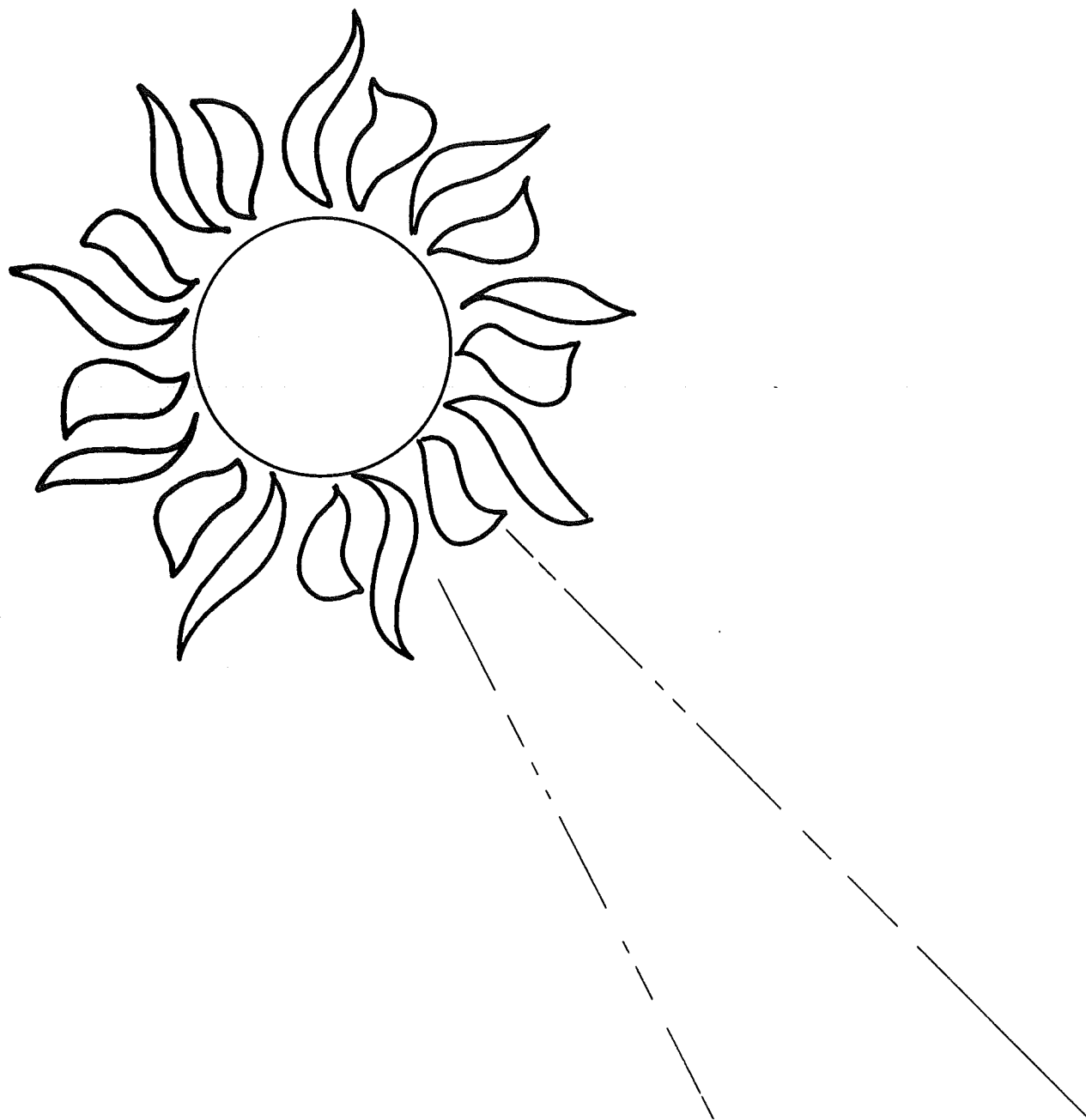




SOLAR RADIATION DATA



noaa

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

ENVIRONMENTAL DATA AND
INFORMATION SERVICE

NATIONAL CLIMATIC CENTER
ASHEVILLE, N.C. JUNE 1980

1. SCOPE OF SUMMARY

This summary describes the rehabilitated historical solar radiation data sets and the current National Oceanic and Atmospheric Administration (NOAA) network data. It also explains the various radiation data types, defines technical terms, discusses solar energy products and services that are available from other agencies, and describes the digital products, data processing methods, and publications available from the National Climatic Center (NCC). Appendix A describes the formats of other solar radiation data that may be ordered from the NCC.

