AD NUMBER: AD0854646
LIMITATION CHANGES
TO: Approved for public release; distribution is unlimited.
FROM: Distribution authorized to US Government Agencies only; Export Control; 1 Mar 1969. Other requests shall be referred to US Army Electronics Command, Fort Monmouth, NJ 07703.
AUTHORITY
ECOM ltr dtd 29 Nov 1971

AD

AD854646

Research and Development Technical Report
ECOM - 00240-4

MONTE CARLO CALCULATIONS OF THE TRANSMISSION OF THERMAL RADIATION FROM NUCLEAR DETONATIONS IN MODEL ATMOSPHERES

FINAL REPORT

by

M. B. WELLS, D. G. COLLINS
and
J. D. MARSHALL

1 MARCH 1969

DISTRIBUTION STATEMENT

This Document is subject to special export controls and each transmittal to foreign governments or foreign nationals may by made only with prior approval of CG, U. S. Army Electronics Command, Fort Monmouth, N. J. 07703
Attn: AMSEL-BL-TE

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND · FORT MONMOUTH, N.J.

CONTRACT DA28-043 AMC-00240(E)

DASA NWER Subtask 12.017

RADIATION RESEARCH ASSOCIATES, INC.
Fort Worth, Texas

108

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

Technical Report ECOM-00240-4 1 March 1969
RRA-T810

MONTE CARLO CALCULATIONS OF THE TRANSMISSION OF THERMAL RADIATION FROM NUCLEAR DETONATIONS IN MODEL ATMOSPHERES

FINAL REPORT

Prepared by
M. B. Wells, D. G. Collins
and J. D. Marshall

for
U. S. ARMY ELECTRONICS COMMAND

DASA NWER Subtask 12.017

Distribution Statement

RADIATION RESEARCH ASSOCIATES, INC.
3550 Hulen Street
Fort Worth, Texas 76107

ABSTRACT

Monte Carlo calculations for monochromatic point isotropic sources were used to determine the direct and scattered transmittances for blackbody sources. Atmospheric Transmittances were computed for flat plate receivers oriented so as to be 1) perpendicular to the source-receiver direction, 2) parallel to the ground surface, and 3) perpendicular to the ground surface. The receiver surface was always facing the point isotropic blackbody source. The transmittance calculations were made for blackbody source altitudes of 1, 9, and 50 km, a receiver altitude of 6 m, and receiver horizontal ranges from 0 to 90 km. The transmittance calculations for each of the receiver orientations were performed for model atmospheres designed to represent a morning tropical atmosphere and an afternoon tropical atmosphere. Transmittance calculations for receivers oriented normal to the source-receiver axis were also performed for summer, winter and winter inversion midlatitude atmospheres, and an arctic atmosphere. For the 1 km source altitude in the morning and afternoon tropical atmospheres, transmittance calculations for blackbody sources were performed for cases where these atmospheres contained a cloud layer with the bottom of the cloud layer being at an altitude of either 1.5 km or 3.5 km. The atmospheric transmittance data for blackbody sources as a function of the blackbody source temperature were folded with data giving the time distributions of the temperature and power emission of a fireball produced by an air burst of a nuclear weapon to give atmospheric transmittance data for an air burst. Calculated data are presented showing the dependence of the atmospheric

transmittance for blackbody sources on the blackbody temperature and the dependences of the atmospheric transmittances for an air burst of a nuclear weapon on receiver orientation, burst altitude, horizontal range and the ground albedo.

FOREWORD

The authors wish to acknowledge the assistance of K. Cunningham, K. Tompkins, and Frances Hopper in the preparation of the problem input data and in the analysis of the LITE-III calculations. The assistance of Leon Leskowitz who handled the scheduling and running of LITE-III problems on the B5500 computer at the U. S. Army Electronics Command, Fort Monmouth, New Jersey and David S. McNeely who handled the scheduling and running of LITE-III problems on the IBM-7094-7044 Direct Couple System at White Sands Missile Range is also acknowledged. The work described in this report was carried out under the technical monitorship of 1. Cantor of the Atmospheric Sciences Laboratory, ECOM, Fort Monmouth, New Jersey.

BLANK PAGE

TABLE OF CONTENTS

LIST OF FIGURES

Figure | Page

LIST OF FIGURES (CONT)

LIST OF TABLES

LIST OF TABLES (CONT)

LIST OF TABLES (CONT)

BLANK PAGE

I. INTRODUCTION

The efficiency with which the atmosphere transmits the thermal radiation from a nuclear detonation depends on many parameters. In particular, the efficiency is a function of the scattering and absorption properties of the atmosphere, the ground albedo, the source and receiver positions, the receiver orientation, and the thermal characteristics of the weapon to be used as a source. The parameters describing the scattering and absorption properties of the atmosphere vary continuously with time, but in general it is possible to assign some average values to these parameters so that they are dependent only on the season of the year, the geographical location, and the ground level visibility. By assigning values to these parameters it is possible then to formulate model atmospheres for use in evaluating the atmospheric transmission of thermal radiation.

The thermal pulse from a nuclear weapon is characterized by a rapid rise to a maximum irradiance level, a rapid decline to a minimum, and a slow rise to a second maximum, and then a slow decay to zero irradiance. Because of the relative small amount of irradiance in the first thermal spike, and the fact that it is mostly in the ultra violet region, the thermal pulse is usually assumed to have only one thermal maximum which occurs at the time t_{max} for the second maximum. The thermal radiation source at any particular time following a nuclear detonation is usually described in terms of a blackbody source with a given temperature. The blackblody temperature of a nuclear weapon source in the time interval in which most of the irradiance is produced is usually assumed to vary between about 2000°K and 9000°K. Within this temperature range, most of the thermal radiation emitted by a blackbody source will have wavelengths between 0.3μ and 4.0μ.

Since the scattering and absorbing properties of the atmosphere vary with wavelength, it is necessary that the transmission properties of the atmosphere be known for discrete wavelengths between 0.3μ and 4.0μ so that the transmission properties for the thermal radiation emitted by blackbody sources with given temperatures can be evaluated.

Model atmospheres were formulated to describe morning and afternoon tropical atmospheres, summer, winter and winter inversion midlatitude atmospheres, and an arctic atmosphere. Scattering and absorption coefficients for these atmospheres were then used as input data to the LITE-III Monte Carlo Code (Refs. 1 and 2) for calculation of the scattered and direct fluxes incident on flat plate receivers oriented so as to be normal to the source-receiver axis and facing the point source. The Monte Carlo calculations were run for monochromatic point isotropic sources located at source altitudes of 1, 9, and 50 km and for receivers placed 6 meters above the ground and at horizontal ranges to 90 km. Since the thermal energy incident per unit area on a flat surface is dependent on it's orientation with respect to the point source, transmission calculations for the morning and afternoon tropical atmospheres were also made for cases where the flat plate receivers were facing the source and both perpendicular to the ground surface and parallel to the ground surface.

To study the effect of clouds located above a point source on the thermal energy incident to flat plate receivers, LITE-III calculations were also made for cases where the point source was located at 1 km altitude in the morning and afternoon tropical atmosphere when a cloud layer was present with its base at altitudes of either 1.5 km or 3.5 km.

The LITE-III calculations for each model atmosphere as a function of wavelength and receiver orientation were integrated over blackbody wavelength distributions for given temperatures to determine the transmittance as a function of blackbody temperature. These data were then integrated over blackbody temperature and power emission distributions for a representative air burst to provide transmittance data for a nuclear weapon burst.

II. DESCRIPTION OF MODEL ATMOSPHERES

The atmospheric temperature, pressure and density profiles for each of the model atmospheres were taken from the tabulation given in the Handbook of Geophysics and Space Environments (Ref. 3). The water vapor densities to 10 km altitude for each of the model atmospheres were also taken from the Handbook of Geophysics and Space Environments. Table I gives the absolute humidity at ground level for each of the Model Atmospheres.

Each of the model atmospheres were defined only to an altitude of 50 km since the mean-free-path thickness of the atmospheres above this altitude is negligible for light with wavelengths between 0.3μ and 4.0μ.

The Rayleigh scattering cross section per molecule at 15° C and 1013 mb pressure as a function of wavelength for the 13 wavelengths used in this study were computed by use of the equation reported by Penndorf (Ref. 4). The altitude variation of the Rayleigh scattering coefficient was obtained by multiplying the Rayleigh scattering cross section per molecule by the altitude distribution of the molecular number density for each atmosphere.

The vertical distribution of the aerosol attenuation coefficient was based on the average of 105 measured profiles that were obtained by Elterman from a searchlight scattering experiment in New Mexico (Ref. 5). The aerosol size distribution and ground level visibility used for each of the model atmospheres are given in Table I. The aerosol coefficient, σ_p, for 0.55μ wavelength light is defined at

Table I. Ground Level Absolute Humidities, Meteorological Ranges and Aerosol Size Distributions Used for Model Atmospheres

Atmospheric Model	Ground Level Absolute Humidity (g/m^3)	Ground Level Meteorological Range (km)	Aerosol Size Distribution
Morning Tropical	17	3	* $N(r) \propto r^{-2.5}$
Afternoon Tropical	17	25	$N(r) \propto r^{-3.5}$
Summer Midlatitude	12	25	$N(r) \propto r^{-4}$
Winter Midlatitude	3	25	$N(r) \propto r^{-4}$
Winter Midlatitude			
(Inversion Profile to 2 km altitude)	3	3	$N(r) \propto r^{-3}$ to 2 km altitude $N(r) \propto r^{-4}$ above 2 km altitude
Arctic	0	200	$N(r) \propto r^{-4}$

* r = radius of aerosol particles

N(r) = aerosol concentration as a function of r

ground level by the equation

$$\sigma_R(\lambda = 0.55\mu) + \sigma_P(\lambda = 0.55\mu) = 3.9/V$$

where V is the meteorological range in km and σ_R is the Rayleigh scattering coefficient at ground level. From a knowledge of the aerosol size distribution and the aerosol attenuation coefficient for 0.55μ wavelength light one can then compute the variation of the aerosol attenuation coefficient with wavelength.

The aerosol particles were assumed to be spherical water droplets with indices of refraction as a function of wavelength given by a tabulation reported by Centeno (Ref. 6). The scattering, absorption, and extinction coefficients and phase functions for aerosol scattering were obtained from an integration of Mie data for the various indices of refraction over the aerosol size distributions shown in Table 1.

The water vapor density profiles for the model tropical and mid-latitude atmospheres were extended from an altitude of 10 km to an altitude of 35 km by use of the water vapor mixing ratio profiles reported by Gutnick (Ref. 7). Above 35 km altitude the water vapor density was assumed to be negligible. Table II lists the total amount of pr-cm of water vapor between ground level and altitude h for each of the model atmospheres except the arctic atmosphere which was assumed to have negligible absolute humidity. The absorption coefficient for water vapor was assumed to be negligible for wavelengths below 0.8μ. The absorption coefficients as a function of wavelength for water vapor were taken from data reported by Wyatt, Stull, and Plass (Ref. 8) and Eldridge (Ref. 9).

The relative concentration of CO_2 in the atmosphere was taken to be 0.033% by volume for all altitudes. The CO_2 absorption coefficients as a function of wavelength for wavelengths between 1.31μ and 4.0μ that were used in the LITE-III calculations were taken from data reported by Wyatt, Stull and Plass (Ref. 10). For wavelengths below 1.31μ, absorption by CO_2 was taken to be negligible. The absorption by atmospheric ozone was taken to be described by the ozone absorption coefficients as a function of wavelength reported by Elterman (Ref. 11). At wavelengths

Table II. Water Vapor Density Between Ground Level and Altitude h (pr-cm)

h (km)	Tropical Atmospheres	MIDLATITUDE ATMOSPHERES Summer	Winter
1	1.500	1.000	0.250
2	2.500	1.700	0.430
3	3.125	2.150	0.560
4	3.400	2.340	0.6375
5	3.570	2.550	0.6790
6	3.680	2.625	0.7015
7	3.750	2.665	0.7140
8	3.780	2.6885	0.7200
9	3.800	2.70199	0.7230
10	3.804	2.70950	0.7240
15	3.80994	2.711997	0.7240
20	3.81212	2.711997	0.7240
25	3.81431	2.711997	0.7240
30	3.816774	2.711997	0.7240
35	3.819339	2.711997	0.7240
40	3.819339	2.711997	0.7240
50	3.819339	2.711997	0.7240

greater than 0.8μ the ozone absorption coefficient was taken to be zero.

The ground surface was taken to be a Lambert type reflector with the magnitude of the albedo being independent of the polar angle of incidence to the ground surface. In those problems containing a cloud layer located above the point source, the bottom surface of the cloud was taken to be a Lambert reflector with the magnitude of the albedo being defined in terms of the polar angle of incidence, θ_o, by the equation

$$\alpha(\theta_o,\lambda) = a(\lambda) - 0.154 \cos\theta_o .$$

Values of $a(\lambda)$ were obtained from cloud albedo data given in Refs. 12, 13, and 14. Table III lists the values of $a(\lambda)$ used in the Monte Carlo calculations for the indicated wavelength intervals.

Table III. Cloud Albedo Parameter $a(\lambda)$

Wavelength Interval (μ)	$a(\lambda)$
0.30 - 0.80	0.639
0.80 - 1.00	0.812
1.0 - 1.14	0.765
1.14 - 1.31	0.739
1.31 - 1.46	0.618
1.46 - 1.79	0.623
1.79 - 1.96	0.548
1.96 - 2.47	0.651
2.47 - 3.30	0.406
3.30 - 4.00	0.286

III. Transmittance Calculations for Blackbody Sources

The scattered and direct fluxes in each of the model atmospheres that were incident per source photon on flat plate receivers located at an altitude of 6 meters and oriented normal to the direction to the source and facing the source were computed for source wavelengths of 0.35, 0.45, 0.55, 0.7, 0.9, 1.07, 1.22, 1.39, 1.61, 1.88, 2.2, 2.85, and 3.5 microns, source altitudes of 1, 9, and 50 km, and horizontal ranges of 0, 15, 30, 60, and 90 km. Scattered and direct fluxes incident to flat plate receivers oriented both normal and parallel to the ground and facing the point source were also computed for the morning and evening tropical atmospheres. To study the effect of a cloud layer positioned above the point source on the scattered fluxes at each receiver position, calculations were run for the 1 km source altitude in both the morning and afternoon tropical atmospheres. The cloud bottom was taken to be a reflecting surface and the calculations were made for cloud bottom altitudes of both 1.5 km and 3.5 km.

The results of the LITE-III calculations were integrated over source wavelength distributions for blackbody sources with temperatures between 2000°K and 9000°K. The integrations were performed using the machine procedure, RRA-90, described in Ref. 2. The results of the RRA-90 calculatations give the atmospheric transmittance, where the transmittance is defined as $4\pi R^2$ times the sum of the scattered and direct fluxes per unit source energy that is incident on a unit area of a flat plate receiver located at a slant distance R from the point source. To aid in the conversion of the transmittance calculations to energy flux at a receiver, the variations of both R and $4\pi R^2$ with the horizontal range and source altitude are presented in Table IV.

The variation of the transmittances for flat plate receivers oriented normal to the source-receiver axis and facing the point isotropic source in each of the model atmospheres with blackbody temperature is shown in Tables V through X for ground albedo values of 0.0 and 0.9 and source altitudes of 1, 9, and 50 km. The dependence of the total transmittance on the blackbody temperature for this receiver orientation is characterized by an increase in the transmittance at a given receiver position with temperature to a maximum after which the transmittance decreases with increasing temperature. Fig. 1 shows the dependence of the transmittance on blackbody temperature at a receiver oriented normal to the source-receiver axis for the afternoon tropical atmosphere when the source altitude is 1 km and the ground albedo is 0.0. The blackbody temperature at which the maximum transmittance is obtained varies with range for a given model atmosphere. In general the temperature at maximum transmittance decreases with increasing range. At a given range the blackbody temperature for maximum transmittance usually increases with an increase in the ground albedo.

This dependence of the transmittance on blackbody temperature results from the fact that for a blackbody source the wavelength at which the emissive power is a maximum is dependent on the blackbody temperature. For a blackbody at 2000°K the emissive power is a maximum at a wavelength

(Text continues on page 25.)

Table IV. Variation of the Slant Range R and the Parameter $4\pi R^2$ with Source Altitude and Horizontal Range

Source Altitude (km)	Horizontal Range (km)	Slant Range (km)	$4\pi R^2$ (km^2)
0.1000E 01*	0.000E 00	0.9939E 00	0.1241E 02
0.1000E 01	0.1500E 02	0.1503E 02	0.2839E 04
0.1000E 01	0.3000E 02	0.3001E 02	0.1132E 05
0.1000E 01	0.6000E 02	0.6000E 02	0.4525E 05
0.1000E 01	0.9000E 02	0.9000E 02	0.1018E 06
0.9000E 01	0.0000E 00	0.8993E 01	0.1016E 04
0.9000E 01	0.1500E 02	0.1748E 02	0.3843E 04
0.9000E 01	0.3000E 02	0.3131E 02	0.1232E 05
0.9000E 01	0.6000E 02	0.6067E 02	0.4625E 05
0.9000E 01	0.9000E 02	0.9044E 02	0.1028E 06
0.5000E 02	0.000E 00	0.4999E 02	0.3140E 05
0.5000E 02	0.1500E 02	0.5219E 02	0.3423E 05
0.5000E 02	0.3000E 02	0.5830E 02	0.4271E 05
0.5000E 02	0.6000E 02	0.7809E 02	0.7664E 05
0.5000E 02	0.9000E 02	0.1029E 03	0.1331E 06

*Read 0.1000E 01 as 0.100 X 10^1

TABLE V. VARIATION OF ATMOSPHERIC TRANSMITTANCE FOR BLACKBODY SOURCES LOCATED IN A MORNING TROPICAL ATMOSPHERE WITH BLACKBODY TEMPERATURE

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

GROUND ALBEDO = 0.0
SOURCE ALTITUDE = 1 KM

TEMP. (K°)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	4.001-01	1.105-02	1.695-03	3.050-04	1.802-04
2200	4.297-01	1.369-02	2.166-03	3.430-04	1.958-04
3000	5.163-01	2.445-02	4.431-03	4.872-04	2.483-04
4000	5.906-01	3.639-02	6.988-03	6.277-04	2.984-04
5000	6.556-01	4.544-02	8.405-03	7.066-04	3.228-04
6000	7.086-01	5.092-02	8.780-03	7.292-04	3.216-04
7100	7.424-01	5.311-02	8.455-03	7.088-04	3.012-04
8200	7.479-01	5.232-02	7.759-03	6.616-04	2.716-04
9100	7.345-01	5.025-02	7.093-03	6.140-04	2.455-04

SOURCE ALTITUDE = 9 KM

TEMP. (K°)	0	15	30	60	90
2000	1.103-01	9.438-02	2.196-02	3.801-03	1.308-03
2200	1.275-01	1.112-01	2.573-02	4.347-03	1.437-03
3000	1.917-01	1.714-01	3.936-02	6.091-03	1.738-03
4000	2.446-01	2.124-01	5.119-02	7.325-03	1.807-03
5000	2.664-01	2.257-01	5.710-02	7.844-03	1.719-03
6000	2.672-01	2.256-01	5.851-02	7.895-03	1.570-03
7100	2.546-01	2.182-01	5.674-02	7.598-03	1.386-03
8200	2.352-01	2.063-01	5.305-02	7.085-03	1.206-03
9100	2.174-01	1.948-01	4.937-02	6.588-03	1.071-03

SOURCE ALTITUDE = 50 KM

TEMP. (K°)	0	15	30	60	90
2000	9.115-02	1.085-01	1.036-01	6.365-02	2.400-02
2200	1.064-01	1.240-01	1.172-01	6.951-02	2.555-02
3000	1.759-01	1.852-01	1.653-01	8.709-02	2.978-02
4000	2.498-01	2.409-01	2.042-01	9.910-02	3.217-02
5000	2.924-01	2.673-01	2.196-01	1.023-01	3.237-02
6000	3.075-01	2.715-01	2.185-01	9.960-02	3.109-02
7100	3.031-01	2.605-01	2.064-01	9.262-02	2.872-02
8200	2.863-01	2.411-01	1.889-01	8.386-02	2.592-02
9100	2.679-01	2.228-01	1.773-01	7.641-02	2.359-02

TABLE V. (CONT.)

GROUND ALBEDO = 0.9
SOURCE ALTITUDE = 1 KM

TEMP. (K °)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	4.155-01	1.825-02	2.519-03	4.604-04	2.546-04
2200	4.481-01	2.218-02	3.190-03	5.187-04	2.787-04
3000	5.482-01	3.783-02	6.393-03	7.392-04	3.679-04
4000	6.360-01	5.469-02	1.003-02	9.553-04	4.626-04
5000	7.102-01	6.718-02	1.209-02	1.079-03	5.145-04
6000	7.673-01	7.459-02	1.269-02	1.119-03	5.211-04
7100	8.022-01	7.740-02	1.228-02	1.092-03	4.933-04
8200	8.063-01	7.608-02	1.133-02	1.023-03	4.478-04
9100	7.904-01	7.303-02	1.041-02	9.515-04	4.065-04

SOURCE ALTITUDE = 9 KM

2000	1.193-01	1.128-01	2.951-02	5.382-03	1.697-03
2200	1.377-01	1.323-01	3.472-02	6.164-03	1.865-03
3000	2.075-01	2.020-01	5.507-02	8.610-03	2.290-03
4000	2.688-01	2.512-01	7.449-02	1.014-02	2.440-03
5000	2.980-01	2.689-01	8.497-02	1.056-02	2.357-03
6000	3.052-01	2.705-01	8.802-02	1.034-02	2.163-03
7100	2.975-01	2.625-01	8.580-02	9.695-02	1.908-03
8200	2.806-01	2.487-01	8.034-02	8.854-03	1.655-03
9100	2.633-01	2.349-01	7.476-02	8.121-03	1.464-03

SOURCE ALTITUDE = 50 KM

2000	1.034-01	1.256-01	1.252-01	7.610-02	2.953-02
2200	1.210-01	1.431-01	1.429-01	8.352-02	3.168-02
3000	2.005-01	2.098-01	2.072-01	1.073-01	3.826-02
4000	2.854-01	2.680-01	2.605-01	1.253-01	4.304-02
5000	3.355-01	2.950-01	2.820-01	1.314-01	4.453-02
6000	3.549-01	2.990-01	2.811-01	1.288-01	4.350-02
7100	3.521-01	2.873-01	2.653-01	1.202-01	4.059-02
8200	3.344-01	2.668-01	2.425-01	1.090-01	3.683-02
9100	3.142-01	2.472-01	2.221-01	9.942-02	3.358-02

TABLE VI. VARIATION OF ATMOSPHERIC TRANSMITTANCE FOR BLACKBODY SOURCES LOCATED IN AN AFTERNOON TROPICAL ATMOSPHERE WITH BLACKBODY TEMPERATURE

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

GROUND ALBEDO = 0.0

SOURCE ALTITUDE = 1 KM

TEMP. (K °)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	4.835-01	1.647-01	7.033-02	1.953-02	8.617-03
2200	5.271-01	1.916-01	8.202-02	2.268-02	1.012-02
3000	6.632-01	2.957-01	1.255-01	3.421-02	1.563-02
4000	7.721-01	3.856-01	1.589-01	4.282-02	1.944-02
5000	8.300-01	4.265-01	1.710-01	4.364-02	2.057-02
6000	8.478-01	4.317-01	1.693-01	4.482-02	2.002-02
7100	8.314-01	4.114-01	1.588-01	4.167-02	1.850-02
8200	7.891-01	3.778-01	1.443-01	3.762-02	1.659-02
9100	7.407-01	3.470-01	1.317-01	3.415-02	1.501-02

SOURCE ALTITUDE = 9 KM

TEMP. (K °)	0	15	30	60	90
2000	3.888-01	3.203-01	2.509-01	1.460-01	9.171-02
2200	4.272-01	3.568-01	2.892-01	1.672-01	1.043-01
3000	5.523-01	4.875-01	4.006-01	2.422-01	1.456-01
4000	6.523-01	5.969-01	4.877-01	2.884-01	1.699-01
5000	7.023-01	6.490-01	5.172-01	2.954-01	1.695-01
6000	7.153-01	6.569-01	5.091-01	2.810-01	1.582-01
7100	6.981-01	6.334-01	4.955-01	2.549-01	1.402-01
8200	6.583-01	5.897-01	4.586-01	2.256-01	1.215-01
9100	6.173-01	5.475-01	4.253-01	2.009-01	1.073-01

SOURCE ALTITUDE = 50 KM

TEMP. (K °)	0	15	30	60	90
2000	3.278-01	2.920-01	3.082-01	2.723-01	2.394-01
2200	3.673-01	3.309-01	3.444-01	3.054-01	2.706-01
3000	5.005-01	4.163-01	4.699-01	4.210-01	3.794-01
4000	6.050-01	5.753-01	5.684-01	5.131-01	4.638-01
5000	6.543-01	6.272-01	6.137-01	5.555-01	5.028-01
6000	6.611-01	6.370-01	6.197-01	5.569-01	5.039-01
7100	6.397-01	6.189-01	5.977-01	5.309-01	4.759-01
8200	5.994-01	5.804-01	5.582-01	4.905-01	4.352-01
9100	5.595-01	5.419-01	5.192-01	4.527-01	3.985-01

TABLE VI.(CONT.)

GROUND ALBEDO = 0.9

SOURCE ALTITUDE = 1 KM

TEMP. (K °)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	4.850-01	1.829-01	8.298-02	2.438-02	1.038-02
2200	5.287-01	2.153-01	9.760-02	2.912-02	1.234-02
3000	6.666-01	3.450-01	1.552-01	4.820-02	1.992-02
4000	7.776-01	4.670-01	2.056-01	6.620-02	2.631-02
5000	8.375-01	5.336-01	2.300-01	7.624-02	2.919-02
6000	8.569-01	5.545-01	2.361-01	7.935-02	2.954-02
7100	8.417-01	5.420-01	2.291-01	7.781-02	2.820-02
8200	8.000-01	5.086-01	2.140-01	7.319-02	2.596-02
9100	7.516-01	4.737-01	1.989-01	6.829-02	2.387-02

SOURCE ALTITUDE = 9 KM

TEMP. (K °)	0	15	30	60	90
2000	3.950-01	3.331-01	2.664-01	1.542-01	9.294-02
2200	4.343-01	3.728-01	3.014-01	1.774-01	1.064-01
3000	5.642-01	5.197-01	4.324-01	2.160-01	1.521-01
4000	6.725-01	6.531-01	5.361-01	3.170-01	1.816-01
5000	7.321-01	7.290-01	5.827-01	3.319-01	1.869-01
6000	7.541-01	7.576-01	5.881-01	3.219-01	1.781-01
7100	7.432-01	7.479-01	5.829-01	2.989-01	1.610-01
8200	7.080-01	7.106-01	5.489-01	2.699-01	1.416-01
9100	6.679-01	6.687-01	5.146-01	2.457-01	1.263-01

SOURCE ALTITUDE = 50 KM

TEMP. (K °)	0	15	30	60	90
2000	3.353-01	3.000-01	3.154-01	2.804-01	2.480-01
2200	3.766-01	3.410-01	3.536-01	3.153-01	2.813-01
3000	5.201-01	4.872-01	4.897-01	4.400-01	4.006-01
4000	6.405-01	6.115-01	6.043-01	5.471-01	5.025-01
5000	7.044-01	6.783-01	6.674-01	6.065-01	5.518-01
6000	7.224-01	6.998-01	6.887-01	6.214-01	5.612-01
7100	7.075-01	6.897-01	6.786-01	6.053-01	5.383-01
8200	6.688-01	6.548-01	6.446-01	5.690-01	4.979-01
9100	6.277-01	6.158-01	6.064-01	5.313-01	4.547-01

TABLE VII. VARIATION OF ATMOSPHERIC TRANSMITTANCE FOR BLACKBODY SOURCES LOCATED IN A SUMMER MIDLATITUDE ATMOSPHERE WITH BLACKBODY TEMPERATURE

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

GROUND ALBEDO = 0.0

SOURCE ALTITUDE = 1 KM

TEMP. (K °)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	5.218-01	2.187-01	1.087-01	3.246-02	1.367-02
2200	5.647-01	2.446-01	1.220-01	3.642-02	1.537-02
3000	6.968-01	3.336-01	1.645-01	5.000-02	2.165-02
4000	8.033-01	3.977-01	1.894-01	5.956-02	2.659-02
5000	8.569-01	4.185-01	1.920-01	6.230-02	2.834-02
6000	8.700-01	4.120-01	1.832-01	6.096-02	2.795-02
7100	8.492-01	3.876-01	1.678-01	5.702-02	2.617-02
8200	8.039-01	3.549-01	1.507-01	5.198-02	2.379-02
9100	7.563-01	3.261-01	1.369-01	4.764-02	2.171-02
	SOURCE ALTITUDE = 9 KM				
2000	4.092-01	3.628-01	3.103-01	2.209-01	1.604-01
2200	4.417-01	4.011-01	3.483-01	2.439-01	1.733-01
3000	5.298-01	5.290-01	4.763-01	3.210-01	2.167-01
4000	5.832-01	6.333-01	5.678-01	3.675-01	2.402-01
5000	6.082-01	6.883-01	5.963-01	3.703-01	2.359-01
6000	6.131-01	7.051-01	5.845-01	3.495-01	2.174-01
7100	5.985-01	6.912-01	5.464-01	3.156-01	1.915-01
8200	5.682-01	6.554-01	4.969-01	2.789-01	1.657-01
9100	5.360-01	6.169-01	4.542-01	2.501-01	1.463-01
	SOURCE ALTITUDE = 50 KM				
2000	4.265-01	4.262-01	4.174-01	3.927-01	3.693-01
2200	4.691-01	4.691-01	4.606-01	4.347-01	4.068-01
3000	6.067-01	6.096-01	6.047-01	5.776-01	5.306-01
4000	7.094-01	7.169-01	7.185-01	6.936-01	6.231-01
5000	7.553-01	7.656-01	7.720-01	7.488-01	6.592-01
6000	7.617-01	7.728-01	7.816-01	7.582-01	6.557-01
7100	7.319-01	7.484-01	7.578-01	7.334-01	6.235-01
8200	6.942-01	7.036-01	7.125-01	6.870-01	5.754-01
9100	6.506-01	6.589-01	6.669-01	6.411-01	5.313-01

TABLE VII.(CONT.)

