      P(I) = P(I) * 100.0
    7 CONTINUE
      GO TO 1051
    3 DO 8  I = 1, LEVELS
      H(I) = H(I) * 0.3048
      T(I) = T(I) + 273.15
      P(I) = P(I) * 100.0
    8 CONTINUE
      GO TO 1051
    4 DO 1111 I = 1,LEVELS
      H(I) = H(I) * 1000.
 1111 CONTINUE
 1051 CONTINUE
C
C             OBTAIN PRESSURE PROFILE
C
      IF(P(1).EQ.0.)    P(1)= 101325.0
      DO 1090  I=2,LEVELS
      CALL GETT(H(I-1),H(I),P(I-1),P(I),T(I-1),T(I))
 1090 CONTINUE
      IF(ALTORH) 1100,1150,1100                                          REFR0710
 1100 CONTINUE                                                           REFR0720
C                                                                        REFR0730
C             CONVERT TO GEOPOTENTIAL                                    REFR0740
C                                                                        REFR0750
      DO  1125   I=1,LEVELS                                              REFR0760
      H(I) = FHC(H(I))
 1125 CONTINUE                                                           REFR0780
 1150 CONTINUE                                                           REFR0790
C                                                                        REFR0800
C             COMPUTE GRADIENT AND RATIO OF SPECIFIC HEATS               REFR0810
C                                                                        REFR0820
      DO 1175  I=2,LEVELS                                                REFR0830
      GRAD(I-1)=(T(I)-T(I-1))/(H(I)-H(I-1))                              REFR0840
      GAMMA(I-1)=(CONST1)/(GRAD(I-1)+CONST1)                             REFR0850
      DELTH ( I-1 ) = H(I) - H(I-1)
 1175 CONTINUE                                                           REFR0860
      GAMMA ( LEVELS ) = 1.
      GRAD ( LEVELS ) = 0.
      DELTH( LEVELS ) = 0.0
C                                                                        REFR0870
C             COMPUTE ASSORTED STRATA INFORMATION -- IN PARTICULAR       REFR0880
C             COMPUTE THE DENSITY AT EACH BREAK POINT (ASSUMING SEA      REFR0890
C             LEVEL AS ONE) AND THE OPTICAL AIR MASS ACROSS EACH STRATA  REFR0900
C             (CUMULATIVE FROM ABOVE)                                    REFR0910
C                                                                        REFR0920
      SUMRHO = 0.0
      DO 1190 I = 1,LEVELS
```

```
      ZRHON(I) = AVNME * P(I) /(RSTAR * T(I))
      SUMRHO = SUMRHO + ZRHON(I)  * DELTH ( I )
 1190 CONTINUE
      RHON(1) = ZRHON(1)
C      OMSTRO WILL BE USED LATER TO CALCULATE THE INDEX OF REFRACTION
C     OF THE FIRST LAYER
      OMSTRO = 1.0 -( RHON(1) / 2.5475521 E25 )
      DO  1200     I=2,LEVELS                                              REFR0940
      CALL OM (H(I),H(I-1),H(I-1),T(I-1),GAMMA(I-1),OMEGA,DUMMY)           REFR0950
      NLC=I-1
      OMSTRA(NLC)=OMEGA
C     COMPUTES DENSITY
      RHON(I)=RHON(I-1)*(1.0-OMEGA)                                        REFR0970
C     COMPUTES AIRMASS
      CALL OPT1(H(I-1),H(I),T(I-1),GAMMA(I-1),RHO(I-1),OMEGA,AIRS(I-1)     REFR0980
     1)                                                                    REFR0990
 1200 CONTINUE                                                             REFR1000
      AIRS(LEVELS)=0.0                                                     REFR1010
      DO 1225  I=2,LEVELS                                                  REFR1020
      IND=LEVELS+1-I                                                       REFR1030
      AIRS(IND)=AIRS(IND)+AIRS(IND+1)                                      REFR1040
 1225 CONTINUE                                                             REFR1050
      STARD = AIRS(1)
C     THIS CARD NORMALIZES ALL AIR MASSES TO THE 1962 US STANDARD ATM.