2. HISTORY

The National Climatic Center receives, processes, publishes, archives, and distributes solar radiation data. The NCC archive contains these data mainly from about 1950 to the present, although solar radiation measurements began in the United States around the turn of the century. The U.S. Weather Bureau (now the National Weather Service) made the first systematic observations of solar radiation at Asheville, North Carolina, in 1902 and published the observed direct normal incidence data in the July 1903 issue of the Monthly Weather Review. Seventy-five years later, an upgraded 39-station NOAA network began operating, and its three types of radiation data (global, direct, and diffuse) are now available either in the Monthly Summary, Solar Radiation Data or on SOLMET formatted magnetic tape. During the interim, the solar radiation observational program progressed steadily, with measurements of global insolation added in 1909. The network size increased to 24 sites (14 of which were cooperative) in the Thirties, to a peak of 90 (30 cooperative) in the early Seventies.

In 1973, the energy crisis in the United States spurred a reevaluation of the historical data and the upgrading of the NOAA observational program with new instruments and data processing techniques. Over the years, many instrumental and procedural errors had produced highly suspect data.

3. DATA REHABILITATION

The NCC has rehabilitated observed solar radiation data, in digital form, from 52 U. S. locations for approximately a 25-year period, generally from July 1952 through December 1976, in order to obtain the best possible estimates of the true solar radiation. The first rehabilitation method (Engineering Corrected Data) corrected the original observed data set for all known scale changes and instrument calibrations. This proved inadequate since too many factors were either unknown or intractable. The second method (Standard Year Corrected Data) used the ratio of

the modeled noontime value of Standard Year Irradiance (SYI) to the observed clear solar noon 1-minute value to adjust observed hourly and daily solar radiation totals. Thirdly, the hourly SYI data set was serially completed via a sky cover/sky condition regression model.

The resultant magnetic tape formats for hourly and daily insolation data are called SOLMET and SOLDAY, respectively. Both contain collateral meteorological data. All three estimated values of the true solar radiation appear on the SOLMET data tapes, while only the first two appear on the SOLDAY tapes.

The NCC considers the SYI model corrected data as the best estimate of the actual radiation data recorded through 1976. All other archived solar radiation data in that period are considered questionable. The NCC considers the data in the Post 1976 SOLMET or Research-Cooperator (see sections 5.1 and 5.5) tape formats as the best estimates of solar radiation subsequent to 1976.

4. SOLAR RADIATION DATA TYPES AND DEFINITIONS

4.1 Solar Radiation Observations

Extraterrestrial radiation (ETR) is the amount of solar radiation incident upon the top of the atmosphere and is a function of the time of year, time of day, and latitude. The ETR can be calculated for any location when the date, time, and latitude are specified.

Global, direct, and diffuse radiation are the most commonly measured solar radiation parameters. Somewhat less common measurements include solar radiation on inclined surfaces, infrared radiation, ultraviolet radiation, spectral radiation, net radiation, and circumsolar radiation.

Global solar radiation (total horizontal radiation) is the solar radiation received from a solid angle 2π on a horizontal surface. It includes the solar radiation coming directly from the solid angle of the sun's disk (direct radiation) as well as radiation from the sky, which originated from the sun, but was scattered by clouds, air molecules, dust, etc. (diffuse radiation). Global radiation is measured with a pyranometer which uses a thermoelectric, photoelectric, pyroelectric, or bimetallic element as the sensor. Global radiation data are important in the design of nonconcentrating solar devices and in agricultural and climatological studies.

Direct solar radiation is measured on a surface maintained normal to the solar beam, and as such, is more properly labeled "direct normal radiation." It is measured with a pyrheliometer which has its sensor located at the base of an open tube pointed toward the sun. The instrument aperture is commonly five to six degrees. Since the direct component of solar radiation arrives within a cone of about 0.5 degrees, the pyrheliometer actually measures a significant amount of circumsolar (forward scattered) radiation as well. Direct radiation data are important in the design of concentrating (focusing) solar devices.

Diffuse solar radiation is measured by a pyranometer with a shadow band or occulting disk to eliminate the direct radiation. The shadow band or disk must be periodically adjusted for changes in solar declination. The diffuse solar radiation can be computed from the global and direct radiation measurements. Measurements of diffuse radiation find application in illumination studies.