GROUND ALBEDO = 0.9

SOURCE ALTITUDE = 1 KM

TEMP. (K°)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	5.226-01	2.320-01	1.187-01	3.852-02	1.718-02
2200	5.657-01	2.610-01	1.344-01	4.370-02	1.973-02
3000	7.011-01	3.641-01	1.869-01	6.207-02	2.914-02
4000	8.084-01	4.494-01	2.237-01	7.697-02	3.703-02
5000	8.653-01	4.923-01	2.369-01	8.408-02	4.079-02
6000	8.816-01	5.049-01	2.358-01	8.573-01	4.163-02
7100	8.634-01	4.951-01	2.252-01	8.342-02	4.039-02
8200	8.196-01	4.698-01	2.094-01	7.855-02	3.789-02
9100	7.725-01	4.427-01	1.948-01	7.358-02	3.536-02

SOURCE ALTITUDE = 9 KM

TEMP. (K°)	0	15	30	60	90
2000	4.125-01	3.724-01	3.229-01	2.091-01	1.399-01
2200	4.459-01	4.125-01	3.634-01	2.360-01	1.569-01
3000	5.388-01	5.494-01	5.027-01	3.255-01	2.125-01
4000	6.007-01	6.712-01	6.106-01	3.823-01	2.453-01
5000	6.357-01	7.480-01	6.547-01	3.921-01	2.471-01
6000	6.501-01	7.852-01	6.549-01	3.760-01	2.331-01
7100	6.434-01	7.878-01	6.246-01	3.447-01	2.105-01
8200	6.177-01	7.610-01	5.778-01	3.090-01	1.865-01
9100	5.872-01	7.252-01	5.344-01	2.799-01	1.676-01

SOURCE ALTITUDE = 50 KM

TEMP. (K°)	0	15	30	60	90
2000	4.377-01	4.360-01	4.317-01	4.103-01	4.287-01
2200	4.824-01	4.822-01	4.780-01	4.562-01	4.775-01
3000	6.309-01	6.381-01	6.370-01	6.191-01	6.331-01
4000	7.550-01	7.704-01	7.762-01	7.682-01	7.482-01
5000	8.294-01	8.481-01	8.598-01	8.586-01	8.011-01
6000	8.641-01	8.824-01	8.973-01	8.974-01	8.091-01
7100	8.649-01	8.803-01	8.962-01	8.934-01	7.819-01
8200	8.363-01	8.483-01	8.635-01	8.564-01	7.320-01
9100	7.985-01	8.077-01	8.218-01	8.113-01	6.825-01

TABLE VIII. VARIATION OF ATMOSPHERIC TRANSMITTANCE FOR BLACKBODY SOURCES LOCATED IN A WINTER MIDLATITUDE ATMOSPHERE WITH BLACKBODY TEMPERATURE

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

GROUND ALBEDO = 0.0

SOURCE ALTITUDE = 1 KM

TEMP.	HORIZONTAL RANGE (KM)				
(K°)	0	15	30	60	90
2000	6.144-01	4.896-01	1.724-01	6.354-02	3.164-02
2200	6.566-01	5.265-01	1.858-01	6.745-02	3.451-02
3000	7.766-01	6.016-01	2.208-01	7.737-02	4.310-02
4000	8.595-01	6.071-01	2.317-01	8.027-02	4.663-02
5000	8.965-01	5.741-01	2.228-01	7.748-02	4.509-02
6000	8.983-01	5.275-01	2.056-01	7.211-02	4.138-02
7100	8.693-01	4.720-01	1.840-01	6.511-02	3.659-02
8200	8.185-01	4.178-01	1.627-01	5.798-02	3.188-02
9100	7.679-01	3.764-01	1.464-01	5.242-02	2.834-02

SOURCE ALTITUDE = 9 KM

2000	4.996-01	4.522-01	3.957-01	2.820-01	2.031-01
2200	5.317-01	4.904-01	4.318-01	3.046-01	2.195-01
3000	6.062-01	6.080-01	5.453-01	3.681-01	2.654-01
4000	6.382-01	6.958-01	6.185-01	3.954-01	2.808-01
5000	6.469-01	7.393-01	6.332-01	3.661-01	2.670-01
6000	6.407-01	7.497-01	6.118-01	3.587-01	2.409-01
7100	6.180-01	7.323-01	5.664-01	3.207-01	2.090-01
8200	5.824-01	6.942-01	5.118-01	2.818-01	1.788-01
9100	5.473-01	6.541-01	4.661-01	2.520-01	1.569-01

SOURCE ALTITUDE = 50 KM

2000	5.207-01	5.164-01	5.103-01	4.921-01	4.542-01
2200	5.609-01	5.562-01	5.524-01	5.362-01	4.951-01
3000	6.781-01	6.750-01	6.798-01	6.727-01	6.210-01
4000	7.553-01	7.576-01	7.697-01	7.690-01	7.016-01
5000	7.844-01	7.908-01	8.065-01	8.055-01	7.222-01
6000	7.806-01	7.889-01	8.052-01	8.008-01	7.050-01
7100	7.502-01	7.587-01	7.740-01	7.647-01	6.609-01
8200	7.026-01	7.104-01	7.239-01	7.105-01	6.042-01
9100	6.569-01	6.640-01	6.758-01	6.599-01	5.547-01

TABLE VIII. (CONT.)

GROUND ALBEDO = 0.9
SOURCE ALTITUDE = 1 KM

TEMP. (K °)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	6.156-01	4.465-01	1.877-01	7.148-02	3.600-02
2200	6.579-01	4.739-01	2.034-01	7.645-02	3.960-02
3000	7.791-01	5.501-01	2.473-01	9.050-02	5.082-02
4000	8.646-01	5.929-01	2.689-01	9.831-02	5.695-02
5000	[illegible].050-01	6.000-01	2.698-01	9.967-02	5.733-02
6000	9.099-01	5.858-01	2.600-01	9.719-02	5.485-02
7100	8.835-01	5.549-01	2.429-01	9.175-02	5.061-02
8200	8.342-01	5.149-01	2.227-01	8.474-02	4.582-02
9100	7.840-01	4.790-01	2.054-01	7.851-02	4.186-02

SOURCE ALTITUDE = 9 KM

TEMP. (K °)	0	15	30	60	90
2000	5.050-01	4.684-01	4.195-01	2.902-01	2.089-01
2200	5.380-01	5.090-01	4.582-01	3.143-01	2.262-01
3000	6.168-01	6.367-01	5.816-01	3.834-01	2.753-01
4000	6.566-01	7.411-01	6.687-01	4.169-01	2.941-01
5000	6.750-01	8.051-01	6.971-01	4.124-01	2.835-01
6000	6.781-01	8.347-01	6.863-01	3.882-01	2.601-01
7100	6.632-01	8.325-01	6.476-01	3.520-01	2.303-01
8200	6.321-01	8.027-01	5.950-01	3.135-01	2.013-01
9100	5.985-01	7.647-01	5.482-01	2.830-01	1.795-01

SOURCE ALTITUDE = 50 KM

TEMP. (K °)	0	15	30	60	90
2000	5.321-01	5.353-01	5.336-01	5.205-01	4.891-01
2200	5.745-01	5.784-01	5.795-01	5.689-01	5.337-01
3000	7.032-01	7.114-01	7.231-01	7.251-01	6.759-01
4000	8.022-01	8.163-01	8.373-01	8.523-01	7.818-01
5000	8.597-01	8.767-01	9.021-01	9.222-01	8.281-01
6000	8.842-01	9.007-01	9.271-01	9.451-01	8.307-01
7100	8.781-01	8.920-01	9.169-01	9.287-01	7.989-01
8200	8.454-01	8.561-01	8.784-01	8.829-01	7.453-01
9100	8.054-01	8.135-01	8.334-01	8.326-01	6.935-01

TABLE IX. VARIATION OF ATMOSPHERIC TRANSMITTANCE FOR BLACKBODY SOURCES LOCATED IN A WINTER INVERSION MIDLATITUDE ATMOSPHERE WITH BLACKBODY TEMPERATURE

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

GROUND ALBEDO = 0.0
SOURCE ALTITUDE = 1 KM

TEMP. (K °)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	4.564-01	1.673-02	7.828-04	1.826-04	9.466-05
2200	4.851-01	1.822-02	8.633-04	2.034-04	1.136-04
3000	5.652-01	2.278-02	1.236-03	3.022-04	1.991-04
4000	6.195-01	2.619-02	1.954-03	4.519-04	3.061-04
5000	6.414-01	2.771-02	2.871-03	6.060-04	3.852-04
6000	6.377-01	2.785-02	3.758-03	7.358-04	4.266-04
7100	6.118-01	2.692-02	4.502-03	8.312-04	4.354-04
8200	5.715-01	2.529-02	4.937-03	8.753-04	4.191-04
9100	5.329-01	2.368-02	5.084-03	8.798-04	3.955-04

SOURCE ALTITUDE = 9 KM

TEMP. (K °)	0	15	30	60	90
2000	3.078-01	3.317-01	2.121-01	3.106-02	9.686-03
2200	3.435-01	3.564-01	2.191-01	3.248-02	9.883-03
3000	4.469-01	4.210-01	2.228-01	3.564-02	1.031-02
4000	4.888-01	4.425-01	2.029-01	3.557-02	1.047-02
5000	4.759-01	4.284-01	1.784-01	3.320-02	1.006-02
6000	4.420-01	3.990-01	1.563-01	3.016-02	9.274-03
7100	3.978-01	3.603-01	1.358-01	2.683-02	8.220-03
8200	3.537-01	3.209-01	1.187-01	2.377-02	7.165-03
9100	3.198-01	2.901-01	1.066-01	2.149-02	6.366-03

SOURCE ALTITUDE = 50 KM

TEMP. (K °)	0	15	30	60	90
2000	2.798-01	3.524-01	3.486-01	2.629-01	1.642-01
2200	2.960-01	3.758-01	3.735-01	2.825-01	1.782-01
3000	3.244-01	4.146-01	4.181-01	3.252-01	2.125-01
4000	3.215-01	4.044-01	4.122-01	3.379-01	2.318-01
5000	3.065-01	3.779-01	3.877-01	3.344-01	2.413-01
6000	2.874-01	3.484-01	3.589-01	3.228-01	2.445-01
7100	2.640-01	3.155-01	3.262-01	3.039-01	2.411-01
8200	2.397-01	2.834-01	2.936-01	2.810-01	2.318-01
9100	2.200-01	2.583-01	2.680-01	2.609-01	2.210-01

TABLE IX. (CONT.)

GROUND ALBEDO = 0.9

SOURCE ALTITUDE = 1 KM

TEMP. (K °)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	4.794-01	2.312-02	1.973-03	2.301-04	2.327-04
2200	5.105-01	2.551-02	2.393-03	2.589-04	2.536-04
3000	5.976-01	3.336-02	4.144-03	4.132-04	3.557-04
4000	6.578-01	4.111-02	6.499-03	7.191-04	5.151-04
5000	6.830-01	4.739-02	9.155-03	1.116-03	6.595-04
6000	6.804-01	5.183-02	1.174-02	1.508-03	7.536-04
7100	6.538-01	5.427-02	1.399-02	1.844-03	7.953-04
8200	6.115-01	5.436-02	1.537-02	2.048-03	7.876-04
9100	5.707-01	5.309-02	1.587-02	2.124-03	7.579-04

SOURCE ALTITUDE = 9 KM

2000	3.299-01	3.613-01	2.200-01	3.410-02	1.030-02
2200	3.695-01	3.890-01	2.300-01	3.624-02	1.054-02
3000	4.876-01	4.622-01	2.424-01	4.155-02	1.114-02
4000	5.515-01	4.900-01	2.270-01	4.230-02	1.146-02
5000	5.710-01	4.799-01	2.037-01	3.968-02	1.118-02
6000	5.744-01	4.528-01	1.818-01	3.606-02	1.045-02
7100	5.670-01	4.149-01	1.611-01	3.206-02	9.401-03
8200	5.489-01	3.744-01	1.432-01	2.838-02	8.310-03
9100	5.273-01	3.418-01	1.301-01	2.565-02	7.443-03

SOURCE ALTITUDE = 50 KM

2000	3.406-01	4.164-01	4.250-01	3.302-01	2.049-01
2200	3.584-01	4.436-01	4.569-01	3.559-01	2.237-01
3000	3.881-01	4.898-01	5.193-01	4.152-01	2.756-01
4000	3.846-01	4.831-01	5.247-01	4.451-01	3.192-01
5000	3.675-01	4.576-01	5.047-01	4.572-01	3.496-01
6000	3.449-01	4.265-01	4.752-01	4.554-01	3.645-01
7100	3.164-01	3.895-01	4.371-01	4.391-01	3.641-01
8200	2.866-01	3.515-01	3.963-01	4.122-01	3.505-01
9100	2.624-01	3.211-01	3.630-01	3.857-01	3.331-01

TABLE X. VARIATION OF ATMOSPHERIC TRANSMITTANCE FOR BLACKBODY SOURCES LOCATED IN AN ARCTIC ATMOSPHERE WITH BLACKBODY TEMPERATURE

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

GROUND ALBEDO = 0.0

SOURCE ALTITUDE = 1 KM

TEMP.	HORIZONTAL RANGE (KM)				
(K°)	0	15	30	60	90
2000	8.371-01	7.727-01	7.386-01	6.854-01	6.399-01
2200	8.700-01	8.063-01	7.696-01	7.111-01	6.612-01
3000	9.426-01	8.776-01	8.277-01	7.460-01	6.791-01
4000	9.758-01	8.940-01	8.209-01	7.093-01	6.254-01
5000	9.806-01	8.713-01	7.735-01	6.380-01	5.447-01
6000	9.626-01	8.258-01	7.078-01	5.581-01	4.626-01
7100	9.201-01	7.608-01	6.292-01	4.739-01	3.820-01
8200	8.607-01	6.891-01	5.524-01	3.996-01	3.147-01
9100	8.050-01	6.302-01	4.941-01	3.472-01	2.690-01

SOURCE ALTITUDE = 9 KM

2000	8.055-01	7.209-01	7.781-01	7.538-01	7.333-01
2200	8.395-01	7.662-01	8.121-01	7.860-01	7.635-01
3000	9.164-01	8.710-01	8.848-01	8.456-01	8.117-01
4000	9.519-01	9.163-01	9.031-01	8.347-01	7.810-01
5000	9.563-01	9.171-01	8.829-01	7.802-01	7.077-01
6000	9.368-01	8.898-01	8.396-01	7.077-01	6.216-01
7100	8.929-01	8.380-01	7.764-01	6.234-01	5.294-01
8200	8.331-01	7.730-01	7.056-01	5.429-01	4.471-01
9100	7.777-01	7.158-01	6.468-01	4.828-01	3.887-01

SOURCE ALTITUDE = 50 KM

2000	8.010-01	8.069-01	8.040-01	7.967-01	7.893-01
2200	8.354-01	8.416-01	8.385-01	8.311-01	8.235-01
3000	9.138-01	9.206-01	9.167-01	9.079-01	8.979-01
4000	9.532-01	9.594-01	9.511-01	9.369-01	9.198-01
5000	9.650-01	9.695-01	9.524-01	9.286-01	9.017-01
6000	9.547-01	9.570-01	9.292-01	8.944-01	8.578-01
7100	9.200-01	9.201-01	8.816-01	8.364-01	7.915-01
8200	8.668-01	8.653-01	8.190-01	7.667-01	7.170-01
9100	8.147-01	8.123-01	7.622-01	7.066-01	6.552-01

TABLE X. (CONT.)

GROUND ALBEDO = 0.9
SOURCE ALTITUDE = 1 KM

TEMP. (K°)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	8.373-01	7.765-01	7.437-01	6.900-01	6.447-01
2200	8.703-01	8.111-01	7.758-01	7.169-01	6.671-01
3000	9.436-01	8.884-01	8.406-01	7.580-01	6.901-01
4000	9.782-01	9.178-01	8.474-01	7.312-01	6.429-01
5000	9.848-01	9.118-01	8.166-01	6.692-01	5.672-01
6000	9.685-01	8.821-01	7.664-01	5.960-01	4.880-01
7100	9.273-01	8.302-01	7.001-01	5.160-01	4.085-01
8200	8.688-01	7.663-01	6.302-01	4.429-01	3.407-01
9100	8.134-01	7.100-01	5.742-01	3.900-01	2.939-01

SOURCE ALTITUDE = 9 KM

TEMP. (K°)	0	15	30	60	90
2000	8.064-01	7.248-01	7.825-01	7.586-01	7.378-01
2200	8.408-01	7.714-01	8.175-01	7.920-01	7.691-01
3000	9.203-01	8.841-01	8.963-01	8.576-01	8.226-01
4000	9.617-01	9.415-01	9.259-01	8.556-01	7.993-01
5000	9.736-01	9.538-01	9.183-01	8.097-01	7.319-01
6000	9.615-01	9.356-01	8.859-01	7.437-01	6.496-01
7100	9.239-01	8.902-01	8.309-01	6.634-01	5.589-01
8200	8.678-01	8.282-01	7.643-01	5.842-01	4.763-01
9100	8.138-01	7.712-01	7.064-01	5.237-01	4.168-01

SOURCE ALTITUDE = 50 KM

TEMP. (K°)	0	15	30	60	90
2000	8.052-01	8.142-01	8.138-01	8.085-01	7.986-01
2200	8.408-01	8.506-01	8.508-01	8.453-01	8.347-01
3000	9.279-01	9.411-01	9.438-01	9.367-01	9.208-01
4000	9.899-01	1.004+00	1.005+00	9.919-01	9.655-01
5000	1.033+00	1.045+00	1.036+00	1.010+00	9.726-01
6000	1.054+00	1.061+00	1.037+00	9.988-01	9.501-01
7100	1.046+00	1.048+00	1.006+00	9.564-01	8.995-01
8200	1.010+00	1.006+00	9.525-01	8.937-01	8.325-01
9100	9.644-01	9.577-01	8.969-01	8.343-01	7.720-01

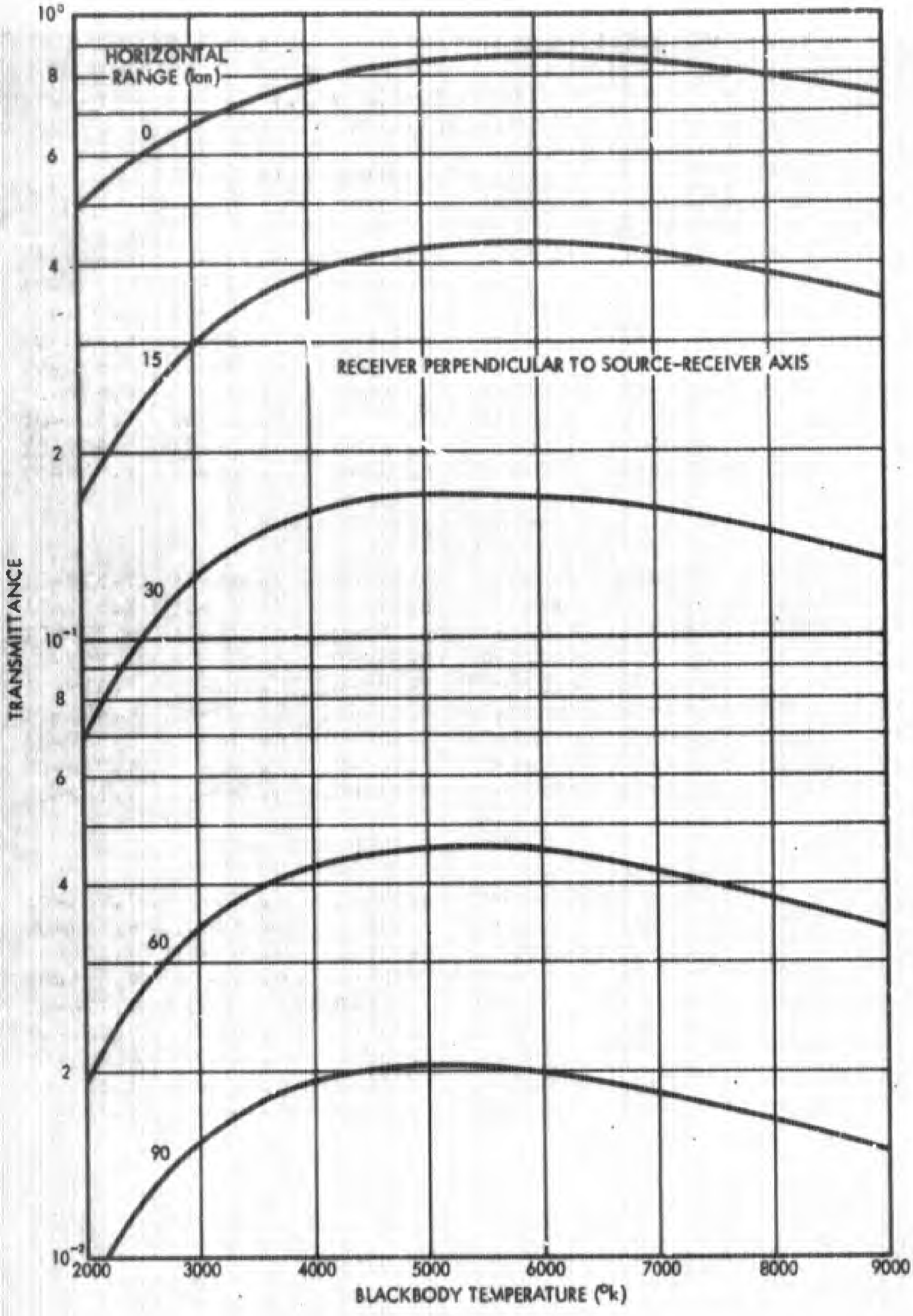

Fig. 1. Transmittance vs Blackbody Temperature for the Afternoon Tropical Atmosphere: Source Altitude = 1 km, Ground Albedo = 0.0

of 1.448μ. When T = 9000°K, the wavelength at which the emissive power is a maximum is 0.321μ. Thus there is a shift toward shorter wavelengths in the wavelength at which the emissive power is a maximum with an increase in blackbody temperature. Since the transmittance for monochromatic point sources varies with wavelength, the blackbody temperature at which the transmittance for blackbody source is a maximum is an indicator of the wavelengths for which the maximum transmittance is obtained.

The variation of the transmittance in the morning and afternoon tropical atmospheres with blackbody temperature for flat plate receivers facing the source and oriented both parallel and perpendicular to the ground surface is shown in Tables XI through XIV.

The effect of a cloud layer at altitudes of 1.5 and 3.5 km on the variation of the transmittance with blackbody temperature and horizontal range is shown in Tables XV through XXII for the 1.0 km source altitude in both the morning and afternoon tropical atmospheres. Table XV gives the variation of the transmittance in the morning tropical atmosphere with blackbody temperature and horizontal range for receivers facing the source and oriented normal to the source-receiver axis when the bottom of the cloud layer is at 1.5 km altitude and the ground albedo is either 0.0 or 0.9 for all wavelengths. Table XVI lists similar data for a cloud bottom altitude of 3.5 km. Tables XVII and XVIII list data for cloud bottom altitudes of 1.5 and 3.5, respectively, when the receiver is facing the source and oriented parallel to the ground surface. Tables XIX through XXII list for the afternoon tropical atmosphere the variation of the transmittance with blackbody temperature and horizontal range for blackbody sources located at 1 km altitude. Transmittance data are tabulated for ground albedo values of 0.0 and 0.9, receivers facing the source and oriented both normal to the source-receiver axis and parallel to the ground surface, and cloud bottom altitudes of 1.5 and 3.5 km. Table XXIII lists the transmittance in both the morning and afternoon tropical atmospheres at a horizontal range of 0.0 km as a function of blackbody temperature. Transmittances are given for ground albedo values of 0.0 and 0.9 and for cloud bottom altitudes of both 1.5 and 3.5 km in each of the two tropical atmospheres. At horizontal ranges of 15 km and greater, the transmittance for a receiver facing the source and oriented normal to the ground surface is the same as that given in Tables XV and XVI for the morning tropical atmosphere and Tables XIX and XX for the afternoon tropical atmosphere when the receiver is oriented normal to the source-receiver axis.

The variation of the transmittance with blackbody temperature at horizontal ranges between 0 and 90 km for receivers facing the source and oriented both parallel and perpendicular to the ground surface in each of the tropical atmospheres, with and without clouds, follows the same general trends as that described above for receivers facing the source and oriented normal to the source-receiver axis.

An examination of the transmittances for a receiver facing the source and oriented normal to the source-receiver axis, which are tabulated in Tables V through X as a function of blackbody temperature for each of the model atmospheres, shows that the temperature T_{MAX} at which the maximum transmission is obtained is dependent on the scattering and absorption properties of the model atmosphere. The parameters affecting T_{MAX} are the water vapor content and the aerosol coefficient variation with wavelength. These parameters define how the longer wavelengths (0.8μ - 4.0μ) are being attenuated with respect to the shorter wavelengths (0.3μ- 0.8μ). This can be illustrated by the differences in T_{MAX} between the morning and afternoon tropical atmosphere which is due entirely to differences in the variations of the aerosol attenuation coefficient with wavelength for the two model atmospheres in the wavelength range between 0.3μ and 4.0μ. The extinction coefficient for the morning tropical atmosphere does not fall off as fast with an increase in wavelength as does the extinction coefficient for the afternoon tropical atmosphere. Thus the morning tropical atmosphere tends to remove the longer wavelengths more than does the afternoon tropical atmosphere, thereby resulting in maximum transmission at lower blackbody source temperatures in the morning tropical atmosphere than that which would be observed for the afternoon tropical atmosphere. In the case of the summer and winter atmospheres, the differences in the temperatures at which maximum transmittance occurs for a given source altitude and horizontal range is due entirely to the amount of water vapor absorption occurring for wavelengths between 0.8 and 4.0μ that results from the different absolute humidities assumed for the two model atmospheres.

(Text continues on page 45.)

TABLE XI. VARIATION OF ATMOSPHERIC TRANSMITTANCE FOR BLACKBODY SOURCES LOCATED IN A MORNING TROPICAL ATMOSPHERE WITH BLACKBODY TEMPERATURE

RECEIVER PARALLEL TO THE GROUND SURFACE

GROUND ALBEDO = 0.0

SOURCE ALTITUDE = 1 KM

TEMP. (K°)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	4.001-01	9.539-03	1.329-03	3.516-04	1.567-04
2200	4.297-01	1.172-02	1.514-03	3.991-04	1.803-04
3000	5.163-01	2.010-02	2.167-03	5.513-04	2.599-04
4000	5.906-01	2.834-02	2.773-03	6.746-04	3.288-04
5000	6.556-01	3.389-02	3.154-03	7.450-04	3.652-04
6000	7.086-01	3.694-02	3.336-03	7.721-04	3.736-04
7100	7.424-01	3.793-02	3.354-03	7.640-04	3.610-04
8200	7.479-01	3.713-02	3.242-03	7.293-04	3.357-04
9100	7.345-01	3.561-02	3.090-03	6.894-04	3.109-04

SOURCE ALTITUDE = 9 KM

TEMP. (K°)	0	15	30	60	90
2000	1.752-01	5.617-02	2.735-02	6.663-03	2.000-03
2200	1.900-01	6.112-02	3.018-02	7.455-03	2.250-03
3000	2.402-01	7.671-02	3.867-02	9.893-03	3.132-03
4000	2.785-01	8.855-02	4.495-02	1.171-02	3.926-03
5000	2.904-01	9.361-02	4.818-02	1.252-02	4.285-03
6000	2.848-01	9.380-02	4.913-02	1.259-02	4.275-03
7100	2.674-01	9.034-02	4.820-02	1.210-02	4.009-03
8200	2.443-01	8.463-02	4.587-02	1.128-02	3.625-03
9100	2.251-01	7.910-02	4.334-02	1.050-02	3.289-03

SOURCE ALTITUDE = 50 KM

TEMP. (K°)	0	15	30	60	90
2000	1.302-01	1.067-01	8.432-02	4.673-02	1.711-02
2200	1.475-01	1.212-01	9.549-02	5.146-02	1.839-02
3000	2.147-01	1.761-01	1.370-01	6.671-02	2.214-02
4000	2.751-01	2.257-01	1.747-01	7.900-02	2.487-02
5000	3.037-01	2.499-01	1.934-01	8.450-02	2.597-02
6000	3.089-01	2.544-01	1.967-01	8.461-02	2.578-02
7100	2.981-01	2.453-01	1.893-01	8.071-02	2.455-02
8200	2.781-01	2.283-01	1.757-01	7.458-02	2.273-02
9100	2.587-01	2.118-01	1.626-01	6.889-02	2.105-02

TABLE XI. (CONT.)

