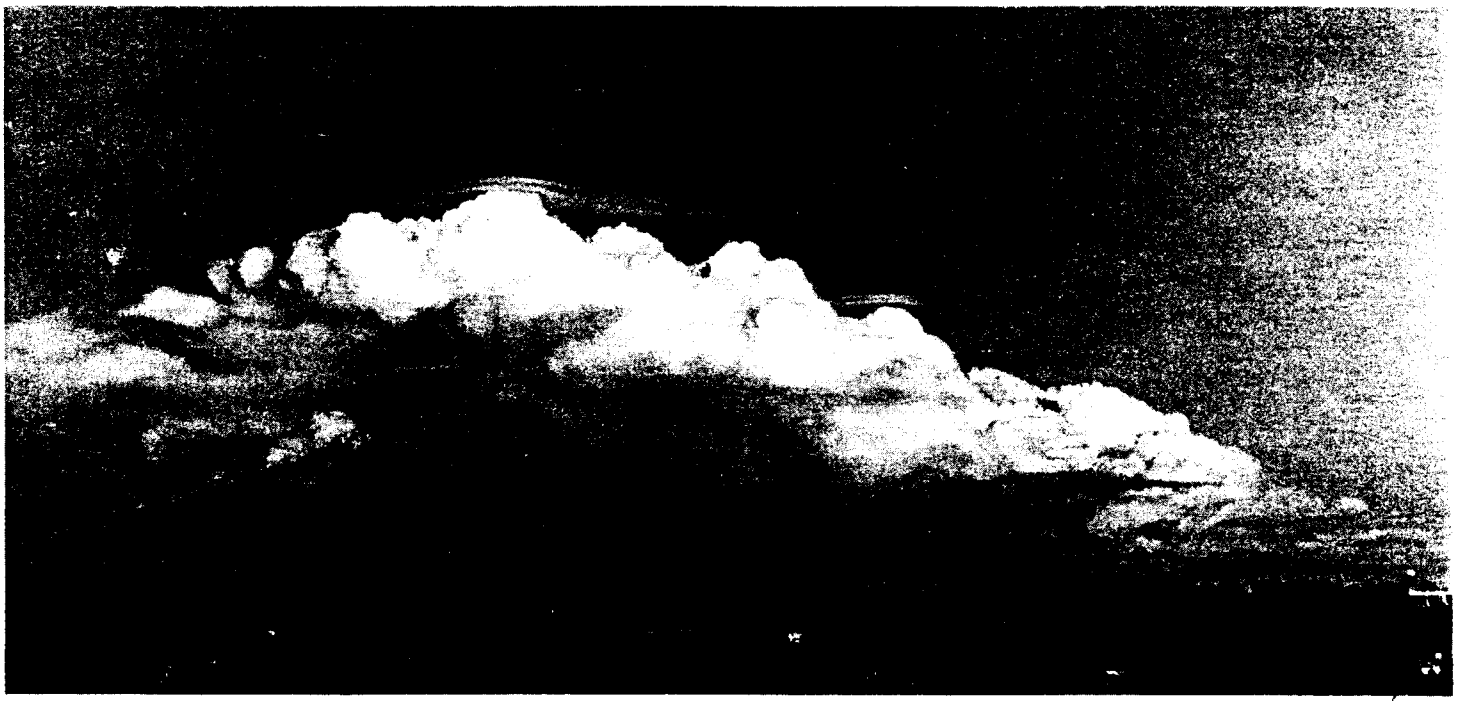
LA-12232-MS

Los Alamos Environmental Restoration Records Processing Facility

ER Record I.D.# 0012016

Los Alamos Climatology Summary



3476

Los Alamos
NATIONAL LABORATORY

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy unaer contract

ENG-36

Edited by Lori S. Tamura, Group IS-11
Composition by Belinda Harrigan, Group EM-8

Cover photo: Cluster of cumulus congestus clouds indicating distant thunderstorms. Several cumulus tops are capped by thin, wavy, cirrus clouds. (Photo taken toward the southeast from Mountain School, Los Alamos, by Brent Bowen.)

An Affirmative Action/Equal Opportunity Employer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither The Regents of the University of California, the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by The Regents of the University of California, the United States Government, or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of The Regents of the University of California, the United States Government, or any agency thereof.

LA-12232-MS

UC-902
Issued: March 1992

Los Alamos Climatology Summary

Including Latest Normals from 1961–1990

Brent M. Bowen

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Contents

Preface ..... *vix*
Acknowledgments ..... *xi*
Abstract ..... *xiii*

1 Background **1**

1.1 Geography 1
1.2 Large-Scale Atmospheric Flow 2
1.3 Observation Network 3

2 Los Alamos Climatology Summary **7**

2.1 Temperature 8
2.2 Precipitation 9
2.3 Changes in Latest Normals 15
2.4 Surface Winds 15
2.5 Humidity 18
2.6 Sunshine 18
2.7 Atmospheric Pressure 19
2.8 Atmospheric Dispersion 19

3 Other Weather Phenomena **21**

3.1 Tornadoes and Dust Devils 21
3.2 Thunderstorms, Lightning, and Hail 21
3.3 Floods 22
3.4 Winter Storms 23
3.5 Ice 23
3.6 Heavy Snow Loading 23
3.7 Wind 24
3.8 Dust, Haze, and Smoke 24
3.9 Fog 25
3.10 Drought 25
3.11 Heat Waves 25
3.12 Cold Waves 25
3.13 Optical Phenomena 26

Appendixes **29**

A Historical Locations of Weather Stations 29
B Degree-Days....31
C Growing-Season Data 33
D Unit Conversion Factors 37

References **41**

Figures

1.1 Regional location of Los Alamos 1
1.2 Aerial view looking west across the Pajarito Plateau toward the Jemez Mountains 2
1.3 Map showing meteorological tower locations and site numbers 4
2.1 Monthly normal temperatures, precipitation, and snowfall at Los Alamos and White Rock 7
2.2 Summer and annual mean precipitation at Los Alamos 13
2.3 Annual day and night wind roses for Los Alamos at TA-50, East Gate, Area G and Bandelier 17

Tables

1.1 Sites and types of meteorological data measured 4
2.1 Monthly mean temperatures and precipitation and median precipitation at Los Alamos and White Rock 8
2.2 Normal means, and extremes (1911-1991) 10
2.3 Three-hour weather variables at two sites for January, April, July, and October 12
A.1 Historical weather station locations (for temperature and precipitation) 30
B.1 Los Alamos and White Rock heating degree-days (65°F base) 31
B.2 Los Alamos and White Rock cooling degree-days (65°F base) 32
C.1 Los Alamos growing-season data, 1919-1990 34
C.2 White Rock growing-season data, 1965-1990 35
D.1 Length conversion factors 38
D.2 Temperature and atmospheric pressure conversion factors 39

Distant pair of mature, cumulonimbus clouds or "thunderheads" with well-developed anvils. (Photo taken toward the south at Ashley Pond, Los Alamos, by Brent Bowen.)

Preface

This report is primarily intended to give the reader a general description of Los Alamos climate. In addition, 30-year normals of weather variables have been updated to include the 1961-1990 period. Engineers, scientists, and other individuals who desire more complete or detailed climatological information or data should read "Los Alamos Climatology," LA-1173-MS (Bowen, 1990).

Because this report is written for a large audience, and because English units are still the standard in National Oceanic and Atmospheric Administration (NOAA) measurements, reporting, and publications, familiar English units are used. Conversion charts are provided in the appendix to enable the reader to convert from English to metric units.

The Los Alamos National Laboratory's Environmental Protection Group (EM-8) is responsible for monitoring effects of Laboratory operations on the environment. The Air Quality and Meteorology Section of EM-8 is responsible for operating a meteorological monitoring network and providing guidance during a possible emergency response resulting from an atmospheric release of toxic pollutants. Meteorological data are also used for routine environmental assessment, Clean Air Act compliance, atmospheric dispersion calculations, weather forecasting, and engineering design. The meteorological tower and monitoring network are maintained to fulfill US Department of Energy (DOE) environmental guidelines (DOE Orders 5400.1 and 5500.3A, and Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Serveillance-DOE/EH-0173T) and US Environmental Protection Agency (EPA) guidelines (On-Site Meteorological Program Guidance for Regulatory Modeling Application).

The Los Alamos cooperative weather station has been collecting general weather data and reporting that data to the National Weather Service since 1910. At that time, the Boys Ranch School began measuring daily precipitation (including snowfall) in what is now Los Alamos. Daily high and low temperatures were added in 1918. The Laboratory took over the cooperative weather station during World War II. The EM-8 Group continues to measure daily high and low temperatures, precipitation, snowfall, and general weather conditions and reports them daily to the Albuquerque National Weather Service Office. The daily reports are distributed to regional television stations, radio stations, newspapers, and reported over the NOAA weather radio and wire service. The National Climatic Center also maintains long-term averages of country-wide cooperative weather data, including those at Los Alamos.

Acknowledgments

I am grateful to Bill Olsen (Environmental Protection Group, EM-8) for his diligence in running our meteorological network and for reviewing the initial draft of this report. Thanks also go to Jean Dewart and Greg Stone for their large efforts in data quality and acquisition and for providing technical reviews of this report. The figures in this report were created by IS-12. Finally, I wish to thank Ken Hargis (Group Leader), Roger Ferenbaugh (Deputy Group Leader), and Craig Eberhart (Section Leader, Air Quality and Meteorology) for committing resources and encouragement for the meteorology effort in EM-8.

Lori Tamura (IS-11) cheerfully edited this report, thereby making it more understandable and accurate. A special thanks goes to Belinda Harrigan (EM-8) who skillfully and quickly composed this report.

Abstract

This report contains a summary of Los Alamos climate and analyses of basic weather variables from late 1910 through 1991. The first few sections offer a description of the local geography and large-scale weather patterns that affect Los Alamos. Temperature and precipitation analyses are presented in the next few sections. Updated 30-year temperature and precipitation normals ending in 1990 are shown for Los Alamos and White Rock. Normal snowfall is also shown for Los Alamos. Extremes of temperature, precipitation, and snowfall and averages of weather variables are also given. A section then discusses the changes of the latest 30-year normals. Another section describes the winds in Los Alamos. Brief descriptions of, humidity, sunshine, atmospheric pressure, and pollutant dispersal appear in following sections. The report ends with brief descriptions of other weather phenomena that occur in Los Alamos. Appendices include locations of weather stations, normal heating and cooling degree-days, growing-season data, and English/metric unit conversions.

1 Background

1.1 Geography

The Los Alamos National Laboratory and the communities of Los Alamos and White Rock are located in Los Alamos County in north-central New Mexico. By air, the Laboratory is located approximately 60 miles (100 km) NNE of Albuquerque and 25 miles (40 km) NW of Santa Fe (Fig. 1.1). Much of Los Alamos County is located on the Pajarito Plateau on the eastern flanks of the Jemez Mountains. The plateau slopes downward to the east-southeast, covering a distance of more than 15 miles (24 km) from the base of the Jemez Mountains (approximately 7800 ft [2380 m] above sea level [ASL]) to a location just above the Rio Grande River Valley (~6200 ft [1890 m] ASL). Numerous alternating "finger" mesas and canyons run along the plateau slope line (see Fig. 1.2). The canyons are 150–300 ft (46–91 m) deep and 300–600 ft (91–183 m) wide. The Sangre de Cristo Mountains lie nearly 40 miles (64 km) to the east. The Rio Grande Valley drains NNE to SSW between the two mountain ranges.