      REFAM = AIRS (1)
      REFAM = 2.15335 E29
C     WRITE (6,100) REFAM ,STARD,  SUMRHO
      WRITE (6,100) REFAM ,STARD
  100 FORMAT ( * THE REFERENCE AIRMASS IS *, E20.8,*   MOLECULES /M2*,//
     1,* FOR THIS PROFILE, THE INTEGRATED AIRMASS IS  *,E20.8)
C     1,* FOR THIS PROFILE, THE INTEGRATED AIRMASS IS  *,E20.8,/ * AND
C     2THE SUMMED AIRMASS IS  *, E20.8, * MOLECULES/SQUARE METER.*///)
C                                                                          REFR1060
C              COMPUTATIONS NECESSARY FOR INITIAL SET UP HAVE              REFR1070
C              BEEN COMPUTED.  THE MODEL ATMOSPHERE HAS BEEN               REFR1080
C              ACCEPTED.  THE NEXT PORTION OF THE PROGRAM IS               REFR1090
C              THE SOLUTION OF THE BASIC PROBLEM                           REFR1100
C                                                                          REFR1110
      WRITE(NTAPA3,1231) (TITLE(I),I=1,10)
 1231 FORMAT(1H ,5X,25HREFRACTION AIRMASS TABLES,5X,10A6,/,2X)
      WRITE(NTAPA3,1239) LEVELS
 1239 FORMAT(1H ,6X,7HLEVELS=,I5,//
     17X,36HTHE ATMOSPHERE PROFILE IS AS FOLLOWS,///,
     2 1X,11HBREAK POINT,5X,15HTEMPERATURE (K),7X,13HPRESSURE      ,12X,
     38HGRADIENT,5X,23HRATIO OF SPECIFIC HEATS,4X17HDENSITY(MOL/M**3),/)
C     2 1X,11HBREAK POINT,5X,15HTEMPERATURE (K),7X,13HPRESSURE (MB),12X,
C     38HGRADIENT,5X,23HRATIO OF SPECIFIC HEATS,//)
      DO 1242 IE=1,LEVELS
C     PTORR ( IE) = 0.0075 * P (IE)
      PTORR I IE) =          P (IE)
      WRITE ( 6,1241 ) H(IE), T(IE), PTORR (IE), GRAD (IE), GAMMA (IE),
     1           ZRHON (IE)
C     1RHON (IE), ZRHON (IE)
C1241 FORMAT ( 1H ,F1 .4,2F2 .4,2F2 .8, E20.8 )
C1241 FORMAT ( 1H ,F1 .4,2F2 .4,2F2 .8, E2 .8 )
 1241 FORMAT ( 1H ,F1 .4,2F2 .4,2F2 .8, E25.8 )
C1241 FORMAT ( 1H ,F1 .4,2F2 .4,2F2 .8,2E12.3 )
C1241 FORMAT(1H ,10X,3F2 .4,2F20.8)
 1242 CONTINUE
      WRITE(6,1243)
```

```
 1243 FORMAT(1H1)
      LINC=-1
 1250 READ (NTAPA2,1255)  DD1,DD2,DD3,DD4,LSTOP,ALTORH
 1255  FORMAT (  F10.7 , F9.6 , F11.6 , F11.3 , I4 , F9.1 )
      DD3=DD3*1000.0
C     DD4 = 50.0
      DD4 = DD4 * 1000.
      JMP=LSTOP+1
      NTF=0
      LINC=-1
C
C             JMP=1 IS BASIC REFRACTION PROGRAM
C             JMP=2 FIND ZO SUCH THAT FOUND ZO +R = READ ZO
C             JMP=3 USE OLD ZO,DHGHT,AND HGHT AND NEW WAVEL
C             JMP=4 CALL EXIT
C             JMP=5 READ NEW PROFILE
C
      GO TO (1257,1257,1258,1256,1000), JMP
 1256 GO TO 1400
C1257 ZO=DD1
 1257 DO 4150 IN= 1,5
      IF ( DD1 .LT. 89.0)     DD1 = DD1 + 1.0
      IF ( DD1 .LT. 89.0) GO TO 1297
      DD1 = DD1 + 0.2
 1297 CONTINUE
      ZO=DD1
      ZOS=ZO
      DHGHT=DD3
      HGHT=DD4
 1258 WAVEL=DD2
      ZD=ZOS
 1270 IF(ALTORH) 1280,1290,1280
 1280 DHGHT=FHC(DHGHT)
      HGHT =FHC( HGHT)
 1290 CONTINUE
      ZOS=ZO                                                    REFR1170
      ZT=ZOS
 1295 CONTINUE
C     NTF=NTF+1
      IF (NTF-10) 1296,1296,4700
 1296 CONTINUE
      SECT2=0.
      SECT3 = 0.0
      SECT4 = 0.0
      RSAVE=0.
      DSAVE=0.
      PSAVE= 0.0
      TSAVE = 0.0
      HDIFF = 0.0
      HTAN = 0.0
      TP = TG = 273.15
C                                                               REFR1140
C             ZO IS IN DEGREES - CONVERT TO RADIANS             REFR1150
C                                                               REFR1160
      ZO=ZO*RADCON                                              REFR1180
      UTEMP=1.0/WAVEL**2                                        REFR1190
C                                                               REFR1200
C             COMPUTE E1 FROM EDLENS FORMULA                    REFR1210
C                                                               REFR1220
      E1 = 0.0
```

```
      E1=.000064328+.0204981/(146.-UTEMP)+.00012554/(41.0-UTEMP)          REFR1230
C                                                                         REFR1240
C             COMPUTE THE REFERENCE AIR MASS                              REFR1250
C             A.  FIND THE STRATA NUMBER OF O                             REFR1260
C             B.  COMPUTE M FOR REMAINDER OF STATUM                       REFR1270
C             C.  ADD IN AIR ABOVE THAT STRATUM                           REFR1280
C                                                                         REFR1290
C     FIND INDEX FOR ATMOSPHERIC SHELL OF THE OBSERVER
      DO 1300 IHT=2,LEVELS                                                REFR1300
      IF(HI(IHT)-OHGHT)  1300,1325,1325                                   REFR1310
 1300 CONTINUE                                                            REFR1320
      CALL COMP                                                           REFR1330
 1325 IHT=IHT-1                                                           REFR1340
C     RHOP = ZRHON ( IHT     )
C     POB = P ( IHT     ) * 0.0075
