NBS TECHNICAL NOTE 838

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

The Use of Weather and Climatological Data in Evaluating the Durability of Building Components and Materials

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U.S. DEPARTMENT OF COMMERCE, Frederick B. Dent, *Secretary*
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Issued August 1974

Library of Congress Catalog Card Number: 74-600106

National Bureau of Standards Technical Note 838
Nat. Bur. Stand. (U.S.), Tech. Note 838, 101 pages (Aug. 1974)
CODEN: NBTNAE

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1974

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
(Order by SD Catalog No. C13.46:838). Price $1.45

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GLOSSARY

Absolute humidity. The ratio of the mass of water vapor to the volume of the air containing the moisture or the density of the water vapor component. This is usually expressed as g (water vapor)/m^3 (air) or grains/ft^3. Sometimes called Vapor density. Specific humidity is called Absolute humidity in air-conditioning practice.

Aging. A change in a property of a building component or material caused by one or more environmental factors.

Air contaminants. Substances which are not normal constituents of the atmosphere, commonly referred to as air pollutants, which may have a deleterious effect on building components and materials, as well as on the health of humans, animals, and plants.

Albedo. Ratio of the reflected solar radiation to the incident solar radiation on the surface of a material, sometimes expressed as a decimal fraction but usually as a percentage.

Biological factor. An environmental factor associated with biological organisms, such as bacteria, fungi, or organisms closely related to these, which attack building components and materials.

Building component. A part of a building, such as a wall or a roof, formed by combining building materials.

Building material. The matter of which a building component is comprised, such as brick, concrete, lumber, etc.

Building system. A structure or building composed of various components and materials which have been combined in such a way as to provide a shelter for the activities of man or protection for his property.

Climate. A generalization or integration of weathering conditions for a given period of time in a given area.

Climatography. The science that seeks to describe and explain climate, how it differs from place to place, and how it is related to man's activities on earth.

Dew point. The temperature at which water vapor saturation of the air occurs.

Durability. A term used to express the length of time a building system, component, or material will perform its intended functions above a certain minimum acceptable level.

Environment. The sum of all factors to which a building system, component, or material is exposed.

Environmental factor. A factor which is part of the total environment to which a building system, component, or material is exposed. See Biological, Incompatibility, Stress, Use and Weathering Factors.

Freeze, killing. A phenomenon defined by NOAA National Weather Service in terms of "widely destructive effects of stable vegetation, with temperatures usually below 32°F. at the thermometer level in the instrument shelter".

Frost, killing. Synonym for killing freeze.

Freeze cycle period. Period of the year during which killing freezes or killing frosts occur or 365 minus (Freeze-free period in days).

Freeze-free period. Period of the year in days between the last occurrence of a given freeze threshold temperature in the spring and the first occurrence of the same freeze threshold temperature in the fall, normal dates or means over a period of years.

Freeze-thaw cycle. A cycle between temperatures above and below the freezing point of water, 32°F. or 0°C.

Freezing cycle day. A day during which the air temperature exhibits a freeze-thaw cycle or cycles at least once between a temperature above and a temperature below the freezing point of water.

Freeze threshold temperatures. Temperatures used by NOAA instead of killing frost to define the freeze-free period of various locations. The freeze threshold temperature may be 32, 28, 24, 20, or 16°F.

Humidity. The amount of water vapor in the atmosphere, expressed by several different terms [36], [37], [38]. See Absolute, Relative, Specific Humidity, Dew point, Mixing ratio, Vapor density.

Incompatibility factor (chemical and physical). An environmental factor due to deleterious interactions between adjoining or neighboring building components and materials.

Meteorology. The science of the atmosphere in general of which climatography is a branch.

Mixing ratio. The ratio of mass of water vapor to mass of dry air.

Specific humidity may be approximated by the mixing ratio and the terms are sometimes used interchangeably, since the difference is less than the error involved in the measurement of either value. The equation relating specific humidity and mixing ratio is as follows:

$$q = \frac{W}{(1 + W)}, \text{ where}$$

q = specific humidity

W = mixing ratio

Relative humidity. This is what is commonly meant by "humidity" and is the ratio of atmospheric vapor pressure to saturation vapor pressure, usually in percent. The World Meteorological Organization prefers the definition of relative humidity as the ratio of specific humidity or mixing ratio to saturation mixing ratio in percent. Relative humidity, U, in percent may be expressed as

$$U = \frac{\text{Absolute Humidity}}{\text{Saturation Absolute Humidity}} \times 100$$

Sol-air temperature. The fictitious temperature of the outside air that would produce by convection alone the same rate of heat exchange at the surface as actually occurs by convection and short- and long-wave radiation combined.

Solar altitude. Altitude of the sun or angular distance from the horizon. The complement of zenith angle or zenith distance and equal to (90° - zenith angle of the sum).

Stress factor. An environmental factor resulting from stresses, which may be sustained or periodic. Sustained stress is generally due to the load of the building, while periodic stress may be caused by weather conditions.

Use factor. An environmental factor resulting from the use of the building component or material.

Vapor density. Synonym for Absolute humidity.

Specific humidity. Ratio of the mass of water vapor to the mass of air as g (water vapor)/kg (air) or grains/lb. Called Absolute humidity in air conditioning practice.

Weather. The sum total of atmospheric conditions and solar radiation at a given place at a given time.

Weathering factor. An environmental factor associated with weather, such as solar radiation, temperature, water, normal air constituents, air contamination, and wind.

Wetness. State of being wet with liquid water, specifically as applied to materials exposed outdoors, the surfaces of which are wet from precipitation, due, fog, etc.

Zenith angle of the sun. Angular distance of the sun from the zenith or point directly overhead at 90° distance from the horizon; the complement of Solar altitude.

SI CONVERSION UNITS

In view of the present practice in building technology in the United States and in publications of the National Oceanic and Atmospheric Administration (NOAA), common U. S. units of measurements have been used throughout this paper in most cases. However, in recognition of the position of the United States as a signatory to the General Conference on Weights, and Measures, which gave official status to the metric SI system of units in 1960, conversion factors are given as follows:

Length

1 inch (in) = 0.0254* meter (m)

1 foot (ft) = 0.3048* m

1 yard (yd) = 0.9144* m

1 mile (U. S. Statute) = 1.609344×10^3 m

Area

1 sq. mile ($mile^2$) = $2.589988 \times 10^6 m^2$

Velocity

1 mile per hour (mph) = 4.470400×10^7 meters per second (m/s)

= 1.609344 kilometers per hous (km/hr)

Mass

1 (short) ton = 9.071847×10^2 kilogram (kg)

Mass/Area

1 (short) ton per sq. mile = 0.35 g/m^2

Temperature

$t_C = (t_F - 32)/1.8$, where

t_C = degrees Celsius (° C.)

t_F = degrees Fahrenheit (° F.)

Solar Radiation

1 langley = 4.184×10^4 joules/m^2 = $1.162 \times 10^1 \frac{\text{watt-hr}}{m^2}$

*exactly

THE USE OF WEATHER AND CLIMATOLOGICAL DATA IN EVALUATING THE DURABILITY OF BUILDING COMPONENTS AND MATERIALS

Larry W. Masters
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The durability of building components and materials is dependent, to a large extent, on the in-service environment to which they are subjected. Thus, the prediction of durability requires knowledge of the service environment.

Weathering factors, which comprise one group of environmental factors, are the subject of this report. The objectives of the report are to identify the types of climatological and weather data that are available and to indicate how, in the present state of knowledge, weather and climate data can be used to aid in quantifying weathering factors so that durability tests for building components and materials may be designed.

Key Words: Accelerated aging; building components and materials; climatological data; durability; environmental factors; long-term tests; short-term tests; weather data; weathering factors.

1. Introduction

Durability tests are used to predict or determine the long-term performance of building components and materials. Durability can be evaluated by both long-term and short-term tests. In long-term tests, specimens are exposed to natural or simulated environmental factors of importance to closely simulate or duplicate in-service usage. For example, long-term tests for building materials used in the exterior envelope may consist of exposure on test racks at outdoor exposure sites or installation in a testing building [1, 2]. Long-term tests, however, consume considerable time in obtaining results. Therefore, much interest has been devoted to the development of short-term tests which can be used to predict long-term results. One type of short-term test currently being emphasized is based upon increasing the detection sensitivity of changes in the component or material. In this way incipient changes indicative of long-term changes, can be detected in a relatively short time using exposure conditions similar to those used in long-term tests. Other types of short-term tests are often termed "accelerated aging" tests. In these tests, expected in-service exposure factors are intensified in some manner in an attempt to accelerate the effects of long-term exposure.

A general methodology for durability tests consists of at least three parts: Problem Definition, Testing, and Interpretation. The first part of the methodology, Problem Definition, includes defining the performance requirements, identifying properties which can be used as indicators of degradation and identifying and quantifying the exposure parameters (environmental factors) of importance. The second part of the methodology, Testing, includes incorporating the information from the first part of the methodology into tests and conducting tests, and the third part, Interpretation, includes interpreting the test data in terms of long-term performance. For durability tests based upon accelerated aging, one must also postulate how the degradation mechanism can be induced in a relatively short period of time.

Environmental factors are instrumental in causing the degradation of building components and materials. Thus, the success of durability evaluations is highly dependent upon the proper consideration of environmental factors in the tests. The environmental factors of importance in durability testing can be divided into factors relating to: 1) weathering, 2) biological organisms, 3) stress, 4) incompatibility, and 5) use. Table 1 illustrates a breakdown of these factors. Weathering factors include solar radiation, temperature, water, normal air constituents, air contaminants, and wind. Biological factors include fungi and bacteria. Stress factors may be sustained or periodic. Sustained stress is most likely due to the load of the building, while periodic stress is often due to weathering factors such as temperature changes or stress due to earthquakes, tremors, and vibrations from vehicles. Complicating factors in sustained stress are soil/structure interaction and building settlement. Incompatibility factors may be due to deleterious interactions between adjoining or neighboring materials. Use factors reflect misuse or abuse and the normal wear of materials by the user. The effects of the five classes of environmental factors are not independent and substantial interaction between them is observed. Weathering factors, for example, can cause or accelerate the effects of stress or incompatibility factors; e.f., freezing and thawing or absorbed water can cause destructive stresses. Moisture may also be instrumental in inducing corrosion, an incompatibility factor. Biological factors, such as fungal and bacterial growth, are highly dependent upon temperature and moisture conditions.

Weathering factors are of particular importance for products used in the exterior envelope of a housing system because they interact with or cause many other environmental factors resulting in deterioration. The importance of a particular weathering factor varies with the geographic location in which the component or material is used. It is also dependent upon the material itself and how the material is used. For example, solar radiation is an important factor in degrading organic polymers as in coatings and joint sealants. Temperature extremes may also be important for organic polymers. Temperature cycling can be instrumental in degrading concrete or brick by freezing and thawing of liquid water in pores, thus causing spalling and cracking. Water as liquid and vapor can chemically degrade certain polymers by hydrolysis and it is important in the corrosion of metals. Solid water such as hail can cause severe impact damage to materials such as roofing and cladding. Oxygen and ozone can oxidize polymers and carbon dioxide can neutralize the basicity of concrete, leading to the corrosion of steel reinforcing when the depth of neutralization reaches the steel. Air contaminants such as the oxides of sulfur and nitrogen can produce acidic solutions which corrode metals or degrade organic polymers. Wind can produce extreme cyclic loads on buildings. Thus, weathering factors affect many different types of materials.

Since exposure to weathering factors can result in decreased performance of building components and materials, they must be included in durability tests. The inclusion of weathering factors in durability tests requires that these factors be quantified as much as possible. This quantative information can be inferred from climatological and weather data. These data, however, are subject to statistical fluctuations and the evaluations of the effects of weathering factors must consider expected (average) conditions as well as typical extremes. Although climatological and weather data permit the average and extreme values of weathering factors to be identified, the intensity of these factors on or in the building component or material and the effects of these factors in degrading the component or material are the primary concerns. Thus, climatological and weather data provide a means of quantifying weathering factors so that their effect on components and materials can be determined.

The objectives of this report are to identify the types of climatological and weather data that are available and to indicate how, at the present state of knowledge, these data can be used to aid in the durability testing of building components and materials. Although much of the discussion in the report concerns climatological and weather data, the most important theme is the use of this data for durability testing.

The intended audience to which the report is addressed includes those persons involved in developing and conducting durability tests of building components and materials.

2. Weather and Climate

Climatography has been defined as "the science that seeks to describe and explain climate, how it differs from place to place, and how it is related to man's activities on earth" [3]. Meteorology is the science of the atmosphere in general, of which climatography is a branch.

Weather [4] is defined as "the sum total of atmospheric conditions at a given place at a given time" and climate [4] as "a generalization or integration of weathering conditions for a given period of time in a given area."

The process of designing and interpreting tests using either short-term or long-term exposures to predict long-term performance of building components or materials in a selected climate, requires knowledge of the history of the weathering factors listed in table 1. Unfortunately, the necessary data are often not available or not available in the desired detail. For example, in designing freeze-thaw tests it is of interest to determine how many freeze-thaw cycles may be expected to occur each year in a specific region. Such information is not readily available, although it can be obtained by reviewing accumulated weather data. The data needed for designing short-term tests must be obtained from existing weather and climatic data. Weather data are particularly useful in identifying extremes for test conditions such as the highest wind, the highest or lowest temperature, or the greatest snow load. Climatic data, which provides an average of weather data, are useful in identifying the normal expected values of weathering factors and their normal variations. Weather data are much more variable than climatic data and, therefore, are more difficult to simulate experimentally. The difficulty in experimentally simulating weather data leads to the dominant use of climatic data in designing short-term tests although it would be preferable to use weather data to obtain more accurate simulations.

Climatological data, based on years of accumulated weather data, are useful in interpreting long-term test results although some caution must be exercised. For example, since the intensity of weathering factors varies substantially depending on the season of the year, or even the time of day, errors could arise by assuming long-term climatological data to be representative of factors during the exposure. The reliability of using climatological data in this application increases with the time of exposure. For example, the intensity of weathering factors in a given time, such as six months, may be very different from those predicted by climatological data. However, the intensity of factors during a ten year period would be expected to correlate better with climatological data than that in a much shorter time. It is advisable, therefore, particularly for exposures of relatively short duration, to measure the weathering factors during the time of the exposure.

3. Climatological and Weather Data

This chapter of the report includes a listing of some typical sources of climatological and weather data. Also, climatological classifications are discussed to illustrate the large number of climates which are experienced in the United States.

3.1 Sources of Data

Climatological data in the Appendix and for tables 6 through 15 in the text were taken from publications of the United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), Environmental Data Service, Silver Spring, Maryland. Between July 1965 and October 1970, publications of this agency were issued under its previous title, Environmental Science Services Administration (ESSA), Environmental Data Service. Before July 1965, publications were issued by the predecessory of ESSA, The Weather Bureau. These publications are as follows:

°Local Climatological Data, Annual Summary with Comparative Data. Issued for major weather stations and revised annually through 1972.

°Climatography of the United States, Nos. 60-1 through 60-52, Climates of the States. Issued for the 50 states, the District of Columbia, and Puerto Rico; revised periodically through 1972.

°Climate Atlas of the United States, June 1968.

Figures 5, 6, 7, and 8 were derived from maps in the National Atlas of the United States of America, U. S. Department of the Interior, Geological Survey, Washington, D. C., 1970. This includes the use and definition of Standard Metropolitan Statistical Areas, defined on page 293 of the National Atlas, referring to United States Bureau of the Budget, Standard Metropolitan Statistical Areas, 1967, U. S. Government Printing Office, Washington, D. C.

Sources of other information are indicated by footnotes in the text, which refer to the list of references at the end of this report.

3.2 Classification of Climates in the United States

Maps showing the various climates of the world have been devised by climatologists. Although these maps were not originally intended to reflect the effect of climatology on building components and materials, Wessel and Thom [5] utilized a map by Trewartha to better understand this effect. More detailed maps [6] have been developed since Trewartha's.

Climatological classifications will be discussed in this chapter to point out the large range of climates found in the United States and to illustrate the magnitude of the problem in considering the various climates with regard to materials degradation.

Trewartha, in devising his climate map, identified six major divisions of climate:

A. TROPICAL RAINY CLIMATES

B. DRY CLIMATES

C. HUMID MESOTHERMAL CLIMATES

D. HUMID MICROTHERMAL CLIMATES

E. POLAR CLIMATES

F. UNDIFFERENTIATED HIGHLANDS

Figure 1 is a map of the continental United States showing Threwartha's climate classification. Table 2, which is a supplement to figure 1, lists the climate divisions of Trewartha and the geographic areas of the United States which are included in each classification. Table 3 contains a brief description of the criteria used by Trewartha in classifying climates.

Climates within the United States are diversified to the extent that each of Trewartha's six major climate divisions is experienced in some location. Under TROPICAL RAINY CLIMATES, Trewartha includes Tropical Rainforest, Monsoon Rainforest, and Tropical Savanna. These climates are experienced in Hawaii, the southern tip of Florida, and the Florida Keys. The DRY CLIMATES include much of New Mexico, Arizona, and Nevada, and parts of Texas, Colorado, Utah, Oregon, Idaho, Montana, Wyoming, California, the Dakotas, Nebraska and Kansas. The HUMID MESOTHERMAL CLIMATES include most of the Southeast, parts of California and the Oregon and Washington coastal areas. HUMID MICROTHERMAL CLIMATES include the New England states, New York, Michigan, Minnesota, Iowa, Pennsylvania, Wisconsin, and parts of Maryland, West Virgina, Ohio, Illinois, Indiana, Missouri, Kansas, Nebraska, Alaska, and the Dakotas. POLAR CLIMATE is divided by Trewartha into Tundra and Ice Cap climates. The Polar Tundra is experienced by northern Alaska. HIGHLANDS CLIMATE is found in an area of Arizona including Flagstaff, parts of Colorado, Utah, Wyoming, Idaho, Montana, California, Oregon and Washington. The large range of climates experienced in the United States presents a formidable problem to the materials engineer interested in eveluating materials for long-term performance by laboratory techniques. The problem is to simulate the deterioration caused by the desired range of climatic conditions with a minimum number of tests and exposures.

In addition to the broad climate classifications, micro-climates must be considered in evaluating building components and materials. For example, large temperature and humidity gradients may exist close to the ground. Also, weather data recorded at the airport of a major city might not adequately reflect the intensity of factors a few miles away.

Appendix table I contains climatological data for 18 sites with various climatological classifications. Table 4 lists the 18 sites according to the climate classifications in table 2. The data in Appendix table I were taken from the NOAA publication, "Local Climatological Data" for 1972 and represent normal, mean and extreme values of recorded data based upon measurements for a number of years. The data include values for temperature, precipitation, relative humidity, wind and mean sky cover. For some sites, values are also presented for percent of possible sunshine. However, Appendix table I does not contain values for solar radiation as these data were not included by NOAA in the 1972 annual summaries. Therefore, Appendix table II is included to summarize solar radiation values. Values of annual mean daily solar radiation, total and percent sunshine and mean sky cover are included in Appendix table II for each of the 18 sites. The sources of data are shown in the footnotes. Appendix table III lists the names and the total number of months of freeze-thaw cycles for each of the 18 sites. The data presented in these tables will be used throughout this report in illustrating the use of climatological data in durability testing.

4. The Role of Climatological and Weather Data in Durability Testing

4.1 Short-term Tests

4.1.1 Accelerated Aging Tests

Accelerated aging tests consist of two parts -- the simulated aging and the evaluative technique. In the simulated aging, the test specimens are subjected to selected environmental factors in such a manner as to induce, in a much shorter period of time, changes representative of those induced by natural aging at a selected site. The evaluative technique is then applied to provide a measurement of the properties of interest and to allow calculation of the changes in the properties caused by the simulated aging. This discussion is specifically concerned with those environmental factors caused by weathering factors and with the simulated aging part of accelerated aging tests.

The goals of accelerated aging tests are 1) to induce, in a much shorter period of time, changes in properties representative of those caused by natural aging at a selected site and 2) to relate the time required by induce a property change to that required by natural aging so that long-term performance can be predicted from the test results.

To adequately design simulated aging procedures, it is necessary to consider weathering factors. The consideration of weathering factors can be accomplished qualitatively, semi-quantatively or quantatively.

Qualitative considerations is often used, particularly in establishing a single set of simulated aging conditions which incorporate all factors of importance which represent all climatological divisions. This approach has been used in establishing many existing accelerated aging tests. Such tests can serve a useful purpose particularly for quality control tests. They are useful for durability testing of building materials providing the materials are similar to those used extensively in the past. Then the evaluator can compare the test results for the new material with those of similar materials known to perform satisfactorily, incorporate a factor based on scientific and engineering judgment, and predict durability in various climates, often with good reliability. Problems occur with qualitative consideration of climate when new or innovative materials are used because no data base is available for comparison, and when attempts are made to quantitatively relate the results of accelerated tests to long-term exposure in specific climates.

By semi-quantitative consideration of weathering factors the evaluator recognizes the existence of a number of distinctly different climates and establishes various simulated aging conditions to represent these various climates. This approach is used currently in many testing laboratories and simulated aging conditions in some ASTM methods are developed with this philosophy. The semi-quantitative approach is useful when considering new or innovative materials particularly if a wide variety of natural exposures are used. The application of broad climate divisions and maps such as those developed by Trewartha [5] provides a valuable input in this approach.

In building climatology [7] a broad classification and map would simplify the use of climatological data in durability testing if a broad classification could be sufficiently detailed to be useful. One broad classification and map is used in an ASTM test to define grades of brick according to the "Weathering Index" related to freezing and thawing [8].

The quantitative approach to considering weathering factors consists of designing a simulated aging procedure for each specific geographic location. This approach should yield the best correlations between accelerated and long-term test results. In using this approach the weather and climatic data for the location, such as a major city, would be collected and analyzed and, based on the data, a preliminary simulated aging procedure established. The usefulness of the procedure for other locations would not be of concern to the evaluator. This approach is also useful when considering new or innovative materials except that for most durability evaluations, the economic feasibility becomes a problem to be considered. Some question might be raised about the need to be highly quantative in considering weathering factors because of the imprecisions of evaluative measurements.

4.1.2 Tests Based Upon the Detection of Incipient Changes

An alternative to using accelerated aging tests to obtain long-term performance from short-term tests is the use of tests based upon the detection of incipient changes. These tests may also be considered as consisting of two parts -- the aging and the evaluative technique. However, instead of attempting to induce property changes in a short time these tests rely on increasing the sensitivity of the evaluative technique. The aging step, therefore, may be the same as that used in long-term testing. The advantage of increasing the sensitivity of property change detection is that the problems arising in attempting to accelerate changes are overcome.

Accurate information is needed for the intensity of weathering factors during the aging step to permit interpretation of the test results.

4.2 Long-Term Tests Based on Natural Aging by Outdoor Exposure

Natural aging tests are an important part of durability testing of building materials. Since these are often relied upon to determine in which climates or geographic areas materials may be expected to perform adequately, the exposure test sites should include a number of climates.

The National Bureau of Standards (NBS), for example, maintains Exposure Test Sites at seven locations which cover a wide range of climates. Consideration of these sites will illustrate how the climatic and weather data are used. The types of climate in the United States as defined by Trewartha are shown in table 2. The seven NBS Exposure Sites with climate classifications are defined by Trewartha [5] in brackets are:

1. Roosevelt Roads Naval Station, Puerto Rico [Am, Monsoon Rainforest]

2. Nellis Air Force Base, Nevada [BWh, Subtropical Desert]

3. NBS, Gaithersburg, Maryland [Caf, Humid Subtropical (Warm Summer) with No Dry Season]

4. Fort Holabird, Baltimore, Maryland [Caf (also industrial)]

5. Coast Guard Receiving Center, Cape May, New Jersey [Caf (also seacoast, receiving salt spray)]

6. Fort Lewis, Washington [Cb, Marine West Coast (Cool Summer)]

7. Fort Freely, Alaska [Daf, Subarctic - No Dry Season]

Thus, of the six major climate divisions defined by Trewartha [5], the NBS sites include the TROPICAL RAINY CLIMATES, DRY CLIMATES, HUMID MESOTHERMAL CLIMATES, and HUMID MICROTHERMAL CLIMATES. In addition, NBS has used exposure sites in Miami, Florida and Pheonix, Arizona. Miami is located in an Aw, Tropical Savanna climate and Pheonix in a BWh, Subtropical Desert climate.

Although with the exception of the Puerto Rico site, climatological data are not available for these specific sites, data for nearby cities are available. The data for these cities are included in Appendix tables I, II, and III. San Juan, P. R. data can be used for the Roosevelt Roads Naval Station site; Las Vegas, Nevada data for Nellis Air Force Base; Washington, D. C. data for the Gaithersburg, Md. site; Baltimore, Md. data for the Fort Holabird site; Atlantic City, N. J. data for the Cape May, N. J. site; Seattle, Washington data for the Fort Lewis site; and Fairbanks, Alaska data for the Fort Greely site.

Variations in climate stem from geographic and topographic factors. Some consideration must, therefore, be given to these factors in estimating possible errors arising from the use of weather and climatic data collected at stations near the NBS exposure test sites. For discussions purposes, the distances between the NBS Exposure Test Sites and the data collection stations are listed as follows:

NBS Exposure Test Site	Nearest NOAA Station[a]	Distance[b]
Roosevelt Roads Naval Station, Puerto Rico	Isla Verde International Airport, San Juan, P.R.	30 miles SSE
Nellis Air Force Base, Nevada	McCarran International Airport, Las Vegas, Nevada	12 miles NE
National Bureau of Stds. (NBS), Gaithersburg, Md.	Washington National Airport, Wash., D.C.	24 miles NW
Fort Holabird, Baltimore, Maryland	Friendship International Airport, Baltimore, Md.	9 miles NE
Coast Guard Receiving Center, Cape May, New Jersey	Aviation Facilities Experimental Center, Atlantic City, N.J.	40 miles SW
Fort Lewis, Washington	Seattle-Tacoma Airport Washington	45 miles SSW
Fort Greely, Alaska	Fairbanks International Airport, Fairbanks, Alaska	75 miles SE

[a]Appendix table I contains weather and climatological data for these stations.

[b]Distance and compass direction for neareat NOAA Station to the NBS Exposure Test Site.

Comparisons of climatological data for the NBS Exposure Test Sites and the data published for the NOAA stations are likely to show reasonably good agreement. For example, the climatological data in Appendix table I for Washington, D. C. and Baltimore, Maryland, which are approximately 40 miles apart, show close agreement. Also, climatological data for San Juan, Puerto Rico in Appendix table I and data for Roosevelt Roads Naval Station, published in Climatography of the United States, No. 60-52, show reasonably close agreement in terms of temperature, relative humidity, and wind. The average annual rainfall, however, is about 8.5 inches less at Roosevelt Roads than at San Juan. It is expected that climatological data, as described above, are useful in specifying exposure conditions for accelerated tests designed to simulate a particular exposure test site. It is likely that errors arising from the use of these data will not be greater than those arising from the measurement of properties in the evaluative technique.

It is important to remember that distance is not the only source of difference between climates in the same general geographical area, since marked differences in climate may also occur in places a comparatively short distance apart. These differences may be due to geographic factors or to factors relating to the use of the land such as for residential or industrial purposes. For example, the Fort Holabird exposure test site is located in an industrial area, whereas Friendship Airport is not. Also, the geographic factors at Washington National Airport include the Potomac River whereas the NBS Exposure Test Site is not near a body of water. Similar climatic conditions may also extend over a wide area, a great distance, and even throughout widely separated latitudes. One example of this is the United States Pacific Coast where the climate along the coast changes slowly with latitude but differs markedly in areas a short distance east due to mountain ranges. Roosevelt Roads Naval Station, Puerto Rico, is in a fortunate location for an NBS Exposure Site since it is in the same climatic region as San Juan. Both locations are in the North Coastal climatic region according to NOAA Climatography of the United States, Climates of the States, No. 60-52. If the exposure site had been 30 miles S, SW, or SSW of San Juan, it would have been in the Eastern or Western Interior region with lower mean temperatures and greater annual precipitation. If the station had been about 50 miles SW, it would be within the South Coastal region with considerably lower annual precipitation but with approximately the same mean annual temperature.

5. Climatological and Weather Data: Their Relevance to Durability Testing

This chapter will include discussions of the weathering and biological factors listed in table 1. These are solar radiation, temperature, water, oxygen and ozone, air contaminants, wind, fungi and bacteria.

5.1 Solar Radiation

For convenience solar radiation is often divided into several wavelength ranges. The three ranges of interest in degrading building components and materials are 1) the ultraviolet (200-380 nanometers), 2) the visible (380-750 nanometers), and 3) the infrared (750-25000 nanometers).

The energy distribution of the solar spectrum is variable with ∼5% of the total falling in the ultraviolet, ∼43% in the visible and ∼52% in the infrared. The quantum energy of radiation decreases as the wavelength increases; for this reason, light in the ultraviolet range is the primary cause of photochemical degradation. Thus, ultraviolet light is most important in discussing photodegradation, while the visible and infrared light are most important in the transfer of heat because of their higher intensity.

Photochemical degradation by high energy solar radiation is an important degradation mechanism for organic building materials. One of the Photochemical Laws is that "Only the light absorbed by a system can be effective in promoting a photochemical change" [9]. Polymers and organic coatings are sensitive to specific wavelengths (spectral sensitivity). The wavelengths most effective in degradation of polymers are usually in the ultraviolet region but not all energy which is absorbed causes degradation [10]. Just because a polymer, for example, absorbs energy at a given wavelength does not mean that this wavelength necessarily causes photodegradation. The relative extent of degradation caused by different wavelength regions can be determined by isolating various wavelengths bands and studying their effect on the material in question [11]. The extent of degradation also depends on the intensity of the radiation at the particular wavelength.

Although the ultraviolet portion of the solar spectrum is known to be the primary cause of photochemical action, the quantity of ultraviolet radiation in the solar spectrum at any given location is not well known because of the lack of adequate measurement devices. A recent publication by the National Bureau of Standards stresses the present crisis in the field of optical radiation measurements [12] and states that meteorology is more limited by the state of the art in radiometry than any other technical field. Further, it can make proportionally greater progress with better radiometric measurements.

Mean daily solar radiation is determined by the NOAA National Weather Service by integration of curves obtained with the Eppley pyrheliometer. Newland and Tamblyn [13] found that integration of sunlight with the Eppley pyrhliometer, a photoelectric integrator, and two types of actinometers, did not agree with each other when the results were plotted in terms of relative values. One difficulty with the pyreheliometer was that it was under glass, which screened out most of the ultraviolet radiation. Instruments of this type are now available which measure the entire solar spectrum, including ultraviolet. Even so, the pyrheliometer integrates the entire solar spectrum, only a small percentage of which (of the order of 5 percent) is ultraviolet radiation. For this reason, variations in ultraviolet radiation are not measured. The photoelectric integrator needs a filter to reduce its sensitivity; it is not affected by temperature. Using the proper filter, the photoelectric integrator could be used to measure ultraviolet radiation, and temperature could be measured as a separate factor.