Solar radiation measured on inclined surfaces finds its greatest use in building and solar collector design. It includes the direct and diffuse radiation components, as well as radiation reflected from the ground, trees, and nearby structures. The measurements are made with a pyranometer.

Infrared radiation covers the radiation spectrum with wave lengths greater than about 0.7 microns. It is important in satellite sensors, photography, and heating and cooling. Infrared radiation is measured with a pyrriometer. The sensor may be either a pyranometer-type thermal detector or a photon detector.

Ultraviolet radiation is of interest due to its interaction with the atmosphere's ozone layer, physiological effects (sunburn, pigmentation, possible relationship with skin cancer, and production of vitamin D), and degradation of materials. Ultraviolet radiation comprises the wave lengths less than about 0.4 microns. Measurements may be obtained with a spectrometer, monochrometer, or optical filters used with pyranometers or pyrhiometers.

Spectral radiation measurements are important to studies of vision, photosynthesis in plants, photoelectric conversion, and the degradation of materials. These measurements are concerned with specific band widths of radiation, and may be obtained with a spectrometer, monochrometer, or optically filtered pyranometers and pyrhiometers.

Net radiation is the balance of radiative energy flowing from one instrument surface to another through the sensors of a net pyrriometer. A pyrriometer measures the total visible and infrared spectrum incident upon a thermoelectric sensing element. Net radiation is the difference between downward and upward radiation in the atmosphere. Measurements of the net radiative energy are important in heating and cooling applications, agricultural studies, and global energy balance studies.

Circumsolar radiation is that radiation which is scattered into the area of the sky immediately adjacent to the sun. Researchers are interested in determining the effect of circumsolar radiation on the properties of concentrating collectors. It is generally measured using a thermoelectric or photoelectric detector, relying on the geometry of the instrument to restrict the field of view.

4.2 Units and Conversions

Solar radiation data are typically recorded as the energy incident upon a unit surface area over a particular time period. The most common unit is the langley (one thermochemical calorie per square centimeter). Other units one may encounter are thermochemical British thermal units per square foot, watt-hours per square meter, and kilojoules per square meter.

1 langley = 41.840 kilojoules per square meter
 = 11.622 watt-hours per square meter
 = 3.687 British thermal units per square foot

4.3 Data Acquisition Times: Local Standard Time versus True Solar Time

Hourly solar radiation data prior to 1977 were generally recorded in 60-minute blocks bounded by whole hours of True Solar Time (TST). The solar time system is based upon the time that the sun transits a particular meridian. Beginning in

January 1977, hourly solar radiation data from NOAA stations were acquired with respect to Local Standard Time (LST). The relationship between TST and LST varies by day, and with location within a time zone. Variance by day can explain as much as a 16-minute difference between TST and LST; location can explain a 4-minute difference for each degree of longitude between a station and its time zone standard meridian. The day and location factors may complement or cancel each other, resulting in TST-LST differences ranging from zero minutes to nearly an hour.

This means that the position of the LST hourly segments with respect to the diurnal insolation curve changes from day to day. TST hourly segments do not exhibit such changes. On a clear day and in the absence of obstructions, the peak of the diurnal global insolation curve occurs at true solar noon, i.e., when the sun is at its zenith.

5. DIGITAL PRODUCTS AVAILABLE AT NCC

5.1 Post 1976 SOLMET Tapes, Tape Deck (TD)-9736

Observed and edited hourly direct, diffuse, and global solar radiation data as well as computed extraterrestrial radiation values and collateral meteorological observations are available on SOLMET tapes (TD-9736). Data are in metric units for 39 NOAA sites (see figure 1), starting in January 1977. The data are recorded in LST rather than TST, as with TD-9724 data (see section 5.2). Global radiation data are available for 1977 for about 25 of the 39 stations. Some diffuse data for a few of the stations are available after May 1977. Direct radiation measurements began in 1978 at most stations. Ten stations measure diffuse radiation.

5.2 Rehabilitated SOLMET Tapes, Tape Deck (TD)-9724

Tape Deck-9724 contains hourly global solar radiation data, recorded in TST, as they were originally observed at 26 National Weather Service sites (see figure 2); the same set corrected for all known scale, instrument, and calibration problems; and a data set corrected via a standard year irradiance (SYI) model. It also contains modeled direct normal solar radiation, calculated extraterrestrial radiation, and hourly collateral meteorological data. The SOLMET format is a metric conversion of all parameters available in Card Deck 280 (Hourly Solar Radiation) and Tape Data Family 14 (Hourly Surface Meteorological Observations). The period of record varies, but is generally July 1952 through December 1975, and extends through 1976 for 20 stations. Each station's data are on a separate reel of magnetic tape.