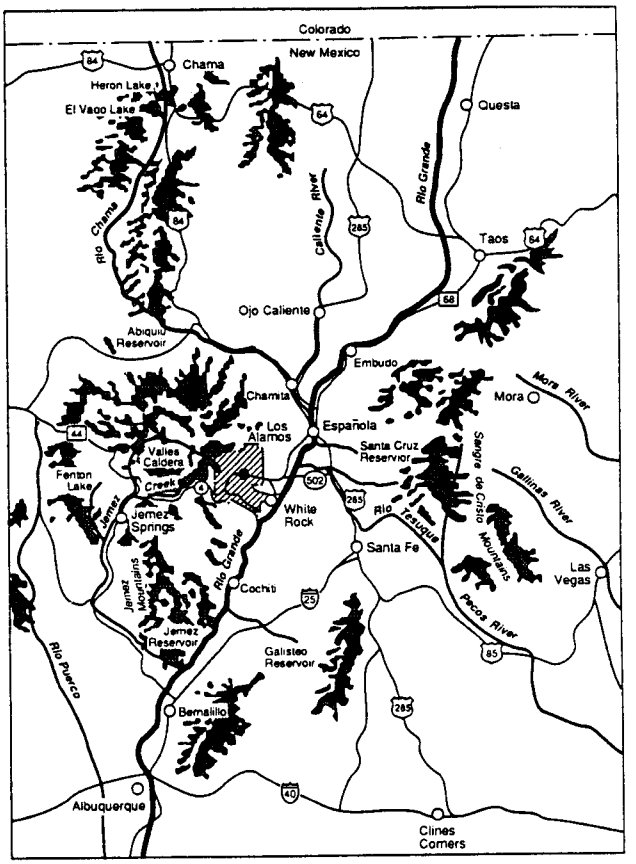


Fig. 1.1. Regional location of Los Alamos.

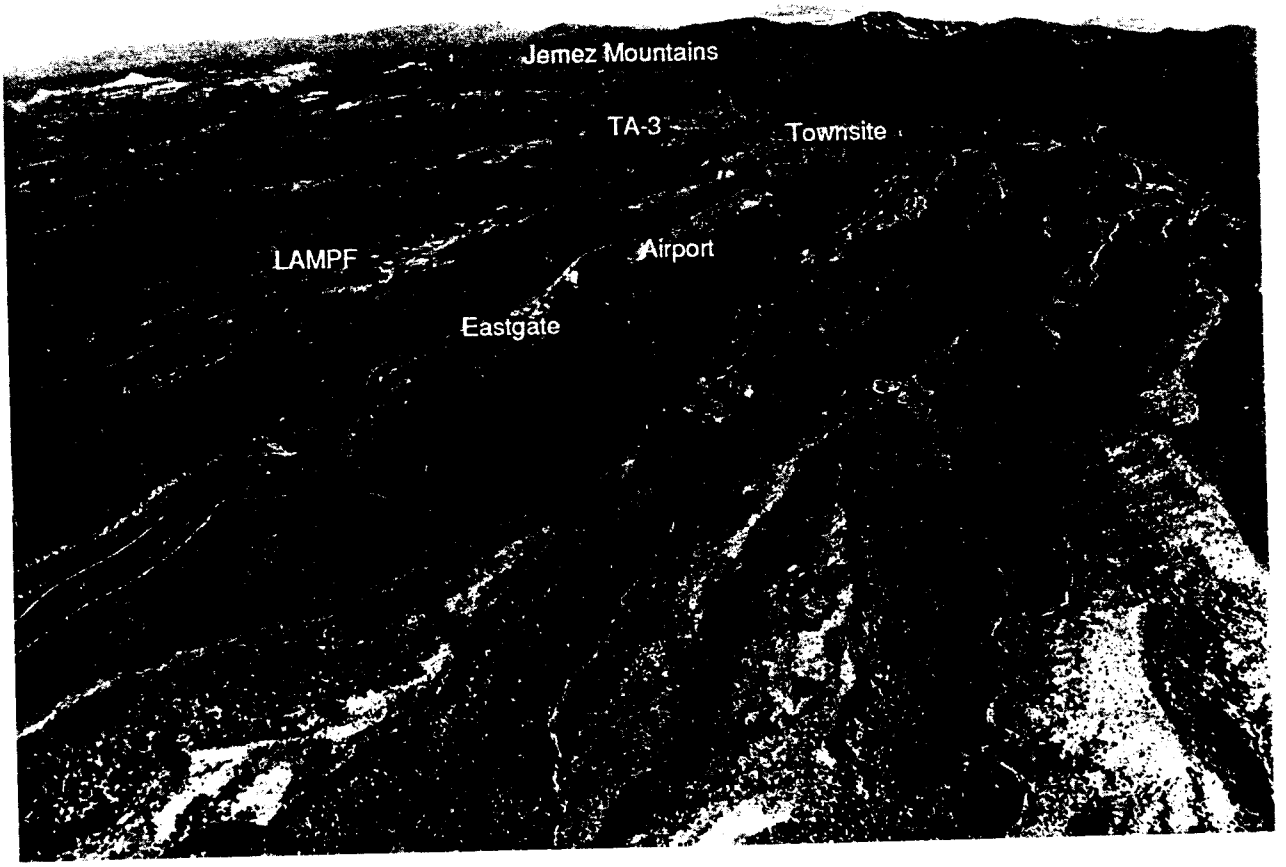


Fig. 1.2. Aerial view looking west across the Pajarito Plateau toward the Jemez Mountains. Los Alamos townsite, the main Laboratory Technical Area (TA-3), the Airport, and the East Gate entrance to Los Alamos are shown. The large technical area at the far left is the Los Alamos Meson Physics Facility (LAMPF) at TA-53.

1.2 Large-Scale Atmospheric Flow

Moisture is transported to north-central New Mexico from the Gulf of Mexico (800 miles [1300 km] to the southeast) and from the Pacific Ocean (800 miles [1300 km] to the west and 650 miles [1050 km] to the southwest). Moisture is transported readily from the Gulf of Mexico because the terrain is relatively smooth and low over most of the distance toward north-central New Mexico. Subtropical moisture from the Pacific Ocean is also transported to north-central New Mexico at times, although the route is over mountains and high terrain.

The terrain in southern California and northern Arizona squeezes out and obstructs much of the moisture transported from the Pacific Ocean lying to the west. Similarly, Pacific moisture transported from the southwest toward New Mexico must pass over the long stretch of mountainous and rough terrain in that direction. Finally, moisture in the westerly flow is also squeezed out by the Jemez Mountains as it reaches Los Alamos.

Northern New Mexico is located on the southern edge of the usual storm track or jet stream. During the cold season (autumn through spring), west-to-east-moving storms quite often bring clouds and precipitation. Storms that move through New Mexico can produce heavy rain and snow at times, and storms that pass just to the north of New Mexico can cause strong winds, especially during the spring. Upper low-pressure systems occasionally break off or cut off from the primary jet stream and establish themselves over the southwest United States. These "cutoff lows" also can produce heavy snows and rains over New Mexico, especially when a cold air mass is located over the state.

Occasionally, the jet stream is directed due southward toward New Mexico during winter, bringing frigid arctic or even Siberian air masses to the state. The jet stream is displaced northward to the northern United States and southern Canada during the summer. A high-pressure system is often located over the eastern United States or the western Atlantic (the "Bermuda" high), resulting in a weak southeasterly flow from the Gulf of Mexico or southerly flow from the Pacific toward New Mexico. This monsoon pattern provides Los Alamos with frequent thundershowers during the summer, especially during July and August.

1.3 Observation Network

The Laboratory's Environmental Protection Group (EM-8) Air Quality and Meteorology Section maintains a meteorological tower and monitoring network. Further information on meteorological monitoring, including quality assurance, can be found in EM-8's Quality Assurance Project Plan for Meteorological Monitoring (Olsen, 1991).

The meteorological data used were obtained from the sites given in Table 1.1. Present locations of the towers and sites are shown in Fig. 1.3. Measured meteorological variables include wind speed and direction, vertical wind speed, temperature, insolation, relative humidity, and precipitation. Not all variables are measured at each site, and some variables are measured at multiple tower levels. Measurements have been taken at the six towers at heights from 4 to 300 ft (1 to 92 m) above ground level (AGL).

Table 1.1. Sites and types of meteorological data measured.

Site Number (see Fig. 1.3)	Location	Elevation (ft ASL)	Wind and Temperature Sensor Height (ft AGL)	Sunshine	Surface Temperature (4 ft AGL)	Relative Humidity	Precipitation	Year Data Taken
1	North Community	7420	None	No	No	No	Yes	1986 - present
2	TA-16	7640	None	No	No	No	Yes	1974 - present
3	TA-59[a,d]	7380	4,[b] 72	Yes	Yes	Yes	Yes	1979 - 1990
4	Bandelier[a]	7040	4,[b] 38, 75, 150	Yes	Yes	Yes	Yes	1987 - present
5	East Gate[a]	7020	4,[b] 39	Yes	Yes	Yes	Yes	1981 - present
6	TA-54[a]	6690	4,[b] 34	Yes	Yes	Yes	Yes	1980 - present
7	White Rock Y	6380	None	No	No	No	Yes	1986 - present
8	White Rock	6380	4[b]	No	Yes	Yes	Yes	1964 - present
9	TA-50[a,e]	7270	4, 38, 75, 150, 300	No	No	No	No	1985 - 1988
10	TA-53[a,f]	6990	79	No	No	No	No	1984 - 1989
3	TA-6[a]	7425	4[a], 38, 75, 150, 300	Yes	Yes	Yes	Yes	1990 - present
3	cooperative weather data[c]	7425	4[b]	—	Yes	Yes	Yes	1911 - present

[a]Meteorological tower location.

[b]Temperature sensor only.

[c]The Laboratory has provided data to the National Weather Service Cooperative Observer Network since the 1940s. Data have been taken at TA-6 since 1990 and were taken at TA-59 from 1979 until 1990. See Appendix A for historical locations of weather stations.

[d]This tower was decommissioned January 1, 1991.

[e]This tower was removed from service April 6, 1989.

[f]This tower will be brought into service during 1991.

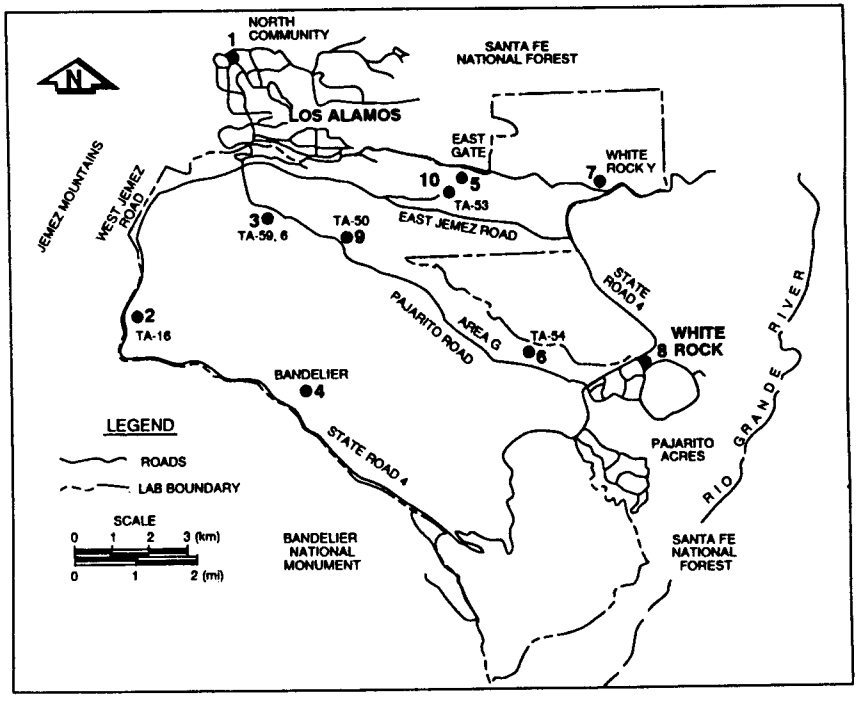


Fig. 1.3. Map showing meteorological tower locations and site numbers (see Table 1.1).