GROUND ALBEDO = 0.9

SOURCE ALTITUDE = 1 KM

TEMP. (K°)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	4.155-01	1.430-02	2.095-03	5.215-04	2.209-04
2200	4.481-01	1.767-02	2.385-03	5.913-04	2.539-04
3000	5.482-01	3.102-02	3.454-03	8.220-04	3.759-04
4000	6.366-01	4.472-02	4.558-03	1.021-03	5.361-04
5000	7.102-01	5.405-02	5.356-03	1.144-03	7.185-04
6000	7.674-01	5.916-02	5.816-03	1.200-03	8.953-04
7100	8.022-01	6.079-02	5.978-03	1.199-03	1.046-03
8200	8.063-01	5.947-02	5.871-03	1.154-03	1.137-03
9100	7.904-01	5.700-02	5.650-03	1.096-03	1.168-03

SOURCE ALTITUDE = 9 KM

TEMP. (K°)	0	15	30	60	90
2000	1.952-01	6.970-02	3.509-02	8.610-03	2.561-03
2200	2.128-01	7.675-02	3.933-02	9.794-03	2.935-03
3000	2.732-01	9.913-02	5.203-02	1.340-02	4.250-03
4000	3.208-01	1.156-01	6.062-02	1.581-02	5.347-03
5000	3.386-01	1.225-01	6.437-02	1.670-02	5.779-03
6000	3.360-01	1.229-01	6.501-02	1.660-02	5.707-03
7100	3.192-01	1.185-01	6.324-02	1.581-02	5.305-03
8200	2.951-01	1.110-01	5.980-02	1.465-02	4.766-03
9100	2.732-01	1.038-01	5.627-02	1.358-02	4.306-03

SOURCE ALTITUDE = 50 KM

TEMP. (K°)	0	15	30	60	90
2000	1.795-01	1.400-01	1.168-01	6.791-02	2.861-02
2200	2.055-01	1.597-01	1.312-01	7.3[illegible]7-02	3.036-02
3000	3.087-01	2.350-01	1.810-01	9.058-02	3.417-02
4000	4.075-01	3.059-01	2.239-01	1.018-01	3.565-02
5000	4.598-01	3.431-01	2.450-01	1.059-01	3.558-02
6000	4.739-01	3.523-01	2.483-01	1.046-01	3.446-02
7100	4.606-01	3.413-01	2.387-01	9.912-01	3.240-02
8200	4.307-01	3.183-01	2.215-01	9.135-01	2.984-02
9100	4.006-01	2.954-01	2.051-01	8.434-01	2.759-02

TABLE XII. VARIATION OF ATMOSPHERIC TRANSMITTANCE FOR BLACKBODY SOURCES LOCATED IN AN AFTERNOON TROPICAL ATMOSPHERE WITH BLACKBODY TEMPERATURE

RECEIVER PARALLEL TO THE GROUND SURFACE

GROUND ALBEDO = 0.0

SOURCE ALTITUDE = 1 KM

TEMP. (K°)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	4.915-01	1.774-02	6.562-03	3.338-03	2.181-03
2200	5.349-01	2.050-02	8.114-03	4.018-03	2.591-03
3000	6.726-01	3.135-02	1.461-02	6.647-03	4.307-03
4000	7.802-01	4.311-02	2.195-02	9.272-03	6.235-03
5000	8.354-01	5.200-02	2.760-02	1.109-02	7.706-03
6000	8.505-01	5.760-02	3.130-02	1.216-02	8.654-03
7100	8.325-01	6.019-02	3.324-02	1.261-02	9.132-03
8200	7.902-01	5.982-02	3.340-02	1.247-02	9.139-03
9100	7.450-01	5.799-02	3.260-02	1.206-02	8.898-03

SOURCE ALTITUDE = 9 KM

2000	4.249-01	1.682-01	7.841-02	2.799-02	1.226-02
2200	4.634-01	1.862-01	8.824-02	3.236-02	1.425-02
3000	5.908-01	2.495-01	1.236-01	4.867-02	2.194-02
4000	6.898-01	3.039-01	1.537-01	6.330-02	2.972-02
5000	7.352-01	3.344-01	1.692-01	7.124-02	3.457-02
6000	7.422-01	3.459-01	1.742-01	7.385-02	3.648-02
7100	7.197-01	3.421-01	1.713-01	7.248-02	3.602-02
8200	6.778-01	3.269-01	1.628-01	6.846-02	3.395-02
9100	6.357-01	3.092-01	1.535-01	6.414-02	3.164-02

SOURCE ALTITUDE = 50 KM

2000	2.883-01	3.438-01	2.963-01	1.982-01	1.348-01
2200	3.246-01	3.799-01	3.275-01	2.199-01	1.499-01
3000	4.684-01	5.035-01	4.342-01	2.937-01	1.998-01
4000	6.010-01	6.026-01	5.186-01	3.507-01	2.361-01
5000	6.711-01	6.476-01	5.556-01	3.742-01	2.491-01
6000	6.924-01	6.532-01	5.586-01	3.745-01	2.469-01
7100	6.781-01	6.297-01	5.369-01	3.582-01	2.342-01
8200	6.404-01	5.885-01	5.005-01	3.326-01	2.161-01
9100	6.005-01	5.484-01	4.656-01	3.086-01	1.996-01

TABLE XII. (CONT.)

GROUND ALBEDO = 0.9
SOURCE ALTITUDE = 1 KM

TEMP. (K °)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	4.936-01	2.105-02	1.092-02	4.384-03	3.485-03
2200	5.375-01	2.479-02	1.349-02	5.330-03	4.293-03
3000	6.778-01	4.097-02	2.560-02	9.403-03	7.974-03
4000	7.888-01	6.238-02	4.236-02	1.470-02	1.266-02
5000	8.467-01	8.252-02	5.762-02	1.962-02	1.663-02
6000	8.635-01	9.833-02	6.907-02	2.347-02	1.947-02
7100	8.464-01	1.090-01	7.646-02	2.609-02	2.[illegible]20-02
8200	8.043-01	1.131-01	7.905-02	2.711-02	2.169-02
9100	7.589-01	1.126-01	7.846-02	2.701-02	2.140-02

SOURCE ALTITUDE = 9 KM

TEMP. (K °)	0	15	30	60	90
2000	4.309-01	1.737-01	8.264-02	2.983-02	1.279-02
2200	4.706-01	1.929-01	9.305-02	3.467-02	1.491-02
3000	6.035-01	2.623-01	1.343-01	5.350-02	2.345-02
4000	7.109-01	3.273-01	1.737-01	7.252-02	3.302-02
5000	7.656-01	3.696-01	1.997-01	8.518-02	3.982-02
6000	7.810-01	3.915-01	2.141-01	9.175-02	4.326-02
7100	7.655-01	3.960-01	2.186-01	9.326-02	4.379-02
8200	7.274-01	3.850-01	2.142-01	9.059-02	4.207-02
9100	6.865-01	3.686-01	2.061-01	8.648-02	3.972-02

SOURCE ALTITUDE = 50 KM

TEMP. (K °)	0	15	30	60	90
2000	2.928-01	3.498-01	3.022-01	2.043-01	1.398-01
2200	3.305-01	3.876-01	3.350-01	2.274-01	1.560-01
3000	4.848-01	5.207-01	4.502-01	3.084-01	2.117-01
4000	6.397-01	6.371-01	5.497-01	3.775-01	2.575-01
5000	7.358-01	7.010-01	6.030-01	4.138-01	2.804-01
6000	7.796-01	7.225-01	6.195-01	4.244-01	2.861-01
7100	7.823-01	7.107-01	6.074-01	4.153-01	2.789-01
8200	7.532-01	6.750-01	5.754-01	3.926-01	2.629-01
9100	7.153-01	6.358-01	5.410-01	3.687-01	2.464-01

TABLE XIII. VARIATION OF ATMOSPHERIC TRANSMITTANCE FOR BLACKBODY SOURCES LOCATED IN A MORNING TROPICAL ATMOSPHERE WITH BLACKBODY TEMPERATURE

RECEIVER NORMAL TO THE GROUND SURFACE

GROUND ALBEDO = 0.0

SOURCE ALTITUDE = 1 KM

TEMP. (K°)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	3.236-02	1.105-02	1.680-03	3.050-04	1.802-04
2200	3.653-02	1.369-02	2.148-03	3.430-04	1.957-04
3000	5.048-02	2.443-02	4.405-03	4.872-04	2.482-04
4000	6.122-02	3.636-02	6.960-03	6.277-04	2.983-04
5000	6.687-02	4.539-02	8.379-03	7.066-04	3.227-04
6000	6.947-02	5.087-02	8.758-03	7.292-04	3.215-04
7100	6.983-02	5.306-02	8.436-03	7.088-04	3.011-04
8200	6.814-02	5.227-02	7.743-03	6.616-04	2.715-04
9100	6.562-02	5.020-02	7.079-03	6.140-04	2.455-04

SOURCE ALTITUDE = 9 KM

TEMP. (K°)	0	15	30	60	90
2000	1.408-02	5.177-02	2.332-02	3.943-03	2.464-03
2200	1.513-02	5.819-02	2.559-02	4.187-03	2.567-03
3000	1.829-02	7.811-02	3.484-02	4.919-03	2.607-03
4000	2.149-02	9.274-02	4.476-02	5.533-03	2.366-03
5000	2.386-02	9.983-02	5.033-02	5.820-03	2.101-03
6000	2.508-02	1.017-01	5.170-02	5.890-03	1.868-03
7100	2.520-02	9.964-02	4.996-02	5.691-03	1.648-03
8200	2.436-02	9.466-02	4.641-02	5.332-03	1.455-03
9100	2.321-02	8.933-02	4.293-02	4.978-03	1.313-03

SOURCE ALTITUDE = 50 KM

TEMP. (K°)	0	15	30	60	90
2000	1.957-02	4.520-02	5.861-02	5.838-02	3.197-02
2200	2.240-02	4.911-02	6.313-02	6.258-02	3.409-02
3000	3.132-02	5.932-02	7.451-02	7.205-02	4.010-02
4000	3.655-02	6.421-02	7.996-02	7.631-02	4.569-02
5000	3.816-02	6.518-02	8.145-02	7.806-02	5.085-02
6000	3.817-02	6.413-02	8.057-02	7.820-02	5.508-02
7100	3.715-02	6.138-02	7.744-02	7.645-02	5.785-02
8200	3.538-02	5.751-02	7.270-02	7.296-02	5.844-02
9100	3.356-02	5.385-02	6.811-02	6.919-02	5.753-02

TABLE XIII (CONT.)

GROUND ALBEDO = 0.9

SOURCE ALTITUDE = 1 KM

TEMP. (K°)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	6.126-02	1.824-02	2.516-03	4.604-04	2.546-04
2200	7.099-02	2.217-02	3.187-03	5.187-04	2.787-04
3000	1.048-01	3.781-02	6.386-03	7.392-04	3.679-04
4000	1.315-01	5.467-02	1.001-02	9.553-04	4.626-04
5000	1.439-01	6.716-02	1.208-02	1.079-03	5.145-04
6000	1.470-01	7.457-02	1.268-02	1.118-03	5.211-04
7100	1.437-01	7.739-02	1.227-02	1.091-03	4.933-04
8200	1.363-01	7.607-02	1.132-02	1.022-03	4.478-04
9100	1.286-01	7.302-02	1.039-02	9.513-04	4.064-04

SOURCE ALTITUDE = 9 KM

TEMP. (K°)	0	15	30	60	90
2000	3.121-02	6.784-02	2.858-02	4.577-03	2.805-03
2200	3.347-02	7.620-02	3.203-02	4.897-03	2.926-03
3000	3.889-02	1.037-01	4.684-02	5.966-03	2.993-03
4000	4.335-02	1.284-01	6.262-02	6.940-03	2.732-03
5000	4.685-02	1.449-01	7.111-02	7.448-03	2.426-03
6000	4.886-02	1.541-01	7.311-02	7.532-03	2.150-03
7100	4.915-02	1.569-01	7.054-02	7.274-03	1.885-03
8200	4.775-02	1.536-01	6.541-02	6.801-03	1.654-03
9100	4.573-02	1.479-01	6.044-02	6.335-03	1.486-03

SOURCE ALTITUDE = 50 KM

TEMP. (K°)	0	15	30	60	90
2000	3.570-02	7.281-02	8.720-02	7.831-02	4.198-02
2200	4.127-02	7.926-02	9.463-02	8.545-02	4.568-02
3000	6.255-02	9.762-02	1.156-01	1.066-01	5.786-02
4000	8.258-02	1.103-01	1.310-01	1.233-01	6.996-02
5000	9.372-02	1.160-01	1.390-01	1.331-01	8.007-02
6000	9.740-02	1.163-01	1.407-01	1.369-01	8.765-02
7100	9.563-02	1.121-01	1.367-01	1.353-01	9.229-02
8200	9.032-02	1.051-01	1.288-01	1.294-01	9.314-02
9100	8.464-02	9.821-02	1.206-01	1.225-01	9.153-02

TABLE XIV. VARIATION OF ATMOSPHERIC TRANSMITTANCE FOR BLACKBODY SOURCES LOCATED IN AN AFTERNOON TROPICAL ATMOSPHERE WITH BLACKBODY TEMPERATURE

RECEIVER NORMAL TO THE GROUND SURFACE

GROUND ALBEDO = 0.0
SOURCE ALTITUDE = 1 KM

TEMP.	HORIZONTAL RANGE (KM)				
(K°)	0	15	30	60	90
2000	1.243-03	1.721-01	7.189-02	1.985-02	8.307-03
2200	1.480-03	1.985-01	8.348-02	2.158-02	9.794-03
3000	2.620-03	2.988-01	1.260-01	2.333-02	1.506-02
4000	4.500-03	3.856-01	1.593-01	3.651-02	1.879-02
5000	6.578-03	4.252-01	1.715-01	4.706-02	1.984-02
6000	8.411-03	4.304-01	1.701-01	5.075-02	1.933-02
7100	9.839-03	4.121-01	1.601-01	4.996-02	1.790-02
8200	1.059-02	3.810-01	1.462-01	4.641-02	1.614-02
9100	1.078-02	3.518-01	1.339-01	3.782-02	1.466-02

SOURCE ALTITUDE = 9 KM

TEMP. (K°)	0	15	30	60	90
2000	8.158-03	2.640-01	2.512-01	1.501-01	7.846-02
2200	8.658-03	2.930-01	2.835-01	1.713-01	8.993-02
3000	1.101-02	3.953-01	3.970-01	2.425-01	1.286-01
4000	1.521-02	4.833-01	4.809-01	2.856-01	1.518-01
5000	2.022-02	5.264-01	5.073-01	2.889-01	1.533-01
6000	2.483-02	5.335-01	4.974-01	2.715-01	1.438-01
7100	2.847-02	5.137-01	4.649-01	2.431-01	1.284-01
8200	3.037-02	4.778-01	4.227-01	2.129-01	1.121-01
9100	3.079-02	4.432-01	3.865-01	1.896-01	9.950-02

SOURCE ALTITUDE = 50 KM

TEMP. (K°)	0	15	30	60	90
2000	9.777-03	1.139-01	1.926-01	2.666-01	2.824-01
2200	1.155-02	1.259-01	2.127-01	2.962-01	3.174-01
3000	2.161-02	1.683-01	2.810-01	3.959-01	4.349-01
4000	3.809-02	2.061-01	3.363-01	4.714-01	5.172-01
5000	5.414-02	2.278-01	3.629-01	5.024-01	5.408-01
6000	6.644-02	2.361-01	3.682-01	5.029-01	5.281-01
7100	7.449-02	2.334-01	3.574-01	4.817-01	4.923-01
8200	7.744-02	2.226-01	3.361-01	4.480-01	4.467-01
9100	7.702-02	2.103-01	3.145-01	4.163-01	4.078-01

TABLE XIV.(CONT.)

GROUND ALBEDO = 0.9
SOURCE ALTITUDE = 1 KM

TEMP. (K°)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	2.513-03	1.889-01	8.589-02	2.514-02	1.128-02
2200	2.983-03	2.200-01	1.008-01	3.002-02	1.342-02
3000	5.271-03	3.436-01	1.586-01	4.960-02	2.146-02
4000	8.960-03	4.608-01	2.088-01	6.799-02	2.814-02
5000	1.294-02	5.246-01	2.321-01	7.784-02	3.108-02
6000	1.643-02	5.454-01	2.360-01	8.102-02	3.147-02
7100	1.913-02	5.353-01	2.269-01	7.951-02	3.018-02
8200	2.054-02	5.052-01	2.107-01	7.501-02	2.797-02
9100	2.087-02	4.731-01	1.952-01	7.022-02	2.589-02

SOURCE ALTITUDE = 9 KM

2000	1.367-02	2.813-01	2.658-01	1.589-01	8.100-02
2200	1.531-01	3.147-01	3.010-01	1.818-01	9.300-02
3000	2.287-02	4.367-01	4.276-01	2.599-01	1.342-01
4000	3.481-02	5.489-01	5.300-01	3.104-01	1.606-01
5000	4.795-02	6.120-01	5.756-01	3.195-01	1.647-01
6000	5.967-02	6.336-01	5.825-01	3.062-01	1.569-01
7100	6.885-02	6.230-01	5.631-01	2.803-01	1.422-01
8200	7.367-02	5.901-01	5.279-01	2.507-01	1.258-01
9100	7.480-02	5.544-01	4.933-01	2.268-01	1.127-01

SOURCE ALTITUDE = 50 KM

2000	2.938-02	1.326-01	2.120-01	2.895-01	3.005-01
2200	3.452-02	1.477-01	2.354-01	3.236-01	3.403-01
3000	6.188-02	2.054-01	3.199-01	4.437-01	4.797-01
4000	1.074-01	2.683-01	4.006-01	5.490-01	5.896-01
5000	1.540-01	3.164-01	4.535-01	6.093-01	6.352-01
6000	1.910-01	3.462-01	4.806-01	6.334-01	6.363-01
7100	2.159-01	3.586-01	4.852-01	6.288-01	6.067-01
8200	2.255-01	3.542-01	4.707-01	6.023-01	5.605-01
9100	2.249-01	3.420-01	4.496-01	5.708-01	5.178-01

TABLE XV. VARIATION OF ATMOSPHERIC TRANSMITTANCE WITH BLACKBODY TEMPERATURE FOR A SOURCE AT 1.00 KM. ALTITUDE IN THE MORNING TROPICAL ATMOSPHERE WITH A CLOUD LAYER AT 1.50 KM. ALTITUDE

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

GROUND ALBEDO = 0.0

TEMP. (K)	HORIZONTAL RANGE (KM) 0	15	30
2000	4.811-01	5.555-03	1.026-06
2200	5.286-01	7.369-03	1.587-06
3000	6.646-01	1.568-02	4.843-06
4000	7.551-01	2.690-02	9.419-06
5000	8.118-01	3.679-02	1.275-05
6000	8.484-01	4.359-02	1.448-05
7100	8.628-01	4.720-02	1.494-05
8200	8.501-01	4.761-02	1.447-05
9100	8.235-01	4.633-02	1.370-05

GROUND ALBEDO = 0.9

TEMP. (K)	0	15	30
2000	5.134-01	6.848-03	1.106-06
2200	5.679-01	9.111-03	1.700-06
3000	7.298-01	2.001-02	5.156-06
4000	8.460-01	3.563-02	1.003-05
5000	9.207-01	4.993-02	1.363-05
6000	9.676-01	6.020-02	1.554-05
7100	9.855-01	6.622-02	1.611-05
8200	9.705-01	6.767-02	1.566-05
9100	9.392-01	6.648-02	1.488-05

TABLE XVI. VARIATION OF ATMOSPHERIC TRANSMITTANCE WITH BLACKBODY TEMPERATURE FOR A SOURCE AT 1.00 KM. ALTITUDE IN THE MORNING TROPICAL ATMOSPHERE WITH A CLOUD LAYER AT 3.50 KM. ALTITUDE

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

GROUND ALBEDO = 0.0

TEMP. (K)	HORIZONTAL RANGE (KM) 0	15	30
2000	3.819-01	1.566-02	1.502-03
2200	4.187-01	1.906-02	1.848-03
3000	5.457-01	3.357-02	2.838-03
4000	6.831-01	5.127-02	3.200-03
5000	8.065-01	6.571-02	3.049-03
6000	9.018-01	7.518-02	2.726-03
7100	9.618-01	7.989-02	2.342-03
8200	9.760-01	7.991-02	1.991-03
9100	9.606-01	7.758-02	1.740-03

GROUND ALBEDO = 0.9

TEMP. (K)	0	15	30
2000	4.064-01	3.276-02	1.088-03
2200	4.461-01	4.015-02	2.297-03
3000	5.881-01	6.849-02	3.452-03
4000	7.533-01	9.836-02	3.868-03
5000	9.084-01	1.203-01	3.689-03
6000	1.030+00	1.332-01	3.307-03
7100	1.110+00	1.381-01	2.851-03
8200	1.133+00	1.358-01	2.431-03
9100	1.119+00	1.305-01	2.130-03

TABLE XVII. VARIATION OF ATMOSPHERIC TRANSMITTANCE WITH BLACKBODY TEMPERATURE FOR A SOURCE AT 1.00 KM. ALTITUDE IN THE MORNING TROPICAL ATMOSPHERE WITH A CLOUD LAYER AT 1.50 KM. ALTITUDE

RECEIVER PARALLEL TO GROUND SURFACE

GROUND ALBEDO = 0.0

TEMP. (K°)	HORIZONTAL RANGE (KM) 0	15	30
2000	4.811-01	3.076-03	1.026-06
2200	5.286-01	3.925-03	1.587-06
3000	6.146-01	7.356-03	4.943-06
4000	7.551-01	1.094-02	9.419-06
5000	8.118-01	1.348-02	1.275-05
6000	8.484-01	1.498-02	1.448-05
7100	8.623-01	1.560-02	1.494-05
8200	8.501-01	1.543-02	1.447-05
9100	8.235-01	1.489-02	1.370-05

GROUND ALBEDO = 0.9

TEMP. (K°)	0	15	30
2000	5.134-01	5.255-03	1.180-06
2200	5.679-01	6.805-03	1.793-06
3000	7.298-01	1.336-02	5.295-06
4000	8.460-01	2.069-02	1.617-05
5000	9.207-01	2.609-02	1.374-05
6000	9.676-01	2.938-02	1.563-05
7100	9.855-01	3.083-02	1.618-05
8200	9.705-01	3.060-02	1.572-05
9100	9.392-01	2.959-02	1.493-05

TABLE XVIII. VARIATION OF ATMOSPHERIC TRANSMITTANCE WITH BLACKBODY TEMPERATURE FOR A SOURCE AT 1.00 KM. ALTITUDE IN THE MORNING TROPICAL ATMOSPHERE WITH A CLOUD LAYER AT 3.50 KM. ALTITUDE

RECEIVER PARALLEL TO GROUND SURFACE

GROUND ALBEDO = 0.0

TEMP. (K)	HORIZONTAL RANGE (KM) 0	15	30
2000	4.811-01	1.927-02	3.818-04
2200	5.286-01	2.273-02	4.585-04
3000	6.646-01	3.626-02	7.243-04
4000	7.551-01	5.353-02	9.307-04
5000	8.118-01	6.061-02	1.026-03
6000	8.484-01	6.631-02	1.048-03
7100	8.628-01	6.828-02	1.018-03
8200	8.501-01	6.697-02	9.568-04
9100	8.235-01	6.432-02	8.947-04

GROUND ALBEDO = 0.9

TEMP. (K)	0	15	30
2000	5.134-01	4.154-02	6.082-04
2200	5.679-01	5.008-02	7.494-04
3000	7.298-01	8.164-02	1.316-03
4000	8.460-01	1.114-01	1.896-03
5000	9.207-01	1.304-01	2.271-03
6000	9.676-01	1.399-01	2.459-03
7100	9.855-01	1.417-01	2.500-03
8200	9.705-01	1.374-01	2.426-03
9100	9.392-01	1.310-01	2.314-03

TABLE XIX. VARIATION OF ATMOSPHERIC TRANSMITTANCE WITH BLACKBODY TEMPERATURE FOR A SOURCE AT 1.00 KM. ALTITUDE IN THE AFTERNOON TROPICAL ATMOSPHERE WITH A CLOUD LAYER AT 1.50 KM. ALTITUDE

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

GROUND ALBEDO = 0.0

TEMP.	HORIZONTAL RANGE (KM)				
(K°)	0	15	30	60	90
2000	5.742-01	1.811-01	5.722-02	8.371-03	1.483-03
2200	6.325-01	2.033-01	6.505-02	9.333-03	1.568-03
3000	8.404-01	2.847-01	9.337-02	1.227-02	1.647-03
4000	1.046600	3.545-01	1.156-01	1.364-02	2.069-03
5000	1.191+00	3.865-01	1.242-01	1.333-02	2.120-03
6000	1.273+00	3.905-01	1.236-01	1.227-02	1.912-03
7100	1.297+00	3.746-01	1.170-01	1.084-02	1.639-03
8200	1.268+00	3.476-01	1.075-01	9.427-03	1.353-03
9100	1.217+00	3.220-01	9.892-02	8.367-03	9.470-04

GROUND ALBEDO = 0.9

TEMP. (K°)	0	15	30	60	90
2000	6.231-01	7.383-01	1.129-01	1.393-02	2.415-03
2200	6.893-01	7.649-01	1.346-01	1.601-02	2.659-03
3000	9.331-01	8.950-01	2.203-01	2.320-02	3.267-03
4000	1.195+00	1.086+00	3.012-01	2.847-02	3.421-03
5000	1.398+00	1.237+00	3.465-01	3.038-02	3.259-03
6000	1.529+00	1.319+00	3.633-01	3.022-02	2.986-03
7100	1.588+00	1.335+00	3.594-01	2.870-02	2.656-03
8200	1.575+00	1.294+00	3.416-01	2.651-02	2.337-03
9100	1.526600	1.234600	3.215-01	2.451-02	2.097-03

TABLE XX. VARIATION OF ATMOSPHERIC TRANSMITTANCE WITH BLACKBODY TEMPERATURE FOR A SOURCE AT 1.00 KM. ALTITUDE IN THE AFTERNOON TROPICAL ATMOSPHERE WITH A CLOUD LAYER AT 3.50 KM. ALTITUDE

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

GROUND ALBEDO = 0.0

TEMP.	HORIZONTAL RANGE (KM)				
(K°)	0	15	30	60	90
2000	4.855-01	2.282-01	9.222-02	1.497-02	2.634-03
2200	5.292-01	2.712-01	1.087-01	1.628-02	2.668-03
3000	6.728-01	4.422-01	1.733-01	2.060-02	2.675-03
4000	7.930-01	6.080-01	2.334-01	2.339-02	2.488-03
5000	8.608-01	7.042-01	2.660-01	2.382-02	2.203-03
6000	8.853-01	7.422-01	2.768-01	2.284-02	1.904-03
7100	8.736-01	7.372-01	2.721-01	2.098-02	1.604-03
8200	8.339-01	7.022-01	2.573-01	1.885-02	1.348-03
9100	7.889-01	6.616-01	2.413-01	1.709-02	1.170-03

GROUND ALBEDO = 0.9

TEMP.	0	15	30	60	90
2000	4.939-01	5.253-01	1.797-01	3.679-02	1.189-02
2200	5.393-01	6.435-01	2.224-01	4.403-02	1.170-02
3000	6.914-01	1.106+00	4.048-01	7.437-02	1.180-02
4000	8.253-01	1.556+00	6.039-01	1.066-01	1.246-02
5000	9.071-01	1.834+00	7.378-01	1.274-01	1.279-02
6000	9.437-01	1.965+00	8.072-01	1.373-01	1.264-02
7100	9.400-01	1.985+00	8.255-01	1.388-01	1.204-02
8200	9.042-01	1.917+00	8.033-01	1.339-01	1.118-02
9100	8.597-01	1.824+00	7.669-01	1.271-01	1.039-02

TABLE XXI. VARIATION OF ATMOSPHERIC TRANSMITTANCE WITH BLACKBODY TEMPERATURE FOR A SOURCE AT 1.00 KM. ALTITUDE IN THE AFTERNOON TROPICAL ATMOSPHERE WITH A CLOUD LAYER AT 1.50 KM. ALTITUDE

RECEIVER PARALLEL TO GROUND SURFACE

GROUND ALBEDO = 0.0

TEMP. (K°)	HORIZONTAL RANGE (KM) 0	15	30	60	90
2000	5.742-01	2.907-02	5.614-03	5.117-04	5.853-05
2200	6.325-01	3.169-02	6.444-03	5.943-04	6.725-05
3000	8.404-01	4.154-02	9.626-03	8.117-04	8.437-05
4000	1.046+00	5.274-02	1.297-02	8.655-04	7.968-05
5000	1.191+00	6.179-02	1.545-02	8.032-04	6.628-05
6000	1.273+00	6.770-02	1.699-02	7.070-04	5.310-05
7100	1.297+00	7.045-02	1.769-02	6.006-04	4.131-05
8200	1.268+00	6.994-02	1.754-02	5.066-04	3.235-05
9100	1.217+00	6.781-02	1.699-02	4.467-04	2.672-05