C     THE FOLLOWING SATEMENTS INTERPOLATE FOR PRESSURE AND DENSITY
      CALL GETT ( H(IHT), OHGHT, PI(IHT), POB, TI(IHT), T(IHT) )
      RHOP = AVNMB * P0B/( RSTAR * TI(IHT) )
      RHOMIN = RHOP
C     POB = POB * 0.0075
      TP = T ( IHT     )
C     FIND INDEX FOR ATMOSPHERIC SHELL OF SOURCE
      DO 1335  IND= 2 ,LEVELS                                             REFR1350
      JHT=IND
      IF(HI(JHT)-HGHT)  1335,1340,1340                                    REFR1360
 1335 CONTINUE                                                            REFR1370
      WRITE (NERROR,1337)                                                 REFR1380
 1337 FORMAT(27H  UPPER HEIGHT RESET)                                     REFR1390
 1330 JHT=IND                                                             REFR1400
 1340 CONTINUE                                                            REFR1410
C                                                                         REFR1490
C            COMPUTE Z AT EACH STRATUM LINE                               REFR1500
C                                                                         REFR1510
C                                                                         REFR1520
C             FIND E AT EACH LAYER (SOPHISTICATE LATER)                   REFR1530
C          THE PERSENT METHOD ASSUMES AN ATMOSPHERE I OF CONSTANT
C     COMPOSITION AND CALCULATES THE REFRACTIVE INDEX FROM THE LORENTZ-
C     LORENTZ FORMULA
C                                                                         REFR1540
C      THE VALUE OF THE (NDEX OF REFRACTION FOR THE FIRST LAYER IS CAL-
C     ULATED FROM THE VALUE AT STP. I T = 15 DEG C AND P = 760 TORR
      ESTRAT (1) = FCNE ( E1 , OMSTRC )
      DO 1350 I=2,LEVELS                                                  REFR1560
      ESTRAT(I)=FCNE(ESTRAT(I-1),OMSTRA(I-1))                             REFR1570
 1350 CONTINUE                                                            REFR1580
C                                                                         REFR1590
C             COMPUTE FIRST ZS AND THETAS                                 REFR1600
C                                                                         REFR1610
      JNS=1
C
C             NEW SECTION TO HANDLE ALL GEOMETRIES
C
      HMINA=OHGHT
      IF (ZOS.LE.90.) IF (HGHT-OHGHT+.05) 4500,4600,1373
C
C     CASE 1. GO TO 1373 ( BASIC PROBLEM )
C     CASE 2. GO TO 4600 ( TRIVIAL CASE )
C     CASE 3. GO TO 4500 ( NO SOLUTION )
C
C             NOT BASIC PROBLEM
```

```
C     THE FOLLOWING SECTION IS USED TO DETERMINE WHETHER THE LIGHT RAY
C     IS OF TYPE 1,/R 2. OR 3.
C
      CALL OM(OHGHT,H(IHT),H(IHT),T(IHT),GAMMA(IHT),OME,XXX)
      EO=FCNE(ESTRAT(IHT),OME)
C
C     ZCRIT(ICAL) IS THE ANGLE OF A TANGENT RAY TO THE SURFACE OF THE EARTH
C
      ZCRIT = ASIN ((1.0 + ESTR (1) ) * ( 1.0 - OHGHT / RADIUS ) / ( 1.0
     1 + EO ))
      ZCRIT=3.141592653-ZCRIT
C     CASE 4 GO TO 4500
C     CASE 5. GO TO 1357
C     CASE 2. GO TO 4600
      IF (ZO.GT.ZCRIT+.00001) IF(OHGHT-HGHT+.5) 4500,4600,1357
C     THIS SECTION CALCULATES FOR A GRAZING RAY THAT DOES NOT
C     INTERSECT THE SURFACE OF THE EARTH ( I.E. CASES 1 THRU 9
C
C           COMPUTE  HM  ( THE TANGENT OR MINIMUM HEIGHT )
C
      FVAL =SIN(ZO)*(1.+E0)/(RADIUS-OHGHT)
      F1=(1.+ESTR(1))/ RADIUS - FVAL
      DO 1351 I=2,LEVELS
      K=I-1
      F2=(1.+ESTR(I))/(RADIUS-H(I))-FVAL
      IF(F2*F1) 1352,1352,1351
 1351 F1=F2
      GO TO 4500
 1352 H1=H(K)
      H2=H(K+1)
      H3=H1-(H2-H1)*F1/(F2-F1)
 1353 CALL OM(   H3,H(K),H(K),T(K),GAMMA(K),W,XXX)
      F3=(1.+FCNE(ESTRAT(K),W))/(RADIUS-H3)-FVAL
      HM=H3-F3*((H3-H2)/(F3-F2)+ (H3-H1)/(F3-F1)-(H2-H1)/(F2-F1))
      IF(ABS(HM-H3).LE.1.)   GO TO 1354
      H1=H2
      H2=H3
      H3=HM
      F1=F2
      F2=F3
      GO TO 1353
C     IF THE MINIMUM HEIGHT IS ABOVE THE SOURCE HEIGHT THERE IS AN ERROR
 1354 IF (HM.GT.HGHT+.05) GO TO 4500
C
C     ZO = 90 DEGREES, AND THE FOLLOWING SECTION CALCULATES FROM THE MINIMUM
C     POINT TO THE OBSERVER
      HMINA=HM
      ZOSAVE=ZO
      HOSAVE=OHGHT
      HSSAVE=HGHT
      ZO=1.570796326
      OHGHT=HM
      HGHT=HOSAVE
C     THE FOLLOWING INTERPOLATES FOR TANGENT HEIGHT PRESSURE AND DENSITY
C     CALL GETT ( H(K), HM, P(K), POB, T(K), T(K) )
C     RHOMIN = AVNMB * POB /( RSTAR * T(K))
C     POB = POB * 0.0075
C     POB = P(K)* 0.0075
C     RHOMIN = ZRHON (  K )
      TG = T ( K )
```

```
      JSAV=JHT
      JHT=IHT+1
      IHT=K
      INS=2
      GO TO 1374
C     HAVING JUST COMPLETEED FROM THE TANGENT HEIGHT TO THE OBSERVER, WE NOW
C     GO FROM TANGENT HEIGHT TO XOURCE
 1355 RSAVE=REFRS
      OSAVE=SECT2
      PSAVE = SECT3
      TSAVE = SECT4
      HGHT=HSSAVE
      JHT=JSAV
      INS=3
      GO TO 1374
C
C     IF THE SOURCE IS LOWER THAN THE OBSERVER FOR Z GREATER THAN 90 DEG.