Los Alamos primary weather data (temperature, precipitation, and snowfall) have been taken at TA-6 since 1990. (Note that these data have also been provided to the National Weather Service Cooperative Observer Network.) Los Alamos weather data were measured at TA-59 from 1978–1990, located nearly 1/2 mile NNE of TA-6.

The weather data from 1956-1978 were taken at SM-43, located slightly less than 1 mile NNW of TA-6. The elevation has remained virtually the same for all three sites, changing only 45 feet. Based on the small changes of location and elevation since 1956, the official Los Alamos weather station has maintained a consistent site according to National Weather Service standards. In fact, the Los Alamos weather station has remained similar since its inception in 1910, except for much of 1950 and 1951, when the data were taken at the Los Alamos Airport.

Temperature, humidity, and precipitation have been measured at White Rock since late 1964. The location and elevation have remained virtually constant throughout the entire period. Although the latest 30-year normals were calculated with approximately 4-1/2 years of missing data, the calculated normal is expected to closely approximate actual 30-year normals ending in 1990.

Precipitation alone is also measured at three other sites.

Additional information on historical locations of weather stations in this network is provided in Appendix A.

2 Los Alamos Climatology Summary

Los Alamos has a semiarid, temperate mountain climate. Normal (30-yr mean) temperatures and precipitation for Los Alamos and White Rock, and snowfall for Los Alamos are plotted in Fig. 2.1 and listed in Table 2.1. Means and extremes of these and other climate variables for Los Alamos are also found in Table 2.2. Three-hour average values of weather variables for January, April, July, and October are given in Table 2.3 for two sites.

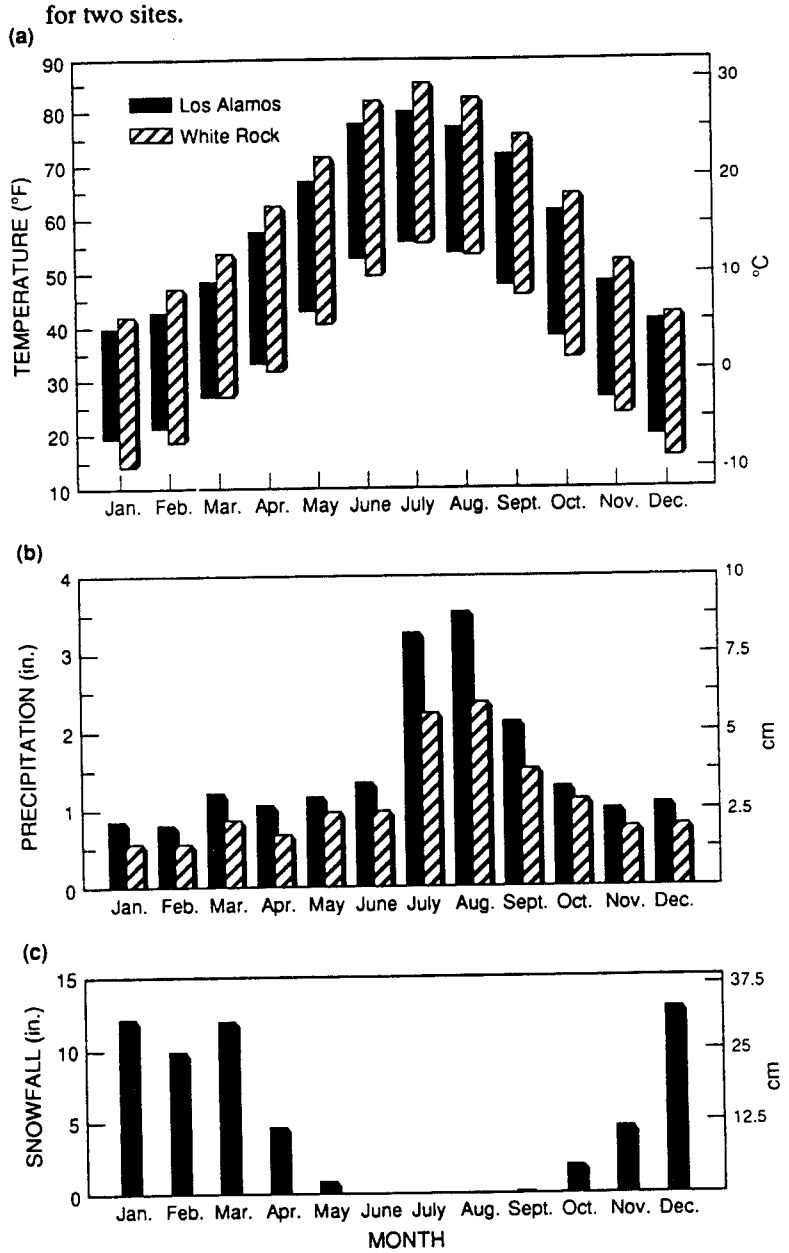


Fig. 2.1. Los Alamos (1961-1990) and White Rock (1965-1990) normal weather. The figure shows (a) temperature; (b) precipitation for both sites; and (c) snowfall for Los Alamos.

Table 2.1. Monthly mean temperatures and precipitation and median precipitation at Los Alamos and White Rock.[a]

	Temperature (°F)				Precipitation (in)	
	Maximum	Minimum	Average	Daily Range	Mean	Median
January	39.5 (41.7)	17.4 (14.6)	28.4 (28.1)	22.1 (27.1)	0.86 (0.57)	0.79 (0.67)
February	43.5 (46.5)	21.1 (19.5)	32.3 (33.0)	22.4 (27.0)	0.80 (0.58)	0.66 (0.48)
March	49.6 (54.9)	26.5 (26.4)	38.0 (40.6)	23.1 (28.5)	1.22 (0.87)	1.07 (0.72)
April	58.4 (63.1)	33.3 (33.1)	45.8 (48.1)	25.1 (30.0)	1.01 (0.68)	0.63 (0.44)
May	67.6 (72.0)	42.0 (41.3)	54.8 (56.6)	25.6 (30.7)	1.17 (0.97)	1.05 (0.96)
June	77.8 (82.7)	51.1 (50.6)	64.5 (66.7)	26.7 (32.1)	1.36 (1.00)	0.91 (0.82)
July	80.6 (85.6)	55.3 (55.9)	68.0 (70.7)	25.3 (29.7)	3.26 (2.23)	3.36 (2.05)
August	77.5 (82.5)	53.5 (54.0)	65.5 (68.3)	24.0 (28.5)	3.52 (2.37)	3.24 (2.21)
September	71.1 (76.0)	47.2 (46.5)	59.1 (61.2)	23.9 (29.5)	2.12 (1.52)	2.01 (1.55)
October	61.5 (65.5)	37.6 (35.2)	49.6 (50.3)	23.9 (30.3)	1.30 (1.13)	1.05 (0.60)
November	48.9 (52.7)	27.1 (24.6)	38.0 (38.7)	21.8 (28.1)	1.02 (0.77)	0.67 (0.56)
December	40.8 (43.0)	19.4 (16.1)	30.1 (29.6)	21.4 (26.9)	1.08 (0.81)	0.74 (0.59)
Annual	59.7 (63.9)	36.0 (34.8)	47.8 (49.3)	23.8 (29.0)	18.72 (13.50)	19.00 (13.52)

[a]White Rock temperatures are in parentheses.

2.1 Temperature

Despite Los Alamos' southern location, temperatures are cool at the nearly 7400-ft (2255-m) ASL elevation. Mean temperatures vary with altitude, averaging 5°F (3°C) higher in and near the Rio Grande Valley (6500 ft [1980 m] ASL) and 5°F to 10°F (3°C to 5.5°C) lower in the nearby Jemez Mountains (8500–10 000 ft [2600–3050 m] ASL).

Winter temperatures typically range from 15°F to 25°F (–9°C to –4°C) during the night and from 30°F to 50°F (–1°C to 10°C) during the day. Cold arctic air masses occasionally invade the Los Alamos area from the N and NE, but often the shallow layer of coldest air is dammed to the east by the Sangre de Cristo Mountains. Occasionally, Los Alamos temperatures drop to 0°F (–18°C) or below. The coldest nights occur with a cold-air mass over the area, fresh snow on the ground, light winds, and clear skies. During these conditions, overnight temperatures are even lower toward the valley. Many winter days are sunny with light winds, so the strong sunshine can make one feel quite comfortable, even when the temperature is low. Extremely low wind chills are rare in Los Alamos because strong winds usually do not occur with very cold temperatures.

Summers have moderately warm days and cool nights. Afternoon temperatures are in the 70s and 80s (°F) (21°C to 32°C) and occasionally reach 90°F (32°C), especially in White Rock. The relatively thin air, light winds, clear skies, and dry atmosphere cause nighttime temperatures to drop to the 50s (°F) (10°C to 15°C), even after the warmest day.

Daily temperature ranges are large at Los Alamos, especially during the summer. Differences between lowest and highest daytime temperatures normally vary between 25°F (14°C) in June and 21°F (12°C) in December and January. The temperature range averages 5°F (3°C) higher in White Rock, resulting primarily from higher daytime temperatures, especially in the summer, and lower nighttime/early morning temperatures, especially in the winter. The thin, dry air and frequent clear skies allow both strong daytime heating and nighttime cooling.

Wind direction can influence surface temperatures because of the large slope of the Pajarito Plateau. Adiabatic cooling (or warming) accompanies rising (or sinking) air movement. Specifically, S'ly or E'ly winds cool the air as the air rises over the plateau, and W'ly winds warm the air as the air descends. A wind switch can cause the temperature to rise or fall 5°F to 10°F (3°C to 6°C) from this effect alone.

The freeze-free growing season is 157 days in Los Alamos. The normal growing season in White Rock is 145 days.

2.2 Precipitation

Los Alamos County mean precipitation for the summer monsoon and the year are shown in Fig. 2.2.

Normal annual precipitation, which includes rainfall and water-equivalent snowfall, totals nearly 19 in. (48 cm). Annual precipitation falls off rapidly toward the valley, with the normal White Rock precipitation at 13.5 in. (34 cm). Annual precipitation normally totals more than 25 in. (64 cm) in the adjacent Jemez Mountains. The increasing amount of precipitation toward the mountains is especially noticeable during the summer when thundershowers develop over the mountains. Showers tend to form, or be stronger, over the mountains for much of the year. Also, winter storms associated with upslope winds drop more snow higher on the plateau.

Los Alamos precipitation is characteristic of a semiarid climate in that variations in precipitation from year to year are quite large. For instance, the annual precipitation extremes range from 6.80 to 30.34 in. (17.77 to 77.06 cm) over a 71-year period. The standard deviation over the same period was 4.81 in. (12.22 cm), or 25% of the mean. In 1986, 30.01 in. fell at the North Community site, near the Jemez Mountains.

Table 2.2. Normal means, and extremes.

Los Alamos, New Mexico Latitude = 35 °32′ N, Longitude = 106 °19′ W Elevation = 7380 ft

	Temperature (°F)										
	Normals (1961–1990)			Extremes (1911–1991)							
				High		Low		Record		Record	
	Maximum	Minimum	Average	Average	Year	Average	Year	Maximum	Date	Minimum	Date
January	39.5	17.4	28.4	37.6	1986	20.9	1930	64	1/12/81	−18	1/13/63
February	43.5	21.1	32.3	37.4	1934	23.0	1939	69	2/25/86	−14	2/01/51
March	49.6	26.5	38.0	45.8	1972	32.1	1948	72	3/09/89[a]	−3	3/11/48
April	58.4	33.3	45.8	54.3	1954	39.7	1973	79	4/23/38	5	4/09/28
May	67.6	42.0	54.8	60.5	1956	50.1	1957	89	5/29/35	24	5/01/76[a]
June	77.8	51.1	64.5	69.6	1990	60.4	1965	95	6/22/81	28	6/03/19
July	80.6	55.3	68.0	71.4	1980	63.3	1926	95	7/11/35	37	7/07/24
August	77.5	53.5	65.5	70.3	1936	60.9	1929	92	8/10/37	40	8/16/47
September	71.1	47.2	59.1	65.8	1956	56.2	1965	94	9/11/34	23	9/29/36
October	61.5	37.6	49.6	54.7	1963	42.8	1984	84	10/01/80	9	10/31/91
November	48.9	27.1	38.0	44.4	1949	30.5	1972	72	11/01/50	−14	11/28/76
December	40.8	19.4	30.1	38.4	1980	24.0	1990	64	12/27/80	−13	12/09/78
Annual	59.7	36.0	47.8	52.0	1954	46.2	1932	95	6/22/81[a]	−18	1/13/63

[a]Most recent occurrence (more than one occurrence).