GROUND ALBEDO = 0.9

TEMP. (K°)	0	15	30	60	90
2000	6.231-01	1.056-01	1.374-02	1.159-03	1.750-04
2200	6.893-01	1.284-01	1.697-02	1.391-03	1.947-04
3000	9.331-01	2.408-01	3.224-02	2.163-03	2.405-04
4000	1.195+00	4.137-01	5.369-02	2.705-03	2.425-04
5000	1.398+00	5.848-01	7.331-02	2.902-03	2.183-04
6000	1.529+00	7.213-01	8.796-02	2.894-03	1.884-04
7100	1.588+00	8.159-01	9.729-02	2.755-03	1.577-04
8200	1.575+00	8.559-01	1.004-01	2.548-03	1.316-04
9100	1.526+00	8.569-01	9.952-02	2.359-03	1.137-04

TABLE XXII. VARIATION OF ATMOSPHERIC TRANSMITTANCE WITH BLACKBODY TEMPERATURE FOR A SOURCE AT 1.00 KM. ALTITUDE IN THE AFTERNOON TROPICAL ATMOSPHERE WITH A CLOUD LAYER AT 3.50 KM. ALTITUDE

RECEIVER PARALLEL TO GROUND SURFACE

GROUND ALBEDO = 0.0

TEMP.	HORIZONTAL RANGE (KM)				
(K°)	0	15	30	60	90
2000	4.855-01	6.418-02	2.322-02	3.112-03	5.978-04
2200	5.292-01	7.442-02	2.618-02	3.293-03	5.997-04
3000	6.728-01	1.133-01	3.686-02	3.678-03	5.441-04
4000	7.930-01	1.546-01	4.764-02	3.688-03	4.370-04
5000	8.608-01	1.854-01	5.542-02	3.469-03	3.440-04
6000	8.853-01	2.046-01	5.997-02	3.171-03	2.725-04
7100	8.736-01	2.133-01	6.159-02	2.824-03	2.142-04
8200	8.339-01	2.118-01	6.050-02	2.491-03	1.712-04
9100	7.889-01	2.052-01	5.824-02	2.239-03	1.442-04

GROUND ALBEDO = 0.9

TEMP. (K°)	0	15	30	60	90
2000	4.939-01	2.479-01	8.305-02	1.269-02	1.620-03
2200	5.393-01	3.007-01	1.022-01	1.456-02	1.773-03
3000	6.914-01	5.225-01	1.824-01	2.056-02	2.140-03
4000	8.253-01	7.819-01	2.720-01	2.464-02	2.197-03
5000	9.071-01	9.837-01	3.391-01	2.603-02	2.051-03
6000	9.434-01	1.113+00	3.811-01	2.579-02	1.842-03
7100	9.400-01	1.177+00	4.012-01	2.447-02	1.605-03
8200	9.042-01	1.177+00	4.002-01	2.260-02	1.387-03
9100	8.597-01	1.145+00	3.886-01	2.090-02	1.229-03

TABLE XXIII. VARIATION OF ATMOSPHERIC TRANSMITTANCE WITH BLACKBODY TEMPERATURE FOR A SOURCE AT 1.00 KM. ALTITUDE AND A RECEIVER AT 0.0 KM. HORIZONTAL RANGE IN THE MORNING AND AFTERNOON TROPICAL ATMOSPHERE

RECEIVER PERPENDICULAR TO GROUND SURFACE

MORNING TROPICAL ATMOSPHERE

TEMP.	CB = 1.5 ALBEDO		CB = 3.5 ALBEDO	
(K°)	0.0	0.9	0.0	0.9
2000	2.107-02	6.224-02	1.458-02	2.843-02
2200	2.190-02	6.804-02	1.684-02	3.261-02
3000	2.581-02	9.075-02	2.590-02	4.917-02
4000	3.070-02	1.155-01	3.615-02	6.833-02
5000	3.460-02	1.352-01	4.451-02	8.449-02
6000	3.705-02	1.484-01	5.035-02	9.598-02
7100	3.798-02	1.550-01	5.366-02	1.027-01
8200	3.738-02	1.546-01	5.419-02	1.041-01
9100	3.608-02	1.505-01	5.309-02	1.021-01

AFTERNOON TROPICAL ATMOSPHERE

TEMP. (K°)	CB = 1.5, 0.0	CB = 1.5, 0.9	CB = 3.5, 0.0	CB = 3.5, 0.9
2000	2.124-02	1.092-01	6.281-03	3.460-02
2200	2.295-02	1.177-01	7.478-03	4.218-02
3000	2.811-02	1.446-01	1.126-02	7.420-02
4000	3.380-02	1.755-01	1.351-02	1.148-01
5000	3.924-02	2.060-01	1.387-02	1.512-01
6000	4.345-02	2.308-01	1.324-02	1.786-01
7100	4.598-02	2.472-01	1.208-02	1.963-01
8200	4.638-02	2.518-01	1.076-02	2.023-01
9100	4.547-02	2.486-01	9.714-03	2.006-01

CB = CLOUD BOTTOM ALTITUDE (KM)

IV. Transmittance Calculations for Nuclear Weapons

For a nuclear weapon burst the blackbody temperature and power emission varies with time. Fig. 2 shows the time distributions of the fireball temperature and relative irradiance for a representative air burst as described in Ref. 15 by Cahill, Gauvin, and Johnson. An air burst is usually defined as one for which the height of burst is such that the fireball does not touch the ground. To use point source data for predicting transmittances for nuclear weapons one must assume that the fireball radius is small compared to the slant range to the receiver position, thereby assuming that the fireball can be approximated as a point source. The RRA-90 procedure (Ref. 2) was used to fold the scattered, direct, and total transmittances as a function of blackbody temperature for each atmosphere and receiver orientation with the temperature and relative irradiance distributions with respect to time shown in Fig. 2 to obtain transmittance data for nuclear weapons.

The results of the calculations giving the direct, scattered, and total transmittance at horizontal ranges to 90 km for a representative air burst of a nuclear weapon at altitudes of 1, 9, and 50 km in each of the model atmospheres are given in Table XXIV for cases where the receiver is facing the source and is oriented normal to the source-receiver axis. Data are given in Table XXIV for cases where the ground albedo was either 0.0 and 0.9. Scattered transmittance data for other values of the ground albedo, where the ground albedo is a constant as a

(Text continues on page 50.)

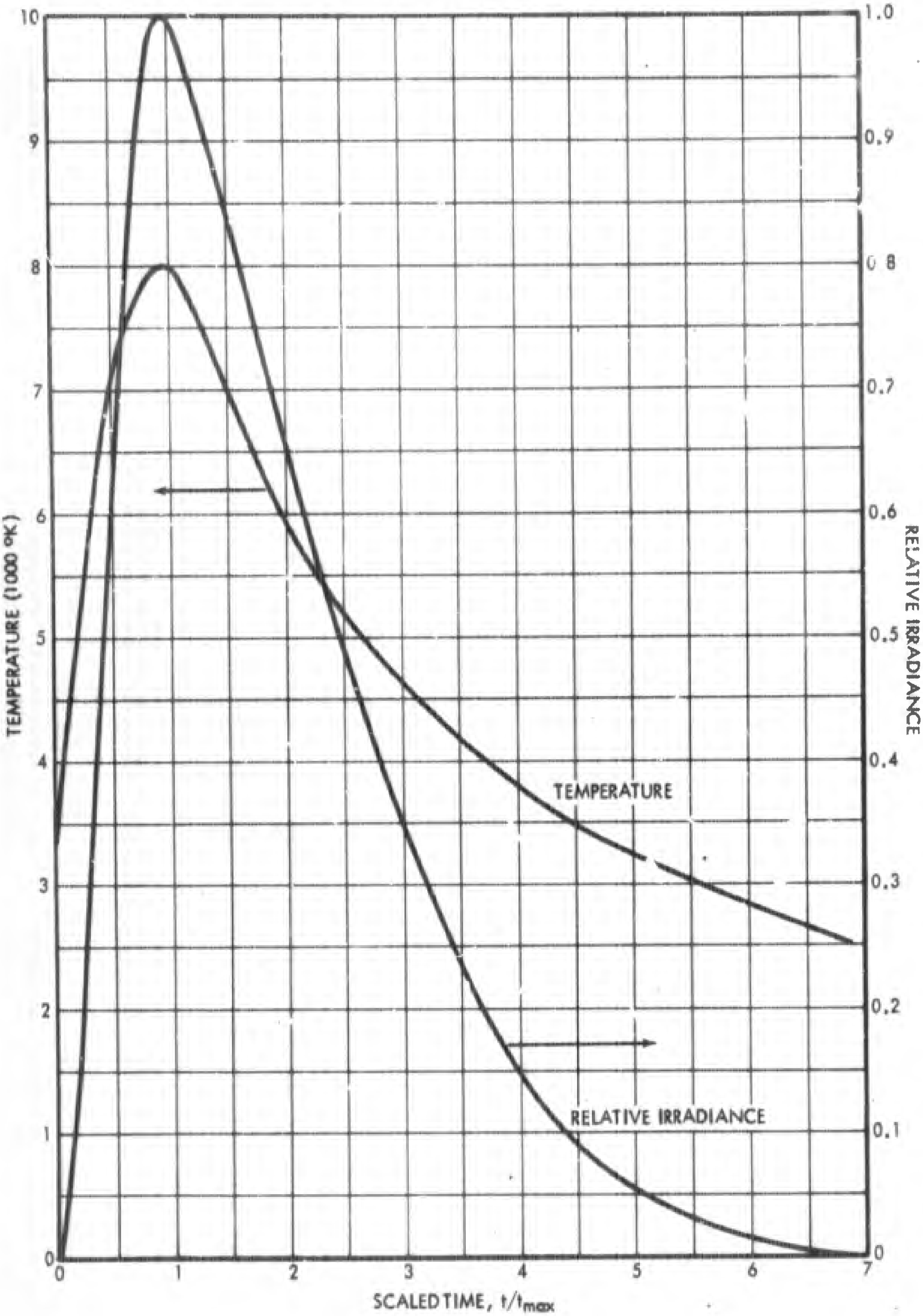

Fig. 2. Temperature and Relative Irradiance vs Scaled Time for a Representative Air Burst

TABLE XXIV. ATMOSPHERIC TRANSMITTANCES FOR NUCLEAR WEAPON THERMAL RADIATION IN MODEL ATMOSPHERES

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

MORNING TROPICAL ATMOSPHERE

HS (KM)	HR (KM)	TRANSMITTANCE DIRECT	SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
1	0	3.232-01	3.755-01	4.315-01	6.987-01	7.547-01
	15	3.987-07	4.850-02	7.114-02	4.850-02	7.114-02
	30	2.505-13	8.060-03	1.167-02	8.060-03	1.167-02
	60	0.000-00	6.858-04	1.053-03	6.858-04	1.053-03
	90	0.000-00	3.002-04	4.847-04	3.002-04	4.847-04
9	0	6.308-02	1.884-01	2.262-01	2.515-01	2.892-01
	15	5.604-03	2.105-01	2.533-01	2.161-01	2.589-01
	30	1.135-04	5.503-02	8.252-02	5.514-02	8.263-02
	60	3.170-08	7.504-03	9.802-03	7.504-03	9.802-03
	90	7.163-11	1.497-03	2.049-03	1.497-03	2.049-03
50	0	4.530-02	2.432-01	2.884-01	2.885-01	3.337-01
	15	3.899-02	2.159-01	2.427-01	2.549-01	2.817-01
	30	2.723-02	1.783-01	2.367-01	2.055-01	2.640-01
	60	8.570-03	8.573-02	1.130-01	9.430-02	1.215-01
	90	2.027-03	2.759-02	3.919-02	2.962-02	4.122-02

AFTERNOON TROPICAL ATMOSPHERE

HS (KM)	HR (KM)	TRANSMITTANCE DIRECT	SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
1	0	7.534-01	5.986-01	6.884-02	8.133-01	8.223-01
	15	1.506-01	2.532-01	3.705-01	4.039-01	5.212-01
	30	3.545-02	1.231-01	1.869-01	1.586-01	2.223-01
	60	2.669-03	3.930-02	7.191-02	4.197-02	7.458-02
	90	2.518-04	1.849-02	2.740-02	1.847-02	2.765-02
9	0	5.679-01	1.155-01	1.541-01	6.835-01	7.221-01
	15	4.060-01	2.166-01	3.148-01	6.227-01	7.209-01
	30	2.603-01	2.291-01	3.059-01	4.895-01	5.663-01
	60	1.042-01	1.595-01	1.992-01	2.637-01	3.034-01
	90	4.376-02	1.042-01	1.227-01	1.480-01	1.665-01
50	0	5.208-01	1.087-01	1.675-01	6.295-01	6.883-01
	15	5.049-01	1.010-01	1.623-01	6.059-01	6.673-01
	30	4.861-01	1.028-01	1.711-01	5.890-01	6.573-01
	60	4.086-01	1.172-01	1.804-01	5.259-01	5.891-01
	90	3.353-01	1.376-01	1.930-01	4.730-01	5.284-01

TABLE XXIV. (CONT.)

SUMMER MIDLATITUDE ATMOSPHERE

HS (KM)	HR (KM)	DIRECT	TRANSMITTANCE SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
1	0	7.668-01	6.794-02	7.962-02	8.347-01	8.464-01
	15	1.866-01	2.032-01	2.955-01	3.898-01	4.821-01
	30	5.795-02	1.153-01	1.664-01	1.733-01	2.244-01
	60	8.058-03	4.954-02	7.346-02	5.760-02	8.152-02
	90	1.461-03	2.479-02	3.795-02	2.625-02	3.941-02
9	0	5.254-01	6.708-02	1.044-01	5.924-01	6.298-01
	15	4.749-01	1.992-01	2.795-01	6.742-01	7.545-01
	30	3.650-01	1.866-01	2.551-01	5.516-01	6.202-01
	60	1.919-01	1.372-01	1.625-01	3.291-01	3.544-01
	90	1.216-01	8.285-02	9.800-02	2.040-01	2.196-01
50	0	5.927-01	1.361-01	2.406-01	7.289-01	8.334-01
	15	5.838-01	1.548-01	2.650-01	7.387-01	8.489-01
	30	5.604-01	1.855-01	3.015-01	7.460-01	8.620-01
	60	4.943-01	2.217-01	3.635-01	7.215-01	8.579-01
	90	4.274-01	1.952-01	3.437-01	6.226-01	7.711-01

WINTER MIDLATITUDE ATMOSPHERE

HS (KM)	HR (KM)	DIRECT	TRANSMITTANCE SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
1	0	7.935-01	7.083-02	8.251-02	8.643-01	8.760-01
	15	2.097-01	2.976-01	3.543-01	5.074-01	5.641-01
	30	7.209-02	1.244-01	1.773-01	1.965-01	2.494-01
	60	1.282-02	5.627-02	8.047-02	6.710-02	9.329-02
	90	3.094-03	3.615-02	4.915-02	3.924-02	5.225-02
9	0	5.532-01	6.816-02	1.059-01	6.214-01	6.591-01
	15	5.156-01	2.051-01	2.902-01	7.208-01	8.059-01
	30	3.921-01	1.876-01	2.603-01	5.797-01	6.525-01
	60	2.151-01	1.252-01	1.538-01	3.403-01	3.689-01
	90	1.405-01	8.752-02	1.065-01	2.281-01	2.471-01
50	0	6.227-01	1.274-01	2.328-01	7.501-01	8.556-01
	15	6.075-01	1.495-01	2.621-01	7.570-01	8.696-01
	30	5.881-01	1.833-01	3.052-01	7.714-01	8.934-01
	60	5.221-01	2.423-01	3.840-01	7.644-01	9.061-01
	90	4.549-01	2.159-01	3.381-01	6.709-01	7.930-01

TABLE XXIV. (CONT.)

WINTER (INVERSION PROFILE) ATMOSPHERE

HS (KM)	HR (KM)	DIRECT	TRANSMITTANCE SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
1	0	3.679-01	2.448-01	2.857-01	6.127-01	6.537-01
	15	4.221-06	2.666-02	5.053-02	2.666-02	5.054-02
	30	1.477-10	3.795-03	1.191-02	3.795-03	1.191-02
	60	7.148-19	7.259-04	1.532-03	7.259-04	1.532-03
	90	0.000-00	4.000-04	7.186-04	4.000-04	7.186-04
9	0	2.114-01	2.101-01	3.496-01	4.215-01	5.610-01
	15	7.468-02	3.072-01	3.597-01	3.818-01	4.343-01
	30	1.890-02	1.346-01	1.595-01	1.535-01	1.784-01
	60	3.136-03	2.601-02	3.163-02	2.915-02	3.477-02
	90	7.415-04	8.083-03	9.213-03	8.828-03	9.958-03
50	0	2.160-01	6.278-02	1.180-01	2.788-01	3.340-01
	15	2.035-01	1.351-01	2.102-01	3.386-01	4.137-01
	30	1.726-01	1.757-01	2.869-01	3.484-01	4.596-01
	60	1.031-01	2.091-01	3.364-01	3.122-01	4.396-01
	90	5.606-02	1.818-01	2.952-01	2.378-01	3.513-01

ARCTIC ATMOSPHERE

HS (KM)	HR (KM)	DIRECT	TRANSMITTANCE SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
1	0	9.123-01	2.019-02	2.614-02	9.325-01	9.385-01
	15	7.156-01	7.959-02	1.364-01	7.952-01	8.521-01
	30	6.048-01	7.486-02	1.335-01	6.796-01	7.383-01
	60	4.754-01	6.098-02	9.758-02	5.363-01	5.729-01
	90	3.950-01	5.167-02	7.572-02	4.466-01	4.707-01
9	0	8.369-01	7.017-02	9.525-02	9.071-01	9.322-01
	15	7.687-01	8.872-02	1.335-01	8.574-01	9.022-01
	30	7.039-01	1.050-01	1.508-01	8.090-01	8.547-01
	60	6.055-01	7.358-02	1.083-01	6.791-01	7.139-01
	90	5.407-01	5.540-02	8.184-02	5.962-01	6.226-01
50	0	8.091-01	1.178-01	2.197-01	9.269-01	1.028-00
	15	8.057-01	1.229-01	2.281-01	9.287-01	1.033-00
	30	7.942-01	1.044-01	2.102-01	8.986-01	1.004-00
	60	7.608-01	1.010-01	2.031-01	8.619-01	9.640-01
	90	7.255-01	9.918-02	1.899-01	8.246-01	9.154-01

function of wavelength in the range $0.3\mu<\lambda<4.0\mu$, can be obtained by use of an exponential interpolation.

Fig. 3 shows the total transmittance for burst altitudes of 1, 9, and 50 km vs horizontal range in the model afternoon tropical atmosphere for cases where the receiver is facing the source and is oriented normal to the source-receiver axis and the ground albedo was 0.0 and 0.9. It is seen that the total transmittance is highly dependent on the burst altitude. Plots of the total transmittance as a function of horizontal range for flat plate receivers facing the source and oriented normal to the source-receiver axis are shown for each of the model atmospheres in Figs. 4 through 9. Figs. 4 and 5 are for a burst altitude of 1 km and ground albedos of 0.0 and 0.9 respectively. Figs. 6 and 7 show similar data for a burst altitude of 9 km and Figs. 8 and 9 show data for a burst altitude of 50 km. From these figures, it is seen, for receivers facing the source and oriented normal to the source-receiver axis, that the rate at which the total transmittance falls off with horizontal range for a given source altitude is dependent on both the ground level meteorological range and the water vapor content used for each atmosphere. The basic difference between the summer and winter midlatitude model atmospheres is in the water vapor content of each atmosphere. The water vapor content in the model summer atmosphere is approximately four times that used for the model winter atmosphere The differences between the transmittance data seen in Figs. 4 through 9 for the summer and winter model atmospheres illustrates the effect of increasing the water vapor content on the total transmittance.

The effect of decreasing the ground level meteorological range from 25 km to 3 km is illustrated by the differences between the transmittances given in Figs. 4 through 9 for the afternoon and morning tropical atmospheres.

Table XXV lists the direct, scattered, and total transmittances for nuclear detonations at 1, 9, and 50 km altitude in the morning and afternoon tropical atmospheres for the case where the receiver is facing the source and is oriented parallel to the ground surface and the ground albedo was either 0.0 or 0.9. Table XXVI lists the direct, scattered, and total transmittances for nuclear detonations at 1, 9, and 50 km altitude in the morning and afternoon tropical atmospheres for the case where the receiver is facing the source and is oriented perpendicular to the ground surface and the ground albedo was either 0.0 or 0.9. Figs. 10 through 15 show the effect of the receiver orientation on the variation of the total transmittance with horizontal range for the morning and afternoon tropical atmospheres when the ground albedo is either 0.0 or 0.9. For a burst of 1 km altitude, the transmittance at a receiver located at a horizontal range of 0 km is the same for receivers oriented both parallel to the ground and perpendicular to the source receiver axis. The transmittance is the lowest for the receiver oriented perpendicular to the ground surface since that orientation does not allow the receiver to see any of the direct radiation. For a burst altitude of 1.0 km and horizontal ranges of 15 km and greater, the transmittances for receivers oriented normal to the source-receiver axis and perpendicular to the ground are approximately the same. As the

(Text continues on page 66.)

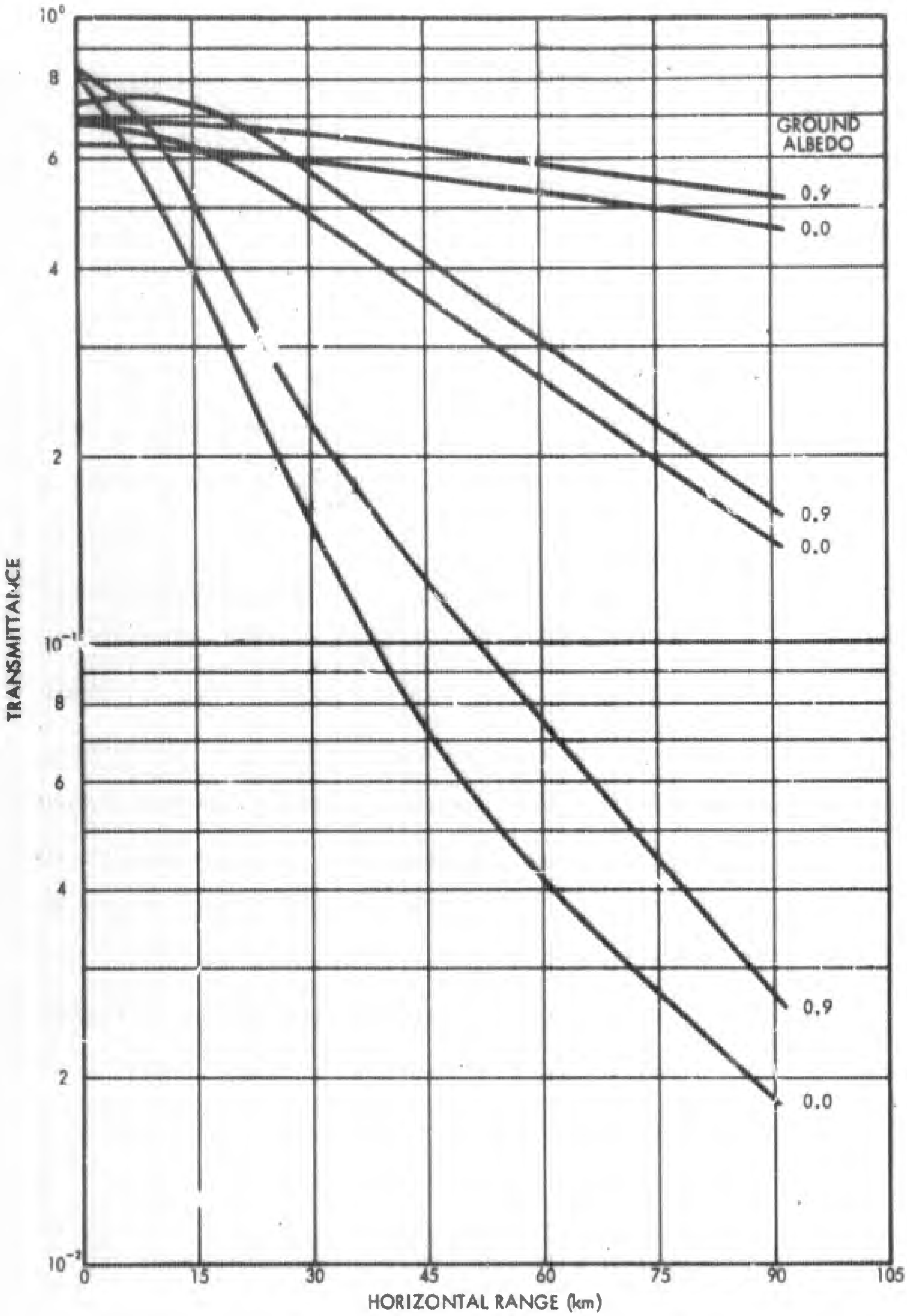

Fig. 3. Transmittance for a Nuclear Weapon Burst in the Afternoon Tropical Atmosphere: Receiver Normal to Source-Receiver Axis

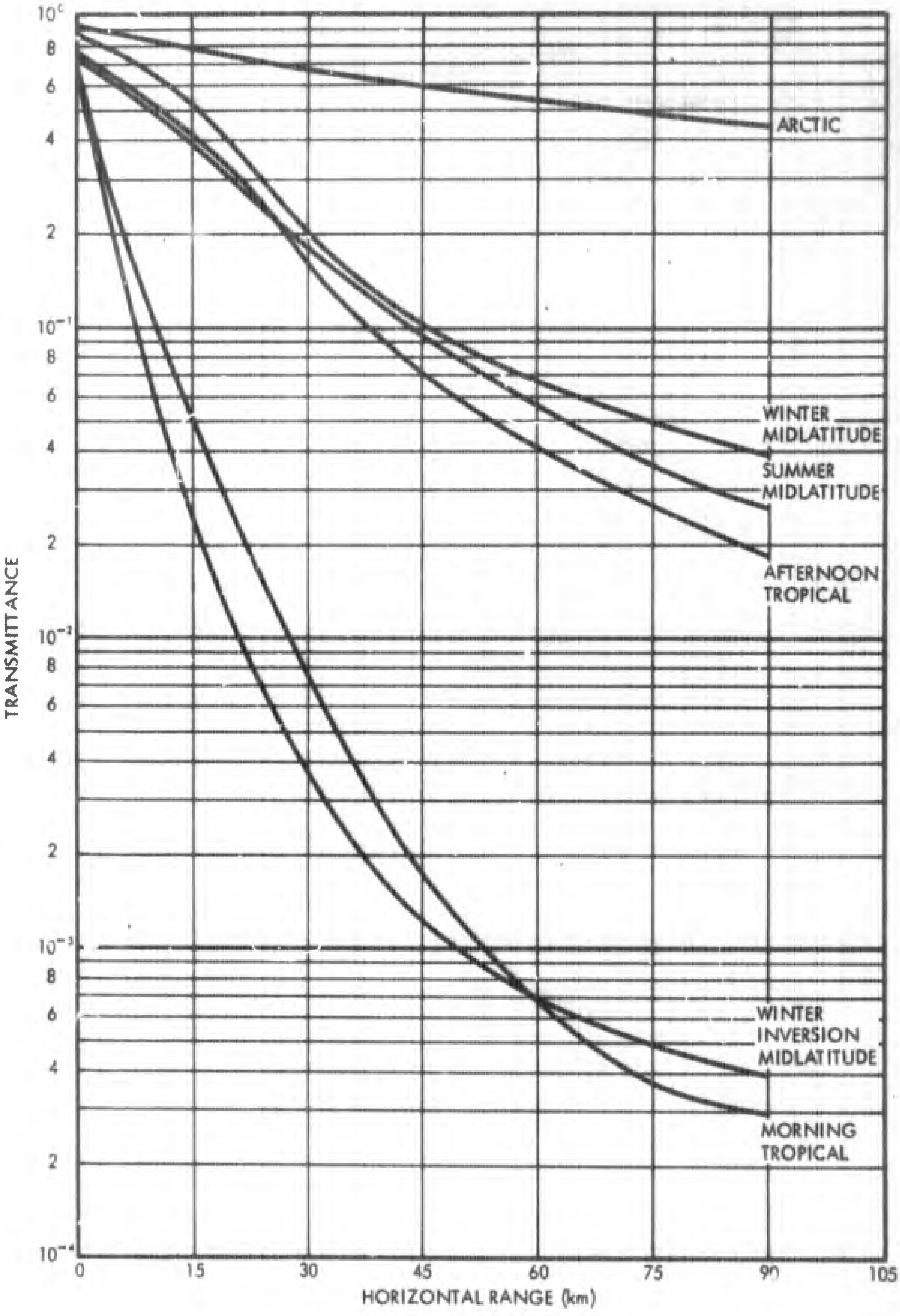

Fig. 4. Transmittance for Representative Air Burst in Model Atmospheres: Burst Altitude = 1 km, Ground Albedo = 0.0, Receiver Normal to Source-Receiver Axis