Outisde the earth's atmosphere, about 10 percent of the solar energy is concentrated in the ultraviolet range [14]. But the ultraviolet contribution at the earth's surface is reduced because most of the wavelengths shorter than 295 nm are absorbed by the atmosphere. The relative amount of atmosphere through which solar radiation passes is called the "air mass"; its value is 1.0 when the sun is at the zenith and is greater for any other position of the sun. For places near sea level, Moon [15] suggested using the value 2.0 for air mass for energy calculations. Moon calculated solar radiation at sea level and found 2.7 percent ultraviolet radiation for an air mass of 2.0 and wavelengths of 290 to 400 nm. Searle and Hirt [16] measured the spectral energy distribution of sunlight in Stamford, Connecticut over a period of several years and found that the fraction of ultraviolet to total energy varied from 1.0 to 7.0 percent. The percentage of ultraviolet was a function of time of day and season of the year, generally a maximum at noon, and was extremely dependent on sky conditions. Coblentz [17] found that the shortest wavelengths in sunlight increase from January to a maximum in August and September, then decrease.

The amount of total solar radiation varies with latitude and time of day, or with the solar altitude (90° - zenith angle of the sun). Variation of irradiance with time of day is illustrated in table 5. The data, expressed in Btuh/sq. ft. in table 5, were taken from the ASHRAE Handbook of Fundamentals [18] and the values converted to Watts/meter^2 by a conversion factor. The irradiance values vary from 358 W/m^2 at 6 AM to 882 W/m^2 at 12 AM. In high latitudes, twilight conditions, or low solar altitude prevails during 30 to 40 percent of the annual cycle as compared to 10 to 15 percent in the tropics [19].

Kimuar and Stephenson [20] suggested estimating solar intensity using the "cloud cover factor", estimated visually in somewhat the same manner as Mean Sky Cover, reported by NOAA National Weather Service in Appendix table I.

An exhaustive discussion of spectral distribution, total solar radiation, and instrumentation was presented by Robinson [21].

Although problems exist in measuring solar radiation and determining the quantity of ultraviolet radiation, solar radiation data are available. Solar radiation data are presented in Appendix table II for the 18 sites listed in table 4. These data reflect total solar intensities, not just ultraviolet intensities. Some questions have been raised by NOAA National Weather Service as to the accuracy of its solar radiation data. These questions are reflected by a footnote "a" in Appendix table II. On the basis of conversations with the staff of the National Weather Service Radiation Program at NOAA, the primary concern is that the values of mean daily solar radiation probably have an uncertainty on the order of 10 to 20 percent. Such an uncertainty may not be prohibitive in applying the available data to durability testing.

The xenon arc light source closely approximates solar radiation in the ultraviolet portion of the spectrum and, for this reason, it is considered to be the most suitable source for accelerating photochemical degradation. However, the spectral energy distribution is not exactly the same as that of sunlight, so that it is not surprising that correlation between outdoor exposure and accelerated aging is not the same for all polymers [22].

It is advantageous, in establishing approximate exposure times in accelerated tests, to estimate the time required to simulate the natural annual solar radiation by accelerated devices, such as the xenon arc. A means of calculating this time is illustrated in table 6 using the sites for which solar radiation data are available in Appendix table II. The first column of table 6 lists the mean daily solar radiation in langleys at each site. Based upon a xenon arc radiance of 910 W/m^2 [23] at the drum of a light exposure apparatus, it can be shown that 1.277×10^{-2} hours of xenon arc radiation is equivalent to 1 langley. Using this factor, the number of hours of xenon arc exposure required to equal the annual solar radiation can be calculated and these values are presented in the second column of table 6. For example, the total annual solar energy as obtained from climatological data, for Fairbanks, Alaska can be approximated by 1063 hours of xenon arc exposure. However, values in table 6 are <u>only</u> a guideline for establishing initial exposure times. It is not to be expected that the xenon arc exposure times in table 6 will produce the same property changes observed in one year of natural exposure. It must be remembered that other factors in addition to solar radiation contribute to changes observed in materials. These factors will be discussed in subsequent sections of this paper. An example is the combined effect of temperature and humidity. Also, the spectral distribution of the xenon arc does not approximate solar radiation at higher wavelengths.

Table 7 lists the latitude, altitude, and average solar radiance in $Watts/m^2$ for each site listed in table 6. The latitude and elevation for each site were obtained from Appendix table I and the annual hours of sunshine from Appendix table II. The Annual Solar Radiation in $watt/hrs/m^2$ was calculated from the first column of table 6 by converting the data to an annual basis and changing the units.

The Average Solar Radiance column was then obtained by dividing the Annual Solar Radiance in $watt\text{-}hrs/m^2$ by the annual total hours of sunshine for each site. As can be seen in table 7, these stations vary considerably in latitude and also in altitude, although none are high enough to be classified as "highland" types. The values in table 7 for Solar Radiance in W/m^2 are all well below the radiance of the xenon arc lamp at the drum of the light exposure apparatus of 910 W/m^2.

In addition to photodegradation of polymers, solar radiation can cause thermal degradation. The sun is the source of most of the heat experienced by extorior building materials. Visible and infrared radiation causes increases in temperature, which may cause thermal degradation or secondary degradation following photochemical attack. Thermal and secondary degradation will be considered in the following discussion under <u>Temperature</u>.

5.2 <u>Temperature</u>

This discussion is concerned with the relation between observed atmospheric temperatures and the properties of building components and materials which serve as indicators of deterioration.

Air temperature data for the sites listed in table 4 are contained in Appendix table I. The temperature values in this table represent daily temperature expressed as 1) the record highest and lowest ever recorded in each month of the year, 2) the normal daily maximum and minimum for each month and the annual average of these values and, 3) the average monthly for each month and the annual average of these values. Appendix table III contains a summary of the freeze-thaw temperature data for each site listed in table 4.

The effect of temperature on building components and materials may depend on the high and low temperatures, the times in which they are sustained and the rate of cycling. In any particular location, temperature variations show a pattern of daily and yearly cycles with superimposed short-term and long-term fluctuations as illustrated in figure 2 by Stringer [24]. Figure 3 contains a plot of temperature data extracted from Appendix table I for Washington, D. C. The record highest daily temperatures for each month are plotted and connected by a line to form "curve" D-D and the record lowest daily temperatures are plotted and connected to form "curve" E-E. (Actually, the record daily extreme values are single points recorded sometime during each month during the total time of the data collection at Washington National Airport. The points are connected to add clarity to the figure.) The record highest temperature recorded at Washington National Airport was 101°F and was recorded in July 1966 while the record lowest temperature was 3°F recorded in the month of January 1972. Thus the differences between the record highest and lowest temperatures is 98°F. These record highest and lowest values, which represent the extremes which might occur on unusually hot or cold days, are useful in identifying extreme temperature limits for simulated tests. The average temperature data, Curve A-A, present a more reasonable estimate of the expected daily temperatures for each month. The daily maximum temperature curve, denoted as B-B, represents the long-term average of daily maximum temperatures for each month, while curve C-C represents the long-term average of daily minimums. The difference between the maximum of the B-B curve, 87°F, and the minimum of the C-C curve, 29°F, is 58°F and represents the difference between the maximum average maximum and the minimum average minimum. This difference is, of course, much less than the extreme variation of 98°F mentioned earlier. Curve A-A is the monthly mean temperature, calculated using the average daily maximum and minimum values. The average daily maximum and minimum temperatures are frequently exceeded. For example, in Washington, D. C., the daily maximum temperature in July is often above the normal maximum of 87°F. The average temperatures, though, are very useful in identifying climatological divisions based on temperature. Table 8 represents the ranges in temperature for each site listed in table 4. The greatest extreme temperature range occurred in Havre, Montana, with a record high of 111°F and a record low of -52°F -- a difference of 163°F. The greatest normal annual range is expected in Fairbanks, Alaska with a difference of 93°F. Table 8 also contains the normal maximum and minimum daily temperatures expressed as annual averages. This column provides an indication of the temperature range expected each day. For example, the average daily temperature range, throughout the year, for Pheonix Arixona, varies from a maximum of 85°F to a minimum of 53°F -- a difference of 32°F.

H. D. Parry [25] discussed the state of the art of atmospheric temperature measurements by the Weather Bureau (now NOAA National Weather Service) in 1962. At that time, the usual mercury-in-glass thermometer was used in a ventilated standard shelter so that the thermometer was not exposed to the sun. Parry stated that the error or uncertainty of measurement of atmospheric temperature was 3°F or more.

Consideration of the effect of temperature on building components and materials is subdivided, in this discussion, into Extremes and Cycling.

5.2.1 Temperature Extremes

Temperature extremes define the limits of temperature to which building components and materials are exposed in-service. The values can be used in specifying the temperatures used in tests.

Studies have been conducted to measure the surface temperature of various building materials. For example, Stephenson [26] found that dark roof surfaces in Canada may reach temperatures as high as 230°F in summer and wall surfaces as high as 190°F. Cullen [27] reported a maximum temperature of 166°F on a black asphalt built-up roof in Washington, D. C. in August 1962. This measured surface temperature was 81°F above the air temperature of 85°F. Thus, surface temperatures may differ greatly from the ambient air temperature. Since air temperature data is readily available, it is advantageous to relate measured air temperature to the surface temperature of building materials; however, these relationships are often difficult to quantify.

Surface temperatures of materials can be estimated by means of equations for the heat balance at a surface exposed to sunlight. Equations for heat balance at the surface generally make use of the "sol-air" temperature concept [18], [26]. The definition of the "sol-air" temperature is "the fictitious temperature of the outside air that would produce by convection alone the same rate of heat exchange at the surface as actually occurs by convection and long- and short-wave radiation combined" [18]. Wengert [28], in his equation for heat balance, used an estimated value of air temperature near the surface. Air temperature values from NOAA data at the nearest weather station were considered by Wengert to be satisfactory for small surfaces but for large surfaces, such as roofs, the actual temperature near the surface is probably several degrees higher than the air temperature reported at the NOAA weather station and an actual measurement may be necessary.

Wengert's equation is between energy gains and energy losses at the surface of the material. Experimental values used to estimate energy gains in the equation included the albedo of the surface and the incident solar radiation. The emissivity of the surface enters into both sides of the equation. Air temperature, surface temperature, and convection coefficeint were used to estimate energy losses. The convection coefficient was previously determined by Wengert to be 0.2 langley/min/deg. K [29]. The values of emissivity were used by Wengert [28] were 0.95 for painted surfaces and 0.85 for natural wood surfaces.

In equations using the "sol-air" temperature [18], [26], the absorptivity or absorbance of the surface was used instead of the emissivity. Wengert's calculations involved estimates of the amounts of short-wave (275-4000 nm) and long-wave (4000-25000 nm) [29] radiation. He also assumed that the temperature of emitting objects is the same as the air temperature and that their emissivity, ε, is about 1.00. These estimates and assumptions should be investigated before relying on Wengert's calculations for surface temperature of materials exposed to sunlight. While no values for surface temperature were given directly, diagrams were included in Wengert's paper [28] to estimate surface temperatures from solar radiation and albedo in percent.

From various sources, the albedo of various surfaces on the earth varies from 3 to 90 percent [28], [30], [31], [32]. Some of these values are given in table 9, which also includes extreme values for the albedos of painted surfaces. In table 9, both percent albedo and percent absorption are given. For opaque surfaces, Percent Absorption = 100 - (Percent Albedo). Sometimes absorption, absorptivity, or absorption factor is given as a decimal fraction, sometimes as a percentage. Absorptivity is the ratio of radiant energy absorbed to total incident energy [30], [32].

In addition to surface temperatures, the temperatures within the exterior envelope of the system are often of interest in evaluating materials. Otto Heyer [33] reported a study of measurements of temperatures in walls and roofs, in which thermocouples were placed in various positions in wood parts and inside the insulation. Locations chosen were Tucson, Arizona (house); Athens, Georgia (house); Portland, Oregon (2 houses); Diboll, Texas (house); and Madison, Wisconsin (house and office building). The buildings were of various constructions. Heyer found that the maximum temperature in walls reached 130°F, but did not exceed 120°F for more than 32 hours in any one year. Roofs reached a maximum temperature of 170°F but temperatures of 160°F or more were not obtained for more than 21 hours in any one year.

The effect of low temperatures on building materials and components must be considered apart from cycling between high and low temperatures. In a study published in 1950, Roberts [34] reported that the chief problem with concrete was freezing and thawing while wet. Plastics vary in their reaction to extreme cold and care must be taken in selection of these materials for housing applications. Properties of plastics at low temperatures are discussed by Lever and Rhys [35], including brittleness, flexibility, stress decay, and low temperature shock resistance. Plastics may crack when subjected suddenly to low temperature.

To predict durability of materials exposed to extreme temperatures and to design tests for this prupose, knowledge of the thermal behavior of materials must be combined with climatological and weather data, such as that summarized in table 8.

5.2.2 Temperature Cycling

The chief effect of temperature cycling, other than freeze-thaw cycling, is thermal expansion and contraction. Temperature cycling may also cause changes in such properties as viscosity. Viscosity changes may adversely affect asphalt or coal tar based products, such as bituminous roofing membanes [36]. Temperature cycling may result in failures from thermal shock [36]. Building components must be designated to withstand movement due to the expansion and contraction of materials of which they are composed. This is particularly true of plastic exterior cladding or sandwich panels with plastic skins. According to Everard [37], assuming an extreme seasonal range of 160°F, "the change of length of plastic materials over a 10-ft. length will be approximately 1 in. as compared to below 0.2 in. for established materials". Sealants and the structures in which they are installed must be designed to function over a specified range of temperatures, to insure that thermal movements are not so great as to cause failure of the bond to the joint surfaces [38] or failure of the component by buckling.

Temperature cycling and temperature differentials between the interior and exterior of buildings can be instrumental in the formation of dew. Dew results from the condensation of moisture on a cool surface. Dew is frequently observed in the interior walls of basements or other masonry structures during the day. Dew formation will be discussed further in section 5.3.1.

Thus, in designing and conducting durability tests, temperature cycles must be considered. Data, such as that in Appendix table I are useful in deciding on the temperature limits.

5.2.3 Freeze-Thaw Cycling

Freeze-thaw cycling is a special case of temperature cycling in which the temperature cycles above and below the freezing point of water. This is important in the deterioration of porous materials which are sufficiently close to water saturation at the time the freezing occurs. Water-filled pores and freezing cycles must both be present to obtain this specific type of aging or weathering. The deterioration is due to the expansion of the water when it solidifies. Repeated freezing and thawing cycles increase the damage and result in disintegration of the material.

Building stone [39], [40], often has pores and cleavage cracks that can be penetrated by water which can subsequently freeze and thaw. This is a major cause of the weathering and disintegration of stone. Damage of water-saturated concrete from freezing and thawing is well known and has been studied extensively [41].

It has also been known for a long time that freezing and thawing causes deterioration of brick, otherwise durable to weathering, and that this is related to the porosity and water absorption of the brick [42].

In ASTM C 62 [8], three grades of brick are defined by physical requirements. Two grades are specified for exposure to weather, while one grade is not to be used for outdoor exposure. Grade requirements for the exterior brick depend on the type of exposure in the building (whether or not vertical or in contact with the earth) and on a Weathering Index.

Figure 4 is a copy of the map, which appears as figure 1 in ASTM C 62 [8], reproduced by permission of the American Society for Testing and Materials. The numbers on the map refer to the Weathering Index, the product of the average annual number of freezing cycle days and the average winter rainfall in inches. The average number of freezing cycle days may be calculated from data in NOAA Local Climatological Data Annual Summaries, using the figures under MEAN NUMBER OF DAYS, Temperature (a) Max. 32°F and (b) Min. 32°F. The parehtheses (a) and (b) were added by the authors for convenience. The difference (b) - (a) is "the average number of freezing cycle days". Table 10 presents results of calculations for those sites listed in Appendix table I which experience freezing and thawing cycles. Data for calculation of Winter Rainfall is also taken from the Appendix table I using figures for total precipitation and for "Snow, Ice pellets".

The calculation of winter rainfall is not as simple as that for "average number of freezing cycle days". Killing frost [43] dates are not always given in NOAA publications but complete data is given for freeze-free periods at "freeze threshold" temperatures of 32, 28, 24, 20, and 16°F. The freeze cycle period can be taken at 365 minus (the freeze-free period in days). The authors calculated winter rainfall and Weathering Index for all these temperatures but negative values were obtained for several stations at threshold temperatures of 24°F and below. Table 11 presents the results of calculations of winter rainfall from NOAA data [44] and of Weathering Index from data in table 10. When the locations in table 11 are compared with the map, figure 4, values of the Weathering Index for Atlantic City, Baltimore, Bismark, Great Falls, Havre, and Washington agree with the map at a threshold temperature of 32°F. Only Atlantic City's, Baltimore's, Bismarck's and Washington's Weathering Index agree with the map at a threshold temperature of 28°F. Las Vegas and Minneapolis Weathering Index figures do not agree with the map at either threshold temperature. Las Vegas should belong in the "negligible" weathering region with an Index under 100 and Minneapolis should be in the "moderate" region, with an Index 100-500. Fairbanks is outside the map so this location can be disregarded.

One possible reason for discrepancies between the calculated figures in table 11 and the map, figure 4, is the assumption that the "winter rainfall" equals "total winter precipitation" minus 1/10 of the solid precipitation as snow, sleet, and hail. According to Peter and Schriever [45], the specific gravity of snow varies from about 0.05 to 0.1 (1/20 to 1/10 that of water). Procedures are available to determine the water equivalent of solid precipitation [43].

Freezing and thawing is also probably a factor in the degradation of composite plastics exposed outdoors. Blaga [46] found evidence that surface spalling of glass fiber reinforced polyester is followed by water penetration into the voids or cavaties resulting from the incipient degradation; further damage is then caused by freezing and thawing. Table 12 lists the number of months classified as freezing, freezing and thawing, or above freezing for each site listed in table 4. The months in each category are also listed; the data were extracted from Appendix table I. A "freezing" month is defined as one in which the daily maximum temperature in Appendix table I is 32°F or below. A "freezing and thawing" month is one in which the daily maximum temperature is above freezing (32°F) and the daily minimum temperature is 32°F or below. "Above freezing" months are those in which the daily maximum temperature is greater than 32°F. The sum of the "freezing" and "above freezing" months must equal 12.

Since the presence of moisture is important in freeze-thaw cycles for many materials, it is advantageous to determine the extent of wetness during periods of freezing and thawing. Table 13 presents data to show the extent of precipitation during freeze-thaw months listed in table 12 for the various sites. The precipitation measure is the number of days in which 0.01 inch or more of precipitation fell during the total period of freeze-thawing. This data was extracted from Appendix table I. Wetness can occur by means other than the precipitation included in table 13. A more complete discussion of wetness is included in section 5.3.

5.3 Water

Water can be a substantial factor in degrading products used in the exteriors of buildings. It can hydrolyze groups such as esters, amides, nitriles, and acetals, which are present in many plastic or other polymer-based building materials. Rain can also physically erode materials and solid precipitation, such as snow, sleet, and hail, can damage materials by erosion and impact. Further mechanisms for water attack are provided by combinations of water with other weathering factors, such as soluble air contaminants (sections 5.5.2, 5.5.3) and freeze-thaw cycling (5.2.3).

The discussion of water as a weathering factor will be divided into 1) Vapor, 2) Liquid Water, and 3) Frozen Water.

5.3.1 Vapor

The amount of water vapor in the atmosphere is expressed by several different terms [30], [31], [32]. These terms are defined in the Glossary and are as follows:

Absolute humidity

Specific humidity

Mixing ratio

Relative humidity

Dew point

Relative humidity is what is commonly referred to as "humidity" in meteorological and climatological reports and summaries. Relative humidity may be computed from wet and dry bulb temperatures and other psychrometric data. Charts are available of relative humidity versus wet and dry bulb temperatures or dew point depression [47]. Although there is some difference of opinion about the definition of relative humidity it is used by meteorologists and climatologists because it is a conservative property, while absolute humidity is not. That is, the measurement of relative humidity is not dependent of adiabatic compression or expansion [32], [48]. The wet and dry-bulb psychrometer is customarily used by the NOAA National Weather Service to obtain temperature measurements which are used to calculate various indices of humidity, although work is being done to improve the instrumentation [43], [48].

High humidity and ranges in relative humidity are likely to have a deleterious effect on building materials as can be seen from the following examples.

According to Hall [49], who included a bibliography on the subject, wood and wood products are adversely affected by fluctuations in moisture content. Water absorption causes swelling which stresses the surface layers, and eventually results in splitting and checking. Changes in the moisture content of coatings, together with photochemical degradation, cause stresses which result in checking and cracking. Experiments by Dantuma [50] showed that about 4 to 15 percent increase in moisture content of painted wood panels resulted from exposure to 18 to 20°C to an atmosphere of 94 to 98 percent relative humidity over a period of 16 days. The increase in moisture content of panels depended on the number of coats of paint. The moisture content decreased from 1 to 5 percent on exposure of the panels to conditions of 18 to 20°C and 55 to 70 percent relative humidity.

According to Sereda [51], the presence of water is necessary for the corrosion of steel. This can be in the form of liquid water as in rain or as high humidity.

The effect of moisture on porous materials is reviewed by Sereda and Feldman [52], who present sorption isotherms for wood, concrete, and brick as curves of moisture content versus relative humidity.

As mentioned in section 5.2.2, temperature cycling and temperature differentials between the outside and inside of buildings can cause condensation of moisture inside the walls. This is sometimes referred to as dew formation. Formation of dew is a function of temperature and humidity. For example, differences in temperature and humidity between the outside and inside of a building can result in condensation of moisture on any surface that falls below the dew point. In building interiors which are heated and humidified in winter, moisture migrates through the porous wall to the colder exterior portions and dew formation results in the accumulation of liquid water in the components of the system.

Average relative humidity data based on long term measured values for various times of the day and for each month of the year are included in Appendix table I for the sites listed in table 4. The time of day in these tables is expressed as Local Standard Time (LST). Also included in the tables is the annual average relative humidity for each time of the day at each site. Humidity data are usually reported four times daily, but sometimes only twice daily, so that the values in the tables may be far from the extremes.

Published data do not include a separate listing of extreme high and low humidities but the measured extremes can be extracted from the data in Appendix table 1. Table 14, for example, lists relative humidity data for each site to show the normal expected ranges. The columns of Highest and Lowest Annual Mean R.H. were extracted from the average annual values in Appendix table 1. The difference between these two values represents the average daily ranges. The difference between the Highest Monthly Average and the Lowest Monthly Average relative humidity represents the expected ranges on an annual basis.

The Highest Monthly Average relative humidity in table 14 is found in Eureka, California at 94 percent. The lowest is for Las Vegas at 12 percent, with Phoenix at 13 and Yuma at 15 percent. But since the humidity measurements are not made continuously during the day, more extreme values undoubtedly occur. For example, the atmosphere is sometimes saturated, as in a heavy mist, and it is likely that relative humidities in the desert drop to below 10 percent.

Two of the desert sites, Phoenix and Yuma, show apparent daily humidity cycling of over 30 percent, with values ranging from over 50 percent to about 20 percent. These two sites also have a higher expected daily maximum relative humidity than Las Vegas. In addition, Phoenix and Yuma show greater seasonal variation in relative humidity than Las Vegas. Of course, daily ranges are not likely to approach the seasonal ranges because the seasonal ranges represent the difference between the highest average monthly value in the wettest season and the lowest average monthly value in the driest season.

External relative humidity changes with air temperature and we can normally expect it to be lower in the hottest part of the day and higher at night and early morning.

5.3.2 Liquid Water

Water can degrade building materials in several ways. It can chemically decompose compounds comprising building materials by hydrolysis. It may be essential for corrosion, as with some metals. It can, in combination with other factors, physically alter or dimensionally change materials so that they either fail to perform their functions or are susceptible to further degradation by other factors. For example, swelling induced by the absorption of moisture plays a major role in warping materials which often makes them unusable. Moisture causes the blistering of coatings through the hydrostatic pressure of the liquid under the films which causes them to lift. Moisture also provides a medium by which soluble salts in materials can migrate and recrystallize at other locations.

Wetness refers to the presence of liquid water on the surface of materials. This may be a surface film or water may be absorbed by the material. Deposition of water or wetness can occur by the condenstation of moisture from the air, (dew), by precipitation (rain, mist, and fog), or from ground moisture. Building components on or below grade may become wet from ground moisture, and moisture from the ground may migrate upward by capillary action. Ground moisture may result from standing water or from wet soil.

To evaluate the effect of wetness it is advantageous to estimate the length of time during the exposure or in-service application in which the material is wet. The time of wetness can be measured using commercially available instrumentation but it is not possible to obtain accurate time of wetness data from available climatological or weather data. Climatological and weather data does, however, permit relative wetness comparisons between various sites. Included in Appendix table I are data for mean precipitation per month and per year; maximum and minimum monthly precipitation, representing extreme values; and mean number of days per month and year with precipitation greater than 0.01 inch. Appendix table I also included data for snow and ice pelets, thunderstorms, and fog. The data discussed in section 5.3.1 on Vapor is also relevant in comparing the relative wetness of various sites. Table 15 provides, in the first column, a tabulation of the mean number of days having a maximum temperature above 32°F and a total precipitation of 0.01 inch or more for the 18 sites discussed in this report. Only the number of days with temperatures above 32°F were tabulated so that the values would reflect the liquid precipitation. The annual number of days in the first column of table 15, then, provides a measure of the relative wetness of the particular location.

Three sites in table 15 have more than 150 days of precipitation per year under the criteria used; these are San Juan, Puerto Rico with 202, Seattle with 162, and Astoria with 200. Sites with more than 100 but less than 150 days are, Miami, 126; Washington, D. C., 111, Baltimore, 112;

Atlantic City, 112; and Eureka, 117. Sites with more than 50 but less than 100 days are: Great Falls, 90; Havre, 61; Fort Worth, 78; Minneapolis-St. Paul, 88; Bismarck, 74; Fairbanks, 65; and Flagstaff, 74. The three desert sites have less than 50 days precipitation with Las Vegas having 24, Phoenix 34, and Yuma 15.

In their discussion of wetting and drying of porous materials, Sereda and Feldman [52] presented sorption isotherms showing the relationship between moisture content and relative humidities at various temperatures. While the rate of change of moisture content with relative humidity and temperature depends on several other factors, such as wind velocity, it is reasonable to expect more rapid drying at lower relative humidities. In table 15, columns are listed to show the number of days in which liquid precipitation is 0.01 inch or more for various ranges of lowest monthly average relative humidity. The number of days with precipitation of 0.01 inch or more is a measure of days of wetness and number of periods of wetness. If materials exposed outdoors have an opportunity to dry before the next period of wetness, days of wetness can be equated to wetting and drying cycles. Hence, it can be postulated that the relative number of days of precipitation in table 5 under columns of low relative humidity (49 percent and below) provide a rough measure of the number of wetting and drying cycles. A more precise measure would require:

(1) data on intervals between days of wetness and temperatures on days of wetness

(2) data on rates of drying of various building materials likely to be exposed outdoors under various conditions of temperature and relative humidity.

Like other applications of climatological data this would be complex but might be possible through the use of computers.

In table 15, the relative humidity columns are divided into 1) over 70 percent, 2) 50 to 69 percent, 3) 20 to 49 percent, and 4) lower than 20 percent. San Juan, Miami, Atlantic City, Astoria, Eureka, and Minneapolis-St. Paul have no days of precipitation in low humidity columns. At the other extreme are the desert sites which have all the precipitation days in the low humidity columns.

The authors have been informed by NOAA National Climatic Center at Asheville, North Carolina, that the values for days of precipitation 0.01 inch or more include rain, fog, and dew. If data for precipitation are based only on total rainfall, it is important to distinguish between rain, fog, and dew [53]. Thornthwaite's "precipitation effectiveness" is a measure of wetness and wetting and drying, based on precipitation and temperature, the precipitation data being based only on rainfall [55]. Surface moisture and time of wetness may be measured directly at exposure sites and in laboratory accelerated aging devices [56].

5.3.3 Frozen Water

Erosion of materials exposed outdoors is due to a combination of factors including weather elements such as rain, sleet, snow, hail, wind, sand and dust. The rate of erosion depends on the weather element impinging on the material, the position of the material, and other factors to be discussed later. The position of the building material varies according to whether it is the outer part of a flat roof, a sloping roof, a horizontal flat wall, or a piece of cladding at an angle to the wall. The position of the building material is important since one factor in erosion is the angle of impingement. Figure 5 shows the locations of hail storms in the continental United States between 1960 and 1969, caused more than $5,000 in damage during the storm. This map is useful in defining geographical areas in which hail damage to building materials might be expected to occur. Studies in the period around 1950 [39] indicated that rain and sleet have a serious erosive effect on plastics and organic coatings on high speed airplanes. Also, intense sleet storms were found to damage both moving and stationary objects. More recently, studies have been reported [57], [58] of the effects of various factors on rain erosion from the standpoint of aerospace engineering. The rate of erosion for plastics was found to depend on the velocity of the vehicle, air pressure, temperature, relative humidity, the angle of incidence of the rain, and drop size. Various mechanical properties were used as evaluative techniques, such as notch-impact strength and hardness. Brittle plastics were found to be less resistant to rain erosion than tough plastics. Further studies of this type are needed from the standpoint of building materials, the difference being in the nature of the materials and the fact that the buildings are stationary.

5.4 Normal Air Constituents

The following is a table of estimated concentrations of gases in normal dry air, compiled from various sources [59]:

Nitrogen	780,900 ppm (78.09% by volume)
Oxygen	209,400 ppm (20.94% by volume)
Nitrogen and oxygen	990,300 ppm (99.03%)
Argon	9,300 ppm (0.93%)
Carbon dioxide	315 ppm (0.03%)
Nitrogen, oxygen, argon and carbon dioxide	999,915 ppm (99.99%)
Other constituents	85 ppm (0.085%)
Neon	18 ppm
Helium	5.2 ppm
Methane	1.0-1.2 ppm
Krypton	1 ppm
Nitrous oxide	0.5 ppm
Hydrogen	0.5 ppm
Xenon	0.08 ppm
Nitrogen dioxide	0.02 ppm
Ozone	0.01-0.04 ppm

5.4.1 Natural Sources of Air Contaminants

There have been a number of definitions of air pollutants or contaminants implying that these are harmful constituents not present in normal air or atmosphere. Normal constituents of the atmosphere may be defined as those arising from "natural" processes or processes other than from man's activities. Oxygen and carbon dioxide are normal constituents of the atmosphere which are essential to life but these gases have a deleterious effect on some materials. The extent to which these gases are harmful depends largely on their concentrations which are increased in some areas by man's activities. About 85 percent of hydrocarbon emission is from natural sources [60], primarily agterepenes from forests and other vegetation and methane from the bacterial decomposition of organic matter. Methane is a normal constituent of the atmosphere and is part of the carbon cycle of the biosphere [59]. Sources of air contamination from man's activities will be discussed in section 5.5. Discussion of air constituents in section 5.4 is confined to oxygen, ozone, and carbon dioxide. These gases are the only atmospheric constituents present in sufficient quantities in normal dry air to have an appreciable effect on materials.

5.4.2 Oxygen and Ozone

Oxygen constitutes about 21 percent of the atmosphere and the proportion does not vary so that it is a constant factor in all geographic areas. Ozone is formed naturally outside the earth's atmosphere by the irradiation of oxygen with ultraviolet radiation less than 220 nm in wavelength. Various natural and man-made processes also contribute to the ozone concentration. Ozone normally constitutes only 0.01 to 0.04 ppm of "normal dry air" [59] but was reported to be about 1 ppm in Los Angeles during a severe smog. Ozone is being monitored on a regular basis by NOAA Air Resources Laboratory in cooperation with several universities at ten stations throughout the United States, including Alaska and Hawaii.

As has been discussed in review articles [39], [61], oxygen and ozone may have deleterious effects on organic materials including rubber, organic coatings, and cellulosic materials; and they may contribute to the corrosion of metals. Solar radiation and high temperatures are contributing factors in the oxidation of organic materials. Moisture together with oxygen and acid gases in the atmosphere is the chief contributing factor in the corrosion of metals. This is discussed in section 5.5.2.