	Means (1980–1987)								
	Relative Humidity (%)			Mean	Mean Wind			Percentage	Average
	Daily	Daily	Daily	Dew Point	Speed	Direction		of Possible	Station
	Maximum	Minimum	Average	(°F)	(mph)	Day	Night	Sunshine	Pressure (in.)
January	71	39	55	15.0	5.0	SSE	WNW	80.4	22.86
February	75	37	56	18.0	5.5	SSE	WNW	80.6	22.83
March	70	34	52	20.5	7.1	S,W	WNW	74.3	22.77
April	60	26	42	22.5	8.0	S,W	WNW	77.5	22.84
May	62	24	44	31.0	7.8	S,W	WNW	75.7	22.86
June	58	22	39	38.0	7.3	S	WNW	78.6	22.96
July	69	30	48	46.0	6.0	S	WNW	72.3	23.03
August	77	35	57	48.0	5.7	S	WNW	71.4	23.04
September	72	32	55	41.5	6.3	S	WNW	73.5	23.00
October	70	34	56	31.0	6.2	S	WNW	75.4	22.94
November	70	36	55	21.5	5.9	SSE	WNW	74.1	22.87
December	72	40	56	17.0	5.0	SSE	WNW	75.0	22.86
Annual	69	32	51	29.0	6.3	S	WNW	75.7	22.91

Table 2.2 (Continued)

	Precipitation (in.)											
	Water Equivalent						Snow					
	Normal Mean	Median	Max	Year	Max Daily	Date	Normal Mean	Median	Max	Year	Max Daily	Date
January	0.86	0.79	6.75	1916	2.45	1/12/76	12.1	11.3	64.8	1987	22.0	1/15/87
February	0.80	0.66	2.78	1987	1.05	2/20/15	9.9	5.2	48.5	1987	20.0	2/19/87
March	1.22	1.07	4.11	1973	2.25	3/30/16	12.0	7.4	36.0	1973	18.0	3/30/16
April	1.01	0.63	4.64	1915	2.00	4/12/75	4.6	2.5	33.6	1958	20.0	4/12/75
May	1.17	1.05	4.47	1929	1.80	5/21/29	0.9	0.0	17.0	1917	12.0	5/02/78
June	1.36	0.91	5.67	1986	2.51	6/10/13	—	—	—	—	—	—
July	3.26	3.36	7.98	1919	2.47	7/31/68	—	—	—	—	—	—
August	3.52	3.24	11.18	1952	2.26	8/01/51	—	—	—	—	—	—
September	2.12	2.01	5.79	1941	2.21	9/22/29	0.1	0.0	6.0	1913	6.0	9/25/13
October	1.30	1.05	6.77	1957	3.48	10/05/11	2.0	0.0	20.0	1984	9.0	10/31/72
November	1.02	0.67	6.60	1978	1.77	11/25/78	4.6	4.5	34.5	1957	14.0	11/22/31
December	1.08	0.74	3.21	1984	1.60	12/06/78	12.8	8.8	41.3	1967	22.0	12/06/78
Annual	18.72	19.00	30.34	1941	3.48	10/05/11	59.0	52.3	178.4	1987	22.0	1/15/87 &
Season									153.2	1986–87		12/06/78

	Mean Number of Days (1980–1987)										
	Temperature (°F)										
	Maximum		Minimum		Water Equivalent (in.)			Snowfall (in.)			
	90 and Above	32 and Below	32 and Below	0 and Below	0.01 or More	0.10 or More	0.50 or More	1.0 or More	4.0 or More	Thunder-storms	Fog (Visibility 0.6 mile [1 km] or less)
January	0.0	6.4	29.4	1.3	5.4	2.1	0.4	3.0	1.0	0.0	0.6
February	0.0	3.9	26.9	0.4	5.9	2.2	0.4	2.3	1.0	0.3	0.4
March	0.0	1.5	24.2	—	7.3	3.2	0.4	3.1	1.1	0.6	0.4
April	0.0	0.2	13.5	—	5.9	2.8	0.5	1.2	0.3	2.5	0.3
May	0.0	0.0	2.9	—	6.8	3.4	0.5	0.2	0.0	6.4	0.3
June	1.0	—	0.0	—	7.2	3.2	0.8	—	—	8.8	0.1
July	1.3	—	0.0	—	15.0	7.8	1.7	—	—	17.6	0.0
August	0.2	—	0.0	—	15.2	8.3	2.2	—	—	16.0	0.1
September	0.0	—	0.3	—	9.8	5.1	1.4	0.0	0.0	7.7	0.4
October	0.0	0.1	6.8	—	5.8	3.2	0.9	0.6	0.2	0.7	0.4
November	0.0	1.5	21.8	0.1	5.6	2.4	0.6	1.5	0.2	0.3	0.7
December	0.0	5.6	30.1	0.5	5.9	2.8	0.4	3.1	1.0	0.1	1.1
Annual	2.5	19.2	155.9	2.3	95.8	46.5	10.3	15.0	4.8	61.0	4.8

Table 2.3. Three-hour weather variables at two sites for January, April, July, and October (1980–1987).

	TA-59						TA-54 (Area G)				
Hour (MST)	Temp. (°F)	Dew Point (°F)	Relative Humidity (%)	Wind Direction	Wind Speed (mph)	Atmospheric Pressure (in.)	Temp. (F)	Dew Point (F)	Relative Humidity (%)	Wind Direction	Wind Speed (mph)
January											
03	25	14	61	N	5	22.87	24	15	70	N	5
06	24	13	65	N	4	22.87	22	15	73	N	5
09	28	15	58	NNE	4	22.88	25	16	67	NNE	5
12	35	16	46	SSE	6	22.88	34	18	50	NE,S	7
15	38	17	43	SSE	6	22.83	38	19	46	SSW	7
18	32	16	53	W	5	22.84	34	18	55	SSW	6
21	29	15	57	WNW	5	22.86	29	17	63	SW	6
24	27	14	59	WNW	5	22.87	26	16	67	N	6
April											
03	38	22	53	WNW	7	22.83	39	23	53	SSW	7
06	36	21	55	WNW	6	22.83	36	22	57	N	6
09	45	23	42	SE	7	22.87	46	24	43	NE,SSW	8
12	52	23	32	S	9	22.86	54	25	32	SSW	10
15	55	24	30	W	10	22.82	58	26	29	SSW	11
18	52	23	32	W	9	22.80	55	25	31	SSW	10
21	44	22	41	WNW	9	22.82	47	24	40	WNW	8
24	42	23	47	WNW	8	22.84	43	24	47	WSW	7
July											
03	59	45	59	WNW	5	23.02	61	46	57	WSW	5
06	58	46	65	WNW	4	23.03	59	47	63	N	5
09	68	47	47	SE	5	23.06	69	47	46	S	6
12	76	47	36	S	6	23.05	78	47	34	S	7
15	75	47	37	S	8	23.02	79	47	32	SSW	9
18	73	47	38	S	7	22.99	76	45	34	S	9
21	65	46	50	WNW	7	23.02	68	46	45	SW	8
24	62	46	52	WNW	6	23.04	65	46	49	SW	6
October											
03	41	30	66	NW	5	22.94	42	32	66	SW,WNW	6
06	39	29	70	NW	5	22.94	39	30	72	N	5
09	47	32	55	SSE	5	22.97	46	32	58	SSW	6
12	54	32	44	SSE	7	22.97	55	32	41	SSW	8
15	56	32	40	S	8	22.93	58	31	37	SSW	10
18	49	32	50	WNW	6	22.92	52	31	44	SSW	7
21	45	31	58	WNW	7	22.93	47	31	54	WNW	7
24	42	29	61	WNW	7	22.94	43	30	59	SW	6

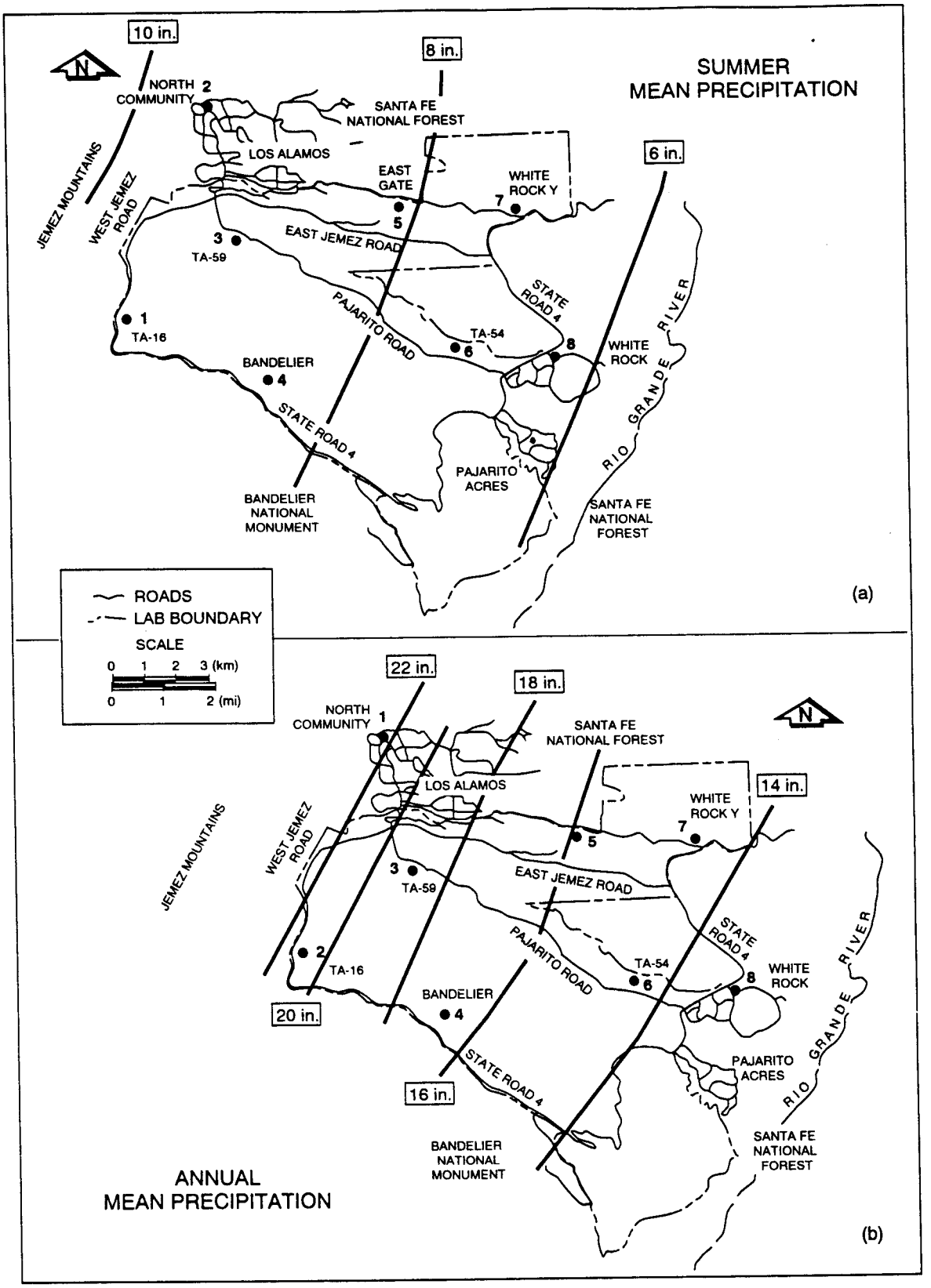


Fig. 2.2. (a) Summer monsoon (July - September) mean precipitation and (b) annual mean precipitation at Los Alamos. Isolines of precipitation are based on the eight sites shown on the maps.

