



# Modeling the Spatial and Temporal Variation of Monthly and Seasonal Precipitation on the Nevada Test Site and Vicinity, 1960-2006



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**U.S. Department of the Interior**  
**U.S. Geological Survey**



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By Joan B. Blainey, Robert H. Webb, and Christopher S. Magirl

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# Contents

Abstract.....	1
Introduction .....	1
Purpose and Scope .....	4
Acknowledgements.....	4
Study Area .....	4
Geography and Topography .....	4
Climate .....	4
Precipitation Data and Geospatial Characteristics.....	7
Data Sources and Quality .....	7
Data Trends With Elevation and Position.....	10
Time-Series Analysis .....	13
Multivariate Statistical Analyses.....	15
Results of Spatial Interpolation of Precipitation.....	16
Period of Record Precipitation Averages .....	16
Seasonal Precipitation for 1969, 1989, and 1998 .....	21
Seasonal Coefficients of Variations .....	26
Time Series at Specific Sites.....	31
Study Limitations .....	32
Conclusions .....	32
References Cited .....	33

# Figures

<b>Figure 1.</b> Prominent topographic features illustrated with a hillshade model based on a 30-m digital elevation model and selected place names of the Nevada Test Site, Nevada. The Nevada Test Site boundary is outlined in black, and the Beatley plots are discussed in the text and on figure 15.....	2
<b>Figure 2.</b> Locations of precipitation gages of the Nevada Test Site and vicinity, Nevada, illustrated with 30-m digital elevation model (DEM) and hillshade based on the 30-m DEM. The precipitation gage symbol represents the data source. The model domain is the extent of the DEM.....	3
<b>Figure 3.</b> Mean annual precipitation at the Nevada Test Site presented by source of data and time period, as a function of elevation.....	6
<b>Figure 4.</b> Median monthly gage precipitation at the Nevada Test Site from 1960 to 2006. Error bars represent the 25 <sup>th</sup> and 75 <sup>th</sup> percentiles. ....	6
<b>Figure 5.</b> Annual number of actively recording precipitation gages in the period of 1960 to 2006 for the Nevada Test Site. <i>A.</i> The average elevation of the active precipitation gage network is given in red. <i>B.</i> and <i>C.</i> The number of actively recording precipitation gages by data source.....	8
<b>Figure 6.</b> Change in annual and seasonal precipitation with elevation for two periods of record on the Nevada Test Site. <i>A.</i> 1960 to 2006. <i>B.</i> 1992 to 1996.....	11
<b>Figure 7.</b> Time series of annual precipitation on the Nevada Test Site from 1960 to 2006. The dashed line is the mean annual precipitation averaged over all the gages for the same time period, and the red squares represent the average elevation of the actively recording precipitation stations.....	13

**Figure 8.** Time series of winter (November through April) and summer (May through October) season precipitation, an average of all the precipitation gages, from 1960 to 2006 for the Nevada Test Site. .... 14

**Figure 9.** Time series of percent of winter season (November through April) and summer season (May through October) precipitation from 1960 to 2006 for the Nevada Test Site. Because the winter season starts November 1, the percentages are based on the sum of the winter and summer precipitation and therefore correspond to the year from November 1 through October 31..... 15

**Figure 10A.** Average annual precipitation over the period from 1960 to 2006 for the Nevada Test Site. .... 17

**Figure 10B.** Average winter season (November through April) precipitation over the period from 1960 to 2006 for the Nevada Test Site..... 18

**Figure 10C.** Average summer season (May through October) precipitation over the period from 1960 to 2006 for the Nevada Test Site..... 19

**Figure 10D.** Average winter season (November through April) precipitation as a percent of average annual precipitation over the period from 1960 to 2006 for the Nevada Test Site. .... 20

**Figure 11A.** Winter season (November through April) precipitation for 1969, a wet year on the Nevada Test Site..... 22

**Figure 11B.** Winter season (November through April) precipitation, as a percent of average winter precipitation, for 1969, a wet year on the Nevada Test Site. .... 23

**Figure 12A.** Winter season (November through April) precipitation for 1998, a wet year for the Nevada Test Site..... 24

**Figure 12B.** Winter season (November through April) precipitation for 1998, expressed as a percent of average winter precipitation, for the Nevada Test Site. .... 25

**Figure 13A.** Annual precipitation for 1989, a year of severe drought, for the Nevada Test Site. .... 27

**Figure 13B.** Annual precipitation for 1989, expressed as a percent of average annual precipitation, for the Nevada Test Site..... 28

**Figure 14A.** The coefficient of variation (CV) of winter season (November through April) precipitation for the Nevada Test Site..... 29

**Figure 14B.** The coefficient of variation (CV) of summer season (May through October) precipitation for the Nevada Test Site..... 30

**Figure 15.** Time series of annual precipitation from 1960 to 2006 for a high elevation (2,274 m, Beatley plot 64), an intermediate elevation (1,245 m, Beatley plot 46), and a low elevation (961 m, Beatley plot 8) permanent ecological study plot on the Nevada Test Site. .... 32

## Tables

**Table 1.** Regression equations for annual and seasonal precipitation as a function of climate-station elevation for two time periods on the Nevada Test Site (fig. 6). .... 12

**Table 2.** Regression equations for annual and seasonal precipitation as a function of climate-station position (n = 115 stations) on the Nevada Test Site. .... 12

## Appendix

**Table A1.** Metadata for precipitation stations on or adjacent to the Nevada Test Site, Nye County, Nevada. The only data used were from January 1, 1960, through December 31, 2006..... 35

## Conversion Factors

### SI to Inch/Pound

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
kilometer (km)	0.6214	mile (mi)
Area		
square kilometer (km <sup>2</sup> )	0.3861	square mile (mi <sup>2</sup> )
Volume		
cubic meter (m <sup>3</sup> )	35.31	cubic foot (ft <sup>3</sup> )
Mass		
gram (g)	0.03527	ounce, avoirdupois (oz)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).  
Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

## Abbreviations and Acronyms

ARL-SORD	Air Resource Laboratory Special Operations and Research Division, Department of Energy
BECAMP	Basic Environmental Compliance And Monitoring Program, Reynolds Electric and Engineering Company and Department of Energy
CV	Coefficient of Variation
DEM	Digital Elevation Model
ENSO	El Niño – Southern Oscillation
GPS	Geographic Positioning System
NCDC	National Climatic Data Center
NDFE	Nevada Desert FACE (Free Air Carbon dioxide Enrichment) Facility
NTS	Nevada Test Site, Department of Energy
PDO	Pacific Decadal Oscillation
PRISM	Parameter-Elevation Regressions on Independent Slopes
YMMP	Yucca Mountain Meteorological Monitoring
YMP	Yucca Mountain Project, Department of Energy

# Modeling the Spatial and Temporal Variation of Monthly and Seasonal Precipitation on the Nevada Test Site and Vicinity, 1960-2006

