REPORT UAG-89

WORLD DATA CENTER A
for
Meteorology

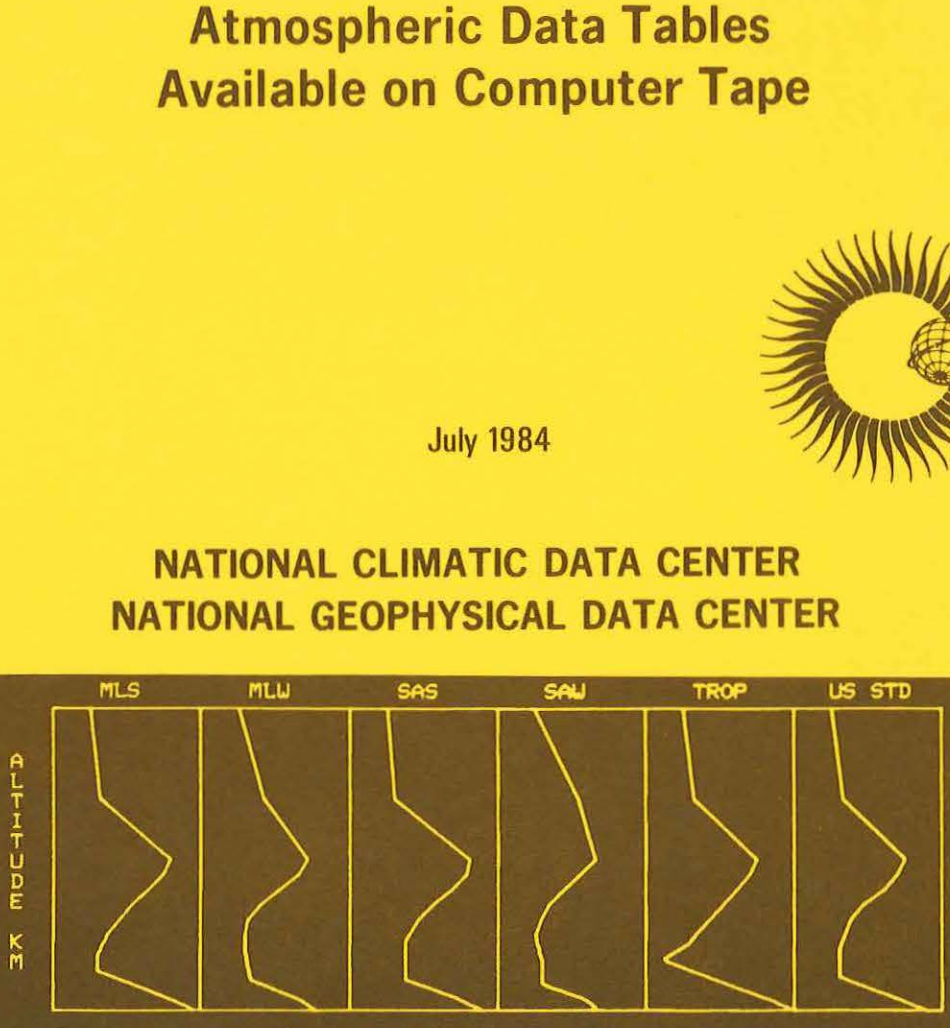
and

WORLD DATA CENTER A
for
Solar-Terrestrial Physics

ATMOSPHERIC HANDBOOK
Atmospheric Data Tables
Available on Computer Tape

July 1984

NATIONAL CLIMATIC DATA CENTER
NATIONAL GEOPHYSICAL DATA CENTER



TEMPERATURE (K) VS. ALTITUDE (KM) FOR SIX MODEL ATMOSPHERES

WORLD DATA CENTER A
National Academy of Sciences
2101 Constitution Avenue, NW
Washington, D.C. 20418 USA

World Data Center A consists of the Coordination Office
and the following eight Subcenters:

COORDINATION OFFICE
World Data Center A
National Academy of Sciences
2101 Constitution Avenue, NW
Washington, D.C. 20418 USA
[Telephone: (202) 334-3359]

GLACIOLOGY (Snow and Ice)
World Data Center A: Glaciology
(Snow and Ice)
Cooperative Inst. for Research in
Environmental Sciences
University of Colorado
Boulder, Colorado 80309 USA
Telephone: (303) 492-5171

MARINE GEOLOGY AND GEOPHYSICS
(Gravity, Magnetics, Bathymetry,
Seismic Profiles, Marine Sediment,
and Rock Analyses):

World Data Center A for Marine
Geology and Geophysics
NOAA, E/GC3
325 Broadway
Boulder, Colorado 80303 USA
Telephone: (303) 497-6487

METEOROLOGY (and Nuclear Radiation)
World Data Center A: Meteorology
National Climatic Data Center
NOAA, E/CC
Federal Building
Asheville, North Carolina 28801 USA
Telephone: (704) 259-0682

OCEANOGRAPHY
World Data Center A: Oceanography
National Oceanographic Data Center
NOAA, E/OC
2001 Wisconsin Avenue, NW
Page Bldg. 1, Rm. 414
Washington, D.C. 20235 USA
Telephone: (202) 634-7510

ROCKETS AND SATELLITES
World Data Center A: Rockets and
Satellites
Goddard Space Flight Center
Code 601
Greenbelt, Maryland 20771 USA
Telephone: (301) 344-6695

ROTATION OF THE EARTH
World Data Center A: Rotation
of the Earth
U.S. Naval Observatory
Washington, D.C. 20390 USA
Telephone: (202) 254-4547

SOLAR-TERRESTRIAL PHYSICS (Solar and
Interplanetary Phenomena, Ionospheric
Phenomena, Flare-Associated Events,
Geomagnetic Variations, Aurora,
Cosmic Rays, Airglow):

World Data Center A
for Solar-Terrestrial Physics
NOAA, E/GC2
325 Broadway
Boulder, Colorado 80303 USA
Telephone: (303) 497-6323

SOLID-EARTH GEOPHYSICS (Seismology,
Tsunamis, Gravimetry, Earth Tides,
Recent Movements of the Earth's
Crust, Magnetic Measurements,
Paleomagnetism and Archeomagnetism,
Volcanology, Geothermics):

World Data Center A
for Solid-Earth Geophysics
NOAA, E/GC1
325 Broadway
Boulder, Colorado 80303 USA
Telephone: (303) 497-6521

World Data Centers conduct international exchange of geophysical observations in accordance with the principles set forth by the International Council of Scientific Unions. WDC-A is established in the United States under the auspices of the National Academy of Sciences. Communications regarding data interchange matters in general and World Data Center A as a whole should be addressed to World Data Center A, Coordination Office (see address above). Inquiries and communications concerning data in specific disciplines should be addressed to the appropriate subcenter listed above.

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ATMOSPHERIC HANDBOOK
Atmospheric Data Tables Available on Computer Tape

by

V.E. Derr
NOAA Environmental Research Laboratories
325 Broadway
Boulder, Colorado 80303 USA

July 1984

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
Boulder, Colorado, USA 80303

DESCRIPTION OF WORLD DATA CENTERS

World Data Centers conduct international exchange of geophysical observations in accordance with the principles set forth by the International Council of Scientific Unions (ICSU). They were established in 1957 by the International Geophysical Year Committee (CSAGI) as part of the fundamental international planning for the IGY program to collect data from the numerous and widespread IGY observational programs and to make such data readily accessible to interested scientists and scholars for an indefinite period of time. WDC-A was established in the U.S.A.; WDC-B in the U.S.S.R.; and WDC-C in Western Europe, Australia, and Japan. This new system for exchanging geophysical data was found to be very effective, and the operations of the World Data Centers were extended by ICSU on a continuing basis to other international programs; the WDC's were under the supervision of the Comite International de Geophysique (CIG) for the period 1960 to 1967 and are now supervised by the ICSU Panel on World Data Centres.

The current plans for continued international exchange of geophysical data through the World Data Centers are set forth in the *Fourth Consolidated Guide to International Data Exchange through the World Data Centres*, issued by the ICSU Panel on World Data Centres. These plans are broadly similar to those adopted under ICSU auspices for the IGY and subsequent international programs.

Functions and Responsibilities of WDC's

The World Data Centers collect data and publications for the following disciplines: Meteorology; Oceanography; Rockets and Satellites; Solar-Terrestrial Physics disciplines (Solar and Interplanetary Phenomena, Ionospheric Phenomena, Flare-Associated Events, Geomagnetic Phenomena, Aurora, Cosmic Rays, Airglow); Solid Earth Geophysics disciplines (Seismology, Tsunamis, Gravimetry, Earth Tides, Recent Movements of the Earth's Crust, Rotation of the Earth, Magnetic Measurements, Paleomagnetism and Archemagnetism, Volcanology, Geothermics), and Marine Geology and Geophysics. In planning for the various scientific programs, decisions on data exchange were made by the scientific community through the international scientific unions and committees. In each discipline, the specialists themselves determined the nature and form of data exchange, based on their needs as research workers. Thus, the type and amount of data in the WDC's differ from discipline to discipline.

The objects of establishing several World Data Centers for collecting observational data were: (1) to insure against loss of data by the catastrophic destruction of a single center, (2) to meet the geographical convenience of, and provide easy communication for workers in different parts of the world. Each WDC is responsible for: (1) endeavoring to collect a complete set of data in the field or discipline for which it is responsible, (2) safe-keeping of the incoming data, (3) correct copying and reproduction of data, maintaining adequate standards of clarity and durability, (4) supplying copies to other WDC's of data not received directly, (5) preparation of catalogs of all data in its charge, and (6) making data in the WDC's available to the scientific community. The WDC's conduct their operation at no expense to ICSU or to the ICSU family of unions and committees.

World Data Center A

World Data Center A, for which the National Academy of Sciences through the Geophysics Research Board and its Committee on Data Interchange and Data Centers has overall responsibility, consists of the WDC-A Coordination Office and seven subcenters at scientific institutions in various parts of the United States. The GRB periodically reviews the activities of WDC-A and has conducted several studies on the effectiveness of the WDC system. As a result of these reviews and studies, some of the subcenters of WDC-A have been relocated so that they could more effectively serve the scientific community. The addresses of the WDC-A subcenters and Coordination Office are given inside the front cover.

The data received by WDC-A have been made available to the scientific community in various ways: (1) reports containing data and results of experiments have been compiled, published, and widely distributed; (2) synoptic-type data on cards, microfilm, or tables are available for use at the subcenters and for loan to scientists; (3) copies of data and reports are provided upon request.

CONTENTS

NOTE: Tape file name (in capitals) and number are given in brackets following section names. See Appendix B for a description of these files.

ATMOSPHERIC HANDBOOK: ATMOSPHERIC DATA TABLES AVAILABLE ON COMPUTER TAPE

by

V.E. Derr
NOAA Environmental Research Laboratories
NOAA/R/E
325 Broadway
Boulder, Colorado 80303, USA

ABSTRACT: Atmospheric data tables stored on computer tape and available for public use are described in this catalog/manual. These data are largely taken from results published in scientific journals. Data areas cover attenuation coefficients for the atmosphere and H_2O, atmospheric parameters for 1962 standard atmospheres, cloud drop size distributions for water and ice spheres, solar spectral irradiance, sky spectral radiance, Rayleigh mass and volume scattering coefficients and scattering cross section for air, the relative reflectance of ice and saline environmental waters, and refractive indices for liquid water, ice, air, and various atmospheric aerosols. Information in the report includes descriptions of the data (summarized from journal abstracts), information on the range and units of the data parameters, the FORTRAN format statements used to create the data files, and two FORTRAN programs for retrieving select data.

1. INTRODUCTION [INTRO, 1]

During the course of a number of years of work in atmospheric spectroscopy, I compiled several very useful tables of atmospheric data from the literature, and stored these data on computer disk and tape for ready access during theoretical calculations. Often, colleagues borrowed copies of these data, and some provided me with additional data. Invariably they suggested that it might be useful for fellow workers to have access to the data in a user-friendly format accessible by a computer. I resisted these urgings for a long time because the burden of selecting the "best" values, and the most useful and relevant material and assuring the accuracy of the values quoted, is intolerably large for one person aided by even a very competent part-time student. To do the job fully requires a critical review and fine judgement to distinguish between the many published sources of such data. For example, there are at least a dozen tables of refractive indices of water, many of which don't agree. To sit in Solomon-like judgement on these discrepancies requires the devotion of several full careers. These considerations, until recently, blocked any thoughts of publishing this material, and I confined its use to calculations of my own and those of colleagues aware of the pitfalls.

There is, however, a better way, by publishing this "Atmospheric Handbook: Atmospheric Data Tables Available on Computer Tape" as a compromise between fully verified and uncertain values. We make every effort to ensure the faithfulness of the tables to the source and to avoid degradation of interpolated values. If more than one source appears authoritative, both are quoted. Under this compromise, the researcher is advised to use the values cautiously, but by and large a very valuable set of data is provided for researchers in atmospheric radiation. The accuracy of the data can be determined only by reference to the source.

The Atmospheric Handbook exists in two forms: as a bound, paper report and as a computer tape. The report serves as a descriptive catalog/manual for the computer tape; it does not contain complete copies of the atmospheric data tables. Information in the report ranges from descriptions of the data in the tables, summarized from scientific journal abstracts, to information on the range and units of the data parameters, to the FORTRAN format statements used to create the data files. The computer tape version of the Handbook contains all information in the bound report, as well as the data tables themselves. Currently, two programs for accessing certain kinds of data are available in the report as well as on the tape. The computer tape is available through the National Environmental Satellite, Data, and Information Service (NESDIS). There is a charge for copying the tape.

.... Direct Requests To	....	Direct Questions To:
National Geophysical Data Center NOAA/NESDIS E/GC2 325 Broadway Boulder, CO 80303, USA	Climatological Services Section National Climatic Data Center NOAA/NESDIS E/CC423 Federal Building Asheville, NC 22801, USA	Dr. Vernon Derr NOAA/R/E 325 Broadway Boulder, CO 80303, USA
(303) 497-6136; FTS: 320-6136	(704) 259-0682; FTS: 672-0682	(303)497-6000; FTS: 320-6000

Because a future edition of the handbook is planned, I invite interested users to refer me to any additional data that may be included, and of course note any errors found. Suggestions on more useful formats are welcome. Any definitive reviews of the tables that appear in the literature will be used to discriminate between sources and eliminate less accurate versions.

2. DATA DESCRIPTIONS [DATAXDESCRIP, 3]

This section contains brief descriptions of the sources for data found in the Handbook. Each description is preceded by a definition of the data file variables and their ranges and units, as well as a list of the file names (in capital letters).

2.1 ATTENUATION COEFFICIENTS

2.1.1

Atmospheric Absorption (km^{-1}) and Scattering (cm^{-1}) vs. Altitude (0 to 85 km)
ATTENHT, AERXCLR, AERXHAZ, MIDLATSUM, MIDLATWIN, SUBARCSUM, SUBARCWIN, TROPIC (all accessed by Program ATTENCOEF)

The tables contain values of attenuation coefficients as a function of altitude for five atmospheric and two aerosol models from McClatchey et al. (1972). The altitude range is 0 to 85 km and the radiation wavelength is 0.6943 micrometers. Numerical values for the coefficients were computed and then logarithmically interpolated for each atmospheric layer. The aerosol attenuation coefficients are identical for all geographical and seasonal models. If the total attenuation (G) is required, the four coefficients can be summed: G = molecular absorption + molecular scattering + aerosol absorption + aerosol scattering. The tables are accessed by program ATTENCOEF.

2.1.2

Attenuation (m^{-1}) and Scattering (m^{-1}) vs. Wavelength (3.75E-7 to 8E-7 meters) for Water
H2OXATTENSCAT

Jerlov (1968) collected the observed attenuation coefficients of Clarke and James (1939) and the theoretical scattering coefficients of LeGrand (1939) for pure water in the range 3.75E-7 to 8E-7 meters. In their experiments Clarke and James found no palpable differences between the attenuances of distilled water and ocean water, and therefore the values for distilled water can be used when attenuation coefficients for salt water are needed.

2.2 STANDARD ATMOSPHERES

Pressure (mb), Temperature (K), and Number Densities (mols cm^{-3}) vs. Altitude (0 to 100 km) of H_2O, CO_2, O_3, N_2O, CO, CH_4, O_2, and N_2
MLS, MLW, SAS, SAW, TROPICAL, USXSTAN

These tables are taken from the Air Force Geophysics Lab computer code for FSCDATM, Gallery et al. (1981). Data were originally derived from McClatchey et al. (1972). They originate from "Handbook of Geophysics and Space Environments" (Valley, 1965). The six profiles consist of the pressure, temperature, and number densities of H_2O, CO_2, O_3, N_2O, CO, CH_4, O_2, and N_2 vs. altitude for the following atmospheric types: Tropical (15 deg. N.), Midlatitude Summer (45 deg. N., July), Midlatitude Winter (45 deg. N., January), Subarctic Summer (60 deg. N., July), Subarctic Winter (60 deg. N., January), and the 1962 U.S. Standard Atmosphere.

A draft version of a section of the report on FSCDATM states:

> "The water vapor density for the 1962 Standard corresponds to relative humidities of approximately 50% for altitudes up to 10 km, whereas the relative humidity values for the other models tend to decrease with altitude from approximately 80% at sea level to approximately 30% at 10 km. Above 12 km the water vapor number densities of all models but the 1962 Standard are identical and represent volume mixing ratios which reach a minimum of about 6.5 ppmv at 17 km, increase to 30 ppmv at 30 km, then decrease to 10 ppmv at 50 km. For all models, the gases CO_2, N_2O, CO, CH_4, O_2, and N_2 are considered uniformly mixed with volume mixing ratios of 330, 0.28, 0.075, 1.6, 1.095E05, and 7.905E05 ppmv respectively."

In correspondence with us, W.O. Gallery of AFGL commented that the data on which these profiles are based are old. The report continues:

> "The stratospheric water vapor concentrations for the six profiles are now known to be too large by a factor of 5 at 30 km. The models may still be considered representative of their respective conditions up to about 50 km for temperature, up to 30 km for ozone densities, and up to the tropopause (approximately 15 km in the Tropics to 8 km in the Arctic) for water vapor."

Two useful recent reports are WMO (1982) and M. Smith (1982). The U.S. Standard Atmosphere for 1976 updates the 1962 Standard for temperature above 50 km and provides revised estimates for the surface concentrations of what was previously termed the "uniformly mixed gases". New values for the volume mixing ratios of CO_2, N_2O, CO, and CH_4 are 322, 0.27, 0.19, and 1.60 ppmv respectively. The 1976 Standard gives equations for the computation of the number density of individual species. When updated tables are released by AFGL, we plan to incorporate them into the Handbook.

2.3 CLOUD DROP SIZE DISTRIBUTIONS

NOTE: All cloud files contain the number density of drops or ice particles per unit interval (m^{-3} m^{-1}). The number density (m^{-3}) in the interval is given by multiplying the number density per unit interval (m^{-3} m^{-1}) by the absolute difference between the beginning and ending radius (m).

2.3.1

Number Density of Drops (m^{-3} m^{-1}) vs. Radius (meters)
CLOUD1 to CLOUD8

Carrier et al. (1967) presented theoretical scattering parameters for eight different water cloud models at 4.88E-7, 6.94E-7, 1.06E-6, 4E-6, and 1.06E-5 meter radiations. These wavelengths, excluding 4E-6, correspond to the monochromatic wavelengths of operationally significant lasers. The authors presented representative cloud drop size distributions and concentrations for major water cloud types, assuming spherical water droplets only, and calculated the optical extinction coefficients for each model using the exact Mie theory. Consequently the calculated optical properties are accurate only for the cloud models used. We calculated data values in the CLOUD1 - 8 tables from both tabular and graphed data in Carrier et al. (1965, 1967).

Carrier gives these figures for the concentrations of the drop size distributions:

Type	File Name	Concentration (number/cm^3)
Stratus I	CLOUD1	464 (458)
Stratocumulus	CLOUD2	350 (370)
Fairweather Cumulus	CLOUD3	300 (157)*
Stratus II	CLOUD4	260 (260)
Cumulonimbus	CLOUD5	72 (63)
Cumulus Congestus	CLOUD6	207 (198)
Nimbostratus	CLOUD7	330 (326)
Altostratus	CLOUD8	450 (461)

*The numbers in parentheses represent the results of calculations we performed on histograms derived from Carrier's figures. The concentration for Fairweather Cumulus, CLOUD3, is different enough that we suggest taking our value as correct for the data as presented.

2.3.2

Number Density of Ice Particles (m^{-3} m^{-1}) vs. Radius (1.5E-6 to 7.5E-5 meters)
CLOUD9

Schickel (1975) took samplings from fifty-six 1980 publications on droplet distributions of water clouds. CLOUD9 is a sampling for ice fog.

2.3.3

Number Density of Ice Particles (m^{-3} m^{-1}) vs. Radius (1E-6 to 5E-5 meters (CLOUD10) and 5E-5 to 5E-4 meters (CLOUD11))
CLOUD10 and CLOUD11

Heymsfield (1975) studied the growth of the ice phase in cirrus uncinus and cirrostratus clouds through aircraft measurements of cloud particle spectra at different altitudes. The temperature range was -14 to -46 degrees. CLOUD10 and CLOUD11 are taken from data for particle spectra taken near the top of a cirrostratus deck. The cirrostratus clouds sampled had their nucleation regions near the top of the clouds; crystals sedimented and grew from this source region near the top to near the base, and then evaporated to the base. The crystal concentrations were about 0.2 cm^{-3}, with 0.01 cm^{-3} longer than 100 micrometers. The mean length of crystals larger than 100 micrometers ranged between 0.2 and 0.5 mm. The ice water content ranged between 0.01 and 0.16 g m^{-3}.