C     THERE EXIST 2 POSSIBLE SOLUTIONS TO THE PROBLEM
C
 1356 IF(HSSAVE.LT.HOSAVE)  JNS=2
      OHGHT=HOSAVE
      GO TO 3950
C
C     START HERE FOR CASE 5 ( TYPE U RAY AND HS LESS THAN HO
C
 1357 CALL OMI(HGHT,H(JHT),H(JHT),T(JHT),GAMMA(JHT),W,XXX)
      ZSAVE=ASIN((1.+EO)/(1.+FCNE(ESTRI(JHT),W))*(RADIUS-HGHT)/(RADIUS-
     1OHGHT))
      IHT=JHT
      ZZ=ZO
      ZO=ZSAVE
      HOSAVE=OHGHT
      HSSAVE=HGHT
      OHGHT=HSSAVE
      HGHT=HOSAVE
      ZO=ZZ
      INS=4
      GO TO 1374
 1358 JNS=1
      OHGHT=HOSAVE
      HGHT =HSSAVE
      GO TO 3950
 1373 INS=1
 1374 CONTINUE
      CALL OM(OHGHT,H((HT),H(IHT),TI(HT),GAMMA((HT),OME,DUMMY)
      CALL OM(H((HT+1),OHGHT,H(IHT),TI(HT),GAMMA((HT),OMO,TOO)
      EO=FCNE(ESTRAT((HT),OME)
      VARCOM(19)=RHO((HT)*(1.-OME)
      IF(JHT.EQ.IHT+1)  GO TO 1380
      US=FCNU(FCNA(EO),FCNB(EO),EO,OMO)                                  REFR1630
      CALL ZCOMP(ZO,Z((HT+1),OHGHT,H((HT+1),US,DELZ,THETAS(IHT+1)        REFR1640
     1)                                                                  REFR1650
      CALL QUAD(THETAS(IHT+1),ZO,OHGHT,TOO,P(IHT+1),GAMMA(IHT),EO,SECT1,
     1SECT2,SECT3,SECT4)
      REFR =(DELZ +SECT1)
      REFRS=REFR*RADSEC
 2010 DELRS=REFRS
C                                                                        REFR1660
C            COMPUTE SUCCEEDING Z S                                      REFR1670
C                                                                        REFR1680
```

```
 2000 INDU=JHT-2
      IHT1=IHT+1                                                        REFR1700
      IF(INDU.LT.IHT1)  GO TO 1376
 1360 CONTINUE
      DO 1375 I=IHT1,INDU                                               REFR1710
C                                                                       REFR1720
C          ************************************************************REFR1730
C                                                                       REFR1740
      U=FCNU(FCNA(ESTR(I)),FCNB(ESTR(I)),ESTR(I),CMSTRA(I))
      CALL ZCOMP(Z(I  ),Z(I+1),H(I  ),H(I+1),U,DELZ,THETAS(I+1)         REFR1760
     1)                                                                 REFR1770
      DELZT=DELZT+DELZ
      VARCOM(19)=RHO(I)
      CALL QUADI(THETAS(I+1),Z(I),HI(),T(I),P(I),GAMMA(I),ESTR(I),ADD1,
     1ADD2,ADD3,ADD4)
      SECT2=SECT2+ADD2
      SECT3 = SECT3 + ADD3
      SECT4 = SECT4 + ADD4
      DELR =(DELZ+ADD1)
      REFR =DELR+REFR
      REFRS=REFR*RADSEC
      DELD=DELR*RADSEC
 1375 CONTINUE                                                          REFR1780
 1376 CONTINUE
      ROLAST=RHO(JHT-1)
      ZLAST=Z(JHT-1)
      ELAST=ESTR(JHT-1)
      PLAST = P(JHT - 1)
      TLAST=T(JHT-1)
      GLAST=GAMMA(JHT-1)
      HLAST=HI(JHT-1)
 1377 CONTINUE
      CALL OM(HGHT,HLAST,HI(JHT-1),TLAST,GLAST,GLAST,XXX)
      U=FCNU(FCNA(ELAST),FCNB(ELAST),ELAST,GLAST)
      CALL ZCOMP(ZLAST,ZFIN,HLAST,HGHT,U,DELZ,THFIN)
      VARCOM(19)=ROLAST
      CALL QUADI(THFIN,ZLAST,HLAST,TLAST,PLAST,GLAST,ELAST,ADD1,ADD2,ADD3
     1,ADD4)
      SECT3 = SECT3 + ADD3
      SECT4 = SECT4 + ADD4
      DELR=DELZ+ADD1
      REFR=DELR+REFR
      REFRS=REFR*RADSEC
      SECT2=SECT2+ADD2
      DELD=DELR*RADSEC
      IF (INS.EQ.2)  GO TO 1355
      KJHT=JHT-1
      GO TO (3950,1355,1356,1358),(NS
C     CALCULATES WHEN YOU GET TO THE LAST LEVEL
 1380 ROLAST=VARCOM(19)
      ZLAST=ZO
      ELAST=EO
      HLAST=OHGHT
      TLAST=T(JHT-1)
      PLAST = P(JHT - 1)
      GLAST=GAMMA(JHT-1)
      REFR=0.