By Joan B. Blainey, Robert H. Webb, and Christopher S. Magirl

## Abstract

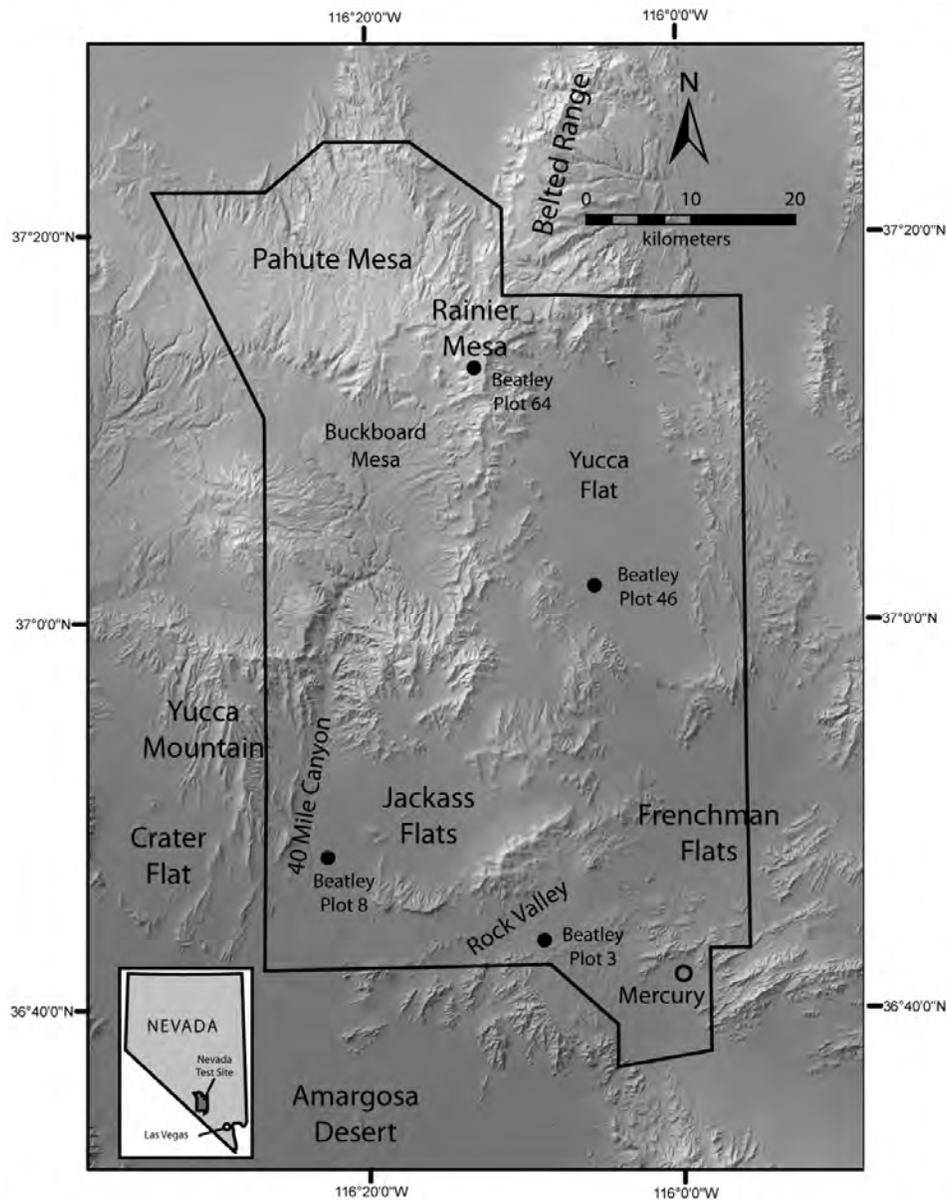
The Nevada Test Site (NTS), located in the climatic transition zone between the Mojave and Great Basin Deserts, has a network of precipitation gages that is unusually dense for this region. This network measures monthly and seasonal variation in a landscape with diverse topography. Precipitation data from 125 climate stations on or near the NTS were used to spatially interpolate precipitation for each month during the period of 1960 through 2006 at high spatial resolution (30 m). The data were collected at climate stations using manual and/or automated techniques. The spatial interpolation method, applied to monthly accumulations of precipitation, is based on a distance-weighted multivariate regression between the amount of precipitation and the station location and elevation. This report summarizes the temporal and spatial characteristics of the available precipitation records for the period 1960 to 2006, examines the temporal and spatial variability of precipitation during the period of record, and discusses some extremes in seasonal precipitation on the NTS.

## Introduction

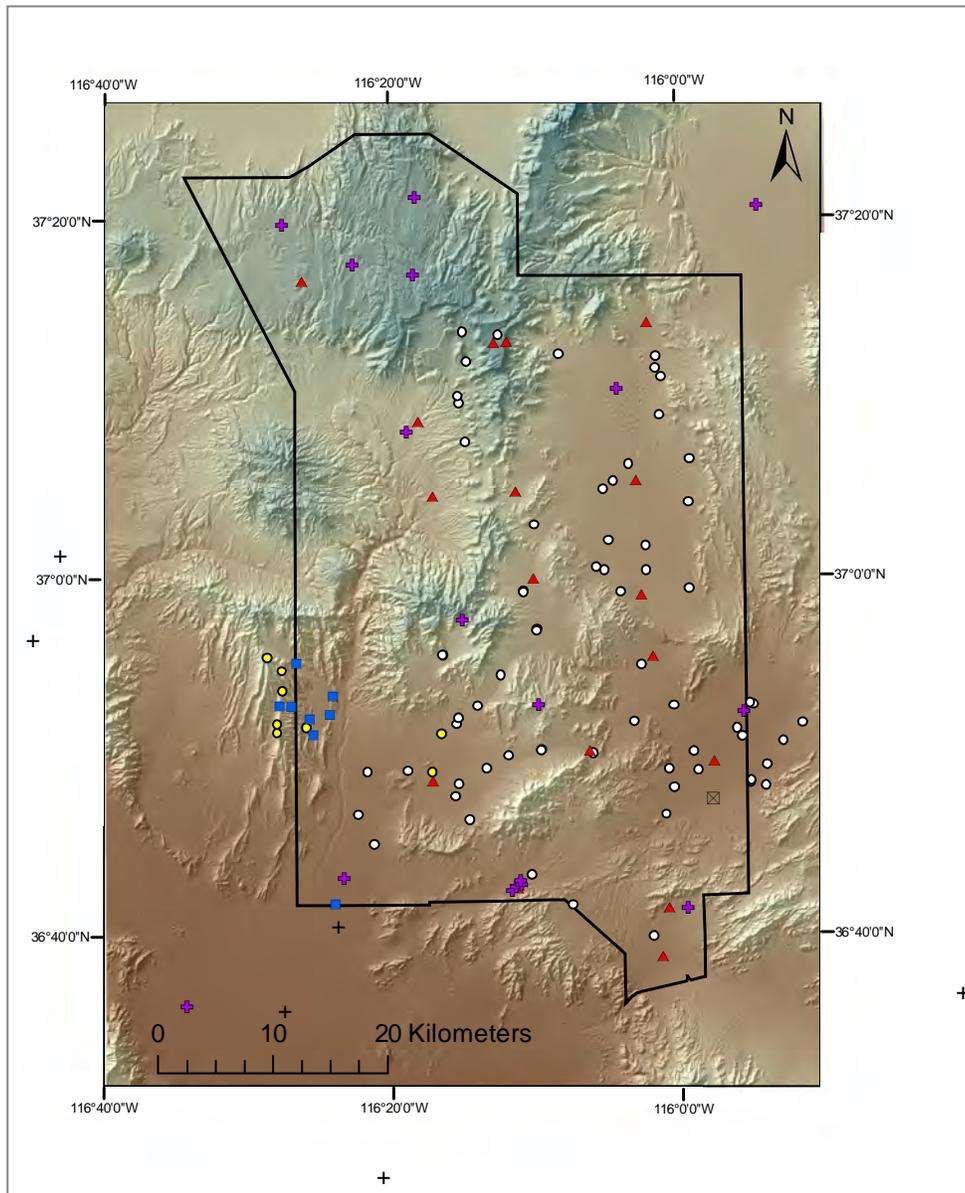
High-resolution spatial interpolation of rainfall data is extremely useful in the mountainous areas of the western United States, where precipitation gages generally are widely dispersed (see <http://www.wrcc.dri.edu/summary/Climsmnv.html>). Some existing approaches, such as the Parameter-elevation Regressions on Independent Slopes Model (PRISM; Daly and others, 1994), use multivariate techniques to estimate regional patterns of precipitation at coarse spatial scales (typically 4 km). These methods are advantageous for scales on the order of states or continents because they take into account, among other things, rain-shadow effects, temperature inversions, distance from large surface water bodies, and group climate stations according to similarity, but in many cases their coarse resolution limits the applicability to specific sites or questions.

Many landscape-scale analyses benefit from high-resolution climate data, particularly long-term ecological study plots. Long-term changes in permanent vegetation plots in the Mojave Desert, such as those on the Nevada Test Site (NTS, fig. 1), are caused by variation in annual or seasonal precipitation. This Department of Energy facility has a large number of climate stations (table A1, fig. 2), which provides sufficient data for relatively high-resolution estimations of seasonal precipitation that are essential for evaluating long-term vegetation change. In this report, we use a distance-weighted multiple-linear regression technique (Nalder and Wein, 1998) to estimate monthly precipitation, then combine monthly totals to obtain seasonal and annual

precipitation for the NTS (fig. 1). We discuss the precipitation data for the period 1960 through 2006, discuss our estimation technique, and provide examples of time series and spatial variability of seasonal and annual precipitation for the NTS and for specific permanent vegetation plot locations. We provide maps depicting selected wet and dry years, winters, and summers for the NTS and vicinity.



**Figure 1.** Prominent topographic features illustrated with a hillshade model based on a 30-m digital elevation model and selected place names of the Nevada Test Site, Nevada. The Nevada Test Site boundary is outlined in black, and the Beatley plots are discussed in the text and on figure 15.