Other SOLMET products available, based on the SYI model corrected global insolation, include:

(1) Typical Meteorological Year (TMY) data in the (TD)-9734 format for 26 stations (see section 5.7)

(2) Global solar radiation data in the (TD)-9723 format for 248 stations (see section 5.8)

(3) Modeled direct normal radiation data, also in the TD-9723 format, for 26 stations.

5.3 Derived SOLMET Tapes

Tape Deck-9724 also contains the hourly global solar radiation data based on regression analysis of sky cover and sky condition observations, for an additional 222 U.S. stations (see figure 3). Tapes contain most of the data types of the rehabilitated SOLMET data, but only present one radiation type: regression estimated global radiation. The period of record is generally from January 1952 through December 1976, with each reel containing one station's data.

5.4 Rehabilitated SOLDAY Tapes, Tape Deck-9739

Tape Deck-9739 contains the daily global solar radiation data as they were originally observed at 26 National Weather Service sites (see figure 2); the same set corrected for all known scale, instrument, and calibration problems; and the same set corrected via the SYI model. It also contains calculated daily extraterrestrial radiation and daily collateral meteorological data. The SOLDAY format is a metric conversion of all parameters available in Card Deck 480 (Daily Solar Radiation) and TD-9750 (WBAN Summary of Day - Daily Surface Meteorological Data). The period of record varies, but is generally July 1952 through December 1976. All data for the 26 stations may be obtained on one reel of tape.

5.5 Research-Cooperator Tapes

Solar radiation and meteorological data recorded by some cooperative observers are available on Research-Cooperator Tapes. Data resolution on these magnetic tapes ranges from 1 minute to 60 minutes. Each logical record represents a time series of a radiation or meteorological variable spanning an hour or a day. The content of the time series is specified by a special code within the record. Each data element is accompanied by a two digit "flag" which describes the origin and quality of the data.

5.6 Input Data for Solar Systems, Tape Deck-9744

Tape Deck-9744 provides a digital set of the same data described by the publication in section 6.4.

5.7 Typical Meteorological Year (TMY) Data, Tape Deck-9734

Typical meteorological year (TMY) data provides a more manageable data base for simulations or system studies for a particular geographic area. The TMY tapes contain data for specific calendar months selected from the entire recorded SOLMET period of record for a given station as the most representative, or typical, for that station and month. For example, a statistical comparison method chooses a single January from all the recorded Januarys on the basis of its data being most nearly like the composite of all the Januarys. This process is repeated for the remaining months for each of the 26 rehabilitated hourly solar radiation data stations (see figure 2).

5.8 Global and Modeled Direct Normal Solar Radiation Data, Tape Deck-9723

Tape Deck-9723 contains hourly SYI-corrected and regression modeled global solar radiation data for 26 rehabilitated data stations and only regression modeled global radiation for 222 derived data stations. Also contains hourly modeled direct solar radiation data for the 26 rehabilitated data stations only. Data for the 26 stations for each data type may be obtained on three reels of tape.

6. PUBLICATIONS

6.1 Monthly Summary, Solar Radiation Data

This publication contains hour-versus-day listings of solar radiation data for selected stations. Also included are daily totals, monthly means for hourly intervals, and mean daily solar radiation for the month. The publication began with January 1977 data from the NOAA Solar Radiation Station Network (see figure 1). Only edited global radiation were published for 1977. Subsequent years include direct and diffuse solar radiation data. Appendix A, note 5, contains subscription information.

6.2 SOLMET, Volume 1 - User's Manual

This manual describes the contents of TD-9724 (see sections 5.2 and 5.3). It provides a sample of the SOLMET tape format of the solar radiation and collateral meteorological data. SOLMET, Volume 1 also contains station notes for stations with either rehabilitated radiation data or regression estimated data. Information on the differences between TD-9724 and TD-9736 tape formats may be obtained from the source listed in Appendix A, note 5.

6.3 SOLMET, Volume 2 - Final Report

This report discusses the methods used to rehabilitate and model the solar radiation data contained in TD-9724. It describes the rehabilitation process, the standard year irradiance model, and the regression model. It also includes sensor histories, 15-day average plots at clear solar noon, and daily noontime SYI values for the SOLMET stations.