5.4.3 Carbon Dioxide

Carbon dioxide comprises about 0.03 percent of normal dry air and, like oxygen, does not vary in proportion with geographic area.

Hamada [62] and others have shown carbon dioxide to exhibit a slow neutralizing action on the alkali (calcium hydroxide) in concrete. Neutralization of the concrete may be detrimental because reinforcing steel has been found to rust when the depth of neutralization reaches the steel. The corrosion of the steel is dependent upon the pH of the concrete aggregate with rusting occurring at a pH of less than about 9.

5.5 Air Contaminants

Air contaminants not only include gaseous pollutants but also mists and particulates. The term "mist" is used in section 5.5.2 to denote suspended water droplets in the form of fog, mist, or spray, in which air contaminants are dissolved or suspended. These contaminants are mostly from man's activities but salt spray is a special case of a natural air contaminant confined to the seashore. The phenomenon of "smog" is a special case of a mist which results from photochemical oxidation of a mixture of reative hydrocarbons such as olefins and nitrogen dioxide [59]. The term "particulate" in section 5.5.3 refers to solid suspensions or aerosols. The suspended solids may be harmful or may absorb, adsorb, or occlude air contaminants most likely dissolved in water. Particulates may consist of "natural" materials such as sand or dirt from soil or may result from manufacturing other human activities. The deleterious action of particulates on materials may be chemical or physical. The main physical effect is erosion resulting from the combined action of particulates and wind, as discussed in section 5.6.

Data on concentrations of pollutants in various geographic areas have not been accumulated for as many years as other weather and climatological data. Data that are available will be discussed in sections 5.5.1, 5.5.2, 5.5.3, and 6.2. The lack of data and the uncertainty of the interactions between pollutants and materials are reasons for the lack of understanding of the effects of pollutants on building materials.

5.5.1 Gases

The major gaseous pollutants or air contaminants include sulfur compounds, oxides of nitrogen, hydrocarbons, and carbon monoxide. These pollutants are concentrated largely in industrial and urban areas and can be extremely damaging to building materials. Mixing of these pollutants with the atmosphere due to circulation of air distributes these pollutants to rural areas. The major sources of these pollutants in industrial areas are motor vehicles, manufacturing, electrical power plants, space heating, and refuse disposal [60].

Gaseous sulfur pollutants in the air include sulfur dioxide, sulfur trioxide, and hydrogen sulfide. Sulfur oxides and nitrogen dioxide form acid mists, as discussed in section 5.5.2. Natural occurrence of sulfur oxides does not occur to any measurable extent. The principal source of sulfur oxides in the combustion of coal and the quantity of their emission is directly proportional to the quantity and sulfur content of the coal used. In industrial areas, the concentration of sulful dioxide may be as high as 3.2 ppm [59] although the average maximum concentration in United States cities in about 0.42 ppm. About 20 percent of the sulfur dioxide in the air results directly from emissions with the remaining portion arising from oxidized hydrogen sulfide. Sulfur dioxide measurement is usually used as an indicator of the concentration of sulfur pollutants. Hydrogen sulfide (H_2S) is produced largely by decaying organic matter and by volcanoes. It is also emitted by some industrial operations. Data on H_2S concentrations in the atmosphere are incomplete but available information indicates that it is not significant on a global basis [60]. However, in urban areas, hydrogen sulfide may be a pollutant problem as for example, in causing the darkening of lead based paints [63]. It also causes the tarnishing of copper and silver. Hydrogen sulfide is oxidized in the air to form sulfur and sulfur dioxide.

One reaction of sulfur dioxide which can be particularly damaging to building materials is its oxidation to form sulfuric acid. This is discussed further in section 5.5.2.

As already mentioned, man-made processes yield only about 15% of the tota global hydrocarbon emissions, the remainder being emitted mainly from "natural processes. Much of the man-made hydrocarbon emissions are concentrated in urban areas. The primary man-made sources of hydrocarbon emissions are in the manufacture and use of petroleum, including exhaust from motor vehicles. In this processing-use chain, gasoline is the major source of hydrocarbon emissions. Hydrocarbons are regarded as air pollutants chiefly because of the phenomenon of "smog". Olefins and other reactive hydrocarbons, mixed with nitrogen dioxide, undergo photochemical reaction in the presence of sunlight, resulting in "smog".

Carbon monoxide is the product of incomplete oxidation of organic compounds during combustion and this pollutant appears to be almost exclusively man-made. Motor vehicles are estimated to contribute more than 80% of the global carbon monoxide emission. Smaller amounts result from other combustion processes and from plant and animal sources. Although the maximum global concentration of carbon monoxide is about 0.1 ppm, the level for off street sites in five major United States cities have been measured at about 7 ppm [60].

Carbon monoxide can be a health hazard but there seems to be no direct evidence that it is a factor in the deterioration of presently used building materials.

5.5.2 Mists

Soluble gaseous pollutants and salts formed from pollutants, such as ammonium sulfate and ammonium nitrate, dissolve in water to form mists which can degrade building materials. Acid mists result from oxides of sulfur and nitrogen as in the following discussion. Also discussed is salt spray from sea water which can be considered as an air contaminant.

Sulfur pollutants, in addition to the oxides and hydrogen sulfide mentioned previously, include sulfuric acid and sulfate salts. Sulfur dioxide can be oxidized to sulfur trioxide which dissolves in water to form sulfuric acid. The acid may then further react to form salts such as ammonium sulfate. Sulfur dioxide is oxidized photochemically in the presence of nitrogen dioxide and certain hydrocarbons to produce aerosols containing sulfuric acid. It can also be oxidized in water containing ammonia to form ammonium sulfate aerosol. These aeorsols are removed from the air primarily by precipitation but also by gravitational settling. The presence of sulfuric acid and sulfates in the precipitated or deposited aerosol results in a more acidic solution, the effect being reflected by a lower pH.

Acid mists of this type may cause serious deterioration of a variety of building materials, including metals, organic coatings, and stone [63]. Nylon is a well know example of a polymer which is attacked by sulfur dioxide and sulfur trioxide dissolved in water in the form of a mist.

Nitrogen dioxide gas can also combine with water vapor to form nitric acid. This results in another type of acid mist. The acid may then further react with ammonia to form ammonium nitrate which is somewhat less corrosive than nitric acid for most materials. Nitrogen dioxide that does not react photochemically is ultimately converted to nitrate salt aerosol, which settles by gravitation or is removed from the air by moisture in the form of precipitation.

Particulate pollutants can be removed from the air by rain and thus deposit on materials. However, this removal by rainfall is negligible for particles less than 2 μm in diameter unless the particles originate in clouds. Cloud particles are more effective than rain drops in collecting small particles [65].

Seawater salt spray is a factor in the deterioration of materials in areas close to the seacoast. The effect of salt spray is confined to a distance of only a few hundred yards inland [63]. The chief effect of salt spray is to increase the corrosion of metals including those coated with porcelain enamel. Considerable difference in gloss and color retention of porcelain enamel specimens on steel and aluminum were noted at two sites at Kure Beach, North Carolina [66]. Specimens exposed 80 feet from the ocean deteriorated more rapidly than specimens exposed 800 feet inland.

5.5.3 Particulates

Particulate pollutants or particles in suspension, as aerosols, or gas ions, are complex and are widespread types of air contaminants [60]. The size and chemical content of particles vary depending on the source. For example, those larger than 10 μm in diameter come mainly from mechanical processes, such as erosion, grinding, and spraying. These from 1 to 10 μm stem partly from mechanical processes but also include industrial dusts and ash; these are more numerous in the atmosphere than those greater than 10 μm and generally include the largest weight fraction. Smaller size particles, between 0.1 and 1 μm in diameter, tend to contain more ammonium sulfate and combustion products and to form aerosols primarily by photochemical reactions in the air. Little is known of the chemical nature of particles less than 0.1 μm but their concentration is highest over cities, a fact attributed largely to combustion. Those smaller than 0.1 μm may also act as what are called "mixed nuclei", which can act as condensation nuclei.

"Mixed nuclei" probably arise from agglomeration of smaller particles or by adsorption of gases or vapors. This action is postulated [67] to form a water-soluble crust on a particle larger than 0.1 μm. These appear to be made up largely of sodium chloride, sodium carbonate, and ammonium sulfate.

Aerosols formed by fine particles are complex with respect to size, structure, chemical composition, and concentration. It is important to study the chemical composition of these particulates in relation to size to determine their effect on materials, both as to type and duration of exposure. It is also important, for the same reason, to extend out knowledge of the behavior of aerosols in the atmosphere.

The importance of particulates in deterioration of materials is shown by chemical analysis of dustfall and other suspended particulates, which shows them to contain a variety of pollutants, such as tar, sulfates, nitrates, and various metals.

5.6 Particulates and Wind

In addition to factors already discussed, winds of high velocities, combined with particulate matter, may produce an effect similar to that of sandblasting on building materials [63]. Wind also contributes to the erosive effect of water, as discussed in section 5.3.3. Peak gust wind velocity data are presented in Appendix table 1 as are mean wind speed and prevailing direction. These data can be related to erosive action and also to estimate the expected wind load on structures in specific locations. Wind load is an example of an environmental factor which imposes a stress on building components.

5.7 Biological factors [68], [69], [70,] [71], [72]

Living organisms are an important environmental factor in the deterioration of organic building materials, particularly wood and wood products. While biological attack is not a weathering factor, it is dependent on such weathering factors as solar radiation, temperature, and water. These factors determine optimum conditions for survival and growth of living organisms and therefore for deterioration of organic building materials which they attack. Materials attacked may be a source of food, a barrier to food, or provide shelter or attachment for the organisms. The material may also be attacked by a product of the life process of the organisms, such as sulfuric acid from bacteria which digest sulfides or organic acids.

5.7.1 Fungi

Fungi are a class of plants which do not contain chlorophyll, cannot manufacture food by photosynthesis, and feed on organic materials. Fungi multiply by means of very small and numerous spores, which germinate and grow like seeds under moist conditions. The rotting of wood is caused by the spread of a network of tubes, called hyphae, which forms a tissue, called the mycelium. This network feeds on the wood, weakens the structure, and causes it to disintegrate. At the advanced stage of decay, the fungus may form visible bodies on the surface of the wood as toadstools, fleshy or woody shelves, or crusts. Wood decay is of two main types, known as brown rot and white rot. Brown rot causes the wood to darken and shrink into cubes or oblong pieces. White rot causes overall disintegration and a pale color. Figure 10 shows regions of the contiguous United States which experience various degrees of wood decay.

The growth of fungi is determined by available food, oxygen, and optimum conditions of temperature and moisture. Optimum conditions vary between species of fungi. The optimum temperature for many species is 58 to 86°F and for others 65 to 95°F. Above 95°F, fungi grew more slowly and may be killed by temperatures over 100°F. However, it is possible for fungi to grow at any temperature above freezing and some species can survive severe winters with several month of temperatures below 0°F. Fungi can attack wood if the moisture content is 20% or more but the optimum moisture content is 35 to 50 percent. Ultraviolet radiation of wavelengths less than 320 nanometers kills bacteria and fungi and hence is called biologically active ultraviolet light. However, very little of this short wavelength ultraviolet reaches the earth's surface.

Attack by fungi on building materials usually occurs as rot of wood or mildew on organic coatings. Mildew attacks organic coatings based on linseed oil, generally causing it to turn black. Coatings based on synthetic resins are not generally attacked by mildew but thickeners and stabilizers used in latex paints may cause these coatings to be attacked by mildew. Linseed oil putty does not usually support mildew because of its low content of linseed oil. Synthetic materials, such as plastics, do not generally contain food for living organisms unless they contain edible additives such as plasticizers and fillers. Organisms may grow on asphalt roofs but do not usually cause damage. If organisms penetrate the outer surface, they may thrive inside building components, possibly in the insulation, if the insullation or other material inside the component contains nutrients for the organisms. Organisms penetrating the outer skin of structural building panels might attack edible adhesives such as casein.

5.7.2 Bacteria

Bacteria differ from fungi in that they are microscopic in size, do not form hyphae or mycelia, and generally require liquid water for growth, while fungi thrive under high humidities and high moisture content of supporting media, such as wood. Bacteria requiring oxygen are called aerobic and those which do not need oxygen are called anaerobic. Bacteria and fungi which attack wood, cotton, and other cellulosic materials are cellulolytic microorganisms [73] which decompose the cellulose molecule by enzymatic action. Decay from attach by these organisms is accelerated by high temperatures, dampness, and rain, and seldom occurs in areas where the annual rainfall is 10 inches or less. Cellulosic materials degrade when soaked in water as well as under high humidities, due to the action of cellulolytic microorganisms.

As already mentioned, bacteria may also attack building materials by a product of their life process, such as sulfuric acid from bacteria which digest sulfides. Bacteria can also form a variety of aliphatic or fatty acids from fermentation or attack on organic materials. Fatty acids include the stronger formic, acetic, and propionic acids as well as the weaker higher fatty acids. Information regarding the effect of fatty acids on building materials is not available.

6. Use of Climatological and Weather Data in Durability Testing

6.1 A General Methodology for Short-Term Durability Tests

As mentioned briefly in the Introduction, a general methodology for short-term durability tests can be considered to consist of three parts: Problem Definition, Testing and Interpretation.

Following is an outline of a proposed general methodology:

I. Problem Definition.

   A. Define the performance requirements

   B. Characterize the specific building component or material

      1. Identify important properties to be measured as indicators of degradation.

      2. Identify environmental factors expected to be encountered by the component or material in-service.

      3. Identify, where possible, the degradation mechanisms.

   C. For short-term tests based upon accelerated aging, deduce how the degradation mechanism or the property change can be accelerated using the environmental factors of importance or, for short-term tests based upon incipient property changes, determine how the property changes can be measured following exposure to the environmental factors of importance.

II. Testing

   A. Design the testing program and include tests to accelerate all likely degradation mechanisms.

   B. Conduct the tests to identify the major degradation mechanisms and to allow prediction of their rates under in-service conditions.

III. Interpretation

   A. Interpret the data obtained from the testsby using the data from IIB. to predict service life under the conditions of interest.

Although all environmental factors listed in table 1 must be considered in all parts of the general methodology, weathering factors are of particular interest in this report.

In the Problem Definition part of the methodology, important weathering factors must be identified, quantified and related to the property changes or to the degradation mechanisms.

The second part of the methodology, Testing, requires selection and control of the intensities of the various weathering factors to be used in the test.

The third part of the methodology, Interpretation, requires consideration of the weathering factors used in the test so that quantitative durability predictions may be made.

The weathering factors data needed for designing and interpreting short-term durability tests must be obtained from existing climatological and weathering data such as that presented in the various tables in this report. Also, maps, tables, and indices can be useful in the durability testing. These are discussed in the following section of this report.

6.2 Use of Climatological Maps, Tables and Indices for Durability Prediction

With the exception of the map and index designed for brick [8], systematic maps and indices are not available to show the degradation of building materials in various geographic areas; however, existing climatological data can be used to some extent in designing accelerated tests and interpreting natural exposure tests.

The effect of solar radiation and temperature on materials was discussed in sections 5.1 and 5.2. Also discussed were uncertainties in measurement particularly of solar radiation. Appendix table II compares mean daily solar radiation in langleys, annual hours of sunshine, percent of possible sunshine and mean sky cover for the sites listed in table 4. Table 16 illustrates the consideration of these values as an index with Las Vegas representing the value of 100. Such indices are useful in considering climatological values in different geographical areas. Figure 6 indicates both mean daily solar radiation and total annual hours of sunshine for areas in the contiguous United States and for sites listed in table 4. In spite of the uncertainty of measurement locations can be classified semi-quantitatively. Prediction of durability to solar radiation and correlation of outdoor exposure and accelerated aging in light exposure apparatus might be based on the calculations illustrated in table 6 which show the number of hours of xenon arc exposure required to simulate the annual solar radiation. The values in table 6, however, do not reflect the effect of other weathering factors so that the values can be used only as a guideline.

Maps from the National Atlas [74] showing solar radiation and temperature in various sections of the United States are available and these are helpful in designing test conditions. Figure 7, for example, shows a map of the contiguous United States with solar radiation and maximum temperatures in July.

Durability of materials to low temperatures may be predicted by the use of Trewartha's map [5] illustrated in figure 1. Areas of extremely low temperatures are found in D. HUMID MICROTHERMAL CLIMATES and BSk, Middle Latitude Steppe, as in table 2.

One map and Index designed specifically for building materials is in the ASTM specifications for brick [8] which was discussed in section 5.2.2 under the subject of freezing and thawing. It was mentioned in this discussion that freezing and thawing affects not only brick but other porous building materials. The map designating weathering areas with respect to brick appears in figure 4. Freezing and thawing is a combination of temperature cycling about the freezing point of water and wetness. In order for damage to occur to materials this temperature cycling and wetness must coincide or the material must be wet during cycling between temperatures above and below freezing. Time of wetness would be of greater signficiance than total winter rainfall as used in the Index and map just discussed. Table 13 gives the frequency of precipitation during months of freezing and thawing for stations in Appendix table I for which freezing and thawing temperatures are recorded. While this is not a perfect criterion for this type of damage to building materials it may be a better indication than the Weathering Index for brick [8]. It may be possible to obtain data on periods of wetness which coincide more precisely with freezing and thawing temperature cycling.

Maps, which may be useful in predicting the durability of materials to attack by air pollutants are shown in figures 8 and 9, adapted from The National Atlas [74].

In figure 8, isolines represent the total number of days of high air pollution (including major gaseous pollutants) that were recorded since the national air pollution potential forecasting began through December 31, 1966. In the eastern part of the United States forecasting began August 1, 1960 and in the west forcastning began October 3, 1963. According to The National

Atlas, in 1957 the Public Health Service set up a National Air Sampling Network, now National Air Surveillance Networks (NASN), to measure solid pollutants in the air. In 1960 it began limited sampling for gaseous pollution and in 1962 initiated the Continuous Air Monitoring Program (CAMP) to intensively measure concentrations of major gaseous pollutants in six representative usban areas. The 164 urban and 30 non-urban NASN stations and the six CAMP stations are being supplemented to an increasing extent by State and local sampling networks. Currently about 300 stations are being operated by these networks.

Figure 9 shows emission of sulfur dioxide in tons/sq. mile/year for Standard Metropolitan Statistical Areas (SMSA's) which have 40,000 or more persons employed in manufacturing. At the time the original data was published a SMSA was defined as a county or counties including a city or town cities with a population of 50,000 or more. In New England, towns or cities rather than counties were used to define a SMSA. Also, certain areas were counted as SMSA's which are "metropolitan in character" even if they do not qualify under the above definition [74], [75]. While these areas are sources of sulfur dixoide and concentrations are correspondingly high mixing of the atmosphere distributes such pollutants as shown in figure 8. Table 17 is a list of SMSA's which appear in figure 9.

Also in The National Atlas is a map of ESTIMATED ANNUAL CONCENTRATION OF SUSPENDED PARTICULATES AND NITROGEN DIOXIDE, 1961-1965, for 302 urban areas in the National Air Surveillance Networks. Particulates in the map are given as total suspended particulates (size of circles) and organic suspended particulates (color of circles). Suspended particulates might be significant, in combination with data on average wind speed, in predicting the durability of materials to erosion. Also needed for prediction of erosion is data on erosive solid precipitation, especially hail and sleet. Information on hail is mainly directed at hail damage form destructive hailstorsm. Figure 5, showing the location of hail storms causing more than $5,000 damage, is a useful indicator as to where hail damage might be expected. Data on wind and application to building climatology is from the standpoint of design loads on buildings [76].

Some type of map or chart is needed to predict the durability of building components and materials to biological factors. This would be based either on data on such damage or on climatological conditions which are optimal for the growth of organisms which attack buildings. Such organisms would include fungi and bacteria which attack wood and organic coatings.

A "comfort index" and Comfort Chart have been prepared, based on "effective temperature" scale, in which temperature and relative humidity are related to human sensations and physiological reactions [18]. It is very likely that similar indexes and charts could be prepared for durability of a specific material to high temperatures and relative humidities knowing the combination most harmful to the material. Such an index or chart could also be based on optimum conditions for the growth of harmful living ogranisms.

6.3 Economic Importance of Various Climatological Divisions

In Section 3.2, it was pointed out that a large number of climates are observed in the United States. Thus, durability tests are often needed to determine in which climates building components or materials might be expected to perform well. Therefore, in the selection of exposure sites and in the design of short-term tests, it is important to consider what types of climate or conditions of exposure are most important with respect to this country and its most populated areas. To obtain an estimate of the relative distribution of buildings it can be assumed that building distrubution is roughly proportional to population. Durability tests to simulate the most highly populated climate regions would provide a means of identyfying problem climates for specific components or materials. For example, some regions such as tropical, desert, and subarctic areas may not be of great economic importance but are proving grounds for materials as other areas experience periods of extremes such as are found in the climates prevailing in these areas. To estimate the relative economic importance of each type of climate as defined by Trewartha [5] to material's durability, the population in each climate was estimated. These data are illustrated in the table 18. The first, part, 18-1, of table 18 shows the estimated percent population in each climate and the second part, 18-2, lists the areas used to obtain the estimate. It is evident that monsoon rainforest, tropical savanna, steppe, desert and subartic types of climates are of relatively little economic importance in building climatology in the United States when population is used as the criterion. The HUMID MESOTHERMAL and the HUMID MICROTHERMAL CLIMATES are estimated to contain over 95 percent of the population; these climates obviously would be of major importance in building climatology.

6.4 Feasibility of a Climatological and Weather Data Retrieval System

Existing climatological and weather data, such as that included in Appendix tables I and II, provides a means of obtaining quantative information on weathering factors to be included in durability tests for building components and materials. The existing data, however, are often not tabulated in a form most useful to durability testing. Data for use in durability testing, therefore, must be extracted from the existing data as has been done in the tables included in the text of this report. Also, existing data are often not presented in the desired detail so that referral to detailed weather data is necessary. For example, it would be necessary to tabulate the number of freeze-thaw cycles experienced in a specific location by referring to the detailed weather data.

To simplify the techniques for obtaining climatological and weather data for use in durability testing, a data retrieval system may be useful. One means of obtaining the needed information is to develop a retrieval system utilizing computer facilities. Computer printouts would then provide data in the form most usable in durability testing. Such a retrieval system would greatly simplify the process of obtaining the needed information. Feasibility studies for such a system may be a worthwhile effort to pursue in further studies.

7. Summary

1. The durability or long-term performance of building components and materials is dependent, to a large extent, on the environment to which they are subjected in-service.

2. Environmental factors affecting the durability and performance of building components and materials include weathering, biological, stress, imcompatibility and use factors.

3. Of the environmental factors affecting building components and materials, weathering factors are of particular importance for products used in the exterior envelope because they interact with, or cause, many other environmental factors resulting in deterioration.

4. Reliable durability evaluations are needed for the selection of appropriate components and materials for specific applications, for assessing claims that new products have cost or other advantages and for ensuring against catastrophic failures.

5. Ideally, durability evaluations would be based upon the results of long-term tests using exposure conditions which duplicate those in the service application; however, because of the length of time required to obtain

results, long-term tests are often not practicable. The alternative is to devise short-term tests based upon the measurement of incipient property changes or accelerated aging which yield meaningful measures of long-term performance.

6. To evaluate the durability of components and materials comprising the exterior envelope of a building system, weathering factors must be quantified. This quantitative weathering data can then be used in designing and interpreting both short-term and long-term test results.

7. Weather or climatic data to permit the quantification of weathering factors is often not available or not available in the desired detail; available data, however, must be used to better design and interpret durability tests. The statistical fluctuations in the data must also be considered in establishing test conditions for weathering factors.

8. In quantifying weathering factors for the design of simulated aging procedures it would be preferable to use weather data; however, the problems in experimentally simulating weather data, which is highly variable, often leads to the use of climatic data which is an average of weather data, and hence, less variable.

9. Weather data is particularly useful in identifying extremes for test conditions such as the fastest wind, the highest or lowest temperature or the greatest snow load.

10. Climatic data can be used to assist in interpreting the results of long-term natural aging although it is best to record weather data at the site used for the natural aging.

11. The large range of climates experienced in the United States presents a formidable problem to the materials engineer interested in evaluating materials for long-term performance by laboratory techniques.

12. Durability tests for building components and materials must be designed on the basis of the type of material, the type of application, and the climatic conditions in which it will be used.

13. Data to specify the conditions for each durability test must be obtained from weather or climatic data at the site of interest and micro-climates must be considered in establishing test conditions.

14. To simplity the techniques for obtaining climatological and weather data for use in durability testing from existing data, a data retrieval system may be useful. Such a system might well be based on the use of computer facilities

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Table 1. Environmental Factors in Deterioration of Building Components and Materials

I. WEATHERING FACTORS

A. Solar Radiation

B. Temperature

B1. Extremes

B2. Cycling

C. Water

C1. Vapor

C2. Liquid

C3. Solid

D. Normal Air Constituents

D1. Oxygen and ozone

D2. Carbon dioxide

E. Air Contaminants

E1. Gases (as oxides of nitrogen and sulfur)

E2. Mists (as aerosols gases, salt, acies, and alkalies dissolved in water)

E3. Particulates (as sand, dust, dirt)

F. Wind

II. BIOLOGICAL FACTORS

A. Fungi

B. Bacteria

III. STRESS FACTORS

A. Stress, Sustained

B. Stress, Periodic (resulting from weathering factors)

B1. Physical action of water, as rain, hail, sleet and snow

B2. Physical action of wind

B3. Combination of physical action of water and wind

B4. Thermal movement resulting from temperature changes combined with thermal incompatibility factors

B5. Movement due to other factors, such as settlement or vehicles

Table 1. Environmental Factors in Deterioration of Building Components and Materials (cont.)

IV. INCOMPATIBILITY FACTORS

  A. Chemical

  B. Physical

V. USE FACTORS

  A. Abuse of material, either before or after installation

  B. Wear

Table 2. Types of Climate in the United States as Defined by Trewartha

A. TROPICAL RAINY CLIMATES

Af, Tropical Rainforest

Parts of Hawaii

Am, Monsoon Rainforest

Parts of Hawaii and Puerto Rico

Aw, Tropical Savanna

Southern tip of Florida, including Keys
Parts of Hawaii and Puerto Rico

B. DRY CLIMATES

BS, STEPPE

BSh, Tropical and Subtropical Steppe

Small part of southern California; most of central Arizona parts of New Mexico and Western Texas; western part of Oklahoma panhandle

BSk, Middle Latitude Steppe

Parts of eastern Washington and Oregon and of southeastern Idaho and northern Nevada; parts of Utah, Montana, Wyoming, Colorado, New Mexico; western North Dakota, South Dakota, and Nebraska; western end of Kansas

BW, DESERT

BWh, Tropical and Subtropical Steppe

Small part of southern California; most of southern Nevada; western, southern, and northern Arizona except for highlands; parts of southern New Mexico and western Texas

BWk, Middle Latitude Desert

Parts of northern Nevada; small part of northeastern Utah

C. HUMID MESOTHERMAL CLIMATES

Cs, Mediterranean or Dry Summer Subtropical

Most of coastal and central valley California

Ca, Humid Subtropical

Caf - with no dry seasons

Southeastern United States, including most of Kentucky, Tennessee, and Virginia; southern Maryland; Delaware; southern end of Illinois; most of Oklahoma, Arkansas; eastern and central Texas

Table 2. Types of Climate in the United States as Defined by Trewartha (cont.)

Cb, Marine West Coast (Cool Summer)

North Pacific coast from northern California to southern Alaska; southern Appalachians

D. HUMID MICROTHERMAL CLIMATES

Da, Humid Continental (Warm Summer)

No sub-classification: Parts of northern Utah and southern Idaho

Daf - with no dry season

Parts of West Virginia, northwest Virginia, western Maryland and southern Pennsylvania; southern end of New York and New England; most of Ohio, Indiana, Illinois, Iowa, Missouri, Kansas, and Nebraska; parts of southern Wisconsin and Minnesota; southeastern part of South Dakota

Db, Humid Continental (Cool Summer)

No sub-classification: Parts of eastern Washington

Dbf - with no dry season

Most of New England and New York; central and northern Appalachians; Great Lakes region, including northern Pennsylvania, northeastern Ohio, Michigan, and most of Wisconsin and Minnesota; eastern North Dakota; northeastern South Dakota

Dc, Subarctic

Most of Alaska

E. POLAR CLIMATES

ET, Tundra

Alaska North Slope

F. UNDIFFERENTIATED HIGHLANDS

Sierra Nevada, Cascade, and Rocky Mountain regions

Table 3. Description of the Types of Climate Found in the United States as Defined by Trewartha

A. TROPICAL RAINY CLIMATES (Temperature of coolest month over 64.4 deg. F)

Af, Tropical Rainforest (No distinctly dry season)

Uniformly high temperatures and heavy rainfall distributed throughout the year. Yearly temperature averages between 77 deg. and 80 deg. F. or higher and annual temperature range is usually less than 5 deg. F. Daily temperature range may be 10 to 25 deg. F. Has no distinctly dry season. Normally has dense tropical forest.

Am, Monsoon Rainforest (Short dry season)

A modified tropical rainforest climate, intermediate between Tropical Rainforest and Tropical Savanna. Has the heavy yearly rainfall of the Tropical Rainforest but the seasonal distribution of the Tropical Savanna. Normally situated along coastlines adjacent to Tropical Rainforest climates.

Aw, Tropical Savanna (Much more rain in summer than in winter)

High temperature but less rainfall than Tropical Rainforest. Normal rainfall about 40 to 60 inches annually. Has three temperature seasons: a cooler dry season, a hotter dry season, and a hot wet season. The hot wet season is very similar to the Tropical Rainforest climate. Daily temperature ranges may be 30 deg. F or more during cooler dry and hotter dry seasons. Usually has open, tropical, deciduous forests and grasslands.

B. DRY CLIMATES (Evaporation exceeds precipitation)

BS, Steppe (Semi-arid)

BSh, Tropical and Subtropical Steppe (Average annual temperature over 64.4 deg. F)

Normally surrounds the northern and southern parts of BWh, Tropical and Subtropical Desert. Average annual rainfall 10 to 20 inches. Temperatures normally high but are less than those in the desert. Essentially an intermediate area between desert and a more moderate climate.

BSk, Middle Latitude Steppe (Average annual temperature under 64.4 deg. F)

Hottest and driest regions of the earth. Rainfall may approach or equal that of Steppe but is extremely variable. Deserts have long periods, sometimes years, without rainfall and rain occurs in scattered heavy storms with rapid run-off, so that the area supports little or no vegetation. Extreme deserts have less than 5 inches annual rainfall and some areas have no recorded rainfall. Summer season temperatures normally well over 100 deg. F in the daytime but may drop 25 to 45 deg. F at night. Characterized by abundance of sunlight. Dust and sandstorms are often a problem.

Table 3. Description of the Types of Climate Found in the United States as Defined by Trewartha (cont.)

BWk, <u>Middle Latitude Desert</u> (Average annual temperature under 64.4 deg. F)

Generally found in the interior or large land masses or where high mountains block an area from the ocean and prevent entrance of humid air. Have meager and unpredictable precipitation. Are marked by a definite cold season and summers are warm to hot.