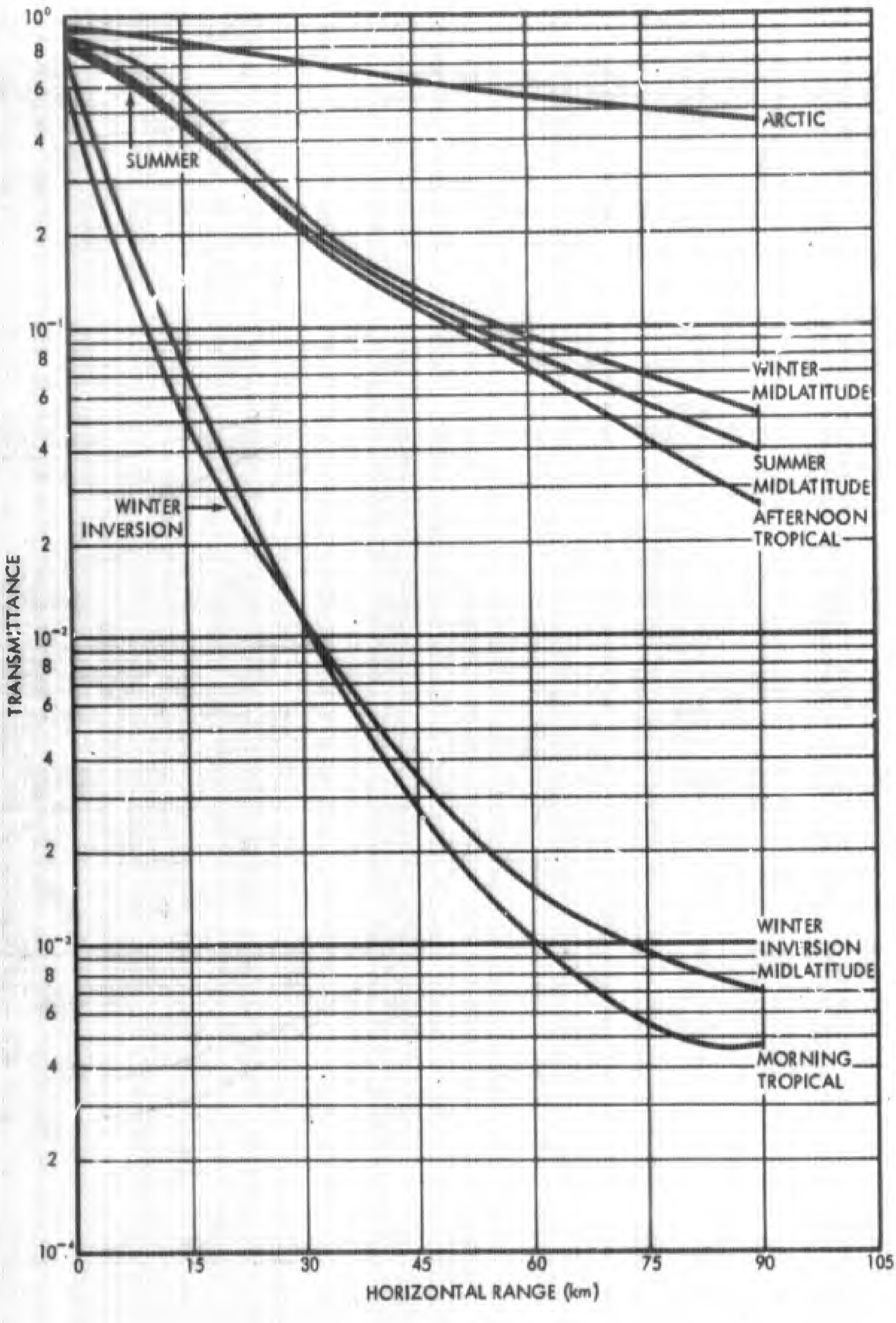

Fig. 5. Transmittance for Representative Air Burst in Model Atmospheres: Burst Altitude = 1 km, Ground Albedo = 0.9, Receiver Normal to Source-Receiver Axis

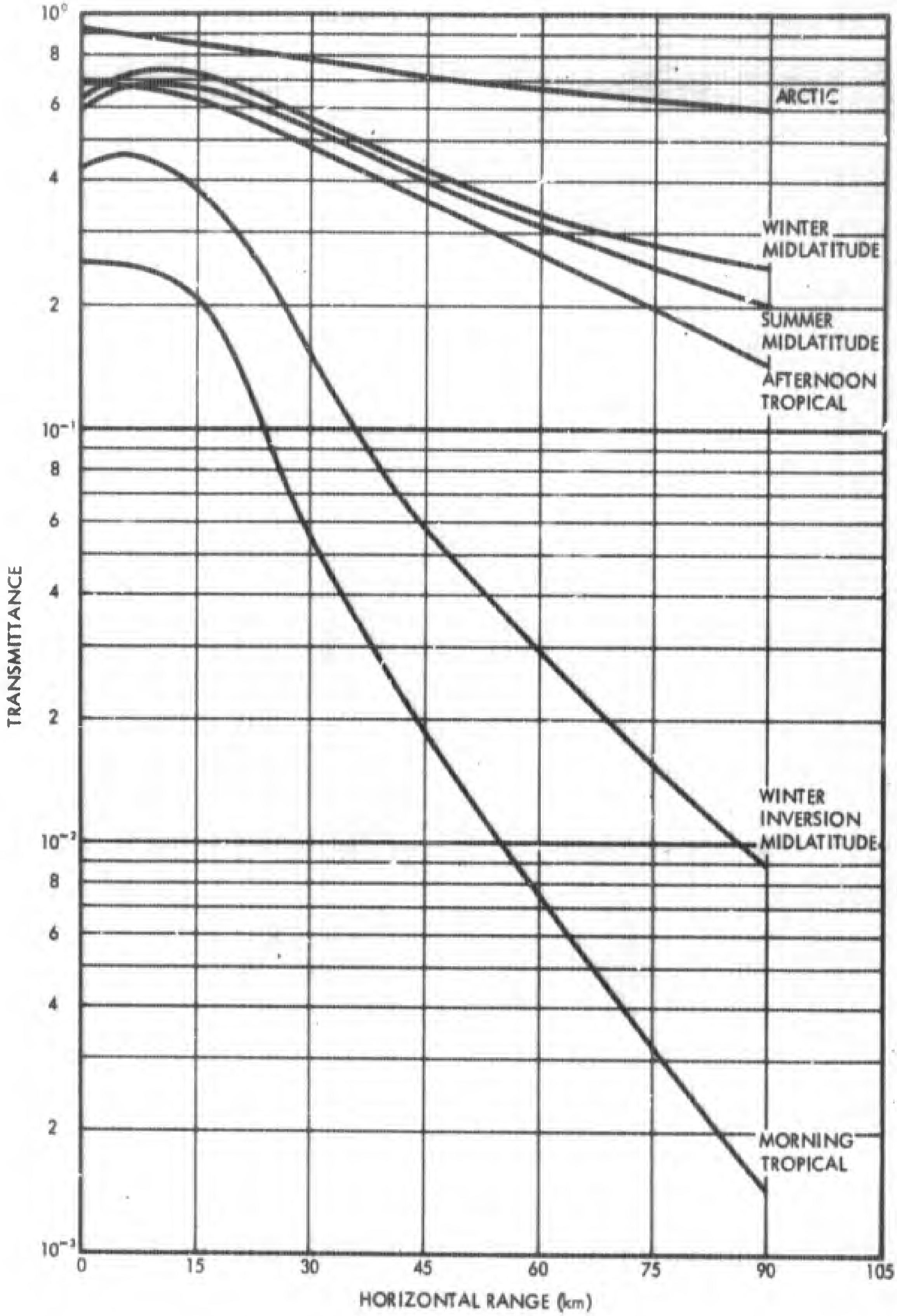

Fig. 6. Transmittance for Representative Air Burst in Model Atmospheres: Burst Altitude = 9 km, Ground Albedo = 0.0, Receiver Normal to Source-Receiver Axis

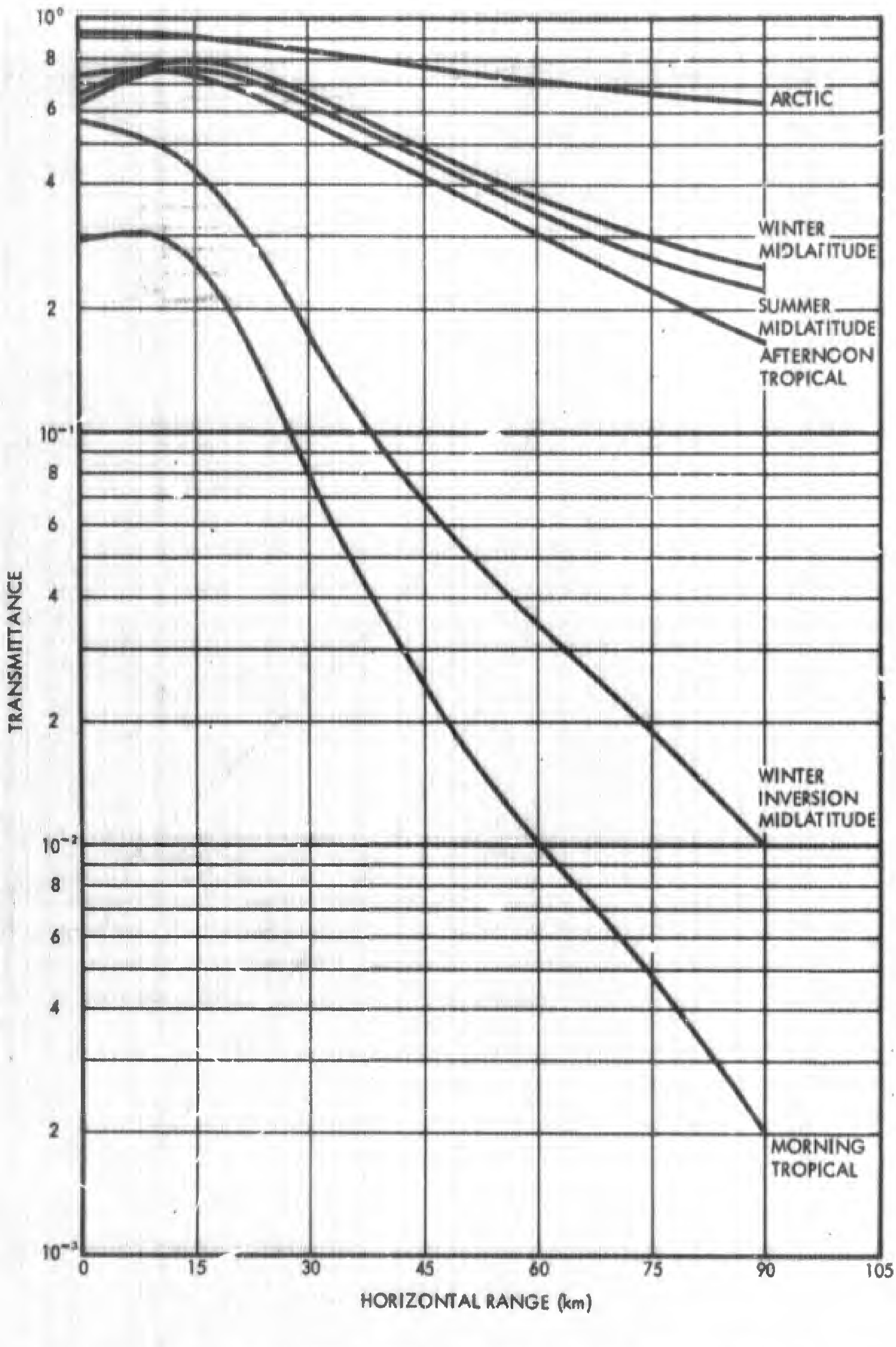

Fig. 7. Transmittance for Representative Air Burst in Model Atmospheres: Burst Altitude = 9 km, Ground Albedo = 0.9, Receiver Normal to Source-Receiver Axis

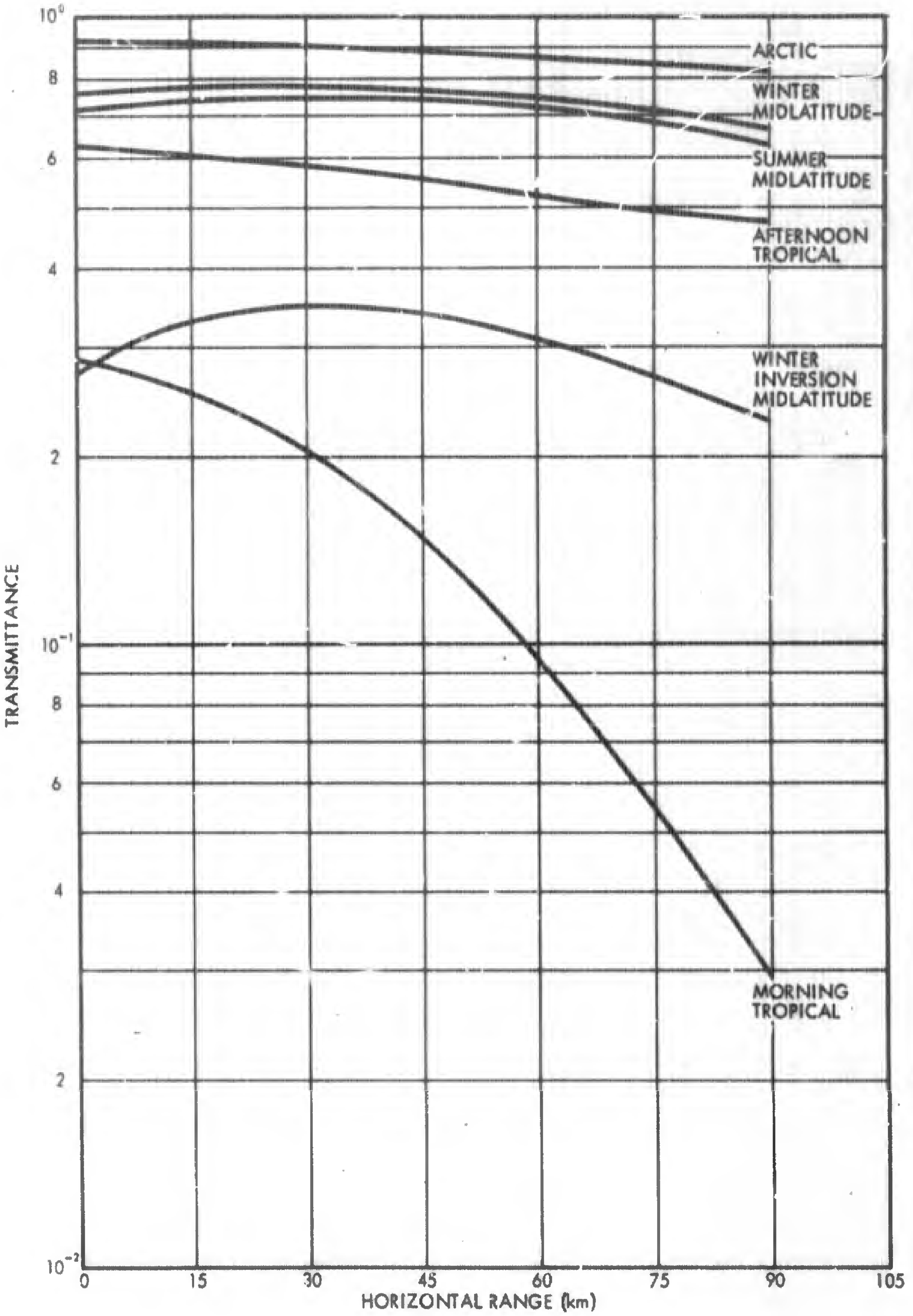

Fig. 8. Transmittance for Representative Air Burst in Model Atmospheres: Burst Altitude = 50 km, Ground Albedo = 0.0, Receiver Normal to Source-Receiver Axis

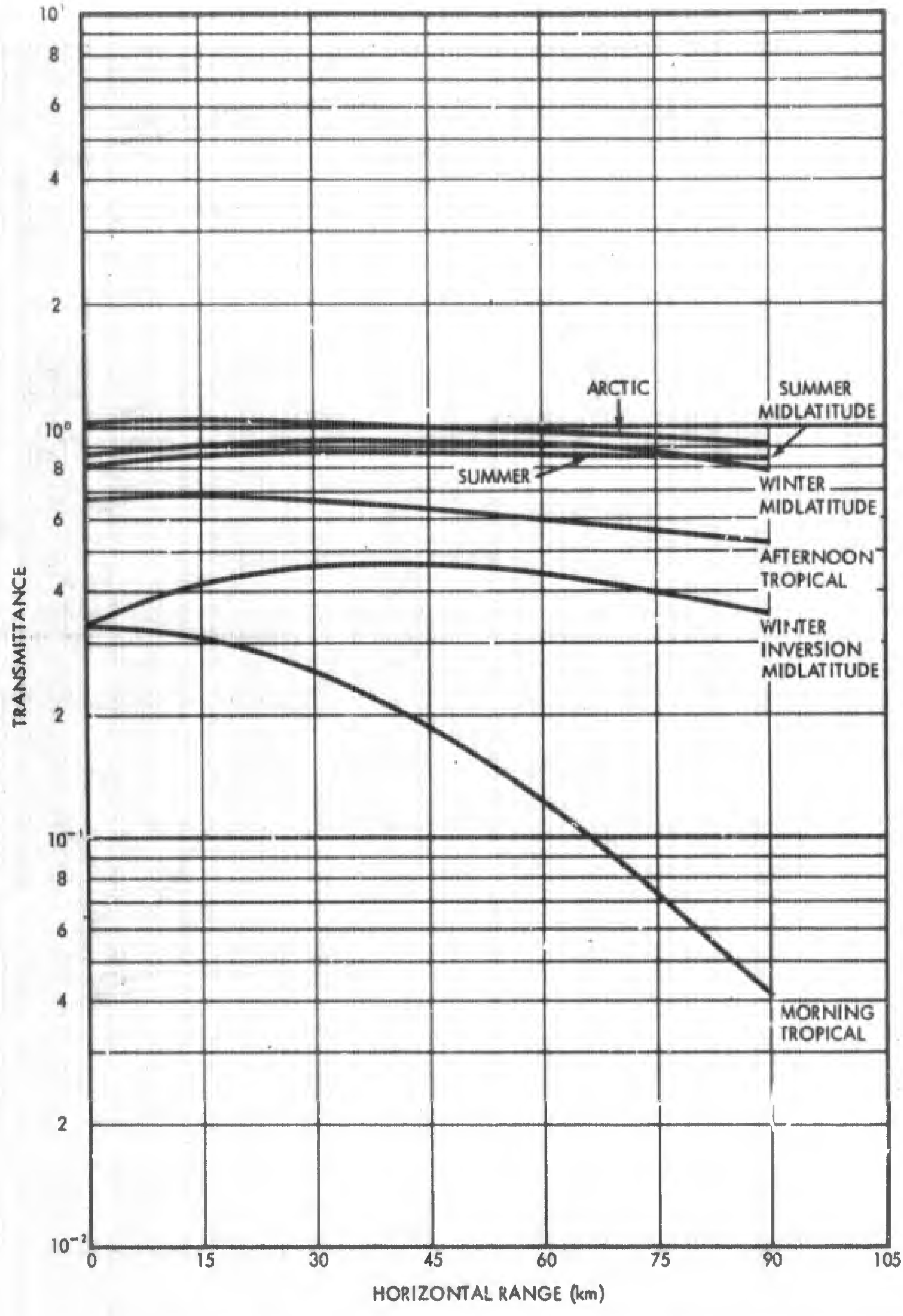

Fig. 9. Transmittance for Representative Air Burst in Model Atmospheres: Burst Altitude = 50 km, Albedo = 0.9, Receiver Normal to Source-Receiver Axis

TABLE XXV. ATMOSPHERIC TRANSMITTANCES FOR NUCLEAR WEAPON THERMAL RADIATION IN MODEL ATMOSPHERES

RECEIVER PARALLEL TO THE GROUND SURFACE

MORNING TROPICAL ATMOSPHERE

HS (KM)	HR (KM)	TRANSMITTANCE DIRECT	SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
1	0	3.232-01	3.755-01	4.315-01	6.987-01	7.547-01
	15	2.635-08	3.527-02	5.636-02	3.527-02	5.636-02
	30	8.296-15	3.192-03	5.586-03	3.192-03	5.586-03
	60	0.000-00	7.383-04	1.149-03	7.383-04	1.149-03
	90	0.000-00	3.517-04	9.047-04	3.517-04	9.047-04
9	0	6.308-02	2.071-01	2.559-01	2.702-01	3.190-01
	15	2.881-03	8.679-02	1.146-01	8.967-02	1.174-01
	30	3.259-05	4.718-02	6.234-02	4.722-02	6.238-02
	60	4.703-09	1.197-02	1.578-02	1.197-02	1.578-02
	90	7.112-12	3.988-03	5.318-03	3.988-03	5.318-03
50	0	4.430-02	2.471-01	4.013-01	2.914-01	4.456-01
	15	3.733-02	2.023-01	2.940-01	2.397-01	3.313-01
	30	2.334-02	1.618-01	2.109-01	1.851-01	2.343-01
	60	5.485-03	7.462-02	9.416-02	8.011-02	9.965-02
	90	9.844-04	2.360-02	3.220-02	2.458-02	3.319-02

AFTERNOON TROPICAL ATMOSPHERE

HS (KM)	HR (KM)	TRANSMITTANCE DIRECT	SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
1	0	7.547-01	6.162-02	7.411-02	8.163-01	8.208-01
	15	1.016-02	4.525-02	8.594-02	5.542-02	9.611-02
	30	1.188-03	2.892-02	6.585-02	3.011-02	6.704-02
	60	4.294-05	1.165-02	2.289-02	1.169-02	2.293-02
	90	2.545-06	8.324-03	1.884-02	8.326-03	1.884-02
9	0	5.764-01	1.334-01	1.723-01	7.099-01	7.488-01
	15	2.138-01	1.173-01	1.627-01	3.312-01	3.766-01
	30	7.375-02	9.247-02	1.322-01	1.662-01	2.059-01
	60	1.524-02	5.465-02	7.229-02	6.990-02	8.753-02
	90	4.370-03	2.990-02	3.645-02	3.427-02	4.082-02
50	0	5.102-01	1.457-01	2.318-01	6.560-01	7.421-01
	15	5.052-01	1.162-01	1.844-01	6.215-01	6.897-01
	30	4.293-01	1.019-01	1.615-01	5.312-01	5.909-01
	60	2.725-01	8.320-02	1.319-01	3.557-01	4.044-01
	90	1.705-01	6.390-02	1.021-01	2.344-01	2.726-01

TABLE XXVI. ATMOSPHERIC TRANSMITTANCES FOR NUCLEAR WEAPON THERMAL RADIATION IN MODEL ATMOSPHERES

RECEIVER NORMAL TO THE GROUND SURFACE

MORNING TROPICAL ATMOSPHERE

HS (KM)	HR (KM)	DIRECT	TRANSMITTANCE SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
1	0	0.000-00	6.737-02	1.402-01	6.737-02	1.402-01
	15	3.975-07	4.846-02	7.112-02	4.846-02	7.112-02
	30	2.501-13	8.039-03	1.166-02	8.039-03	1.1[illegible]6-02
	60	0.000-00	6.858-04	1.053-03	6.858-04	1.053-03
	90	0.000-00	3.001-04	4.847-04	3.001-04	4.847-04
9	0	0.000-00	2.415-02	4.748-02	2.415-02	4.748-02
	15	4.810-03	9.274-02	1.441-01	9.755-02	1.489-01
	30	1.085-04	4.840-02	6.823-02	4.851-02	6.834-02
	60	3.131-08	5.636-03	7.170-03	5.636-03	7.170-03
	90	7.135-11	1.836-03	2.107-03	1.836-03	2.107-03
50	0	0.000-00	3.688-02	9.197-02	3.688-02	9.197-02
	15	1.120-02	5.076-02	1.002-01	6.197-02	1.114-01
	30	1.401-02	6.389-02	1.209-01	7.790-02	1.349-01
	60	6.587-03	6.961-02	1.252-01	7.619-02	1.318-01
	90	1.773-03	5.260-02	8.419-02	5.437-02	8.597-02

AFTERNOON TROPICAL ATMOSPHERE

HS (KM)	HR (KM)	DIRECT	TRANSMITTANCE SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
1	0	0.000-00	8.363-03	1.631-02	8.363-03	1.631-02
	15	1.500-01	2.544-01	3.646-01	4.045-01	5.146-01
	30	3.598-02	1.237-01	1.857-01	1.597-01	2.217-01
	60	2.591-03	4.399-02	7.369-02	4.658-02	7.629-02
	90	2.304-04	1.790-02	2.934-02	1.813-02	2.957-02
9	0	0.000-00	2.479-02	5.941-02	2.479-02	5.941-02
	15	3.565-01	1.485-01	2.459-01	5.050-01	6.024-01
	30	2.459-01	2.227-01	3.075-01	4.686-01	5.535-01
	60	1.017-01	1.526-01	1.864-01	2.544-01	2.882-01
	90	4.371-02	9.093-02	1.033-01	1.346-01	1.470-01
50	0	0.000-00	6.446-02	1.859-01	6.446-02	1.859-01
	15	1.516-01	7.406-02	1.818-01	2.256-01	3.334-01
	30	2.576-01	9.352-02	2.037-01	3.511-01	4.614-01
	60	3.271-01	1.512-01	2.789-01	4.783-01	6.060-01
	90	3.070-01	1.913-01	2.942-01	4.983-01	6.013-01

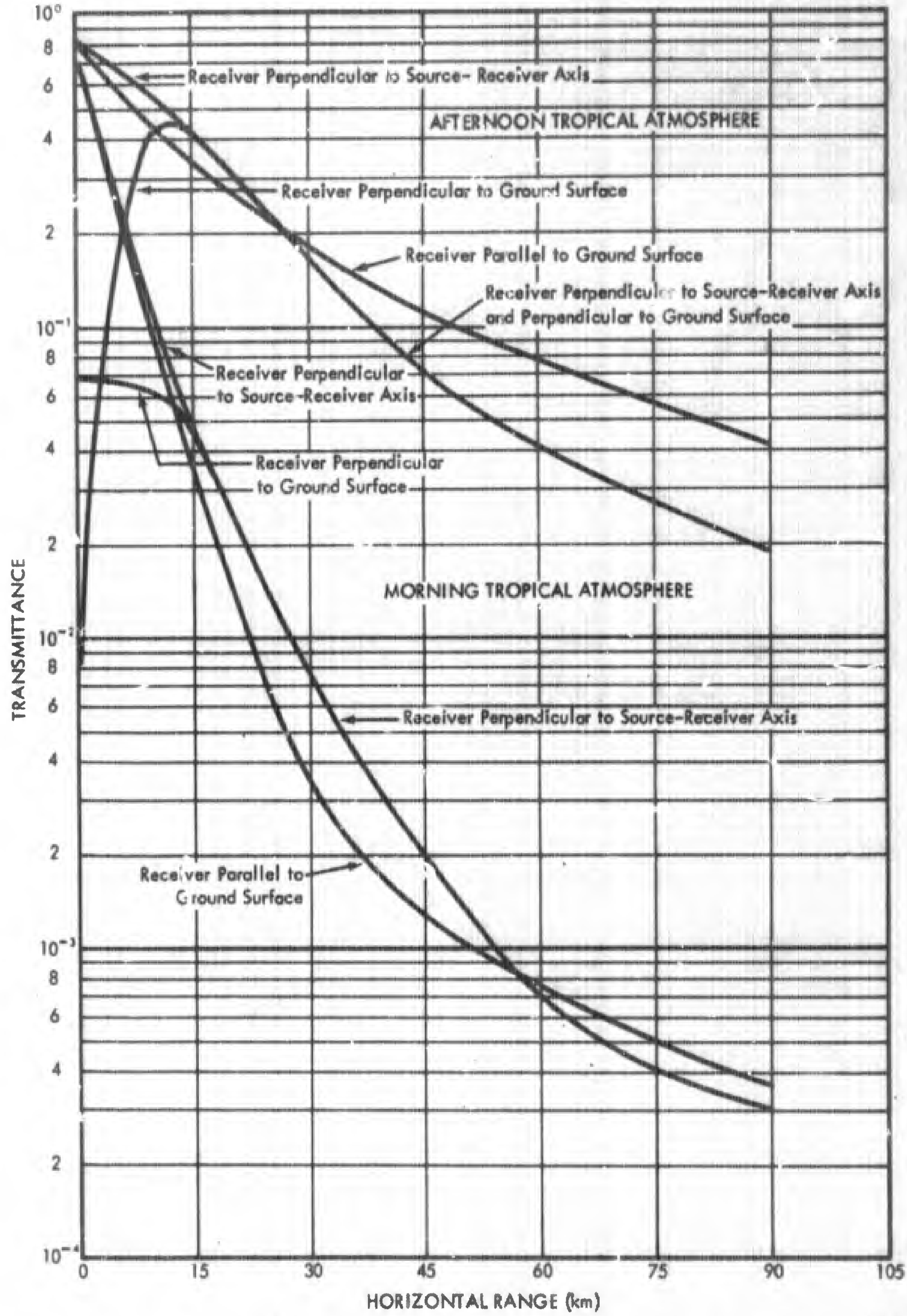

Fig. 10. Comparison of the Transmittances for Receivers Oriented Perpendicular to the Source-Receiver Axis, Parallel to the Ground Surface, and Perpendicular to the Ground Surface for a Nuclear Weapon Burst at 1 km Altitude in the Morning and Afternoon Tropical Atmospheres: Ground Albedo = 0.0