2.3.4

Number Density of Ice Particles (m^{-3} m^{-1}) vs. Radius (3E-6 to 1.33E-5 meters)
CLOUD12

Heymsfield and Jahnsen (1974) sampled thin, nearly invisible tropopause cirrus layers by aircraft over the continental United States and Pacific Ocean. In the data set used, samplings took place in a thin cirrus layer between 55,000 and 52,000 ft topped at the tropopause, near the Marshall Islands in the Pacific in December of 1973. There were no clouds below this level. There was a double tropopause, one at 55,000 ft and a weak one between 53,000 and 54,000 ft. The ice water content increased from the cloud top at the tropopause to 300 feet below the tropopause, decreased to 54,000 ft, increased in the second tropopause to 53,500 ft, and evaporated below. The "source" region of the ice crystals was at the cloud top where there were high concentrations of small crystals; there was a secondary source region at 53,800 ft. An SRI lidar also indicated two cloud layers, one topped at 55,000 ft, the other at 53,800 ft.

2.3.5

Number Density of Ice Particles (m^{-3} m^{-1}) vs. Radius (3.97E-7 to 3.97E-5 meters)
CLOUD13

CLOUD13 contains ice size distributions for cirrus clouds at 13.3 km as reported by Kraus and Barnes (1976b). The freezing level was between 4.6 and 4.9 km, and tropopause was at approximately 15.5 km.

2.3.6

Number Density of Ice Particles (m^{-3} m^{-1}) vs. Radius (3.97E-7 to 2E-4 meters)
CLOUD14

CLOUD14 contains the ice size distributions for cirrus clouds at 12.5 km. They represent Kraus and Barnes's (1976a) best estimate of the worst case situation along their missile trajectory. The freezing level was near 4.9 km, and the tropopause was at 15.8 km.

2.3.7

Number Density of Ice Particles (m^{-3} m^{-1}) vs. Radius (3.97E-7 to 1.58E-4 meters)
CLOUD15

Barnes (1977) reported ice size distributions for cirrus clouds at approximately 15 km.

2.3.8

Number Density of Ice Particles (m^{-3} m^{-1}) vs. Radius (8.05E-6 to 5.64E-4 meters)
CLOUD16

CLOUD16 was taken from Glass and Varley's (1978) report of data collected during a morning flight through a layer of thin cirrus in December 1977 by AFGL cloud physics research aircraft over northern Arizona and New Mexico. The aircraft flew at an altitude of approximately 7 km MSL and the ambient temperature was -25 degrees C. The 500-mb synoptic chart on this day indicated a weakening ridge pattern over this region.

2.3.9

Number Density of Ice Particles (m^{-3} m^{-1}) vs. Radius (1E-6 to 8.6E-4 meters)
CLOUD17

Varley and Brooks (1978) reported data from a February 1978 cirrus sampling flight in Albuquerque, New Mexico, aimed at acquiring information on the typical type and concentration of ice particles in cirrus clouds.

2.3.10

Number Density of Ice Particles (m^{-3} m^{-1}) vs. Radius (1E-6 to 3.1E-5 meters)
CLOUD18

CLOUD18 is a cirrus cloud distribution synthesized from several sources by Dr. Vernon Derr of NOAA/ERL to be a small particle distribution (<31 micrometers) for test purposes.

2.4 SOLAR SPECTRAL IRRADIANCE*

2.4.1

Solar Spectral Irradiance (watts m^{-2} m^{-1}) vs. Wavelength (1.27E-7 to 1E-4 meters)
FLUX1

Thekaekara (1972) presented results of experiments made by NASA Goddard Space Flight Center on the solar constant and solar spectrum from a research aircraft at 11.6 km. In the wavelength range 3E-7 to 1.5E-5 meters these values were based mainly on measurements made from the research aircraft. The instruments used were a Perkin-Elmer model 112 spectrometer with a lithium-based fluoride window, a Leiss double quartz prism monochrometer, a filter radiometer, a polarization type interferometer and, for the infrared range beyond 4 micrometers, a Michelson type interferometer. In the wavelength range 3E-7 to 2.6E-6 meters an independent set of data is available from the Eppley-JPL measurements, made with a filter radiometer during several series of flights. The wavelength range covered is 1.2E-7 to 1E-4 meters. Thekaekara writes, "...the spectral irradiance is determined in narrow wavelength ranges and the integral energy is computed to give the solar constant. The solar constant...is the energy due to the sun incident on unit area exposed normally to the sun's rays at the average sun-earth distance in the absence of the earth's atmosphere. The solar spectral irradiance is the distribution of this energy as a function of wavelength."

The data in FLUX1 are reprinted from Thekaekara (1972) with permission from Photonics Spectra, copyright holder.

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*NGDC holds NIMBUS and SMM satellite solar irradiance data.

2.4.2

Solar Spectral Irradiance (watts m^{-2} m^{-1}) vs. Wavelength (2.5E-10 to 1.95E-2 meters)
FLUX2

From Smith and Gottlieb (1974), the tables in FLUX2 represent solar irradiance data as derived from various sources by the authors, in the wavelength range 2.5E-10 to 1.95E-2 meters. Smith and Gottlieb used the formula

$$H = \pi \ [(r^2)/(R^2)]F = 6.80 \times (10^{-5})F$$

to derive the solar irradiance (the solar flux at 1 AU) from the total solar flux, where H is the solar irradiance, F is the total solar flux, r is the radius of the sun, and R is 1 AU. "AU" is defined as "Astronomical Unit", the mean distance from the earth to the sun, where 1 AU = 1.49E11 meters.

The data in FLUX2 are reproduced from Smith and Gottlieb (1974) with permission from D. Reidel Publishing, copyright holder.

2.5 SKY SPECTRAL RADIANCE

NOTE: Sky spectral radiance is the power falling on area A per unit optical aperture (steradians), per unit wavelength range.

Sky Spectral Radiance (watts m^{-2} m^{-1}) vs. Wavelength (3.1E-7 to 7.2E-7 meters)
SKYBAC10, SKYBACSL

SKYBACSL and SKYBAC10 are files of the spectral radiance of the sky at sea level and at 10,000 feet. Walter Clark (1969) designed, built, and calibrated a spectrophotometer that was used at sea level and carried in an aircraft to collect the data. The data are for the wavelength region 3.1E-7 to 7.2E-7 meters. Clark reports that error computations of sky luminance using the root mean square method resulted in 6.5% to 11.5% error depending upon the signal amplitudes, and thus the spectral radiance absolute accuracy probably varies between 13% and 16%.

2.6 RAYLEIGH COEFFICIENTS, AIR

Mass Scattering Coefficient (m^2 kg^{-2}), Volume Scattering Coefficient (m^{-1}), and Scattering Cross Section (m^2) vs. Wavelength (2E-7 to 2E-5 meters) for Air
MASSXSCAT, VOLXSCAT, RAYXSCATCROSS

Penndorf (1957) calculated the real refractive indices of standard air based on Edlen's formula for the wavelength range 2E-7 to 2E-5 meters (2.7.2). Computations of the Rayleigh scattering cross sections and mass and volume scattering coefficients were tabulated in the same range. Standard air is defined as dry air containing 0.03% CO_2 by volume at normal pressure 760 mm Hg (=1013.25 mb) and having an air temperature of 15 degrees C. When calculating the refractive indices Penndorf made allowances for the influence of temperature and pressure. Penndorf used a standard textbook formula in figuring the Rayleigh scattering coefficient, and advised that its accuracy is correct to about +/- 10%; his computations for the coefficient can be considered correct to four figures. Refer to the original article for complete discussions of all formulas used.

2.7 REFRACTIVE INDICES

NOTE: In instances where one experiment resulted in data for more than one substance, only one data description is given. It contains parenthesized numerical references to the location of the data for other substances. The aerosol indices are alphabetized according to substance, and then listed according to the file name prefixes "RF", "RFI", or "RFC", in that order. The particular substance, wavelength range (meters), and refractive index type (real, imaginary, or complex, all dimensionless) are as indicated preceding the filenames.

2.7.1 Aerosols

2.7.1.1 ADP (Ammonium Dihydrogen Phosphate)

Real Refractive Index vs. Wavelength (2E-7 to 2E-6 meters)
RFXADPO, RFXADPE

Zernike (1964) measured the real refractive indices of ammonium dihydrogen phosphate (ADP) and potassium dihydrogen phosphate (KDP, 2.7.1.14) in air at wavelengths between 2E-7 and 2E-6 meters, at temperatures ranging from 24.6 to 24.9 degrees C. The accuracy of the indices is +/- 3E-5 or better. Zernike measured the indices using the method of known incidence used by F. Rydberg (1828) and Tilton et al. (1949). The ADP and KDP prisms had angles of approximately 61.5 and 60 degrees respectively. Zernike also included the real refractive indices of fused silica (2.7.1.21) for ten wavelengths between 3.65E-7 and 5.78E-7 meters.

2.7.1.2 Aerosol, Synthetic

Complex Refractive Index vs. Wavelength (4E-7 to 1.5E-5 meters)
RFCXSYNAER

Ivlev and Popova (1973) studied the optical constants of sulfates, silicates, nitrates, metal oxides, and minerals containing the cation $[NH_4]$ in the wavelength range 4E-7 to 1.5E-5 meters. Missing data on the complex indices were calculated by the Kramers-Kronig method from the transmission and reflectance spectra.

The authors collected and analyzed data on the optical constants and other optical characteristics of minerals that are present in the materials of atmospheric aerosols, and the variations of these characteristics on transition from one mineral of a given class to another, within the given wavelength region. On the basis of available observational data on the chemical composition of aerosol particles in the surface layer of the atmosphere, a model was constructed for the matter of the atmospheric-aerosol dispersed phase, and effective values of the complex index were calculated assuming the absence of free water. It was assumed that all the chemical compounds are uniformly distributed in the material of aerosol particles of different sizes. The refractive index values can be recommended for calculations of the optical characteristics of dry atmospheric aerosols.

2.7.1.3 Ammonium Sulphate

2.7.1.3.1

Complex Refractive Index vs. Wavelength (9.3E-6 to 9.5E-6 meters)
RFCXAMSP1 to RFCXAMSP3

Jennings (1981) applied an "attenuated total reflectance" goniometric system to the measurement of complex refractive indices of aerosol constituents at CO_2 laser wavelengths. He demonstrated the reliability of the system through a comparison of his experimental and previously reported values. Jennings chose water (2.7.4.4) and ammonium sulphate solutions for these checks. Water was triply distilled, and any ammonia or carbon dioxide was removed. The final sample was stored under argon. Ammonium sulphate solutions were prepared from finely ground ammonium sulphate powder, and their molality was determined gravimetrically. Our data files are for the three molalities 1.6, 2.4, and 3.2, (as indicated by the first line of the individual files). Polystyrene latex particles (2.7.1.17) with mean diameter 9.1E-8 meters were used in suspensions ranging from 5% to 20% by weight. These percentages correspond to the percentage values in the first line of each data file. From these suspension values, Jennings used the Maxwell Garnet mixture rule and an extrapolation scheme to derive the refractive index (file RFCXPLTX1).

2.7.1.3.2

Complex Refractive Index vs. Wavelength (4.05E-7 to 4E-5 meters)
RFCXAMSP4

Toon et al. (1976) reviewed techniques for finding optical constants and assessed their accuracy. From these sources they compiled the optical constants of sodium chloride (2.7.1.19) and aluminum oxide (2.7.1.20.5) in the wavelength ranges 2E-7 to 1E-4 and 2E-7 to 3E-4 meters respectively. The constants of ammonium sulphate were derived partly from values quoted and partly from their own measurements, for the wavelength range 4.05E-7 to 4E-5 meters.

2.7.1.4 Barium Fluoride

Real Refractive Index vs. Wavelength (4.05E-7 to 7.7E-7 meters)
RFXBARF1 to RFXBARF3

Malitson (1964) presented data from a 1944 National Bureau of Standards experiment on the real refractive indices of barium fluoride for nine visible wavelengths in the range 4.05E-7 to 7.68E-7 meters at 15, 35, and 55 degrees C. The uncertainty of these index measurements was estimated at 3E-6. Malitson included data from a 1958 experiment in which he determined values for the real refractive index of a commercially grown barium fluoride prism with refracting angle near 61 degrees. Measurements were made at temperatures near 25 degrees C for 46 calibrated wavelengths of various emission sources and absorption bands from 2.66E-7 meters in the ultraviolet to 1.03E-5 meters in the infrared. Malitson claims that an average absolute residual of 1.9E-5 indicates that values for the index may be interpolated to five decimal places.

2.7.1.5 Cadmium Sulfide

2.7.1.5.1

Real Refractive Index vs. Wavelength (5.12E-7 to 1.4E-6 meters)
RFXCDS1O, RFXCDS1E

Bieniewski and Czyzak (1963) reported their experimental data for the real refractive index, ordinary and extraordinary rays, of zinc (2.7.1.24.1) and cadmium sulfide in the wavelength range 3.6E-7 to 1.4E-6 meters (ZnS) and 5.12E-7 to 1.4E-6 meters (CdS).

2.7.1.5.2

Real Refractive Index vs. Wavelength (5.5E-7 to 1.4E-6 meters)
RFXCDS2O, RFXCDS2E

Czyzak et al. (1957) determined the real refractive index of single synthetic zinc sulfide (2.7.1.24.2, ordinary ray) and cadmium sulfide crystals (ordinary and extraordinary rays) in the wavelength range 4.4E-7 to 1.4E-6 meters (ZnS) and 5.5E-7 to 1.4E-6 meters (CdS). The prisms used were cut to angles between 10 and 15 degrees.

2.7.1.6 Calcite

Complex Refractive Index vs. Wavelength (2E-7 to 6E-6 meters)
RFCXCALCE, RFCXCALCO

Ivlev and Popova (1974) examined the optical constants of various chemical compounds constituting the atmospheric aerosol including calcite, graphite (2.7.1.12), gypsum (2.7.1.13), mascagnite (2.7.1.15), quartz (2.7.1.18.5), sapphire (2.7.1.20.4), and sodium nitrate (2.7.1.23). In the original data tables, Ivlev and Popova left large gaps between data entries (which correspond to "-1" in the Handbook tables), with no directions for proper interpretation. With the exception of three entries for the real index of graphite at 1.1E-6, 1.2E-6, and 1.9E-6 meters, for which the authors entered "?", there are at least two ways in which to interpret the gaps: 1) values were out of range; 2) values did not change from the last entry before the gap, until the next cited index. Additionally, the authors seemingly distinguished between the value of "10^{-X}", where X is any integer, and "1 x 10^{-X}" with the same value for X; we chose not to draw a distinction between the two representations.

The data in RFCXCALCE and any other associated data files are reproduced from Ivlev and Popova (1972) with permission from Plenum Publishing Corporation, copyright holder.

2.7.1.7 Calcium Fluoride

Real Refractive Index vs. Wavelength (4.05E-7 to 7.68E-7 meters)
RFXCAF1 to RFXCAF3

Malitson (1963) reproduced real refractive index data from experiments done at the National Bureau of Standards in 1944. The indices were determined for two samples of synthetic fluorite prisms for nine visible wavelengths (4.05E-7 to 7.68E-7 meters) at temperatures of 15, 35, and 55 degrees C. Malitson states that the real refractive index values of both prisms were averaged. The values were taken from previously published reports by Stockberger and Early (1944) and Stockberger (1949). Malitson states that the uncertainty of these index measurements is estimated at 2E-6.

2.7.1.8 Dust

2.7.1.8.1

Imaginary Refractive Index vs. Wavelength (3E-7 to 1.7E-6 meters)
RFIXDUST1 to RFIXDUST10

Lindberg et al. (1976) determined the imaginary part of the complex refractive index for dust samples from the Panama Canal Zone, Germany, France, Denmark, the Netherlands, Great Britain, Israel, and various locations in the United States in the wavelength range 3E-7 to 1.7E-6 meters. The samples were collected by air filtration using ultra-thin cellulose membranes. Their values for the imaginary index are dependent on the assumption that the specific gravity of the particulate matter is 2.2. The authors claim their values for the index are an underestimate by some amount less than a factor of 2.

Transmission spectroscopy examination of each sample led to the following profiles of sample composition: samples from Europe were often dominated by ammonium sulphate and some strong spectrally broad absorber such as free carbon which led to a relatively high imaginary index in the visible spectrum. Samples from less populated desert areas in the U.S. and Israel showed the presence of silicate clay minerals, quartz, calcite, and gypsum, and proportionately less ammonium sulfate and carbon. Samples from industrial or high population density areas had a significantly higher imaginary index than those from more remote desert locations. This presumably was because urban samples contained more free carbon from various man-made combustion sources, whereas desert areas had a stronger soil component which tended to reduce the overall imaginary index.

2.7.1.8.2

Complex Refractive Index vs. Wavelength (3E-7 to 1.7E-6 meters)
RFCXDUST1 to RFCXDUST3

These tables (Lindberg, 1977) contain imaginary index data from experiments at White Sands Missile Range in New Mexico in the wavelength range 3E-7 to 1.7E-6 meters. Dust from three geographic locations was measured by diffuse reflectance methods. The dry material as collected on cellulose ester membrane filters was dissolved in acetone and centrifuged to recover the particulate matter. The tables contain infrared laser line imaginary index measurements Lindberg obtained using a spectrophone technique.

Lindberg suggests 1.55 as a reasonable estimate for the real refractive index in the 3E-6 to 5E-6 meter region. However the silicate absorption band near the 10E-6 meter region makes both parts of the index strongly wave dependent. (As an example of this, Lindberg suggests an examination of the index values in Peterson & Weinman - see 2.7.1.18.4: "Quartz": RFCXQUA1+).

2.7.1.9 Fly Ash

2.7.1.9.1
No data files.

In September 1970 (Grams et al., 1972) the National Center for Atmospheric Research (NCAR) obtained data on the vertical distribution of particulate material over Boulder, Colorado. Particles from a layer of matter at approximately 13 km differed from normal tropospheric particles. NCAR assumed the particles were fly ash created by forest fires in California during the previous week. Assuming the real part of the refractive index to be 1.55, the imaginary part was estimated at 0.044 +/- 0.001. An analysis of errors due to the expected statistical variability of the number of particles counted and the combined instrumental and measurement errors led to an estimate of approximately 40% error. By considering that the error results in a factor of 1.4 uncertainty, the error in the measurement of the imaginary index is 0.011.

2.7.1.9.2
No data files.

P.B. Russell et al. (1974) measured the angular variation and size distribution of the intensity of light scattered from a collimated beam by airborne soil particles 1.5 meters above the ground. From their measurements they derived an estimate of the complex index of refraction of the soil particles. For the real refractive index, the value 1.525 was taken as representative. By applying Mie scatter theory to each of the observed distributions of particle size, the expected angular variation of the intensity of the scattered light was calculated for a fixed value of the real index and a wide range of values of the imaginary index. For each set of simultaneous measurements the representative value for the imaginary index was taken to be that value which provided the best fit to the experimental data. The upper limit of the value of the imaginary index for the airborne soil particles studied was determined to be 0.005 with an overall uncertainty factor of 2.3.

2.7.1.9.3
No data files.

Wyatt (1980) examined several hundred single fly ash particles. More than 40 particles were suspended in a controlled high humidity environment to permit detailed light scattering measurement. Computerized analyses of the light scattering data from six typical ash particles showed considerable refractive index variation from particle to particle. Refractive indices, both real and complex, were observed spanning the range 1.48 to 1.57 (real) and 0 to 0.1 (imaginary). The accuracy of the values was +/- 0.01 for the real parts and +/- 0.002 for the imaginary.

2.7.1.10 Germanium

2.7.1.10.1
Real Refractive Index vs. Wavelength (2.55E-6 to 1.24E-5 meters)
RFXGERM1 to RFXGERM4

Icenogle et al. (1976) examined the real refractive indices of silicon (2.7.1.22.1, 2.55E-6 to 1.03E-5 wavelength meters) and germanium (2.55E-6 to 1.24E-5 wavelength meters). They stated their errors to be about +/-6E-4 for germanium and +/-3E-4 for silicon. The indices for germanium were taken at temperatures of 297, 275, 204, and 94 kelvins. The indices for silicon were taken at 296, 275, 202, and 104 kelvins.

2.7.1.10.2
Real Refractive Index vs. Wavelength (2.06E-6 to 1.65E-5 meters)
RFXGERM5

Salzburg and Villa (1957) determined data for the infrared real refractive index for single crystal germanium, silicon (2.7.1.22.2), and modified selenium glass (2.7.11.2), at about 27 degrees C. The respective wavelength ranges are 2.06E-6 to 1.6E-5, 1.36E-6 to 1.1E-5, and 1.01E-6 to 1.1E-5, all in meters. They estimate their accuracy of the index measurements to be +/-2 in the fourth decimal place.

2.7.1.11 Glass

2.7.1.11.1
Real Refractive Index vs. Wavelength (3.65E-7 to 2.6E-6 meters)
RFXGLASS1 to RFXGLASS17

Kingslake and Conrady (1937) measured the real refractive indices of 17 different types of 60-degree prism Bausch & Lomb and Parra-Mantois optical glass, in the wavelength range 3.65E-7 to 2.6E-6 meters. They cite their indices as correct to five or six in the fifth decimal place.

NOTE: The Kingslake article contained only the data for glasses 1 through 11. The remainder of the Kingslake-Conrady data was reprinted by Herzberger (1942), where we obtained it. Note that Dr. Herzberger found some minor errors in the far red and near infrared region of the spectrum. These errors resulted from Kingslake's use of some early and slightly inaccurate data on the temperature coefficient of the refractive index of rock salt in calibrating the wavelength scale of his refractometer.