Thirty-six percent of the annual precipitation falls in July and August during the height of the monsoon season. Thundershowers develop over the Jemez Mountains during the afternoons and early evenings and drift out over the Pajarito Plateau, causing brief, but frequently intense, rains. The rainfall is often accompanied by small hailstones. A SE'ly to S'ly wind pattern typically transports moisture from the Gulf of Mexico and the Pacific Ocean to New Mexico. This moisture, combined with strong surface heating, produces an unstable atmosphere that leads to clouds, thundershowers, and rain, especially over the mountains. Because upper-level winds most often have a westerly component, they frequently transport the thunderstorms formed over the Jemez Mountains toward Los Alamos.

Winter precipitation falls primarily as snow, with accumulations of about 59 in. (150 cm) seasonally. White Rock snowfall is not currently measured but is estimated to be 25 to 30 in. (64 to 76 cm) annually. Rainfall occurs occasionally during the winter, but freezing rain rarely occurs. Winter precipitation usually results from west-to-east-moving storms that originate over the Pacific Ocean; however, much of the Pacific Ocean moisture precipitates or dries out before reaching New Mexico. Gulf of Mexico or tropical Pacific moisture is occasionally tapped by storms, resulting in heavy snow or rain.

Snowfall varies considerably from season to season. The seasonal snowfall extremes range from the minimum 9.3 in. (23.6 cm) during 1949–1950 to the record 153.2 in. (389.1 cm) that fell during 1986–1987. Snowfall is greatest in December, followed by that in January and March.

Snowstorms with accumulations exceeding 4 in. (10 cm) are common in Los Alamos. However, heavy snow cover seldom remains in exposed areas for lengthy periods because of strong sunshine and relatively mild temperatures. A few storms are associated with strong winds, frigid air, and dangerous wind chills, especially in the mountains. Many of the large Los Alamos snowstorms are caused by a persistent upslope (S'ly or SE'ly) wind over the top of a shallow arctic air mass. The preceding conditions were responsible for the largest single snowfall on record, 48 in. (122 cm) during January 15–17, 1987, with 70 in. (178 cm) falling in the Los Alamos North Community.

The ratio of snowfall to water equivalent averages about 20 to 1 from November to February, although the ratio occasionally reaches 30 to 1 or higher. The large ratio (dryness) is typical of mountain areas where the air at the higher elevations is thinner and generally colder than at sea level and, therefore, can can hold less water vapor. The ratio generally is lower in the other months, averaging 15 to 1. Some very wet snows can yield ratios of 10 to 1 or lower.

2.3 Changes in Latest Normals

The normal temperature during the 30-year period ending 1990 was 47.8°F, or about 0.3°F below the average in the 30-year period ending 1980. The slightly cooler normal was quite small and spread out sporadically over various months. The latest normal nearly equals the average of 47.9°F during the entire temperature record from 1919 through 1990.

Annual precipitation increased to 19.72 inches in the latest 30-year period, an increase of 0.89 inches over the 30-year period ending 1980. Monthly averages increased in all months except for August and October, when decreases took place, and January, which remained essentially unchanged. The latest normal precipitation nearly equals the entire station record (1911–1990) average.

Normal annual snowfall showed a large increase of 8.2 inches during the latest 30-year period, averaging 59.0 inches. The increase was primarily caused by the snowy years in the 1980s, especially the yearly snowfalls of 178, 113, and 100 inches in 1987, 1984, and 1982, respectively. The normal snowfall increased in the heavier snowfall months of December through March; however, the normals remained the same or decreased in the other months that receive snow. The latest normal is about 5 inches above the entire station record normal.

2.4 Surface Winds

Surface (11–12 m AGL) winds are quite light at Los Alamos, averaging 7 mph (3 m/s). Winds are light because New Mexico lies at the southern edge of the band of W'ly winds common over central North America. Wind speeds are strongest from March through June and weakest in December and January. Intense storms and associated cold fronts, occurring especially during the spring months, cause the strongest winds. Sustained winds exceeding 25 mph (11 m/s) with peak gusts exceeding 50 mph (22 m/s) are common during the spring. Thunderstorms can also cause brief strong winds, especially during spring and summer. The strongest winds are generally SW'ly through NW'ly and occur in the afternoon or evening. The highest recorded wind gust in recent history was 77 mph (34 m/s) from the SSW at East Gate on November 15, 1988, resulting from a storm system moving through the Rockies. Thunderstorms produced 76-mph (34-m/s) peak gusts from the SE at both East Gate and Area G on May 9 and 27, 1989, respectively. Average night winds are WNW'ly at the western part of the Pajarito Plateau because of persistent cold-air drainage down the plateau. Daytime winds are generally SSE-SSW'ly, caused by upslope and up-valley winds, but daytime winds are also frequently W'ly during the windy season, March through May.

Mean, annually averaged wind directions are plotted in wind roses at four sites in Fig. 2.3. A wind rose is a circle with lines extending from the center representing the direction from which the wind blows. Open lines represent daytime and dark lines represent nighttime. The length of each line is proportional to the wind direction frequency. Each direction is 1 of 16 primary compass points (for example, N, NNE, etc.) and is centered on a 22.5°-wide sector. The frequency of calm winds, or winds with speeds < 1 mph, is given in the circle's center. Day and night are defined by the times of sunrise and sunset. The wind directions were taken at a height above ground of about 36 feet (11 m) at four sites: TA-50, East Gate, Bandelier, and TA-54. The wind direction at 300 ft (92 m) is also given for TA-50.

Los Alamos surface winds often vary dramatically with time of day, location, and height above ground because of the complex terrain. On days with sunshine and light, large-scale winds, a 600- to 1000-ft-deep (180- to 300-m-deep), thermally driven upslope wind develops over the Pajarito Plateau. Upslope winds are generally light, less than 6 mph (3 m/s). Winds usually become more SSW'ly and S'ly at locations toward the Rio Grande Valley, where a larger-scale, thermally driven, up-valley wind predominates. This wind can reach speeds of 11 mph (5 m/s).

With clear skies and light large-scale winds, these locally produced winds reverse at night. At sunset, shallow drainage winds from the W to NW begin to flow down the plateau, especially near the Jemez Mountains and in areas with a larger slope. These winds reach speeds of 6–8 mph (3–3.5 m/s). The annual wind roses show nighttime drainage winds are more frequent on the plateau. Toward the valley, the drainage winds are less frequent as valley winds become increasingly predominant. Wind directions at only 150 ft (46 m) or so above ground level (AGL) are often NNE'ly or SSW'ly, whereas surface winds are WNW'ly. One can see the shallowness of the drainage wind at TA-50, where the 300-ft winds follow the Rio Grande Valley and are dramatically different from those at the surface.

Late at night, a larger-scale and deeper drainage wind often flows down the Rio Grande River Valley, accounting for the frequent N-NE'ly winds at the TA-50, 300-ft level and at the other sites lower on the plateau. Because of the larger size of this wind, it often extends into the morning (and early afternoon in the winter) as can be seen in the daytime wind frequencies. By the same token, thermally driven, up-valley winds from the SSW-SW extend well into the evening. Some of the winds are also channeled along the valley, especially the N-NE'ly winds. Wind records (not shown) show that down-valley winds are more frequent in the winter when nights are longer and large-scale winds are more N'ly. Similarly, summer winds are more frequently up-valley because of longer days and less frequent N'ly large-scale winds.

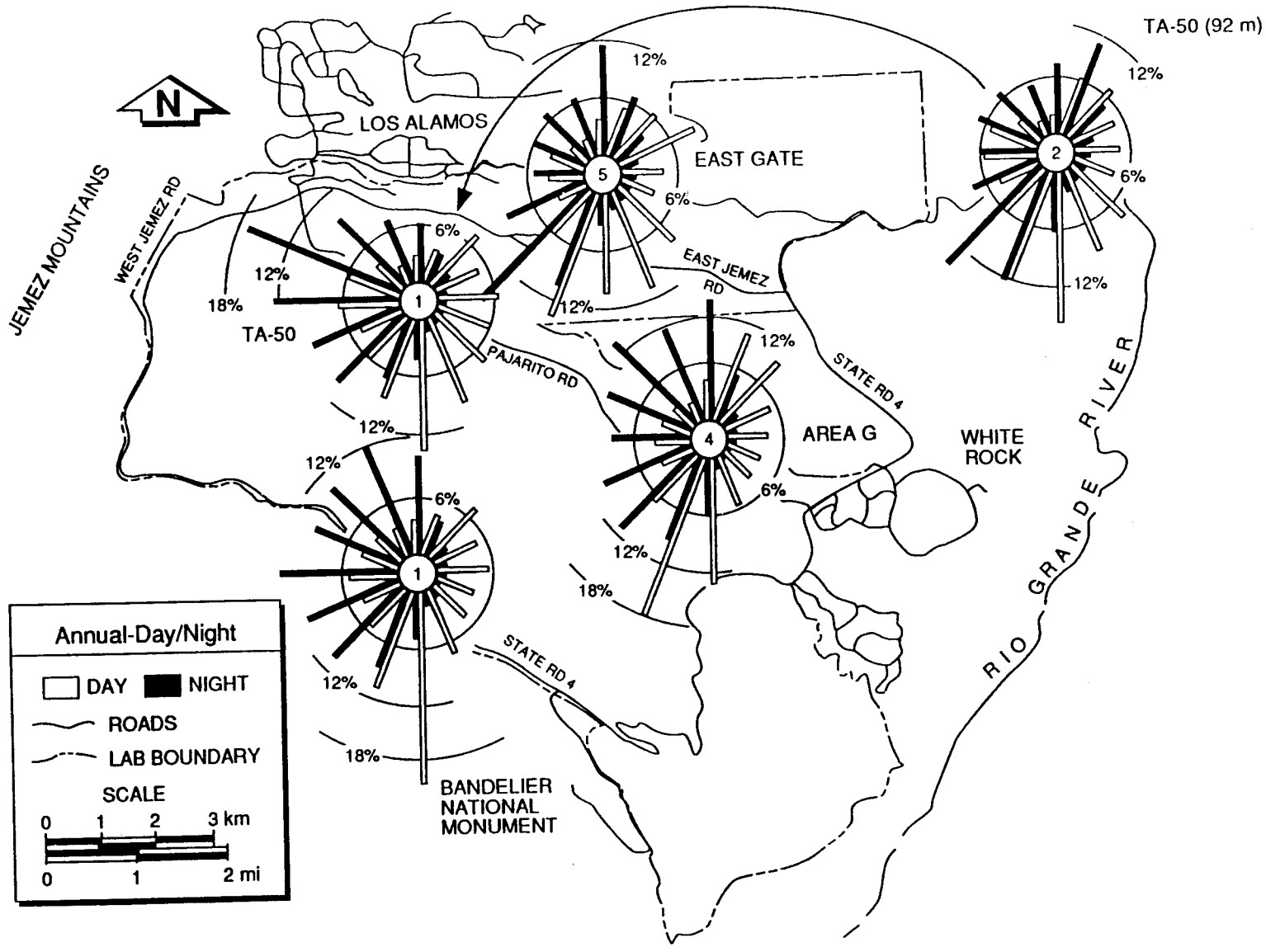


Fig. 2.3. Annual wind roses during daytime and nighttime for Los Alamos at TA-50, East Gate, Area G, and Bandelier. Winds were measured at a height of about 39 ft (11-12 m) for all sites and also at the 300 ft (93 m) level at TA-50.