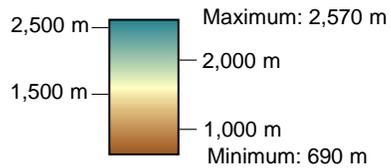


**Precipitation gage data source**

- ▲ Air Resource Laboratory Special Operations and Research Division (ARL-SORD)
- Beatley
- Flint and Davies
- ⊠ Nevada Desert FACE Facility (NDFF)
- ⊕ Basic Environmental Compliance And Monitoring Program (BECAMP)
- + National Climatic Data Center (NCDC)
- Yucca Mountain Meteorological Monitoring (YMMP)

— Nevada Test Site boundary

**Elevation, in meters (m)**



**Figure 2.** Locations of precipitation gages of the Nevada Test Site and vicinity, Nevada, illustrated with 30-m digital elevation model (DEM) and hillshade based on the 30-m DEM. The precipitation gage symbol represents the data source. The model domain is the extent of the DEM.

## **Purpose and Scope**

The purpose of this report is to document the methods and data sources used to estimate annual and seasonal precipitation on the Nevada Test Site from 1960 through 2006. The time series of precipitation at each gage is examined with respect to seasonal precipitation and variability in annual precipitation. Changes in the gage network over the study period are examined to assess that influence on estimates of regional precipitation. We provide examples of point estimates of annual and seasonal precipitation as well as estimates for distributed precipitation at the NTS.

## **Acknowledgements**

Phil Medica (USGS), Richard Hunter (Salisbury College, Maryland), and Paul Gregor (Bechtel Nevada) told us about the availability of the BECAMP data, accessed in files archived on the NTS.

## **Study Area**

### **Geography and Topography**

The NTS encompasses about 3,567 square kilometers (km<sup>2</sup>) in southern Nevada (Nye County) and is bounded by latitudes 37°20'45" N and 36°40'43" N and by longitudes 116°34'20" W and 115°55'37" W (fig. 1). The NTS is approximately a rectangle 40 km wide (west-east) and 80 km long (north-south). Precipitation on the NTS is strongly influenced by topography, with the highest elevations in the north (Rainer Mesa, 2,341 m) and lowest elevations near the southwest corner (819 m). Prominent low-elevation topographic features of the terrain include two large closed basins—Yucca and Frenchman Flats—bearing dry lakebeds (playas), and Jackass Flats, a broad area in the southwest of the NTS drained by 40-Mile Wash (fig. 1). Three large, relatively flat, and higher-elevation plateaus—Rainier, Buckboard, and Pahute Mesas—dominate the northwestern part of the NTS (fig. 1).

We used a 30-m resolution digital-elevation model (DEM) of the topography of the NTS in our analyses. This 30-m DEM was obtained from the U.S. Geological Survey's National Elevation Dataset (see U.S. Geological Survey, 1999). We also obtained 10-m DEMs (Kent Ostler, Bechtel Nevada, 2004), but we chose to use the less-accurate 30-m data because the computational requirements of using 10-m data would be beyond the computational power of normal personal computers for an area the size of the NTS.

### **Climate**

The NTS spans the transition between the Mojave and Great Basin Deserts, and this transition is created by a strong variation in topography and climate. Climate at the NTS has been described in detail by Quiring (1968), French (1983a; 1983b), Spaulding (1985), and Soulé (2006). Three climatological processes create precipitation, the sum of accumulated rain and water produced by snowmelt, in the Mojave Desert (Hereford and others, 2004; 2006) and the NTS. Winter precipitation generally results from frontal systems bearing moisture from the North Pacific Ocean; wetter storms may be enhanced by moisture from the tropical Pacific Ocean. In the spring and fall, cutoff low-pressure systems advect tropical moisture in the region, which can result in considerable precipitation. Both of these sources of moisture are influenced by mountain masses,

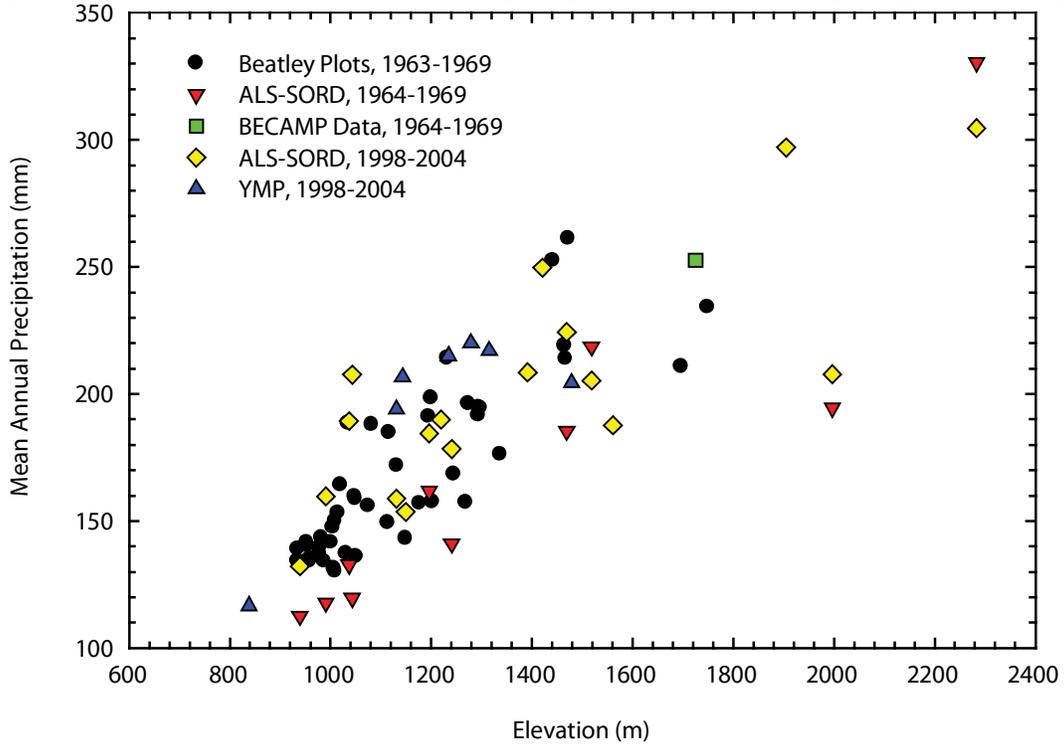
creating orographic effects of increasing precipitation with elevation (Spaulding, 1985). In the summer, local convective thunderstorms cause precipitation with high spatial variability (Hereford and others, 2004; 2006). Typically, moisture originates in either the Pacific Ocean – especially the Gulf of California – and (or) the Gulf of Mexico and is advected north during the North American monsoon. Summer precipitation can also result from low-pressure systems passing over the Great Basin to the north of the NTS (Quiring, 1968). Summer thunderstorms are characterized by widespread high intensity precipitation with durations on the order of hours. Some summer thunderstorms are associated with heavy rains, flash floods, and strong surface winds. The combined effects of moisture from the Gulfs of Mexico and California cause a general trend of increasing precipitation from west to east across southern Nevada (French, 1983a).

Annual and winter precipitation is highly affected by hemispheric- or global-scale climate processes, especially the El Niño – Southern Oscillation (ENSO) (see discussion of ENSO effects in Hereford and others, 2004; 2006) which is defined by an oscillation of the ocean-atmosphere system, specifically persistent warm sea-surface temperatures, in the equatorial Pacific Ocean. Rainfall in the Southwest tends to be greatly increased in nearly all El Niño years, which generally have increased strength of westerly winds and increased sea-surface temperatures off the west coast of California. Examples of years with El Niño conditions include 1969, 1978, and 1983; persistent El Niño conditions occurred from about 1991 through 1995 and again from 1997 to 1998. In contrast, cooler ocean waters off California occur during La Niña years, which tend to induce drought. Examples of years with La Niña conditions and drought include 1989 and 2002. The influence of these large-scale processes on summer precipitation is unknown and difficult to determine because of the high spatial and temporal variability of summer precipitation in the Mojave Desert.