2.7.1.11.2

Real Refractive Index vs. Wavelength (1.01E-6 to 1.1E-5 meters)
RFXGLASS18, RFXGLASS19

See 2.7.1.10.2: "Germanium": RFXGERM5.

2.7.1.11.3

Real Refractive Index vs. Wavelength (5.77E-7 to 1.19E-5 meters)
RFXGLASS20

Rodney et al. (1958) determined the real refractive indices of an arsenic trisulfide prism with refracting angle of 25 degrees in the wavelength range 5.77E-7 to 1.19E-5 meters. The sample was measured at temperatures near 19, 25, and 31 degrees C. The averaged thermal coefficients of the refractive index were used to reduce all data to 25 degrees C.

2.7.1.11.4

Complex Refractive Index vs. Wavelength (4.8E-7 to 6.9E-7 meters)
RFCXGLASS1

The data represent the refractive indices for Corning Glass code 0080/0081 glass in the wavelength range 4.8E-7 to 6.9E-7, as taken from correspondence with Herbert Hoover of Corning Glass Works in Corning, New York. Hoover suggests the best guess for the real refractive index at 6.943E-7 meters is 1.505 +/- 0.003. The large uncertainty allows for the fact that normal variations in manufacturing are occasionally this large. In case the index must be known closer than 0.001, consideration must be given the state of annealing, because rapidly cooled glass has a lower index than well-annealed glass.

Hoover estimates an absorption coefficient for code 0080 glass (having about 0.04% total iron) of 0.14 cm^{-1} in determining refractive indices. He proposes this as a safe upper bound. It should be noted that a substantially clear glass with dissolved iron as a colorant has a smaller spectral absorption coefficient near the middle of the wavelength range (5.5E-7 to 6E-7). Hoover advises if for your use you cannot assume a constant absorption coefficient over the 4.8E-7 to 6.943E-7 meter range, you can make a second approximation by assuming equal values at each end and a value one-half as large at 5.75E-7, and interpolating on a smooth curve through the three points for other values. Since we used the figures derived from an absorption coefficient of 0.14 cm^{-1} for 6.943E-7, all of the other estimates represent upper bounds.

2.7.1.12 Graphite

Complex Refractive Index vs. Wavelength (2.5E-7 to 6E-6 meters)
RFCXGRAPH

See 2.7.1.6: "Calcite".

2.7.1.13 Gypsum

Complex Refractive Index vs. Wavelength (2E-7 to 6E-6 meters)
RFCXGYPS

See 2.7.1.6: "Calcite".

2.7.1.14 KDP (Potassium Dihydrogen Phosphate)

Real Refractive Index vs. Wavelength (2E-7 to 2E-6 meters)
RFXKDPO, RFXKDPE

See 2.7.1.1: "ADP".

2.7.1.15 Mascagnite

Complex Refractive Index vs. Wavelength (2E-7 to 2E-6 meters)
RFCXMASCAG

See 2.7.1.6: "Calcite".

2.7.1.16 Molybdenite

Complex Refractive Index vs. Wavelength (3.3E-4 to 5E-4 meters)
RFCXMOLYB

Meyer (1926) gave the averaged results of experiments which determined the complex refractive index of molybdenite for nine wavelengths in the range 3.3E-4 to 5E-4 meters. Observations were made at various angles of incidence for the same wavelength, (65, 70, and 76 degrees) and averaged. Meyer reported that individual observations varied about 5% from the average.

2.7.1.17 Polystyrene Latex

Complex Refractive Index vs. Wavelength (9.3E-6 to 1.06E-5 meters)
RFCXPLTX1 to RFCXPLTX5

See 2.7.1.3.1: "Ammonium Sulphate": RFCXAMSP1.

2.7.1.18 Quartz

2.7.1.18.1

Real Refractive Index vs. Wavelength (4.96E-5 to 4.95E-4 meters)
RFXQUA1O, RFXQUA1E

Russell and Bell (1967) obtained the real refractive index of crystal quartz in the wavelength range 4.96E-5 to 4.95E-4 meters, with the asymmetric Fourier-Transform method. The extrapolated, zero-frequency real refractive indices are 2.1062 (ordinary), and 2.1538 (extraordinary) with an experimental uncertainty of +/- 0.001.

The total, estimated probable error in the measured values contained in the data table is +/- 0.001, except at frequencies less than 25 cm^{-1} and greater than 175 cm^{-1}, where, the authors claim, the error can be somewhat greater.

2.7.1.18.2

Real Refractive Index vs. Wavelength (1.6E-4 to 3.49E-3 meters)
RFXQUA2

Laikin (1961) measured the real refractive index of a 30-degree synthetic quartz prism for the ordinary ray, in the wavelength range 1.6E-4 to 3.49E-3 meters, at 47 degrees F. The indices were corrected to air. Laikin reported the accuracy of the indices good to 6E-5.

2.7.1.18.3

Real Refractive Index vs. Wavelength (1.44E-7 to 2.31E-7 meters)
RFXQUA3O, RFXQUA3E

Chandrasekharan and Damany (1968) reported the measurements of the ordinary and extraordinary real refractive indices of synthetic quartz in the vacuum ultraviolet in the wavelength range 1.44E-7 to 2.31E-7 meters as deduced from the determination of the orders of interference fringes in a thin parallel plate. The ordinary and extraordinary channeled spectra were obtained by interference in transmission and recorded at room temperature. The authors estimate the absolute error in the indices to be less than 0.001.

2.7.1.18.4

Complex Refractive Index vs. Wavelength (7.68E-7 to 3.6E-5 meters)
RFCXQUA1O, RFCXQUA1E

Peterson and Weinman (1969) tabulated the complex indices of quartz in the wavelength range 7.7E-7 to 3.6E-5 meters. An ensemble of spherical dust particles was utilized in conjunction with Mie theory to determine the extinction coefficient and other optical properties. The data in Peterson and Weinman were originally collected by Spitzer and Kleinman (1961) at a temperature of 24 degrees C. Wavelengths shorter than 5E-6 meters were compiled by D.E. Gray (1963).

2.7.1.18.5

Complex Refractive Index vs. Wavelength (5E-7 to 6E-6 meters)
RFCXQUA2O, RFCXQUA2E

See 2.7.1.6: "Calcite".

2.7.1.18.6

Complex Refractive Index vs. Wavelength (1E-7 to 1.65E-7 meters)
RFCXQUA3, RFCXQUA4

Lamy (1977) gave the near-normal incidence reflectance measurements (complex) of crystal and fused quartz (ordinary ray) in the 1E-7 to 1.65E-7 meter wavelength interval.

2.7.1.19 Salt

Complex Refractive Index vs. Wavelength (2E-7 to 1E-4 meters)
RFCXSALT

See 2.7.1.3.2: "Ammonium Sulphate": RFCXAMSP4.

2.7.1.20 Sapphire

2.7.1.20.1

Real Refractive Index vs. Wavelength (2.54E-7 to 6.91E-7 meters)
RFXSAPPH1O, RFXSAPPH1E

Jeppeson (1958) measured the ordinary and extraordinary real refractive indices for synthetic sapphire at 24 degrees C in the wavelength range 2.54E-7 to 6.91E-7 meters. He reports that between 4E-7 and 6.9E-7 meters the measurements are good to about four parts in the fifth decimal place. This error increases towards the violet.

2.7.1.20.2

Real Refractive Index vs. Wavelength (2.65E-7 to 5.58E-6 meters)
RFXSAPPH2

Malitson (1962) measured the real refractive index of a synthetic sapphire prism, with reflecting angle near 40 degrees, at 46 wavelengths from 2.65E-7 to 5.58E-6 meters at controlled room temperatures near 24 degrees C.

2.7.1.20.3

Real Refractive Index vs. Wavelength (RFXSAPPH3: 2.65E-7 to 4.25E-6, RFXSAPPH4 - 6: 4.05E-7 to 7.07E-7 meters)
RFXSAPPH3 to RFXSAPPH6

Malitson et al. (1958) collected data on the real refractive indices of a synthetic sapphire prism, for the ordinary ray. The indices in the ultraviolet and infrared (2.65E-7 to 4.26E-6 meters) were measured at controlled room temperatures near 19 and 24 degrees C. In the visible region (4.05E-7 to 7.07E-7 meters) measurements were made at three temperatures near 17, 24, and 31 degrees C.

2.7.1.20.4

Complex Refractive Index vs. Wavelength (2E-7 to 6E-6 meters)
RFCXSAPPH1

See 2.7.1.6: "Calcite".

2.7.1.20.5

Complex Refractive Index vs. Wavelength (RFCXSAPPH2O: 2E-7 to 3.3E-4, RFCXSAPPH2E: 9E-6 to 3.3E-4 meters)
RFCXSAPPH2O, RFCXSAPPH2E

See 2.7.1.3.2: "Ammonium Sulphate": RFCXAMSP4.

2.7.1.21 Silica

Real Refractive Index vs. Wavelength (3.65E-7 to 1.53E-6 meters)
RFXSILICA

See 2.7.1.1: "ADP".

2.7.1.22 Silicon

2.7.1.22.1

Real Refractive Index vs. Wavelength (2.55E-6 to 1.03E-5 meters)
RFXSILIC1 to RFXSILIC4

See 2.7.1.10.1: "Germanium": RFXGERM1.

2.7.1.22.2

Real Refractive Index vs. Wavelength (1.36E-6 to 1.1E-5 meters)
RFXSILIC5

See 2.7.1.10.2: "Germanium": RFXGERM5.

2.7.1.23 Sodium Nitrate

Real Refractive Index vs. Wavelength (4E-7 to 7E-7 meters)
RFXSODNITO, RFXSODNITE

See 2.7.1.6: "Calcite".

2.7.1.24 Zinc Sulfide

2.7.1.24.1

Real Refractive Index vs. Wavelength (3.6E-7 to 1.4E-6 meters)
RFXZNS1O, RFXZNS1E

See 2.7.1.5.1: "Cadmium Sulfide": RFXCDS1+.

2.7.1.24.2

Real Refractive Index vs. Wavelength (4.4E-7 to 1.4E-6 meters)
RFXZNS2

See 2.7.1.5.2: "Cadmium Sulfide": RFXCDS2+.

2.7.2 Air

Real Refractive Index vs. Wavelength (2E-7 to 2E-5 meters)
RFXAIR+ (N30,N15,0,15,30)

See 2.6: Rayleigh Coefficients, Air.

2.7.3 Ice

2.7.3.1

Complex Refractive Index vs. Wavelength (9.5E-7 to 1.52E-4 meters)
RFCXICE1

Irvine and Pollack (1968) critically reviewed existing literature on the absorption coefficient and reflectivity of water (2.7.4.5) and ice in the infrared, and chose best values for the complex index of refraction for wavelengths in the range 9.5E-7 to 1.5E-4 meters.

2.7.3.2

Complex Refractive Index vs. Wavelength (2E-6 to 3.3E-5 meters)
RFCXICE2

Schaaf and Williams (1973) measured the normal-incidence spectral absolute reflectance of ice at -7 degrees C in the wavelength range 2E-6 to 3.3E-5 meters (2.8.1). They employed a Kramers-Kronig phase-shift analysis of the measured spectral reflectance to provide values of the real and imaginary parts of the refractive index.

2.7.3.3

Complex Refractive Index vs. Wavelength (1.25E-6 to 3.3E-4 meters)
RFCXICE3

Bertie et al. (1969) measured the absorbance of several samples of Ice Ih at 100 K in the wavelength range 1.25E-6 to 3E-4 meters, and scaled it to that of a particular film of unknown thickness. They obtained the complex index, permittivity, and the normal incidence reflectivity from the absorptivity and from Kramers-Kronig relations.

2.7.3.4

Complex Refractive Index vs. Wavelength for Ice, Microwave Range. See 3.2.7.3: "Data File Formats" for wavelength ranges.
RFICEM+ (N50,N30,N10,0) (accessed by program MICRO)
(Note that additional microwave ice refractive index data were acquired after the completion of program MICR0, and thus are not available to the user through the program. See 2.7.3.6.)

Program MICRO handles microwave refractive indices for water and ice as a function of wavelength at different temperatures, using data taken from the following sources:

Ryde and Ryde (1945) found values for the complex refractive index of ice in the millimeter and microwave region using a combination of the Debye formula and constants taken from Saxton (1945) and Dunsmuir and Lamb (1945).

Lane and Saxton (1952) measured the refractive index of water at 6.2 micrometers, 1.24 cm, and 3.21 cm over the temperature range -10 to 50 degrees C. They used the Debye formula, as well as a method based on the fact that the rate of attenuation of radio frequency energy along a wave guide filled with the liquid is dependent upon both the absorption coefficient and the refractive index when the guide is operated near to cut-off conditions. The authors believe their measurements to be accurate to about +/- 1%.

Collie et al. (1948) measured the dielectric constant and loss angle of water and heavy water at widely separated wavelengths in the region of anomalous dispersion. In addition to the Debye formula, they used a method involving the observation of the attenuation in transmission through wave guides of differing cross-sectional dimensions containing the liquid.

The data taken from Collie et al. (1948) are reproduced with permission from the Institute of Physics, copyright holder.

Deirmendjian (1963) calculated the complex index for water and ice at two temperatures by means of the Debye formula.

2.7.3.5

Complex Refractive Index vs. Wavelength (4.43E-8 to 1.67E-4 meters)
RFCXICE4

Warren (1984) compiled the optical constants of Ice Ih for temperatures within 60 degrees of the melting point in the wavelength range 4.43E-8 to 1.67E-4 meters. The imaginary part of the complex index of refraction is obtained from measurements of spectral absorption coefficients; the real part is computed to be consistent with the imaginary part by use of known dispersion relations.

Warren states that the compilation of the imaginary part requires subjective interpolation in the near ultraviolet and microwave, a temperature correction in the far-infrared, and a choice between two conflicting sources in the near-infrared.

Warren advises that for intermediate wavelengths not given in the table one should interpolate the real index linearly in the log of the wavelength and the log of the imaginary index linearly in the log of the wavelength.

2.7.3.6

Complex Refractive Index vs. Wavelength (1.67E-4 to 8.6 meters)
RFCXICE5 to RFCXICE8

Warren (1984) found the complex refractive indices of Ice Ih for four temperatures: -1, -5, -20, and -60 degrees C, in the wavelength range 1.67E-4 to 8.6 meters. For intermediate wavelengths Warren advises interpolating the real index linearly in the log of the wavelength, the log of the imaginary index linearly in the log of the wavelength, the real index linearly in the temperature, and the log of the imaginary index linearly in the temperature. See also 2.7.3.5.

2.7.4 Liquid Water

2.7.4.1

Complex Refractive Index vs. Wavelength (5.46E-7 to 2.53E-5 meters)
RFCXH2O1

Data in this table were compiled from various experiments by Zuev et al. (1974) in the 5E-7 to 2.53E-5 meter wavelength interval for pure water at 18 to 20 degrees C. In the original data tables, Zuev left gaps between numerous data entries; in preparing RFCXH2O1, a cubic interpolation routine was used to approximate these missing data values. In the event that finer accuracy is needed, the real refractive indices at the following wavenumbers (cm^{-1}) should be modified using the measured real indices of the wavenumbers that bound these ranges with a more precise interpolation method: 18100-17550, 17200-16700, 16450-16350, 16200-16000, 15800-15700, 15500-15100, 14900, 14600, 14300, 14100, 13850-13550, 13300-13150, 12900-12650, 12400-12150, 11950, 11700, 11450, 11200, 10900, 10650, 10350, 10100, 9800, 9500, 9190, 8900, 8600, 8320, 8060, 7800, 7540, 7275, 7100, 6660, 6470, 6200, 5880, 5635, 5602, 5376, 5277, 5165, 5040, 4938, 4830, 4746, 4646, 4546, 4446, 4346, 4296, 4196, 4146. For example, if greater accuracy is needed in a wavenumber range including 18100-17550, take the wavenumbers preceding 18100 and following 17550, 18300 and 17400, and use them and any other neighboring measured values not included in the above list of ranges in the interpolation method of your choice. The real refractive indexes at wavenumbers in the above ranges were calculated using cubic interpolation.

The data in RFCXH2O1 are reproduced from Zuev et al. with permission of Keter Publishing House Ltd., copyright holder.

2.7.4.2

Complex Refractive Index vs. Wavelength (2E-7 to 2E-4 meters)
RFCXH2O2

Hale and Querry (1973) determined extinction coefficients for water at 25 degrees C through a broad spectral region by manually smoothing a point-by-point graph of extinction coefficients vs. wavelength, that was plotted for data obtained from a review of the scientific literature on the optical constants of water. Where data in the vacuum UV and soft X-ray regions were not available, they postulated absorption bands representing extinction coefficients. A subtractive Kramers-Kronig analysis of the combined postulated and smoothed portions of the extinction coefficient spectrum provided the index of refraction for the spectral wavelength region 2E-7 to 2E-4 meters.

2.7.4.3

Complex Refractive Index vs. Wavelength (2E-6 to 1E-3 meters)
RFCXH2O3

Downing and Williams (1975) compiled values for the optical constants of liquid H_2O from current studies. Their values were based primarily on a study by Robertson et al. (1971) which measured Lambert absorption coefficients, and a Rusk et al. (1971) experiment measuring spectral reflectance at near normal incidence. They used the work of Palmer and Williams (1974) in the near infrared and the work of National Physical Labs in the extreme infrared (100 to 20 cm^{-1}). They determined real and imaginary indices in other regions using Fresnel's equation and Kramers-Kronig analysis. All the data were obtained for liquid H_2O at 27 degrees C in the wavelength range 2E-6 to 1E-3 meters.

2.7.4.4

Complex Refractive Index vs. Wavelength (9.6E-6 to 1.05E-5 meters)
RFCXH2O4

See 2.7.1.3.1: "Aerosols": Ammonium Sulphate: RFCXAMSP1.

2.7.4.5

Complex Refractive Index vs. Wavelength (2E-7 to 2E-4 meters)
RFCXH2O5

See 2.7.3.1: "Ice": RFCXICE1.

2.7.4.6

Complex Refractive Index vs. Wavelength (2E-6 to 2E-5 meters)
RFCXH2O6 to RFCXH2O11

By using distilled water as the standard reflection, Querry et al. (1977) measured the relative specular reflectance spectra in the 2E-6 to 2E-5 meter wavelength region of the infrared for surface water samples collected from San Francisco Bay, the Pacific and Atlantic Oceans, the Great Salt Lake (Utah), the Dead Sea (Israel), and an effluent phosphate mine in central Florida (2.8.2). They compiled spectral values for the complex refractive index for each water sample by applying a Kramers-Kronig analysis to the relative reflectance spectra. For a chemical analysis of the monatomic and polyatomic ions of the natural waters, refer to the original article.

2.7.4.7

Complex Refractive Index vs. Wavelength for water in the microwave range. See 3.2.7.4: "Data File Formats" for wavelength ranges.
RFH2OM+ (N8,0,10,18,20,30,40,50,60,75) (accessed by program MICRO)

See 2.7.3.4:"Ice": RFICEM+ (microwave ice files).

2.8 RELATIVE REFLECTANCE: ICE, WATER

2.8.1

Relative Reflectance (dimensionless) vs. Wavelength (2E-6 to 3.3E-5 meters) for Ice
RRXICE1

See 2.7.3.2: "Ice": RFCXICE2.

2.8.2

Relative Reflectance (dimensionless) vs. Wavelength (2E-6 to 2E-5 meters) for Water
RRXH2O1 - 6

See 2.7.4.6: "Liquid Water": RFCXH2O6.

3. DATA FILE AND COMPUTER TAPE INFORMATION

3.1 GUIDE [GUIDE, 4]

3.1.1 Introduction to Tape Organization

A single data set is referred to as a data file. Each separate data file comprises one computer tape file. Sections of informational text such as the data descriptions and data file and computer tape information, are also divided into distinct computer tape files.

Section 2, the Data Description (tape file 3) contains brief descriptions of each atmospheric area covered by the Handbook data files: definition of data file variables, ranges, and units, listing of data file names, and description of data source. Section 3.1, the Guide, (tape file 4) gives general user notes and technical information needed to access or understand the computer tape, data files, and computer programs. Section 3.2, Data File Formats (tape file 5), summarizes technical information on each data file in tabular form: data file variable definitions, units, and ranges in the order in which they appear on each line of a given data file, FORTRAN format statements used to create the data files, temperature, source, and computer tape file number. Appendix A (tape file 0) contains a list of all data files on the Handbook tape along with their corresponding tape file numbers. Appendix B (tape file 9) briefly describes the contents of single or groups of files on the tape. The computer programs for retrieving attenuation coefficient data and microwave refractive index data are located in tape files 171-187 and 188-217 respectively.

There are numerous cross references throughout the Handbook between section name and number and tape file name and number, both at the beginning of a section and within the text. In general, the tape file name (in capital letters) and number are given in brackets following a section name.

A typical use of the Atmospheric Handbook might entail three steps:

(1) Find the area of interest in the table of contents. Look up and read about your topic in the data description, section 2. Take note of the pertinent file name(s).

(2) Read through the Guide until any general technical questions you may have are answered and you are familiar with the data file formats, notation, and composition. Look up the specific format, parameter, and tape file number information on your desired files in Data File Formats.

(3) Load the file(s) from the tape onto your disk.

3.1.2 Data File Structure

Each tape file corresponds to a single data file. In general, sections of files are grouped according to atmospheric area. All tape files contain no more than 80 characters per line.

Numerical values in the data files are arranged in increasing order, where applicable. Data values of "-1" indicate the value was not given in the original source. The first line of all data files, except those associated with programs ATTENCOEF and MICRO, is informational text, in most cases identifying the data type, substance, and source. Precaution should be taken to read over or delete this line when accessing disk files after they have been loaded from the tape.