6.4 Input Data for Solar Systems

This 192 page report contains tables of monthly and annual normals (1941-70) of temperature and of total heating and cooling degree days and corresponding values of average daily global solar radiation for 248 U.S. stations. Data are based upon SYI - corrected hourly solar radiation measurements for 26 stations and based upon derived hourly values for the remaining 222 stations (see figures 2 and 3). Most of the means were calculated using a 24-25 year period, generally from 1952-76.

6.5 SOLDAY - User's Manual

This manual describes both the contents of TD-9739 and the daily solar radiation data rehabilitation process. Its format parallels that of the two SOLMET

volumes, but does not contain tables or figures that appear in the SOLMET publications (see section 5.4).

7. DATA PROCESSING USED

7.1 Processing beginning in 1977

Global, direct, and diffuse radiation data from the 39-station NOAA Solar Radiation Station Network are recorded on digital cassette tapes, printed paper tapes, and strip charts. The cassettes contain 1-minute measurements; the printed paper tapes contain hourly integrated values.

Cassette tapes serve as the primary data source. They are integrated to hourly resolution and an observed data file and an edited data file are created for each radiation variable. Initially, the two files contain the same information. Printed paper tape and strip chart data are added to the files as necessary to fill data gaps.

Global radiation measurements are compared with values from a clear sky global radiation model. Measurements which exceed the model by prescribed amounts are flagged as questionable with a qualifying symbol linked to the data value. Additionally, measurements which undershoot the model by similar amounts during clear sky periods are flagged. Measurements are also compared with computed ETR values and flagged when they approach or exceed the ETR.

Diffuse solar radiation measurements are increased by a 4 to 23 percent correction factor to account for shadow band screening of sky radiation. The corrected measurements are flagged or deleted if they exceed the global measurements by prescribed amounts.

Flagged radiation data are given a subjective review. Data are displayed graphically as time series and reviewed along with hourly surface weather observations, ETR listings, and modeled data listings. Particular attention is paid to observations of clouds, fog, and precipitation which might justify questioned solar radiation measurements. As a result of this review, some questionable flags are removed; some new flags may be assigned, or some data may be deleted. Changes are only made to the edited data set. The observed data set remains unchanged.

Following the final edit, radiation data are used as input to produce SOLMET tapes and the publication, Monthly Summary, Solar Radiation Data (see section 6.1).

7.2 Processing prior to 1977

Computer processing of SOLMET and SOLDAY solar radiation data are described in SOLMET, Volume 2 and SOLDAY - User's Manual.

8. PRODUCTS AND SERVICES AVAILABLE ELSEWHERE

8.1 NOAA Calibration Facility

The solar radiation instrument calibration facility was established by NOAA at Boulder, Colorado, in the summer of 1975. The main purposes of the facility are:

- (1) to maintain standard instruments
- (2) to calibrate pyranometers and pyrhemliometers
- (3) to test specimen instruments
- (4) to make radiation measurements and establish interrelationships.

For further information contact the National Oceanic and Atmospheric Administration (NOAA), ERL-GMCC, R329, Boulder, CO 80302, or call (303) 499-1000, extension 6811. The Federal Telecommunications System (FTS) Number is 323-6811.

8.2 University of Alabama in Huntsville

The Kenneth E. Johnson Environmental and Energy Center, the University of Alabama in Huntsville, under contract with the U. S. Department of Energy, prepared a summary of solar radiation data available both at the NCC and elsewhere. Its January 1979 report entitled, "Solar Radiation Observation Stations, Updated to 1979" by Williams, Cristina, and Carter contains maps showing solar radiation stations with data archived at the National Climatic Center; SOLMET (see section 5.3) stations; the updated (beginning January 1977) NOAA Solar Radiation Station Network; solar radiation stations which operated in the past and/or are still operating but which have not systematically forwarded their data to the NCC; and a map of National Solar Heating and Cooling Demonstration Sites. Detailed information on the types of measurements, media, and periods of record are given in several tables. This report may be ordered from: The Kenneth E. Johnson Environmental and Energy Center, The University of Alabama in Huntsville, P. O. Box 1247, Huntsville, AL 35807; telephone (205) 895-6331. The FTS Number is 872-0380.

8.3 National Solar Heating and Cooling Information Center

This organization, sponsored by the U. S. Departments of Housing and Urban Development, and Energy, provides information on how solar energy can be put to work at home. It is part of a Federal program to develop solar energy as an important alternate fuel resource. Address inquiries to the National Solar Heating and Cooling Information Center, P. O. Box 1607, Rockville, MD 20850, or call toll free (800) 523-2929. In Pennsylvania, call (800) 462-4983. In Alaska and Hawaii, call (800) 523-4700.