      GO TO 1377
 3950 CONTINUE
      SECT3 = SECT3 + PSAVE
```

```
      SECT4 = SECT4 + TSAVE
      REFRS=REFRS+RSAVE
      SECT2=SECT2+OSAVE
      DERF=REFRS/3600.
      ZEND=ZOS+DERF
C     PEFF = SECT3/SECT2 * 0.0075
      PEFF = SECT3/SECT2
      TEFF = SECT4/SECT2
C     THIS DOES THE CALCULATION WHEN YOU START FROM THE AST. ZENITH ANG.
      IF(JMP.EQ.2)    GO TO 4100
 3980 CONTINUE
      IF (LINC)   3990,3999,3999
 3990 WRITE (NTAPA3,3991) TITLE
 3991 FORMAT(1H1,5X25HREFRACTION AIRMASS TABLES,5X13A6,/,
     340X38HALL HEIGHTS ARE IN GEOMETRIC METERS    /,40X,*ALL TEMPERATUR
     3ES ARE IN DEGREES KELVIN*/,40X,*ALL PRESSURES ARE IN N/SQ M */
     440X40HTHE APPARENT AND ASTRONOMICAL ANGLES ARE/
     540X34HIN DECIMAL DEGREES FROM THE ZENITH/)
      WRITE ( 6 , 3993 ) WAVEL
 3993 FORMAT ( 40X *THE WAVELENGTH FOR THIS TABLE IS *,F5.2,* MICROMETER
     1S.*//)
      WRITE(6,3992)
 3992 FORMAT(11X5HLOWER,5X5HUPPER,5X4HMIN., 7 X7HCHAPMAN ,  5X7HOPTICAL)
      WRITE(6,3995)
C3995 FORMAT(1X6HAPP. Z,4X6HHEIGHT,4X6HHEIGHT,4X6HHEIGHT,3X8HAIR MASS,4X
 3995 FORMAT(1X6HAPP. Z,4X6HHEIGHT,4X6HHEIGHT,4X6HHEIGHT,5X8HAIR MASS,4X
     18HAIR MASS,4X5HDIFF,3X10HREFRACTION,  4X6HAST. Z,6X 6HP(EFF),4X6H
     1T(EFF),6X6HP(TAN)  )
      WRITE(6,3996)
C3996 FORMAT(3X3H(1),7X3H(2),7X3H(3),7X3H(4),7X3H(5), 8X3H(6),7X3H(7),
C     1 9X3H(8),9X3H(9),9X4H(10),6X4H(11), 8X4H(12) ,/,1X )
 3996 FORMAT(3X3H(1),7X3H(2),7X3H(3),7X3H(4),8X3H(5), 8X3H(6),10X3H(7),
     1 6X3H(8),9X3H(9),9X4H(10),6X4H(11), 9X4H(12) ,/,1X )
      LINC=42
 3999 LINC=LINC-1
      ZFIN = ZEND * RADCON
      OHGHT = FZC ( OHGHT )
      HGHT = FZC ( HGHT )
      HMINA = FZC ( HMINA )
      SCALHP = RSTAR *   TP   / AIRWT / G
      XP = ( RADIUS + OHGHT ) / SCALHP
      WHY = SQRT ( 0.5 * XP ) * ABS ( COS ( ZFIN ))
      FERF = EXP((WHY)**2.0) * ( 1.0 - ERFN( WHY))
      IF ( ZEND .LE. 70.0 ) GO TO 4035
      IF ( ZEND.LE. 90.0 ) GO TO 4030
C     THE FOLLOWING COMPUTES THE CHAMAN FUNCTION FOR THE OPTICAL PATH
C     OF A GRAZING RAY.
C     THE FOLLOWING EXPRESSION CALCULATES THE TANGENT HEIGHT FOR THE
C     CASE OF NO REFRACTION.
      HTAN = ( RADIUS + OHGHT ) * SIN ( ZFIN ) - RADIUS
      IF ( HTAN.LE. 0.0) GO TO 4002
      HDIFF = HMINA - HTAN
      DO 4000 JND = 2,LEVELS
      L = JND
      IF ( H(L) - HTAN ) 4000,4001,4001
 4000 CONTINUE
      WRITE (6,1337)
 4001 L=JND-1
      TG = T(L)
      CALL GETT ( H(L),HTAN,P(L), PGB, T(L), T(L) )
```

```
      RHOMIN = AVNMB * PCB /( RSTAR * T(L))
      SCALHG = RSTAR *   TG    / AIRWT / G
      XG = ( RADIUS + HMINA ) / SCALHG
      WHY2 = SQRT ( 1.570796326 * XG )
      (P = WHY2 * SCALHG * ( 2.C * RHOMIN - RHOP          * FERF          )
      GO TO 4040
 4030 CONTINUE
C     THE FOLLOWING COMPUTES THE CHAMAN FUNCTION FOR THE OPTICAL PATH
C     WHICH IS NOWHERE TANGERT TO THE SURFACE OF THE EARTH
      WHY1 = SQRT ( 1.570796326 * XP )
      IP = RHOP          * SCALHP * WHY1 * FERF
      GO TO 4040
 4035 IP =A(RS((HT)/COS(ZFIN)
 4040 CONTINUE
      IP = (P/ REFAM
      WRITE (NTAPA3,4089) ZOS,OHGHT,HGHT,HM(NA, (P   ,SECT2,HD(FF,DERF,
     1ZEND ,PEFF, TEFF, PCB
 4089 FORMAT(1X,F7.3,3F10.1,F11.3, F11.3,F12.1 ,F11.5, F12.2, F12.2,
     1F9.2, F12.2 )