3.1.3 Deciphering File Names

File names consist of capital letters, numbers, and the delimiter "X". The "X" is used as one might use a period to visually, or logically, break up the parts of information used in naming files. Within the informational text of the Handbook, three types of abbreviating methods are used to refer to sets of data files with similar names. A "+" following a file name and preceding a parenthesized set of numbers indicates an alphanumeric extension; it is not part of the actual file name; e.g., "FIL+(1A,2,3)" refers to three files, "FIL1A", "FIL2", and "FIL3". A "+" following a file name not followed by a parenthesized set of numbers indicates an alphanumeric extension of some type; the specific type isn't pertinent in the given context. A file name ending in the character set "E,O", such as "FILE,O", actually refers to two separate data files, "FILE" with data for the Extraordinary ray, and "FILO" with data for the Ordinary. An entry such as "FIL1 - 4" refers to four distinct files; the dash is not part of the actual data file name.

On some computer systems the length of the file names as given will be too long. All data file names are intended only as suggestions. At the time of loading a file from the tape onto disk, the naming of the file is at the discretion of the user.

The refractive index data file name prefixes "RF", "RFI", and "RFC" refer to real, imaginary, and complex refractive index data sets, respectively.

3.1.4 Unit Notation

All Handbook data files are uniformly in Systeme Internationale Units ("MKS": Meters, Kilograms, Seconds) with the exception of: the attenuation coefficient data files, for which altitude is measured in kilometers, and absorption and scattering are measured per kilometer; and the standard atmosphere data files for which altitude, pressure, temperaure, and density are measured in kilometers, millibars, kelvins, and molecules per cubic centimeter, respectively.

A double asterisk, "**", stands for "raised to the power of", e.g., "m**-3 m**-1" means "per meter cubed per meter". In a numerical context, the letter "E" refers to exponent, e.g., "2.5E-3" means "2.5 x 10^{-3}", where "x" is multiplication.

3.1.5 Significant Figures

In instances where our data sources reported an error estimate for their experiments, this estimate was included in the data description. Our refractive index and relative reflectance data have six digits after the decimal. This large number of significant figures was implemented to ensure sufficient space for increased accuracy in the event of interpolation on small computer systems. In most cases the refractive index data are good to 3 or 4 decimal places. Generally, Handbook data with 4 digits after the decimal can be considered significant to 2 to 3 places, unless otherwise specified. The original source should be consulted by those to whom the accuracy precision is important. The number of figures quoted in the tables is not a good guide to significance.

3.1.6 Computer Programs: ATTENCOEF (files 171-187) and MICRO (files 178, 188-217)

Program ATTENCOEF gives the attenuation coefficients as a function of altitude for five atmospheric and two aerosol models. The altitude range is 0 to 85 kilometers, and wavelength = 0.6943 micrometers. Program MICRO gives the refractive indices for select water and ice data in the microwave region. Both programs were written following standard FORTRAN 77 guidelines; however some Data General FORTRAN V options were used. The drivers of both programs list all non-standard FORTRAN characteristics; for easy identification their occurrences within the program are delimited by a "C" in column one followed by a series of "+" signs. Additionally, non-standard format codes are listed by their statement label in the comment section at the beginning of each subroutine. Make sure to load all the files belonging to a program from the tape, or the programs won't run. Additional ice refractive index data for the microwave region, located in files 222-225, were acquired after the completion of program MICRO, and thus are not available to the user through the program.

Program ATTENCOEF will request the following information:

(1) ATTENCOEF retrieves attenuation and scattering coefficients using user-entered parameters for atmospheric and aerosol types, and altitude. Do you want to enter each set of these three parameters individually, or multiply into an array? The maximum length for this array is 100.

(2) Would you like your results typed to the screen, sent to a diskfile, or both? When either of the diskfile options are used, input is sent to one standard diskfile. Care should be taken to rename this file before subsequent runs of the program occur.

(3) What atmospheric type: tropical, midlatitude summer, midlatitude winter, subarctic summer, or subarctic winter?

(4) What altitude(s) in the 0.0 to 85.0 km range?

(5) What aerosol type: clear or hazy?

(6) You may be asked to make a choice between the coefficients nearest the altitude requested or the values derived from using a linear interpolation which approximates these coefficients by using available heights.

(7) If (in response to question 1) you have been entering data parameters singly, after you receive the attenuation coefficients requested you may a) continue, using a different altitude, b) continue, using a different atmosphere, c) continue, but transfer to array entry mode, or d) terminate. If already in array entry mode, once your data parameter array has been exhausted, you may either start over in the entry mode of your choice or terminate.

Program MICRO will request the following information:

(1) Would you like your results typed to the screen, sent to a diskfile, or both? If either of the diskfile options are used, output is sent to one standard file. Care should be taken to rename this file before subsequent runs of the program occur.

(2) Do you want refractive indices for water or ice?

(3) The refractive indices are separated according to temperature and then sorted by wavelength. Do you want to request each temperature individually, or enter multiple temperatures into an array? Temperatures are in degrees C.

(4) You will be shown the entire data file for each temperature requested. If using the diskfile option, you may have this entire file sent to disk. You will be asked if you would like interpolations between any of the wavelengths shown. These wavelengths must be entered in meters. Because of the spareness of data in the microwave region, interpolation may not be accurate.

(5) If you have been entering temperatures singly, you have the choice to repeat step 4 with another temperature. Otherwise, you have the choice to repeat steps 2-4 or to terminate.

The effort to make these programs easily adapted by computer systems other than the one it was written on resulted in cumbersome interactive user-input formats. Special care must be taken to enter data exactly as specified in the programs' main routines.

The parameter lists for subroutine and function statements and calls in programs ATTENCOEF and MICRO were based on specifications as described in "A Technique for Making FORTRAN Programs More Readable" (J. Tant Priestley, NOAA, Wave Propagation Laboratory, unpublished). All parameter lists are divided into, and conform exactly with, the following categories: inputs, inputs/outputs, outputs. Priestley defines these categories:

(1) Input - arguments that transmit information into the subprogram but whose values remain unchanged on output.

(2) Input/Output - arguments used to transmit information both into and out of the subprogram, plus any other arguments that do not fit into categories 1 or 3.

(3) Output - arguments that transmit information out of the subprogram but no information into the subprogram; their values on input are irrelevant.

To distinguish between the three argument categories when referencing subprograms, the arguments are ordered according to category, and the categories separated by spaces. Priestley gives the following rules to ensure an unambiguous and uniform use of spaces: inputs are followed by a space, inputs/outputs are bracketed by spaces, and outputs are preceded by a space. Any double spaces are merged into a single space. Note that it is each category, not each individual argument, that is delimited by a space.

Consult the main routines of each program for examples and additional useful information.

3.1.7 Data Retrieval Example

"I have briefly read the Handbook Guide. I would like some microwave refractive index data for ice. How do I find it?"

Looking at the Contents, note that section 2.7.3 contains the description of data for the refractive indices of ice in the optical, infrared, and microwave regions, and section 3.2.7.3 contains the data file format information. In 2.7.3 read about the sources of the data. Notice that there are two sets of microwave data, one which is handled by program MICRO. In 3.2.7.3, the entry key explains the data files' variables and their units, and the format key shows the FORTRAN format statements used to create the files. Check the wavelength and temperature ranges that the data files cover, and note the data tape file numbers. Then turn back to the Guide to read the section on using program MICRO, which will retrieve select data. The final step is to load the desired files from the tape onto your disk.

3.1.8 Data Table Examples

File Name, Entry Key, and Range information was taken from "Data File Formats" (section 3.2) and is not part of the data file. The first line of the data file contains identifying information in capital letters.

Example 1:

File Name: RFXQUA2

Entry Key: Sequence #, Wavelength(m), wavenumber (cm^{-1}), Real Refractive Index (dimensionless)

Range: 1.6E-4 to 3.49E-3 meters

```
REFRACTIVE INDICES: SYNTHETIC QUARTZ, 47 DEGREES F. (LAIKIN)
    1    1.596060E-04    6.265430E 01    1.760350E 00
    2    1.616580E-04    6.185900E 01    1.750650E 00
    3    1.644390E-04    6.081282E 01    1.738620E 00
    4    1.647690E-04    6.069102E 01    1.737310E 00
    5    1.651790E-04    6.054040E 01    1.735740E 00
    6    1.849500E-04    5.406880E 01    1.677210E 00
    7    1.942300E-04    5.148540E 01    1.659060E 00
    8    2.378320E-04    4.204660E 01    1.608930E 00
    9    2.536520E-04    3.942413E 01    1.598390E 00
   10    2.652040E-04    3.770683E 01    1.592110E 00
   (etc.)
```

Example 2:

File Name: MLS

Entry Key: Sequence #, Altitude (km), Pressure (mb), Temp. (K), Density (mols cm^{-3}) for H_2O, CO_2, O_3, N_2O, CO, CH_4, O_2, N_2

Range: 0 to 100 km

```
STANDARD ATMOSPHERE - MIDLATITUDE SUMMER
    1       .0  1.0130E 03  2.9400E 02  4.6810E 17  8.0840E 15  7.5300E 11
                6.8590E 12  1.8370E 12  3.9190E 13  5.1320E 18  1.9130E 19
    2      1.0  9.0200E 02  2.9000E 02  3.1100E 17  7.3340E 15  7.5300E 11
                6.2230E 12  1.6670E 12  3.5560E 13  4.6560E 18  1.7360E 19
    3      2.0  8.0200E 02  2.8500E 02  1.9730E 17  6.6630E 15  7.5300E 11
                5.6540E 12  1.5140E 12  3.2310E 13  4.2300E 18  1.5770E 19
    4      3.0  7.1000E 02  2.7900E 02  1.1030E 17  6.0480E 15  7.7810E 11
                5.1320E 12  1.3750E 12  2.9320E 13  3.8400E 18  1.4310E 19
    5      4.0  6.2800E 02  2.7300E 02  6.3530E 16  5.4790E 15  8.0320E 11
                4.6490E 12  1.2450E 12  2.6570E 13  3.4780E 18  1.2970E 19
   (etc.)
```

3.2 DATA FILE FORMATS [FORMATS, 5]

This section contains technical information on each data file in tabular form: data file variable definitions, units, and ranges, Data General FORTRAN V format statement used to create the file(s), temperature, source, and computer tape file number. We have used scientific notation here in keeping with the style and format of our data files.

Entry Key:

The entry key contains explanations of the variables and their units in the order in which they appear in the data files. A double asterisk, "**", stands for "raised to the power of"; e.g., "m**-3 m**-1" means "per meter cubed per meter".

Format:

The format section contains the Data General FORTRAN V format code used to generate a given data file. The scale factor "P" changes the location of the decimal point in the external representation of a real number, with respect to its internal value. The format is "nP", where n is an integer constant that specifies the number of positions you want to move the decimal point to the right.

3.2.1: Attenuation Coefficients

3.2.1.1: Atmospheric Attenuation Coefficients (program ATTENCOEF)

Entry Key: With the exception of ATTENHT, which is a file of altitude (km), the entries are: absorption (km^{-1}), and scattering (km^{-1}). These values are in a one-to-one correspondence with the altitudes in file ATTENHT.

Format: ATTENHT - [F7.1], all others [2(2X,1PE11.4)]

File Name	Range	Temp.	Source/ Tape File #
ATTENHT	0 - 85 (km)	----	McClatchey et al.(1972)/180
AERXCLR	"	----	"/ 181
AERXHAZ	"	----	"/ 182
MIDLATSUM	"	----	"/ 183
MIDLATWIN	"	----	"/ 184
SUBARCSUM	"	----	"/ 185
SUBARCWIN	"	----	"/ 186
TROPIC	"	----	"/ 187

3.2.1.2: Attenuation and Scattering: Water

Entry Key: sequence #, wavelength (m), attenuation (m^{-1}), scattering (m^{-1})

Format: [I5,3(2X,1PE10.4)]

File Name	Range	Temp.	Source/ Tape File #
H2OXATTENSCAT	3.75E-7 - 8E-7	----	Jerlov (1968)/10

3.2.2: Standard Atmospheres

Entry Key: sequence #, altitude (km), pressure (mb), temp. (K), density (mols cm^{-3}) for H_2O, CO_2, O_3, N_2O, CO, CH_4, O_2, N_2.

Format: [I5,2X,F7.1,5(2X,1PE10.4)] (lines with sequence #)
[14X,5(2X,1PE10.4)] (lines without sequence #)

File Name	Range	Temp.	Source/ Tape File #
MLS	0 - 100 (km)	----	Program FSCDATM (1981)/ 11
MLW	"	----	"/ 12
SAS	"	----	"/ 13
SAW	"	----	"/ 14
TROPICAL	"	----	"/ 15
USXSTAN	"	----	"/ 16

3.2.3: Cloud Drop Size Distributions

Entry Key: sequence #, number density of drops or ice particles (m^{-3} m^{-1}), begining radius (m), ending radius (m)

Format: [I5,3(2X,1PE10.4)]

File Name	Range	Temp.	Source/ Tape File #
CLOUD1	1E-7 - 1.6E-5	----	Carrier et al. (1965, 1967)/17
CLOUD2	1E-7 - 1.07E-5	----	"/ 18
CLOUD3	1E-7 - 1E-5	----	"/ 19
CLOUD4	1E-7 - 2E-5	----	"/ 20
CLOUD5	1E-7 - 3E-5	----	"/ 21
CLOUD6	1E-7 - 1.6E-5	----	"/ 22
CLOUD7	1E-7 - 2E-5	----	"/ 23
CLOUD8	1E-7 - 1.3E-5	----	"/ 24
CLOUD9	1.5E-6 - 7.5E-5	----	Schickel (1975)/25
CLOUD10	1E-6 - 5E-5	----	Heymsfield (1975)/ 26
CLOUD11	5E-5 - 5E-4	----	"/ 27
CLOUD12	3E-6 - 1.3E-5	----	Heymsfield & Jahnsen (1974)/28
CLOUD13	3.97E-7 - 3.97E-5	----	Kraus & Barnes (1976b)/29
CLOUD14	3.97E-7 - 2E-4	----	Kraus & Barnes (1976a)/30
CLOUD15	3.97E-7 - 1.58E-4	----	Barnes (1977)/ 31
CLOUD16	8.05E-6 - 5.64E-4	----	Glass & Varley (1978)/32
CLOUD17	1E-6 - 8.6E-4	----	Varley & Brooks (1978)/33
CLOUD18	1E-6 - 3.1E-5	----	34

3.2.4: Solar Spectral Irradiance

Entry Key: sequence #, wavelength (m), solar spectral irradiance (watts m^{-2} m^{-1})

Format: [I5,2(2X,1PE11.4)]

File Name	Range	Temp.	Source/ Tape File #
FLUX1	1.2E-7 - 1E-4	----	Thekaekara (1972)/ 35
FLUX2	2.5E-10 - 1.95E-2	----	Smith & Gottlieb (1974)/ 36

3.2.5: Sky Spectral Radiance

Entry Key: sequence #, wavelength (m), spectral radiance (watts m^{-2} m^{-1})
NOTE: This quantity is spectral radiance density: watts per square meter, per meter of wavelength.

Format: [I5,2(2X,1PE11.4)]

File Name	Range	Temp.	Source/ Tape File #
SKYBACSL	3.1E-7 - 7.2E-7	----	Clark (1969)/37
SKYBAC10	"	----	"/ 38

3.2.6: Rayleigh Coefficients: Air

Entry Key: MASSXSCAT - sequence #, wavelength (m), mass scattering coefficient (m^2 kg^{-1})
: VOLXSCAT - sequence #, wavelength (m), volume scattering coefficient (m^{-1})
: RAYXSCATCROSS - sequence #, wavelength (m), scattering cross section (m^2)

Format : [I5,2(2X,1PE10.4)]

File Name	Range	Temp.	Source/ Tape File #
MASSXSCAT	2E-7 - 2E-5	0°C	Penndorf (1957)/39
VOLXSCAT	"	"	"/ 40
RAYXSCATCROSS	"	"	"/ 41

3.2.7 Refractive Indices: Aerosols, Air, Ice, Liquid H_2O (in alphabetic order)

NOTE: The file name prefixes "RF", "RFI", and "RFC" refer to real, imaginary, and complex refractive index files, respectively, with the exception of the microwave files used by program MICRO, which contain complex data. Aerosol files are divided into these three data types, and then listed alphabetically within these categories.

File names preceded by "**" indicate they are the microwave refractive index files, used in program MICRO; these asterisks are not part of the file name.

Entry Key: RF+ files: sequence #, wavelength (m), wavenumber (cm^{-1}), real refractive index
: RFI+ files: sequence #, wavelength (m), wavenumber (cm^{-1}), imaginary refractive index
: RFC+ files: sequence #, wavelength (m), wavenumber (cm^{-1}), real refractive index, imaginary refractive index
: MICRO files: sequence #, wavelength (m), real refractive index, imaginary refractive index, source (real index), source (imaginary index)

Format: RF and RFI files: [I5,3(2X,1PE13.6)]
: RFC files: [I5,4(2X,1PE13.6)]
: Microwave files: [I5,3(2X,1PE13.6),2(5X,A2)]

3.2.7.1: Aerosols

File Name	Range	Temp.	Source/ Tape File #
RFXADPE,O	2E-7 - 2E-6	24°C	Zernike (1964)/42, 43
RFXBARF1 - 3	4.05E-7 - 7.68E-7	15,35,55°C	Malitson (1964)/49 - 51
RFXBARF4	2.65E-7 - 1.03E-5	25°C	"/ 52
RFXCAF1 - 3	4.05E-7 - 7.68E-7	15,35,55°C	Malitson (1963)/59 - 61
RFXCDS1E,O	5.12E-7 - 1.4E-6	----	Bieniewski & Czyzak (1963)/53, 54
RFXCDS2E,O	5.5E-7 - 1.4E-6	----	Czyzak et al. (1957)/ 55, 56
RFXGERM1 - 4	2.55E-6 - 1.24E-5	297,275, 204, 94 K	Icenogle et al. (1976)/75 - 78
RFXGERM5	2.06E-6 - 1.6E-5	27°C	Salzburg & Villa (1957)/ 79
RFXGLASS1 - 17	3.65E-7 - 2.6E-6	----	Kingslake & Conrady (1937)/80 - 96
RFXGLASS18,19	1.01E-6 - 1.1E-5	27°C	Salzburg & Villa (1957)/ 97, 98
RFXGLASS20	5.77E-7 - 1.19E-5	25°C	Rodney et al. (1958)/ 99
RFXKDPE,O	2E-7 - 2E-6	24°C	Zernike (1964)/103, 104
RFXQUA1E,O	4.96E-5 - 4.95E-4	----	Russell & Bell (1967)/ 112, 113
RFXQUA2	1.6E-4 - 3.49E-3	47°F	Laikin (1961)/114
RFXQUA3E,O	1.44E-7 - 2.31E-7	----	Chandrasekharan & Damany (1968)/115, 116
RFXSAPPH1E,O	2.54E-7 - 6.91E-7	24°C	Jeppeson (1958)/124, 125
RFXSAPPH2	2.65E-7 - 5.58E-6	24°C	Malitson (1962)/126
RFXSAPPH3	2.65E-7 - 4.25E-6	19°C	Malitson et al. (1958)/ 127
RFXSAPPH4 - 6	4.05E-7 - 7.07E-7	17,24,31°C	"/ 128-130
RFXSILIC1 - 4	2.55E-6 - 1.03E-5	296,275, 202, 104 K	Icenogle et al. (1976)/135 - 138
RFXSILIC5	1.36E-6 - 1.1E-5	26°C	Salzburg & Villa (1957)/139
RFXSILICA	3.65E-7 - 1.53E-6	----	Zernike (1964)/134
RFXSODNITE,O	4E-7 - 7E-7	----	Ivlev & Popova (1974)/ 140, 141
RFXZNS1E,O	3.6E-7 - 1.4E-6	----	Bieniewski & Czyzak (1963)/142, 143
RFXZNS2	4.4E-7 - 1.4E-6	----	Czyzak et al. (1957)/ 144
RFIXDUST1 - 10	3E-7 - 1.7E-6	----	Lindberg et al. (1976)/62 - 71
RFCXAMSP1 - 3	9.3E-6 - 9.5E-6	24°C	Jennings (1981)/45 - 47
RFCXAMSP4	4.05E-7 - 4E-5	----	Toon et al. (1976)/ 48
RFCXCALCE,O	2E-7 - 6E-6	----	Ivlev & Popova (1974)/ 57,58
RFCXDUST1 - 3	3E-7 - 1.7E-6	----	Lindberg (1977)/72 - 74
RFCXGLASS1	4.8E-7 - 6.9E-7	----	Hoover/ 100
RFCXGRAPH	2.5E-7 - 6E-6	----	Ivlev & Popova (1974)/ 101
RFCXGYPS	2E-7 - 6E-6	----	"/ 102
RFCXMASCAG	"	----	"/ 105
RFCXMOLYB	3.3E-4 - 5E-4	----	Meyer (1926)/106
RFCXPLTX1 - 5	9.3E-6 - 1.06E-5	24°C	Jennings (1981)/107 - 111
RFCXQUA1E,O	7.68E-7 - 3.6E-5	"	Peterson & Weinman (1969)/117, 118
RFCXQUA2E,O	5E-7 - 6E-6	----	Ivlev & Popova (1974)/119, 120
RFCXQUA3,4	1E-7 - 1.65E-7	----	Lamy (1977)/121, 122
RFCXSALT	2E-7 - 1E-4	----	Toon et al. (1976)/ 123
RFCXSAPPH1	2E-7 - 6E-6	----	Ivlev & Popova (1974)/131
RFCXSAPPH2E	9E-6 - 3.3E-4	----	Toon et al. (1976)/ 132
RFCXSAPPH2O	2E-7 - 3.3E-4	----	"/ 133
RFCXSYNAER	4E-7 - 1.5E-5	----	Ivlev & Popova (1973)/ 44