8.4 Solar Energy Research Institute (SERI)

SERI is a Department of Energy funded, research oriented, organization. It provides many wide-ranging services to solar energy users that vary from answering general questions to specific ones concerning application of complex models to predict insolation properties. Direct requests for information to Solar Energy Research Institute, National Solar Inquiry and Referral Service, 1617 Cole Boulevard, Golden, CO 80401; or, telephone toll free (800) 525-5000. In Colorado, call (800) 332-8339.

APPENDIX A - HISTORICAL SOLAR RADIATION DATA

1. Modern Past Products (1950-1976)

a. Publications

Climatological Data, National Summary contains daily total hemispheric (global) solar radiation data for the periods January 1950 through August 1972, and July 1975 through December 1976. Publication of normal incidence (direct) solar radiation data for a few stations began in January 1950 and continues to the present.

Local Climatological Data, Annual Summary With Comparative Data contains mean daily total hemispheric (global) solar radiation data for a National Weather Service network of 62 stations. Data were published for the years 1963 through 1971, listing monthly and annual data for the current year and averages for the period of record.

Climatic Atlas of the United States contains a chart with maps (available separately) of mean daily solar radiation, monthly and annual, based upon data through 1962. The data, in tabular form, for 117 stations are also listed on the chart.

Note 1: The NCC considers the solar radiation data in these publications to be questionable. The use of these data is not recommended. Instead, current products, after 1976, should be used (see section 3 of this appendix).

b. Digital Products

TD-9725, Hourly Solar Radiation (Hemispheric) Data is the card image version of Card Deck 280, and contains data for the general period December 1951 through December 1976. This tape format includes hourly collateral meteorological data.

TD-9726, Daily Solar Radiation (Hemispheric) Data is the card image version of Card Deck 480, and contains data for the general period December 1951 through December 1976. This tape format includes daily sunshine data.

Note 2: A large portion of the data in TD-9725 and TD-9726 have been rehabilitated into the TD-9724 (SOLMET) and the TD-9739 (SOLDAY) formats. The NCC considers SOLMET and SOLDAY the best estimates of the true hourly and daily hemispheric (global) solar radiation data through 1976. All other digitized solar radiation data for that period are considered questionable. The use of TD-9725 and TD-9726 is therefore not recommended. Reference manuals for TD-9724, -9725, -9726, and -9739 are available from the NCC.

c. Forms

Form 610C, Hourly Solar Radiation is an unpublished computer listing generated from Card Deck 280. Data are generally available 1952 through 1976.

Form 610D, Daily Solar Radiation is an unpublished computer listing generated from Card Deck 480. Data are generally available 1952 through 1976.

Form B-52 (supersedes Forms 1091 and 610-8), Hourly and/or Daily Solar Radiation (Hemispheric) data. These forms were generally used to record observed data from 1950 through 1976.

Form B-55 (supersedes Form 610-9), Normal Incidence (Direct) Solar Radiation data. Only a few stations recorded this type of data, for the general period 1961 through 1975.

During this period, general purpose forms have frequently been used to record hourly and/or daily values. The most common ones are Forms 1078, 1078D, 612-14A, 612-11-2, 612-25, and 620-11. Another form is 620-19, Hemispheric and Net Radiation, used by a few selected stations.

d. Autographic Records

Roll (strip) charts with recorded hourly and daily total hemispheric data, and occasionally normal incidence data are available in NCC's files. Also available are circular charts which were used to record daily total hemispheric data. The roll and circular recorders did not record data directly into normally used solar radiation units, such as langleys. Therefore, the use of solar radiation data in these forms is not recommended.

Note 3: The NCC considers SOLMET and SOLDAY the best estimates of the true hourly and daily radiation through 1976. All other solar radiation data for that period are considered questionable. This recommendation applies to both data listings and autographic records.

2. Early Products (prior to 1950)

a. Publications

The Monthly Weather Review contains daily solar radiation data during the period January 1914 through December 1949 (under the heading of Aerology until December 1918). Included are data from stations that measured solar radiation on a horizontal and a normal surface. Throughout the period of record, the number of stations published varied from 3 horizontal and 4 normal surfaces to about 33 and 5, respectively.

b. Digital Products - none.

c. Forms

Several solar radiation and general purpose forms were used to record values measured prior to 1950. The most common ones are Forms 1091, 1023, 1078, and 1078D.

d. Autographic Records

See paragraph 1.d.