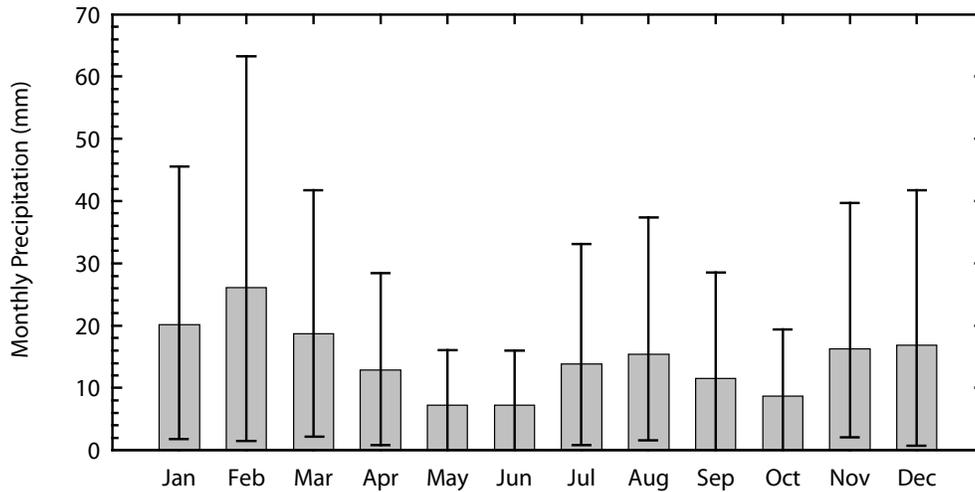
The Pacific Decadal Oscillation (PDO) is another climate index known to reflect climatic processes affecting the Mojave Desert (Hereford and others, 2004; 2006) and the western United States. The PDO represents low-frequency fluctuations in the North Pacific Ocean occurring on a decadal-time scale (each phase lasting 10 to 30 years) and can be greatly influenced by phases in the ENSO. Generally, when the PDO is positive (e.g., 1977 to 1998; 2002 to present), the Mojave Desert tends to experience above-average precipitation; in contrast, when the PDO is negative (e.g., 1947 to 1976; 1998 to 2002), the Mojave Desert tends to experience extended or short-term drought (Hereford and others, 2004; 2006).

Annual precipitation at the highest elevations in the NTS averages about 330 mm and includes significant accumulation of snow. At lower elevations, annual precipitation typically ranges from 110 to 200 mm (fig. 3) and infrequent snow accumulations typically persist less than twenty-four hours (Bechtel Nevada, 2001). In general, snow frequently occurs above 1,800 m but is relatively rare for locations below 1,200 m (Soulé, 2006). At only six stations (see footnote in Appendix table A1) in the precipitation network record is snowfall recorded in addition to precipitation, and all these stations are at low elevation. Three of these stations, at elevations of 665, 747, and 814 m, did not record snowfall over the period of record. Three stations recorded measurable snow (located at elevations of 952, 1,007, and, 1,082 m) between October and April. For these three stations, the highest average-monthly snowfall (41 mm) occurred in January, followed by December (12.5 mm). Assuming a snow density of 0.10 g/cm<sup>3</sup> (Dingman, 1994), these snow accumulations represent 32 percent and 13 percent of the total precipitation for January and February, respectively. Average accumulated snow during February, March, April, and November is similar, ranging from 4.2 to 6.8 mm which is an insignificant fraction of total precipitation, less than 6 percent.

As previously discussed, precipitation is seasonally bimodal, with most of the precipitation occurring during the winter and summer. Little precipitation occurs during the periods of April



**Figure 3.** Mean annual precipitation at the Nevada Test Site presented by source of data and time period, as a function of elevation.



**Figure 4.** Median monthly gage precipitation at the Nevada Test Site from 1960 to 2006. Error bars represent the 25<sup>th</sup> and 75<sup>th</sup> percentiles.

through June and September through October (fig. 4). Winter precipitation, between November and April, accounts for 63 percent of the average annual precipitation on the NTS. Summer

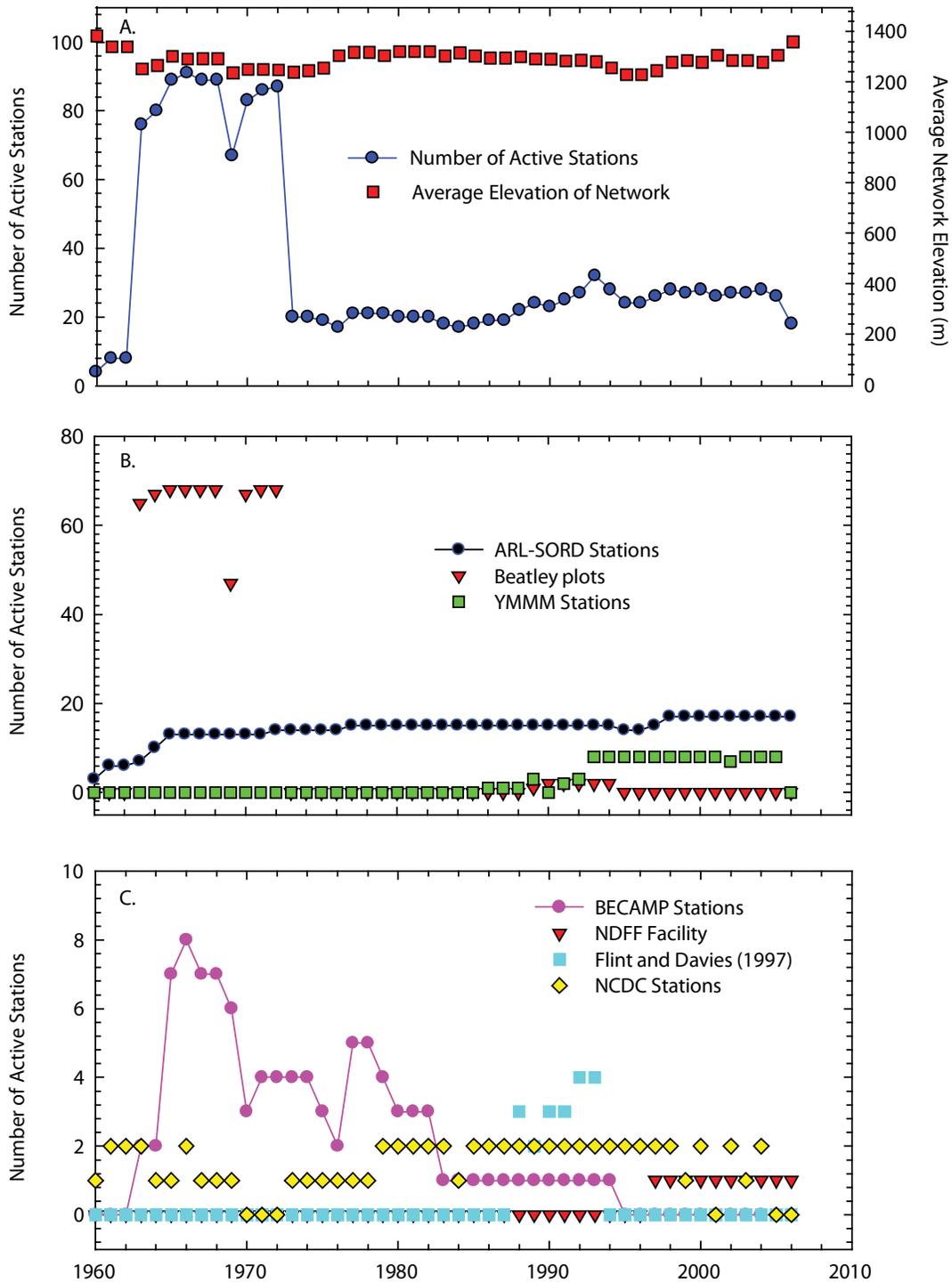
precipitation, between July and August, accounts for 12 percent of average annual precipitation. The driest months at the NTS are May and June (fig. 4), which have average precipitation accumulations of 2.8 mm and 2.5 mm, respectively. February is the wettest month, receiving 12.2 mm of precipitation on average; it is also the month with the highest variability in precipitation (fig. 4).

## Precipitation Data and Geospatial Characteristics

A total of 125 precipitation gages recorded a year or more of data between 1960 and 2006 (fig. 2). The locations of climate stations and the sources of the data are given in the Appendix (table A1). Although the stations are referred to as precipitation gages, the vast majority of the gages record only rainfall. From 1960 through 2006, as many as 91 precipitation gages actively recorded during a single year (fig. 5). This represents a maximum gage density equivalence of 1 gage per 39 km<sup>2</sup> and results from data at 68 permanent ecological study plots established by Janice C. Beatley and measured between 1963 and 1973 (Webb and others, 2003). During most of the period of record, however, the gage density equivalence is about 1 gage per 142 km<sup>2</sup>, with typically about 20 precipitation stations collecting data (fig. 5). The minimum gage density occurred during the period of 1960 to 1962 when 8 or fewer gages in the station network were actively recording.

## Data Sources and Quality

Precipitation data were obtained from several sources (table A1, fig. 2) and represent a wide range of temporal scales for each month between January 1960 and December 2006. All data were obtained from publicly accessible websites with the exception of some data from the National Climatic Data Center (NCDC). Data from NCDC stations (National Climatic Data Center, 2003) that have not undergone quality control checks are available on the internet from the Western Regional Climate Center (<http://www.wrcc.dri.edu/summary/Climsmnv.html>). Geospatial data for many of the sites were obtained from station metadata available from the source. We used several different types of hand-held global positioning system (GPS) units to determine the locations and elevations of unpublished climate data sets, such as those established by Beatley (see below). In those cases, our data generally had an estimated position error of  $\pm 4$ -6 m using a World Geodetic System (WGS) 84 coordinate system. For all climate stations, we checked elevations acquired from



**Figure 5.** Annual number of actively recording precipitation gages in the period of 1960 to 2006 for the Nevada Test Site. *A.* The average elevation of the active precipitation gage network is given in red. *B.* and *C.* The number of actively recording precipitation gages by data source.

the station metadata or using handheld GPS units with the elevation reported for that location on the 10-m digital-elevation model. Where significant differences were noted, we recollected data in the field using handheld GPS units.