C. HUMID MESOTHERMAL CLIMATES (Coldest month between 64.4 and 32 deg. F)

Cs, <u>Mediterranean or Dry Summer Subtropical</u> (Much more rain in winter than in summer)

Normally found on western sides of continents. Climate is mild and pleasant. Have dry summers with warm to hot temperatures. Summer temperatures average 70 to 80 deg. F and winter temperatures from 40 to 50 deg. F. Rainfall is normally low, from 15 to 25 inches annually, and occurs mostly in the winter season. Coastal regions have a goodly amount of fog. Bordered equator-ward by Subtropical Steppe and Desert areas.

Ca, <u>Humid Subtropical (Warm Summer)</u> (Warmest month over 71.6 deg. F)

Caf, <u>With no Dry Season</u>

Normally found on eastern sides of continents. Summers usually humid, with sultry heat. Rainfall fairly abundant and generally spread out over the entire year. Annual rainfall averages from 30 to 65 inches. Average summer temperatures from 75 to 80 deg. F. Average relative humidity in summer as high as 70 to 80 percent. Winter average temperatures usually moderate, from 40 to 50 deg. F. Caw type with dry winter not found in the United States.

Cb, <u>Marine West Coast (Cool Summer)</u> (Warmest month below 71.6 deg. F)

Normally found on west coast of continents at higher latitudes than Cs, Mediterranean climate. Climate considered mild. Does not have a definite dry season. Annual rainfall may vary from 20-150 inches, with the higher amounts being found in the mountain ranges. Cloudiness, fog, and mist are characteristics. Summers are cool with average temperatures from 60 to 70 deg. F. Winter temperatures are warmer than would be expected at higher latitudes. Cc type similar but less than 4 months above 50 deg. F; not found in the United States.

D. HUMID MICROTHERMAL CLIMATES

(Temperature of coldest month under 32 deg. F; warmest month over 50 deg. F)

Da, Humid Continental (Warm Summer) (Warmest month over 71.6 deg. F)

Table 3. Description of the Types of Climate Found in the United States as Defined by Trewartha (cont.)

Daf, With no Dry Season

Normally found from 35° to 45° N latitude. Summers are long, hot, and humid. Winters are cold but some spells of mild but unpleasantly foggy weather. Rainfall is a maximum in the summer. Daw type with dry winter not found in the United States.

Db, Humid Continental (Cool Summer) (Warmest month below 71.6 deg. F)

Dbf, With no Dry Season

Generally located north of Da climates and have much colder winters than Da, sometimes as much as 10 to 30 deg. F. Summers are cooler than Da summers by 5 to 10 deg. F. Summers are short and winter dominates the year. Sub-zero temperatures are not unusual. Dbw type with dry winter not found in the United States.

Dc, Subarctic (Warmest month below 71.6 deg. F; less than 4 months above 50 deg. F)

Dcf, With no Dry Season

Gnerally found north of Da and Db climates in the range of 50° to 65°N latitude. The Subarctic is the most extreme climate of the Continental type with temperature ranges as much as 110° deg. F. Summers are extremely short and winters are long and extremely severe. Precipitation is sparse, from 10 to 20 inches annually, and is concentrated in the summer. Dcs type with dry winter and Dd type (coldest month below -36.4 deg. F) not found in the United States.

E. POLAR CLIMATES (Temperature of warmest month under 50 deg. F)

ET, Tundra; EF, Ice Cap

Polar climates are confined to the high latitudes. A climate is termed Tundra when at least one month has an average temperature above 32 deg. F but less than 50 deg. F. EF, ice cap climate (average temperature of all months below freezing and no vegetable life is possible) is not found in the United States.

F. UNDIFFERENTIATED HIGHLANDS

Locations over 6,000 ft. altitude with no "type" of climate, variations being great from one highland spot to another.

Table 4. Climate Classifications of Sites for Which Climatological Date are Presented in Appendix Tables I, II, and III

A. TROPICAL RAINY CLIMATES

Am, <u>Monsoon Rainforest</u>

- San Juan, Puerto Rico

Aw, <u>Tropical Savanna</u>

- Miami, Florida

B. DRY CLIMATES

BS, STEPPE

BSk, <u>Middle Latitude Steppe</u>

- Great Falls, Montana
- Havre, Montana

BW, DESERT

BWh, <u>Tropical and Subtropical Desert</u>

- Las Vegas, Nevada
- Phoenix, Arizona
- Yuma, Arizona

C. HUMID MESOTHERMAL CLIMATES

Ca, <u>Humid Subtropical</u>

Caf - With No Dry Season

- Washington, D. C.
- Baltimore, Maryland
- Atlantic City, New Jersey
- Fort Worth, Texas

Cb, <u>Marine West Coast</u> (Cool Summer)

- Seattle, Washington
- Astoria, Oregon
- Eureka, California

D. HUMID MICROTHERMAL CLIMATES

Da, <u>Humid Continental</u> (Warm Summer)

Daf - With No Dry Season

- Minneapolis-St. Paul, Minnesota

Db, <u>Humid Continental</u> (Cool Summer)

Dbf - With No Dry Season

- Bismarck, North Dakota

Table 4. Climate Classifications of Sites for Which Climatological Data are presented in Appendix Tables I, III, and III (cont.)

Dc, Subarctic

- Fairbanks, Alaska

F. UNDIFFERENTIATED HIGHLANDS

- Flagstaff, Arizona

Table 5. Typical Solar Radiation at Different Times of Day at 32 Degrees North Latitude on July 21

Solar Time A.M.	Direct Normal Irradiance Btuh/sq. ft.	W/m^2
6	113	358
7	203	644
8	241	764
9	261	828
10	271	859
11	277	878
12	278	882

Table 6. Time of Xenon Arc Exposure Required to Simulate One Year of Solar Radiation

Location[a]	Mean Daily Solar Radiation (Langleys)	Hours of Xenon Arc Exposure to Simulate Annual Solar Radiation
San Juan, Puerto Rico	512	2387
Miami, Florida	447	2084
Great Falls, Montana	356	1660
Las Vegas, Nevada	504	2349
Phoenix, Arizona	503	2345
Washington, D. C.	350	1632
Fort Worth, Texas	435	2028
Seattle, Washington	302	1408
Astoria, Oregon	302	1408
Bismarck, North Dakota	366	1706
Fairbanks, Alaska	228	1063

a. See Appendix Tables I and II

Table 7. Latitude, Altitude, and Average Solar Radiance at the Sites Listed in Table 6

Location[a]	Latitude, N	Elevation, Ground Ft.	Annual Sunshine Hours	Annual Solar Radiation, Watt-hr/m^2 x 10^5	Average Solar Radiance, Watts/m^2
San Juan, P. R.	18°26'	13	2878	21.72	755
Miami, Florida	25°48'	7	2903	18.96	653
Great Falls, Mont.	47°29'	3662	2884	15.10	524
Las Vegas, Nevada	36°05'	2162	3838	21.38	557
Phoenix, Arizona	33°26'	1117	3832	21.34	557
Washington, D. C.	38°51'	10	2576	14.85	576
Fort Worth, Texas	32°50'	537	2911	18.45	634
Seattle, Washington	47°27'	400	2019	12.81	635
Astoria, Oregon	46°09'	8	--	--	--
Bismarck, N. D.	46°46'	1647	2686	15.53	578
Fairbanks, Alaska	64°49'	436	2105	9.67	459

a. See Appendix tables I and II.

Table 8. Temperature Data from Appendix Table I for Various Sites

Location	Normal Daily Temperatures[a]			Normal Highest and Lowest Annual Temps.[b]			Extreme Temperatures[c]		
	Maximum Annual	Minimum Annual	Diff.[d]	Highest Annual Maximum	Lowest Annual Minimum	Diff.[e]	Record Highest	Record Lowest	Diff.[f]
San Juan, Puerto Rico	85	71	14	88	67	19	96	60	36
Miami, Florida	83	67	16	90	58	32	96	34	62
Great Falls, Montana	57	33	24	85	13	72	106	-43	149
Havre, Montana	55	29	26	85	4	81	111	-52	163
Las Vegas, Nevada	79	53	26	104	32	72	116	8	109
Phoenix, Arizona	85	53	32	105	34	70	116	19	97
Yuma, Arizona	87	58	29	107	40	67	116	24	92
Washington, D. C.	66	48	18	87	20	58	101	3	98
Baltimore, Maryland	66	45	21	87	25	62	102	-7	109
Atlantic City, New Jersey	63	45	18	84	26	58	106	-8	114
Fort Worth, Texas	77	55	22	96	35	61	108	4	104
Seattle, Washington	59	43	16	76	33	43	99	6	93
Astoria, Oregon	58	43	15	69	35	34	100	6	94
Eureka, California	58	47	11	62	41	21	85	21	64
Minneapolis-St. Paul, Minnesota	55	33	22	84	2	82	99	-34	133
Bismarck, North Dakota	54	31	23	86	0	86	108	-43	151
Fairbanks, Alaska	37	14	23	72	-21	93	96	-61	157
Flagstaff, Arizona	61	30	31	81	14	67	96	-22	118

a. Annual averages of normal daily maximum and minimum temperatures, Appendix table I.
b. Highest maximum and lowest minimum monthly averages of daily temperatures Appendix table I.
c. Record highest and lowest temperatures, Appendix table I.
d. Represents expected normal daily variations in any one day of the year.
e. Represents seasonal variations over a period of one year.
f. Represents the most extreme variation in temperature ever recorded.

Table 9. Albedo and Absorption of Various Surfaces

	Percent Albedo	Percent Absorption
Surfaces of the earth [34], [36], [37], [38]		
Green forest	3-10	90-97
Black mold, wet	8	92
Black mold, dry	14	86
Ground, 70-95 percent bare, wet	8-9	81-82
Ground, 70-85 percent bare, dry	10-20	80-90
Sand, wet	9	91
Sand, dry	18	82
Grass, dry	15-25	75-85
Grass, wet, in sun	33-37	63-67
Fresh snow, highest value	87	13
Glossy oil based paints [34]		
Black, with carbon black pigment	7	93
White, titanium dioxide pigment	85	15
White, titanium dioxide pigment, lead primer	88	12

Table 10. Freezing Cycle Days for the Sites Listed in Table 4 Experiencing Freeze-Thaw Conditions

Location	Mean Number of Days[a]		Difference, Average Freezing Cycle Days
	Maximum 32 deg. F or below	Minimum 32 deg. F or below	
Great Falls, Montana	51	155	104
Havre, Montana	69	185	116
Las Vegas, Nevada	0	42	42
Washington, D. C.	10	80	70
Baltimore, Maryland	14	101	87
Atlantic City, New Jersey	17	115	98
Minneapolis-St. Paul, Minnesota	84	160	76
Bismarck, North Dakota	86	186	100
Fairbanks, Alaska	162	227	65
Flagstaff, Arizona	16	214	198

a. Data from Appendix table I.

Table 11. Winter Rainfall and Weathering Index for Sites Listed in Table 10

Location	Winter Rainfall, in.[a] at Freeze Threshold Temperature, deg. F.		Weathering Index[b] at Freeze Threshold Temperature, deg. F	
	32	28	32	28
Great Falls, Montana	1.0	-0.2[c]	104	--
Havre, Montana	1.1	0.2	128	23
Las Vegas, Nevada	1.6	1.1	67	46
Washington, D. C.	11.5	9.2	805	644
Baltimore, Maryland	15.6	12.6	1357	1096
Atlantic City, New Jersey	14.6	11.0	1431	1078
Minneapolis-St. Paul, Minnesota	3.6	2.4	274	182
Bismarck, North Dakota	1.9	1.1	190	110
Fairbanks, Alaska	-1.8[c]	-2.3[c]	--	--
Flagstaff, Arizona	2.7	2.2	535	436

a. Difference between total winter precipitation and 1/10 (winter snowfall), both in inches, from data in Appendix table I. Winter precipitation and snowfall are those occuring during the freezing cycle period for each location. The freezing cycle period for each location was calculated by subtracting from 365 the freeze-free period in days. Freeze-free periods were obtained from FREEZE DATA, Climatography of the United States, Climates of the States. The freeze-free period is defined as the period between the last occurrence in the spring. Since precipitation and snowfall are recorded monthly, these values were pro-rated for some months according to the freeze threshold dates.

b. (Winter rainfall in inches) times (Average Freezing Cycle in days). Average Freezing Cycle Days from table 10.

c. Calculated winter rainfall was negative, since 1/10 (Winter Snowfall) exceeded value for total winter precipitation. Density of snow is not always 1/10 that of liquid water.

Table 12. Months of Freezing[a], Freezing and Thawing[b], and Above Freezing[c] for Sites Listed in Table 4

Location and Months	Number of Months: Freezing[a]	Freezing and Thawing[b]	Above Freezing[c]
San Juan, Puerto Rico	0	0	12
Miami, Florida	0		12
Great Falls, Montana			
Jan.	1		
Feb., Mar., Apr., Nov., Dec.		5	
Feb. through Dec.			11
Havre, Montana			
Jan., Feb., Dec.	3		
Mar., Apr., Oct., Nov.		4	
Mar. through Nov.			9
Las Vegas, Nevada	0		12
Jan.		1	
Phoenix, Arizona	0	0	12
Yuma, Arizona	0	0	12
Washington, D. C.	0		12
Jan., Feb., Dec.		3	
Baltimore, Maryland	0		12
Jan., Feb., Dec.		3	
Atlantic City, New Jersey	0		12
Jan., Feb., Mar., Dec.		4	
Fort Worth, Texas	0	0	12
Seattle, Washington	0	0	12
Astoria, Oregon	0	0	12
Eureka, California	0	0	12
Minneapolis-St. Paul, Minnesota			
Jan., Feb., Dec.	3		
Mar., Nov.		2	
Mar. through Nov.			9
Bismarck, North Dakota			
Jan., Feb., Dec.	3		
Mar., Apr., Nov.		3	
Mar., through Nov.			9
Fairbanks, Alaska			
Jan., Feb., Mar., Nov., Dec.	5		
Apr., Oct.		2	
Apr. through Oct.			7
Flagstaff, Arizona	0		12
Jan., Feb., Mar., Apr., Oct., Nov., Dec.		7	

a. Months in which the daily maximum temperature is 32°F or below. See Note c.
b. Months in which the normal daily maximum temperature is above freezing and the normal daily minimum is 32°F or below.
c. Months in which the daily maximum temperature is above 32°F. Obviously a plus c must equal 12.

Table 13. Frequency of Precipitation During Freezing and Thawing Months

Location and Months	Frequency of Precipitation Number of Days 0.01 Inch or More During Months of Freezing and Thawing*
Great Falls, Montana (Feb., Mar., Apr., Nov., Dec.) (5)	40
Havre, Montana (Mar., Apr., Oct., Nov.) (4)	22
Las Vegas, Nevada (Jan.) (1)	3
Washington, D. C. (Jan., Feb., Dec.) (3)	28
Baltimore, Maryland (Jan., Feb., Dec.) (3)	28
Atlantic City, New Jersey (Jan., Feb., Mar., Dec.) (4)	41
Minneapolis-St. Paul, Minnesota (Mar., Nov.) (2)	18
Bismarck, North Dakota (Mar., Apr., Nov.) (3)	22
Fairbanks, Alaska (Apr., Oct.) (2)	1
Flagstaff, Arizona (Jan., Feb., Mar., Apr., Oct., Nov., Dec.) (7)	39

*Data from Appendix table I.

Table 14. Variations in Relative Humidity for the Sites Listed in Table 4

Location	Highest Annual Mean[a]	Lowest Annual Mean[a]	Diff.[b]	Highest Monthly Average[c]	Lowest Monthly Average[d]	Diff.[e]
San Juan, Puerto Rico	84	65	19	86	61	25
Miami, Florida	85	61	24	90	55	35
Great Falls, Montana	65	45	20	71	27	44
Havre, Montana	74	47	27	78	23	55
Las Vegas, Nevada	39	30	19	57	12	45
Phoenix, Arizona	53	23	30	70	13	57
Yuma, Arizona	53	22	31	62	15	47
Washington, D. C.	73	52	21	80	48	32
Baltimore, Maryland	77	54	23	84	49	35
Atlantic City, New Jersey	82	56	26	90	50	40
Fort Worth, Texas	83	54	29	88	44	44
Seattle, Washington	83	63	20	87	49	38
Astoria, Oregon	90	73	17	93	69	24
Eureka, California*	90	78	12	94	75	19
Minneapolis-St. Paul, Minnesota	80	61	19	88	52	36
Bismarck, North Dakota	78	54	24	84	37	47
Fairbanks, Alaska	71	56	15	82	38	44
Flagstaff, Arizona	70	38	32	77	21	56

a. Annual Mean of Daily maximum and minimum values Appendix table I.
b. Difference between annual daily maximum and minimum, representing average daily variation.
c. Highest average relative humidity for any month in the year.
d. Lowest average relative humidity for any month in the year.
e. Difference between c and d, representing expected seasonal variation.

*Data from Climatography of the United States, No. 60-4, Climates of the States, Dec. 1959.

Table 15. Frequency of Precipitation at Various Relative Humidities at Various Locations in Appendix Table I

Location	Mean number of days precipitation 0.01 inch or more				
		With relative humidity in percent[b]			
	Annual[a]	70 or over	50 - 69[c]	20 - 49[c]	19 or lower
San Juan, Puerto Rico	202	0	202	0	0
Miami, Florida	126	0	126	0	0
Great Falls, Montana	90	0	22	68	0
Havre, Montana	61	8	10	43	0
Las Vegas, Nevada	24	0	0	9	15
Phoenix, Arizona	34	0	0	30	4
Yuma, Arizona	15	0	0	21	0
Washington, D. C.	111	0	90	21	0
Baltimore, Maryland	112	0	101	11	0
Atlantic City, New Jersey	112	0	112	0	0
Fort Worth, Texas	78	0	68	10	0
Seattle, Washington	162	59	100	3	0
Astoria, Oregon	200	181	19	0	0
Eureka, California[d]	117	117	0	0	0
Minneapolis-St. Paul, Minn.	88	0	88	0	0
Bismarck, North Dakota	74	0	26	48	0
Fairbanks, Alaska	65	0	44	21	0
Flagstaff, Arizona	74	0	6	68	0

a. Sum of days of precipitation 0.01 inch or more for all months in which the daily maximum temperature is "above freezing" as in table 12.

b. Mean daily number of days precipitation 0.01 inch or more for months in which the lowest value for relative humidity is in the range indicated and in which the daily maximum temperature is "above freezing" as in table 12.

c. Inclusive, as 50 through 69, etc.

d. Data on relative humidity from Climatography of the United States, No. 60-4, Climates of the States, December 1959.

Table 16. Index of Annual Mean Daily Solar Radiation, Total and Percent Sunshine and Mean Sky Cover at Sites Listed in Appendix Table II[a]

Location	Mean Daily Solar Radiation (langleys)	Total Hours of Sunshine	Percent of Possible Sunshine	Mean Sky Cover, Sunrise to Sunset
San Juan, Puerto Rico	102	75	74	62
Miami, Florida	89	76	74	64
Great Falls, Montana	71	75	74	55
Havre, Montana	--	75	78	55
Las Vegas, Nevada	100	100	100	100
Phoenix, Arizona	100	100	100	100
Yuma, Arizona	--	106	106	111
Washington, D. C.	69	67	66	61
Baltimore, Maryland	--	69	67	62
Atlantic City, New Jersey	--	--	64	59
Fort Worth, Texas	86	76	79	73
Seattle, Washington	60	53	56	39
Astoria, Oregon	60	--	--	36
Eureka, California	--	57	58	47
Minneapolis-St. Paul, Minn.	--	68	67	59
Bismarck, North Dakota	73	70	72	58
Fairbanks, Alaska	45	55	51	45
Flagstaff, Arizona	--	--	--	85

a. $\text{Index} = \frac{\text{Value for Site}}{\text{Value for Las Vegas}} \times 10.$

b. Based on "Clear Sky", which equals 1 - (Mean Sky Cover).

Table 17. Standard Metropolitan Statistical Areas for Which Sulfur Dioxide Emissions and Concentrations were Reported*, 1961-1965

Emissions over 200 tons per square mile per year

1. Baltimore, Maryland
2. Chicago, Illinois
3. Cleveland, Ohio
4. El Paso, Texas
5. Indianapolis, Indiana
6. Louisville, Kentucky
7. New York, New York
8. Salt Lake City, Utah
9. Toledo, Ohio
10. Wheeling - Steubenville, West Virginia

Emissions 100 - 200 tons per square mile per year

11. Baton Rouge, Louisiana
12. Boston, Massachusetts
13, Cincinnati, Ohio
14. Detroit, Michigan
15. Los Angeles, California
16. Philadelphia, Pennsylvania
17. Pittsburgh, Pennsylvania
18. St. Louis, Missouri
19. Springfield - Hartford, Massachusetts
20. Tacoma, Washington

Emissions 50 - 100 tons per square mile year

21. Atlanta, Georgia
22. Canton - Youngstown, Ohio
23. Charleston, West Virginia
24. Charlotte, North Carolina
25. Columbus, Ohio
26. Dayton, Ohio
27. Evansville, Indiana
28. Houston, Texas
29. Milwaukee, Wisconsin
30. Minneapolis-St. Paul, Minnesota
31. Reading, Pennsylvania
32. Richmond, Virginia
33. Seattle, Washington
34. Washington, D. C.

Table 17. Standard Metropolitan Statistical Areas for Which Sulfur Dioxide Emissions and Concentrations were Reported*, 1961-1965 (cont.)

Emissions 10 - 50 tons per square mile per year

35. Albany - Schnectady, New York
36. Altoona, Pennsylvania
37. Chattanooga, Tennessee
38. Davenport, Iowa - Moline, Illinois
39. Huntington, West Virginia - Ashland, Kentucky
40. Kansas City, Missouri - Kansas
41. Knoxville, Tennessee
42. Nashville, Tennessee
43. New Haven, Connecticut
44. New Orleans, Louisiana
45. Omaha, Nebraska
45. Providence, Rhode Island
47. San Francisco - Oakland, California
48. Syracuse, New York

Emissions under 10 tons per square mile per year

49. August, Georgia
50. Birmingham, Alabama
51. Columbus, Georgia
52. Dallas, Texas
53. Denver, Colorado
54. Duluth - Superior, Minnesota
55. Eugene, Oregon
56. Fargo, North Dakota
57. Fort Worth, Texas
58. Grand Rapids, Michigan
59. Greensboro, North Carolina
60. Medford, Oregon
61. Phoenix, Arizona
62. Portland, Oregon
63. San Bernardino, California
64. San Jose, California
65. Shreveport, Louisiana
66. Utica, New York
67. Wichita, Kansas

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*Emissions in tons per square mile per year shown in this table and in figure 9. The original map in The National Atlas also showed sulfur dioxide concentrations.

Table 18. Percent Population in the Various Climatic Divisions of the United States*

18-1. Estimated Distribution of Population in the United States* Among Various Climates

A.	TROPICAL RAINY CLIMATES		1.1 percent
	Am, Monsoon Rainforest	0.3 percent	
	Aw, Tropical Savanna	0.8 percent	
B.	DRY CLIMATES		2.9 percent
	BSh, Tropical and Subtropical Steppe	0.6	
	BSk, Middle Latitude Steppe	1.6	
	BWh, Tropical and Subtropical Desert	0.7	
C.	HUMID MESOTHERMAL CLIMATES		46.2
	Cs, Mediterranean	9.3	
	Caf, Humid Subtropical - no dry season	35.5	
	Cb, Marine West Coast (Cool Summer)	1.4	
D.	HUMID MICROTHERMAL CLIMATES		49.6
	Daf, Humid Continental (Warm Summer) no dry season	31.9	
	Dbf, Humid Continental (Cool Summer) no dry season	17.5	
	Dcf, Subarctic - no dry season	0.2	
			99.8

*Including all 50 states, the District of Columbia, and Puerto Rico.

Table 18. Percent Population in the Various Climatic Divisions of the United States* (cont.)

18-2. Areas Used to Estimate Population Distribution Among Various Climates

Am, Monsoon Rainforest

San Juan, Puerto Rico

Aw, Tropical Savanna

Pence, Puerto Rico
Miami, Florida metropolitan area

BSh, Tropical and Subtropical Steppe

Honolulu, Hawaii metropolitan area
West Texas, estimate based on population of cities and metropolitan areas in that area as compared to those in east Texas; ration applied to total population of Texas

BSk, Middle Latitude Steppe

Albuquerque, New Mexico metropolitan area
Denver, Colorado metropolitan area
Montana and Wyoming, entire states

BWh, Tropical and Subtropical Desert

Phoenix and Tucson, Arizona, metropolitan areas

Cs, Mediterranean

California counties on or near Pacific coast except three northern most coastal counties

Caf, Humid Subtropical - no dry season

Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Oklahoma, Tennessee, Virginia - entire states
Maryland except for Alleghany, Garrett, and Washington counties
Southern New Jersey
Philadelphia metropolitan area
East Texas, estimated as under BSh
Washington, D. C.

Cb, Marine West Coast (Cool Summer)

California north coast counties - Del Norto, Humboldt, and Mendocine
Oregon coastal and Willamette valley counties
Washington coastal and Puget Sound counties

Table 18. Percent Population in the Various Climatic Divisions of the United States* (cont.)

18-2. Areas Used to Estimate Population Distribution Among Various Climates

Daf, Humid Continental (Warm Summer) - no dry season

Ohio, Indiana, Illinois, Missouri, Iowa, Kansas, Nebraska - entire states
Southern Michigan - metropolitan areas of Detroit, Flint, Grand Rapids, and Lansing
Northern New Jersey
New York City metropolitan area

Dbf, Humid Continental (Cool Summer) - no dry season

New England, Minnesota, North Dakota, Wisconsin - entire states
Upstate New York, including all of state outside New York City metropolitan area
Western Pennsylvania, based on Erie (city) and Pittsburgh metropolitan area

Dcf, Subarctic

State of Alaska

References:

1971 World Almanac

1970 Census of Outlying Areas, page 409

Population and Areas of Counties by States, pages 444-461

American Almanac for 1973 and The Statistical Abstract of the United States

No. 20, Metropolitan areas, pages 19-20

No. 12, pages 12-13, Population Bank etc. - States and Puerto Rico

No. 22, Cities with 100,000 inhabitants or more in 1970, pages 21-23

No. 5, Population and Area - United States and Outlying Areas, page 7

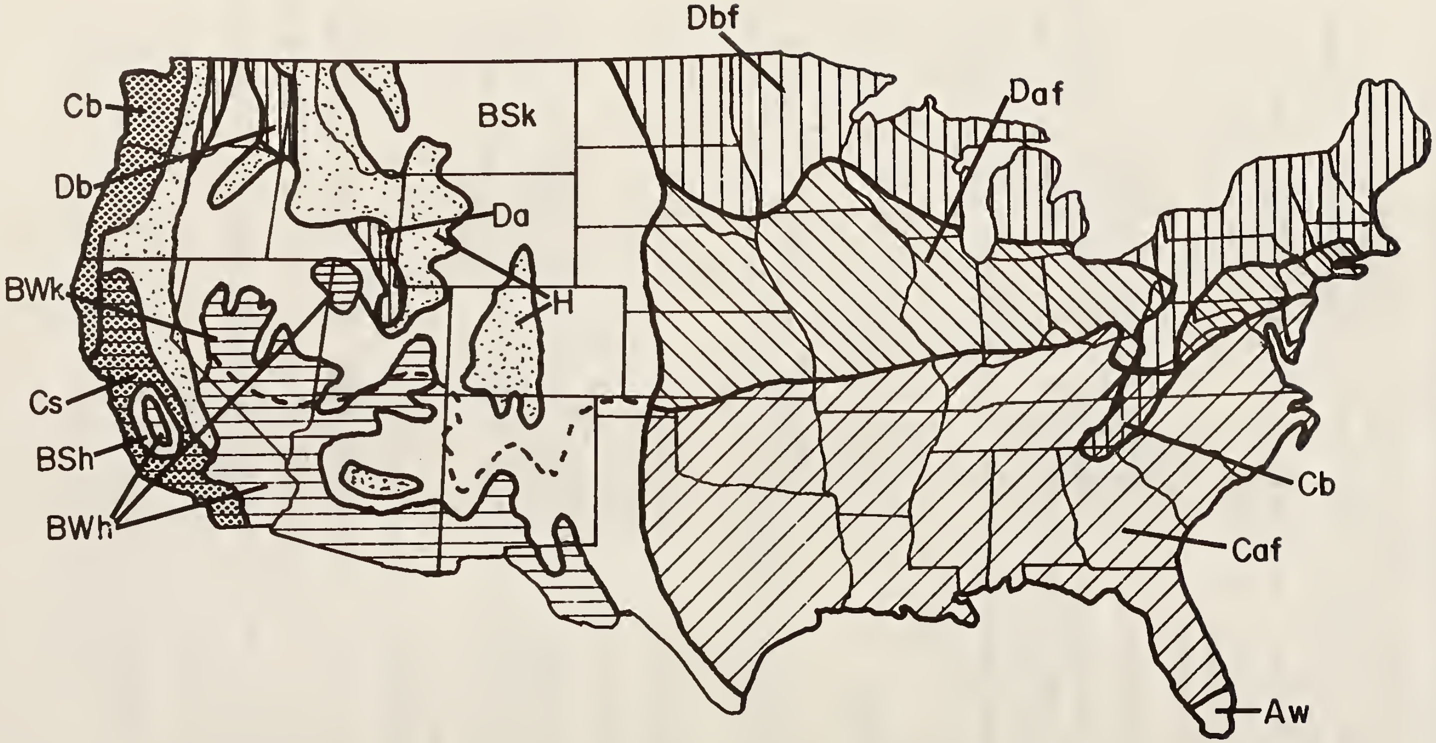


Figure 1. Map of the Contiguous United States showing Climatic Divisions according to Trewartha

Aw	=	Tropical Savanna	Cb	=	Marine West Coast
BSh	=	Tropical and Subtropical Steppe	Caf	=	Humid Subtropical, no dry season
BSk	=	Middle Latitude Steppe	Da	=	Humid Continental (Warm Summer)
BWh	=	Tropical and Subtropical Desert	Daf	=	Humid Continental (Warm Summer), no dry season
BWk	=	Middle Latitude Desert	Db	=	Humid Continental (Cool Summer)
Cs	=	Mediterranean	Dbf	=	Humid Continental (Cool Summer), no dry season

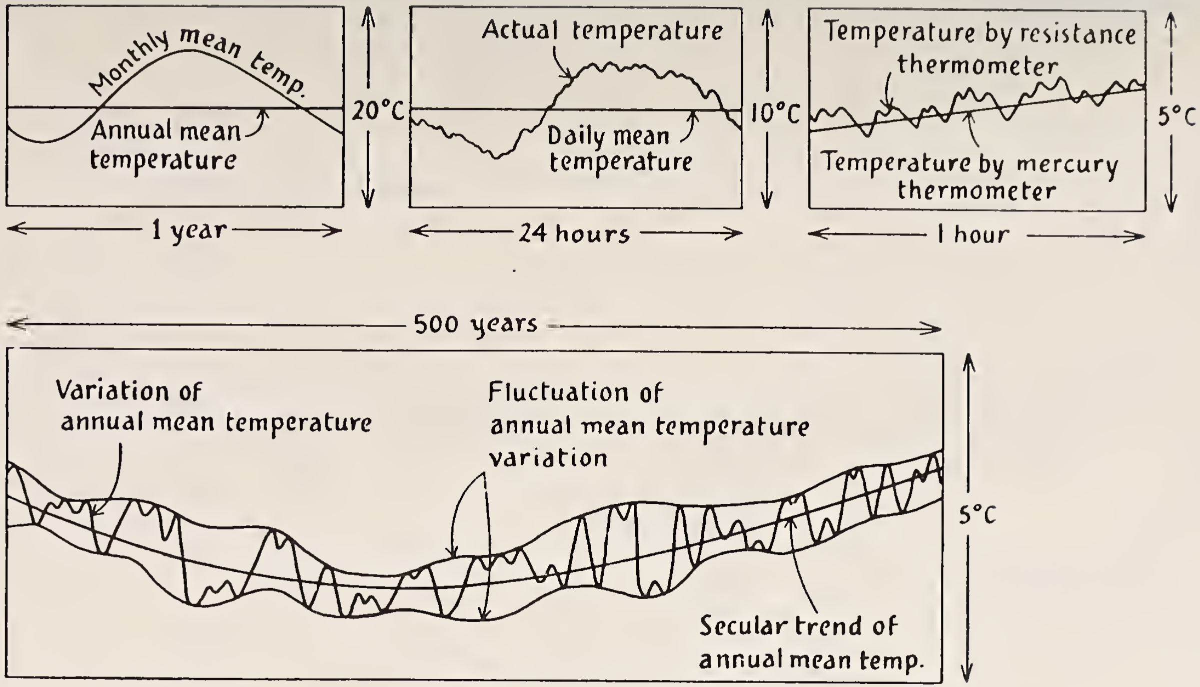


Figure 2. Variations in Temperature Outdoors at a Given Location (Diagrammatic)