Note 4: See Note 3, which applies also to all solar radiation data recorded prior to 1950.

3. Current Products (post 1976) - These include the publications, records, and magnetic tape data discussed in the main body of this summary, as well as data from cooperative stations. The latter are archived at the NCC on various paper forms and magnetic tape formats, and the degree of data validation and documentation varies significantly among stations.

Note 5: For information on these and other solar radiation data at the NCC, write to the Director, National Climatic Center, Federal Building, Asheville, NC

28801. Call (704) 258-2850, extension 203, or FTS 672-0203, for information on magnetic tape data; and (704) 258-2850, extension 683, or FTS 672-0683, with questions on other solar radiation data available at the NCC. Charges for obtaining data tapes, publications, copies of out of print publications, and subscriptions will be provided upon request.

NOAA Solar Radiation Network

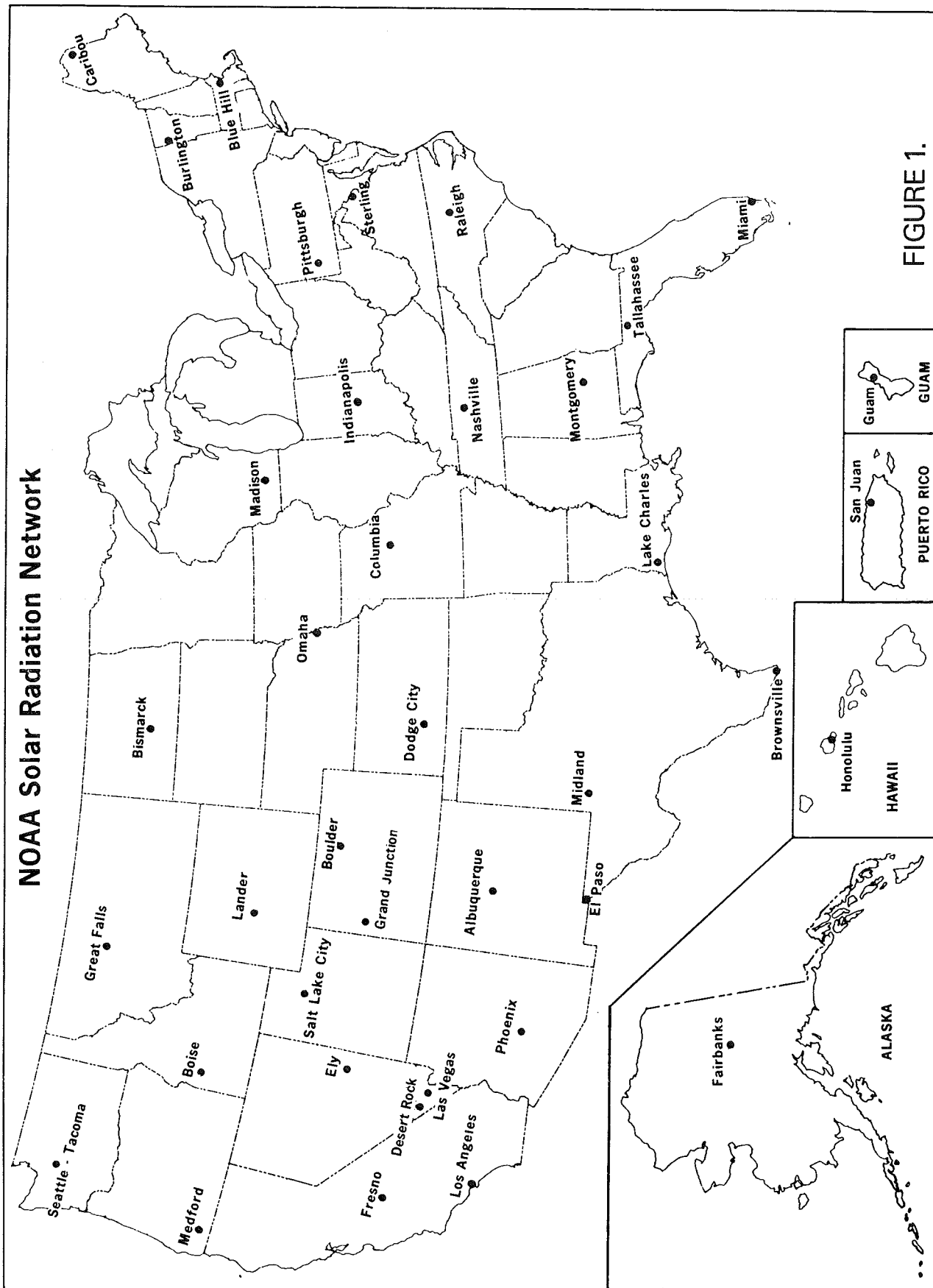


FIGURE 1.