3.2.7.2 Air

RFXAIRN30	2E-7 - 2E-5	-30°C	Penndorf (1957)/ 145
RFXAIRN15	"	-15°C	"/ 146
RFXAIR0	"	0°C	"/ 147
RFXAIR15	"	15°C	"/ 148
RFXAIR30	"	30°C	"/ 149

3.2.7.3 Ice

RFCXICE1	9.5E-7 - 1.52E-4	----	Irvine & Pollack (1968)/ 150
RFCXICE2	2E-6 - 3.3E-5	-7°C	Schaaf & Williams (1973)/ 151
RFCXICE3	1.25E-6 - 3.3E-4	100 K	Bertie et al. (1969)/152
RFCXICE4	4.43E-8 - 1.67E-4	-7°C	Warren (1984)/ 221
RFCXICE5	1.67E-4 - 8.6	-1°C	" 222
RFCXICE6	"	-5°C	" 223
RFCXICE7	"	-20°C	" 224
RFCXICE8	"	-60°C	" 225
** RFICEMN50	3E-2 - 1E-1	-50°C	Ryde & Ryde (1945)/ 204
** RFICEMN30	"	-30°C	"/ 205
** RFICEMN10	"	-10°C	"/ 206
** RFICEM0	"	0°C	"/ 207

3.2.7.4 Liquid H_2O

File Name	Range	Temp.	Source/ Tape File #
RFCXH2O1	5.46E-7 - 2.53E-5	18-20°C	Zuev et al. (1974)/ 153
RFCXH2O2	2E-7 - 2E-4	25°C	Hale & Querry (1973)/ 154
RFCXH2O3	2E-6 - 1E-3	27°C	Downing & Williams (1975)/ 155
RFCXH2O4	9.6E-6 - 1.05E-5	24°C	Jennings (1981)/ 156
RFCXH2O5	2E-7 - 2E-4	----	Irvine & Pollack (1968)/157
RFCXH2O6	2E-6 - 2E-5	300 K	Querry et al. (1977)/ 158
RFCXH2O7	"	"	"/ 159
RFCXH2O8	"	"	"/ 160
RFCXH2O9	"	"	"/ 161
RFCXH2O10	"	"	"/ 162
RFCXH2O11	"	"	"/ 163
** RFH2OMN8	6.2E-3 - 3.21E-2	-8°C	Lane & Saxton (1952)/ 208
** RFH2OM0	5E-3 - 1E-1	0°C	Ryde & Ryde (1945); Lane & Saxton (1952); Collie et al. (1948); Deirmendjian (1963)/ 209
** RFH2OM10	1E-3 - 1E-1	10°C	"/ 210
** RFH2OM18	5E-3 - 1E-1	18°C	Ryde & Ryde (1945)/ 211
** RFH2OM20	"	20°C	Ryde & Ryde (1945); Lane & Saxton (1952); Collie et al. (1948)/ 212
** RFH2OM30	"	30°C	"/ 213
** RFH2OM40	"	40°C	"/ 214
** RFH2OM50	6.2E-3 - 1E-1	50°C	Lane & Saxton (1952); Collie et al. (1948)/ 215
** RFH2OM60	1.27E-2 - 1E-1	60°C	Collie et al. (1948)/ 216
** RFH2OM75	"	75°C	"/ 217

3.2.8 Relative Reflectance: Ice, H_2O

Entry Key: sequence #, wavelength (m), relative reflectance
Format: [I5,2(2X,1PE13.6)]

File Name	Range	Temp.	Source/ Tape File #
RRXH2O1 - 6	2E-6 - 2E-5	----	Querry et al. (1977)/ 165 - 170
RRXICE1	2E-6 - 3.3E-5	-7°C	Schaaf & Williams (1973)/ 164

4. ACKNOWLEDGMENTS [THANKS, 6]

Much gratitude is owed to Margot Ackley for her professional aid in giving the project a firm basis and a good start. Without a succession of devoted students, Kris Yoshida, Karen Umemoto, and Denise Nagode, the effort would have foundered. The editing talents of Lindsay Murdock of NOAA and Helen Coffey of NESDIS contributed to a grammatically intact publication. Above all, hard and intelligent work by Suchi Psarakos brought the project to a conclusion. Much of the compilation was made while the author was in Wave Propagation Laboratory, ERL/NOAA, Boulder, Colorado. A great deal of the data was collected at the Air Force Geophysical Laboratory, Hanscom Field, Massachusetts, by many researchers, too numerous to mention.

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APPENDIX A: List of Files on Atmospheric Handbook Computer Tape
[LISTFILE0, tape files 0 and 8]

The following list is the linear layout of the files on the Atmospheric Handbook computer tape. Each tape file corresponds to a single data file. Sections of files are grouped according to atmospheric area; an explanation of the grouping breakdown is located in APPENDIX B, tape file 9, "FILEXDESCRIP". All tape files contain 80 characters per line. For further information, see section 3.1, tape file 4, "GUIDE".

Tape File Number	File Name
0	LISTFILE0
1	INTRO
2	CONTENTS
3	DATAXDESCRIP
4	GUIDE
5	FORMATS
6	THANKS
7	REF
8	LISTFILE0
9	FILEXDESCRIP
10	H2OXATTENSCAT
11	MLS
12	MLW
13	SAS
14	SAW
15	TROPICAL
16	USXSTAN
17	CLOUD1
18	CLOUD2
19	CLOUD3
20	CLOUD4
21	CLOUD5
22	CLOUD6
23	CLOUD7
24	CLOUD8
25	CLOUD9
26	CLOUD10
27	CLOUD11
28	CLOUD12
29	CLOUD13
30	CLOUD14
31	CLOUD15
32	CLOUD16
33	CLOUD17
34	CLOUD18
35	FLUX1
36	FLUX2
37	SKYBACSL
38	SKYBAC10
39	MASSXSCAT
40	VOLXSCAT
41	RAYXSCATCROSS
42	RFXADPE
43	RFXADPO
44	RFCXSYNAER
45	RFCXAMSP1
46	RFCXAMSP2
47	RFCXAMSP3
48	RFCXAMSP4
49	RFXBARF1
50	RFXBARF2
51	RFXBARF3
52	RFXBARF4
53	RFXCDS1E
54	RFXCDS1O
55	RFXCDS2E
56	RFXCDS2O
57	RFCXCALCE
58	RFCXCALCO
59	RFXCAF1
60	RFXCAF2
61	RFXCAF3
62	RFIXDUST1
63	RFIXDUST2
64	RFIXDUST3
65	RFIXDUST4
66	RFIXDUST5
67	RFIXDUST6
68	RFIXDUST7
69	RFIXDUST8
70	RFIXDUST9
71	RFIXDUST10
72	RFCXDUST1
73	RFCXDUST2
74	RFCXDUST3
75	RFXGERM1
76	RFXGERM2
77	RFXGERM3
78	RFXGERM4
79	RFXGERM5
80	RFXGLASS1
81	RFXGLASS2
82	RFXGLASS3
83	RFXGLASS4
84	RFXGLASS5
85	RFXGLASS6
86	RFXGLASS7
87	RFXGLASS8
88	RFXGLASS9
89	RFXGLASS10
90	RFXGLASS11
91	RFXGLASS12
92	RFXGLASS13
93	RFXGLASS14
94	RFXGLASS15
95	RFXGLASS16
96	RFXGLASS17
97	RFXGLASS18
98	RFXGLASS19
99	RFXGLASS20
100	RFCXGLASS1
101	RFCXGRAH
102	RFCXGYPS
103	RFXKDPE
104	RFXKDPO
105	RFCXMASCAG
106	RFCXMOLYB
107	RFCXPLTX1
108	RFCXPLTX2
109	RFCXPLTX3
110	RFCXPLTX4
111	RFCXPLTX5
112	RFXQUA1E
113	RFXQUA1O
114	RFXQUA2
115	RFXQUA3E
116	RFXQUA3O
117	RFCXQUA1E
118	RFCXQUA1O
119	RFCXQUA2E
120	RFCXQUA2O
121	RFCXQUA3
122	RFCXQUA4
123	RFCXSALT
124	RFXSAPPH1E
125	RFXSAPPH1O
126	RFXSAPPH2
127	RFXSAPPH3
128	RFXSAPPH4
129	RFXSAPPH5
130	RFXSAPPH6
131	RFCXSAPPH1
132	RFCXSAPPH2E
133	RFCXSAPPH2O
134	RFXSILICA
135	RFXSILIC1
136	RFXSILIC2
137	RFXSILIC3
138	RFXSILIC4
139	RFXSILIC5
140	RFXSODNITE
141	RFXSODNITO
142	RFXZNS1E
143	RFXZNS1O
144	RFXZNS2
145	RFXAIRN30
146	RFXAIRN15
147	RFXAIR0
148	RFXAIR15
149	RFXAIR30
150	RFCXICE1
151	RFCXICE2
152	RFCXICE3
153	RFCXH2O1
154	RFCXH2O2
155	RFCXH2O3
156	RFCXH2O4
157	RFCXH2O5
158	RFCXH2O6
159	RFCXH2O7
160	RFCXH2O8
161	RFCXH2O9
162	RFCXH2O10
163	RFCXH2O11
164	RRXICE1
165	RRXH2O1
166	RRXH2O2
167	RRXH2O3
168	RRXH2O4
169	RRXH2O5
170	RRXH2O6
171	ATTENCOEF
172	AERRD
173	ATMRD
174	ATTEN
175	BUILDVEC
176	ERCHK
177	INPT
178	LINTERP
179	NEAR
180	ATTENHT
181	AERXCLR
182	AERXHAZ
183	MIDLATSUM
184	MIDLATWIN
185	SUBARCSUM
186	SUBARCWIN
187	TROPIC
188	MICRO
189	DAT
190	H2OPEN
191	H2OTEMP
192	HEADER
193	ICEOPEN
194	ICETEMP
195	INTERP
196	INTVEC
197	KEY
198	RD
199	READANS
200	RFPRINT
201	SUBHDR
202	TEMPCHK
203	VECTOR
204	RFICEMN50
205	RFICEMN30
206	RFICEMN10
207	RFICEM0
208	RFH2OMN8
209	RFH2OM0
210	RFH2OM10
211	RFH2OM18
212	RFH2OM20
213	RFH2OM30
214	RFH2OM40
215	RFH2OM50
216	RFH2OM60
217	RFH2OM75
218	APPENDIXC
219	APPENDIXD
220	FACTS
221	RFCXICE4
222	RFCXICE5
223	RFCXICE6
224	RFCXICE7
225	RFCXICE8

APPENDIX B: Computer Tape File Descriptions [FILEXDESCRIP, 9]

This section briefly describes the contents of single or groups of files on the Atmospheric Handbook computer tape, as listed in APPENDIX A, tape file 0, "LISTFILE0".

Tape File Number	Description
0:	"LISTFILE0" - List of all data files on Atmospheric Handbook tape and corresponding tape file number. Each file corresponds to a singular data file. Sections of files are grouped according to atmospheric area. (NOTE: When printed as a bound document, file 0 should not be considered part of the text, and should therefore not be printed. File 0 exists solely as an aid for someone using the Atmospheric Handbook in tape format, to enable easy initial identification of the tape and its contents.)
1:	"INTRO" - Introduction to the evolution, present aims, and future prospects of the Atmospheric Handbook.
2:	"CONTENTS" - Table of contents of the Atmospheric Handbook.
3:	"DATAXDESCRIP" - A brief description of each atmospheric area covered by the Handbook data files: definition of data file variables, ranges, and units, listing of file names, and description of data source.
4:	"GUIDE" - General user notes and technical information needed to access/understand the computer tape, data files, and computer programs: Introduction to Tape Organization, Data File Structure, Deciphering File Names, Unit Notation, Significant Figures, Computer Programs: ATTENCOEF and MICRO, Data Retrieval Example, Data File Examples.
5:	"FORMATS" - Technical information on each data file in tabular form: data file variable definitions, units, and ranges, FORTRAN format statements used to create the file(s), temperature, source, and computer tape file number.
6:	"THANKS" - Acknowledgments.
7:	"REF" - A list of all references cited in file 3.
8:	"LISTFILE0" - See file 0.
9:	"FILEXDESCRIP" - Brief description of files listed in file 0.
10:	Attenuation Coefficients, H_2O
11- 16:	Standard Atmospheres
17-34:	Cloud Drop Size Distributions
35-36:	Solar Spectral Irradiance
37-38:	Sky Spectral Radiance
39-41:	Rayleigh Air Coefficients
42-144:	Refractive Indices, Aerosols
145-149:	Refractive Indices, Air
150-152:	Refractive Indices, Ice (does not include microwave files). See also files 221-225.
153-163:	Refractive Indices, Liquid H_2O (does not include microwave files)
164-170:	Relative Reflectance: Ice, H_2O
171-187:	Attenuation Coefficients, Atmospheric; Program ATTENCOEF
188-217:	Select Refractive Indices for H_2O and Ice, microwave; Program MICRO. (Note that file 178 is used by both ATTENCOEF and MICRO and thus should be loaded with both file sets). Additional microwave ice refractive index data, located in files 222-225, were acquired after the completion of program MICRO, and thus are not available to the user through the program.
218-219:	"APPENDIXC" and "APPENDIXD" - Programs ATTENCOEF and MICRO. These two files were made by appending files 171-187 and 188-217. The individual program and subroutine files should be loaded as needed to run the programs; tape files 218 and 219 should be printed as needed for casual reference or interest, as when compiling an Atmospheric Handbook reference manual.
220:	"FACTS" - A list of useful atmospheric constants and conversions.
221-225:	Refractive Indices, Ice (includes some data for microwave wavelengths)