2.5 Humidity

Atmospheric moisture content is relatively low in Los Alamos. Dew point, a good indicator of atmospheric water-vapor content, reaches a peak during July and August, averaging 46°F and 48°F (8°C and 9°C), respectively (see Table 2.2). During an active monsoon phase, the dew point reaches the 50s (°F) (10°C to 15°C) and occasionally even exceeds 60°F (15.5°C). In contrast, much of the eastern United States experiences dew points in the 60s and 70s (°F) (16°C to 26°C) and occasionally in the low 80s (°F) (27°C to 29°C) during summer. Therefore, even on the warmest days, conditions are quite comfortable in Los Alamos. The air is driest in the winter, with a mean dew-point temperature of 15°F (-9.5°C) in January. Indoor relative humidities can become extremely low (<5%), thereby requiring the use of a humidifier. The average atmospheric moisture content in August is nearly 7 times higher than in January.

Relative humidity, a variable strongly dependent on temperature, has a different annual distribution. The months from August through March have nearly the same relative humidity, averaging between 52% and 57%. The late spring and early summer months have the lowest relative humidity, with the minimum average of 39% occurring during June. Early summer relative humidity occasionally dips to 5% or less during warm afternoons. Relative humidities approaching 100% (saturation) occur frequently on cold winter mornings and also in the summer during showers and during mornings following showers.

Evaporation of free-standing water in Los Alamos is much greater than the amount of annual precipitation. Annual mean Class A pan* evaporation ranges from approximately 65 in. (165 cm) in the Jemez Mountains to 75 in. (190 cm) at White Rock (NOAA 1979). Annual lake evaporation is estimated to be 68% of the Class A pan evaporation, ranging from approximately 44 in. (112 cm) in the Jemez Mountains to 51 in. (130 cm) at White Rock.

2.6 Sunshine

Sunshine is plentiful at Los Alamos because of its southerly location and frequent clear skies. Los Alamos receives more than 75% of possible sunshine (measured incoming solar radiation) annually. Possible sunshine is defined as the amount received assuming a perfectly cloud-free sky. Sunshine is especially prevalent during January and February, when more than 80% of possible sunshine is received (see Table 2.2). The fraction of possible insolation received is almost as high in April and June, with 79% occurring in June.

*Class A pan refers to the standard pan that meteorologists and hydrologists use to measure evaporation of shallow, free-standing water.

Frequent thundershowers and clouds during the monsoon season decrease the percentage of possible insolation, with a minimum of 71% occurring during August. Even though cloudiness is greater during July and August than during January and February, Los Alamos receives twice as much sunshine during July and August because of the higher sun angle and longer days.

The high altitude with its thin air allows more sunshine to reach the ground. Therefore, care must be taken to protect exposed skin, especially during the summer, while engaging in water activities, and while skiing.

2.7 Atmospheric Pressure

The atmospheric pressure at 7380 ft (2249 m) ASL averages 22.91 in. (775.7 mbar) of mercury, or 76%–77% of the standard sea-level pressure. In other words, Los Alamos lies above more than 24% of the atmosphere. Similarly, the air density is about 75% of the standard sea-level air density.

Annual, seasonal, and diurnal pressure variations are modest at Los Alamos. Pressure reaches a minimum during March (averaging 22.77 in. [771.2 mbar]) when intense storms travel west to east across the central and southern Rockies. Average pressure reaches a maximum during the monsoon season, July and August, averaging 23.04 in. (780.1 mbar). The strong belt of subtropical high pressure is usually farthest north during this time of year.

The pressure displays a noticeable diurnal cycle on most days: a maximum during the late morning and a minimum during the late afternoon. This cycle results from the ground's diurnal heating and cooling of the low-level air (up to ~3000 ft [900 m] AGL). The effects of the atmospheric heating and cooling lag behind the surface maximum and minimum temperatures by several hours. A secondary cycle with smaller amplitude is apparent, especially during summer, when a secondary maximum occurs near midnight and a secondary minimum occurs 4 to 6 hours later. This secondary cycle agrees with other mid latitude stations and has no satisfactory explanation. (Berry etal., 1945)

2.8 Atmospheric Dispersion

The irregular terrain at Los Alamos favorably and unfavorably affects the consequences of an air-pollution release by affecting atmospheric turbulence and dispersion. Favorable effects occur because increased dispersion promotes greater dilution of contaminants released into the atmosphere. The complex terrain and forests create an aerodynamically rough surface, forcing increased horizontal and vertical turbulence and dispersion. Although the dispersion generally decreases at lower elevations where the terrain becomes smoother and less vegetated, the frequent clear skies and light winds cause good daytime

vertical dispersion, especially during the warm season. The strong daytime heating during the summer can force strong vertical mixing up to 4000–8000 ft (1200–2400 m) AGL.

Unfavorable effects occur because the generally light winds are limited in diluting contaminants horizontally. The same clear skies and light winds have a negative effect on dispersion at night, creating strong, shallow surface inversions. These inversions severely restrict near-surface vertical and, to a lesser extent, horizontal dispersion. The inversions are especially strong during the winter. Smoke from wood-burning stoves is often noticeable on clear winter evenings. Shallow drainage winds fill lower areas with cold air, thereby creating deeper inversions, which are common toward the Rio Grande Valley (White Rock) on clear nights with light winds. Canyons also limit dispersion by channeling air flow. Strong, large-scale inversions during the winter can limit vertical mixing to under 10 000 ft (3050 m) ASL.

Overall dispersion is greater in the spring during strong winds. However, deep vertical mixing is the greatest during summer afternoons when the atmosphere is well mixed up to 5000 ft (1500 m) or more AGL. Low-level dispersion is generally the least during summer and autumn when winds are light. However, even though low-level dispersion is generally greater in the winter, occasional intense surface inversions can greatly restrict low-level dispersion during nights and early mornings.

3 Other Weather Phenomena

3.1 Tornadoes and Dust Devils

Historically, no tornadoes have ever been reported in Los Alamos County. However, a funnel cloud in Santa Fe County was reported from White Rock on August 23, 1983. Also, numerous funnel clouds were reported near Santa Fe on August 24–25, 1987. A relatively strong tornado did occur in Albuquerque on September 20, 1985.

Because tornadoes occur more often at lower elevations, a tornado would be more likely toward the Rio Grande Valley than in Los Alamos. Besides being less likely in Los Alamos, tornadoes that might occur at the townsite or in the Jemez Mountains would be weaker than ones at lower elevations. Tornadoes occur in the afternoon, especially early afternoon, during the warm season. Fujita (1972) predicts a maximum wind speed of 200 mph (89 m/s) should a tornado occur in the Los Alamos area. The design wind speed was obtained by adding a 50-mph (22-m/s) safety factor to 150 mph (67 m/s), the upper wind-speed range of an "F2 tornado" that is possible, but unlikely, to occur in Los Alamos. The design tornado is estimated to have a maximum pressure drop of ~1.5 in. of mercury (40 mbar), a maximum pressure-change rate of 0.67 in./s (23 mbar/s), and a maximum rotational wind diameter of 100 ft (30.5 m).

Dust devils are more likely to cause locally damaging winds in Los Alamos. Fujita (1972) states that dust devils theoretically could develop uppermost F1 winds of 112 mph (50 m/s). Strong dust devils can commonly produce 75-mph (34-m/s) winds. Several have been reported that caused damage in Los Alamos. A strong dust devil on April 24, 1973, knocked a trailer off its supports and rolled it one complete revolution at Los Alamos Meson Physics Facility (LAMPF), causing extensive damage to the trailer and contents. Dust devils occur during sunny, warm days with light winds.

3.2 Thunderstorms, Lightning, and Hail

Thunderstorms are common at Los Alamos, with 61 occurring in an average year. A thunderstorm day is defined as a day in which either a thunderstorm occurs or thunder is heard nearby. Most thunderstorm days occur during July and August, the so-called monsoon season. During this time of year, large-scale southerly and southeasterly winds bring moist air into New Mexico, from the Gulf of Mexico and the Pacific Ocean. The combination of moist air, strong sunshine, and warm surface temperatures encourages the formation of afternoon and evening thundershowers, especially over the Jemez Mountains. Upper winds often move the thunderstorms over Los Alamos.

Lightning in Los Alamos can be frequent and intense during some thunderstorms, and people should avoid being outdoors during lightning activity. Because lightning can cause occasional brief power outages, lightning protection is, and should be, an important design factor for most facilities at the Laboratory and the surrounding area.

Hail is also very common at Los Alamos. In fact, the area around Los Alamos has the most frequent hailstorms in New Mexico (NOAA 1977). Typically, the hailstones have diameters of about 0.25 in. (0.6 cm), with a few somewhat larger. Some storms produce measurable accumulation on the ground. Rarely, hailstorms cause significant damage to property and plants. The most damaging hailstorm occurred on July 20, 1990, when golf-ball-sized and some baseball-sized hail pummelled homes, vehicles, and vegetation in White Rock. Nine million dollars of insurance claims were paid out. A thunderstorm on August 11, 1982, dropped about 3 in. (7.6 cm) of hail near the Los Alamos airport, primarily damaging windshields and vegetation in the area. Thunderstorms on May 9, 1989, dropped hailstones up to 1 in. (2.5 cm) in diameter at White Rock and the White Rock Y, causing damage to cars, roofs, and vegetation. The same storms left 2 in. (5 cm) of hail accumulation in the North Community.

Remnants of hurricanes and tropical storms originating in the Gulf of Mexico and the Pacific Ocean occasionally reach New Mexico during the summer and autumn. These storms are weak by the time they reach northern New Mexico and, therefore, do not produce strong winds. However, the storms can produce widespread and strong thunderstorms and heavy rains.

3.3 Floods

Large-scale flooding is not common in New Mexico. However, flash floods from heavy thunderstorms are possible in susceptible areas, such as arroyos, canyons, and low spots. During heavy thunderstorms, these areas should be avoided. Severe flooding has never been observed in Los Alamos. A heavy downpour combined with already saturated soil caused flash flooding in Los Alamos on August 4, 1991. Flooding washed out sewer lines in Pueblo Canyon, and there was extensive flooding of streets and basements.

Flooding is possible in the spring from snowmelt, although snowmelt flooding is usually confined to the larger rivers in the state. However, snowmelt can cause muddy conditions in the Los Alamos area, along with minor flooding of streams in the Jemez Mountains.

3.4 Winter Storms

Snowfalls of 4 in. (10 cm) or more are common in Los Alamos during the winter. Storms with winds above 15 mph (7 m/s) can be associated with cold temperatures, resulting in dangerous wind-chill/apparent temperatures, considerable drifting, and low visibility. The combination of heavy snowfall and restricted visibility makes driving conditions dangerous, if not impossible. Occasionally, snowstorms cause heavy snowfall in the mountains, while little snow falls in Los Alamos. Drivers should be prepared for winter storms, especially when traveling in mountainous areas.

3.5 Ice

Ice storms do not occur in Los Alamos and surrounding areas. However, a little freezing rain does occasionally fall. Melted snow or rain may freeze on roadways and sidewalks after a temperature drop, but these occurrences do not cause large ice accumulations on utility lines or trees.

Rime icing occasionally occurs on cold nights when fog droplets come in contact with objects, such as trees, utility lines, and roads. Rime icing occurs more frequently in low spots where cold air settles.

The accumulation of snow on trees, followed by strong winds, may result in downed trees and utility lines, especially after a wet snow, which is common in the late fall and during spring months.

3.6 Heavy Snow Loading

The potential exists for heavy snows to accumulate on roofs, stressing them and even caving them in. In the record snowfall of January 1987, snow from a single storm totaled 4 ft (1.2 m) at TA-59 and 5–6 ft (1.5–1.8 m) in North Community. Another 4 ft (1.2 m) of snow fell at TA-59 during February 1987. The snow's weight damaged or collapsed several roofs in Los Alamos. The water equivalent from the 1987 snowfall totaled 2.43 in. (6.17 cm) in January and 2.71 in. (6.88 cm) in February.