The data for six precipitation stations from the NCDC Summary of the Day database were aggregated into monthly totals. Precipitation was measured in increments of 0.25 mm or reported as trace precipitation of less than 0.13 mm. Trace amounts of precipitation were set equal to zero for subsequent analyses. These are the only stations that recorded both rainfall and snowfall.

Six NCDC stations (table A1) were incorporated in the NTS precipitation network over the period 1960 to 2006 (fig. 5C). The stations Amargosa Farms Garey and Lathrop Wells are southwest of the NTS in a low-elevation portion of the modeling domain (fig. 2). The Beatty and Beatty 8 N stations are about 5 km west of the western boundary of the modeling domain and are the western-most climate stations in the network. The lowest-elevation station – Lathrop Wells 16 SSE – is about 9 km south of the modeling domain at 665.1 m elevation. The Indian Springs station, the eastern-most precipitation gage, is approximately 13 km east of the eastern boundary of the modeling domain.

Precipitation was measured at Beatley vegetation plots from 1963 through 1972 (Webb and others, 2003). An above-ground funnel collected precipitation that was stored in an underground storage gage with a small amount of added oil to minimize evaporation. The storage gage was emptied and measured periodically (approximately every 2 weeks). We aggregated these data into monthly precipitation using methods discussed in Webb and others (2003). Most of the 68 Beatley precipitation stations are located in the eastern and southern portion of the NTS (fig. 2). Between 1987 and 1994, the Basic Environmental Compliance And Monitoring Program (BECAMP) also measured precipitation on the NTS (Hunter, 1994) using standard storage gages placed on posts at about 2-m height. Some of the 17 BECAMP gages are located within or adjacent to the Beatley plots (e.g., plots 3 and 46, fig. 1), extending the monthly precipitation record beyond 1972 at these sites. Several of the BECAMP gages are located on Pahute Mesa in the northern high elevation portion of the NTS (fig. 2); this area has a relatively low precipitation gage density.

The Air Resource Laboratory, Special Operations and Research Division (ARL-SORD) is a cooperative project between the National Oceanic and Atmospheric Administration and the Department of Energy that has collected climate data on the NTS since 1957. The 17 precipitation stations range in elevation between 939 m to 2,283 m (<http://www.sord.nv.doe.gov/arlsord-1.htm>) and are located throughout the NTS (fig. 2). The rain gages are storage gages with recording strip charts set to record for 1-week periods; however, in the mid-1990s, the recording strip charts were set to record for 30 days (Soulé, 2006) thereby lowering the data resolution.

Yucca Mountain, a proposed high-level radiation waste-storage site on the southwestern side of NTS (fig. 1) operated by the Department of Energy, has monitored climate as part of its site characterization since the beginning of the project in the early 1980s. Between April 1987 and September 1997, Flint and Davies (1997) operated 5 weather stations at 8 sites on the NTS (fig. 2). The elevation of these sites ranged from 1,055 to 1,789 m. Tipping bucket rain gage data was collected every 10 seconds and averaged into 15 minute increments. The Yucca Mountain Meteorological Monitoring (YMMM) network consists of nine meteorological stations that collect daily precipitation (fig. 2). Data are available for these stations from December 1985 through December 2004 (<http://www.ymp.dri.edu>).

Since 1996, precipitation events have been recorded at the Nevada Desert FACE (Free Air Carbon dioxide Enrichment) Facility (NDFE). Data are available for this station ([https://www.unlv.edu/Climate\\_Change\\_Research/NDFE/](https://www.unlv.edu/Climate_Change_Research/NDFE/)), which is located in Frenchman Flats; daily

precipitation values are reported with a resolution of 0.1 mm.

At the beginning of our analysis period in 1960, there were four actively recording precipitation gages in the network, and all four of these were NCDC stations. In 1963, the number of stations in the network greatly increased with the addition of the 68 gages on Beatley permanent plots (fig. 5A, fig. 5B). These stations were monitored until 1973, whereupon the number of actively recording gages in the network decreased to 20. The number of gages since 1973 increased slightly to 28 stations in 2004 and 18 stations at the end of the analysis period in December 2006. The large decrease in the number of actively recording precipitation gages from 26 in 2005 to 18 in 2006 is a reflection that not all of the 2006 data have been quality checked and made publically available; no rapid changes to the precipitation network occurred during this period.

The average elevation of the gages is a consideration for the data representation of the NTS in the multivariate extrapolation techniques. The elevation of precipitation stations ranges from 665 m for a site south of the NTS to 2,283 m on Rainer Mesa in the north. The elevation of the DEM varies between 690 and 2,570 m (fig. 2), which indicates that the available climate data is appropriate for describing variation of precipitation, both annual and seasonal, on the NTS. Over the study period, the average elevation of the precipitation network varied between 1,229 m and 1,382 m (fig. 5A). The maximum average precipitation network elevation occurred in 1960 when only a few stations were active. Based on the long-term relation between elevation and average annual precipitation (fig. 6A), an elevation difference of 153 m (the maximum change in the average precipitation network elevation over the study period 1960 to 2006) corresponds to a difference of 19.6 mm of average annual precipitation.

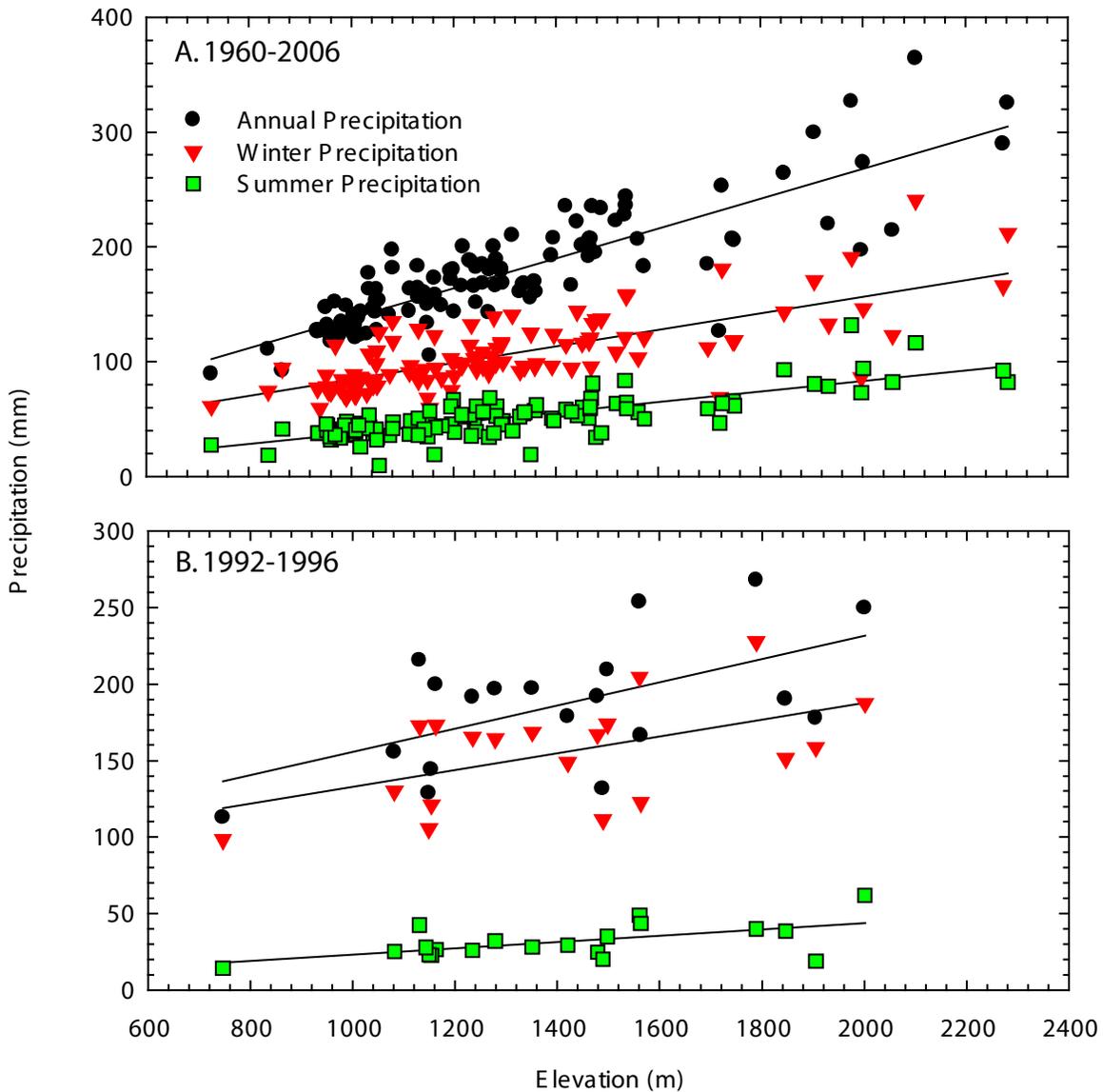
## Data Trends With Elevation and Position