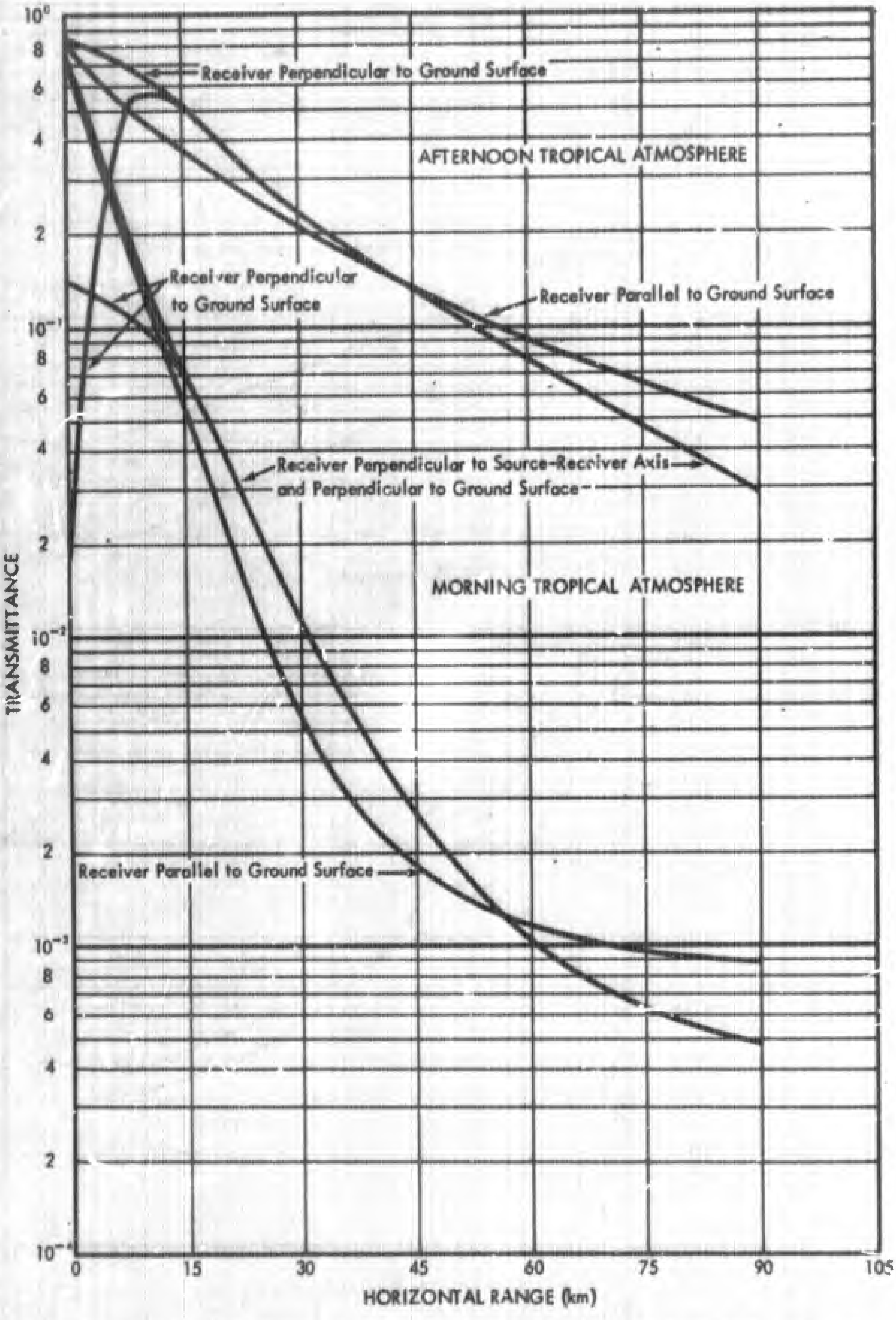

Fig. 11. Comparison of the Transmittances for Receivers Oriented Perpendicular to the Source-Receiver Axis, Parallel to the Ground Surface, and Perpendicular to the Ground Surface for a Nuclear Weapon Burst at 1 km Altitude in the Morning and Afternoon Tropical Atmospheres: Ground Albedo = 0.9

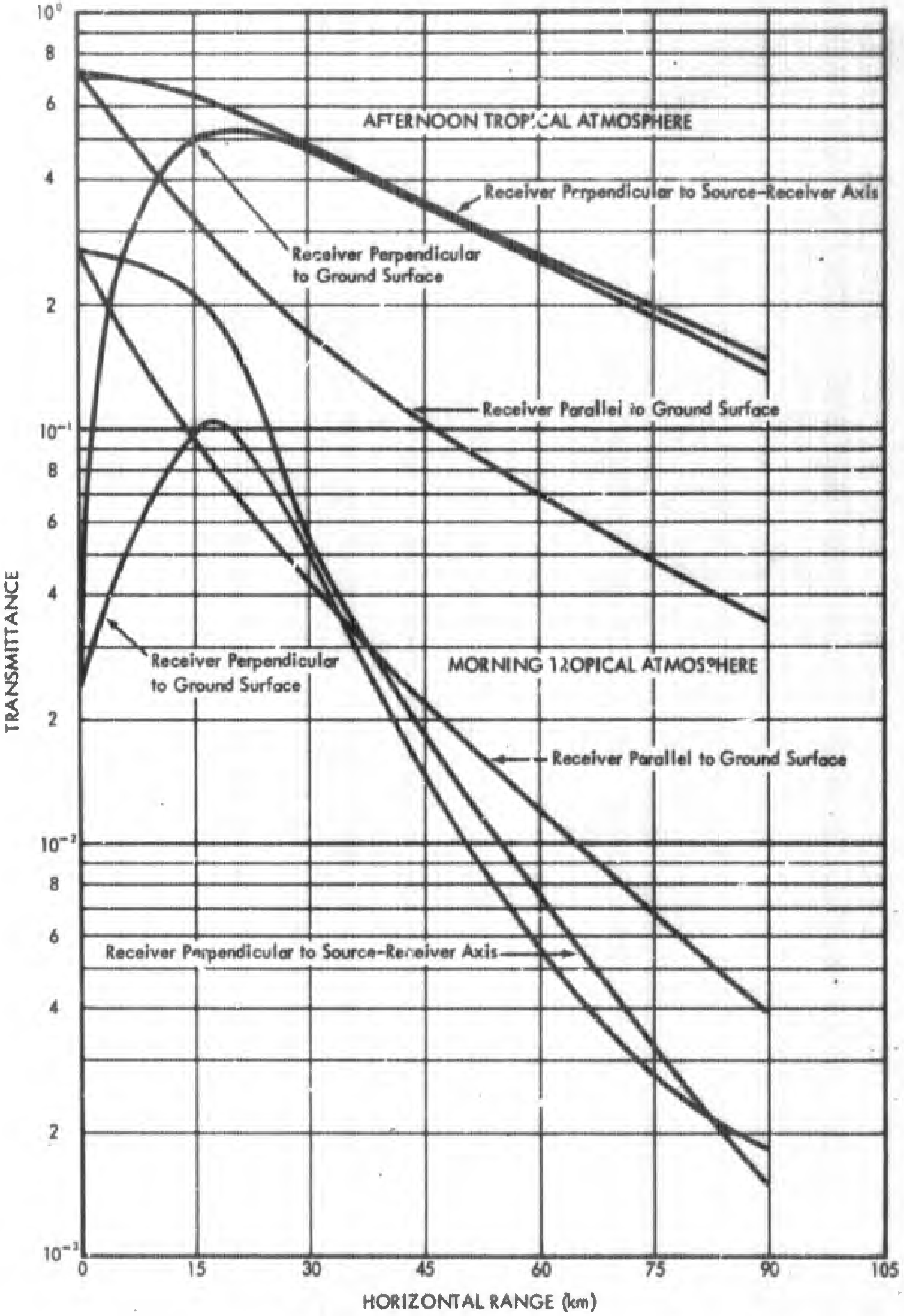

Fig. 12. Comparison of the Transmittances for Receivers Oriented Perpendicular to the Source-Receiver Axis, Parallel to the Ground Surface, and Perpendicular to the Ground Surface for a Nuclear Weapon Burst at 9 km Altitude in the Morning and Afternoon Tropical Atmospheres: Ground Albedo = 0.0

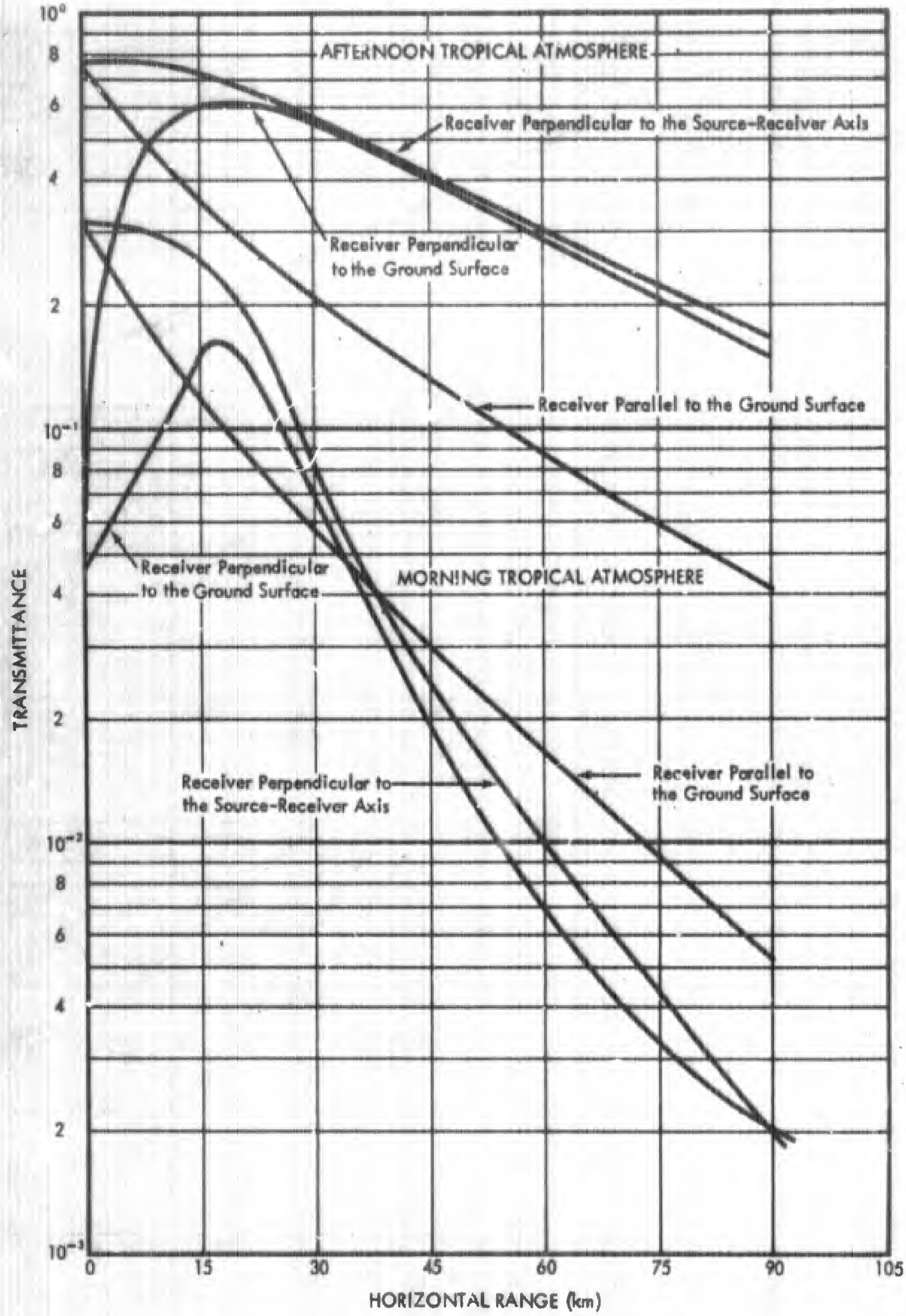

Fig. 13. Comparison of the Transmittances for Receivers Oriented Perpendicular to the Source-Receiver Axis, Parallel to the Ground Surface and Perpendicu!-· to the Ground Surface for a Nuclear Weapon Burst at 9 km Altitude in the Morning and Afternoon Trop!cal Atmospheres: Ground Albedo = 0.9

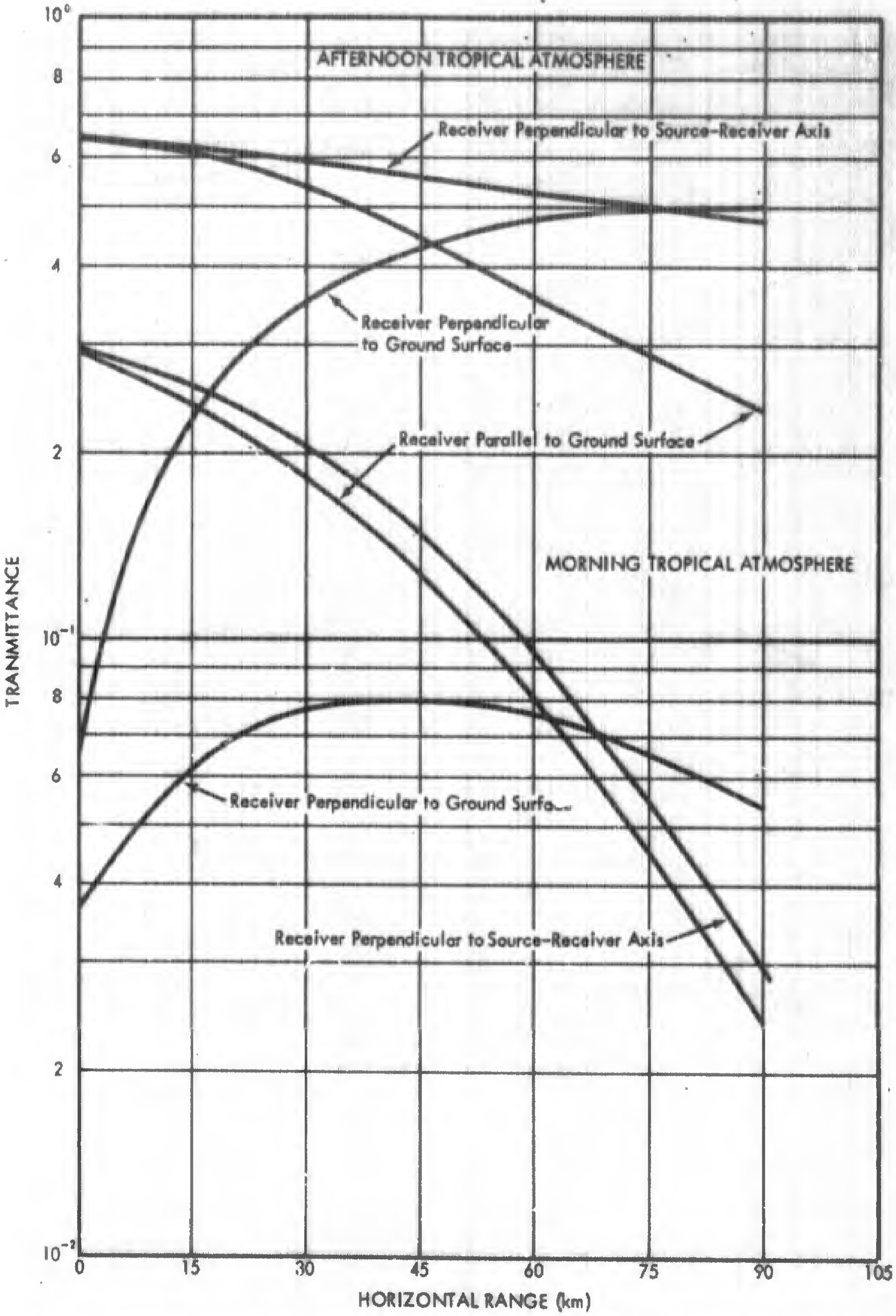

Fig. 14. Comparison of the Transmittances for Receivers Oriented Perpendicular to the Source-Receiver Axis, Parallel to the Ground Surface, and Perpendicular to the Ground Surface for a Nuclear Weapon Burst at 50 km Altitude in the Morning and Afternoon Tropical Atmospheres: Ground Albedo = 0.0

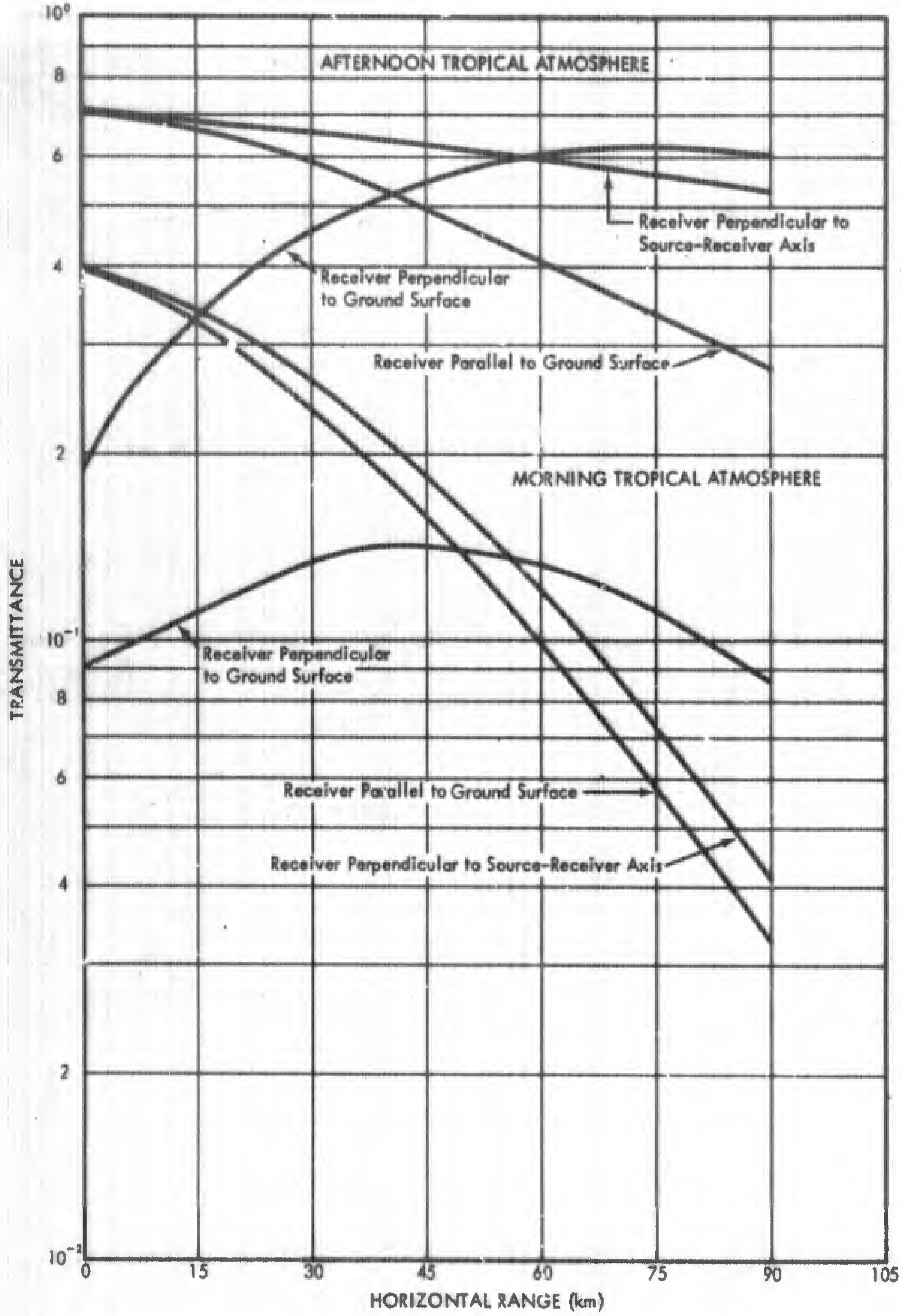

Fig. 15. Comparison of the Transmittances for Receivers Oriented Perpendicular to the Source-Receiver Axis, Parallel to the Ground Surface, and Perpendicular to the Ground Surface for a Nuclear Weapon Burst at 50 km Altitude in the Morning and Afternoon Tropical Atmospheres: Ground Albedo = 0.9

burst altitude increases, the horizontal range at which the transmittance for a receiver oriented normal to the ground surface approaches that for a receiver oriented normal to the source receiver axis increases. In general the transmittance is the greatest for a horizontal receiver only when the direct radiation is negligible and most of the transmittance is due to scattered radiation. The importance of the scattered transmittance with respect to the direct transmittance increases with horizontal range and the ground level meteorological range. It decreases with an increase in the source altitude.

The direct, scattered, and total transmittances as a function of horizontal range in the morning and afternoon tropical atmospheres for the case where a nuclear detonation occurs at an altitude of 1 km are tabulated in Tables XXVII and XXVIII, respectively, for ground albedo values of 0.0 and 0.9 and for receivers facing the source and oriented normal to the source-receiver axis, parallel to the ground surface, and perpendicular to the ground surface. The data for receivers oriented perpendicular to the ground at horizontal ranges of 15 km and greater are the same as those tabulated for receivers oriented normal to the source-receiver axis. Because of this fact, only data for a horizontal range of 0 km are tabulated for the case where the receiver is perpendicular to the ground surface.

The effect of a cloud cover on the transmittance for a nuclear weapon burst at 1 km altitude in the morning and afternoon tropical atmospheres is seen in Figs. 16 through 19 for a receiver facing the source and oriented normal to the source-receiver axis to be dependent on the altitude of the bottom of the cloud. It is seen in Figs. 16 and 17 that directly under the source and out to horizontal ranges of approximately 15 to 20 km in the morning tropical atmosphere containing a cloud layer the transmittance for a nuclear weapon burst is larger than that computed for the morning tropical atmosphere with no clouds. This results from the reflection by the bottom of the cloud. At horizontal ranges greater than 15 to 20 km the transmittance in the morning tropical atmosphere without a cloud layer exceeds that computed for the case where the cloud bottom was at either 1.5 or 3.5 km. This results from the fact that photons can travel larger distances between collisions in an atmosphere not containing clouds, whereas the cloud layer reflects these photons and keeps them from moving out to larger horizontal ranges.

In Figs. 18 and 19 it is seen that the transmittance for a nuclear weapon burst at 1 km altitude in the afternoon tropical atmosphere is the greatest directly under the source when the cloud bottom altitude is 1.5 km. At intermediate ranges, the transmittance in the afternoon tropical atmosphere is the greatest when the cloud bottom is at 3.5 km altitude. At larger horizontal ranges the transmittance in the afternoon tropical atmosphere with no cloud cover is greater than that with clouds at 1.5 and 3.5 km altitude.

From Figs. 16 through 19 it is seen that the magnitude of the transmittance for a nuclear weapon burst at 1 km altitude in the atmosphere is highly dependent on the ground albedo. An increase in the

(Text continued on page 74.)

TABLE XXVII. ATMOSPHERIC TRANSMITTANCE FOR A NUCLEAR WEAPON BURST AT 1.00 KM. ALTITUDE IN THE MORNING TROPICAL ATMOSPHERE WITH A CLOUD LAYER

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

CLOUD BOTTOM AT 1.50 KM.

HR (KM)	TRANSMITTANCE DIRECT	SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
0	3.232-01	5.073-01	6.211-01	8.305-01	9.444-01
15	3.987-07	4.166-02	5.778-02	4.166-02	5.778-02
30	2.505-13	1.345-05	1.447-05	1.345-05	1.447-05

CLOUD BOTTOM AT 3.50 KM.

HR (KM)	DIRECT	SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
0	3.232-01	5.601-01	6.872-01	8.834-01	1.010+00
15	3.987-07	7.205-02	1.271-01	7.205-02	1.271-01
30	2.505-13	2.568-03	3.118-03	2.568-03	3.118-03

RECEIVER PARALLEL TO GROUND SURFACE

CLOUD BOTTOM AT 1.50 KM.

HR (KM)	DIRECT	SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
0	3.232-01	5.073-01	6.211-01	8.305-01	9.444-01
15	2.635-08	1.432-02	2.805-02	1.432-02	2.805-02
30	8.295-15	1.345-05	1.455-05	1.345-05	1.455-05

CLOUD BOTTOM AT 3.50 KM.

HR (KM)	DIRECT	SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
0	3.232-01	5.601-01	6.872-01	8.834-01	1.010+00
15	2.637-08	6.339-02	1.333-01	6.339-02	1.333-01
30	8.295-15	9.925-04	2.334-03	9.925-04	2.334-03

RECEIVER PERPENDICULAR TO GROUND SURFACE

CLOUD BOTTOM AT 1.50 KM.

HR (KM)	DIRECT	SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
0	0.000+00	3.595-02	1.439-01	3.595-02	1.439-01

CLOUD BOTTOM AT 3.50 KM.

HR (KM)	DIRECT	SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
0	0.000+00	4.877-02	9.314-02	4.877-02	9.314-02

TABLE XXVIII. ATMOSPHERIC TRANSMITTANCE FOR A NUCLEAR WEAPON BURST AT 1.00 KM. ALTITUDE IN THE AFTERNOON TROPICAL ATMOSPHERE WITH A CLOUD LAYER

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

CLOUD BOTTOM AT 1.50 KM.

TRANSMITTANCE

HR (KM)	DIRECT	SCATTERED A=0.0	SCATTERED A=0.9	TOTAL A=0.0	TOTAL A=0.9
0	7.547-01	4.716-01	7.232-01	1.226+00	1.478+00
15	1.537-01	2.150-01	1.112+00	3.688-01	1.266+00
30	3.600-02	8.052-02	3.072-01	1.165-01	3.432-01
60	2.593-03	8.988-03	2.599-02	1.158-02	2.858-02
90	2.305-04	1.326-03	2.626-02	1.556-03	2.856-03
	CLOUD BOTTOM AT 3.50 KM.				
0	7.547-01	9.501-02	1.520-01	8.497-01	9.067-01
15	1.537-01	5.477-01	1.712+00	7.014-01	1.866+00
30	3.600-02	2.253-01	7.288-01	2.613-01	7.648-01
60	2.593-03	1.902-02	1.273-01	2.162-02	1.299-01
90	2.305-04	1.609-03	1.190-02	1.839-03	1.214-02
	RECEIVER PARALLEL TO GROUND SURFACE				
	CLOUD BOTTOM AT 1.50 KM.				
0	7.547-01	4.716-01	7.232-01	1.226+00	1.478+00
15	1.016-02	5.531-02	6.947-01	6.648-01	7.048-01
30	1.188-03	1.518-02	8.406-02	1.637-02	8.525-02
60	4.294-05	6.274-04	2.692-03	6.704-04	2.735-03
90	2.545-06	4.886-05	1.775-04	5.140-05	1.801-04
	CLOUD BOTTOM AT 3.50 KM.				
0	7.547-01	9.501-02	1.520-01	8.497-01	9.069-01
15	1.016-02	1.867-01	1.059+00	1.969-01	1.069+00
30	1.188-03	5.653-02	3.646-01	5.772-02	3.658-01
60	4.294-05	3.008-03	2.442-02	3.051-03	2.446-02
90	2.545-06	2.708-04	1.758-03	2.733-04	1.761-03
	RECEIVER PERPENDICULAR TO GROUND SURFACE				
	CLOUD BOTTOM AT 1.50 KM.				
0	0.000+00	4.254-02	2.270-01	4.254-02	2.270-01
	CLOUD BOTTOM AT 3.50 KM.				
0	0.000+00	1.245-02	1.737-01	1.245-02	1.737-01

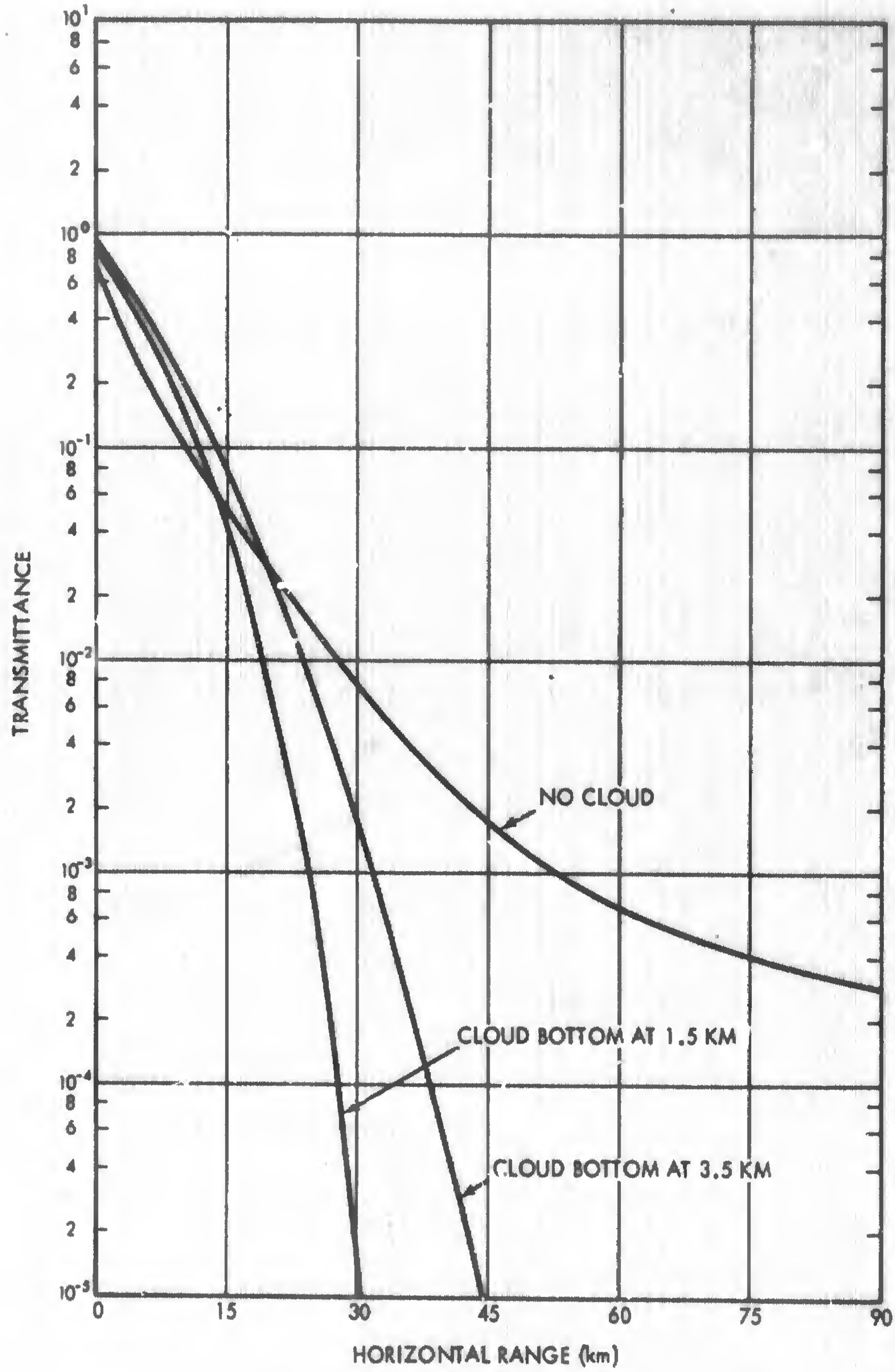

Fig. 16. Variation of the Transmittance for a Nuclear Weapon Burst at 1 km Altitude in the Morning Tropical Atmosphere with Horizontal Range for Cloud Bottom Altitudes of 1.5 and 3.5 km: Receiver Normal to Source-Receiver Axis, Ground Albedo = 0.0