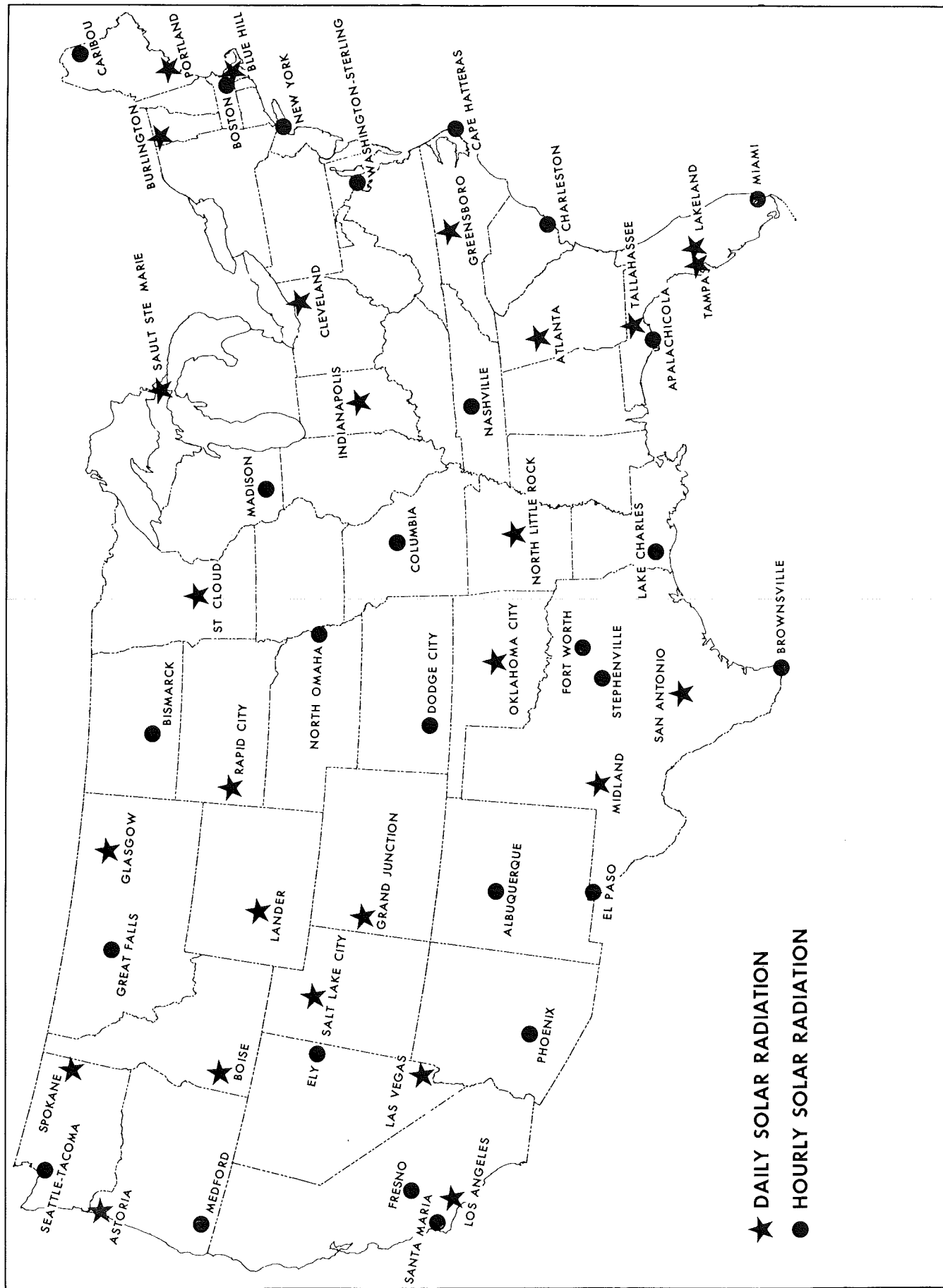


FIGURE 2. SOLAR RADIATION DATA REHABILITATION STATIONS

FIGURE 3. SOLMET STATION NETWORK