 4150 CONTINUE
      GO TO (1250,4100,1250,1256,1000),JMP
 4100 CONTINUE
      IF(ABS(ZT-ZEND).LT..00001)  GO TO 4200
      ZOS=ZT-DERF
      ZO=ZOS
      GO TO 1295
 4200 JMP=1
      GO TO 3980
 4500 WRITEINTAPA3,4510) ZOS
C4500 WRITEINTAPA3,4510) ZOS,OHGHT,HGHT,WAVEL
 4510 FORMAT(1XF14.5,        60X2CH *** NO SOLUTION ***)
      LINC=LINC-1
      GO TO 1250
C     THIS HANDLES THE CASE 2 WHEN SORCE AND OBSERVER ARE CLOSE TOGRTHER IN SAME
C     SHELL
 4600 REFRS=0.
      SECT2=0.
      SECT3 = 0.
      SECT4 = 0.
      GO TO 3950
 4700 IF(ABS(ZT-ZEND).LT..001   )  GO TO 4200
      LINC=LINC-2
      WRITE INTAPA3,4089) ZOS,OHGHT,HGHT,HM(NA,WAVEL,SECT2,REFRS,DERF,
     1ZEND
      WRITE (NTAPA3,4705)
 4705 FORMAT(1H ,37H***NO GOOD SOLUTION FOR LINE ABOVE***)
 4002 WRITE (6,4003)
 4003 FORMAT ( 1H *             UNREFRACTED RAY STRIKES DISC    * )
      GO TO 1250
 1400 CONTINUE
      STOP
      END
      SUBROUTINE DUMP(XNEY)
      XNEY=0.0
      RETURN
      END
      FUNCTION ERFN(X)                                                  ****   1
      X1=ABS(X)                                                         ERFN   2
      X2=X1*X1                                                          ERFN   3
      (F(X1.GT..47)GOTO 2                                               ERFN   4
```

```
      A1=((-.0356098437C1815385*X2+6.9963834886191355)*X2                ERFN   5
     1+21.97926161829415 2)*X2+242.66795523053175                        ERFN   6
      A2=((X2+15.082797630407787)*X2+91.16490540451490 1)*X2             ERFN   7
     1+215.0588758698612                                                 ERFN   8
      A1=X1*A1/A2                                                        ERFN   9
      GOTO 4                                                             ERFN  10
    2 IF(X1.GT.4.)GOTO 3                                                 ERFN  11
      A1=((((((-1.3686485738271670 67E-7*X1+.56419551747897397 11)*X1    ERFN  12
     1+7.2117582508830936 59)*X1+43.16222722205673530)*X1                ERFN  13
     2+152.98928504694040 39)*X1+339.32081673434368 70)*X1               ERFN  14
     3+451.9189537118729422)*X1+300.4592610201616005                     ERFN  15
      A2=((((((X1+12.78272731962942)*X1+77.00015293522947295)*X1         ERFN  16
     1+277.5854447439876434)*X1+638.9802644656311665)*X1                 ERFN  17
     2+931.3540948506096211)*X1+790.9509253278980272)*X1                 ERFN  18
     3+300.4592609569832933                                              ERFN  19
      A1=1.-EXP(-X2)*A1/A2                                               ERFN  20
      GOTO 4                                                             ERFN  21
    3 X3=1./X2                                                           ERFN  22
      A1=(((.0223192459734184686*X3+.27866130860964778 8)*X3             ERFN  23
     1+.22695659353968693 0)*X3+.04947309106232507 34)*X3                ERFN  24
     2+.00299610707703542174                                             ERFN  25
      A2=(((X3+1.98733201817135256)*X3+1.05167510706793207)*X3           ERFN  26
     1+.19130892610782984 1)*X3+.0106209230528467918                     ERFN  27
      A1=1.-EXP(-X2)/X1*(.56418958354775627-X3*A1/A2)                    ERFN  28
    4 IF(X.LT.0.)A1=-A1                                                  ERFN  29
      ERFN=A1                                                            ERFN  30
      RETURN                                                             ERFN  31
      END                                                                ERFN  32

      SUBROUTINE OM(H,HO,HN,TN,GAMMA,OMEGA,TO)                           OM000050
C             SUBROUTINE TO COMPUTE OMEGA                                OM000030
C             HN IS A BASE HEIGHT FOR THE LEVEL
C             HO IS THE LOWER HEIGHT
C             H  IS THE UPPER HEIGHT
C             OMEGA IS FROM THE LOWER HEIGHT TO THE UPPPER HEIGHT
C                                                                        OM000040
C     DOUBLE PRECISION Y,ONEG
      COMMON  G       , AIRWT   , RSTAR   , RADIUS , CONST1              OM000060
      GM=ABS(GAMMA)
      IF(GM.LT.0.0000001)GO TO 801
      ONEG=1.0-GAMMA                                                     OM000080
      ONG=ONEG
      IF(RADIUS+HN)     500,500,600                                      OM000090
  500 CONTINUE                                                           OM000100
      X=CONST1*H*(RADIUS-HO)/TN                                          OM000110
      GO TO 700                                                          OM000120
  600 CONTINUE                                                           OM000130
      A=CONST1*(H-HO)                                                    OM000140
      TO=TN+CONST1*(HO-HN)*(ONG)/GAMMA
      X=A/TO                                                             OM000160
  700 CONTINUE                                                           OM000170
      Y=-X/GAMMA                                                         OM000180