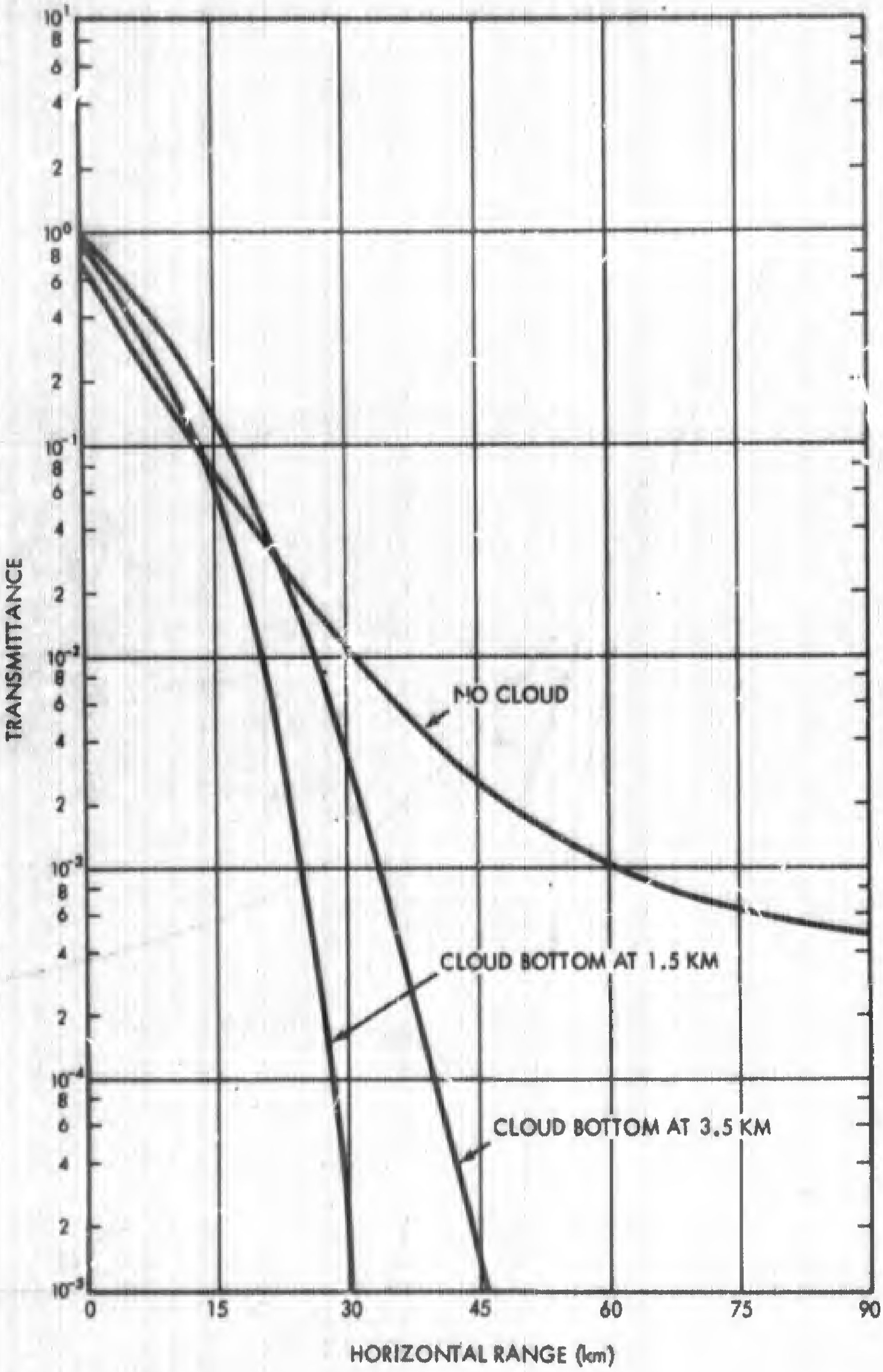

Fig. 17. Variation of the Transmittance for a Nuclear Weapon Burst at 1 km Altitude in the Morning Tropical Atmosphere with Horizontal Range for Cloud Bottom Altitudes of 1.5 and 3.5 km: Receiver Normal to Source-Receiver Axis, Ground Albedo = 0.9

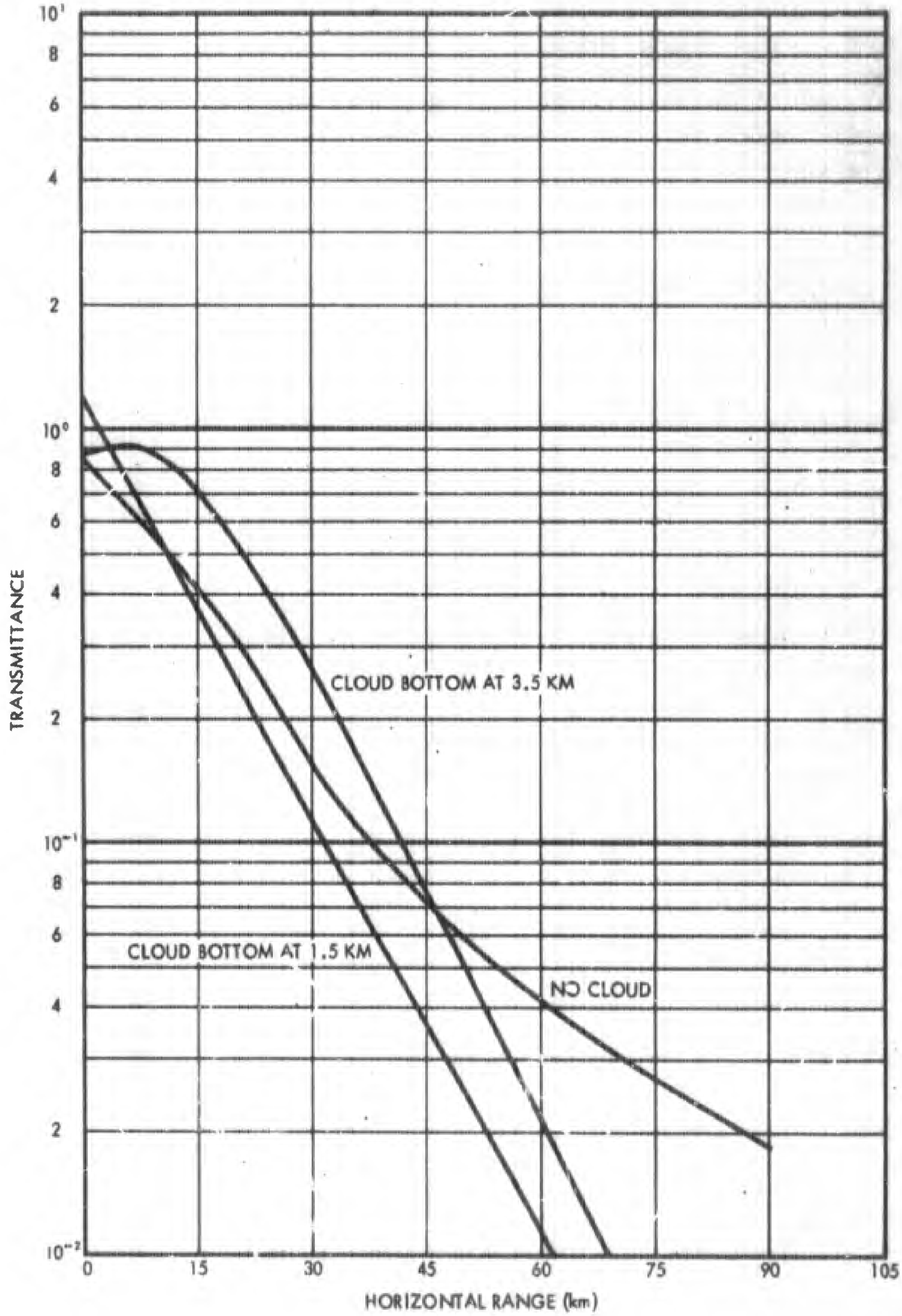

Fig. 18. Variation of the Transmittance for a Nuclear Weapon Burst at 1 km Altitude in the Afternoon Tropical Atmosphere with Horizontal Range for Cloud Bottom Altitudes of 1.5 and 3.5 km: Receiver Normal to Source-Receiver Axis, Ground Albedo = 0.0

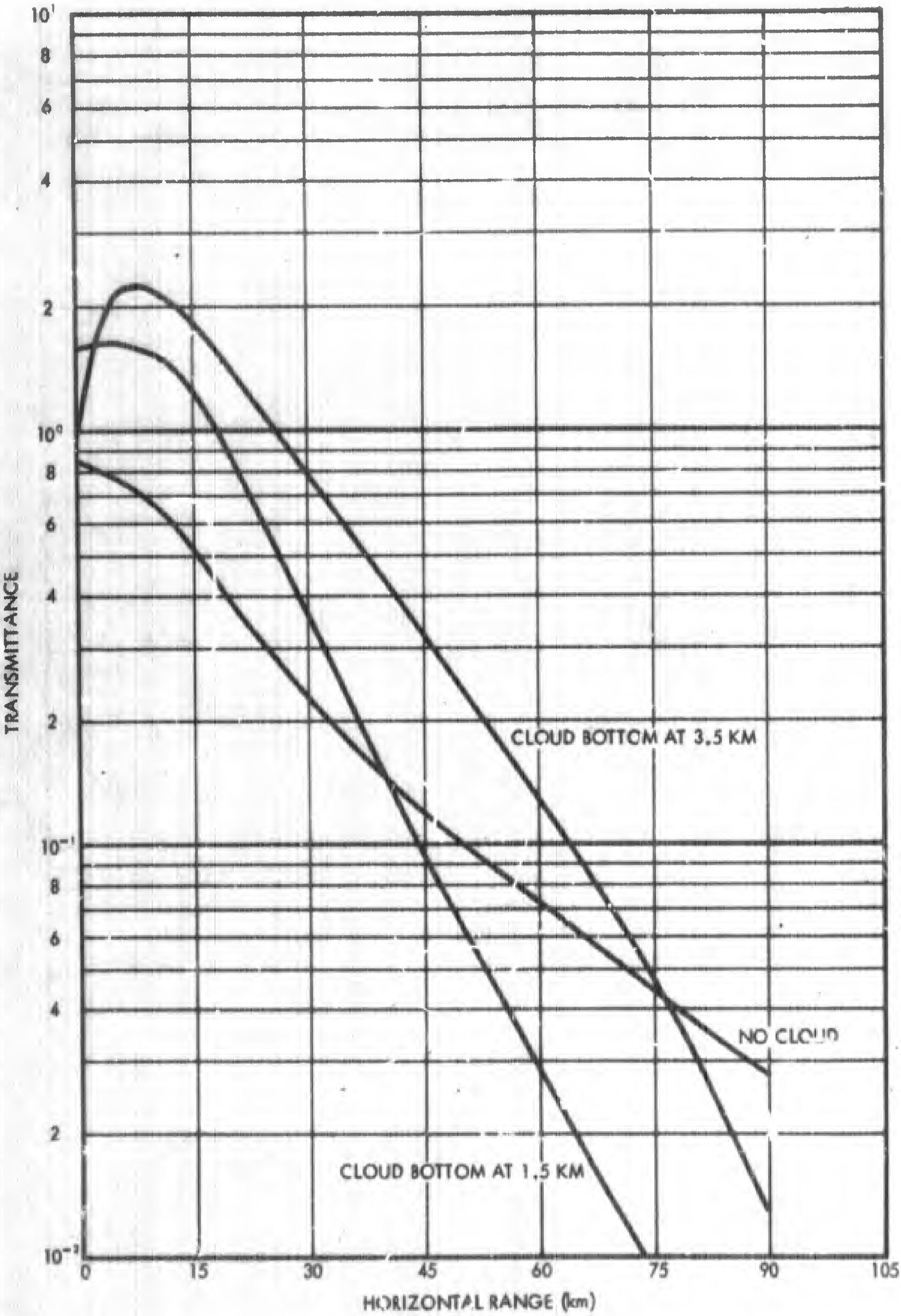

Fig. 19. Variation of the Transmittance for a Nuclear Weapon Burst at 1 km Altitude in the Afternoon Tropical Atmosphere with Horizontal Range for Cloud Bottom Altitudes of 1.5 and 3.5 km: Receiver Normal to Source-Receiver Axis, Ground Albedo = 0.9

ground albedo from 0.0 to 0.9 results in a much larger increase in the transmittance for the case where the atmosphere contains a cloud layer with its base at either 1.5 and 3.5 km than that observed for an atmosphere without a cloud layer.

The dependence of the transmittance for a nuclear weapon burst on burst altitude is illustrated in Figs. 20 through 25 for receivers facing the source and oriented normal to the source-receiver axis at horizontal ranges of 0, 15, 30, 60 and 90 km in each of the six model atmospheres. Transmittances are given in these figures for cases where the ground albedo is either 0.0 or 0.9 for all wavelengths. Except for the 0 km horizontal range, the transmittance increases with an increase in the burst altitude. It must be noted that the curves shown in Figs. 20 through 25 are drawn through only three points, and as a result, the shape of the transmittance curves at burst altitudes above 10 km are questionable.

The importance of the scattered radiation contribution to the total transmittance is shown in Table XXIX. This table lists the ratio of the total transmittance to the direct transmittance for receivers facing the source and oriented normal to the source receiver axis. It is noted for the morning tropical and winter inversion atmospheres that the scattered radiation makes up a significant portion of the total transmittance at all burst altitudes. Fig. 26 shows the variation of the total-to-direct transmittance with horizontal range for burst altitudes of 1, 9, and 50 km and ground albedos of 0.0 and 0.9

for the afternoon tropical atmosphere. It is seen that the importance of scattered radiation increases with horizontal range. The ratio of the total-to-direct transmittance for a nuclear weapon burst in the summer and winter midlatitude atmospheres do not differ appreciably as a function of horizontal range for burst altitudes of 9 and 50 km. For the 1 km burst altitude in the summer and winter midlatitude atmospheres, the ratio of the total-to-direct transmittance increases slightly faster with horizontal range in the winter midlatitude atmosphere than it does in the summer midlatitude atmosphere.

The ratio of the total-to-direct transmittance in the arctic atmosphere listed in Table XXIX indicates that scattered radiation does not contribute significantly to the total transmittance for a nuclear burst in the arctic atmosphere.

The transmittance for an atmosphere with a ground surface albedo that varies with wavelength would fall between the values tabulated in this report for ground albedo values of 0.0 and 0.9. Although it is possible to compute transmittances from use of the LITE-III data for cases where the ground albedo varies with wavelength, it is believed that the reader can, with a reasonable degree of accuracy, estimate transmittances for those cases from a knowledge of the transmittances when the albedo is either 0.0 or 0.9 for all wavelengths.

(Text continues on page 85.)

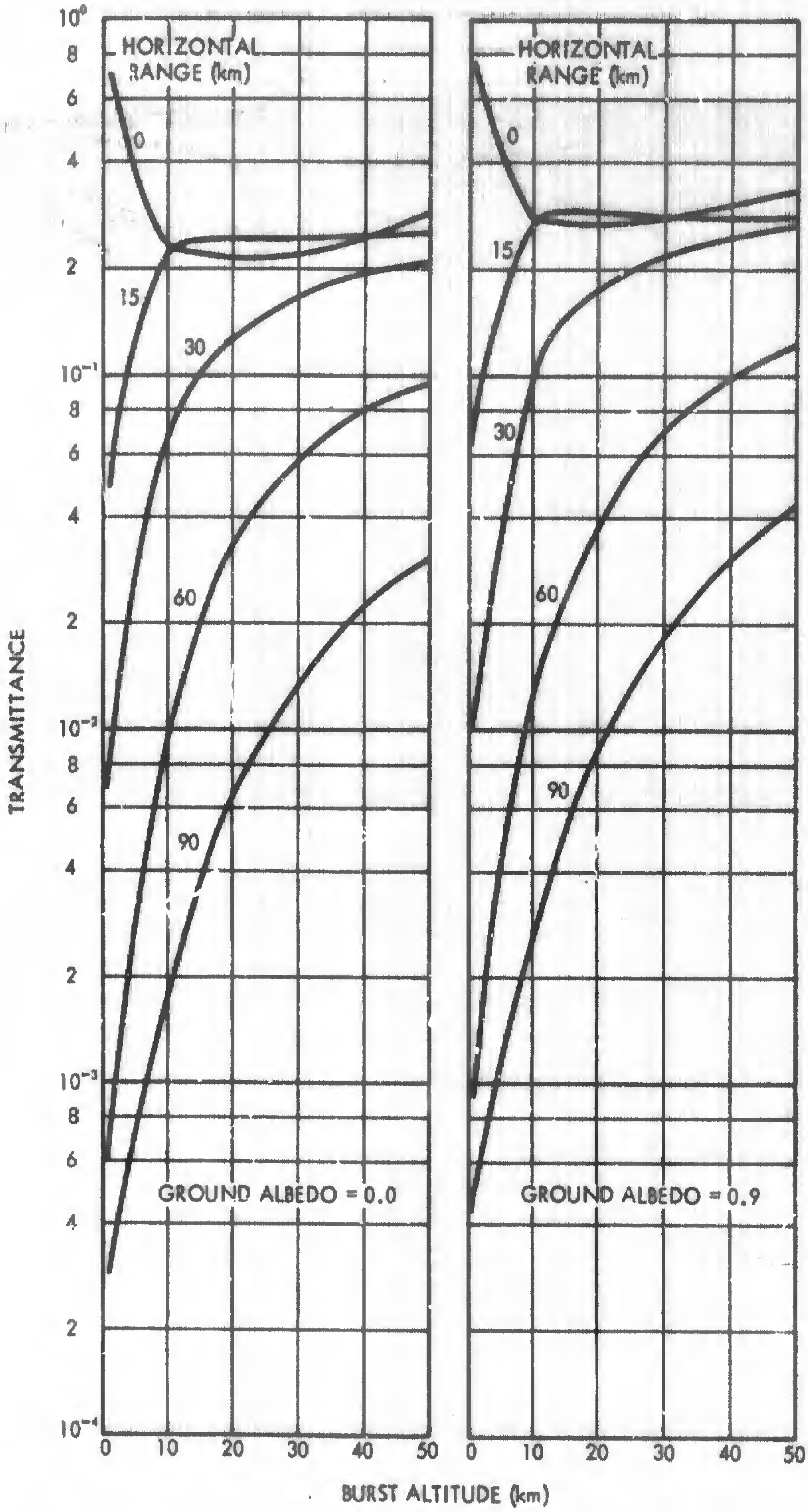

Fig. 20. Variation of the Transmittance for a Nuclear Weapon Burst in the Morning Tropical Atmosphere with Burst Altitude: Receiver Normal to Source-Receiver Axis

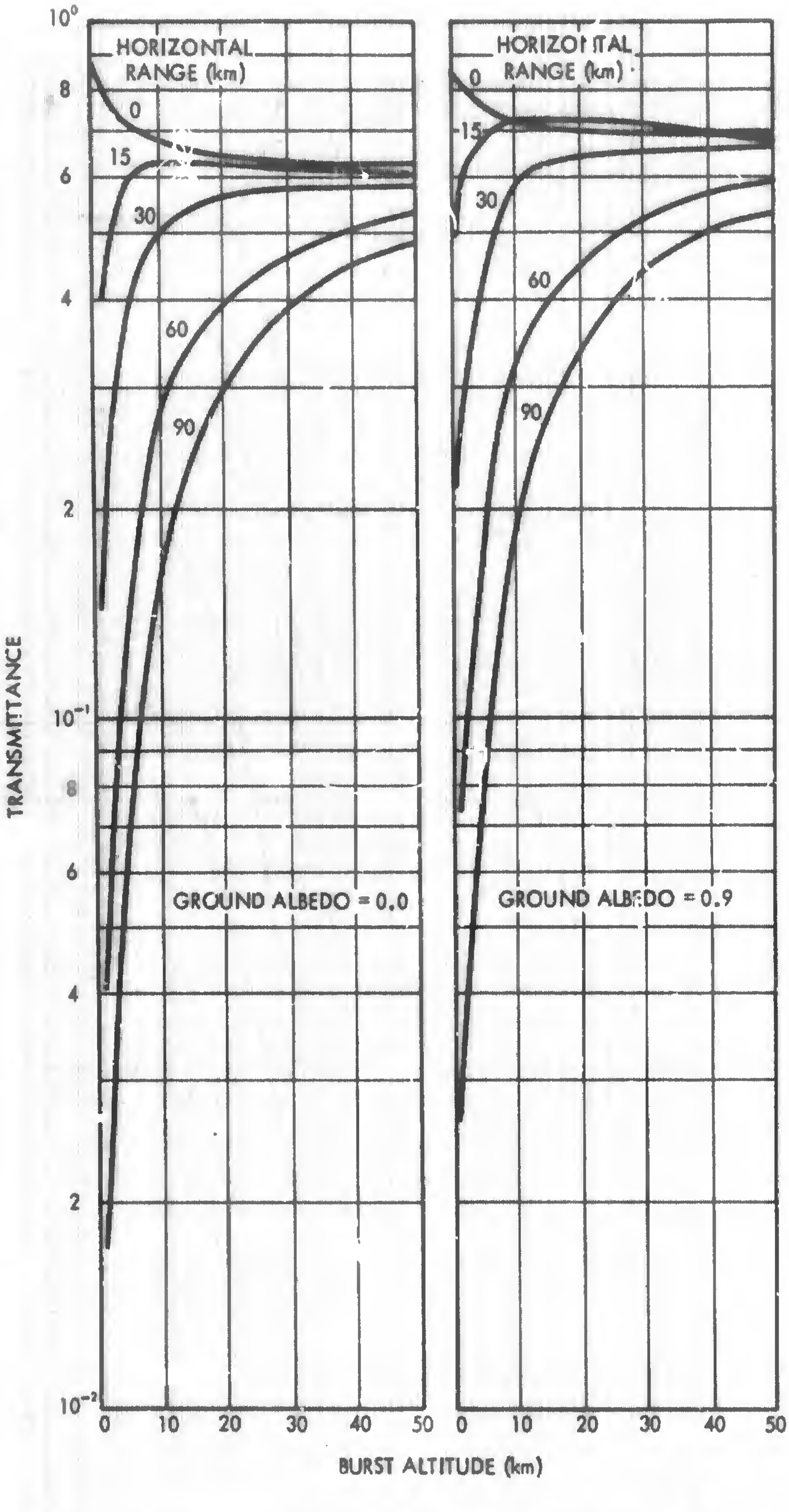

Fig. 21. Variation of the Transmittance for a Nuclear Weapon Burst in the Afternoon Tropical Atmosphere with Burst Altitude: Receiver Normal to Source-Receiver Axis

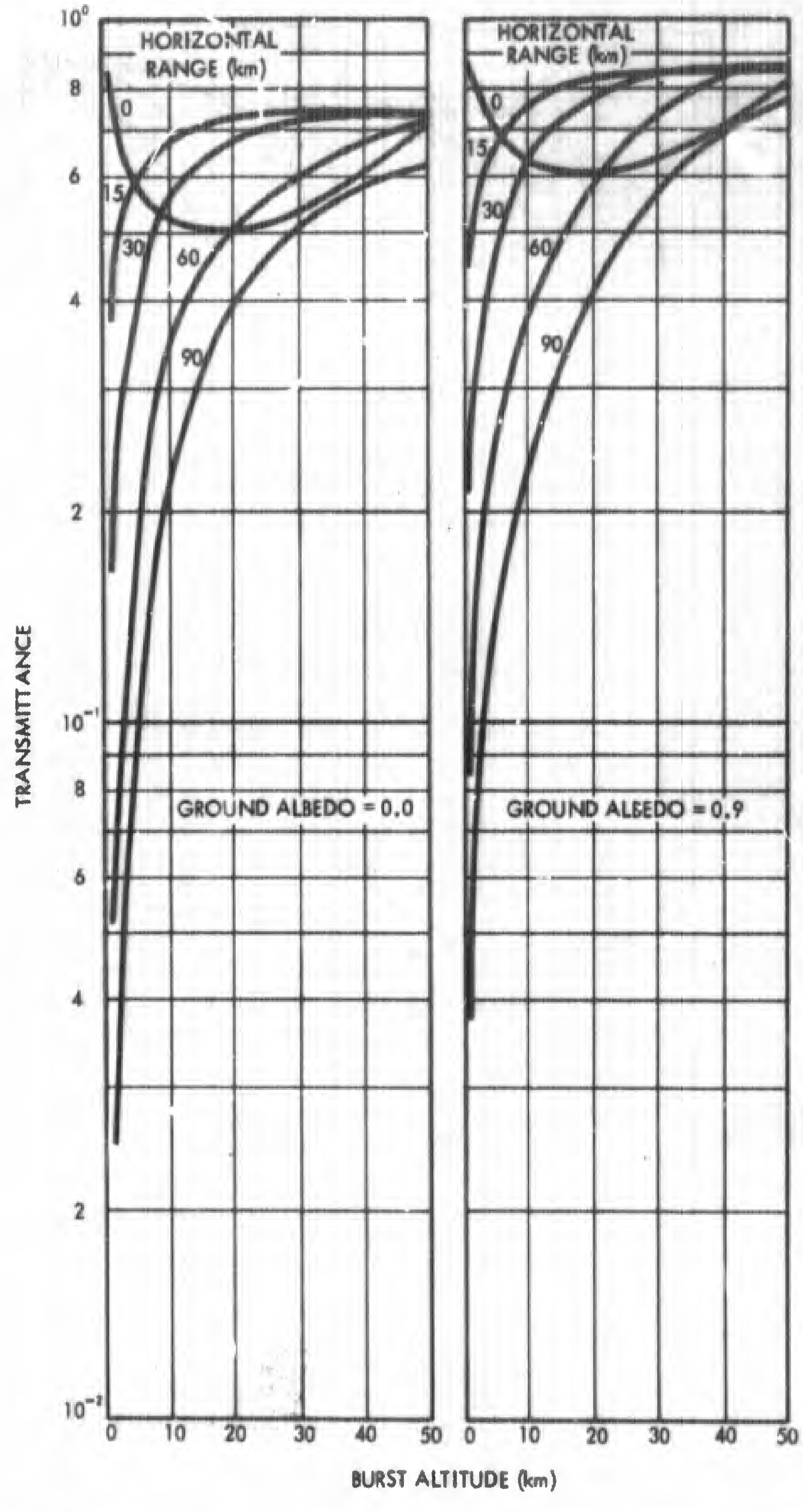

Fig. 22. Variation of the Transmittance for a Nuclear Weapon Burst in the Summer Midlatitude Atmosphere with Burst Altitude: Receiver Normal to Source-Receiver Axis