APPENDIX C: FORTRAN Code for Program ATTENCOEF (and Related Subroutines): Atmospheric Absorption and Scattering Coefficients [APPENDIXC, 218]

```
C############################################################
C       PROGRAM ATTENCOEF
C       -----------------


C------ Program ATTENCOEF gives the attenuation coefficients as a
C------ function of altitude for 5 atmospheric and 2 aerosol models.
C------ The altitude range is 0 - 85 km, and wavelength = 0.6943 microns.

C------    The following list describes all non-standard FORTRAN
C------ characteristics in the Handbook programs. For easy access,
C------ their occurrences within the routines are marked by a "C" in
C------ column one, followed by a series of plus signs: '+'. Format
C------ statements in which non-standard format codes appear are listed
C------ in the comment section 'Non-standard Format Codes'.

C------ General Suggestions for Improvement: Due to the need to
C------ standardize the programs, it was necessary to format inter-
C------ active input. This often presents awkward restrictions for
C------ the user. It is advised that, if available, free-formatted reads
C------ be implemented to handle numerical input. In addition, the
C------ use of one standard output filename for all program runs is
C------ impractical and potentially hazardous. Although the 'A'
C------ attribute will provide protection against overwriting on
C------ some systems, it is only meant as a temporary alternative.
C------ It is advisable that something such as string formatting
C------ be used to allow character input, in particular, for the
C------ interactive naming of output files.
C------    Additionally, individual users should implement precautions
C------ against careless user inputting, such as illegal characters.
C------ The program contains only minor precautions. The user should
C------ beware that some systems accept entry of a carriage return or a
C------ mathematical sign character (+,-) or decimal as if a zero had
C------ been entered.

C------ Non-standard FORTRAN options:
C       -----------------------------
C------ STATIC: The STATIC option places all non-COMMON variables and
C------ arrays in a fixed area in memory, rather than on the run-time
C------ stack. It initializes all static variables to zero at load time,
C------ unless you data-initialize them. You may retrieve the values of
C------ static variables within a subprogram upon re-entry to the
C------ subprogram for the second and subsequent times.

C------ OPEN, CLOSE, and REWIND: Although the purpose of these
C------ input/output statements is obvious, their implementation
C------ may differ from system to system. The 'OPEN' statement used
C------ with the 'ATT=A' option specifies that appending is to be
C------ performed onto the file associated the the channel opened.
C------ This protects against overwriting the previous contents of the
C------ file, if any existed. REWIND repositions the record pointer to
C------ the beginning of the specified file.

C------ 'P' and 'Z' format code: The scale factor 'P' changes the
C------ location of the decimal point in the external representation
C------ of a real number, with respect to its internal value. The
C------ format is 'nP', where 'n' is an integer constant that specifies
C------ the number of positions you want to move the decimal point to
C------ the right. 'Z' format code suppresses the newline character
C------ on output of the current record. It is represented internally,
C------ and as it is used to build many of the Handbook output files,
C------ its presence should be considered if any of these files are
C------ edited.

C------ Non-Standard Format Codes (statement labels): 554
C       -------------------------------------------
C------ User options:
C       -------------
C------    entry modes: single or array entry
C------    print to screen and/or diskfile
C------    linear interpolation or closest values at unavailable
C------       data points
C------ Output:
C       -------
C------    Output diskfile 'ATTENOUT'; should be renamed after each run
```

```
C------ File unit #s:
C       -------------
C------    0: aerosol
C------    1: atmospheric model
C------    2: diskfile
C------   11: terminal
C------
C------ Data Files Used
C       ---------------
C------    AERXCLR,AERXHAZ,ATTENHT,MIDLATSUM,MIDLATWIN,SUBARCSUM,
C------    SUBARCWIN,TROPIC
C------ Subroutines:
C       ------------
C------    AERRD: opens and reads aerosol file
C------    ATMRD: opens and reads atmosphere files
C------    ATTEN: writes coefficients to output
C------    BUILDVEC: creates a user-entered array of data information
C------    ERCHK: user error check function
C------    INPT: interactively prepares variables entered singly
C------       for input to ATTEN
C------    LINTERP: linear interpolation function
C------    NEAR: finds the value closest to the user-entered height
C------ Variables:
C       ----------
C------    Logical
C------       ANSR,ERCHK: check for user input error
C------       DATSET: determines entry mode
C------       INTERP: determines whether interpolation is used
C------       OPEN2: determines if output file is open for writing
C------       SCREEN,DISK: determine if text has been written to screen
C------          and/or disk
C------    Integer:
C------       ATM: user-entered atmosphere model
C------       OUT: user print option

C       Suchi Psarakos
C       N.O.A.A.
C       325 Broadway
C       R/E/WP2
C       Boulder, Colorado 80303

C       Please direct questions to Dr. Vernon Derr, (303) 497-6002,
C       or Suchi Psarakos, (303) 497-5361.
C###############################################################
C+++++++++++++++
        STATIC OPEN2,SCREEN,DISK
C+++++++++++++++

        INTEGER ATTENOUT
        INTEGER ATM, ANS, OUT
        LOGICAL ANSR, ERCHK, DATSET, INTERP, OPEN2, SCREEN, DISK

        OPEN2 = .FALSE.
        SCREEN = .FALSE.
        DISK = .FALSE.

C------ entry mode?
9       WRITE (11,550)
10      WRITE (11,552)
100     READ (11, 525,ERR=10)  ANS
        ANSR = ERCHK (ANS )
        IF (ANSR) GOTO 100
        IF (ANS .EQ. 0) DATSET = .FALSE.
        IF (ANS .EQ. 1) DATSET = .TRUE.

C------ print option?
125     WRITE (11,554)
126     WRITE (11,556)
        READ (11, 525, ERR = 126) ANS

        IF ((ANS .NE. 0) .AND. (ANS .NE. 1) .AND.
     $     (ANS .NE. 2)) GOTO 126

        OUT = ANS
        IF (((OUT .EQ. 1).OR.(OUT .EQ. 2)).AND.(.NOT.OPEN2)) GOTO 225
        GOTO 250
```

```
C------ open output file
C+++++++++++++++
225     OPEN 2, "ATTENOUT", ATT="A"
C+++++++++++++++
        OPEN2 = .TRUE.

C------ write heading to output
250     IF ((SCREEN).AND.(DISK)) GOTO 450
        IF ((.NOT.SCREEN).AND.(.NOT.DISK).AND.(OUT.EQ.2)) GOTO 255
        IF (.NOT.DISK) GOTO 252
        IF ((OUT.EQ.0).OR.(OUT.EQ.2)) GOTO 255
252     IF ((OUT.EQ.1).OR.(OUT.EQ.2)) GOTO 260
255     IF (SCREEN) GOTO 450
        SCREEN=.TRUE.
        WRITE (11,575)
        IF (OUT.NE.2) GOTO 450
260     IF (DISK) GOTO 450
        DISK=.TRUE.
        WRITE (2,575)

450     IF (.NOT. DATSET) GOTO 501

C------ interpolation?
        WRITE (11,560)
475     WRITE (11,552)

500     READ (11, 525,ERR=475) ANS
        ANSR = ERCHK (ANS )
        IF (ANSR) GOTO 500

        IF (ANS .EQ. 0) INTERP = .TRUE.
        IF (ANS .EQ. 1) INTERP = .FALSE.
        GOTO 502

501     INTERP = .FALSE.

C------ call to ATTEN
        IF (.NOT.(DATSET)) CALL ATTEN (ATM,ALT,AER,DATSET,INTERP, OUT )
C------ call to BUILDVEC
502     IF (DATSET) CALL BUILDVEC (DATSET,INTERP, OUT )

C------ continue program?
        IF (OUT .EQ. 10) GOTO 505
        IF (OUT .EQ. 11) GOTO 506

C------ terminate
        IF (OPEN2) WRITE (11, 650)
        STOP

C------ continue
505     DATSET = .TRUE.
        GOTO 125

506     GOTO 9

525     FORMAT (I1)
550     FORMAT (/"WILL YOU BE ENTERING DATA SINGLY (0),"/
     $     " OR AS A SET (1)?")
552     FORMAT (/"ENTER 0 OR 1")
554     FORMAT (/"PRINT OPTION:"/3X,"0: RESULTS TO SCREEN ONLY"
     $     /3X,"1: RESULTS TO DISKFILE"/3X,"2: RESULTS TO BOTH",Z,
     $     " SCREEN AND DISKFILE")
556     FORMAT (/"ENTER 0,1, OR 2")
560     FORMAT (/"IF USER-SPECIFIED HEIGHT FALLS AT THE MIDPOINT"/
     $     "BETWEEN TWO DATA VALUES, THE PROGRAM INTERPOLATES"/
     $     "LINEARLY. IN OTHER CASES, DO YOU WANT INTERPOLATION (0)"/
     $     "OR DO YOU WANT THE COEFFICIENTS AT THE NEAREST"/
     $     "AVAILABLE HEIGHT (1)?")
575     FORMAT ("ATTENUATION COEFFICIENTS AS A FUNCTION OF ALTITUDE",
     $  /T15,"LAMBDA = 0.6943 MICRONS",/
     $  "Source: 'Optical Properties of the Atmosphere',"/3X,"McClatchey,"
     $  " Fenn, Selby, Volz, Garing, (1971)."//T8,"K↑M = MOLECULAR ABSORPTION",
     $  /T8,"S↑M = MOLECULAR SCATTERING",/T8,"K↑A = AEROSOL ABSORPTION",
     $  /T8,"S↑A = AEROSOL SCATTERING",//
     $  /"VALUES OF ZERO INDICATE A COEFFICIENT LESS THAN E-06",
     $  /"'***' PRECEDE INTERPOLATED VALUES")
650     FORMAT ("CHECK 'ATTENOUT' FOR OUTPUT. REMEMBER TO RENAME THIS FILE.")
        END
```

```
        SUBROUTINE AERRD (AER, AERABS,AERSCAT)

C------ Opens and reads one of the two aerosol files.
C------ The files contain absorption and scattering
C------ coefficients for aerosols as a function of altitude
C------ in the range 0 - 85 km.

C------ Non-standard Format Code (statement labels): 263

        DIMENSION AERABS(33), AERSCAT(33)
        INTEGER AER


C------ open AER
C++++++++++++++
        IF (AER .EQ. 0) OPEN 0, "AERXCLR", ERR = 250
        IF (AER .EQ. 1) OPEN 0, "AERXHAZ", ERR = 260
C++++++++++++++

C------ read AER
        DO 60 I = 1, 33
           READ (0,263) AERABS(I), AERSCAT(I)
60      CONTINUE

C++++++++++++++
        CLOSE 0
C++++++++++++++

        RETURN

250     WRITE (11, 261)
        STOP
260     WRITE (11, 262)
        STOP

261     FORMAT (/"ERROR OPENING AERXCLR")
262     FORMAT (/"ERROR OPENING AERXHAZ")
263     FORMAT (2 (2X,1PE11.4))

        END
```

```
        SUBROUTINE ATMRD (ATM, RABS,SCAT)

C------ Opens and reads the 5 atmospheric model files.
C------ The files contain absorption and scattering
C------ coefficients as a function of altitude in the
C------ range 0 - 85 km.

C------ Non-standard Format Code (statement label): 245

        DIMENSION RABS(33), SCAT(33)
        INTEGER ATM

C------ open ATM file
C++++++++++++++
        IF (ATM .EQ. 1) OPEN 1, "TROPIC", ERR = 200
        IF (ATM .EQ. 2) OPEN 1, "MIDLATSUM", ERR = 210
        IF (ATM .EQ. 3) OPEN 1, "MIDLATWIN", ERR = 220
        IF (ATM .EQ. 4) OPEN 1, "SUBARCSUM", ERR = 230
        IF (ATM .EQ. 5) OPEN 1, "SUBARCWIN", ERR = 240
C++++++++++++++

C------ read ATM file
        DO 35 I = 1, 33
           READ (1,245) RABS(I), SCAT(I)
35      CONTINUE

C++++++++++++++
        CLOSE 1
C++++++++++++++

        RETURN

200     WRITE (11,250)
        STOP
210     WRITE (11,252)
        STOP
220     WRITE (11,254)
        STOP
230     WRITE (11,256)
        STOP
240     WRITE (11,258)
        STOP
245     FORMAT (2 (2X,1PE11.4))
250     FORMAT (/"ERROR OPENING TROPIC")
252     FORMAT (/"ERROR OPENING MIDLATSUM")
254     FORMAT (/"ERROR OPENING MIDLATWIN")
256     FORMAT (/"ERROR OPENING SUBARCSUM")
258     FORMAT (/"ERROR OPENING SUBARCWIN")

        END
```

```
      SUBROUTINE ATTEN (ATM,ALT,AER,DATSET,INTERP, OUT )

C------ ATTEN is called by ATTENCOEF and BUILDVEC. It calls INPT,ATMRD,
C------ AERRD,NEAR, and LINTERP. Does all writing to output files.
C------ Contains choice for user to start over and enter a new entry mode.

C------ Non-standard Format Code (statement label): 7100,7200,9140,9145,9146

C------ Variables
C------    data arrays
C------       molecular data:
C------          RABS: absorption
C------          SCAT: scattering
C------       aerosol:
C------          AERABS: absorption
C------          AERSCAR: scattering
C------    logical
C------       ATM2,AER2,HEIGHT: determine structural positions
C------          in the program as well as whether informational text
C------          has been printed; prevent unnecessary printing
C------    real
C------       ALT: user entered altitude
C------       ABS1,ABS2,HT1,HT2,SCAT1,SCAT2: output
C------       LINTERP: linear interpolation function
C------    integer
C------       AERSL: current aerosol model
C------       NEAR: function, returns the index of ALT in HT, or the
C------          index to the next closest value
C------       OLDATM: current atmospheric model
C------       OUT: print option, multi-usage variable;
C------          within ATTEN, its value may change:
C------             = 10: return to driver, enter array mode
C------             = 11: return to driver with option for new entry mode
C------       UNIT: current output unit #


      DIMENSION HT(33), RABS(33), SCAT(33), AERABS(33), AERSCAT(33)

      LOGICAL AER2, ATM2, INTERP, DATSET,HEIGHT,
     $   ANSR,ERCHK

C+++++++++++++++
      STATIC OLDATM,AERSL/-1/,HT,HEIGHT/.FALSE./,ATM2/.TRUE./

C+++++++++++++++



      INTEGER OLDATM,ATM, AER, AERSL, OUT,NEAR, ANS,UNIT
      REAL ALT,HT1,HT2,ABS1,ABS2,SCAT1,SCAT2,LINTERP

C------ user finished?
      IF (OUT .LT. 0) GOTO 1120


      IF (HEIGHT) GOTO 19

C------ open/read height file
C+++++++++++++++
      OPEN 1, "ATTENHT", ERR = 3
C+++++++++++++++
      GOTO 4
3     WRITE (11,5000)
      STOP
4     DO 5 I = 1, 33
         READ (1,4600) HT(I)
5     CONTINUE
      HEIGHT = .TRUE.
C+++++++++++++++
      CLOSE 1
C+++++++++++++++

19    IF (.NOT. DATSET) CALL INPT (DATSET,ATM2, ATM,ALT,AER)

      IF (ATM.EQ.0) GOTO 1120
      IF (OLDATM .NE. ATM) CALL ATMRD (ATM, RABS,SCAT)
      IF (OLDATM .NE. ATM) GOTO 21
      IF (OLDATM .EQ. ATM) ATM2 = .FALSE.
      GOTO 22
21    ATM2 = .TRUE.
22    OLDATM = ATM
```

```
30      IF (AERSL .NE. AER) CALL AERRD (AER, AERABS,AERSCAT)
        IF ((ATM2) .OR. (AERSL .NE. AER)) GOTO 31
        IF ((.NOT. ATM2) .OR. (AERSL .EQ. AER)) AER2 = .FALSE.
        GOTO 32
31      AER2 = .TRUE.
32      AERSL = AER

C------ call to NEAR
        J = NEAR (ALT,HT,DATSET,INTERP )

        IF ((OUT .EQ. 0) .OR. (OUT .EQ. 2)) GOTO 84
82      IF ((OUT .EQ. 1) .OR. ((OUT .EQ. 2) .AND.
     $     (UNIT .EQ. 11))) UNIT = 2
        GOTO 85

84      UNIT = 11


85      IF (ATM2) GOTO 90
        IF ((.NOT. ATM2) .AND. (AER2)) GOTO 91
        IF ((.NOT. ATM2) .AND. (.NOT. AER2)) GOTO 95

C------ atmosphere model
90      WRITE ( UNIT, 7100)

        IF (ATM .EQ. 1) WRITE (UNIT, 9100)
        IF (ATM .EQ. 2) WRITE (UNIT, 9105)
        IF (ATM .EQ. 3) WRITE (UNIT, 9110)
        IF (ATM .EQ. 4) WRITE (UNIT, 9115)
        IF (ATM .EQ. 5) WRITE (UNIT,9120)

        GOTO 92
91      IF ((DATSET).OR.((.NOT.DATSET).AND.(UNIT.EQ.2)))
     $     WRITE (UNIT, 7000)

C------ aerosol
92      WRITE (UNIT, 7200)
        IF (AER .EQ. 0) WRITE (UNIT, 9125)
        IF (AER .EQ. 1) WRITE (UNIT, 9130)

C------ column headings
        WRITE (UNIT, 9135)

C------ if j not negative, don't interpolate
95      IF (J .GE. 0) GOTO 140

        IF ((OUT .EQ. 2) .AND. (UNIT .EQ. 2)) GOTO 139
        J = ABS (J)
        HT1 = HT(J)
        HT2 = HT(J+1)
C------ call to LINTERP
        ABS1 = LINTERP (HT1,HT2,RABS(J),RABS(J+1),ALT )
        SCAT1 = LINTERP (HT1,HT2,SCAT(J),SCAT(J+1),ALT )
        ABS2 = LINTERP (HT1,HT2,AERABS(J),AERABS(J+1),ALT )
        SCAT2 = LINTERP (HT1,HT2,AERSCAT(J),AERSCAT(J+1),ALT )

C------ write interpolated coefficients
139     WRITE (UNIT, 9140)
        WRITE (UNIT,9145) ALT,ABS1,SCAT1,ABS2,SCAT2
        IF ((.NOT.DATSET).AND.(OUT .EQ. 1)) WRITE (11,5100)
        J = -J
        GOTO 141

C------ write coefficients
140     WRITE (UNIT, 9146) HT(J),RABS(J), SCAT(J), AERABS(J), AERSCAT(J)
        IF ((.NOT.DATSET).AND.(OUT .EQ. 1)) WRITE (11,5100)

C------ check output option - writing done?
141     IF ((OUT .EQ. 2) .AND. (UNIT .EQ. 11)) GOTO 82

        IF (DATSET) GOTO 1100

C------ another height?
        WRITE (11,5400)
143     WRITE (11,5200)
145     READ (11,4800,ERR=143) ANS
        ANSR = ERCHK (ANS )
        IF (ANSR) GOTO 145
```

```
C------ no
        IF (ANS .EQ. 0) GOTO 154
C------ yes
        ATM2 = .FALSE.
        CALL INPT (DATSET,ATM2, ATM,ALT,AER)
        GOTO 30
C------ another atm?
154     WRITE (11,5600)
155     WRITE (11,5200)
156     READ (11,4800,ERR=155) ANS
        ANSR = ERCHK(ANS )
        IF (ANSR) GOTO 156
C------ no
        IF (ANS .EQ. 0) GOTO 1000
C------ yes
        ATM2 = .TRUE.
        GOTO 19
C------ start over? (from single entry mode)
1000    WRITE (11,5800)
1001    WRITE (11,5200)
1002    READ (11, 4800,ERR = 1001) ANS
        ANSR = ERCHK(ANS )
        IF (ANSR) GOTO 1002

C------ no
        IF (ANS .EQ. 0) GOTO 1200
C------ yes
        OLDATM = 0
        ATM2 = .TRUE.
        AERSL = -1
        OUT = 10
        RETURN

1100    RETURN
C------ start over? (from array entry mode)
1120    WRITE (11,6000)
1130    WRITE (11,5200)
1140    READ (11, 4800,ERR = 1130) ANS
        ANSR = ERCHK(ANS )
        IF (ANSR) GOTO 1140
C------ no
        IF (ANS .EQ. 0) GOTO 1200
C------ yes
        OLDATM = 0
        ATM2 = .TRUE.
        AERSL = -1
        IF (OUT .EQ. -10) OUT = 0
        IF (OUT .LT. 0) OUT = ABS(OUT )
        OUT = 11
        RETURN

C------ terminate
1200    RETURN

4600    FORMAT (F4.1)
4800    FORMAT (I1)
5000    FORMAT (/"ERROR OPENING ATTENHT")
5100    FORMAT (/"COMPLETED")
5200    FORMAT (/"ENTER 0 OR 1")
5400    FORMAT (/"WOULD YOU LIKE ANOTHER HEIGHT? (0=NO, 1=YES)")
5600    FORMAT (/"WOULD YOU LIKE A DIFFERENT ATMOSPHERE? (0=NO, 1=YES)")
5800    FORMAT (/"WOULD YOU LIKE TO CONTINUE, BUT ENTER"/
     $     "YOUR DATA INTO AN ARRAY? (0=NO, 1=YES)")
6000    FORMAT (/"WOULD YOU LIKE TO START OVER? (0=NO, 1=YES)")
7000    FORMAT ()
7100    FORMAT (//"ATMOSPHERE:",Z)
7200    FORMAT ("AEROSOL:",Z)
9100    FORMAT ("TROPICAL")
9105    FORMAT ("MIDLATITUDE SUMMER")
9110    FORMAT ("MIDLATITUDE WINTER")
9115    FORMAT ("SUBARCTIC SUMMER")
9120    FORMAT ("SUBARCTIC WINTER")
9125    FORMAT ("CLEAR"/)
9130    FORMAT ("HAZY"/)
9135    FORMAT (4X,"HT(KM)",4X,"K↑M(KM**-1)",4X,"S↑M(KM**-1)",
     $  4X,"K↑A(KM**-1)",4X,"S↑A(KM**-1)",/)
9140    FORMAT ("***",Z)
9145    FORMAT (2X,F5.2,4(5X,1PE10.2))
9146    FORMAT (5X,F5.2,4(5X,1PE10.2))
        END
```

```
       SUBROUTINE BUILDVEC (DATSET,OUT,INTERP )

C------ When DATSET is true, BUILDVEC is called by ATTEN to
C------ create the user-entered array. BUILDVEC calls INPT
C------ and ATTEN. The maximum array size is 50.

C------ WARNING: If the user does not enter at least one value
C------ the array, the program terminates immediately.

       INTEGER   ATMVEC(50), AERVEC(50)
       DIMENSION ALTVEC (50)
       INTEGER ATM, AER, VECSIZ, OUT
       REAL ALT
       LOGICAL ATM2,DATSET, INTERP

       ATM2 = .FALSE.
C------ entry specifications
       WRITE (11,310)

C------ create array
       DO 100 K = 1, VECSIZ
75        READ (11,312, ERR = 80) ATM
          IF (ATM.EQ.0) GOTO 110
76        READ (11, 313, ERR=85) ALT
77        READ (11, 312, ERR=90) AER
C------ call to INPT
C------ Note that when INPT is called from BUILDVEC, all variables
C------ in the parameter list are input variables.
          CALL INPT (DATSET,ATM2,ATM,ALT,AER )
          ATMVEC(K) = ATM
          ALTVEC(K) = ALT
          AERVEC(K) = AER
          WRITE (11,315)
          GOTO 100
80        WRITE (11,320)
          GOTO 75
85        WRITE (11, 321)
          GOTO 76
90        WRITE (11, 322)
          GOTO 77
100    CONTINUE

       GOTO 199

110    IF (K.EQ.1) GOTO 111
       VECSIZ = K - 1
       GOTO 199
111    WRITE (11,400)
       STOP
C------ call to ATTEN
199    DO 200 K = 1,VECSIZ
          CALL ATTEN (ATMVEC(K),ALTVEC(K),AERVEC(K),DATSET,INTERP, OUT )
200    CONTINUE

       IF (OUT.EQ.1) WRITE (11, 330)
C------ prepare for termination
       IF (OUT .EQ. 0) GOTO 250
       IF (OUT .NE. 0) OUT = -OUT
       GOTO 300
250    OUT = -10
300    CALL ATTEN (ATM,ALT,AER,DATSET,INTERP, OUT )
       RETURN
310    FORMAT (/"ATMOSPHERIC MODELS ARE:"/3X,"1 - TROPICAL"/3X,
     $    "2 - MIDLATITUDE SUMMER"/3X,"3 - MIDLATITUDE WINTER"/3X,
     $    "4 - SUBARCTIC SUMMER"/3X,"5 - SUBARCTIC WINTER"//
     $    "ENTER: 1. # OF ATMOSPHERIC MODEL (1-5)"/7X,
     $    "2. ALTITUDE IN km (0.0 - 85.0)"/11X,
     $    "AN ALTITUDE OTHER THAN ZERO THAT IS A WHOLE NUMBER"/11X,
     $    "MUST BE ENTERED WITH A DECIMAL, E.G. '12' WOULD BE"/11X,
     $    "ENTERED AS '12.0'."/7X,
     $    "3. AEROSOL TYPE - CLEAR (0) OR HAZY (1)"//
     $    "ENTER EACH VALUE ON A SEPARATE LINE. AFTER THE THIRD"/
     $    "VALUE IN EACH SET HAS BEEN ENTERED, WAIT FOR THE"/
     $    "PROMPT, '$', THEN CONTINUE."//
     $    "WHEN YOU WISH TO STOP ENTERING VALUES, ENTER A ZERO"/
     $    "AFTER YOU RECEIVE THE PROMPT.")
```

```
312     FORMAT (I1)
313     FORMAT (F5.2)
315     FORMAT ("$")
320     FORMAT (/"RE-ENTER ATMOSPHERE")
321     FORMAT ("RE-ENTER ALTITUDE")
322     FORMAT ("RE-ENTER AEROSOL")
330     FORMAT (/"COMPLETED")
400     FORMAT ("ERROR: THERE MUST BE AT LEAST ONE SET OF VALID "/
     $     "ENTRIES IN THIS ARRAY. PROGRAM TERMINATED")
        END





        FUNCTION ERCHK (ANS )

C------ Checks for errors in user answers. In general,
C------ 0 = NO and 1 = YES.
C------ Note that on some systems inputting '+', '-', or '.' is
C------ identical to inputting a zero.

        LOGICAL ERCHK
        INTEGER ANS


        IF ((ANS .NE. 0) .AND. (ANS .NE. 1)) GOTO 10
        ERCHK = .FALSE.
        RETURN

10      ERCHK = .TRUE.
        WRITE (11, 20)
        RETURN
20      FORMAT (/"INCORRECT ENTRY. ENTER 0 OR 1")

        END
```

```
        SUBROUTINE INPT (DATSET,ATM2, ATM,ALT,AER)

C------ INPT is called by BUILDVEC to check for user input error,
C------ and by ATTEN to obtain the ATM, ALT, and AER from the user
C------ when the program is in single entry mode.
C------ Note that when INPT is called from within BUILDVEC, 'ATM,ALT,
C------ AER' are input variables; when called from within ATTEN, these
C------ variables are output variables.

        LOGICAL ATM2,DATSET
        INTEGER ATM, AER
        REAL ALT

        IF (DATSET) GOTO 15
        IF (.NOT. ATM2) GOTO 350

        WRITE (11, 420)

C------ input atmospheric type
        WRITE (11, 425)
14      READ (11, 410, ERR=20) ATM
15      IF ((ATM .NE. 1).AND.(ATM .NE. 2)
     $  .AND.(ATM .NE. 3).AND.(ATM .NE. 4)
     $  .AND.(ATM .NE. 5)) GOTO 20
        GOTO 30

20      WRITE (11, 430)
        GOTO 14

30      IF (DATSET) GOTO 352

C------ input altitude
350     WRITE (11, 435)
351     READ (11, 415, ERR = 355) ALT
352     IF ((ALT .GT. 85.0) .OR. (ALT .LT. 0.0)) GOTO 355
        IF (DATSET) GOTO 402
        GOTO 400
355     WRITE (11, 440)
        GOTO 351

C-----  input aerosol
400     WRITE (11, 445)
401     READ (11, 410,ERR=400) AER
402     IF ((AER .NE. 0).AND.(AER .NE. 1)) GOTO 403

        RETURN

403     WRITE (11, 450)
        GOTO 401

410     FORMAT (I1)
415     FORMAT (F5.2)
420     FORMAT (/"ATMOSPHERIC MODELS ARE:"/7X,"1 - TROPICAL"/7X,
     $     "2 - MIDLATITUDE SUMMER"/7X,"3 - MIDLATITUDE WINTER"/7X,
     $     "4 - SUBARCTIC SUMMER"/7X,"5 - SUBARCTIC WINTER"//)
425     FORMAT (/"ENTER THE NUMBER OF THE ATMOSPHERE YOU WOULD LIKE")
430     FORMAT (/"RE-ENTER ATMOSPHERIC MODEL")
435     FORMAT (/"ENTER ALTITUDE IN km (0.0 - 85.0)"/7X,
     $     "AN ALTITUDE OTHER THAN ZERO THAT IS A WHOLE NUMBER"/7X,
     $     "MUST BE ENTERED WITH A DECIMAL, E.G. '12' WOULD BE"/7X,
     $     "ENTERED AS '12.0'")
440     FORMAT (/"RE-ENTER ALTITUDE (0.0 TO 85.0)")
445     FORMAT (/"AEROSOL: CLEAR (0) OR HAZY (1)? ENTER 0 OR 1")
450     FORMAT (/"RE-ENTER AEROSOL: CLEAR (0) OR HAZY (1)?")
        END
```

```
      FUNCTION LINTERP (DAT1,DAT2,RES1,RES2,X )

C------ DAT and RES correspond to 'data' and 'result', and
C------ constitute an ordered pair. X is the known value for
C------ which a Y is needed. LINTERP determines Y by linear
C------ interpolation.


      REAL DAT1,DAT2,RES1,RES2,X,LINTERP

      Y = ((X - DAT1) * (RES2 - RES1)/(DAT2 - DAT1)) + RES1
      LINTERP = Y

      RETURN
      END




      FUNCTION NEAR (ALT,HT,DATSET,INTERP )

C------ NEAR searches for the value equal or closest to ALT
C------ in the array HT. HT is sorted in increasing order. In
C------ the case of an exact match, NEAR returns the index of
C------ the value in HT. If a match does not exist and
C------ the user has asked for interpolation, NEAR
C------ returns the negative index of the value in HT
C------ which is closest to ALT. If interpolation is not
C------ requested, the positive index is returned, and the
C------ program outputs the coefficients at that closest
C------ value. If ALT is the midpoint between 2 HT values,
C------ a negative index is returned, and the program interpolates.
C------ If the user is in single entry mode, NEAR offers a
C------ choice between interpolation or the coefficients at
C------ the closest value. If the user is entering data as
C------ an array, this choice is made earlier in the driver ATTENCOEF.

      DIMENSION HT(33)
      INTEGER ANS,NEAR
      LOGICAL ANSR,ERCHK,INTERP, DATSET

C------ search for ALT in HT
      DO 10 I = 1, 32
         IF ((HT(I) .LT. ALT) .AND. (HT(I+1) .GT. ALT)) GOTO 20
         IF (HT(I) .EQ. ALT) GOTO 36
10    CONTINUE

20    IF (INTERP) GOTO 50
      IF ((ALT - HT(I)) .LT. (HT(I+1) - ALT)) GOTO 30
      IF ((ALT - HT(I)) .EQ. (HT(I+1) - ALT)) GOTO 50
      IF ((ALT - HT(I)) .GT. (HT(I+1) - ALT)) GOTO 21

21    IF (DATSET) GOTO 26
      WRITE (11,45) HT(I+1)
24    WRITE (11, 70)
25    READ (11, 40, ERR = 24) ANS
      ANSR = ERCHK(ANS )
      IF (ANSR) GOTO 25
      IF (ANS .EQ. 0) GOTO 50
26    NEAR = I+1
      GOTO 60

30    IF (DATSET) GOTO 36
      WRITE (11, 45) HT(I)
31    WRITE (11, 70)
34    READ (11, 40,ERR=31) ANS
      ANSR = ERCHK(ANS )
      IF (ANSR) GOTO 34
      IF (ANS .EQ. 0) GOTO 50
36    NEAR = I
      GOTO 60

40    FORMAT (I1)
45    FORMAT ("THE CLOSEST HT IN KM IS ",F4.1)
50    NEAR = -I
60    RETURN
70    FORMAT ("DO YOU WANT AN INTERPOLATION (0) OR THE "/
     $   "COEFFICIENTS (1) AT THIS VALUE? ENTER 0 OR 1")
      END
```