      IF(ONEG.EQ.0.)  GO TO 800
      IF(1.0 -ONEG*Y) 803,803,400
  400 IF(1.0-(1.0-ONEG*Y))800,800,300
  300 OMEGA=1.-(1.-ONEG*Y)**(-1./ONEG)
      RETURN
  800 CONTINUE
      IF(Y.LT.(-30.0))Y=0.0
C     OMEGA=1.0-DEXP(Y)
```

```
C      IF( ABS( Y ) .GT. 25.0 )  PRINT 1, Y,X, GAMMA, A, T0,TN,H,H0,HN,
     1  CONST1
    1 FORMAT ( 1H  , 5E20.8)
      IF( ABS( Y ) .GT. 25.0 )  GO TO 10
      OMEGA=1.0- EXP(Y)
   10 CONTINUE
      RETURN                                                          OM000290
  801 WRITE(6,802)
  802 FORMAT(1X,8H GAMMA=0)
  803 WRITE (6,804) ONEG,X,Y, GAMMA
  804 FORMAT(* BOOBOO *, 4E20.8 )
                        WRITE (6,11) H,H0,HN,TN,CONST1,RADIUS ,A,T0,X
   11 FORMAT (1H ,  4E20.8 )
      RETURN
      END                                                             OM000300
C
      SUBROUTINE OPT1(H0,H,T0,GAMMA,RHO0,OMEGA,AIRM)                  OPT10060
C                                                                     OPT10020
C             SUBROUTINE TO COMPUTE OPTICAL AIRMASS                   OPT10030
C                                                                     OM000020
C             THIS ROUTINE COMPUTES AIR MASS WITHIN ONE STRATA        OPT10040
C                                                                     OPT10050
      COMMON  G       , AIRWT  , RSTAR  , RADIUS , CONST1             OPT10070
      RAD=RADIUS-H0                                                   OPT10090
      XK=CONST1*RAD/(T0*GAMMA)                                        OPT10100
      SMALLH=(H-H0)/(RADIUS-H0)                                       OPT10110
      ONEH=1.0-SMALLH                                                 OPT10120
      ONEG=GAMMA-1.0                                                  OPT10130
      XK2=(1.0-ONEG*SMALLH*XK)/ONEH                                   OPT10140
C                                                                     OPT10150
C             COMPUTE U AND V SERIES                                  OPT10160
C                                                                     OPT10170
      SUMU=0.0                                                        OPT10180
      SUMV=0.0                                                        OPT10190
      XN=0.0                                                          OPT10200
      DENOM=1.0                                                       OPT10210
      TERMU=1.0                                                       OPT10220
      TERMV=1.0                                                       OPT10230
      TEST=.00000001/(XK*GAMMA)                                       OPT10240
      KOUNT=0                                                         OPT10250
 1000 CONTINUE                                                        OPT10260
      KOUNT=KOUNT+1                                                   OPT10270
      XN=XN+1.0                                                       OPT10280
      DENOM=DENOM+ONEG                                                OPT10290
      FACT=XN/(XK*DENOM)                                              OPT10300
      TERMU=TERMU*FACT                                                OPT10310
      TERMV=TERMV*FACT*XK2                                            OPT10320
      SUMU=SUMU+TERMU                                                 OPT10330
      SUMV=SUMV+TERMV                                                 OPT10340
      IF (KOUNT-31)   1040,1040,1060
 1040 IF(ABS(TEST)-ABS(TERMV)) 1000,1000,1050
 1050 IF(ABS(TEST)-ABS(TERMU)) 1000,1000,1075                         OPT10360
 1075 IF (KOUNT-30)            1100,1100,1080
 1080 WRITE (6,1085)                                                  OPT10380
 1085 FORMAT(17HO  BOOBOO IN OPT1)                                    OPT10390
C
C     THIS IS A SERIES APPROXIMATION TO THE INTEGRAL FOR THE AIRMASS.
C
 1100 AIRM=(RADIUS**2/RAD)*RHO0*(SUMU-(1.0-OMEGA)*SUMV/ONEH)          OPT10400
      RETURN                                                          OPT10410
```

```
      END                                                               OPT10420
      FUNCTION ASINX(X)
      Z=X**2
      ASINX=X*(1.+Z/6.+.075*Z**2)
      RETURN
      END                                                               ASIN0180
      SUBROUTINE ZCOMP(ZO,ZS,HO,HS,US,DELZ,THETA)                       ZCOM0050
C                                                                       ZCOM0020
C           THIS SUBROUTINE COMPUTES ZS                                 ZCOM0030
C                                                                       ZCOM0040
      COMMON  G       , AIRWT   , RSTAR   , RADIUS , CONST1             ZCOM0060
      SMALLH=(HS-HO)/(RADIUS-HO)                                        ZCOM0080
      ONEH=1.0-SMALLH                                                   ZCOM0090
      TWOH=SMALLH*(2.0-SMALLH)                                          ZCOM0100
      C=COS(ZO)                                                         ZCOM0110