From FOUNDATIONS OF CLIMATOLOGY by E. T. Stringer

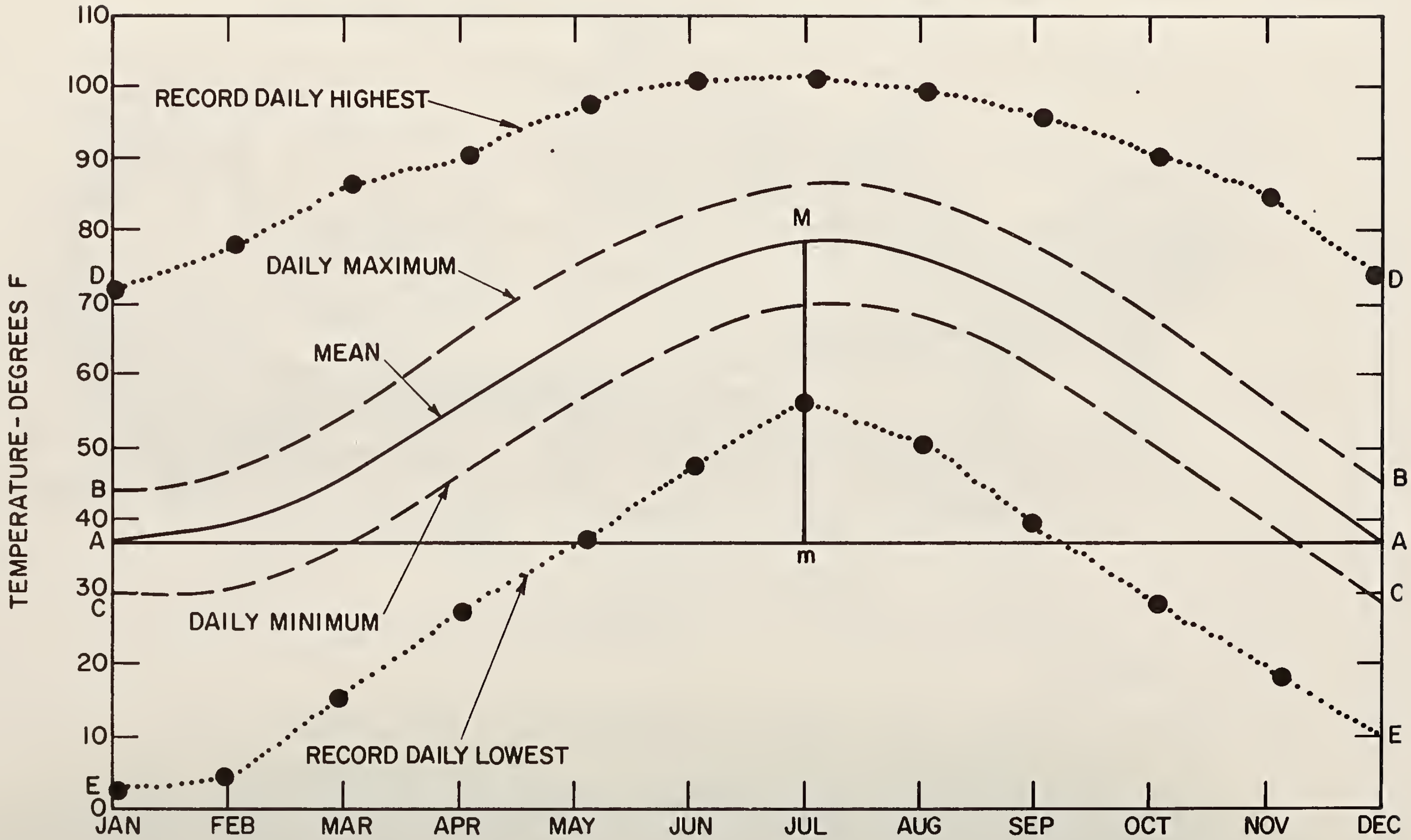


Figure 3. Mean and Extreme Temperatures for Washington, D.C. by Month of the Year.

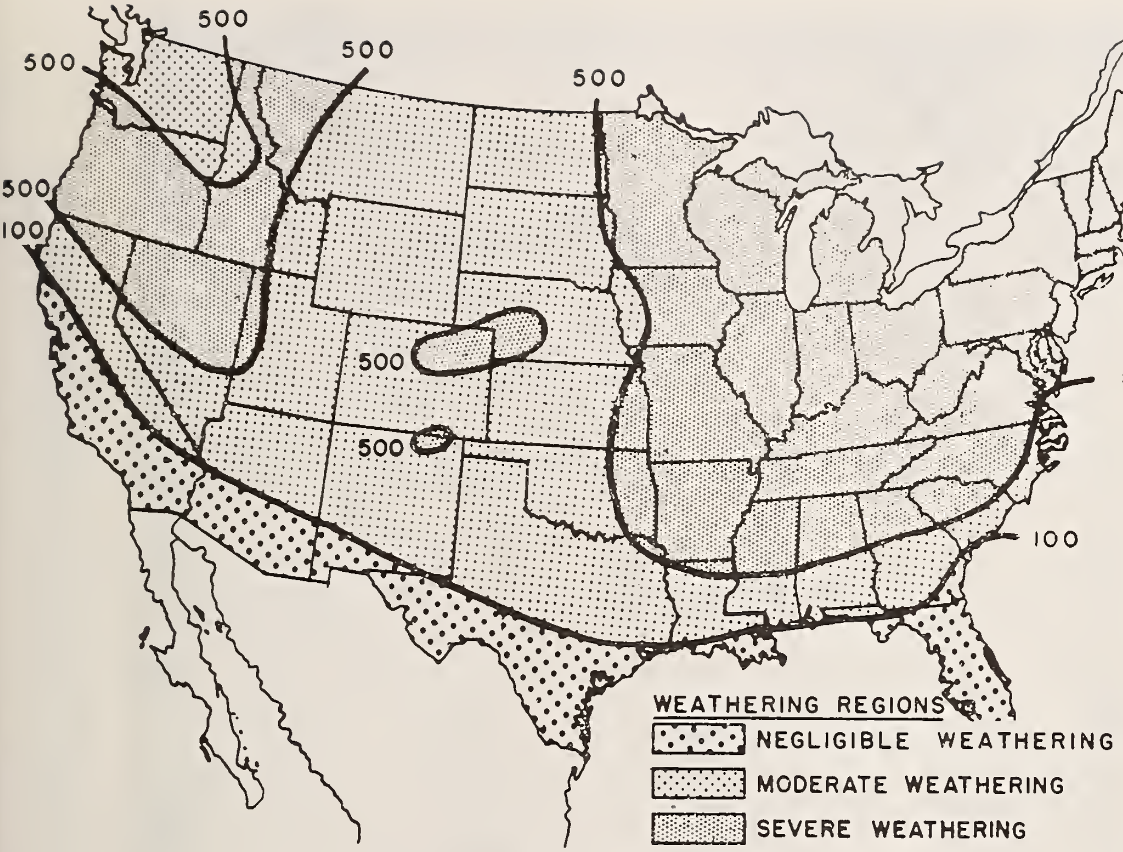


Figure 4. Map of the Contiguous United States showing Areas of Negligible, Moderate, and Severe Weathering of Brick

from Standard Specifications for BUILDING BRICK (SOLID MASONRY UNITS MADE FROM CLAY OR SHALE), ASTM C 62 - 69

Weathering Index* values at isolines

Weathering Index*
- less than 100 in Negligible Weathering Region
- 100-500 in Moderate Weathering Region
- 500 and over in Severe Weathering Region

*Product of the average annual number of freezing cycle days and average winter rainfall in inches, for a given locality.

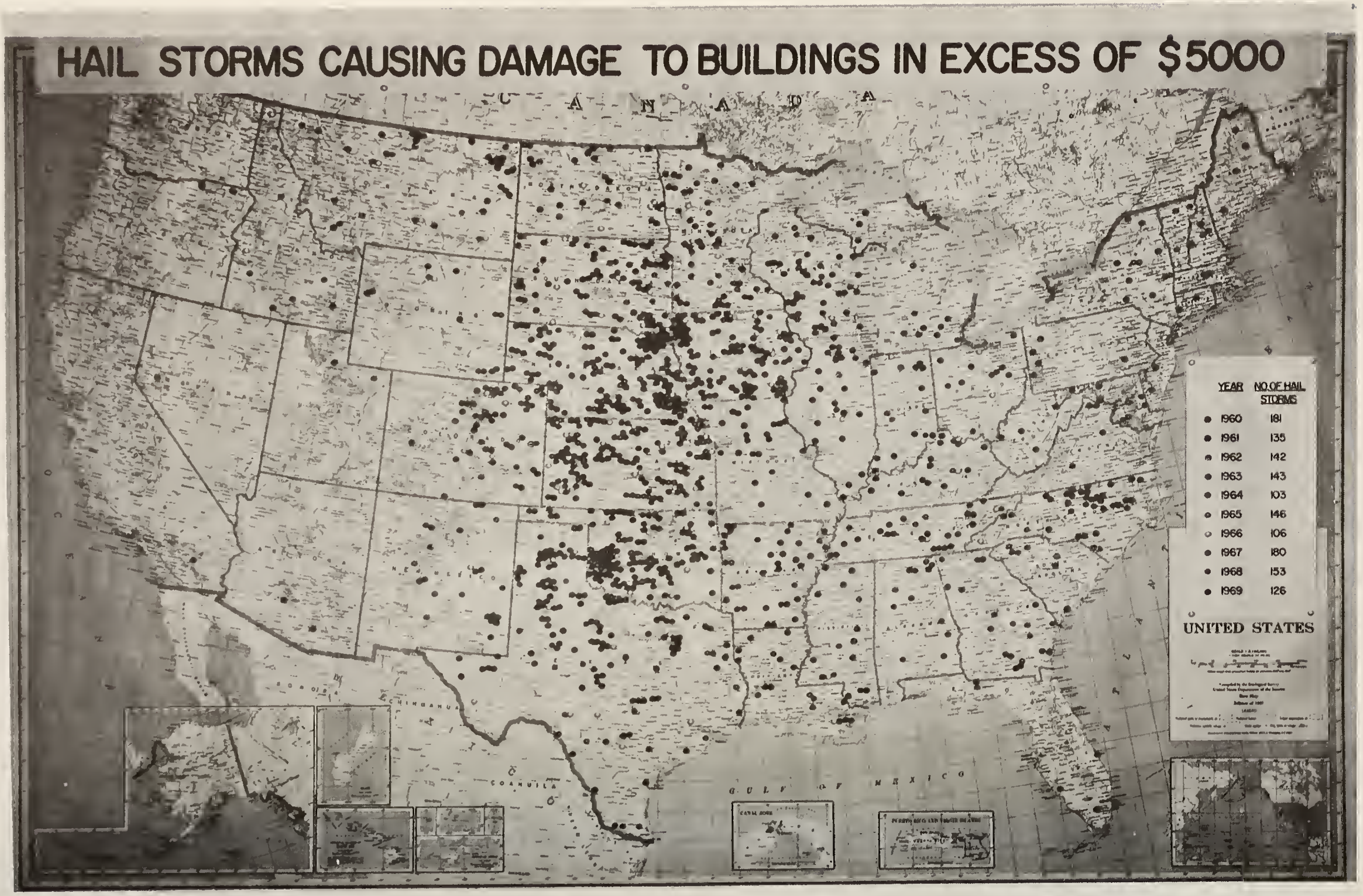
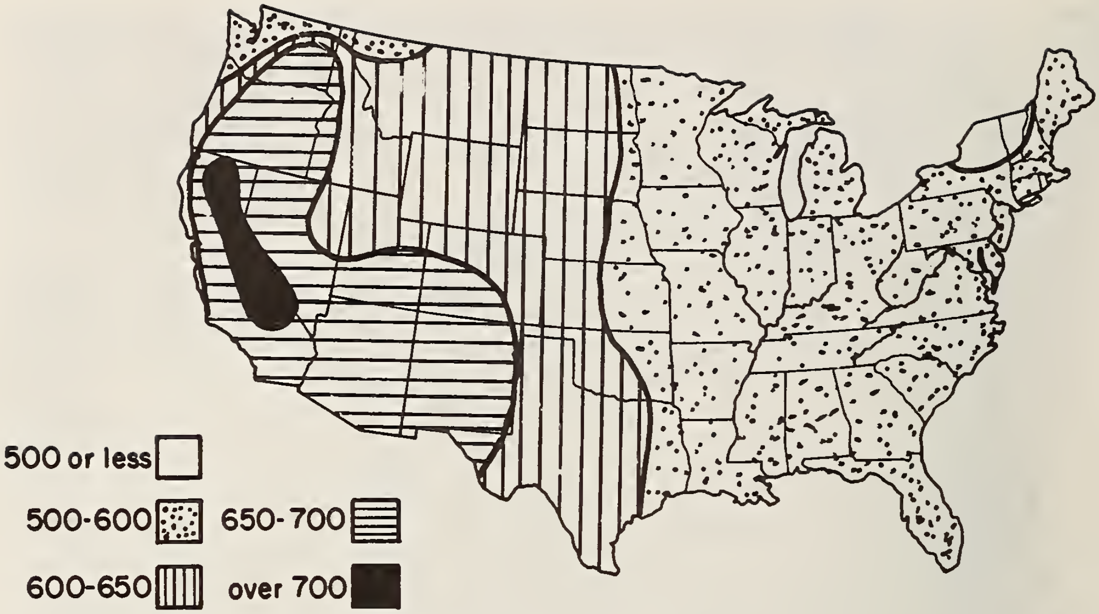


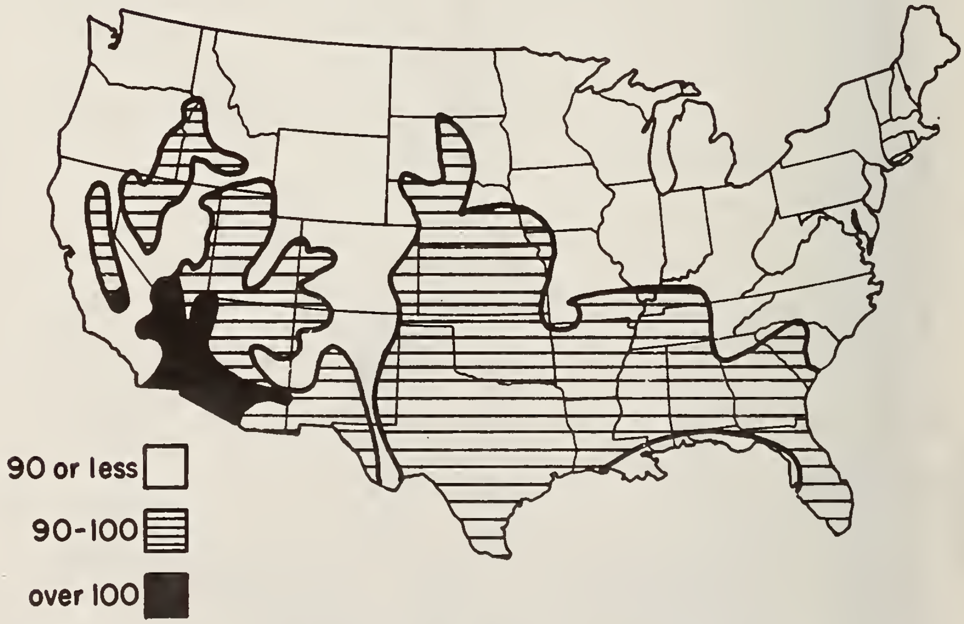
Figure 5. Hail Storms causing Damage to Buildings in Excess of $5000

Figure 6. Mean Daily Annual Solar Radiation (langleys) and Mean Total Annual Sunshine (hours) Adapted from The National Atlas, 1970

Solar radiation values at isolines and locations (Hours sunshine values in parentheses)



JULY SOLAR RADIATION
MEAN DAILY - Langleys



JULY MEAN MAXIMUM TEMPERATURE, deg. F

Figure 7. Solar Radiation and Maximum Temperatures in July Adapted from The National Atlas, 1970

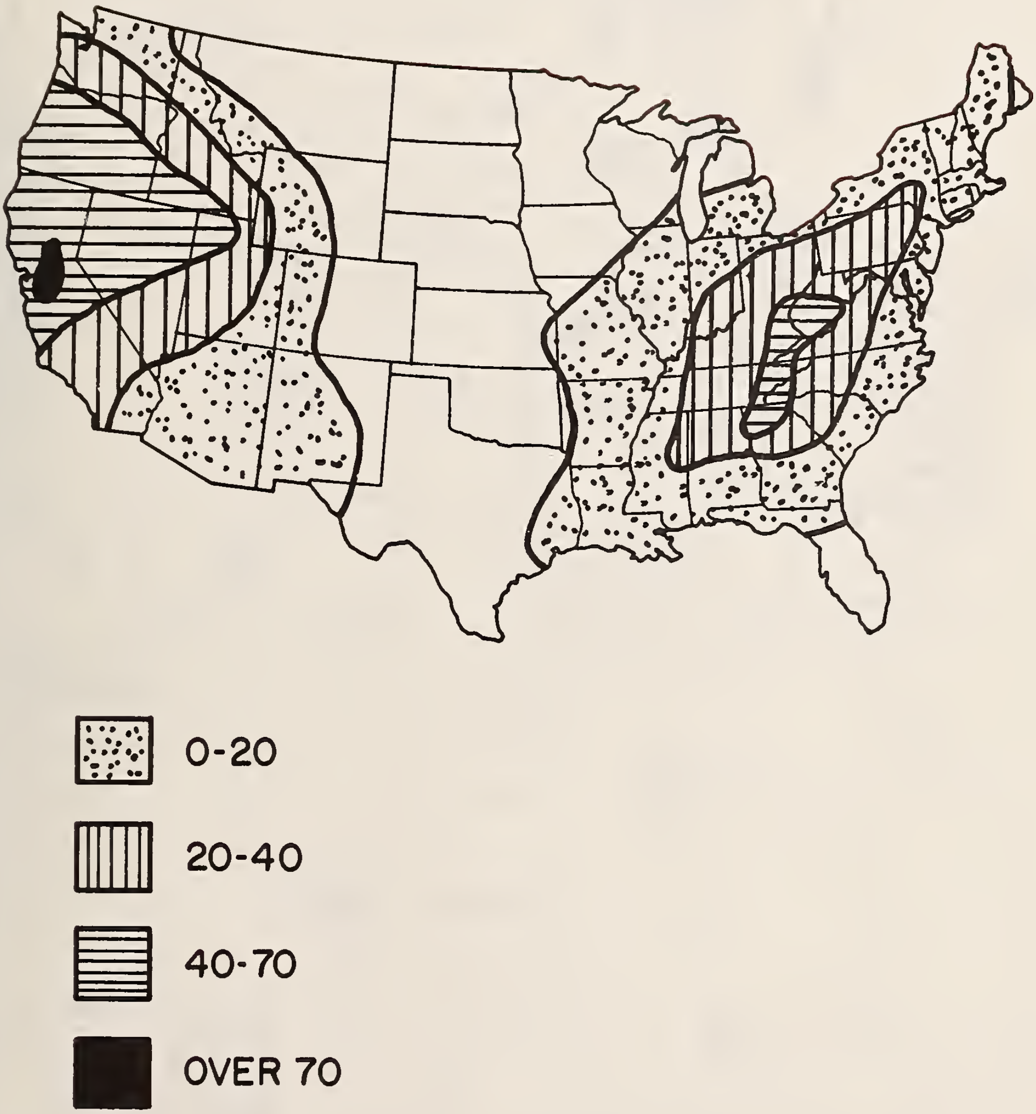


Figure 8. Total Days of High Air Pollution Potential Forecasted, 1960-1966 from The National Atlas, 1970.

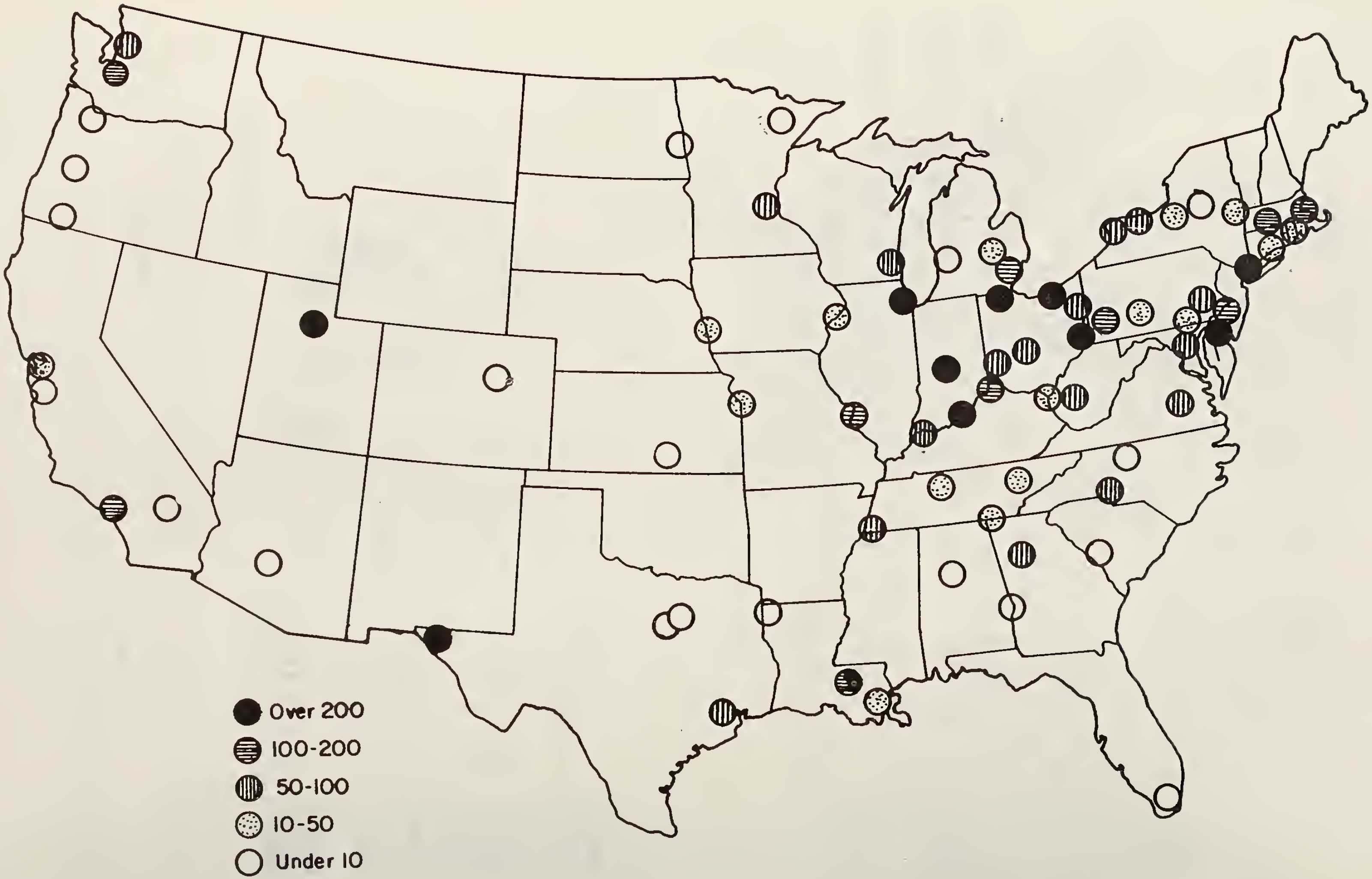
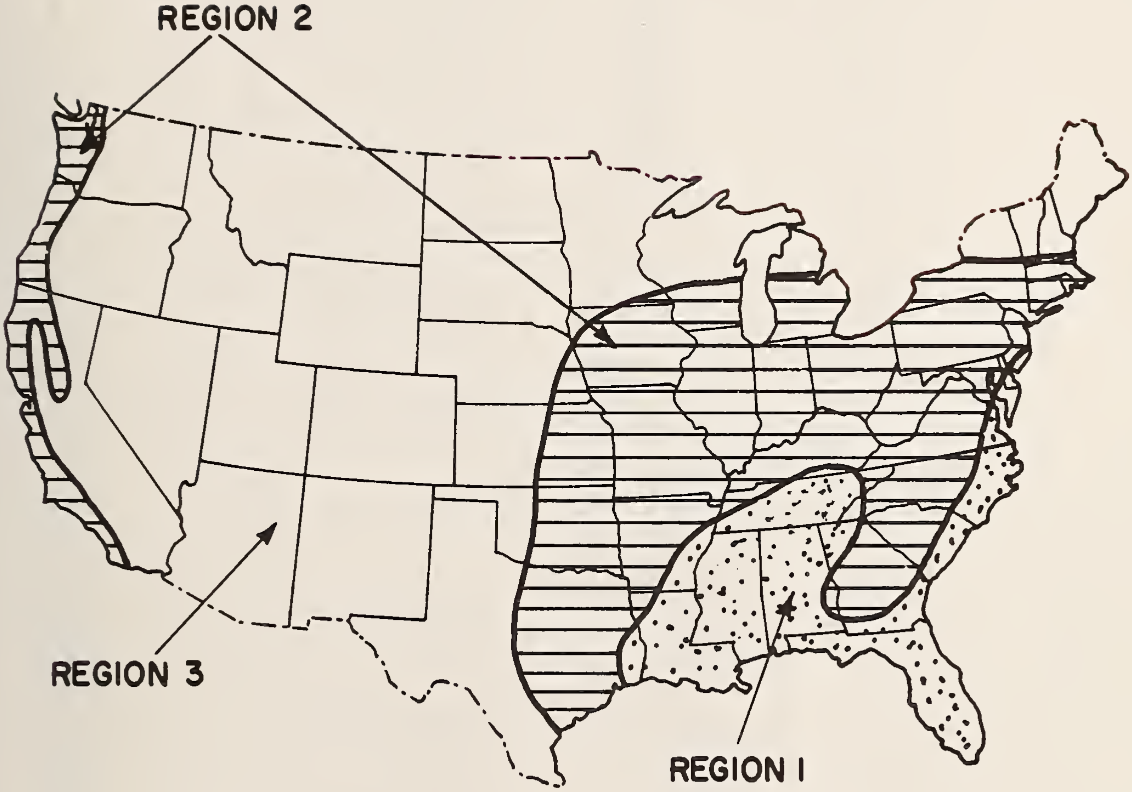


Figure 9. Estimated Annual Emissions of Sulfur Dioxide, 1961-1965 in Standard Metropolitan Statistical Areas, Tons per Square Mile per Year

From The National Atlas, 1970



DECAY HAZARD

Figure 10. Regions in the Contiguous United States defined by Decay Hazard

REGION 1: Moderate to severe probability of decay (Includes Hawaii and Puerto Rico)
REGION 2: Slight to moderate probability of decay
REGION 3: Little probability of decay (Includes Alaska)

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)
(a)	(b)	(b)	(b)	18		18		(b)
J	81.3	67.4	74.4	90	1958	61	1962	
F	81.8	67.0	74.4	92	1968	62	1968+	
M	83.1	67.5	75.3	93	1958	60	1957	
A	84.0	69.2	76.6	93	1956	64	1968	
M	85.8	71.5	78.7	93	1972+	66	1962	
J	87.1	72.9	80.0	96	1972	69	1957+	
J	87.1	73.7	80.4	93	1965	69	1959	
A	87.8	74.0	80.9	94	1972	70	1956	
S	87.8	73.2	80.5	94	1971+	69	1960+	
O	87.1	72.8	80.0	95	1970	67	1959	
N	85.0	71.4	78.2	92	1960	66	1969+	
D	82.7	69.6	76.2	90	1965+	63	1964	
YR	85.0	70.9	78.0	96	JUN. 1972	60	MAR. 1957	

Month	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs	Year
(a)	(b)	18		18		18		17	18		18	
J	4.70	7.49	1969	0.94	1960	5.08	1969	0.0	0.0		0.0	
F	2.90	6.44	1956	0.79	1965	2.73	1969	0.0	0.0		0.0	
M	2.20	5.41	1958	0.72	1970	3.91	1969	0.0	0.0		0.0	
A	3.72	6.38	1964	0.50	1968	3.15	1959	0.0	0.0		0.0	
M	7.12	14.99	1965	0.44	1972	3.08	1965	0.0	0.0		0.0	
J	5.66	10.96	1965	1.24	1971	3.55	1965	0.0	0.0		0.0	
J	6.25	9.35	1961	1.69	1971	2.28	1969	0.0	0.0		0.0	
A	7.13	11.76	1955	3.06	1972	5.08	1955	0.0	0.0		0.0	
S	6.76	10.85	1963	1.93	1961	3.08	1963	0.0	0.0		0.0	
O	5.83	15.06	1970	1.63	1963	5.00	1970	0.0	0.0		0.0	
N	6.49	11.11	1968	2.31	1971	3.72	1968	0.0	0.0		0.0	
D	5.45	10.00	1961	0.68	1963	3.54	1961	0.0	0.0		0.0	
YR	64.21	15.06	OCT. 1970	0.44	MAY 1972	5.08	JAN. 1969+	0.0	0.0		0.0	

Month	Relative humidity: Hour 02 (Local time)	Hour 08	Hour 14	Hour 20	Wind &: Mean speed	Prevailing direction	Fastest mile: Speed	Direction #	Year	Pct of possible sunshine	Mean sky cover sunrise to sunset
(a)	17	17	17	17	17	8	17	17		17	17
J	83	83	65	76	8.9	ENE	34	NE	1967+	65	5.2
F	82	82	63	74	9.2	ENE	40	E	1965	69	5.1
M	82	79	61	74	9.5	ENE	37	NE	1969	74	5.0
A	81	77	63	75	9.2	ENE	35	E	1970+	68	5.6
M	84	79	66	77	8.7	ENE	34	S	1969	60	6.7
J	85	80	67	78	8.9	ENE	38	NE	1970	58	6.7
J	84	80	67	78	9.9	ENE	34	SE	1958	65	6.3
A	85	81	66	78	9.1	ENE	80	NE	1956	67	6.2
S	86	81	67	79	7.5	ENE	34	NE	1972+	60	6.4
O	86	82	67	79	6.6	ENE	44	NE	1972	62	6.4
N	85	83	66	78	7.5	ENE	35	NE	1961	60	5.8
D	83	82	66	77	8.6	ENE	46	NE	1970	56	5.8
YR	84	81	65	77	8.6	ENE	80	NE	AUG. 1956	64	5.9

Month	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max: 90 and above ‡	Max: 32° and below	Min: 32 and below	Min: 0 and below	Average daily solar radiation - langleys
(a)	17	17	17	17	17	17	17	17	17	17	17	
J	8	18	5	17	0	*	0	*	0	0	0	
F	7	16	5	13	0	*	0	1	0	0	0	
M	9	18	4	12	0	*	0	2	0	0	0	
A	6	17	7	14	0	1	0	2	0	0	0	
M	2	17	12	18	0	4	0	3	0	0	0	
J	2	16	12	17	0	6	0	5	0	0	0	
J	3	19	9	21	0	5	0	4	0	0	0	
A	3	18	10	19	0	6	0	5	0	0	0	
S	2	18	10	18	0	8	0	7	0	0	0	
O	3	17	11	17	0	8	0	5	0	0	0	
N	4	18	8	18	0	3	0	1	0	0	0	
D	5	18	8	19	0	*	0	*	0	0	0	
YR	54	210	101	202	0	41	0	34	0	0	0	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Annual extremes have been exceeded at City Office locations as follows (1890 - 1964 record): Highest temperature 96 in October 1963 and earlier; maximum monthly precipitation 16.88 in May 1936; minimum monthly precipitation 0.05 in February 1941; maximum precipitation in 24 hours 10.55 in December 1910.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≤ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

\# To 8 compass points only.