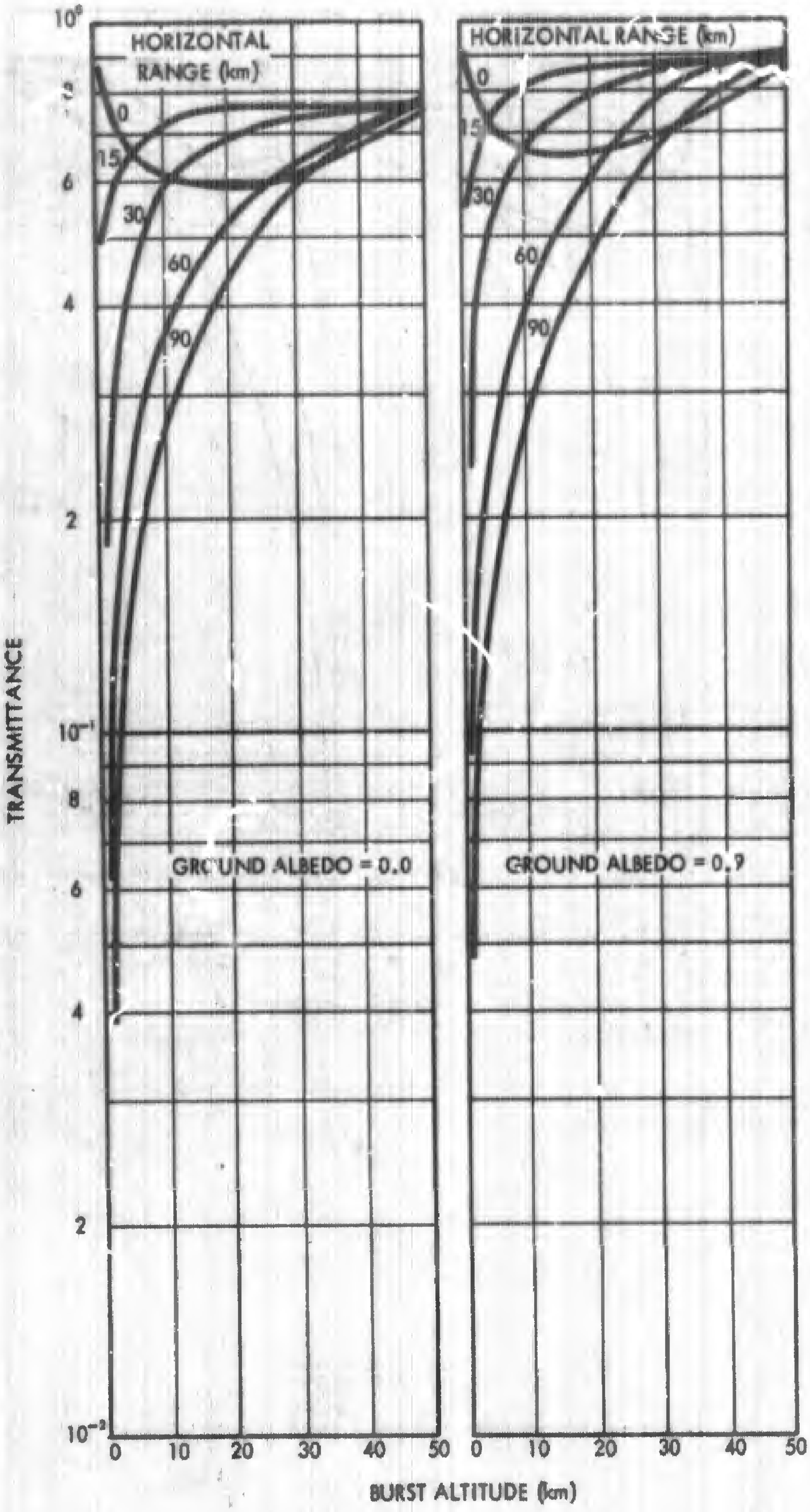

Fig. 23. Variation of the Transmittance for a Nuclear Weapon Burst in the Winter Midlatitude Atmosphere with Burst Altitude: Receiver Normal to Source-Receiver Axis

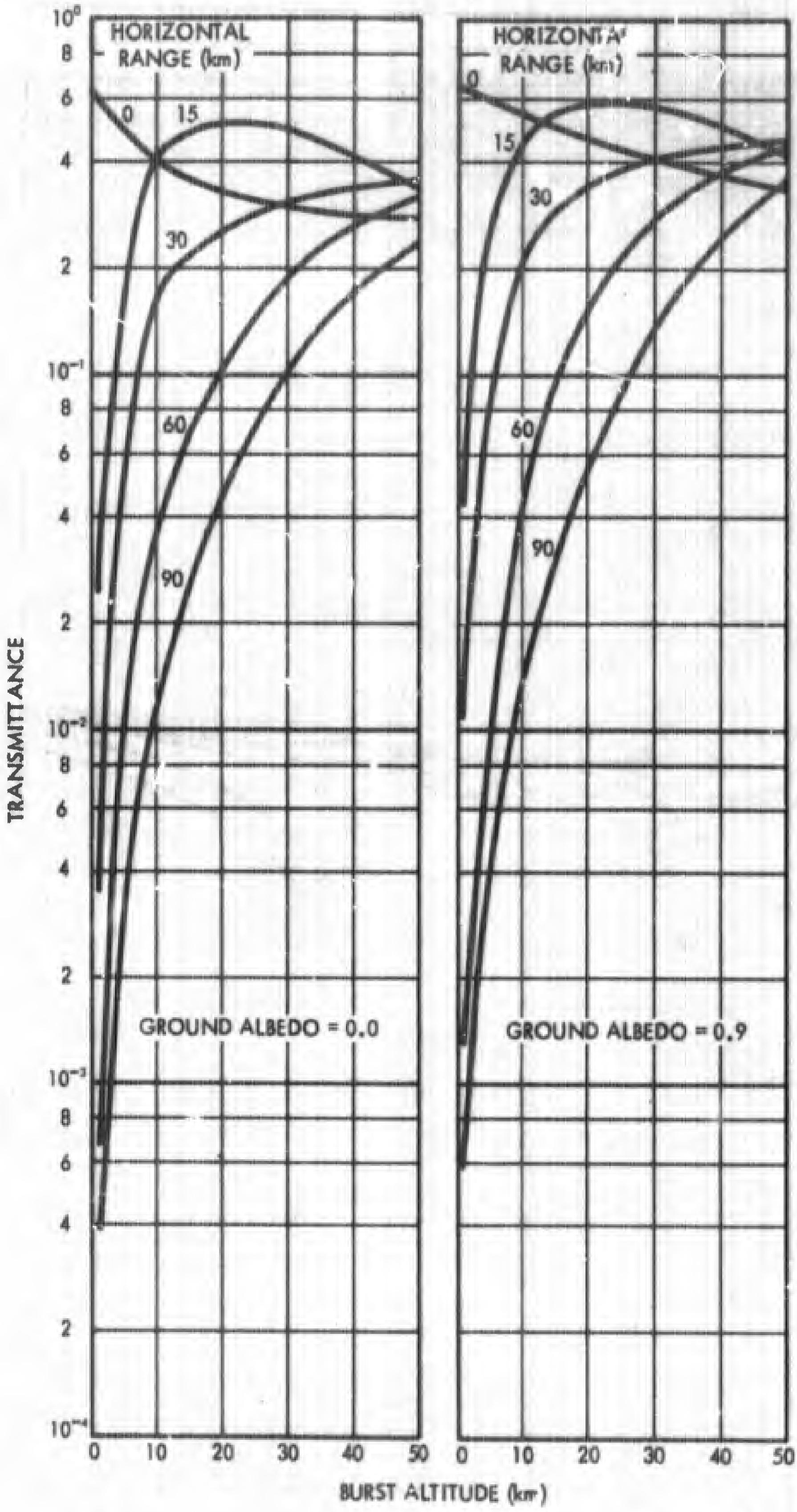

Fig. 24. Variation of the Transmittance for a Nuclear Weapon Burst in the Winter Inversion Midlatitude Atmosphere with Burst Altitude: Receiver Normal to Source-Receiver Axis

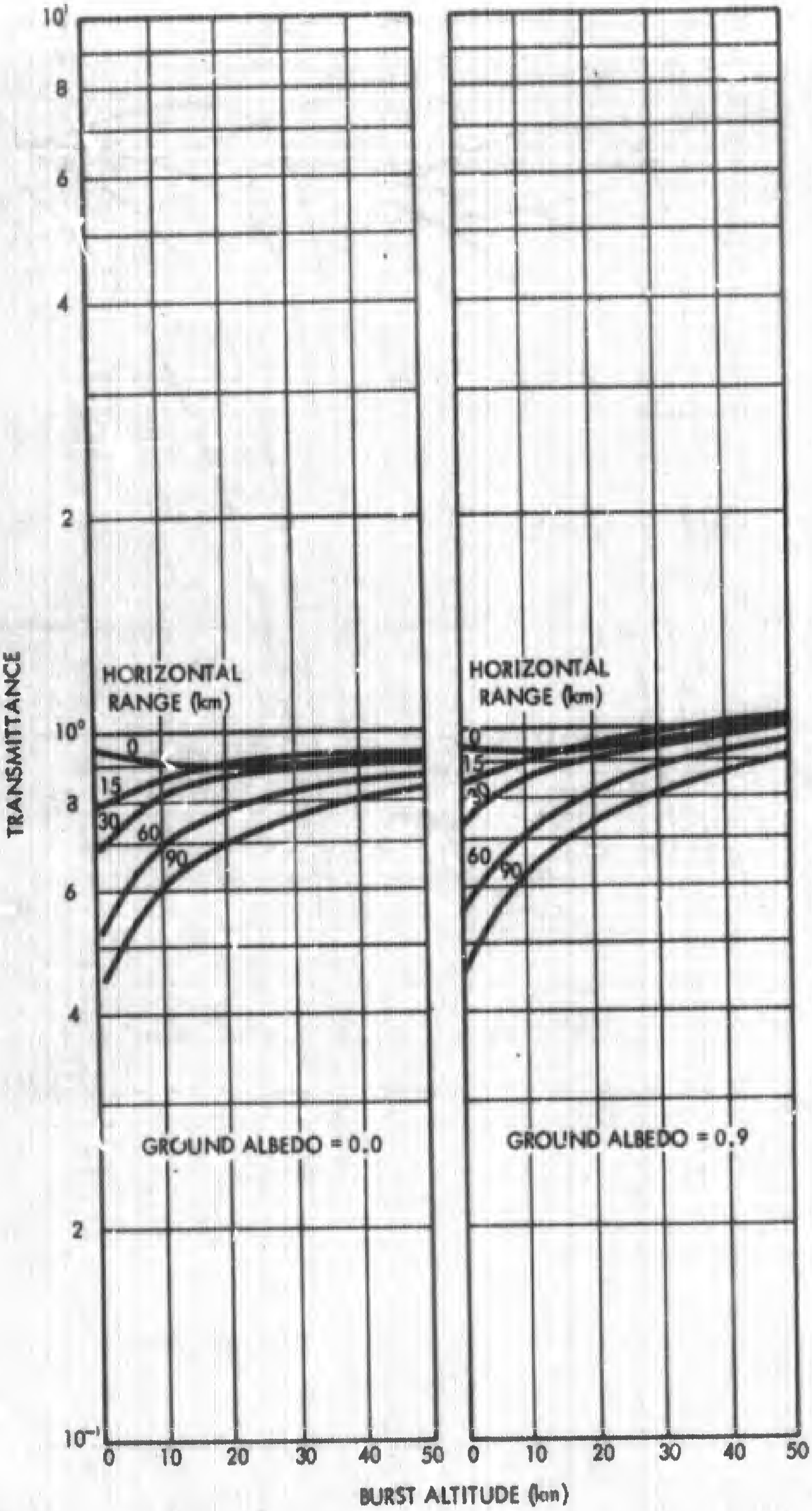

Fig. 25. Variation of the Transmittance for a Nuclear Weapon Burst in the Arctic Atmosphere with Burst Altitude: Receiver Normal to Source-Receiver Axis

TABLE XXIX. RATIO OF THE TOTAL-TO-DIRECT TRANSMITTANCE FOR NUCLEAR WEAPON BURSTS IN THE MODEL ATMOSPHERE

RECEIVER NORMAL TO SOURCE-RECEIVER AXIS

MORNING TROPICAL ATMOSPHERE

HS (KM)	ALBEDO	HORIZONTAL RANGE (KM) 0	15	30	60	90
1	0.0	2.16+00	1.22+05	3.22+10		
1	0.9	2.33+00	1.78+05	4.66+10		
9	0.0	3.99+00	3.85+01	4.86+02	2.37+05	2.09+07
9	0.9	4.58+00	4.62+01	7.28+02	3.09+05	2.86+07
50	0.0	6.37+00	6.54+00	7.55+00	1.10+01	1.46+01
50	0.9	7.37+00	7.22+00	9.69+00	1.42+01	2.03+01

AFTERNOON TROPICAL ATMOSPHERE

HS (KM)	ALBEDO	0	15	30	60	90
1	0.0	1.08+00	2.68+00	4.47+00	1.57+01	7.33+01
	0.9	1.09+00	3.46+00	6.27+00	2.79+01	1.10+02
9	0.0	1.20+00	1.53+00	1.88+00	2.53+00	3.38+00
9	0.9	1.27+00	1.77+00	2.18+00	2.91+00	3.80+00
50	0.0	1.20+00	1.20+00	1.21+00	1.29+00	1.41+00
50	0.9	1.32+00	1.32+00	1.35+00	1.44+00	1.58+00

SUMMER MIDLATITUDE ATMOSPHERE

HS (KM)	ALBEDO	0	15	30	60	90
1	0.0	1.09+00	2.09+00	2.99+00	7.14+00	1.80+01
1	0.9	1.10+00	2.58+00	3.87+00	1.01+01	2.70+01
9	0.0	1.13+00	1.42+00	1.51+00	1.71+00	1.68+00
9	0.9	1.20+00	1.59+00	1.70+00	1.85+00	1.81+00
50	0.0	1.23+00	1.26+00	1.33+00	1.46+00	1.46+00
50	0.9	1.41+00	1.45+00	1.54+00	1.74+00	1.80+00

TABLE XXIX. (CONT.)

WINTER INVERSION ATMOSPHERE

1	0.0	1.67+00	6.23+03	2.57+07	1.10+15	
1	0.9	1.78+00	1.20+04	8.07+07	2.14+15	
9	0.0	2.00+00	5.11+00	8.12+00	9.30+00	1.19+01
9	0.9	2.65+00	5.82+00	9.44+00	1.11+01	1.34+01
50	0.0	1.29+00	1.65+00	2.02+00	3.03+00	4.24+00
50	0.9	1.55+00	2.03+00	2.66+00	4.27+00	6.27+00

ARTIC ATMOSPHERE

1	0.0	1.02+00	1.11+00	1.12+00	1.13+00	1.13+00
1	0.9	1.03+00	1.19+00	1.22+00	1.21+00	1.19+00
9	0.0	1.08+00	1.11+00	1.15+00	1.12+00	1.10+00
9	0.9	1.11+00	1.17+00	1.21+00	1.18+00	1.15+00
50	0.0	1.19+00	1.15+00	1.13+00	1.13+00	1.14+00
50	0.9	1.27+00	1.28+00	1.26+00	1.27+00	1.26+00

WINTER MIDLATITUDE ATMOSPHERE

1	0.0	1.09+00	2.42+00	2.73+00	5.23+00	1.27+01
1	0.9	1.10+00	2.69+00	3.46+00	7.28+00	1.69+01
9	0.0	1.12+00	1.40+00	1.48+00	1.58+00	1.57+00
9	0.9	1.19+00	1.56+00	1.66+00	1.72+00	1.76+00
50	0.0	1.20+00	1.25+00	1.31+00	1.47+00	1.47+00
50	0.9	1.37+00	1.43+00	1.52+00	1.74+00	1.74+00

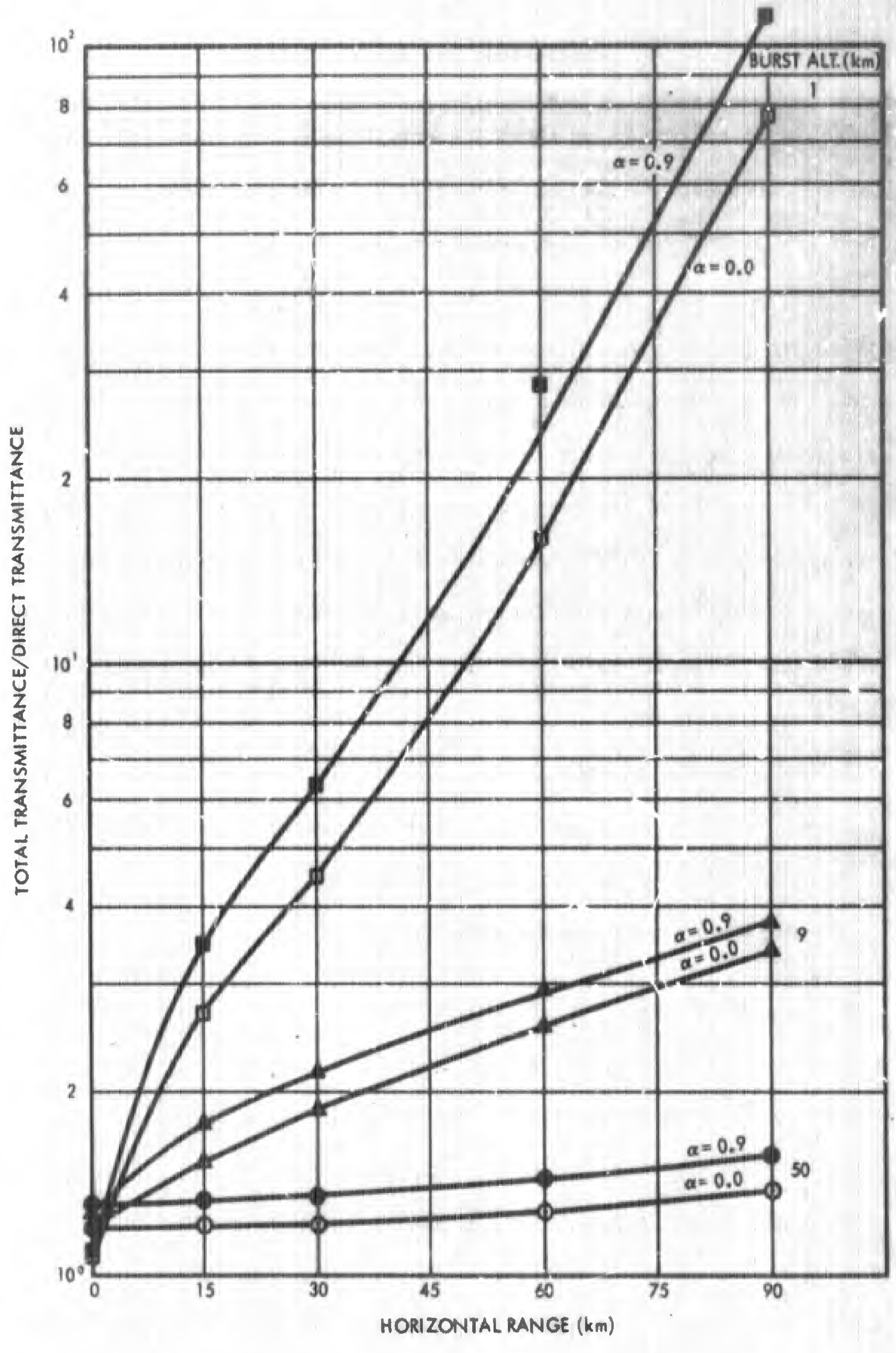

Fig. 26. Variation of the Ratio of the Total-To-Direct Transmittances in the Afternoon Tropical Atmosphere with Horizontal Range for Burst Altitudes of 1, 9 and 50 km and Ground Albedo Values of 0.0 and 0.9: Receiver Oriented Normal to Source-Receiver Axis

V. Conclusions and Recommendations

The transmittance of thermal energy from a point isotropic source in the atmosphere to flat plate receivers facing the source and located near the ground surface has been shown to be highly dependent on the amount of water vapor in the atmosphere, the ground level meteorological range, the aerosol size distribution, the ground albedo, the source altitude, and the receiver orientation with respect to the source. For a given source altitude, the transmittance was found to be more dependent on the ground level meteorological range than on any other parameter. The transmittance for a given source altitude, horizontal range and ground albedo is observed to increase with an increase in the ground level meteorological range. The rate at which the transmittance for a given horizontal range increases with an increase in the meteorological range is dependent on the source altitude. It is observed that the increase in the transmittance as the meteorological range increases from 3 km to 25 km is greater than the increase in transmittance as the meteorological range increases from 25 km to 200 km.

The effect of varying the water vapor content at ground level from 3 g m^{-3} to 17 g m^{-3} in the morning tropical and winter inversion atmospheres with a 3 km ground level meteorological range is observed to be much greater than that computed for the atmospheres with a 25 km ground level meteorological range. The amount of the reduction in the transmittance at 90 km horizontal range that resulted from an increase in the water vapor content at ground level from 3 g m^{-2} to 17 g m^{-3} was observed to increase from a factor of about 1.5 to a factor of 8 with an increase in the source altitude from 1 km to 50 km for the 3 km meteorological range atmospheres. The amount of the reduction in the transmittance at 90 km horizontal range with an increase in the water vapor content from 3 g m^{-2} to 17 g m^{-3} at ground level in the atmospheres with a 25 km meteorological range was observed to not vary significantly with source altitude. The rate at which the transmittance was reduced as the water vapor content was increased from 3 g m^{-3} to 17 g m^{-3} was found to be independent of the magnitude of the ground albedo.

Some of the differences in the transmittance observed at large horizontal ranges when going from the winter inversion atmosphere to the morning tropical atmosphere is probably due to the differences in the aerosol size distributions used to compute the aerosol attenuation coefficient as well as to the different water vapor densities in the atmospheres. The aerosol attenuation coefficient in the morning tropical atmosphere does not decrease as rapidly with increasing wavelength as does the aerosol attenuation coefficient in the winter inversion atmosphere. Therefore the aerosol attenuation of the direct radiation for wavelengths > 0.55μ is greater for the morning tropical atmosphere than it is for the winter inversion atmosphere. In addition, the scattered transmittance at the larger horizontal ranges were higher in the winter inversion atmosphere than in the morning tropical atmosphere. It is felt that the differences in the transmittance for the morning tropical and the winter inversion atmosphere are due as much to the differences in the aerosol size distribution as they are due to the differences in the water vapor content of the two model atmospheres.

The results of the calculation for a point source located at 1 km altitude in both the morning and evening tropical atmosphere containing a cloud layer with cloud bottom altitudes of 1.5 and 3.5 km show that the presence of a cloud layer could result in transmittances greater than 1.0 for horizontal ranges to about 25 km. It is observed that for a high ground albedo, the presence of a cloud layer could increase the transmittance in the evening tropical atmosphere by a factor of 2 to 3 over that computed for a cloudless atmosphere at horizontal ranges to 60 km. At large horizontal ranges (60 to 90 km), it was found that the presence of a cloud layer reduces the transmittance below that computed for a cloudless atmosphere.

The calculated transmittance data presented in this report show how changes in the scattering and absorption properties of the atmosphere will affect the transmission of nuclear weapons thermal radiation in the atmosphere. The results of the calculations clearly show the importance of multiple scattering on the transmittance for atmospheres with ground level meteorological ranges of 25 km or less.

The transmittance data given in this report for nuclear weapons are based on an integration of the LITE-III calculations as a function of wavelength for each of the six different model atmospheres with the time distributions of the fireball temperature and relative irradiance as reported by Cahill, Gauvin, and Johnson. It is recommended that the LITE-III calculations for the six model atmospheres be folded with time distributions of the fireball temperature and relative irradiances as given by more recent studies than that from which Cahill, et al, obtained the data shown in Fig. 2. The results of such calculations would provide information on the effect of the height of burst, weapon yield, and weapon design on transmittance data for nuclear weapons.

The LITE-III calculations run for this study provide information on the wavelength dependence of atmospheric transmittance of light for six different model atmospheres. It is proposed that this data be further analyzed to determine the dependence of the transmittance data on the ground level meteorological range and the absolute humidity of the atmosphere so that the data could be extended to other visibility conditions. The results of the proposed study, combined with further LITE-III calculations for cloudy atmospheres, could be used to develop a simplified calculational model for determining atmospheric transmittances for nuclear weapons that would allow one to accurately predict transmittance data for a wide range of weapon yields, burst altitudes and atmospheric conditions.

REFERENCES

1. D. G. Collins, K. Cunningham and M. B. Wells, Monte Carlo Studies of Light Transport, Radiation Research Associates, Inc. Report ECOM-00240-2 (28 February 1967).

2. M. B. Wells and D. G. Collins, Monte Carlo Studies of Light Transport in a Model Afternoon Tropical Atmosphere, Radiation Research Associates, Inc. Report ECOM-00240-3 (22 November 1967).

3. S. L. Valley, Editor, Handbook of Geophysics and Space Environments, McGraw-Hill Book Company, Inc., New York (1965).

4. R. Penndorf, Tables of Refractive Index for Standard Air and the Rayleigh Scattering Coefficient for the Spectral Region Between 0.2 and 20.0μ and their Application to Atmospheric Optics, JOSA, 47, (February 1957).

5. L. Elterman, An Atlas of Aerosol Attenuation and Extinction Profiles for the Troposphere and Stratosphere, Air Force Cambridge Research Laboratories Report AFCRL-66-828 (December 1966).

6. M. Centeno, The Refractive Index of Liquid Water in the Near Infrared Spectrum, JOSA, 31 (March 1941).

7. M. Gutnick, Mean Mid-Latitude Moisture Profiles to 31 km, Air Force Surveys in Geophysics No. 147, Air Force Cambridge Research Laboratories (1962).

8. P. V. Wyatt, V. R. Stull, and G. N. Plass, Infrared Transmission Studies, Volume II, The Infrared Absorption of Water Vapor, SSD-TRD-62-127, Vol. II (September 1962).

9. R. G. Eldridge, A Comparison of Computed and Experimental Spectral Transmissions Through Haze, Journal of Applied Optics, 6, 929 (1967).

10. P. V. Wyatt, V. R. Stull, and G. N. Plass, Infrared Transmission Studies, Volume III, The Infrared Absorption of Carbon Dioxide, SSD-TDR-62-127, Vol. III (January 1963).

11. L. Elterman, Atmospheric Attenuation Model, 1964, in the Ultraviolet, Visible, and Infrared Regions for Altitudes to 50 km, Air Force Cambridge Research Laboratories Report AFCRL-64-740 (September 1964).

12. M. B. Wells, D. G. Collins, and K. Cunningham, Light Transport in the Atmosphere, Volume I: Monte Carlo Studies, Radiation Research Associates, Inc. Report ECOM-00240-1, Volume I (September 1966).

REFERENCES (CONT.)

13. Ye. P. Novosel'toev, Spectral Reflectivity of Clouds, NASA Technical Translation NASA TT F-328 (April 1965).

14. E. M. Feigel'son, Light and Heat Radiation in Stratus Clouds, Translated from Russian by the Isreal Program for Scientific Translations, Jerusalem (1966). (NASA Accession Number N67-23418).

15. J. P. Cahill, H. P. Gauvin, and J. C. Johnson, Effective Transmission of Thermal Radiation from Nuclear Detonations in Real Atmospheres, Air Force Cambridge Research Laboratories Report AFCRL-62-456 (April 1962).

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

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

1. ORIGINATING ACTIVITY (Corporate author) Radiation Research Associates, Inc. Fort Worth, Texas 76107	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE
MONTE CARLO CALCULATIONS OF THE TRANSPORT OF THERMAL RADIATION FROM NUCLEAR DETONATIONS IN MODEL ATMOSPHERES

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

5. AUTHOR(S) (First name, middle initial, last name)
Wells, Michael B., Collins, Dave G., and Marshall, Joe D.

6. REPORT DATE 1 March 1969	7a. TOTAL NO. OF PAGES 91	7b. NO. OF REFS 15
8a. CONTRACT OR GRANT NO. DA 28-04-AMC-00240(E) b. PROJECT NO. DASA NWER Subtask 12.017 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) RRA-T810 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ECOM-00240-4	

10. DISTRIBUTION STATEMENT
This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of CG, U.S. Army Electronics Command, Fort Monmouth, New Jersey, Attn: AMSEL-BL-TE

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Headquarters, U. S. Army Electronics Command Ft. Monmouth, New Jersey, 07703

13. ABSTRACT
Monte Carlo calculations for monochromatic point isotropic sources were performed to determine the direct and scattered fluxes incident on flat plate receivers oriented so as to be 1) perpendicular to the source-receiver direction, 2) parallel to the ground surface, and 3) perpendicular to the ground surface. The receiver surface was always facing the point isotropic source. The calculations were run for 13 monochromatic wavelengths between 0.3μ and 4.0μ, source altitudes of 1, 9 and 50 km, a receiver altitude of 6 m, and receiver horizontal ranges from 0 to 90 km. The transmission calculations for each of the receiver orientations were performed for model atmospheres designed to represent a morning tropical atmosphere and an afternoon tropical atmosphere. Transmission calculations for a receiver oriented normal to the source-receiver axis were also performed for summer, winter and winter inversion midlatitude atmospheres, an an arctic atmosphere. For the 1 km source altitude in the morning and afternoon tropical atmospheres, transmission calculations were performed for cases where these atmospheres contained a cloud layer with the bottom of the cloud layer being at an altitude of either 1.5 km or 3.5 km. The Monte Carlo calculated scattered and direct fluxes for each receiver orientation were integrated over the power emission spectrum for a blackbody source at temperature T to determine atmospheric transmittance as a function of the blackbody temperature for each of the source altitudes and atmospheres considered. The atmospheric transmittance data as a function of the blackbody source temperature were then folded with data giving the time distributions of the temperature and power emission of a fireball produced by an air burst of a nuclear weapon to give atmospheric transmittance data for an air burst. Calculated data are
(Abstract continued on next page)

DD FORM 1 NOV 65 1473

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Thermal Radiation						
Atmospheric Transmittance						
Nuclear Weapons						
Blackbody Radiation Transmittance						
Atmospheric Scattering						
Model Atmosphere Transmittance						

13. Abstract (continued)

presented showing the dependence of the atmospheric transmittance for blackbody sources on the blackbody temperature and the dependence of the atmospheric transmittances for an air burst of a nuclear weapon on receiver orientation, burst altitude, horizontal range and the ground albedo.