APPENDIX D: FORTRAN Code for Program Micro (and Related Subroutines): Ice and Water Refractive Indices in the Microwave Region [APPENDIXD,219]

```
C############################################################
C------ Program MICRO
C       -------------


C------ Program MICRO gives the refractive indices for ice
C------ and water in the microwave region.

C------    The following list describes all non-standard FORTRAN
C------ characteristics in the Handbook programs. For easy access,
C------ their occurrences within the routines are marked by a "C"
C------ in column one, followed by a series of signs: '+'.  Format
C------ statements in which non-standard format codes appear are
C------ listed in the comment section, 'Non-standard Format Codes'.

C------ General Suggestions for Improvement: Due to the need to
C------ standardize the programs, it was necessary to format inter-
C------ active input. This often presents awkward restrictions for
C------ the user. It is advised that, if available, free-formatted reads
C------ be implemented to handle numerical input. In addition, the
C------ use of one standard output filename for all program runs is
C------ impractical and potentially hazardous. Although the 'A'
C------ attribute will provide protection against overwriting on
C------ some systems, it is only meant as a temporary alternative.
C------ It is advisable that something such as string formatting
C------ be used to allow character input, in particular, for the
C------ interactive naming of output files.
C------    Additionally, individual users should implement precautions
C------ against careless user inputting, such as illegal characters. The
C------ program contains only minor precautions. The user should beware
C------ that some systems accept entry of a carriage return or a
C------ mathematical sign character (+,-) or decimal as if a zero had
C------ been entered.

C------ Non-standard FORTRAN options:
C       -----------------------------
C------ STATIC: The STATIC option places all non-COMMON variables and
C------ arrays in a fixed area in memory, rather than on the run-time
C------ stack. It initializes all static variables to zero at load time,
C------ unless you data-initialize them. You may retrieve the values of
C------ static variables within a subprogram upon re-entry to the
C------ subprogram for the second and subsequent times.

C------ OPEN, CLOSE, and REWIND: Although the purpose of these
C------ input/output statements is obvious, their implementation
C------ may differ from system to system. The 'OPEN' statement used
C------ with the 'ATT=A' option specifies that appending is to be
C------ performed onto the file associated the the channel opened.
C------ This protects against overwriting the previous contents of the
C------ file, if any existed. REWIND repositions the record pointer to
C------ the beginning of the specified file.

C------ 'P' and 'Z' format code: The scale factor 'P' changes the
C------ location of the decimal point in the external representation
C------ of a real number, with respect to its internal value. The
C------ format is 'nP', where 'n' is an integer constant that specifies
C------ the number of positions you want to move the decimal point to
C------ the right. 'Z' format code suppresses the newline character
C----- on output of the current record. It is represented internally,
C------ and as it is used to build many of the Handbook output files,
C------ its presence should be considered if any of these files are
C------ edited.

C------ Non-Standard Format Codes (statement numbers): 90
C       ----------------------------------------------
```

```
C------ Special Input Format Procedures:
C       --------------------------------
C------ When entering wavelength data, use exponential notation
C------ of the form "digit'E'exponent", where
C------     : 'digit' is any number. The number must include
C------       a decimal and must occupy 4 spaces;
C------     : 'E' is the letter 'E';
C------     : 'exponent' is a signed or unsigned integer constant.
C------       'exp' must occupy 2 spaces.
C------ EXAMPLES:       NUMBER          YOU ENTER
C------                 ------          ---------
C------                 2E6             2.00E06
C------                 2E-6            2.00E-6
C------                 275E-8          275.E-8, 2.75E-6, etc.

C------ User Options
C       ------------
C------    - desired temperatures entered singly or as an array
C------    - print output to screen and/or diskfile

C------ Output - output diskfile named "MICOUT"; should be renamed after each run
C       ------

C------ File unit #s
C       ------------
C------    1: data file (h2o or ice)
C------    2: diskfile
C------   11: terminal

C------ Data Files used:
C       ----------------
C------    RFICEMN50,RFICEMN30,RFICEMN10,RFICEM0,RFH2OMN8,RFH2OM0,
C------    RFH2OM10,RFH2OM18,RFH2OM20,RFH2OM30,RFH2OM40,RFH2OM50,
C------    RFH2OM60,RFH2OM75

C------ Subroutines
C       -----------
C------    DAT: reads indices data into arrays
C------    H2OPEN: opens h2o data file
C------    H2OTEMP: checks temperature validity
C------    HEADER: prints informational header
C------    ICEOPEN: opens ice data file
C------    ICETEMP: checks temperature validity
C------    INTERP: uses linear interpolation to build
C------       output arrays
C------    INTVEC: builds a user-entered integer array
C------    KEY: prints variable key
C------    LINTERP: two-point linear interpolation
C------    RD: transfers a data array to output
C------    READANS: checks user answers for error
C------    RFPRINT: prints output arrays
C------    SUBHDR: prints substance and temperature
C------    TEMPCHK: checks temperature array for errors
C------    VECTOR: builds user-entered real array

C------ Arrays
C       ------
C------  Input
C------    DATIMAG: imaginary index data
C------    DATREAL: real index data
C------    DATVEC: wavelength data
C------    MICFIL: character array; used to transfer
C------       data arrays to output
C------    TEM: temperature

C------  Output
C------    IMAG: imaginary indices (in general, interpolated)
C------    LAM: wavelength
C------    RFREAL: real indices (in general, interpolated)
C------
C------ Variables
C       ---------
C------    Logical
C------       CHK: used in checking temperature validity
C------       DATSET: indicates whether temps. are being
C------          entered singly or as an array
C------       H2O,ICE: indicate current substance
C------       OPEN2: indicates whether unit 2 is open
```

```
C------ Integer
C------    ANS: user answer
C------    DATSIZ: length of current data array
C------    MICOUT: output filename
C------    LAMLEN: length of user wavelength array
C------    OUT: indicates print option
C------    TEMP: temperature
C------    TEMPLEN: length of temperature array

C       Suchi Psarakos
C       N.O.A.A.
C       325 Broadway
C       R/E/WP2
C       Boulder, Colorado 80303

C       Please direct questions to Dr. Vernon Derr, (303) 497-6002,
C       or Suchi Psarakos, (303) 497-5361.

C#############################################################

        LOGICAL OPEN2,H2O,ICE,DATSET,CHK,H2OTEMP,ICETEMP
        DIMENSION MICFIL(29),DATVEC(23),
     $     DATREAL(23),DATIMAG(23),RFREAL(50)
        INTEGER ANS,OUT,TEMPLEN,TEMP,LAMLEN,DATSIZ,TEM(50),MICOUT
        REAL LAM(50),IMAG(50)

C------ initialize
        CALL HEADER (0 )
        WRITE (11, 98)
        OPEN2=.FALSE.
C------ print option
        WRITE (11,90)
        WRITE (11,91)
5       READ (11,95,ERR=8) ANS
        IF ((ANS .NE. 0).AND.(ANS.NE.1).AND.(ANS.NE.2)) GOTO 8
        OUT = ANS
        IF ((OUT.EQ.1).OR.(OUT.EQ.2).AND.(.NOT.OPEN2)) GOTO 6
        GOTO 9
C------ name for output file?
C++++++++++++++
6       OPEN 2, "MICOUT", ATT="A"
C++++++++++++++
        OPEN2 = .TRUE.
        IF ((OUT.EQ.1).OR.(OUT.EQ.2)) CALL HEADER (1)
        GOTO 9
C------ incorrect entry
8       WRITE (11,94)
        WRITE (11,91)
        GOTO 5

C------ substance?
9       WRITE (11,100)
        WRITE (11,125)
        CALL READANS (ANS )
        IF (ANS.EQ.0) GOTO 20
C------ ice
        ICE = .TRUE.
        H2O = .FALSE.
        GOTO 30

C------ h2o
20      H2O=.TRUE.
        ICE=.FALSE.

C------ entry mode?
30      WRITE (11,225)
        WRITE (11,125)
        CALL READANS (ANS )
        IF (ANS.EQ.0) GOTO 40

C------ data set
        DATSET=.TRUE.
        WRITE (11, 150)
        IF (H2O) WRITE (11, 175)
        IF (ICE) WRITE (11, 200)
        WRITE (11,1000)
        CALL INTVEC (H2O, TEMPLEN, TEM)
        IF (TEMPLEN.LT.0) GOTO 89
        CALL TEMPCHK (TEM,TEMPLEN,ICE )
```

```
C------ begin DO
        DO 72 I=1,TEMPLEN
           TEMP=TEM(I)
           GOTO 47

C------ single entry mode
40      DATSET=.FALSE.
C------ enter temperature
41      WRITE (11,150)
        IF (ICE) GOTO 43
        WRITE (11, 175)
        WRITE (11, 1000)
42      READ (11, 96, ERR=46) TEMP
        CHK=H2OTEMP(TEMP )
        GOTO 45
43      WRITE (11, 200)
        WRITE (11, 1000)
44      READ (11, 97, ERR=46) TEMP
        CHK=ICETEMP(TEMP )
45      IF (.NOT.CHK) GOTO 46
        GOTO 47
46      WRITE (11,1001)
        IF (H2O) GOTO 42
        GOTO 44

47      IF (ICE) CALL ICEOPEN (TEMP )
        IF (H2O) CALL H2OPEN (TEMP )
        CALL SUBHDR (-OUT,TEMP,ICE )
        CALL KEY (0 )
        CALL RD (11, MICFIL)


C------ save values?
        IF (OUT.EQ.0) GOTO 50
        WRITE (11,1100)
        WRITE (11,125)
        CALL READANS (ANS )
        IF (ANS.EQ.0) GOTO 50
        CALL SUBHDR (1,TEMP,ICE )
        CALL KEY (1 )
        CALL RD (2, MICFIL)
        WRITE (2,999)

C------ interpolation?
50      WRITE (11,1200)
        WRITE (11,125)
        CALL READANS (ANS )
        IF (ANS.EQ.1) GOTO 68
C++++++++++++++
        CLOSE 1
C++++++++++++++
        IF (DATSET) GOTO 70
        GOTO 69

C------ yes; create wavelength array,prepare data
C------ array,interpolate
68      IF (ANS.EQ.1) WRITE (11,1300)
        CALL VECTOR ( LAMLEN, LAM)
        IF (LAMLEN.LT.0) GOTO 89
        CALL DAT ( DATVEC,DATREAL,DATIMAG,DATSIZ)
        CALL INTERP (LAM,LAMLEN,DATVEC,DATREAL,DATIMAG,
     $     DATSIZ, RFREAL,IMAG)
        CALL SUBHDR (OUT,TEMP,ICE )
        CALL KEY (OUT )
        CALL RFPRINT (LAM,LAMLEN,RFREAL,IMAG,OUT )
        IF (OUT.EQ.1 WRITE (11,250)
        IF (DATSET) GOTO 70

C------ another temp?
69      WRITE (11,1400)
        WRITE (11,125)
        CALL READANS (ANS )
        IF (ANS.EQ.0) GOTO 74
        GOTO 41
C------ end DO
70         WRITE (11,999)
72         CONTINUE
```

```
C------ different substance?
74      WRITE (11,1500)
        WRITE (11,125)
        CALL READANS (ANS )
        IF (ANS.EQ.0) GOTO 89
        GOTO 9

89      IF ((OUT.EQ.1).OR.(OUT.EQ.2)) WRITE (11,1600)
        STOP

90      FORMAT (/"PRINT OPTION:"/3X,"0: RESULTS TO SCREEN ONLY"
     $     /3X,"1: RESULTS TO DISKFILE"/3X,"2: RESULTS TO BOTH",Z,
     $     " SCREEN AND DISKFILE"/)
91      FORMAT ("ENTER 0, 1, OR 2")
94      FORMAT ("INCORRECT ENTRY")
95      FORMAT (I1)
96      FORMAT (I2)
97      FORMAT (I3)
98      FORMAT ("USE EXPONENTIAL NOTATION OF THE FORM 'digit'E'exponent'"/
     $          "WHERE"/7X,
     $          ": 'digit' IS ANY NUMBER. THE NUMBER MUST INCLUDE"/10X,
     $          "A DECIMAL AND MUST OCCUPY 4 SPACES;"/7X,
     $          ": 'E' IS THE LETTER 'E';"/7X,
     $          ": 'exponent' IS A SIGNED OR UNSIGNED INTEGER CONSTANT."/10X,
     $          "'exp' MUST OCCUPY 2 SPACES."//
     $          "EXAMPLES:      NUMBER          YOU ENTER"/
     $          "               ------          ---------"/
     $          "               2E6             2.00E06"/
     $          "               2E-6            2.00E-6"/
     $          "               275E-8          275.E-8, 2.75E-6"/)
100     FORMAT (/"REFRACTIVE INDICES FOR WATER (0) OR ICE (1)?")
125     FORMAT ("ENTER 0 OR 1")
150     FORMAT (/"AVAILABLE TEMPERATURES (degrees C):"/)
175     FORMAT ("-8"/"0"/"10"/"18"/"20"/"30"/"40"/"50"/"60"/
     $     "75"/)
200     FORMAT ("-50"/"-30"/"-10"/"0"/)
225     FORMAT (/"WILL YOU BE ENTERING TEMPERATURES SINGLY (0)"/
     $     "OR INTO AN ARRAY (1)?")
250     FORMAT ("COMPLETED")
999     FORMAT ()
1000    FORMAT (/"ENTER TEMPERATURE (C):")
1001    FORMAT ("RE-ENTER TEMPERATURE")
1100    FORMAT (/"DO YOU WANT THIS FILE SENT TO DISK? (0=NO, 1=YES)")
1200    FORMAT (/"DO YOU WANT ANY INTERPOLATIONS? (0=NO, 1=YES)")
1300    FORMAT (/"ENTER WAVELENGTH (meters):")
1400    FORMAT (/"WOULD YOU LIKE ANOTHER TEMPERATURE? (O=NO,1=YES)")
1500    FORMAT (/"WOULD YOU LIKE A DIFFERENT SUBSTANCE? (0=NO,1=YES)")
1600    FORMAT (/"CHECK 'MICOUT' FOR OUTPUT. REMEMBER TO RENAME THIS FILE.")
        END
```

```
        SUBROUTINE DAT ( DATVEC,DATREAL,DATIMAG,DATSIZ)

C------ Reads values from data file into arrays

C------ Non-standard Format Code (statement number): 23

C------ Parameter list
C------    output - real
C------    DATIMAG,DATREAL,DATVEC: imaginary,real, and
C------       wavelength data arrays
C------    output - integer
C------       DATSIZ: data array length

        DIMENSION DATVEC(23),DATREAL(23),DATIMAG(23)
        INTEGER DATSIZ

        DO 10 I=1,23
           READ (1,23,ERR=21,END=20) DATVEC(I),DATREAL(I),
     $        DATIMAG(I)
           DATSIZ = DATSIZ+1
10      CONTINUE

C+++++++++++++++
20      CLOSE 1
C+++++++++++++++
        DATSIZ=I-1
        RETURN
21      WRITE (11,22)
22      FORMAT ("ERR READING DATFILE")
23      FORMAT (5X,3(2X,1PE13.6))
        STOP
        END
```

```
      SUBROUTINE H2OPEN (TEMP )

C------ opens h2o data file

      INTEGER TEMP

C+++++++++++++++
      IF (TEMP.EQ. - 8) OPEN 1,"RFH2OMN",ERR=1000
      IF (TEMP.EQ.   0) OPEN 1,"RFH2OM0",ERR=1500
      IF (TEMP.EQ.  10) OPEN 1,"RFH2OM10",ERR=2000
      IF (TEMP.EQ.  18) OPEN 1,"RFH2OM18",ERR=2500
      IF (TEMP.EQ.  20) OPEN 1,"RFH2OM20",ERR=3000
      IF (TEMP.EQ.  30) OPEN 1,"RFH2OM30",ERR=3500
      IF (TEMP.EQ.  40) OPEN 1,"RFH2OM40",ERR=4000
      IF (TEMP.EQ.  50) OPEN 1,"RFH2OM50",ERR=4500
      IF (TEMP.EQ.  60) OPEN 1,"RFH2OM60",ERR=5000
      IF (TEMP.EQ.  75) OPEN 1,"RFH2OM75",ERR=5500
C+++++++++++++++

      RETURN

1000  WRITE (11,1001)
      STOP
1500  WRITE (11,1501)
      STOP
2000  WRITE (11,2001)
      STOP
2500  WRITE (11,2501)
      STOP
3000  WRITE (11,3001)
      STOP
3500  WRITE (11,3501)
      STOP
4000  WRITE (11,4001)
      STOP
4500  WRITE (11,4501)
      STOP
5000  WRITE (11,5001)
      STOP
5500  WRITE (11,5501)
      STOP

1001  FORMAT ("ERR OPENING RFH2OMN8")
1501  FORMAT ("ERR OPENING RFH2OM0")
2001  FORMAT ("ERR OPENING RFH2OM10")
2501  FORMAT ("ERR OPENING RFH2OM18")
3001  FORMAT ("ERR OPENING RFH2OM20")
3501  FORMAT ("ERR OPENING RFH2OM30")
4001  FORMAT ("ERR OPENING RFH2OM40")
4501  FORMAT ("ERR OPENING RFH2OM50")
5001  FORMAT ("ERR OPENING RFH2OM60")
5501  FORMAT ("ERR OPENING RFH2OM75")
      END
```

```
      FUNCTION H2OTEMP (T )

C------ Checks a user-requested h2o temperature for validity

      LOGICAL H2OTEMP
      INTEGER T

      H2OTEMP=.TRUE.
      IF ((T.NE.-8).AND.(T.NE.0).AND.(T.NE.10).AND.
     $   (T.NE.18).AND.(T.NE.20).AND.(T.NE.30).AND.
     $   (T.NE.40).AND.(T.NE.50).AND.(T.NE.60).AND.
     $   (T.NE.75)) H2OTEMP=.FALSE.
      RETURN
      END




      SUBROUTINE HEADER (OUT )

C------ Prints informational header

C------ Parameter list
C------    input - integer
C------       OUT: print entry option


      INTEGER OUT,UNIT

      IF (OUT.EQ.0) UNIT=11
      IF (OUT.EQ.1) UNIT=2
      WRITE (UNIT,100)
      WRITE (UNIT,200)
      WRITE (UNIT,300)
      WRITE (UNIT,400)
      WRITE (UNIT,500)

      RETURN

100   FORMAT ("REFRACTIVE INDICES: MICROWAVE"//"SOURCES:"/
     $   "1:RYDE,D. AND J.W. RYDE"/"2:LANE,J.A. AND",
     $   " J.A. SAXTON"/"4:COLLIE, C.H., J.B. HASTED, AND",
     $   " D.M. RITSON"/"5:DEIRMENDJIAN, D."/)
200   FORMAT ("-ALPHANUMERIC COLUMNS SHOW SOURCE(REAL)"/3X,"AND",
     $   " SOURCE(IMAGINARY)")
300   FORMAT ("-NUMBERS  ALONE REFER TO SOURCE AND"/
     $   3X,"INDICATE EXPERIMENTAL VALUES"/"-'A' REFERS TO VALUES",
     $   " CALCULATED WITH THE DEBYE FORMULA")
400   FORMAT ("-'**' CORRESPONDS TO INTERPOLATED VALUES")
500   FORMAT ("-N=REAL, K=IMAGINARY"//)
      END
```

```
        SUBROUTINE ICEOPEN (TEMP )

C------ opens ice data file

        INTEGER TEMP

C++++++++++++++
        IF (TEMP.EQ. -50) OPEN 1, "RFICEMN50",ERR=1000
        IF (TEMP.EQ. -30) OPEN 1, "RFICEMN30",ERR=2000
        IF (TEMP.EQ. -10) OPEN 1, "RFICEMN10",ERR=3000
        IF (TEMP.EQ. 0) OPEN 1, "RFICEM0",ERR=4000
C++++++++++++++

        RETURN

1000    WRITE (11,1001)
        STOP
2000    WRITE (11,2001)
        STOP
3000    WRITE (11,3001)
        STOP
4000    WRITE (11,4001)
        STOP

1001    FORMAT ("ERR OPENING RFICEMN50")
2001    FORMAT ("ERR OPENING RFICEMN30")
3001    FORMAT ("ERR OPENING RFICEMN10")
4001    FORMAT ("ERR OPENING RFICEM0")
        END
```

```
        FUNCTION ICETEMP (T )

C------ Checks user-requested ice temperatures for validity

        LOGICAL ICETEMP
        INTEGER T

        ICETEMP=.TRUE.
        IF ((T.NE.-50).AND.(T.NE.-30).AND.(T.NE.-10)
     $     .AND.(T.NE.0)) ICETEMP=.FALSE.
        RETURN
        END
```

```
      SUBROUTINE INTERP (VEC,VECSIZ,DATVEC,DATREAL,
     $   DATIMAG,DATSIZ, RFREAL,IMAG)

C------ Matches appropriate two neighboring values in the
C------ available data wavelength array,DATVEC, to the requested
C------ wavelengths in VEC. Calls function INTERP. In the case
C------ of a user-request which outlies the endpoint values
C------ in DATVEC, the routine substitutes the indices of the
C------ appropriate endpoint. The DATVEC array is increasing.

C------ Note: Some data arrays have multiple indices for
C------ a given wavelength (due to more than one source).
C------ The arrays have been arranged such that either the
C------ most recent source or the experimental (rather
C------ than predicted) values come first.

C------ Parameter list
C------    input - real
C------       DATIMAG, DATREAL, DATVEC: imaginary,real,
C------          wavelength data arrays
C------       VEC: user-entered wavelength array
C------    input - integer
C------       VECSIZ, DATSIZ: length of VEC and DATVEC
C------    output - real
C------       IMAG, RFREAL: output imaginary and real arrays

      DIMENSION VEC(VECSIZ), DATVEC(DATSIZ),DATREAL(DATSIZ),
     $   DATIMAG(DATSIZ), RFREAL(VECSIZ)
      REAL IMAG(VECSIZ),LINTERP
      INTEGER VECSIZ, DATSIZ

      DO 100 I=1,VECSIZ
         DO 15 J=1,(DATSIZ-1)
C------ user wavelength out of range
            IF (DATVEC(J).EQ.VEC(I)) GOTO 25
            IF ((DATVEC(1).GT.VEC(I)).OR.
     $         DATVEC(DATSIZ).LT.VEC(I)) GOTO 30
            IF ((DATVEC(J).LT.VEC(I)).AND.
     $         (DATVEC(J+1).GT.VEC(I))) GOTO 20
15       CONTINUE
C------ call to INTERP
20       RFREAL(I)=LINTERP(DATVEC(J),DATVEC(J+1),DATREAL(J),
     $         DATREAL(J+1),VEC(I))
         IMAG(I)=LINTERP(DATVEC(J),DATVEC(J+1),DATIMAG(J),
     $         DATIMAG(J+1),VEC(I))
C------ mark interpolated values for future id.
         VEC(I) = -VEC(I)
         GOTO 100

25    RFREAL(I)=DATREAL(J)
      IMAG(I)=DATIMAG(J)
      GOTO 100

30       IF ((J.NE.1).AND.(DATVEC(DATSIZ).EQ.DATVEC(DATSIZ-1))) GOTO 40
C------ substitute endpoint indices for user request
         IF (DATVEC(DATSIZ).LT.VEC(I)) J=DATSIZ
32       VEC(I)=DATVEC(J)
         RFREAL(I)=DATREAL(J)
         IMAG(I)=DATIMAG(J)
         GOTO 100

C------ multiple values for a given wavelength; position
C------ 'J' at most reliable source
40       J=DATSIZ-1
41       IF (DATVEC(J).EQ.DATVEC(J-1)) GOTO 42
         GOTO 32
42       J=J-1
         GOTO 41

100   CONTINUE

      RETURN
      END
```

```
        SUBROUTINE INTVEC (H2O, LEN, VEC)

C------ Creates a user-entered integer array; max. length
C------ = 50. Input session is terminated upon entry of a
C------ '99'.
C------ Note: The program stops if there is not at least one
C------ value entered into the array.

C------ Non-standard Format Code (statement number): 1100, 1200

C------ Parameter list
C------    Input - logical
C------       H2O: specifies which substance is being used
C------    Input/Output - integer
C------       LEN: length of the array
C------    Output - integer
C------       VEC: integer array

        INTEGER   VEC(50)
        INTEGER LEN
        LOGICAL H2O

C------ entry procedure
        WRITE (11,1000)
C------ build vector
        DO 15 I=1,50
           WRITE (11,1200)
10      IF (H2O) READ (11, 900, ERR=11) VEC(I)
        IF (.NOT.H2O) READ (11, 920, ERR=11) VEC(I)
           IF ((VEC(I).EQ.99).OR.(VEC(I).EQ.990)) GOTO 20
           GOTO 15
11         WRITE (11,1100)
           GOTO 10
15      CONTINUE
        GOTO 21
C------ check array length for error; return
20      IF (I.EQ.1) GOTO 22
        LEN = I-1
        RETURN
21      LEN=I
        RETURN
22      WRITE (11,1300)
        LEN=-1
        RETURN

900     FORMAT (I2)
920     FORMAT (I3)
1000    FORMAT ("ENTER EACH VALUE IN CORRECT UNIT, WAIT FOR"/
     $     "PROMPT ':', THEN CONTINUE. TYPE '99' WHEN FINISHED."/)
1100    FORMAT ("INCORRECT ENTRY. PLEASE RE-ENTER"/":",Z)
1200    FORMAT (":",Z)
1300    FORMAT ("ERROR: YOU MUST HAVE AT LEAST ONE VALUE"/
     $     "IN THIS ARRAY. PROGRAM TERMINATED.")
        END
```

```
        SUBROUTINE KEY (OUT )

C------ Prints a variable key for output

C------ Parameter list
C------    input - integer
C------       OUT: print entry option


        INTEGER UNIT,OUT

        IF ((OUT.EQ.0).OR.(OUT.EQ.2)) GOTO 10
        GOTO 15
10      UNIT =11
        GOTO 20
15      UNIT = 2
20      WRITE (UNIT,100)
        IF ((OUT.EQ.2).AND.(UNIT.EQ.11)) GOTO 15
        RETURN


100     FORMAT (11X,"LAM (m)",14X,"N",14X,"K",3X,"S(N)",
     $     3X,"S(K)"/)
        END




        FUNCTION LINTERP (DAT1,DAT2,RES1,RES2,X )

C------ 2 point linear interpolation
C------ DAT and RES correspond to 'data' and 'result', and
C------ constitute an ordered pair. X is the known value for
C------ which a Y is needed. LINTERP determines Y by linear
C------ interpolation.


        REAL DAT1,DAT2,RES1,RES2,X,LINTERP,Y

        Y = ((X - DAT1) * (RES2 - RES1)/(DAT2 - DAT1)) + RES1
        LINTERP = Y

        RETURN
        END
```

```
        SUBROUTINE RD (UNIT, MICFIL)

C------ Transfers a data array to output

C------ Non-standard Format Code (statement number): 5000
C       Note that the use of 'A' format code is system dependent.
C       Depending on the system, it will have to be modified
C       according to the form 'xAy', where 'x' is a repetition
C       count, and 'y' represents the number of characters you
C       want read in per computer word (note that the characters
C       will be left-justified, and padded with blanks).


C------ Parameter list
C------    input - integer
C------       UNIT: the device to which the data file
C------          will be written
C------    output
C------       MICFIL: array used to transfer one
C------          of the data arrays to output, line by line


        DIMENSION MICFIL (29)
        INTEGER UNIT

10      READ (1,5000,END=20) (MICFIL(I), I=1,29)
        WRITE (UNIT,5000) (MICFIL(I), I=2,29)
        GOTO 10

C++++++++++++++
20      REWIND 1
C++++++++++++++
        RETURN

5000    FORMAT (6X,29A2)
        END
```

```
      SUBROUTINE READANS (ANS )

C------ checks user answers for error

      INTEGER ANS

      GOTO 10
5     WRITE (11,100)
10    READ (11,110,ERR=5) ANS
      IF ((ANS.NE.0).AND.(ANS.NE.1)) GOTO 5

      RETURN
100   FORMAT ("INCORRECT ENTRY. ENTER 0 OR 1")
110   FORMAT (I1)
      END
```

```
      SUBROUTINE RFPRINT (LAM,LEN,RFREAL,IMAG,OUT )

C------ Prints wavelength, real, and imaginary arrays
C------ to output. Interpolated values have been marked as
C------ negative in the wavelength array.

C------ Non-standard Format Code (statement number): 100, 200, 300

C------ Parameter list
C------    input - real
C------       IMAG,LAM,RFREAL: imaginary, wavelength, and real
C------          arrays
C------    input - integer
C------       LEN: length of output arrays
C------       OUT: indicates print option


      REAL LAM(LEN),RFREAL(LEN),IMAG(LEN)
      INTEGER LEN,OUT,UNIT

      DO 10 I=1,LEN
         IF ((OUT.EQ.0).OR.(OUT.EQ.2)) GOTO 5
         GOTO 6
5        UNIT=11
         GOTO 7
6        UNIT=2
7        IF (LAM(I).GE.0) GOTO 8
         WRITE (UNIT,100)
         LAM(I)=ABS(LAM(I))
         WRITE (UNIT,300) LAM(I),RFREAL(I),IMAG(I)
         IF ((OUT.EQ.2).AND.(UNIT.EQ.11)) LAM(I)=-LAM(I)
         GOTO 9
8        WRITE (UNIT,200) LAM(I),RFREAL(I),IMAG(I)
9        IF ((OUT.EQ.2).AND.(UNIT.EQ.11)) GOTO 6
10    CONTINUE

      RETURN

100   FORMAT ("**",Z)
200   FORMAT (3X,3(2X,1PE13.6),2(3X,"----"))
300   FORMAT (1X,3(2X,1PE13.6),2(3X,"----"))
      END
```

```
        SUBROUTINE SUBHDR (OUT,TEMP,ICE )

C------ Prints current substance and temperature to output

C------ Non-standard Format Code (statement number): 100, 200

C------ Parameter list
C------ input - logical
C------    ICE: indicates current substance
C------ input - integer
C------    OUT: indicates print option
C------    TEMP: temperature


        LOGICAL ICE
        INTEGER OUT,TEMP

        IF (OUT.LT.0) GOTO 10
        IF ((OUT.EQ.0).OR.(OUT.EQ.2)) GOTO 10
        GOTO 20
10      UNIT = 11
        GOTO 40
20      UNIT=2

40      IF (ICE) GOTO 90

        WRITE (UNIT,100)
        IF (TEMP.EQ.-8) WRITE (UNIT,300)
        IF (TEMP.EQ.  0) WRITE (UNIT,400)
        IF (TEMP.EQ. 10) WRITE (UNIT,500)
        IF (TEMP.EQ. 18) WRITE (UNIT,550)
        IF (TEMP.EQ. 20) WRITE (UNIT,600)
        IF (TEMP.EQ. 30) WRITE (UNIT,700)
        IF (TEMP.EQ. 40) WRITE (UNIT,800)
        IF (TEMP.EQ. 50) WRITE (UNIT,900)
        IF (TEMP.EQ. 60) WRITE (UNIT,1000)
        IF (TEMP.EQ. 75) WRITE (UNIT,1100)
        GOTO 91


90      WRITE (UNIT,200)
        IF (TEMP.EQ.-50) WRITE (UNIT,1200)
        IF (TEMP.EQ.-30) WRITE (UNIT,1300)
        IF (TEMP.EQ.-10) WRITE (UNIT,1400)
        IF (TEMP.EQ.0) WRITE (UNIT,400)

91      IF ((OUT.EQ.2).AND.(UNIT.EQ.11)) GOTO 20

        RETURN

100     FORMAT (/"SUBSTANCE: H2O",3X,"TEMP: ",Z)
200     FORMAT (/"SUBSTANCE: ICE",3X,"TEMP: ",Z)
300     FORMAT ("-8"/)
400     FORMAT ("0"/)
500     FORMAT ("10"/)
550     FORMAT ("18"/)
600     FORMAT ("20"/)
700     FORMAT ("30"/)
800     FORMAT ("40"/)
900     FORMAT ("50"/)
1000    FORMAT ("60"/)
1100    FORMAT ("75"/)
1200    FORMAT ("-50"/)
1300    FORMAT ("-30"/)
1400    FORMAT ("-10"/)

        END
```

```
      SUBROUTINE TEMPCHK (TEMP,TEMPLEN,ICE )

C------ Checks user-entered temperature array for validity.
C------ Calls H2OTEMP or ICETEMP.

C------ Non-standard Format Code (statement label): 110

C------ Parameter list
C------    input - logical
C------       ICE: indicates current substance
C------    input - integer
C------       TEMP: temperature array
C------       TEMPLEN: length of TEMP array

      LOGICAL ICE,CHK,H2OTEMP,ICETEMP,MESS
      INTEGER TEMP(TEMPLEN),T,TEMPLEN,NEWT

      MESS=.FALSE.
      DO 20 I=1,TEMPLEN
         T=TEMP(I)

C------ check for valid temperature
         IF (.NOT.ICE) CHK=H2OTEMP(T)
         IF (ICE) CHK=ICETEMP(T)
C------ invalid
         IF (.NOT.CHK) GOTO 10
         GOTO 20
C------ re-enter correction
10       IF (.NOT.MESS) WRITE (11,100)
         MESS=.TRUE.
11       WRITE (11,110) T
12       IF (.NOT.ICE) READ (11,130,ERR=15) NEWT
         IF (ICE) READ (11,135,ERR=15) NEWT
         IF (((.NOT.ICE).AND.(NEWT.EQ.99)).OR.
     $      ((ICE).AND.(NEWT.EQ.990)))
     $        GOTO 14

C------ check correction
         IF (.NOT.ICE) CHK=H2OTEMP(NEWT)
         IF (ICE) CHK=ICETEMP(NEWT)
C------ invalid
         IF (.NOT.CHK) GOTO 15

         TEMP(I)=NEWT
         GOTO 20
C------ reprint available temperatures
14       WRITE (11,150)
         IF (.NOT.ICE) WRITE (11,175)
         IF (ICE) WRITE (11,200)
         GOTO 11
15       WRITE (11,120)
         GOTO 12
20       CONTINUE

      RETURN

100   FORMAT (/"INVALID ENTRIES:"/"NOTE: IF YOU NEED TO SEE THE"/
     $   "LISTING OF AVAILABLE TEMPERATURES, TYPE '99' INSTEAD"/
     $   "OF THE CORRECTED VALUE"/)
110   FORMAT (I3,2X,"CORRECTION: ",Z)
120   FORMAT ("RE-ENTER")
130   FORMAT (I2)
135   FORMAT (I3)
150   FORMAT ("AVAILABLE TEMPERATURES (degrees C):"/)
175   FORMAT ("-8"/"0"/"10"/"18"/"20"/"30"/"40"/"50"/"60"/
     $   "75"/)
200   FORMAT ("-50"/"-30"/"-10"/"0"/)
      END
```

```
        SUBROUTINE VECTOR ( LEN, VEC)

C------ Creates a user-entered array of exponents; max. length = 50.
C------ Input session is terminated upon entry of '-1'.

C------ Note: the program stops if there is not at least one
C------ value entered into the array.

C------ Non-standard Format Code (statement label): 1100, 1200

C------ Parameter list
C------ input/output - integer
C------    LEN: length of array
C------ output - real
C------    VEC: real array

        DIMENSION VEC(50)
        INTEGER LEN

C------ entry procedure
        WRITE (11, 950)
        WRITE (11,1000)
C------ build vector
        DO 15 I=1,50
           WRITE (11,1200)
10         READ (11, 900, ERR= 11) VEC(I)
           IF (VEC(I).LT.0) GOTO 20
           GOTO 15
11         WRITE (11,1100)
           GOTO 10
15      CONTINUE
        GOTO 21
C------ check array length for error; return
20      IF (I.EQ.1) GOTO 22
        LEN = I-1
        RETURN
21      LEN=I
        RETURN
22      WRITE (11,1300)
        LEN=-1
        RETURN

900     FORMAT (E7.2)
950     FORMAT ("USE EXPONENTIAL NOTATION OF THE FORM 'digit'E'exponent'"/
     $          "WHERE THE ENTIRE EXPRESSION OCCUPIES 7 SPACES"/)
1000    FORMAT ("ENTER EACH VALUE IN CORRECT UNIT, WAIT FOR"/
     $     "PROMPT ':', THEN CONTINUE. TYPE '-1' WHEN FINISHED."/)
1100    FORMAT ("INCORRECT ENTRY. PLEASE RE-ENTER"/":",Z)
1200    FORMAT (":",Z)
1300    FORMAT ("ERROR: YOU MUST HAVE AT LEAST ONE VALUE"/
     $     "THIS ARRAY. PROGRAM TERMINATED")
        END
```