A short, but heavy, snowfall can also be damaging to structures. Generally, wet snowstorms during the spring have the most water equivalent. The heaviest in recent history was a 32-in. (81-cm) snowfall on April 10–12, 1975, with 30 in. (76 cm) falling on the 11th and 12th. The water equivalent totaled 3.12 in. (7.92 cm) during the storm. The January 1987 and April 1975 cases represent levels near the 100-year estimates for snow loading over a period of time and from one storm. Much of the snow in January–February 1987 melted soon after it fell.

3.7 Wind

Although Los Alamos winds are generally light, strong winds with gusts exceeding 50 mph (22 m/s) are common and widespread during the spring. Occasionally, the strong winds cause some damage to structures and trees. Brief, gusty winds are also common in and near thunderstorms.

3.8 Dust, Haze, and Smoke

Strong spring winds pick up and blow dust into the atmosphere. Visibility is reduced during blowing dust, especially near the Rio Grande Valley where the ground is open. Blowing dust can also be caused by thunderstorms. Haboob is the name given to a dust storm produced by thunderstorm downdrafts in desert regions.

Haze occasionally restricts visibility to 20 miles (32 km) or less, in some cases to as close as 10 miles (16 km). The haze is caused by aerosols with diameters less than 10 μm. Sulfate or nitrate aerosols, which are products of power plants, motor vehicle exhaust, smelters, and other industrial sources, can be transported from faraway places and can severely limit the usually good visibility (approximately 60 miles [96 km]). Haze has been observed in Los Alamos when brisk southwesterly winds occur. The brisk winds usually follow times of light winds over southern Arizona and the adjacent Mexico region. Haze is probably caused by emissions from large cities (including automobile exhaust) and large industrial plants located toward the southwest in southern Arizona and northwestern Mexico. There also have been several haze occurrences when a deep easterly wind flow was present over New Mexico, suggesting possible haze transport from Texas.

Distant forest fires also can cause haze in Los Alamos. Hazy conditions persisted in Los Alamos and much of New Mexico for nearly a week in September 1987 when forest fires burned out of control in many of the western states, including California, Nevada, Arizona, and Utah. Westerly upper-air winds transported the aerosols toward the east during and after the fires.

Nearby forest fires, of course, also cause reduced visibility. Heavy smoke was present in the Los Alamos air and other nearby areas during June 18–21, 1977, when the La Mesa fire was burning.

On rare occurrences, distant volcanoes can cause haze by spewing ash into the atmosphere. The eruptions of the Mount St. Helens volcano (Washington) on May 18, 1980, and shortly thereafter caused widespread haze over much of the United States, including Los Alamos.

3.9 Fog

General fog seldom occurs in Los Alamos. The greatest number of fog days occurs during December; the average number then is slightly more than 1.5. Fog most often forms on clear nights following snow or rain (radiational fog), sometimes with an upslope wind. Fog formation is greatest in December because nights are longest then. The other cold months average <1 fog day per month. The warm months have even less fog, with no fog days reported in August. Fog tends to be more frequent in the valley and in local low spots.

3.10 Drought

Extended periods of extreme dryness are uncommon in Los Alamos, largely because of the reliable summer thundershowers. Los Alamos escaped the drought of the "dustbowl '30s" and received adequate precipitation. The worst drought occurred during 1956 when only 6.80 in. (17.3 cm) of precipitation fell during the entire year, 38% of normal. The drought was especially severe toward the end of the year, with only 0.32 in. (0.81 cm) falling from August 24, 1956, through January 2, 1957. More recently, very dry weather occurred during the summer of 1980. Rainfall totaled only 0.35 in. (0.89 cm) in June and July and 2.32 in. (5.89 cm) during the entire summer (June–August), the driest summer on record.

3.11 Heat Waves

Extreme heat in Los Alamos is very rare, and even when it does occur, low relative humidity makes it tolerable. A heat wave can be defined as three consecutive days with the temperature reaching 90°F or higher. Los Alamos averages only two or three days per year with temperatures reaching 90°F. The summer of 1980 stands out as the hottest summer on record: 22 times during 1980 the temperature reached 90°F, including 20 times in June and July. Previously, the most 90°F days (7) occurred in 1936. More recently, nine days of 90°F occurred during summer 1989. Temperatures in 1980 reached 90°F or higher on the last eight days of June and three times on three consecutive days during July. Temperatures at White Rock reach 90°F more often than at Los Alamos and occasionally climb above 95°F. The highest recorded Los Alamos temperature was 95°F on July 11, 1935, and June 22, 1981; the highest recorded White Rock temperature was 100°F on July 12, 1971, and June 21, 1981.

3.12 Cold Waves

Frigid weather occasionally occurs in Los Alamos when polar or Siberian air masses settle over the region. Normally, the temperature drops to 0°F or below only once or twice a year. Los Alamos cold waves can be defined as times

when the temperature drops to −10°F or lower or when the temperature drops to 0°F or below for at least two consecutive days. Cold waves are usually preceded by a fresh snowfall. The lowest temperatures generally occur with clear skies, light winds, and snow cover. Clear skies allow radiation from the ground to escape, while light winds allow the resulting colder air to remain near the surface. The snow cover acts as a blanket, preventing heat in the ground from heating the air above the surface. Cold-air drainage gives more sub-0°F days and lower temperatures at White Rock than at Los Alamos. However, during the day or at night, when clouds or moderate winds are present, temperatures at Los Alamos are usually colder than at White Rock.

The lowest temperature ever recorded in Los Alamos was −18°F occurring on January 13, 1963. Probably the most severe cold wave occurred during the week beginning January 3, 1971. Temperatures plunged after a snowstorm dropped 10 in. (25.5 cm) of snow on Los Alamos and 15 in. (38 cm) on White Rock. Los Alamos low temperatures reached −9°F, −13°F, −16°F, −15°F, and −9°F, respectively, on five consecutive mornings beginning on the 3rd. High temperatures only reached 4°F, 8°F, 8°F, and 9°F on January 4–8. White Rock low temperatures were considerably colder, reaching −5°F, −25°F, −29°F, −18°F, and 0°F on January 4–9. The low of −29°F represents the all-time low at White Rock.

A cold wave at the end of November 1976 was unusual in that it occurred so early. Los Alamos temperatures dipped to −11°F, −14°F, −12°F, and −5°F on November 27–30. Daytime highs did manage to reach 19°F, 17°F, 23°F, and 33°F on those days. White Rock saw low temperatures of −11°F, −14°F, and −4°F on the 27th 28th, and 29th, respectively.

The longest string (13 days) of temperatures at 0°F or below occurred in White Rock from December 28, 1966, through January 9, 1967. Low temperatures included −11°F on one day and −9°F on two days. Another string (10 days) of temperatures at 0°F or below occurred in White Rock from December 30, 1970, through January 8, 1971.

The most recent cold wave occurred in December 1990. Temperatures in Los Alamos dipped to 0°F or below from the 22nd–25th, including −10°F on the 23rd and 24th. The frigid weather caused many pipes to burst in Los Alamos and White Rock.

3.13 Optical Phenomena

Rainbows occur frequently during the summer monsoon season. Thundershowers are often scattered or isolated, causing alternate areas of rain and sunshine, which is necessary for rainbow formation. Lightning, sometimes intense, is quite frequent. Virga, precipitation that falls from clouds but evaporates before reaching the ground, occurs frequently because of the relatively dry atmosphere. Halos around the sun and moon and sun dogs

(parhelia) can be brilliant at Los Alamos because of the dry, thin, and unpolluted mountain air. A rare display of various optical phenomena occurred in much of northern New Mexico, including Los Alamos, on February 25, 1988 when a thin overcast of high clouds caused refraction of sunlight. The viewing of meteors, stars, and planets is excellent because of the clear, thin air. The northern lights (aurora borealis) appear infrequently and lack the brilliance observed in areas farther north.

Appendix A

Historical Locations of Weather Stations

Climate record reliability depends on instrument accuracy, data recovery, and siting consistency. The Los Alamos cooperative weather station, in operation since late 1910, has been moved several times. Table A.1 lists historical station site information. Notice that although the Los Alamos station has been moved several times, the elevation and locations have changed very little except for a brief period during 1950–1951 when the site was located farther east at the airport. Airport temperatures are higher and precipitation is lower than at the other sites because of the lower elevation and greater distance from the Jemez Mountains. The station was moved to the Laboratory in 1952 at a site only slightly higher in elevation than the sites for 1910–1950. The station was again moved a short distance in 1956, when temperatures were measured on the roof of a building at SM-43 for a 5-month period. Temperatures generally would have had a decreased diurnal range on the roof, with lower high temperatures and higher low temperatures. Later in 1956, the temperatures were measured at the standard ground level (4 to 5 ft above ground). The station was moved again a short distance to TA-59 in late 1978 or early 1979, where it was located until 1990. In August of that year, the station was moved to a location 0.5 mile (800 m) south of TA-59, at a slightly higher elevation of 7 425 ft.

The Los Alamos weather station siting has actually stayed uniform, despite the moves. The elevations above sea level have remained within a 100-ft range, and the locations are within a 1-mile (1.6-km) distance, except for the 1950–1951 period. Temperatures probably showed more moderate diurnal ranges during the 5-month period in 1956 when temperatures were measured on the roof. Generally, however, the temperature and precipitation records are thought to be little affected by the different locations, except for the above examples. Data recovery has been good, except for some periods from 1917 to 1923 and 1943 to 1945.

The White Rock station has remained at the same site since it was started in late 1964. Data recovery at this station has been mostly complete, except for eight months beginning in late 1979 and two months in early 1981. This station will be merged in 1992 with a new tower west of White Rock.

Table A.1. Historical weather station locations (for temperature and precipitation).

Site	Dates	Elevation (ft ASL)	Latitude	Longitude	Comments
Los Alamos Weather Station:					
Ranch School	11/1/1910–3/10/1946	7320	35°53′ N	106°18′ W	Temperature records began, 10/19/1918 No data: 11/1916–2/1917, 8/1917–1/1918, 3/1918–7/1918, 9/1920–3/1922, 12/1922–1/1923, 10–11/1923, 1/1943, 4–5/1943, 9/1945
Townsite	3/19/1946–4/30/1950	7320	35°53′ N	106°18′ W	Very close to previous site
Airport	5/1/1950–12/31/1951	7150	35°53′ N	106°16′ W	Temperatures not representative (too high during 1950)
Laboratory Sites:					
H/Ad	1/1/1952–3/20/1956	7410	35°52′ N	106°19′ W	
SM-43	3/21/1956–8/31/1956	7400	35°52′ N	106°19′ W	Temperature measured on roof
SM-43	9/1/1956–1978	7400	35°52′ N	106°19′ W	Thermometer moved to ground
TA-59	1978–7/1990	7380	35°52′ N	106°19′ W	Station moved to TA-59 in 1978 or
TA-6	8/1990–present	7425	35°51′ N	106°19′ W	New site
White Rock Weather Station:					
Fire Station	9/21/1964–present	6380	35°50′ N	106°12′ W	Data missing: 11/1979–6/1980; 2/1981–3/1981

Appendix B

Degree Days

Heating Degree-Days

A heating degree-day is defined as the number of degrees (Fahrenheit) the daily mean temperature is *below* a certain temperature; 65°F is a commonly used base. For example, if a certain day has a high temperature of 60°F and a low temperature of 40°F, the daily mean would be 50°F, which would give 15 heating degree-days (from the 65°F base) for this day. Heating degree-days (65° base) are good for estimating fuel requirements for heating and are also used for structural design considerations.