We used linear-regression techniques to evaluate the influence of elevation and geospatial position on annual and seasonal precipitation on the NTS. A simple linear regression (Freedman and others, 1998) takes the form of

$$Y = c + aX, \quad (1)$$

where  $Y$  = the dependent variable (precipitation total),  $c$  = a regression constant that is the x-axis intercept,  $X$  = the independent variable (e.g., elevation), and  $a$  = the independent variable constant that is the slope of the regression line. The regression coefficient  $r^2$  is a measure of goodness-of-fit that can be interpreted as the amount of variance explained by equation 1 (Freedman and others, 1998). Finally, a standard error of estimate is the square root of the average sum-of-square residual deviations from the mean and is another measure of goodness-of-fit that depends on the accuracy of predictions made with the regression relation.

Elevation has a strong influence on precipitation on the NTS (fig. 6A). For 115 stations reporting a minimum of 5 years of record on or adjacent to the NTS, we used equation 1 to estimate the relation between elevation and annual, winter, and summer precipitation (table 1). The elevation coefficient (slope) for winter precipitation (0.070) was more than 1.5 times that for summer precipitation (0.045), indicating a stronger orographic effect of increasing precipitation with elevation. This effect was more pronounced for annual precipitation, which had an elevation coefficient of 0.128 (table 1).



**Figure 6.** Change in annual and seasonal precipitation with elevation for two periods of record on the Nevada Test Site. A. 1960 to 2006. B. 1992 to 1996.

The difference in orographic effect varies with time. For the period of 1992 through 1996, a period with a constant network of 19 climate stations and persistent El Niño conditions (Hereford and others, 2004; 2006), we again examined the relation between elevation and precipitation (fig. 6B). For this time period, the regression coefficient  $r^2$  indicates that only 33 percent of the variance in annual precipitation can be explained by the linear dependence on elevation. The regression for winter precipitation is similar to that for annual precipitation, albeit with a slightly lower slope (0.055 versus 0.076; table 1). However, summer season precipitation, or precipitation that occurs during May to October, has less of an orographic dependence as indicated by an even lower slope (0.0207), which is less than half of the slope for average annual precipitation or winter season precipitation (table 1).

**Table 1.** Regression equations for annual and seasonal precipitation as a function of climate-station elevation for two time periods on the Nevada Test Site (fig. 6).

Time period	Season	Number of stations $n$	Regression constant $c$	Elevation coefficient $a$	Regression coefficient $r^2$	Standard error of estimate
1960-2006	Annual	115	9.612	0.128	0.67	28.42
1960-2006	Winter	115	13.776	0.070	0.46	24.06
1960-2006	Summer	115	-7.963	0.045	0.60	11.73
1992-1996	Annual	19	80.072	0.0757	0.33	35.38
1992-1996	Winter	19	77.631	0.055	0.27	29.83
1992-1996	Summer	19	2.441	0.0207	0.32	10.04

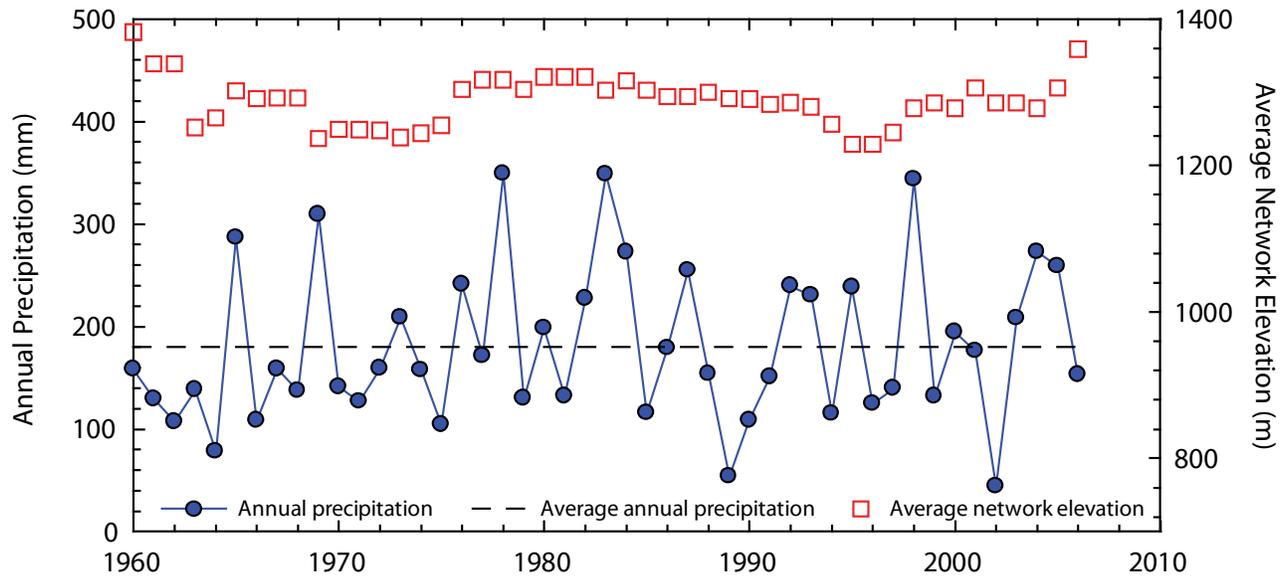
Precipitation varies little north-south and east-west on NTS, with less trend than the effect of elevation (table 2). Although the  $r^2$  values obtained by using equation 1 with latitude as the independent variable suggest that there is a statistically significant relation of increasing precipitation with increasing distance northward, the slope of the regression equation is very low; also, elevation generally increases northwards as well. No statistically significant relations were found between precipitation and east-west position on the NTS (table 2). These results, which show minimal trends in average precipitation with position on the NTS, show the strong influence of elevation and show that a multivariate approach to estimating monthly precipitation using position and elevation may not be compromised by drift imposed by the northing-easting data.

**Table 2.** Regression equations for annual and seasonal precipitation as a function of climate-station position ( $n = 115$  stations) on the Nevada Test Site.

Time period	Season	Independent variable	Regression constant $c$	Coefficient $a$	Regression coefficient $r^2$	Standard error of estimate
1960-2006	Annual	Northing	-6546	0.002	0.42	37.86
1960-2006	Winter	Northing	-3107	0.001	0.22	28.96
1960-2006	Summer	Northing	-2859	0.001	0.56	12.43
1960-2006	Annual	Easting	633	-0.001	0.06	35.38
1960-2006	Winter	Easting	519	-0.001	0.11	30.92
1960-2006	Summer	Easting	57.2	-0.000	0.00	18.63