      S=SIN(ZO)                                                         ZCOM0120
      CONE=C*ONEH                                                       ZCOM0130
      CPLUS=CONE**2+TWOH                                                ZCOM0140
      DEL2=S*(US-TWOH)                                                  ZCOM0150
      DEL3=SQRT(1.0-US)*(CONE+SQRT(CPLUS-US))                           ZCOM0160
      DEL=S*TWOH/(CONE+SQRT(CPLUS))                                     ZCOM0170
      DELZ=ASINX(DEL2/DEL3)                                             ZCOM0180
      ZS=ZO+DELZ                                                        ZCOM0190
      THETA=ASINX(DEL)                                                  ZCOM0200
      RETURN                                                            ZCOM0210
      END                                                               ZCOM0220
C     SUBROUTINE  QUAD(THETA,ZO,HO,T,GAMMA,EO,SUM,VALM)                 QUAD0020
C     SUBROUTINE  QUAD(THETA,ZO,HO,T,P,GAMMA,EO,SUM,VALM,PBAR)
      SUBROUTINE  QUAD(THETA,ZO,HO,T,P,GAMMA,EO,SUM,VALM,PBAR,TBAR)
      DIMENSION VALUEA(6)
149   DIMENSION  VARCOM(50)                                             QUAD0030
      DIMENSION HINT(6)                                                 QUAD0040
      DIMENSION XPTS(6),THTPTS(6),WGHTS(6),VALUES(6)                    QUAD0050
      DIMENSION XPNTS(6)                                                QUAD0060
      DIMENSION WGHT(6)                                                 QUAD0070
      COMMON  VARCOM                                                    QUAD0080
      EQUIVALENCE (VARCOM(1),G),   (VARCOM(2),AIRWT),   (VARCOM(3),     QUAD0150
     1  RSTAR),   (VARCOM(4),RADIUS),   (VARCOM(5),CONST1),  (VARCOM(6) QUAD0160
     2,XPTS),(VARCOM(12),WGHT),(VARCOM(18),FAKE)                        QUAD0170
      EQUIVALENCE(XPTS,XPNTS)                                           QUAD0180
      EQUIVALENCE (WGHT,WGHTS)                                          QUAD0190
      EQUIVALENCE(VARCOM(19),RHO)
      EQUIVALENCE (VARCOM(20),REFAM)
      FCNA(QQQQFL)=(1.0+QQQQFL/2.0)*(1.0+2.0*QQQQFL*(1.0+QQQQFL/2.0)/3.0
     1)/(1.0+QQQQFL)**2
      FCNB(QQQ1FL)=2.0*QQQ1FL*(1.0+QQQ1FL/2.0)/3.0
      FCNU(QQQ2FL,QQQ3FL,QQQ4FL,QQQ5FL)=2.0*QQQ4FL*QQQ5FL*QQQ2FL/(1.0+QQ
     103FL*QQQ5FL)
      FCNH(QQQ8FL,QQQ9FL)=2.0*SIN(QQQ8FL/2.0)**2+COT(QQQ9FL)*SIN(QQQ8FL)QUAD0260
      SMALLR=RADIUS+HO+HO**2/(RADIUS-HO)
      VALC=RHO*SMALLR*SIN(ZO)*THETA/REFAM
      A=FCNA(EO)                                                        QUAD0270
      B=FCNB(EO)                                                        QUAD0280
      DO 1000 I=1,6                                                     QUAD0290
      THTPTS(I)=THETA*(.5+XPNTS(I))                                     QUAD0300
      HINT(I)=FCNH(THTPTS(I),ZO)                                        QUAD0310
1000  CONTINUE                                                          QUAD0320
      DO 2000  I=1,6                                                    QUAD0330
      CALL OM(HINT(I),HO,FAKE,T,GAMMA,OMEGA,DUMMY)                      QUAD0340
      U=FCNU(A,B,EO,OMEGA)
```

```
      ARG1=1.0-U/COSIZO-THTPTS(I))**2                                    QUAD037C
      VALUES(I)=1./SQRT(ARG1)
      VALUEA(I)=VALUES(I)*(1.-OMEGA)*SQRT(1.-U)/SIN(ZO-THTPTS(I))**2
 2000 CONTINUE                                                           QUAD040C
      SUM=0.0                                                            QUAD041C
      VALM=0.
      DO 3000 I=1,6                                                      QUAD042C
      SUM=VALUES(I)*WGHTS(I)+SUM                                         QUAD043C
      VALM=VALM+VALUEA(I)*WGHTS(I)
 3000 CONTINUE                                                           QUAD044C
      SUM=SUM*THETA                                                      QUAD045C
      VALM=VALC*VALM
      PBAR = VALM*P
      TBAR = VALM*T
      RETURN                                                             QUAD046C
      END                                                                QUAD047C
      SUBROUTINE GETT(H1,H2,P1,P2,T1,T2)
      COMMON G,AIRWT,RSTAR,RADIUS,CONST1
      IF(T2.GT.0.)     GO TO 1700
      K=0
      X=P2/P1
      XL=ALOG(X)
      A1=CONST1*(H2-H1)/T1
      CRIT=EXP(-A1)
      A1=1./A1
      IF(ABS(X-CRIT).GT..000001)   GO TO 1000
      T2=T1
      RETURN
 1000 XC=A1*XL+ALOG(A1)
      ACRIT=-1./XL
      A2=.0000011
      IF(A1.LT.ACRIT)   A2=A2+ACRIT
 1100 F=A2*XL+ALOG(A2)-XC
      FP=XL+1./A2
      A3=A2-F/FP
      IF(K.LT.3)     GO TO 1200
      IF(ABS(A3-A2).LT..0000001)  GO TO 1300
 1200 A2=A3
      K=K+1
      GO TO 1100
 1300 T2=T1*A2/A1
      RETURN
 1700 IF(T1.EQ.T2)  GO TO 1800
      P2=P1*(T2/T1)**((CONST1*(H2-H1))/(T1-T2))
      RETURN
 1800 P2=P1*EXP(CONST1*(H1-H2)/T1)
      RETURN
      END
      FUNCTION COT ( X )
C     COT(X)=COS(X)/SIN(X)
      COT   =COS(X)/SIN(X)
      RETURN
      END
*     DATA
```

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