Los Alamos heating degree-days for the 65°F base are listed in Table B.1. Monthly heating degree-days are inversely proportional to mean temperatures: on average, January has the most and July has the least heating degree-days. Heating degree-days average from more than 1100 in January and December down to 16 during July. The cold-season monthly minimum and maximum heating degree-days (65°F base) show that maximums exceed minimums by 60%–100%. Heating-fuel needs are also expected to vary this much.

White Rock heating degree-days are also shown in Table B.1. Monthly heating degree-days are quite similar for Los Alamos and White Rock. Heating degree-days at White Rock are generally fewer than at Los Alamos, except for January and December. Caution should be used in comparing heating degree-day extremes between the sites because of the smaller data record for White Rock.

Cooling Degree-Days

A cooling degree-day differs from a heating degree-day in that it represents the number of degrees (Fahrenheit) that the daily mean temperature is *above* a certain

Table B.1. Los Alamos and White Rock heating degree-days (65°F base).[a]

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Season
Los Alamos													
mean	16	41	185	480	810	1082	1133	922	835	572	320	81	6477
max	73	107	263	686	1037	1270	1321	1194	1038	761	463	154	6993
min	0	0	34	320	618	772	839	657	576	321	154	3	5141
White Rock													
mean	3	14	137	457	788	1096	1148	885	740	513	265	48	6116
max	12	45	218	647	975	1290	1317	1052	930	683	399	120	7026
min	0	0	45	313	676	876	814	705	496	325	131	2	5091

[a]Los Alamos means are taken from 1961–1990 and extremes from 1918–1990. White Rock means and extremes are taken from 1965–1990.

temperature. Cooling degree-days are used for estimating fuel costs for cooling buildings and are also used for structural design considerations. The base of 65°F is commonly used. However, a slightly higher base, such as 70°F, may correlate better with cooling costs, depending on building characteristics. The effect of sunshine must also be considered in calculating cooling needs during the summer. For example, a building would require more cooling on a sunny day than on a cloudy one, assuming an equal number of cooling degree-days for both days.

Cooling degree-days are also known as growing degree-days, especially for some of the lower temperature bases. The growth of many types of plants correlates to the number of growing degree-days of a specified temperature base.

Los Alamos and White Rock cooling (growing) degree-days, calculated for the 65°F temperature bases are shown in Table B.2. The most cooling (growing) degree-days occur in July, followed closely by those in August and June. These three months contain the majority of annual cooling degree-days. White Rock has more cooling degree-days than does Los Alamos. In general, White Rock buildings require some cooling during the summer, whereas Los Alamos buildings generally require very little. From an agricultural standpoint, the greater number of lower-base growing degree-days at White Rock indicates that more types of plants can mature there. However, the shorter White Rock growing season can offset the benefit of more growing degree-days, especially for sensitive plants. As with heating degree-days, one should use caution in comparing extremes of cooling (growing) degree-days between the two sites because the data record is considerably smaller for White Rock.

Table B.2. Los Alamos and White Rock cooling degree-days (65°F base).[a]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Los Alamos													
mean	0	0	0	0	4	65	107	56	10	0	0	0	242
max	0	0	0	0	39	161	204	147	58	2	0	0	467
min	0	0	0	0	0	6	18	1	0	0	0	0	109
White Rock													
mean	0	0	0	0	8	100	180	116	23	0	0	0	432
max	0	0	0	0	47	224	270	202	82	1	0	0	603
min	0	0	0	0	0	27	120	31	1	0	0	0	263

[a]Los Alamos means are taken from 1961–1990 and extremes from 1918–1990. White Rock means and extremes are taken from 1965–1990.

Appendix C

Growing-Season Data

Means and extremes of early- and late-season cold temperature occurrences were calculated from the historical Los Alamos and White Rock temperature data bases. The calculations were based on temperatures of 36°F, 32°F, 28°F, 24°F, 20°F, and 16°F. Because the temperatures are measured at a 4- to 5-ft (1.2- to 1.5-m) height, ground temperatures may actually be lower under some weather conditions. For example, a 36°F low temperature can indicate a light frost, because actual ground temperatures may approach 32°F under clear skies and light winds. A 32°F low temperature is defined as a freeze; a 28°F low temperature represents a hard freeze. The difference between 28°F and 32°F is enough to affect plants differently. A low temperature of 32°F may have little effect on fruit trees (elevated above ground), whereas plants near the ground may be heavily damaged because ground-level temperatures or temperatures in local low spots may be several degrees colder than the indicated temperatures. A 28°F low temperature, however, may be cold enough to damage plants, such as fruit trees, well above the ground.

The duration of low temperatures and atmospheric humidity also affect the amount of plant damage. For example, a brief occurrence of 28°F may not heavily damage sensitive plants, but several hours at that temperature could cause significant damage. Also, a moist atmosphere at 28°F may cause ice and frost to form, thereby reducing damage because heat is liberated as water vapor condenses into ice. In fact, spraying water onto plants is an effective strategy to reduce damage on nights when temperatures are at, or slightly below, freezing. Conversely, frost and ice may not form in a dry atmosphere at 28°F which increases plant damage.

The early and late occurrences of specified temperatures in the spring and autumn are given for Los Alamos and White Rock in Tables C.1 and C.2, respectively. The specified cold temperatures are generally reached later in the spring and earlier in the autumn at White Rock, resulting in a shorter growing season than in Los Alamos. Specifically, the White Rock growing season averages 12 and 14 days fewer for the 32°F and 28°F temperatures, respectively.

Ordinarily, White Rock has a shorter growing season than does Los Alamos. However, the records show a mixed picture for different temperature bases because of early and late freezes. For example, White Rock has the record short growing season at a temperature base of 36°F; Los Alamos has the record at a temperature base of 32°F. The record long growing seasons similarly alternate between the two sites for different bases.

The White Rock growing-season temperature extremes are understated when White Rock data are compared with Los Alamos data because temperature records have been kept for a much shorter time at White Rock.

Table C.1. Los Alamos growing-season data, 1919–1990 (means are based on the 1961–1990 period).

Temperature (°F)	Means: Latest Spring Date	Means: Earliest Fall Date	Means: No. of Days Between Dates
36	5/21	10/02	133
32	5/07	10/11	156
28	4/29	10/19	172
24	4/14	11/02	201
20	3/30	11/06	220
16	3/18	11/20	246

Temperature (°F)	Extremes: Spring Date Earliest	Spring Date Latest	Fall Date Earliest	Fall Date Latest	No. of Days Between Dates Least	Most
36	4/26/37	6/11/75	9/03/61	10/31/63	91 (1941)	184 (1963)
32	4/19/56	6/11/75	9/09/41	11/02/51	110 (1941)	185 (1963)
28	3/27/54	6/03/19	9/19/71	11/15/78	125 (1983)	220 (1967)
24	3/27/90	5/11/46	9/28/36	12/09/54	158 (1976)	256 (1954)
20	3/06/53	4/27/20	10/08/76	12/11/49	173 (1976)	265 (1954)
16	2/12/86	4/20/20	10/19/76	12/23/39	184 (1976)	291 (1939)

Table C.2. White Rock growing-season data, 1965–1990 (means are based on entire period).

Temperature (°F)	Means: Latest Spring Date	Means: Earliest Fall Date	Means: No. of Days Between Dates
36	5/22	9/26	124
32	5/11	10/07	148
28	4/30	10/17	169
24	4/14	10/27	195
20	4/03	11/08	218
16	3/16	11/15	243

Temperature (°F)	Extremes: Spring Date		Extremes: Fall Date		Extremes: No. of Days Between Dates	
	Earliest	Latest	Earliest	Latest	Least	Most
36	5/09/70	6/11/75	8/24/68	10/14/80	74 (1968)	148 (1981)
32	4/09/81	5/30/78	9/17/68	10/21/72	121 (1968)	190 (1981)
28	4/01/90	5/21/74	9/20/71	11/07/85	123 (1971)	217 (1990)
24	3/17/90	5/09/65	10/08/76	11/17/78	161 (1970)	240 (1978)
20	3/06/90	5/03/67	10/08/76	11/27/65	173 (1976)	266 (1990)
16	2/09/79	4/09/73	10/18/76	12/10/86	204 (1975)	301 (1986)

Appendix D

Unit Conversion Factors

The scientific community has adopted the worldwide standard International System of Units (SI) in an effort to simplify technical communication. The United States, however, is only gradually adopting the system. This report generally uses familiar English units, such as degrees Fahrenheit (°F), miles per hour (mph), and inches (in.), because they are the more widely used and because climate data, generally, are still compiled, distributed, and understood in English units.

Tables D.1 and D.2 give conversion factors for various units of length, speed (wind speed), temperature, and atmospheric pressure.

Table D.1. Length conversion factors.

	Multiply	By	To Obtain
Length	inches	2.54	centimeters
	centimeters	0.3937	inches
	feet	0.3048	meters
	meters	3.281	feet
	inches	0.02540	meters
	meters	39.37	inches
	statute miles	1.6093	kilometers
	kilometers	0.6214	statute miles
	statute miles	0.8690	nautical miles
	nautical miles	1.1508	statute miles
	statute miles	5 280	feet
	feet	0.0001894	statute miles
	kilometers	3 281	feet
	feet	0.00030479	kilometers
Speed (Wind)	miles per hour (mph)	0.869	knots
	knots	1.151	mph
	mph	0.447	meters per second (m/s)
	m/s	2.237	mph
	mph	1.609	kilometers per hour (km/h)
	km/h	0.621	mph
	m/s	1.944	knots
	knots	0.514	m/s
	m/s	3.6	km/h
	km/h	0.278	m/s
	km/h	0.540	knots
	knots	1.852	km/h

Table D.2. Temperature and atmospheric pressure conversion factors.

	Multiply	By	To Obtain
Temperature	degrees Fahrenheit (°F) -32	0.5555	degrees Celcius (°C)
	°C	1.80	°F
	°F + 459.67	0.5555	kelvins (K)
	K	1.80	°F - 459.67
	°C + 273.15	1.0	K
	K	1.0	°C - 273.15
Pressure	1 atmosphere[a] (sea level)	29.92	inches
	inches	0.03342	atmospheres
	inches	33.865	millibars
	millibars	0.02953	inches
	inches	25.401	millimeters (torr)
	millimeters (torr)	0.03937	inches
	millibars	0.7501	millimeters (torr)
	millimeters (torr)	1.3332	millibars
	millibars	0.1	kilopascals
	kilopascals	10.0	millibars
	inches	0.4910	lb/in.^{2}, pounds per square inch (psi)
	lb/in.^{2} (psi)	2.0368	inches

[a]1 atmosphere (atm) ≡ 29.92 inches (in.)
≡ 760 millimeters (mm) (torr)
≡ 76.0 centimeters (cm)
≡ 1.0133 bar = 1 013.3 millibar (mbar) = 101.33 kilopascals (kPa)
≡ 1 469 lb/in.^{2}

References

Berry, F. A. Jr., E. Bollay, and N. R. Beers, *Handbook of Meteorology*, (McGraw-Hill Book Company, New York, 1945).

Bowen, B. M., "Los Alamos Climatology," Los Alamos National Laboratory report LA-11735-MS (May 1990).

Fujita, T. T., "Estimate of Maximum Windspeeds of Tornadoes in Southernmost Rockies," Satellite and Mesometeorology Research Paper No. 105, Department of Geophysical Sciences, University of Chicago (June 1972).

NOAA (National Oceanic and Atmospheric Administration), *Climatology of the United States No. 60*, National Climatic Center, Asheville, North Carolina (March 1977).

NOAA (National Oceanic and Atmospheric Administration), *Climatic Atlas of the United States*, US Department of Commerce, National Climatic Center, Asheville, North Carolina (reprinted 1979).

Olsen, W. A., "Quality Assurance Project Plan for Meteorological Monitoring, Los Alamos National Laboratory, Environmental Protection Group, EM-8," Los Alamos National Laboratory Report (in preparation).