## Time-Series Analysis

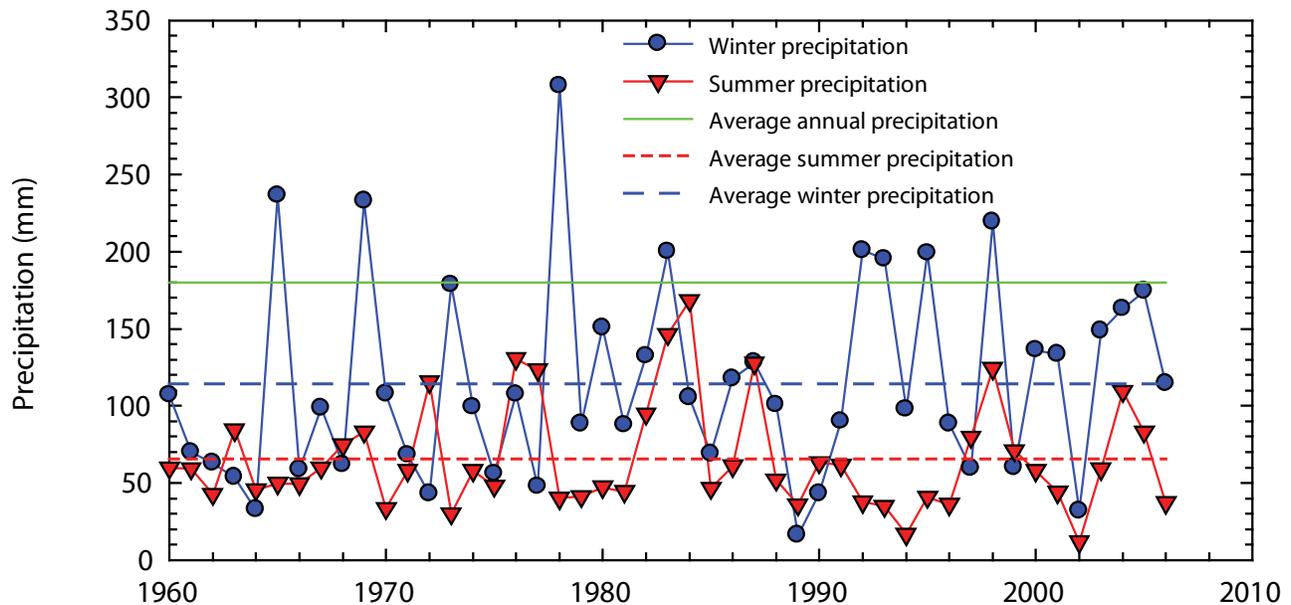
On the basis of all the available rainfall data, the wettest three years on record were 1978 (annual precipitation of 349 mm), 1983 (348 mm), and 1998 (343 mm) (fig. 7). During the period of 1978 through 1984, 5 of the 7 years had above-average precipitation; in contrast, both 1969 and 1998 were preceded and followed by below-average years. The three driest years on record were 2002 (annual precipitation of 44 mm), 1989 (54 mm), and 1964 (78 mm). Two of these driest years are parts of longer droughts that occurred from 1988 through 1991 and 1959 through 1964. For the period of record, above-average annual precipitation was recorded for 20 years, and below-average annual precipitation was recorded for 24 years (fig. 7).



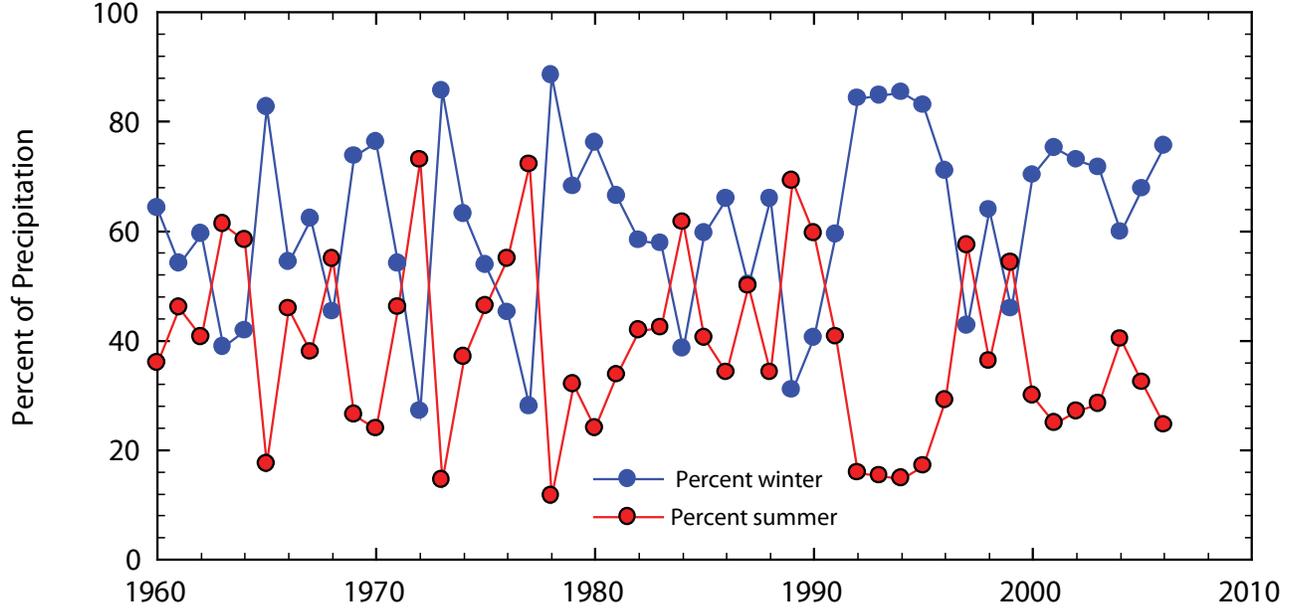
**Figure 7.** Time series of annual precipitation on the Nevada Test Site from 1960 to 2006. The dashed line is the mean annual precipitation averaged over all the gages for the same time period, and the red squares represent the average elevation of the actively recording precipitation stations.

The amount of seasonal precipitation varies from year to year, with winter precipitation generally mirroring annual precipitation and summer precipitation showing a different variation (fig. 8). During the five wettest years on record since 1960 (1965, 1969, 1978, 1983, and 1998), winter season precipitation varied from 57 to 88 percent of the annual precipitation. In some years, particularly 1964, 1972, 1977, 1989, and 1990, winter precipitation was below average and less than summer rainfall. Summer precipitation also was greater than winter season precipitation in some years when winter precipitation was at or above average (1976, 1984, and 1987). The time series data in figure 8 show that for at least some years, summer precipitation can be a high percentage of annual precipitation and therefore is a significant source of moisture to the ecosystem of the NTS. Although summer precipitation can be significant portion of annual precipitation, the timing, duration, and intensity of summer precipitation is distinct from winter precipitation which results in ecological differences for plant mortality and recruitment.

The percentage of precipitation that occurs in each season varies annually (fig. 9). On average, for the extent of the network of climate stations, 61 percent of annual precipitation occurs in winter and 39 percent occurs in summer. During high-rainfall periods, particularly those associated with El Niño conditions, the percentage of winter precipitation is much higher (e.g., 1978-1983, 1991-1995; fig. 9). During some drought years, notably 1989 and 1990 (fig. 9), the percentage of precipitation that occurs in summer is much higher than the percentage in winter. Persistence of the percentages of winter versus summer rainfall, particularly following 1978, is striking compared with the earlier part of the record and may have significant ecological consequences in terms of plant mortality and recruitment.



**Figure 8.** Time series of winter (November through April) and summer (May through October) season precipitation, an average of all the precipitation gages, from 1960 to 2006 for the Nevada Test Site.



**Figure 9.** Time series of percent of winter season (November through April) and summer season (May through October) precipitation from 1960 to 2006 for the Nevada Test Site. Because the winter season starts November 1, the percentages are based on the sum of the winter and summer precipitation and therefore correspond to the year from November 1 through October 31.

## Multivariate Statistical Analyses

Monthly precipitation data were spatially interpolated using a combination of multivariate regression of the geospatial position and inverse distance-square weighting (Nalder and Wein, 1998). Although this technique was developed for northern Canada, it can be applied to any geographic region or climate regime. Nalder and Wein (1998) found that their method outperformed other standard geostatistical techniques for estimating variables in space, including the better known techniques of kriging and co-kriging. Their method was shown to interpolate data more efficiently, which makes it highly desirable in the case of precipitation in the inter-mountain West.

The technique of Nalder and Wein (1998) uses linear-regression coefficients fit to precipitation data for each month along north-south, east-west, and elevation gradients. These coefficients are used to weight the interpolation as follows:

$$Z = \frac{\sum_{i=1}^N \frac{Z_i + (X - X_i) \times C_x + (Y - Y_i) \times C_y + (E - E_i) \times C_e}{d_i^2}}{\sum_{i=1}^N \frac{1}{d_i^2}}, \quad (2)$$

where  $X$  and  $X_i$  are the easting of a grid cell and the easting of precipitation station  $i$ ,  $Y$  and  $Y_i$  are the northing of a grid cell and northing of precipitation station  $i$ , and  $E$  and  $E_i$  are the elevation of a grid cell the elevation of precipitation station  $i$ .  $C_x$ ,  $C_y$ , and  $C_e$  are the multiple linear-regression

coefficients for easting, northing, and elevation, respectively.  $N$  is the number of precipitation stations and  $d_i$  is the distance between the node of a model grid cell and precipitation station  $i$ .