APPENDIX, Table I. Climatological Data for Sites Listed in Table 4

SITE: SAN JUAN, PUERTO RICO (ISLA VERDE INTERNATIONAL AIRPORT)

CLIMATE CLASSIFICATION: TROPICAL RAINY; Am, Monsoon Rainforest

STANDARD TIME USED: ATLANTIC

LATITUDE: 18°26' N

LONGITUDE: 66°00' W

ELEVATION (Ground): 13 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature – Normal – Daily maximum	Temperature – Normal – Daily minimum	Temperature – Normal – Monthly	Temperature – Extremes – Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation – Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	8		8		(b)	(b)	30		30		30	
J	75.8	57.9	66.9	86	1967	35	1971+	74	2.03	6.66	1969	0.04	1951	2.50	1958
F	77.0	58.8	67.9	87	1971	36	1967	56	1.87	6.56	1966	0.01	1944	5.73	1966
M	79.8	61.1	70.5	90	1971	37	1968	19	2.27	7.22	1949	0.02	1956	7.07	1949
A	82.6	65.8	74.2	96	1971	46	1971	0	3.88	10.21	1960	0.07	1971	5.18	1960
M	85.4	69.7	77.6	93	1967	61	1971+	0	6.44	18.54	1968	0.44	1965	8.42	1958
J	88.0	73.5	80.8	94	1967	67	1972+	0	7.37	22.36	1968	1.81	1945	7.63	1966
J	88.8	74.7	81.8	96	1969	70	1965	0	6.75	13.51	1947	1.77	1963	4.55	1952
A	89.7	74.9	82.3	96	1970	70	1967	0	6.97	16.88	1943	1.65	1954	6.92	1964
S	88.0	74.6	81.3	93	1968+	70	1966+	0	9.47	24.40	1960	2.63	1951	7.58	1960
O	84.7	70.9	77.8	90	1969+	56	1968	0	8.21	21.08	1952	1.50	1962	9.95	1948
N	80.2	64.6	72.4	87	1969	40	1970	0	2.83	13.15	1959	0.09	1970	7.93	1959
D	77.1	59.1	68.1	85	1968+	34	1968	65	1.67	6.39	1958	0.13	1968+	4.38	1964
YR	83.1	67.1	75.1	96	APR. 1971+	34	DEC. 1968	214	59.76	24.40	SEP. 1960	0.01	FEB. 1944	9.95	OCT. 1948

Month	Snow, Ice pellets – Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity – Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind & – Mean speed	Prevailing direction	Fastest mile – Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max. ‡ 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	** Average daily solar radiation - langleys
(a)	30	30		30		8	8	8	8	23	15	15	15			24	23	23	23	30	23	23	24	8	8	8	8	
J	0.0	0.0		0.0		81	84	60	70	9.4	NNW	37	31	1966		5.2	10	12	9	6	0	1	2	0	0	0	0	
F	0.0	0.0		0.0		78	82	57	66	10.1	ESE	38	30	1964		5.2	9	11	8	6	0	1	1	0	0	0	0	
M	0.0	0.0		0.0		77	82	56	65	10.3	SE	46	04	1966		5.3	9	14	8	6	0	2	1	*	0	0	0	
A	0.0	0.0		0.0		76	81	55	64	10.4	ESE	32	23	1958		5.4	8	15	7	6	0	3	1	1	0	0	0	
M	0.0	0.0		0.0		80	82	60	70	9.4	ESE	37	32	1961		5.8	6	15	10	10	0	7	*	1	0	0	0	
J	0.0	0.0		0.0		85	87	68	75	8.2	SE	37	13	1967+		6.9	3	14	13	15	0	13	0	7	0	0	0	
J	0.0	0.0		0.0		82	86	64	72	7.9	SE	38	18	1962		6.5	3	17	11	16	0	15	0	8	0	0	0	
A	0.0	0.0		0.0		82	86	65	73	7.6	SE	74	36	1964		6.5	3	18	10	16	0	16	*	10	0	0	0	
S	0.0	0.0		0.0		85	90	67	77	8.2	ESE	69	06	1965		6.8	2	15	13	17	0	11	*	5	0	0	0	
O	0.0	0.0		0.0		84	88	66	75	9.1	ENE	41	05	1966		6.1	6	13	12	15	0	5	*	*	0	0	0	
N	0.0	0.0		0.0		81	85	60	70	9.2	N	32	08	1966		5.3	9	13	8	8	0	1	1	0	0	0	0	
D	0.0	0.0		0.0		79	84	59	70	8.8	N	38	32	1967		5.2	10	12	9	7	0	1	1	0	0	0	0	
YR	0.0	0.0		0.0		81	85	61	71	9.0	ESE	74	36	AUG. 1964		5.8	78	169	118	128	0	76	7	33	0	0	0	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Airport locations; highest temperature 100 in July 1942; lowest temperature 28 in January 1940; maximum precipitation in 24 hours 12.58 in April 1942. City locations; lowest temperature 27 in February 1917; maximum precipitation in 24 hours 15.10 in November 1925; fastest mile of wind 132 from the East in August 1926.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≤ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

APPENDIX, Table I (Continued) SITE: MIAMI, FLORIDA (INTERNATIONAL AIRPORT)

CLIMATE CLASSIFICATION: TROPICAL RAINY; Aw, Tropical Savanna

STANDARD TIME USED: EASTERN

LATITUDE: 25°48' N

LONGITUDE: 80°16' W

ELEVATION (Ground): 7 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes Ø: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year
(a)	(b)	(b)	(b)	12		12		(b)	(b)	35		35		35	
J	31.6	12.5	22.1	61	1968+	-37	1969	1349	0.61	2.05	1969	T	1944	0.74	1966
F	34.0	13.6	23.8	64	1968+	-22	1962	1154	0.74	2.16	1958	0.01	1950	0.88	1951
M	41.1	20.2	30.7	72	1966	-19	1962	1063	0.92	2.18	1967	0.15	1960	1.01	1967
A	55.2	31.9	43.6	83	1969+	5	1964	642	0.98	3.69	1967	0.27	1938	2.43	1951
M	65.7	40.2	53.0	90	1972	19	1967	384	2.10	8.13	1953	0.67	1950	3.20	1953
J	72.9	46.9	59.9	97	1961	32	1969	186	2.90	5.37	1965	0.52	1960	2.74	1964
J	84.7	54.1	69.4	100	1971+	40	1972	28	1.28	4.82	1955	0.04	1959	1.40	1950
A	81.8	51.8	66.8	106	1969+	37	1965	53	1.26	2.94	1950	0.03	1969	1.72	1950
S	71.2	43.5	57.4	98	1967	23	1965	258	1.20	3.56	1941	0.10	1962	1.70	1945
O	59.3	35.6	47.5	85	1964+	-3	1972	543	0.73	1.89	1957	T	1965+	1.15	1954
N	44.2	24.4	34.3	72	1962	-15	1970	921	0.75	2.27	1955	0.02	1954	0.97	1946
D	35.8	18.8	27.3	61	1962	-43	1968	1169	0.60	1.73	1945	T	1954	0.82	1972
YR	56.5	32.8	44.7	106	AUG. 1969+	-43	DEC. 1968	7750	14.07	8.13	MAY 1953	T	OCT. 1965+	3.20	MAY 1953

Month	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: Hour 05 (Local time)	Hour 11	Hour 17	Hour 23	Wind &: Mean speed	Prevailing direction #	Fastest mile: Speed	Direction #	Year
(a)	35	35		35		11	11	11	11	31	15	29	29	
J	10.0	22.6	1969	9.6	1943	66	63	62	66	15.7	SW	65	SW	1946+
F	8.9	26.1	1958	11.0	1951	67	60	56	66	14.8	SW	72	W	1954
M	9.6	21.3	1967	10.0	1967	65	54	47	62	13.4	SW	73	W	1951
A	6.3	35.4	1967	9.2	1960	67	48	41	60	13.2	SW	70	W	1946
M	1.3	8.1	1956	6.2	1967	69	46	40	60	11.4	SW	65	SW	1951
J	0.5	11.1	1950	11.0	1950	71	45	42	61	11.4	SW	70	W	1958
J	T	T	1966+	T	1966+	65	37	28	50	10.3	SW	73	W	1951
A	0.0	0.0		0.0		59	35	27	45	10.5	SW	71	SW	1954
S	1.3	7.7	1954	6.1	1954	64	45	37	56	11.7	SW	73	NW	1945
O	2.7	14.2	1957	8.3	1957	62	45	41	58	13.8	SW	73	W	1949
N	7.3	22.1	1955	10.8	1946	64	55	53	62	15.0	SW	73	SW	1955
D	8.6	25.0	1945	9.8	1945	66	62	61	65	16.0	SW	82	SW	1956
YR	56.5	35.4	APR. 1967	11.0	FEB. 1951+	65	50	45	59	13.1	SW	82	SW	DEC. 1956

Month	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max: 90° and above ‡	Max: 32° and below	Min: 32° and below	Min: 0° and below	Average daily solar radiation - langleys **
(a)	30	31	35	35	35	35	35	35	33	11	11	11	11	
J	50	7.2	5	7	19	9	3	*	1	0	16	27	12	
F	58	7.3	4	7	17	8	3	*	1	0	8	24	4	
M	68	7.2	5	8	18	9	3	*	2	0	8	25	4	
A	64	7.3	4	8	18	9	2	1	2	0	2	17	0	
M	64	6.8	5	10	16	11	*	4	1	*	0	3	0	
J	65	6.5	6	10	14	12	*	7	1	2	0	*	0	
J	80	4.0	15	11	5	7	0	8	*	8	0	0	0	
A	78	4.4	14	10	7	7	0	6	*	10	0	0	0	
S	67	5.7	10	9	11	7	*	2	1	2	*	3	0	
O	61	6.2	8	9	14	6	1	*	1	0	1	10	*	
N	47	7.2	5	7	18	7	3	*	2	0	4	20	2	
D	47	7.2	5	8	18	7	3	*	1	0	13	26	8	
YR	64	6.4	86	104	175	99	20	26	13	22	51	155	30	

ØFor period March 1961 through current year.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Highest temperature 107 in July 1933; lowest temperature -49 in February 1936; maximum precipitation in 24 hours 3.36 in June 1907; maximum snowfall in 24 hours 14.0 in December 1932.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≤ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

\# To 8 compass points only.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

APPENDIX, Table I (Continued) SITE: GREAT FALLS, MONTANA (INTERNATIONAL AIRPORT)

CLIMATE CLASSIFICATION: DRY; BSk, Middle Latitude Steppe

STANDARD TIME USED: MOUNTAIN

LATITUDE: 47°29' N

LONGITUDE: 111°22' W

ELEVATION (Ground): 3662 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)
(a)	(b)	(b)	(b)	12		12		(b)
J	24.2	3.6	13.9	63	1968	-52	1969	1584
F	27.4	5.1	16.3	67	1962	-30	1971+	1364
M	37.8	15.9	26.9	75	1966	-20	1970	1181
A	56.4	29.7	43.1	87	1968	-14	1967	657
M	68.6	40.7	54.7	94	1972+	24	1967+	338
J	73.8	48.2	61.0	100	1961	32	1969	162
J	85.3	54.6	70.0	104	1971+	39	1971	28
A	82.5	51.5	67.0	111	1961	36	1969	53
S	70.4	40.7	55.6	101	1967	21	1961	306
O	59.3	32.3	45.8	88	1970	0	1971	595
N	40.7	18.2	29.5	68	1965+	-23	1964	1065
D	31.2	10.6	20.9	65	1962	-46	1968	1367
YR	54.8	29.3	42.1	111	AUG. 1961	-52	JAN. 1969	8700

Month	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	12		12		12		12	12		12	
J	0.49	2.33	1971	0.18	1962+	0.51	1971	11.4	41.4	1971	11.7	1971
F	0.43	0.78	1963	0.11	1966+	0.26	1972+	5.0	8.5	1972	4.0	1972
M	0.60	1.28	1967	0.07	1971	0.86	1972	5.0	14.4	1967	8.3	1972
A	0.97	2.59	1967	0.33	1969	1.19	1967	7.1	31.1	1967	16.2	1967
M	1.53	2.28	1964	0.28	1967	1.03	1962	0.1	1.7	1967	1.0	1967
J	2.73	4.72	1965	0.54	1972	2.23	1970	T	T	1969	T	1969
J	1.27	3.77	1965	0.01	1967	1.16	1965	0.0	0.0		0.0	
A	1.10	3.03	1968	T	1967	2.34	1968	0.0	0.0		0.0	
S	1.01	2.47	1968	0.07	1969	1.22	1965	0.4	2.8	1965	2.7	1965
O	0.79	1.09	1962	0.06	1965	0.75	1962	1.0	4.6	1972	2.9	1971
N	0.50	0.65	1966	T	1969	0.23	1971	3.2	9.5	1965	5.5	1965
D	0.47	1.06	1964	0.05	1962	0.40	1964	7.2	14.1	1964	5.2	1970
YR	11.89	4.72	JUN. 1965	T	NOV. 1969+	2.34	AUG. 1968	40.4	41.4	JAN. 1971	16.2	APR. 1967

Month	Relative humidity: Hour 05 (Local time)	Hour 11	Hour 17	Hour 23	Wind &: Mean speed %	Prevailing direction #	Fastest mile: Speed	Direction #	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset
(a)	12	12	6	5	10	4	12	12		12	12
J	73	69	71	71	10.7	SW	47	SW	1964	50	7.6
F	78	72	70	77	10.1	SW	58	SW	1963	61	7.3
M	77	61	56	71	10.2	SW	52	SW	1964	67	7.2
A	76	50	41	61	11.3	SW	47	NW	1968	65	7.2
M	74	44	36	60	10.4	E	54	W	1965	68	6.7
J	76	45	37	61	9.8	SW	63	W	1961	70	6.2
J	72	38	28	56	9.3	SW	71	NW	1961	84	4.1
A	65	35	23	48	9.0	W	54	NW	1968	83	4.4
S	73	46	35	59	9.7	E	52	W	1971	72	5.8
O	73	49	44	63	10.2	SW	52	NW	1963	64	6.3
N	75	62	57	69	9.9	SW	49	NW	1968+	48	7.3
D	76	72	70	75	9.8	SW	47	SW	1968	47	7.3
YR	74	53	47	64	10.0	SW	71	NW	JUL. 1961	67	6.4

Month	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms %	Heavy fog %	Temperatures Max: 90° and above ‡	Max: 32° and below	Min: 32° and below	Min: 0° and below	Average daily solar radiation - langleys
(a)	12	12	12	12	12	10	10	12	12	12	12	
J	4	7	20	10	4	0	*	0	20	30	17	
F	5	6	17	6	2	0	2	0	13	27	8	
M	5	8	18	6	1	0	2	0	9	27	6	
A	4	9	17	7	2	1	1	0	1	19	*	
M	5	11	15	10	0	2	1	*	0	4	0	
J	6	12	12	10	0	5	0	4	0	*	0	
J	15	10	6	8	0	7	*	9	0	0	0	
A	14	10	7	5	0	5	*	13	0	0	0	
S	9	8	13	6	*	1	*	2	0	4	0	
O	8	8	15	5	*	*	1	0	1	16	*	
N	5	7	18	4	1	0	2	0	7	27	3	
D	5	7	19	8	3	0	1	0	18	30	13	
YR	85	103	177	84	14	21	10	28	69	185	46	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Lowest temperature -57 in January 1916; maximum monthly precipitation 9.67 in July 1884; maximum precipitation in 24 hours 3.71 in June 1887; maximum snowfall in 24 hours 24.8 in May 1899.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1964.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

% Based on available record through 1964 and complete record beginning January 1968.

To 8 compass points only.

APPENDIX, Table I (Continued) SITE: HAVRE, MONTANA (CITY-COUNTY AIRPORT)

CLIMATE CLASSIFICATION: DRY; BSk, Middle Latitude Steppe

STANDARD TIME USED: MOUNTAIN

LATITUDE: 48°33' N

LONGITUDE: 109°46' W

ELEVATION (Ground): 2584 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Extremes: Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	13		13		(b)	(b)	24		24		24	
J	54.2	32.0	43.1	75	1962	8	1963	688	0.53	2.41	1949	T	1971+	1.01	1952
F	59.4	36.1	47.8	82	1972	19	1972+	487	0.44	0.96	1969	0.00	1967+	0.63	1958
M	67.6	42.0	54.8	91	1966	23	1971+	335	0.35	1.50	1952	0.00	1972+	1.14	1952
A	77.6	51.4	64.5	96	1962	32	1967	111	0.23	2.44	1965	0.00	1962	0.97	1965
M	87.9	59.6	73.8	106	1969+	40	1964	6	0.08	0.96	1969	0.00	1970+	0.80	1969
J	97.2	68.5	82.9	115	1970	51	1971+	0	0.04	0.82	1967	0.00	1958+	0.75	1967
J	103.5	75.8	89.7	116	1972	62	1970+	0	0.50	1.64	1956	0.00	1963	1.32	1956
A	101.0	73.4	87.2	113	1969	56	1968	0	0.48	2.59	1957	0.00	1956	2.59	1957
S	94.3	65.6	80.0	107	1971	46	1965	0	0.34	1.58	1963	0.00	1971+	1.07	1963
O	80.1	53.1	66.6	99	1963	26	1971	78	0.20	1.12	1972	0.00	1967+	0.65	1972
N	65.0	39.9	52.5	83	1967	28	1968+	387	0.31	2.22	1965	0.00	1956	1.78	1960
D	56.2	33.9	45.1	71	1966	15	1968	617	0.40	1.38	1959	0.00	1963+	0.83	1959
YR	78.7	52.6	65.7	116	JUL. 1972	8	JAN. 1963	2709	3.90	2.59	AUG. 1957	0.00	MAR. 1972+	2.59	AUG. 1957

Month	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs	Year	Relative humidity: Hour 04 (Local time)	Hour 10	Hour 16	Hour 22	Wind &: Mean speed	Prevailing direction	Fastest mile ø: Speed	Direction #	Year
(a)	24	24		24		12	12	12	12	24	15	8	8	
J	0.8	16.7	1949	5.0	1949	51	37	27	45	7.0	W	52	SW	1965
F	T	T	1966+	T	1966+	47	34	25	40	8.1	SW	54	NW	1965
M	T	T	1963+	T	1963+	39	25	17	31	9.6	SW	52	SW	1966
A	T	T	1970+	T	1970+	34	21	14	25	10.7	SW	48	N	1969+
M	0.0	0.0		0.0		31	18	12	22	10.9	SW	52	SW	1971
J	0.0	0.0		0.0		27	16	12	18	10.6	SW	46	SW	1965
J	0.0	0.0		0.0		29	19	14	22	9.9	SW	64	SW	1971
A	0.0	0.0		0.0		37	25	19	28	9.2	SW	55	NE	1971
S	0.0	0.0		0.0		33	22	16	26	8.7	SW	54	NW	1971
O	T	T	1956	T	1956	37	26	19	31	7.7	WSW	52	NW	1970
N	0.2	4.0	1964	4.0	1964	49	36	29	44	6.8	W	39	SW	1970+
D	0.1	2.0	1967	2.0	1967	57	43	34	51	6.9	W	54	SW	1964
YR	1.1	16.7	JAN. 1949	5.0	JAN. 1949	39	27	20	32	8.8	SW	64	SW	JUL. 1971

Month	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max: 90° and above ‡	Max: 32° and below	Min: 32° and below	Min: 0° and below	** Average daily solar radiation - langleys
(a)	24	24	24	24	24	24	24	24	24	12	12	12	12	
J	79	4.8	14	6	11	3	*	0	*	0	*	17	0	
F	82	4.5	13	7	8	2	0	*	0	0	0	6	0	
M	84	4.3	15	8	8	2	0	*	*	*	0	3	0	
A	86	3.7	17	7	6	2	0	1	0	2	0	*	0	
M	88	3.3	19	8	4	1	0	1	0	15	0	0	0	
J	93	2.0	23	5	2	1	0	1	0	24	0	0	0	
J	86	3.0	19	9	3	3	0	5	0	31	0	0	0	
A	88	2.6	21	7	3	3	0	5	0	30	0	0	0	
S	91	1.8	23	5	2	1	0	2	0	22	0	0	0	
O	85	2.7	21	6	4	2	0	*	*	5	0	*	0	
N	81	3.8	16	7	7	2	*	*	*	0	0	2	0	
D	78	4.4	15	7	9	2	*	*	*	0	*	15	0	
YR	86	3.4	216	82	67	24	*	15	1	130	*	42	0	

ø For period August 1964 through the current year.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Highest temperature 117 in July 1942; maximum monthly precipitation 3.39 in September 1939.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

\# To 8 compass points only.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

APPENDIX, Table I (Continued) SITE: LAS VEGAS, NEVADA (McCARRAN INTERNATIONAL AIRPORT)

CLIMATE CLASSIFICATION: DRY; BWh, Tropical and Subtropical Desert

STANDARD TIME USED: PACIFIC

LATITUDE: 36°05' N

LONGITUDE: 115°10' W

ELEVATION (Ground): 2162 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	12		12		(b)	(b)	35		35		35		35	35		35	
J	64.0	35.3	49.7	88	1971	19	1971	474	0.73	2.41	1955	0.00	1972+	1.31	1951	T	T	1962+	T	1962+
F	68.1	38.9	53.5	89	1963	26	1964	328	0.85	2.23	1944	0.00	1967	1.07	1944	T	0.6	1939	0.6	1939
M	75.0	42.9	59.0	95	1972+	25	1966	217	0.66	4.16	1941	0.00	1959+	1.32	1941	0.0	0.0		0.0	
A	83.9	50.4	67.2	101	1962	37	1968	75	0.32	2.10	1941	0.00	1962+	1.38	1941	T	T	1949	T	1949
M	92.9	57.1	75.0	108	1970+	40	1967+	0	0.13	0.94	1944	0.00	1952+	0.94	1944	0.0	0.0		0.0	
J	101.6	65.5	83.6	116	1970	51	1965	0	0.09	1.70	1972	0.00	1971+	1.64	1972	0.0	0.0		0.0	
J	104.6	75.0	89.8	115	1972	67	1968+	0	0.77	4.19	1955	T	1947	1.97	1955	0.0	0.0		0.0	
A	101.6	73.4	87.5	116	1972	61	1968+	0	1.12	5.56	1951	0.02	1967	3.07	1943	0.0	0.0		0.0	
S	98.2	67.3	82.8	110	1971	47	1965	0	0.73	4.23	1939	0.00	1968+	2.43	1970	0.0	0.0		0.0	
O	86.7	54.6	70.7	103	1972	34	1971	22	0.46	4.40	1972	0.00	1952+	2.27	1972	0.0	0.0		0.0	
N	73.7	42.4	58.1	92	1967	31	1966	234	0.49	3.04	1952	0.00	1956+	1.07	1952	0.0	0.0		0.0	
D	66.1	37.0	51.6	82	1965	24	1968	415	0.85	3.98	1967	0.00	1958	1.89	1967	T	T	1968+	T	1968+
YR	84.7	53.3	69.0	116	AUG. 1972+	19	JAN. 1971	1765	7.20	5.56	AUG. 1951	0.00	JAN. 1972+	3.07	AUG. 1943	T	0.6	FEB. 1939	0.6	FEB. 1939

Month	Relative humidity: Hour 05 (Local time)	Hour 11	Hour 17	Hour 23	Wind &: Mean speed	Prevailing direction	Peak gust ∅: Speed	Direction	Year	† Pct. of possible sunshine	$ Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max: 90° and above ‡	Max: 32° and below	Min: 32° and below	Min: 0° and below	** Average daily solar radiation - langleys
(a)	12	12	12	12	27	18	35	35		77	27	35	35	35	33	35	33	35	12	12	12	12	
J	66	43	30	56	4.9	E	49	WNW	1965	78	4.7	14	7	10	4	0	*	1	0	0	7	0	
F	59	37	25	48	5.6	E	49	SSE	1959	80	4.4	13	6	9	4	0	1	*	0	0	3	0	
M	57	32	22	42	6.3	E	50	WNW	1956	83	4.2	15	8	8	3	0	1	*	2	0	1	0	
A	44	23	16	29	6.6	E	45	NW	1957+	88	3.5	17	7	6	2	0	1	0	8	0	0	0	
M	36	18	13	22	6.7	E	59	SSE	1954	93	2.7	21	6	4	1	0	*	0	22	0	0	0	
J	36	19	13	23	6.6	E	59	S	1972	94	1.9	23	5	2	1	0	1	0	29	0	0	0	
J	47	28	20	33	6.9	W	71	N	1959	85	3.7	17	10	4	4	0	6	0	31	0	0	0	
A	56	36	25	42	6.4	E	60	SSW	1953	85	3.4	17	10	4	5	0	8	0	31	0	0	0	
S	55	33	24	42	6.1	E	75	SW	1950	89	2.1	22	5	3	3	0	3	0	27	0	0	0	
O	55	30	22	43	5.5	E	48	SSW	1956	88	2.7	20	6	5	3	0	1	*	14	0	0	0	
N	62	39	29	53	5.1	E	45	WSW	1963+	84	3.5	18	6	6	2	0	*	*	*	0	*	0	
D	70	49	36	61	4.9	E	68	W	1953	77	4.0	15	6	10	4	0	1	1	0	0	4	0	
YR	53	32	23	41	6.0	E	75	SW	SEP. 1950	86	3.4	212	82	71	34	0	23	2	163	0	15	0	

∅ Peak Gust observed during Airway observational program from January 1938 through October 1953; from recorder charts thereafter.
† Combined record from Post Office, August 1895 through October 1953, and from Sky Harbor Airport, November 1953 to date.
$ Broken record: 1940, 1941, and 1948 to date.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Highest temperature 118 in July 1958+; lowest temperature 16 in January 1913; maximum monthly precipitation 6.47 in July 1911; maximum precipitation in 24 hours 4.98 in July 1911; maximum monthly snowfall 1.0 in January 1937 and earlier; maximum snowfall in 24 hours 1.0 in January 1937 and earlier.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≲ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

APPENDIX, Table I (Continued) SITE: PHOENIX, ARIZONA (SKY HARBOR INTERNATIONAL AIRPORT)

CLIMATE CLASSIFICATION: DRY; BWh, Tropical and Subtropical Desert

STANDARD TIME USED: MOUNTAIN

LATITUDE: 33°26' N

LONGITUDE: 112°01' W

ELEVATION (Ground): 1117 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature – Normal – Daily maximum	Temperature – Normal – Daily minimum	Temperature – Normal – Monthly	Temperature – Extremes ∅ – Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation – Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year	Snow, Ice pellets – Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	8		8		(b)	(b)	22		22		22		22	22		22	
J	66.8	40.0	53.4	88	1971	24	1971	363	0.39	1.29	1955	T	1970+	0.56	1955	0.0	0.0		0.0	
F	71.1	43.4	57.3	89	1972+	31	1965	228	0.36	1.82	1958	0.00	1972+	1.34	1958	0.0	0.0		0.0	
M	78.0	48.0	63.0	98	1966	34	1971	130	0.24	0.82	1970	0.00	1972+	0.61	1970	0.0	0.0		0.0	
A	86.1	55.0	70.6	102	1965	42	1967	29	0.09	1.20	1965	0.00	1962+	1.08	1965	0.0	0.0		0.0	
M	93.9	62.1	78.0	109	1970	46	1967	0	0.01	0.37	1965	0.00	1970+	0.37	1965	0.0	0.0		0.0	
J	101.9	70.0	86.0	116	1968	56	1971	0	0.01	0.27	1972	0.00	1971+	0.26	1972	0.0	0.0		0.0	
J	106.9	78.7	92.8	115	1972	70	1971+	0	0.23	1.07	1958	T	1971+	1.06	1958	0.0	0.0		0.0	
A	104.9	78.3	91.6	116	1972	63	1968	0	0.50	1.31	1955	0.00	1956+	1.14	1970	0.0	0.0		0.0	
S	101.1	71.5	86.3	114	1971	53	1965	0	0.38	2.47	1963	0.00	1972+	2.42	1963	0.0	0.0		0.0	
O	89.5	59.4	74.5	104	1972+	35	1971	0	0.38	2.68	1957	0.00	1967+	2.20	1972	0.0	0.0		0.0	
N	76.7	46.6	61.7	94	1966	33	1964	148	0.12	1.66	1969	0.00	1971+	1.42	1969	0.0	0.0		0.0	
O	68.4	41.6	55.0	83	1966	27	1968	319	0.32	1.67	1965	0.00	1963+	1.37	1961	T	T	1967	T	1967
YR	87.1	57.9	72.5	116	AUG. 1972+	24	JAN. 1971	1217	3.03	2.68	OCT. 1957	0.00	SEP. 1972+	2.42	SEP. 1963	T	T	OEC. 1967	T	OEC. 1967

Month	Relative humidity – Hour 05 (Local time)	Hour 11	Hour 17	Hour 23	Wind & – Mean speed	Prevailing direction	Fastest mile – Speed	Direction #	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures – Max – 90° and above ‡	Max – 32° and below	Min – 32° and below	Min – 0° and below	Average daily solar radiation - langleys
(a)	8	8	8	8	22	13	22	22		22	22	22	22	22	22	22	22	22	8	8	8	8	
J	55	38	26	46	7.3	N	41	NW	1964	84	4.1	16	7	8	2	0	0	*	0	0	1	0	
F	54	33	22	44	7.5	N	50	W	1964	88	3.6	16	6	6	1	0	*	*	0	0	*	0	
M	51	28	19	39	7.8	WNW	43	N	1956	92	3.5	18	7	6	2	0	*	0	4	0	0	0	
A	46	24	16	34	8.3	W	47	NW	1954	94	2.4	21	5	4	1	0	*	0	9	0	0	0	
M	44	22	15	32	8.3	WNW	38	NW	1957	96	1.8	24	5	2	*	0	*	0	21	0	0	0	
J	45	24	15	31	8.5	SSE	42	SW	1966	98	1.2	26	3	1	*	0	*	0	27	0	0	0	
J	49	32	23	39	9.5	SSE	52	NE	1961	90	2.7	20	8	3	1	0	2	0	31	0	0	0	
A	59	37	27	46	9.0	SSE	54	S	1954	91	2.5	21	7	3	2	0	2	0	31	0	0	0	
S	57	34	23	45	7.1	SSE	42	SE	1969+	94	1.5	25	3	2	1	0	1	*	28	0	0	0	
O	53	30	22	42	6.5	N	47	S	1964	92	2.1	23	5	3	1	0	1	0	15	0	0	0	
N	59	36	29	50	6.8	N	47	N	1957	86	3.1	19	6	5	1	0	*	*	*	0	0	0	
O	62	43	34	54	7.2	N	47	W	1959	82	3.7	17	6	8	2	0	*	1	0	0	1	0	
YR	53	32	22	42	7.8	N	54	S	AUG. 1954	91	2.7	246	68	51	15	0	7	1	167	0	3	0	

∅ For period April 1964 through the current year.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 123 in September 1950; lowest temperature 22 in January 1937 and earlier date; maximum monthly precipitation 6.25 in August 1909; maximum precipitation in 24 hours 4.01 in August 1909; fastest mile of wind 56 from Northwest in March 1949.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North: i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

\# To 8 compass points only.