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APPENDIX E: List of Useful Atmospheric Constants and Conversions [FACTS, 220]

Equatorial Radius of Earth -- 6378.39 km

Polar Radius of Earth -- 6356.91 km

Radius of a Sphere Having the same Volume as Earth -- 6371.22 km

Angular Velocity of Rotation of Earth -- 7.292E-5 s^{-1}

Acceleration of Gravity at Sea Level and 45 degrees latitude -- 980.616 cm s^{-2}

Solar Constant -- 2.00 Langley min^{-1} = 1.388E06 erg cm^{-2} s^{-1}

Mean Solar Distance -- 1.4968E08 km

Sidereal Day
-- 23.93447 hr
-- 23 hr 56'4.09"

Velocity of Light -- 2.9979E08 m s^{-1}

Universal Gas Constant -- 8.3144E07 erg $mole^{-1}$ K^{-1}

Gas Constant for Dry Air -- 2.8704E06 erg g^{-1} K^{-1}

Standard Molar Volume of Ideal Gas
-- 22,413.6E-6 m^3 $mole^{-1}$
-- 22.4136 liters $mole^{-1}$

Molar Constant of Ideal Gas
-- 8.3143 J $mole^{-1}$ K^{-1}
-- 8.3143E07 ergs $mole^{-1}$ K^{-1}

Mean Molecular Weight of Dry Air -- 28.966 g $mole^{-1}$

Molecular Weight of Water -- 18.016 g $mole^{-1}$

Specific Heat Capacity of Dry Air at Constant Pressure -- 0.240 cal g^{-1} K^{-1}

Specific Heat Capacity of Dry Air at Constant Volume -- 0.171 cal g^{-1} K^{-1}

Ratio of the Specific Heats of Dry Air -- 1.400

Specific Heat Capacity for Water Vapor at Constant Pressure -- 1850 J kg^{-1} K^{-1}

Specific Heat Capacity for Water Vapor at Constant Volume -- 1390 J kg^{-1} K^{-1}

Heats of Transformation of Phase of Water Vaporization
-- 2.406E06 J kg^{-1} (40°C)
-- 2.501E06 J kg^{-1} (0°C)
-- 2.635E06 J kg^{-1} (-50°C)

Heats of Transformation Of Phase of Water Fusion -- 0.334 J kg^{-1} (0°C)

Heats of Transformation Of Phase of Water Sublimation
-- 2.834 E06 J kg^{-1} (0°C)
-- 2.839 E06 J kg^{-1} (-30°C)

Stefan-Boltzmann Constant -- 8.128E-11 Langley K^{-4} min^{-1}

Avogadro's Constant -- 6.0225E23 $mole^{-1}$

Boltzmann's Constant -- 1.3805E-23 J K^{-1}

Planck's Constant -- 6.6256E-34 J s^{-1}

Joule's Constant -- 4.186E07 ergs cal^{-1}

1 degree Latitude at 45 degrees N or S
-- 111.1 km
-- 59.96 nautical miles
-- 69.05 statute miles

1 m s^{-1}
-- 1.94 knots
-- 2.24 mph
-- 3.28 ft s^{-1}
-- 3.60 kph

1 atmosphere
-- 1013.25 mb
-- 760.000 mm of mercury
-- 29.921 inches of mercury
-- 1.01325E06 dynes cm^{-2}

1 calorie -- 4.186E07 ergs

Melting Point of Ice
-- 0.00°C
-- 32.00°F
-- 273.16 K