APPENDIX, Table I (Continued) SITE: YUMA, ARIZONA (MCAS/YUMA INTERNATIONAL AIRPORT)

CLIMATE CLASSIFICATION: DRY; BWh, Tropical and Subtropical Desert

STANDARD TIME USED: MOUNTAIN

LATITUDE: 32°40' N

LONGITUDE: 114°36' W

ELEVATION (Ground): 194 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Temperature: Normal: Daily minimum	Temperature: Normal: Monthly	Temperature: Extremes: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs	Year	Relative humidity: Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind &: Mean speed	Prevailing direction	Fastest mile: Speed	Direction #	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max: 90° and above ‡	Max: 32° and below	Min: 32° and below	Min: 0° and below	** Average daily solar radiation - langleys
(a)	(b)	(b)	(b)	12		12		(b)	(b)	31		31		29		29	29		29		12	12	12	12	24	13	24	24		24	24	24	24	24	31	29	24	24	12	12	12	12	
J	44.3	29.5	36.9	71	1967	3	1972+	871	3.03	5.08	1949	0.31	1955	1.73	1948	4.9	21.3	1966	13.8	1966	66	69	54	59	10.1	NW	56	NW	1957	49	6.5	8	7	16	10	2	*	2	0	5	24	0	
F	46.1	29.4	37.8	77	1972	4	1961	762	2.47	5.71	1961	0.80	1968	1.77	1971	5.3	19.0	1967	14.4	1958	64	68	53	56	10.6	S	57	SW	1961+	51	6.4	7	7	14	9	1	*	2	0	3	20	0	
M	53.8	35.8	44.8	86	1963	16	1962	626	3.21	7.43	1953	0.64	1945	3.43	1958	2.6	17.1	1960	7.9	1960	63	68	48	52	11.1	NW	60	E	1951	56	6.3	8	9	14	11	1	1	1	0	*	10	0	
A	65.8	45.6	55.7	90	1969	27	1969	288	3.15	5.97	1952	0.26	1942	3.08	1970	T	0.6	1972	0.6	1972	65	69	48	50	10.5	S	56	N	1952	56	6.4	7	9	14	10	0	3	1	*	0	1	0	
M	75.5	56.0	65.8	97	1969	36	1966	74	4.14	10.69	1953	1.06	1963	4.32	1953	T	T	1963	T	1963	71	71	50	56	9.3	S	48	S	1952	58	6.2	7	11	13	11	0	5	*	2	0	0	0	
J	83.4	64.9	74.2	100	1969+	47	1972+	0	3.21	11.53	1972	1.24	1954	7.19	1972	0.0	0.0		0.0		76	76	52	60	8.8	S	57	NW	1954	64	5.8	8	11	11	9	0	5	*	8	0	0	0	
J	87.0	69.3	78.2	101	1966	56	1963	0	4.15	11.06	1945	0.93	1966	4.69	1970	0.0	0.0		0.0		76	76	53	61	8.2	S	54	E	1951	61	6.0	7	12	12	10	0	6	*	13	0	0	0	
A	85.0	67.9	76.5	99	1962	51	1963	0	4.90	14.31	1955	0.55	1962	6.39	1955	0.0	0.0		0.0		77	78	53	61	8.1	S	49	NE	1955	63	5.6	10	9	12	9	0	5	*	9	0	0	0	
S	78.6	60.7	69.7	96	1970	39	1963	33	3.83	6.87	1966	0.20	1967	4.15	1966	0.0	0.0		0.0		78	80	54	65	8.3	S	56	SE	1952	62	5.4	11	8	11	8	0	2	*	4	0	0	0	
O	68.3	49.6	59.0	91	1967	29	1969	217	3.07	8.18	1942	T	1963	4.98	1955	T	T	1972+	T	1972+	76	79	51	63	8.6	SSW	78	SE	1954	60	5.2	12	7	12	7	0	1	2	*	0	1	0	
N	56.5	38.9	47.7	85	1971	20	1970	519	2.84	6.70	1963	0.37	1965	2.63	1971	0.8	6.9	1967	6.9	1967	70	74	53	61	9.2	S	60	E	1952	50	6.0	9	8	13	8	*	*	1	0	0	5	0	
D	45.6	30.5	38.1	74	1971	10	1963+	834	2.78	6.54	1969	0.22	1955	1.85	1951	3.9	16.2	1962	11.4	1957	68	71	57	62	9.4	NW	62	SW	1957	47	6.4	9	6	16	9	1	*	2	0	2	18	0	
YR	65.8	48.2	57.0	101	JUL. 1966	3	JAN. 1972+	4224	40.78	14.31	AUG. 1955	T	OCT. 1963	7.19	JUN. 1972	17.5	21.3	JAN. 1966	14.4	FEB. 1958	71	73	52	59	9.3	S	78	SE	OCT. 1954	57	6.0	103	104	158	111	5	29	13	37	10	80	0	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 106 in July 1930+; lowest temperature -15 in February 1899; maximum monthly precipitation 17.45 in September 1934; maximum precipitation in 24 hours 7.31 in August 1928; maximum monthly snowfall 35.2 in February 1899; maximum snowfall in 24 hours 25.0 in January 1922.

To 8 compass points only.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

Solar radiation data have been recorded at several locations in the vicinity of Washington. Instruments have been at the Observational Test and Development Center, Sterling, Virginia, since October 1960, elevations (m.s.l.) 276 ft. to 7-13-64 and 281 ft. thereafter.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

APPENDIX, Table I (Continued) SITE: WASHINGTON, D.C. (NATIONAL AIRPORT)

CLIMATE CLASSIFICATION: HUMID MESOTHERMAL; Caf, Humid Subtropical

STANDARD TIME USED: EASTERN

LATITUDE: 38°51' N

LONGITUDE: 77°02' W

ELEVATION (Ground): 10 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature – Normal – Daily maximum	Daily minimum	Monthly	Extremes – Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation – Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year
(a)	(b)	(b)	(b)	22		22		(b)	(b)	22		22		22	
J	44.2	25.3	34.8	75	1967	-7	1963	936	3.43	5.27	1964	0.29	1955	2.54	1968
F	45.5	25.8	35.7	76	1954	-1	1967	820	2.89	6.21	1971	0.72	1968	2.18	1971
M	53.6	32.5	43.1	85	1963	6	1960	679	3.82	6.80	1953	0.93	1966	3.18	1958
A	65.8	42.6	54.2	94	1960	20	1965	327	3.60	8.15	1952	1.61	1968	2.80	1952
M	75.9	52.8	64.4	98	1962	32	1966	90	3.98	7.10	1960	0.43	1964	3.64	1960
J	83.5	61.4	72.5	100	1959	40	1972	0	3.29	9.95	1972	0.15	1954	5.23	1972
J	87.2	66.4	76.8	102	1966+	52	1962+	0	4.22	8.18	1960	0.30	1955	5.86	1952
A	85.0	65.0	75.0	102	1953	48	1952	0	5.19	18.35	1955	0.77	1951	7.82	1955
S	78.6	57.6	68.1	99	1962+	35	1963	48	3.33	8.50	1966	0.21	1967	4.33	1960
O	68.4	45.6	57.0	92	1954+	25	1969+	264	3.18	6.88	1971	T	1963	3.49	1955
N	56.5	34.4	45.5	83	1971+	13	1955	585	3.13	7.68	1952	0.68	1965	3.43	1952
D	45.7	25.9	35.8	74	1951	0	1960	905	2.99	7.44	1969	0.20	1955	1.80	1969
YR	65.8	44.6	55.2	102	JUL. 1966+	-7	JAN. 1963	4654	43.05	18.35	AUG. 1955	T	OCT. 1963	7.82	AUG. 1955

Month	Snow, Ice pellets – Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity – Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind & – Mean speed	Prevailing direction	Fastest mile – Speed	Direction #	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset
(a)	22	22		22		19	19	19	19	22	13	22	22		22	22
J	5.5	21.4	1966	12.1	1966	69	72	57	62	10.1	WNW	63	NE	1958	52	6.1
F	6.5	20.1	1967	15.5	1958	68	72	56	61	10.8	NW	68	W	1956	54	6.2
M	5.3	21.6	1960	13.0	1962	66	71	50	55	11.4	WNW	80	SE	1952	55	6.2
A	0.1	0.4	1964+	0.4	1964+	69	73	49	55	11.1	WNW	70	W	1954	55	6.2
M	T	T	1963	T	1963	76	76	51	59	9.7	W	65	SW	1961+	58	6.1
J	0.0	0.0		0.0		81	79	52	62	8.9	WNW	80	SW	1952	63	5.7
J	0.0	0.0		0.0		81	81	53	64	8.3	W	57	NW	1962	65	5.7
A	0.0	0.0		0.0		82	83	55	66	8.4	W	54	NE	1955	63	5.5
S	0.0	0.0		0.0		83	84	55	68	8.5	S	56	W	1952	62	5.2
O	T	T	1972+	T	1972+	79	82	53	68	9.2	NW	73	SE	1954	59	5.0
N	1.3	8.4	1967	8.4	1967	74	77	54	64	9.6	WNW	58	E	1952	51	6.0
D	4.8	20.4	1966	14.1	1960	72	75	59	66	9.6	WNW	57	W	1953	48	6.3
YR	23.5	21.6	MAR. 1960	15.5	FEB. 1958	75	77	54	62	9.6	W	80	SW	JUN. 1952+	58	5.9

Month	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures – Max – 90 and above ‡	Max – 32 and below	Min – 32 and below	Min – 0 and below	Average daily solar radiation - langleys
(a)	22	22	22	22	22	22	22	22	22	22	22	
J	9	7	15	10	2	*	4	0	6	25	*	
F	8	7	13	9	2	*	4	0	4	22	*	
M	8	9	14	11	2	1	3	0	1	16	0	
A	7	10	13	11	*	2	2	*	0	3	0	
M	8	11	12	11	0	4	2	2	0	*	0	
J	8	12	10	9	0	6	1	7	0	0	0	
J	9	12	10	8	0	6	1	11	0	0	0	
A	10	11	10	10	0	5	1	8	0	0	0	
S	11	9	10	7	0	2	2	4	0	0	0	
O	13	7	11	7	0	1	3	*	0	2	0	
N	9	8	13	9	*	*	3	0	*	12	0	
D	9	7	15	9	1	*	4	0	4	21	*	
YR	109	110	146	112	8	28	30	32	14	101	*	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 107 in July 1936; maximum monthly snowfall 33.9 in February 1899; maximum snowfall in 24 hours 24.5 in January 1922.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

\# To 8 compass points only.

APPENDIX, Table I (Continued) SITE: BALTIMORE, MARYLAND (FRIENDSHIP INTERNATIONAL AIRPORT)

CLIMATE CLASSIFICATION: HUMID MESOTHERMAL; Caf, Humid Subtropical

STANDARD TIME USED: EASTERN

LATITUDE: 39°11' N

LONGITUDE: 76°40' W

ELEVATION (Ground): 148 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes ∅: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation %: Normal total	Maximum monthly $	Year	Minimum monthly $	Year	Maximum in 24 hrs	Year
(a)	(b)	(b)	(b)	8		8		(b)	(b)	29		29		29	
J	42.9	26.6	34.8	78	1967	-8	1965	936	3.56	7.71	1948	0.26	1955	2.86	1944
F	43.3	26.1	34.7	70	1971	-7	1967	848	3.13	5.98	1958	1.46	1946	2.59	1966
M	49.7	32.4	41.1	81	1968	7	1967	741	3.91	6.80	1953	0.62	1945	2.27	1968
A	60.3	41.7	51.0	94	1969	12	1969	420	3.41	7.95	1952	1.24	1945	3.37	1952
M	71.0	51.5	61.3	99	1969	25	1966	133	3.51	11.51	1948	0.40	1957	4.15	1959
J	79.2	60.7	70.0	106	1969	37	1967	15	2.83	6.36	1970	0.10	1954	2.91	1952
J	83.8	66.3	75.1	104	1966	46	1965	0	3.72	13.09	1959	1.30	1957	6.46	1959
A	82.2	65.1	73.7	97	1968	40	1965	0	4.90	11.98	1967	0.34	1943	6.40	1966
S	76.0	58.4	67.2	93	1970+	32	1969+	39	3.31	6.27	1966	0.41	1970	3.98	1954
O	66.5	47.8	57.2	87	1967	23	1969	251	3.20	7.50	1943	0.15	1963	2.95	1958
N	55.5	37.9	46.7	76	1971+	11	1964	549	3.66	9.65	1972	0.72	1946	3.93	1953
D	45.1	28.1	36.6	72	1966	0	1968	880	3.22	7.33	1969	0.62	1955	2.75	1951
YR	63.0	45.2	54.1	106	JUN. 1969	-8	JAN. 1965	4812	42.36	13.09	JUL. 1959	0.10	JUN. 1954	6.46	JUL. 1959

Month	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: Hour 01 (Local time)	Hour 07	Hour 13	Hour 19	Wind &: Mean speed	Prevailing direction	Fastest mile: Speed	Direction	Year
(a)	28	28		28		8	8	8	8	14	5	13	13	
J	5.2	15.9	1961	14.4	1964	74	76	57	69	12.1	WNW	47	29	1971
F	5.2	35.2	1967	13.1	1967	73	76	56	66	12.3	W	43	27	1960
M	3.4	17.6	1969	11.5	1969	75	77	54	65	12.5	WNW	44	30	1964+
A	0.3	3.2	1965	3.2	1965	77	75	50	65	12.1	S	46	07	1961
M	0.0	0.0		0.0		82	76	54	67	10.8	S	32	22	1966
J	0.0	0.0		0.0		88	83	57	72	9.8	S	37	29	1964+
J	0.0	0.0		0.0		89	86	59	74	9.2	S	37	26	1970+
A	0.0	0.0		0.0		90	87	56	75	8.9	S	35	12	1971
S	0.0	0.0		0.0		89	87	58	79	9.4	ENE	60	32	1960
O	T	T	1972+	T	1972+	87	87	57	78	9.9	W	41	29	1961
N	0.5	7.8	1967	7.8	1967	81	84	58	76	11.4	W	40	27	1960
D	2.6	8.6	1960	7.5	1960	77	79	60	73	11.5	WNW	55	36	1960
YR	17.2	35.2	FEB. 1967	14.4	JAN. 1964	82	81	56	71	10.8	S	60	32	SEP. 1960

Month	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max.: 90° and above ‡	Max.: 32° and below	Min.: 32° and below	Min.: 0° and below	Average daily solar radiation - langleys
(a)	12	14	14	14	14	29	28	14	14	8	8	8	8	
J	52	6.1	10	7	14	11	2	*	3	0	9	26	1	
F	49	6.4	7	6	15	10	2	*	4	0	5	23	1	
M	53	6.1	9	8	14	11	1	1	4	0	1	20	0	
A	52	6.3	7	10	13	11	*	2	4	*	0	7	0	
M	55	6.3	7	11	13	10	0	3	4	1	0	*	0	
J	60	6.0	7	11	12	9	0	5	5	4	0	0	0	
J	58	6.4	7	9	15	9	0	6	4	5	0	0	0	
A	62	6.0	8	10	13	9	0	5	4	5	0	0	0	
S	59	5.6	10	8	12	7	0	1	4	2	0	*	0	
O	57	5.3	12	7	12	7	0	1	5	0	0	4	0	
N	50	6.2	8	8	14	9	*	1	3	0	*	14	0	
D	43	6.4	8	8	15	9	1	*	4	0	2	21	*	
YR	54	6.1	100	103	162	112	5	26	48	17	17	115	2	

∅ For period November 1964 through the current year.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Lowest temperature -9 in February 1934; maximum monthly precipitation 14.87 in August 1882; minimum monthly precipitation .01 in September 1941; maximum precipitation in 24 hours 9.21 in October 1903; maximum snowfall in 24 hours 18.0 in February 1902.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≤ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09-East, 18-South, 27-West, 36-North, and 00-Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

% Based on U.S. Naval Air Station and Weather Bureau Airport Station records.

$ Beginning with August 1943.

APPENDIX, Table I (Continued)   SITE: ATLANTIC CITY, NEW JERSEY (AVIATION FACILITIES EXPER. CENTER)

CLIMATE CLASSIFICATION: HUMID MESOTHERMAL; Caf, Humid Subtropical

STANDARD TIME USED: EASTERN

LATITUDE: 39°27' N

LONGITUDE: 74°34' W

ELEVATION (Ground): 64 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature Ø — Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Extremes: Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year
(a)	(b)	(b)	(b)	9		9		(b)	(b)	19		19		19	
J	56.0	34.9	45.5	88	1969	4	1964	614	2.04	3.60	1968	0.19	1971	2.36	1961
F	59.8	38.6	49.2	87	1969	12	1971	448	2.24	6.20	1965	0.15	1963	4.06	1965
M	67.3	44.4	55.9	91	1971	19	1965	319	2.51	6.39	1968	0.10	1972	2.99	1958
A	75.6	53.9	64.8	95	1972	31	1971	99	3.60	12.19	1957	0.92	1959	4.55	1957
M	82.8	62.6	72.7	96	1967	42	1971	0	4.59	12.64	1957	1.06	1961	4.86	1965
J	91.6	71.3	81.5	105	1972	51	1964	0	2.98	6.94	1962	0.40	1964	3.11	1966
J	95.9	74.9	85.4	105	1964+	59	1972+	0	1.75	6.36	1962	0.09	1965	3.22	1958
A	96.2	74.6	85.4	108	1964	56	1967	0	1.68	6.85	1970	0.02	1961	3.30	1970
S	89.3	67.5	78.4	102	1963	46	1971+	0	2.54	9.52	1964	0.23	1956	4.76	1965
O	79.4	56.4	67.9	96	1963	37	1966+	65	2.59	9.22	1959	0.20	1955	5.91	1959
N	66.1	43.5	54.8	88	1965+	24	1970	324	2.46	6.23	1964	0.20	1970	2.83	1964
D	58.2	37.2	47.7	84	1966	10	1963	536	2.35	6.99	1971	0.21	1955	3.10	1971
YR	76.5	55.0	65.8	108	AUG. 1964	4	JAN. 1964	2405	31.33	12.64	MAY 1957	0.02	AUG. 1961	5.91	OCT. 1959

Month	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity Hour 00 (Local time)	Hour 06	Hour 12	Hour 18	Wind &: Mean speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days — Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max: 90 and above ‡	Max: 32 and below	Min: 32 and below	Min: 0 and below	** Average daily solar radiation - langleys
(a)	19	19		19		9	9	9	9	19	10	19	19			19	19	19	19	19	19	19	19	9	9	9	9	
J	1.5	12.1	1964	12.1	1964	75	81	59	58	11.6	S	46	36	1957		6.1	10	5	16	7	1	1	2	0	1	15	0	
F	0.7	2.9	1966+	2.9	1966+	72	79	56	52	12.3	S	51	36	1962+		5.7	10	5	13	7	*	2	2	0	*	11	0	
M	0.4	2.5	1962	2.5	1962	71	80	56	50	13.5	S	55	29	1954		5.8	10	8	13	7	*	4	1	*	0	5	0	
A	0.0	0.0		0.0		75	85	59	54	13.3	S	55	32	1970		6.1	9	7	14	8	0	7	1	1	0	*	0	
M	0.0	0.0		0.0		80	88	62	59	11.8	S	55	14	1955		5.9	8	11	12	8	0	7	*	2	0	0	0	
J	0.0	0.0		0.0		73	86	56	51	11.3	S	52	32	1955		4.8	12	11	7	6	0	6	*	19	0	0	0	
J	0.0	0.0		0.0		66	80	50	44	10.1	S	65	36	1961		4.3	14	10	7	5	0	5	0	27	0	0	0	
A	0.0	0.0		0.0		69	82	52	47	9.5	S	73	36	1959		4.3	15	10	6	5	0	5	*	25	0	0	0	
S	0.0	0.0		0.0		79	88	60	58	9.9	S	53	11	1961+		4.6	13	9	8	7	0	4	*	12	0	0	0	
O	0.0	0.0		0.0		76	85	55	58	10.1	S	44	27	1957		4.5	14	7	10	5	0	3	1	2	0	0	0	
N	T	T	1972+	T	1972+	75	82	55	58	10.9	S	50	34	1957		5.0	13	5	12	6	0	1	1	0	0	3	0	
D	0.2	2.6	1963	2.5	1963	77	82	61	62	11.4	S	53	32	1968		5.6	11	6	14	7	*	1	3	0	*	9	0	
YR	2.8	12.1	JAN. 1964	12.1	JAN. 1964	74	83	57	54	11.3	S	73	36	AUG. 1959		5.2	139	94	132	78	1	45	11	89	2	42	0	

Ø For period July 1963 through the current year.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 112 in August 1936; lowest temperature -8 in February 1899; maximum monthly precipitation 17.64 in April 1922; minimum monthly precipitation 0.00 in November 1903; maximum precipitation in 24 hours 9.57 in September 1932.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≤ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09-East, 18-South, 27-West, 36-North, and 00-Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

APPENDIX, Table I (Continued) SITE: FORT WORTH, TEXAS (GREATER SW INTERNATIONAL AIRPORT)

CLIMATE CLASSIFICATION: HUMID MESOTHERMAL; Caf, Humid Subtropical

STANDARD TIME USED: CENTRAL

LATITUDE: 32°50' N

LONGITUDE: 97°03' W

ELEVATION (Ground): 537 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature – Normal – Daily maximum	Normal – Daily minimum	Normal – Monthly	Extremes – Record highest	Year	Extremes – Record lowest	Year	Normal heating degree days (Base 65°)
(a)	(b)	(b)	(b)	13		13		(b)
J	43.6	33.0	38.3	61	1960	12	1972+	828
F	47.0	34.5	40.8	70	1968	18	1962	678
M	51.3	36.2	43.8	71	1964	23	1971+	657
A	58.2	40.1	49.2	77	1972+	30	1963+	474
M	65.6	45.3	55.5	93	1963	33	1962	295
J	69.9	49.7	59.8	94	1970	41	1962	159
J	75.6	54.1	64.9	97	1961	46	1960	56
A	74.6	53.6	64.1	99	1960	45	1960	62
S	69.3	50.5	59.9	93	1967	35	1972	162
O	60.3	44.4	52.4	80	1961	30	1971	391
N	49.6	38.1	43.9	72	1970	23	1961	633
D	45.9	35.7	40.8	60	1965+	6	1968	750
YR	59.2	42.9	51.1	99	AUG. 1960	6	DEC. 1968	5145

Month	Precipitation – Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets – Mean total	Maximum monthly	Year	Maximum in 24 hrs	Year
(a)	(b)	28		28		28		28	28		28	
J	5.73	12.92	1953	0.86	1949	2.41	1967	7.7	57.2	1950	21.4	1950
F	4.24	9.11	1961	1.66	1964	3.41	1951	1.9	13.1	1949	7.2	1962
M	3.79	8.40	1950	0.57	1965	2.86	1972	1.9	18.2	1951	5.6	1951
A	2.40	4.12	1972	0.33	1956	1.85	1965	0.1	2.3	1972	2.3	1972
M	1.73	4.76	1948	0.35	1947	1.83	1969	T	T	1965	T	1965
J	1.58	3.90	1946	0.13	1951	1.75	1968	0.0	0.0		0.0	
J	0.81	2.10	1955	T	1960+	0.75	1972	0.0	0.0		0.0	
A	0.95	4.58	1968	0.02	1967	1.75	1968	0.0	0.0		0.0	
S	2.05	5.57	1969	0.32	1952	1.77	1953	T	T	1972	T	1972
O	4.02	8.95	1947	0.72	1972	2.27	1947	0.1	2.0	1971	2.0	1971
N	5.35	9.69	1963	1.11	1952	3.41	1959	1.1	13.7	1946	9.4	1946
D	6.29	9.50	1955	3.75	1960	2.53	1959	3.3	22.1	1968	13.0	1968
YR	38.94	12.92	JAN. 1953	T	JUL. 1960+	3.41	NOV. 1959+	16.1	57.2	JAN. 1950	21.4	JAN. 1950

Month	Relative humidity – Hour 04 (Local time)	Hour 10	Hour 16	Hour 22	Wind & – Mean speed	Prevailing direction	Fastest mile – Speed	Direction #	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max – 90° and above ‡	Max – 32° and below	Min – 32° and below	Min – 0° and below	** Average daily solar radiation - langleys
(a)	13	13	13	13	24	15	5	5		7	28	28	28	28	28	28	28	28	13	13	13	13	
J	81	80	76	80	10.5	SSW	45	SW	1971	19	8.6	2	4	25	20	2	*	5	0	2	11	0	
F	80	76	67	76	10.1	SW	36	SW	1972	43	8.2	3	4	21	16	1	*	4	0	0	4	0	
M	82	75	63	76	10.4	SSW	41	SW	1971	48	8.0	3	6	22	18	1	1	3	0	0	4	0	
A	84	72	60	76	10.0	SW	38	SW	1972	49	7.8	3	7	20	14	*	1	1	0	0	*	0	
M	84	69	54	72	9.3	SW	32	SW	1968+	55	7.1	4	10	17	10	0	1	1	*	0	0	0	
J	83	68	54	71	9.1	SW	29	SW	1970	52	7.1	5	7	18	10	0	1	1	*	0	0	0	
J	84	66	49	67	8.6	SW	24	S	1968	67	5.1	11	10	10	5	0	1	2	1	0	0	0	
A	83	69	51	71	8.2	SW	25	N	1972	67	5.7	9	9	13	7	0	1	3	1	0	0	0	
S	87	76	59	77	8.4	N	29	SW	1970	55	6.2	7	9	14	10	0	1	7	*	0	0	0	
O	87	80	69	82	9.1	S	29	SW	1969	38	7.6	4	7	20	15	*	*	8	0	0	*	0	
N	84	81	75	81	9.4	S	31	S	1970+	28	8.4	2	5	23	18	*	1	7	0	0	3	0	
D	82	81	78	81	10.2	SSW	42	S	1969	16	8.8	2	3	26	21	1	*	6	0	1	9	0	
YR	83	74	63	76	9.4		45	SW	JAN. 1971	48	7.4	55	81	229	162	5	8	49	3	3	32	0	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 100 in June 1955 and earlier; lowest temperature zero in January 1950; maximum monthly precipitation 15.33 in December 1933; minimum monthly precipitation 0.00 in July 1922 and earlier. Maximum precipitation in 24 hours 3.52 in December 1921; maximum snowfall in 24 hours 21.5 in February 1916; highest wind (fastest observed 1-minute speed) 55 from 20 degrees in February 1958.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

\# To 8 compass points only.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

APPENDIX, Table I (Continued)　　SITE: SEATTLE, WASHINGTON (SEATTLE - TACOMA AIRPORT)

CLIMATE CLASSIFICATION: HUMID MESOTHERMAL; Cb, Marine West Coast

STANDARD TIME USED: PACIFIC

LATITUDE: 47°27' N

LONGITUDE: 122°18' W

ELEVATION (Ground): 400 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year ‡	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	19		19		(b)	(b)	19		19		19	
J	46.5	34.8	40.7	65	1961	11	1969	753	11.71	18.94	1954	4.76	1963+	4.32	1964
F	49.9	35.7	42.8	72	1968	19	1962	622	9.89	21.89	1961	4.06	1964	2.86	1961
M	51.9	37.1	44.5	73	1964	22	1971	636	8.92	13.47	1956	0.93	1965	2.66	1956
A	56.9	41.0	49.0	83	1956	29	1968+	480	5.18	8.04	1955	1.33	1956	2.26	1965
M	61.6	44.9	53.3	86	1959+	30	1954	363	3.20	6.60	1960	1.03	1958	1.74	1968
J	65.1	49.5	57.3	93	1955	38	1966+	231	3.02	5.48	1954	0.75	1965	2.42	1968
J	68.6	52.5	60.6	100	1961	39	1971	146	1.27	3.42	1955	0.01	1960	1.43	1955
A	69.2	52.7	61.0	93	1972	42	1969	130	1.49	5.22	1968	0.08	1970	1.65	1968
S	67.2	48.8	58.0	95	1972	33	1972+	210	3.13	6.55	1969	0.51	1965	2.63	1953
O	61.1	44.7	52.9	81	1971+	26	1971	375	7.78	12.24	1955	1.96	1972	3.47	1958
N	53.5	39.1	46.3	71	1970+	15	1955	561	11.20	14.64	1955	2.57	1956	3.48	1959
D	49.4	36.8	43.1	63	1963	6	1972	679	13.65	16.57	1955	6.12	1960	3.03	1955
YR	58.4	43.1	50.8	100	JUL. 1961	6	DEC. 1972	5186	80.44	21.89	FEB. 1961	0.01	JUL. 1960	4.32	JAN. 1964

Month	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: Hour 04 (Local time)	Hour 10	Hour 16	Hour 22	Wind &: Mean speed	Prevailing direction	Fastest mile: Speed	Direction	Year
(a)	19	19		19		19	19	19	19	19	10	19	19	
J	3.9	26.3	1969	10.8	1971	87	85	80	87	9.2	E	55	17	1971
F	0.3	4.0	1962	4.0	1962	87	82	75	86	8.9	ESE	46	20	1963
M	1.1	6.7	1966	5.9	1960	88	78	70	86	8.8	SE	44	19	1964
A	T	0.2	1972+	0.2	1972+	89	74	69	85	8.6	WNW	52	20	1962
M	T	T	1971+	T	1971+	90	73	70	85	8.4	NW	35	24	1971
J	0.0	0.0		0.0		91	76	72	87	8.2	NW	29	20	1962
J	0.0	0.0		0.0		91	75	70	87	8.5	NW	26	32	1964
A	0.0	0.0		0.0		93	77	70	89	7.8	NW	28	23	1961+
S	T	T	1972	T	1972	92	76	70	89	7.3	SE	35	20	1959
O	T	T	1971+	T	1971+	91	81	74	90	7.4	SE	44	20	1962
N	0.1	2.2	1955	2.0	1955	89	84	78	88	8.2	SE	46	20	1962
D	2.1	19.0	1964	7.2	1964	88	85	82	87	9.0	ESE	52	25	1961+
YR	7.5	26.3	JAN. 1969	10.8	JAN. 1971	90	79	73	87	8.4	SE	55	17	JAN. 1971

Month	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max. 90 and above ‡	Max. 32° and below	Min. 32° and below	Min. 0 and below	** Average daily solar radiation - langleys
(a)		19	19	19	19	19	19	19	19	19	19	19	19	
J		8.6	3	3	25	24	1	1	4	0	1	9	0	
F		8.2	3	3	22	20	*	*	3	0	0	7	0	
M		8.1	3	5	23	20	1	1	2	0	0	d	0	
A		8.1	3	5	22	19	0	1	2	0	0	2	0	
M		7.7	3	8	20	14	0	*	2	0	0	*	0	
J		7.7	3	7	20	14	0	*	2	*	0	0	0	
J		6.6	6	10	15	7	0	*	2	*	0	0	0	
A		6.4	7	10	14	9	0	*	5	*	0	0	0	
S		6.3	9	6	15	11	0	1	6	*	0	0	0	
O		7.3	5	6	20	17	0	1	7	0	0	1	0	
N		8.1	3	5	22	21	*	1	4	0	*	4	0	
D		8.6	2	4	25	24	1	1	5	0	1	8	0	
YR		7.6	50	72	243	200	2	8	43	1	2	39	0	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 101 in July 1942; lowest temperature 10 in January 1946 and earlier; maximum monthly precipitation 36.07 in December 1933; maximum precipitation in 24 hours 6.98 in January 1919; maximum monthly snowfall 27.3 in January 1916.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.

‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

APPENDIX, Table I (Continued) SITE: ASTORIA, OREGON (CLATSOP COUNTY AIRPORT)

CLIMATE CLASSIFICATION: HUMID MESOTHERMAL; Cb, Marine West Coast

STANDARD TIME USED: PACIFIC

LATITUDE: 46°09' N

LONGITUDE: 123°53' W

ELEVATION (Ground): 8 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature – Normal – Daily maximum	Temperature – Normal – Daily minimum	Temperature – Normal – Monthly	Temperature – Extremes – Record highest	Year	Temperature – Extremes – Record lowest	Year	Normal heating degree days (Base 65°)
(a)	(b)	(b)	(b)	62		62		(b)
J	53.6	41.1	47.4	75	1943	25	1937+	546
F	54.2	42.1	48.2	85	1930	27	1962+	470
M	54.5	42.8	48.7	78	1914	29	1917	505
A	55.7	45.1	50.4	79	1918	32	1929	438
M	57.9	48.1	53.0	84	1939	36	1954	372
J	60.1	50.9	55.5	85	1945	41	1966+	285
J	60.5	52.0	56.3	76	1931	45	1924	270
A	60.9	52.5	56.7	82	1968	44	1935	257
S	61.6	51.1	56.4	85	1958+	41	1946	258
O	60.3	48.5	54.4	82	1917	32	1971	329
N	57.5	44.9	51.2	77	1950+	29	1935	414
D	55.1	42.7	48.9	77	1963	21	1972	499
YR	57.7	46.8	52.3	85	SEP. 1958+	21	DEC. 1972	4643

Month	Precipitation – Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets – Mean total	Maximum monthly	Year	Maximum in 24 hrs	Year	Relative humidity – Hour (Local time)	Hour	Hour	Hour
(a)	(b)	62		62		62		62	62		62					
J	6.70	13.92	1969	1.63	1949	4.42	1912	0.2	3.0	1935	3.0	1935				
F	5.53	13.94	1938	0.50	1923	4.88	1959	T	0.8	1955	0.8	1955				
M	5.25	13.97	1938	0.07	1926	3.09	1939	T	1.0	1966	1.0	1966				
A	2.67	10.68	1963	0.31	1956	2.56	1963	T	T	1948+	T	1948+				
M	2.18	6.05	1960	0.03	1955	2.23	1943	0.0	0.0		0.0					
J	0.74	2.57	1954	0.00	1917	1.73	1943	0.0	0.0		0.0					
J	0.11	1.34	1916	0.00	1967+	1.18	1916	0.0	0.0		0.0					
A	0.10	1.98	1968	0.00	1940+	0.93	1965	0.0	0.0		0.0					
S	0.64	3.56	1925	0.00	1929	1.32	1966	0.0	0.0		0.0					
O	3.19	13.04	1950	0.00	1917	5.83	1950	0.0	0.0		0.0					
N	4.61	13.65	1926	T	1929	4.55	1926	0.0	0.0		0.0					
D	6.71	12.87	1941	1.17	1917	4.17	1939	T	1.9	1972	1.9	1972				
YR	38.43	13.97	MAR. 1938	0.00	JUL. 1967+	5.83	OCT. 1950	0.2	3.0	JAN. 1935	3.0	JAN. 1935				

Month	Wind & – Mean speed c	Prevailing direction #	Fastest mile – Speed	Direction #	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms %	Heavy fog %	Temperatures Max – 90 and above ‡	Max – 32 and below	Min – 32 and below	Min – 0 and below	Average daily solar radiation - langleys
(a)	54	54	62	62		62	30	62	62	62	62	62	54	54	62	62	62	62	
J	6.9	SE	54	S	1955	41	7.3	6	6	19	17	*	1	4	0	0	2	0	
F	7.2	SE	48	SW	1960	46	7.4	6	5	17	14	0	1	3	0	0	1	0	
M	7.6	N	48	SW	1953	50	7.4	6	8	17	15	0	*	2	0	0	*	0	
A	8.0	N	49	N	1915	55	7.1	6	9	15	12	0	*	2	0	0	*	0	
M	7.9	N	40	NW	1955	54	7.0	6	10	15	9	0	*	1	0	0	0	0	
J	7.4	N	39	NW	1949	56	6.6	7	10	13	5	0	*	2	0	0	0	0	
J	6.8	N	35	N	1921	52	6.7	6	11	14	2	0	*	3	0	0	0	0	
A	5.8	NW	34	N	1920	47	6.8	6	11	14	2	0	*	5	0	0	0	0	
S	5.5	N	44	N	1941	53	5.9	9	8	13	5	0	*	7	0	0	0	0	
O	5.6	N	56	SW	1962	49	6.5	8	9	14	9	0	*	9	0	0	*	0	
N	6.0	SE	43	S	1946	43	7.2	6	7	17	13	0	1	7	0	0	*	0	
D	6.4	SE	56	S	1931	41	7.4	6	6	19	15	*	1	4	0	0	1	0	
YR	6.8	N	56	SW	OCT. 1962+	50	6.9	78	100	187	117	*	5	49	0	0	5	0	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Lowest temperature 20 in January 1888; maximum monthly precipitation 19.49 in February 1902; maximum monthly snowfall 6.9 in January 1907; maximum snowfall in 24 hours 3.4 in January 1907.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1964.
‡ ≦ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09-East, 18-South, 27-West, 36-North, and 00-Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

% Through 1964. The station did not operate 24 hours daily. Fog and thunderstorm data may be incomplete.

c Through 1964.

\# To 8 compass points only.

APPENDIX, Table I (Continued) SITE: EUREKA, CALIFORNIA (POST OFFICE BUILDING)

CLIMATE CLASSIFICATION: HUMID MESOTHERMAL; Cb, Marine West Coast

STANDARD TIME USED: PACIFIC

LATITUDE: 40°48' N

LONGITUDE: 124°10' W

ELEVATION (Ground): 43 feet

NORMALS, MEANS, AND EXTREMES

Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Extremes: Record lowest	Year	Normal heating degree days (Base 65°)
(b)	(b)	(b)	13		13		(b)
22.4	2.3	12.4	46	1961	-34	1970	1631
26.3	5.0	15.7	54	1964	-28	1965	1380
37.2	17.6	27.4	83	1968	-32	1962	1166
55.7	32.8	44.3	91	1962	2	1962	621
69.1	45.4	57.3	95	1969	18	1967	288
78.1	55.5	66.8	99	1963	37	1969	81
83.9	60.7	72.3	99	1966	43	1972	22
81.3	58.6	70.0	98	1964	39	1967	31
72.2	48.5	60.4	95	1960	27	1965+	189
60.6	37.2	48.9	87	1969	15	1972	505
40.5	21.8	31.2	69	1964	-17	1964	1014
27.4	8.7	18.1	62	1962	-22	1967	1454
54.6	32.8	43.7	99	JUL. 1966+	-34	JAN. 1970	8382

Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(b)	34		34		34		34	34		34	
0.70	3.63	1967	0.11	1959	1.21	1967	8.6	35.3	1967	7.6	1950
0.78	2.07	1962	0.06	1964	1.10	1966	8.2	26.5	1962	9.3	1939
1.53	4.75	1965	0.32	1958	1.66	1965	10.6	40.0	1951	13.7	1952
1.85	4.07	1967	0.59	1952	1.57	1954	2.5	9.6	1957	9.3	1949
3.19	8.03	1962	0.61	1967	3.03	1965	0.2	3.0	1946	3.0	1946
4.00	7.80	1946	1.26	1950	2.53	1954	0.0	0.0		0.0	
3.27	7.10	1955	0.96	1947	4.12	1949	0.0	0.0		0.0	
3.18	6.60	1959	0.43	1946	3.22	1956	0.0	0.0		0.0	
2.43	7.53	1942	0.41	1940	3.55	1942	0.1	1.7	1942	1.7	1942
1.59	5.68	1971	0.01	1952	2.95	1966	0.3	3.7	1959	2.5	1955
1.40	5.15	1940	0.02	1939	2.91	1940	5.8	26.3	1940	16.2	1940
0.86	2.21	1968	T	1943	1.11	1953	8.8	33.2	1969	9.8	1945
24.78	8.03	MAY 1962	T	DEC. 1943	4.12	JUL. 1949	45.1	40.0	MAR. 1951	16.2	NOV. 1940

Relative humidity: Hour 00 (Local time)	Hour 06	Hour 12	Hour 18	Wind &: Mean speed	Prevailing direction #	Fastest mile: Speed	Direction	Year
13	13	13	13	34	14	34	34	
72	73	67	68	10.5	NW	40	SE	1956+
72	74	65	65	10.6	NW	52	NW	1952
74	77	64	63	11.3	NW	47	E	1951
70	77	55	54	12.4	NW	52	WSW	1964
70	77	54	52	11.5	SE	61	NW	1964
75	80	55	54	10.6	SE	63	NW	1939
78	83	56	55	9.2	S	92	W	1951
78	85	56	56	9.1	SE	63	N	1967
82	88	61	63	9.9	S	47	N	1951
76	84	60	64	10.5	SE	73	S	1949
79	82	67	71	11.1	NW	60	SW	1958
77	78	71	73	10.4	NW	52	W	1946
75	80	61	62	10.6	NW	92	W	JUL. 1951

Pct of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max: 90 and above ‡	Max: 32 and below	Min: 32 and below	Min: 0 and below	Average daily solar radiation - langleys
34	34	34	34	34	34	34	34	34	13	13	13	13	
50	6.4	8	7	16	9	3	*	1	0	25	31	15	
57	6.1	8	7	13	7	2	*	1	0	20	28	10	
55	6.6	7	8	16	10	3	1	1	0	11	27	2	
55	6.5	7	8	15	10	1	2	1	*	*	13	0	
58	6.4	7	9	15	12	*	5	1	1	0	2	0	
62	6.1	7	11	12	12	0	8	1	3	0	0	0	
70	5.1	11	11	9	10	0	8	*	5	0	0	0	
67	5.1	11	11	9	9	0	6	1	4	0	0	0	
61	5.5	10	9	11	9	*	4	1	1	0	1	0	
57	5.5	11	7	13	8	*	2	1	0	0	[illegible]	0	
38	7.1	5	7	18	8	2	1	1	0	6	22	*	
40	7.0	6	7	18	9	3	*	1	0	23	29	8	
58	6.1	98	102	165	113	14	36	11	14	84	160	36	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 108 in July 1936; maximum monthly precipitation 11.87 in July 1892; maximum precipitation in 24 hours 7.80 in July 1892.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

\# To 8 compass points only.

APPENDIX, Table I (Continued) SITE: MINNEAPOLIS - ST. PAUL, MINNESOTA (INTERNATIONAL AIRPORT)

CLIMATE CLASSIFICATION: HUMID MICROTHERMAL; Daf, Humid Continental (Warm Summer)

STANDARD TIME USED: CENTRAL

LATITUDE: 44°53' N

LONGITUDE: 93°13' W

ELEVATION (Ground): 834 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Extremes: Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	13		13		(b)	(b)	33		33		33		33	33		33	
J	19.6	•1	9.9	54	1961	-41	1970+	1708	0.44	1.29	1969	0.02	1940	0.67	1952	7.4	16.9	1950	7.9	1952
F	23.3	3.7	13.5	61	1963	-37	1971	1442	0.43	1.17	1969	0.12	1968+	0.73	1958	6.2	17.4	1969	8.7	1951
M	35.1	17.3	26.2	80	1967+	-28	1962	1203	0.78	2.84	1950	0.11	1961	1.30	1950	7.8	29.7	1950	15.5	1966
A	54.9	32.1	43.5	91	1962	9	1967	645	1.22	4.05	1970	T	1952	1.97	1964	4.0	18.2	1970	8.7	1942
M	68.2	43.6	55.9	95	1969	15	1967	329	1.97	5.18	1965	0.31	1952	1.95	1972	1.2	10.3	1950	11.0	1967
J	76.5	52.4	64.5	100	1961	30	1969	117	3.40	8.29	1947	0.85	1967	3.25	1947	T	T	1969+	T	1969+
J	85.7	57.7	71.7	108	1960	35	1971	34	2.19	5.24	1969	0.18	1968	2.33	1969	0.0	0.0		0.0	
A	83.7	54.8	69.3	106	1960	33	1964	28	1.73	5.05	1944	0.03	1971	2.68	1965	0.0	0.0		0.0	
S	72.6	44.7	58.7	100	1971	18	1965	222	1.19	3.91	1941	0.02	1948	1.99	1941	0.3	4.1	1942	4.1	1942
O	59.4	34.0	46.7	95	1963	5	1960	577	0.85	3.74	1971	0.05	1968	1.62	1971	1.3	7.6	1946	4.9	1946
N	38.6	19.1	28.9	74	1965	-29	1964	1083	0.59	2.56	1944	T	1963	0.99	1944	4.8	16.1	1958	7.5	1959
D	26.9	8.6	17.8	62	1969+	-43	1967	1463	0.36	0.95	1967	T	1944	0.59	1960	6.1	13.7	1969	7.6	1950
YR	53.7	30.7	42.2	108	JUL. 1960	-43	DEC. 1967	8851	15.15	8.29	JUN. 1947	T	NOV. 1963+	3.25	JUN. 1947	39.1	29.7	MAR. 1950	15.5	MAR. 1966

Month	Relative humidity: Hour 00 (Local time)	Hour 06	Hour 12	Hour 18	Wind &: Mean speed	Prevailing direction	Fastest mile: Speed	Direction #	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max.: 90° and above ‡	Max.: 32° and below	Min.: 32° and below	Min.: 0° and below	** Average daily solar radiation - langleys
(a)	13	13	13	13	33	14	33	33		33	33	33	33	33	33	33	33	33	13	13	13	13	
J	71	71	66	67	10.3	WNW	54	NW	1963+	54	6.8	7	7	17	8	3	0	1	0	24	31	19	
F	75	74	68	69	10.2	WNW	59	NW	1972	56	6.9	5	8	15	7	2	0	2	0	19	28	13	
M	75	77	62	59	11.3	WNW	65	NW	1941	60	7.1	5	9	17	8	2	*	2	0	12	29	5	
A	70	77	52	48	12.7	WNW	63	W	1955	59	6.8	6	9	15	8	1	1	1	*	1	17	0	
M	71	78	49	44	12.4	SSE	66	NW	1960	62	6.5	6	11	14	10	*	4	1	1	*	4	0	
J	77	84	55	50	11.1	WNW	66	N	1960+	63	6.2	7	10	13	12	0	9	1	2	0	*	0	
J	75	83	48	43	9.7	SSE	72	W	1946+	76	4.8	12	12	7	9	0	10	1	7	0	0	0	
A	70	81	43	37	9.9	E	72	S	1944	74	4.7	13	11	7	9	0	8	1	10	0	0	0	
S	72	82	49	45	10.5	WNW	66	NW	1959	65	5.5	10	9	11	7	*	3	1	2	0	3	0	
O	69	77	48	48	10.3	WNW	61	W	1959	60	5.7	10	8	13	5	*	1	1	*	1	15	0	
N	75	79	62	64	10.5	WNW	67	NW	1958	44	7.0	6	7	17	6	2	*	1	0	8	29	2	
D	74	74	67	70	9.7	WNW	61	NW	1956	47	6.8	7	7	17	8	2	0	1	0	22	31	14	
YR	73	78	56	54	10.7	WNW	72	W	JUL. 1946+	62	6.2	94	108	163	96	13	34	12	21	86	186	53	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 114 in July 1936; lowest temperature -45 in February 1936 and earlier; maximum monthly precipitation 9.90 in June 1914; maximum precipitation in 24 hours 3.76 in June 1914; maximum monthly snowfall 31.0 in November 1896.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≦ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are; temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North: i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

\# To 8 compass points only.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

APPENDIX, Table I (Continued) SITE: BISMARCK, NORTH DAKOTA (MUNICIPAL AIRPORT)

CLIMATE CLASSIFICATION: HUMID MICROTHERMAL; Dbf, Humid Continental (Cool Summer)

STANDARD TIME USED: CENTRAL

LATITUDE: 46°46' N

LONGITUDE: 100°45' W

ELEVATION (Ground): 1647 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year
(a)	(b)	(b)	(b)	9		9		(b)	(b)	21		21		21	
J	-.8	-21.4	-11.1	38	1965	-61	1969	2359	0.89	1.92	1957	0.01	1966	0.58	1968
F	9.5	-15.3	-2.9	43	1970	-56	1968	1901	0.52	1.75	1966	0.07	1958	0.97	1966
M	23.5	-5.7	8.9	51	1970	-46	1964	1739	0.40	2.10	1963	T	1968	0.92	1963
A	42.1	16.6	29.4	63	1969	-21	1964	1068	0.25	0.84	1967	T	1969+	0.31	1965
M	59.1	35.1	47.1	81	1964	-1	1964	555	0.71	1.67	1955	0.07	1957	0.88	1955
J	71.1	45.6	58.4	96	1969	37	1970+	222	1.39	3.52	1955	0.19	1966	1.52	1955
J	71.7	47.6	59.7	89	1968	37	1964	171	1.84	4.35	1962	0.40	1957	1.63	1962
A	65.3	43.2	54.3	85	1966	30	1965	332	2.20	6.20	1967	0.40	1957	3.42	1967
S	53.9	33.3	43.6	80	1963	11	1972	642	1.10	3.05	1960	0.15	1968+	1.21	1954
O	35.4	17.0	26.2	65	1969	-15	1965	1203	0.85	1.84	1970	0.08	1954	0.68	1970
N	13.4	-5.6	3.9	46	1970	-43	1964	1833	0.60	3.32	1970	T	1953	0.84	1970
D	2.1	-17.5	-7.7	42	1969+	-56	1964	2254	0.54	2.29	1970	T	1969	1.25	1968
YR	37.2	14.4	25.8	96	JUN. 1969	-61	JAN. 1969	14279	11.29	6.20	AUG. 1967	T	DEC. 1969+	3.42	AUG. 1967

Month	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity: Hour 02 (Local time)	Hour 08	Hour 14	Hour 20	Wind &: Mean speed	Prevailing direction	Fastest mile: Speed	Direction	Year
(a)	21	21		21		9	9	9	9	21	12	21	21	
J	10.7	26.3	1957	9.4	1968	67	68	68	68	2.7	N	29	27	1954
F	10.6	43.1	1966	20.1	1966	64	64	62	65	3.9	N	33	27	1955
M	7.5	29.6	1963	12.6	1963	64	63	53	61	4.9	N	40	22	1970
A	3.9	11.1	1967	4.9	1962+	65	60	48	55	6.5	N	31	23	1965
M	0.8	4.7	1964	4.5	1964	66	53	38	45	7.6	N	31	29	1955
J	T	T	1953+	T	1953+	69	58	40	46	6.8	SW	30	21	1971
J	0.0	0.0		0.0		78	68	50	56	6.4	SW	29	09	1957
A	T	T	1969+	T	1969+	82	77	53	67	6.0	N	34	27	1954
S	1.2	7.8	1972	7.0	1972	77	75	51	66	6.0	N	29	21	1971
O	9.5	24.2	1961	7.6	1970	77	77	66	74	5.4	N	40	25	1958
N	13.0	54.0	1970	14.6	1970	74	74	73	74	4.0	N	35	25	1970
D	13.2	33.5	1965	14.7	1968	69	69	68	69	3.1	N	37	24	1970
YR	70.4	54.0	NOV. 1970	20.1	FEB. 1966	71	67	56	62	5.3	N	40	22	MAR. 1970+

Month	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max: 90° and above ‡	Max: 32° and below	Min: 32° and below	Min: 0° and below	** Average daily solar radiation - langleys
(a)		21	21	21	21	21	21	21	21	9	9	9	9	
J		5.9	10	6	15	7	3	0	5	0	31	31	29	
F		6.7	7	5	16	8	3	0	2	0	26	28	23	
M		6.0	9	7	15	6	3	0	1	0	22	31	19	
A		6.9	6	7	17	5	1	0	*	0	7	28	3	
M		7.0	4	10	17	6	*	*	*	2	*	9	*	
J		7.3	3	10	17	10	0	2	*	19	0	0	0	
J		7.6	3	8	20	12	0	2	1	20	0	0	0	
A		7.9	2	7	22	13	0	1	2	9	0	1	0	
S		7.5	5	6	19	9	*	*	1	1	*	10	0	
O		8.0	3	6	22	10	4	0	2	0	17	28	4	
N		6.9	7	5	18	10	4	0	1	0	28	30	18	
D		6.9	7	6	18	8	4	0	4	0	30	31	26	
YR		7.0	66	83	216	103	22	5	20	52	162	227	122	

Ø For period September 1963 through the current year.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 99 in July 1919; lowest temperature -66 in January 1934; maximum monthly precipitation 6.88 in August 1930; minimum monthly precipitation 0.00 in February 1919; maximum monthly snowfall 65.6 in January 1937.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

APPENDIX, Table I (Continued) SITE: FAIRBANKS, ALASKA (INTERNATIONAL AIRPORT)

CLIMATE CLASSIFICATION: HUMID MICROTHERMAL; Dc, Subarctic

STANDARD TIME USED: ALASKAN

LATITUDE: 64°49' N

LONGITUDE: 147°52' W

ELEVATION (Ground): 436 feet

NORMALS, MEANS, AND EXTREMES

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	23		23		(b)	(b)	23		23		23		23	23		23	
J	40.4	14.1	27.3	66	1971	-22	1971	1169	1.83	6.46	1957	0.00	1972	1.78	1952	14.7	44.3	1955	16.6	1962
F	42.6	16.5	29.6	67	1963	-16	1965+	991	1.78	4.15	1962	T	1967	1.72	1965	13.3	42.1	1969	17.6	1959
M	49.5	21.6	35.6	73	1966	-16	1966	911	1.45	6.75	1970	T	1972	2.96	1970	17.7	67.3	1970	26.3	1970
A	58.6	28.0	43.3	78	1962	0	1965	651	1.18	5.62	1965	0.09	1962	1.47	1965	9.2	58.3	1965	15.9	1967
M	67.8	34.0	50.9	87	1951	16	1955	437	0.51	2.02	1957	T	1970+	1.11	1965	2.2	7.1	1951	6.6	1965
J	77.3	41.6	59.5	96	1970	22	1955+	180	0.69	2.92	1955	T	1963+	2.79	1956	T	T	1955	T	1955
J	81.4	49.6	65.5	94	1972	32	1955	46	2.28	5.23	1964	0.32	1963	2.55	1964	0.0	0.0		0.0	
A	78.9	48.8	63.9	89	1972+	24	1968	68	2.84	5.50	1951	0.26	1962	2.65	1951	0.0	0.0		0.0	
S	74.6	42.3	58.5	90	1950	23	1971+	201	1.58	6.60	1958	T	1957+	3.43	1965	0.1	2.0	1965	2.0	1965
O	63.2	30.7	47.0	83	1950	-2	1971	558	1.52	9.86	1972	T	1952+	2.73	1972	2.4	24.7	1971	11.4	1971
N	51.4	20.7	36.1	72	1967	-13	1958	867	1.00	4.97	1965	0.05	1956	2.30	1957	7.5	25.0	1952	13.4	1952
D	43.9	16.9	30.4	68	1950	-18	1971	1073	1.65	7.30	1967	T	1958	3.11	1951	16.2	86.0	1967	27.3	1967
YR	60.8	30.4	45.6	96	JUN. 1970	-22	JAN. 1971	7152	18.31	9.86	OCT. 1972	0.00	JAN. 1972	3.43	SEP. 1965	83.3	86.0	DEC. 1967	27.3	DEC. 1967

Month	Relative humidity: Hour 05 (Local time)	Hour 11	Hour 17	Hour 23	Wind &: Mean speed	Prevailing direction	Fastest mile $: Speed	Direction	Year	Pct of possible sunshine #	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max: 90 and above ‡	Max: 32 and below	Min: 32 and below	Min: 0 and below	Average daily solar radiation - langleys
(a)	18	18	11	11	11	2	11	11			23	23	23	23	23	23	23	23	23	23	23	23	
J	74	51	48	68	7.7	NE	37	02	1962		5.3	13	5	13	6	4	*	1	0	5	30	4	
F	73	49	42	63	7.5	S	30	02	1963		4.9	12	6	10	6	3	*	1	0	3	28	2	
M	70	41	35	59	8.1	SSW	31	23	1966		5.0	13	7	11	6	4	1	1	0	2	30	1	
A	66	35	30	54	8.8	SSW	35	20	1969	91	4.6	13	8	9	5	2	1	1	0	*	25	*	
M	63	27	23	46	8.1	SSW	29	01	1967+	91	3.9	16	9	6	3	1	2	*	0	0	15	0	
J	57	24	21	42	8.0	SSW	31	16	1962	81	2.9	19	7	4	3	0	4	*	1	0	3	0	
J	69	33	39	59	6.1	SSW	23	21	1971+	82	5.5	9	13	9	11	0	16	*	1	0	*	0	
A	77	40	47	71	5.5	S	35	30	1970	76	5.4	9	13	9	11	0	17	*	0	0	*	0	
S	74	37	38	67	6.5	S	40	01	1965	84	3.4	17	9	4	6	*	7	*	*	0	3	0	
O	73	39	36	63	6.6	N	28	05	1967	51	3.4	18	6	7	5	1	2	1	0	*	19	*	
N	73	44	43	67	7.8	NNE	32	02	1964	66	4.1	16	6	8	5	2	1	1	0	1	28	1	
D	73	51	58	78	8.0	NE	29	23	1966+	65	4.7	14	6	11	6	3	*	2	0	5	30	3	
YR	70	39	38	61	7.4	SSW	40	01	SEP. 1965		4.4	169	95	101	74	20	52	9	2	16	214	10	

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Lowest temperature -30 in January 1937; maximum monthly precipitation 8.77 in August 1904; minimum monthly precipitation also 0.00 in June 1942 and earlier dates; maximum precipitation in 24 hours 3.59 in November 1919; maximum monthly snowfall 104.8 inches in January 1949.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

\# Added to observational program 4-1-72.

$ Through 1971.

APPENDIX, Table I (Continued) SITE: FLAGSTAFF, ARIZONA (PULLIAM AIRPORT)

CLIMATE CLASSIFICATION: UNDIFFERENTIATED HIGHLANDS

STANDARD TIME USED: MOUNTAIN

LATITUDE: 35°08' N

LONGITUDE: 111°40' W

ELEVATION (Ground): 7006 feet

Appendix Table II. Annual Mean Daily Solar Radiation, Total and Percent Sunshine, and Mean Sky Cover at Sites Listed in Table 4

Location	Mean Daily Solar Radiation[a] langleys	Annual Hours Sunshine[b]	Percent Possible Sunshine[c]	Mean Sky Cover, Sunrise to Sunset[d]
San Juan, P. R.	512	2878	64	5.9
Miami, Florida	447	2903	64	5.8
Great Falls, Montana	356	2884	64	6.4
Havre, Montana	---	2874	67	6.4
Las Vegas, Nevada	504	3838	86	3.4
Phoenix, Arizona	503	3832	86	3.4
Yuma, Arizona	---	4077	91	2.7
Washington, D. C.	350	2576	57	6.0
Baltimore, Maryland	---	2653	58	5.9
Atlantic City, N. J.	---	----	55	6.1
Fort Worth, Texas	435	2911[e]	68	5.2
Seattle, Washington	302	2019	48	7.4
Astoria, Oregon	302	----	--	7.6
Eureka, California	---	2198	50	6.9
Minneapolis-St. Paul, Minn.	---	2607	58	6.1
Bismarck, North Dakota	366	2686	62	6.2
Fairbanks, Alaska	228	2105	44	7.0
Flagstaff, Arizona	---	----	--	4.4

a. From Local Climatological Data, 1971 Annual Summary, except for San Juan, Puerto Rico, data for which were taken from Climate Atlas of the United States, June 1968, covering a period of 6 years. This data does not appear in the 1972 Annual Summaries, which generally include a footnote: "The National Weather Service considers the accuracy of solar radiation data questionable; therefore publication is suspended pending determination of corrected values".

b. From Climate Atlas of the United States, June 1968, covering the period 1931-1960.

d. From Local Climatological Data, 1972 Annual Summaries with the following exceptions:

Data for Miami from Climatography of the United States, No. 60-8, Climates of the States, published March 1959 and revised November 1962.

Data for Fairbanks from Climatography of the United States, No. 60-49, Climates of the States, published September 1959.

Data for Fort Worth from Climate Atlas of the United States, June 1968.

d. From Local Climatological Data, 1972 Annual Summaries.

e. Data from Dallas, Texas.

Appendix Table III. Number of Months of Freezing and Thawing[a] at Locations Listed in Table 4

San Juan, Puerto Rico	0
Miami, Florida	0
Great Falls, Montana (Feb., March, April, November, December)	5
Havre, Montana (March, April, October, November)	4
Las Vegas, Nevada (January)	1
Phoenix, Arizona	0
Yuma, Arizona	0
Washington, D. C. (January, February, December)	3
Baltimore, Maryland (January, February, December)	3
Atlantic City, New Jersey (January, February, March, December)	4
Fort Worth, Texas	0
Seattle, Washington	0
Astoria, Oregon	0
Eureka, California	0
Minneapolis, Minnesota (March, November)	2
Bismarck, North Dakota (March, April, November)	3
Fairbanks, Alaska (April, October)	2
Flagstaff, Arizona (Jan., Feb., March, April, Oct., Nov., Dec.)	7

a. In which the normal daily maximum is above freezing and the normal daily minimum is freezing (32 deg. F) or below.

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NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS-TN-838	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE The Use of Weather and Climatological Data in Evaluating the Durability of Building Components and Materials			5. Publication Date August 1974
			6. Performing Organization Code
7. AUTHOR(S) Larry W. Masters and Winthrop C. Wolfe			8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			10. Project/Task/Work Unit No.
			11. Contract/Grant No.
12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)* Department of Housing & Urban Development 451 7th Street, SW Washington, D.C. 20410			13. Type of Report & Period Covered Interim
			14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

Library of Congress Catalog Card Numbers: 74-600106

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The durability of building components and materials is dependent, to a large extent, on the in-service environment to which they are subjected in service. Thus, the prediction of durability requires knowledge of the service environment.

Weathering factors, which comprise one group of environmental factors, are the subject of this report. The objectives of this report are to indicate how, in the present state of knowledge, weather and climate data can be used to aid in quantifying weathering factors so that durability tests for building components and materials may be designed.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Accelerated aging; building components and materials; climatological data; durability; environmental factors; long-term tests; short-term tests; weathering factors.

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