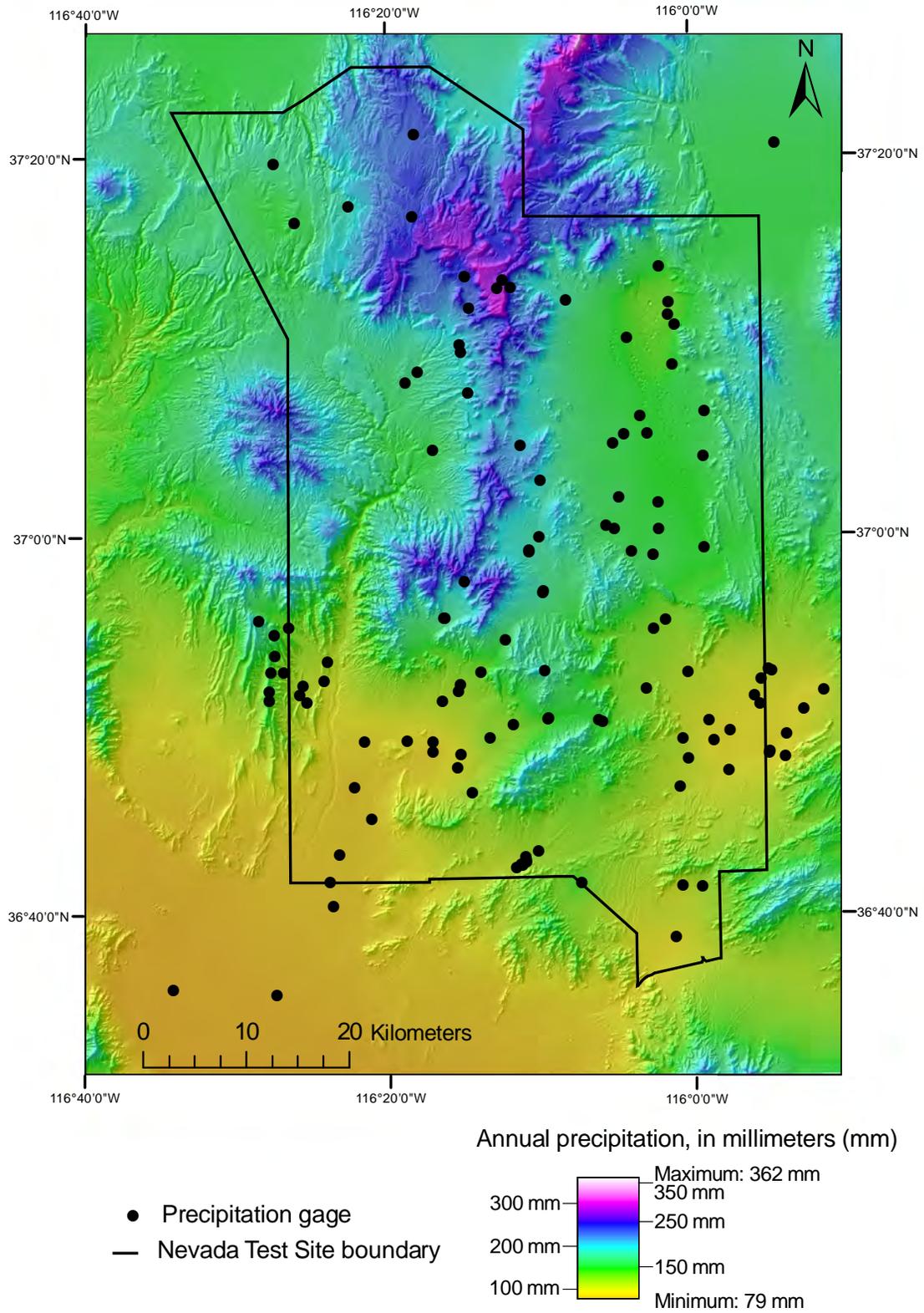
At each node of the 30-m DEM, this method interpolates between stations such that the precipitation between adjacent stations is most strongly influenced by the closest ones. The gradient plus inverse distance-square method (Nalder and Wein, 1998) defaults to the simpler inverse-distance method if the regression fit is statistically insignificant. The validity of the precipitation estimates obtained with this method depends greatly on the structure of the spatial correlation of precipitation as recorded by the climate-station network. Consequently, the density of stations, the topographic gradients between stations, and precipitation gradients between stations has a large influence on the interpolated precipitation.

For example, during the summer months, adjacent stations may record substantially different monthly precipitation due to small-scale convective thunderstorms that generate rainfall over a small (generally 2.5-25 km<sup>2</sup>) area. In this case, the gradient plus inverse distance-square method of interpolation results in a “bullseye” effect where precipitation estimates decrease rapidly in a radial manner with distance from the station that recorded high thunderstorm activity. The bullseye effect reflects the artificial smoothing of precipitation estimates relative to the local scale of the thunderstorm activity. The maps of interpolated precipitation may also look smooth because there is no local directional gradient. More complex spatial interpolation algorithms, such as those in the PRISM model (Daly and others, 1994), use directional gradients to account for effects such as rain shadows. However, the NTS is located a great distance from major mountain ranges, such as the Sierra Nevada, which is more than 350 km to the west and, consequently, rain shadow effects do not appear to exert a significant influence on the local distribution of precipitation.

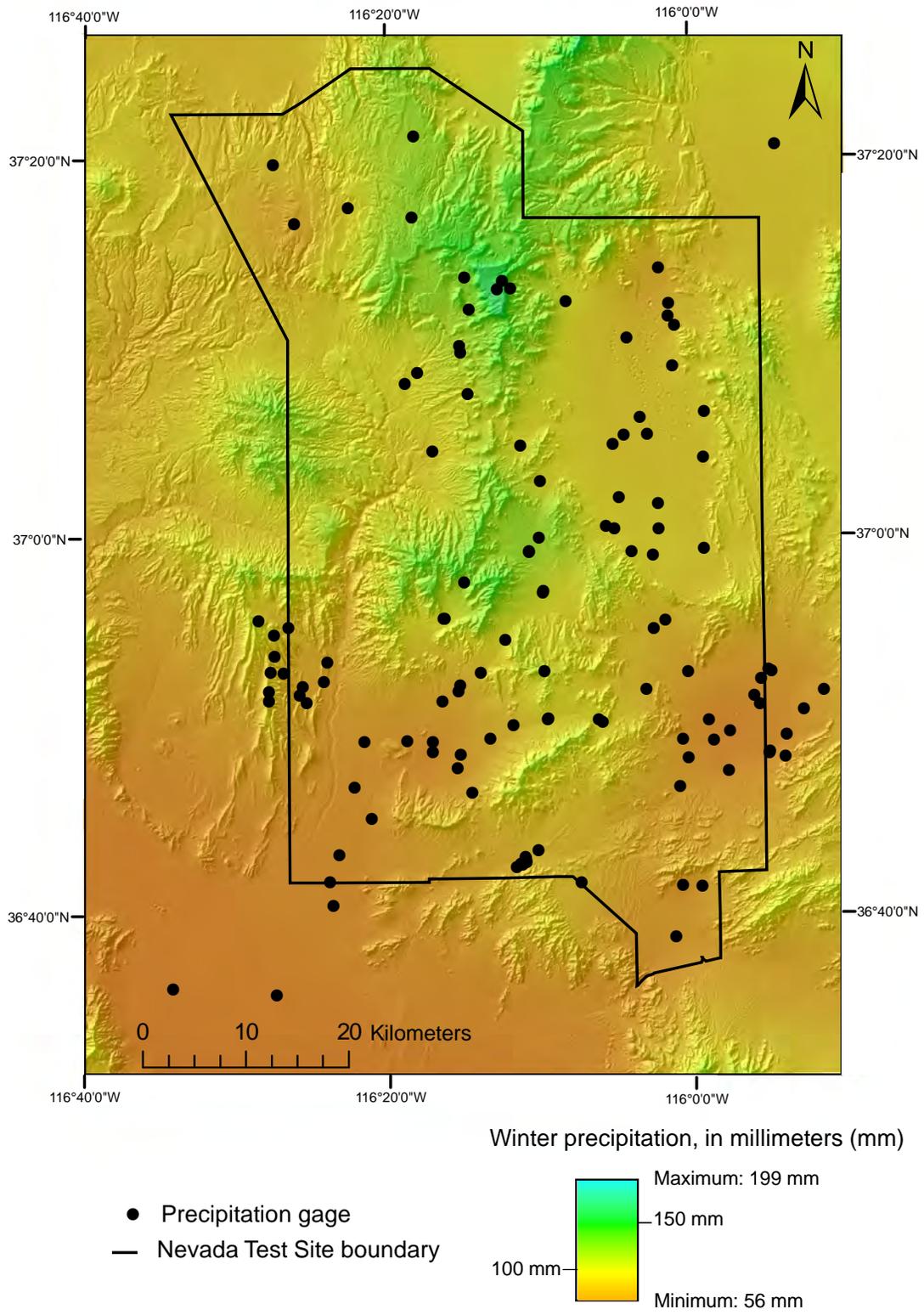
## Results of Spatial Interpolation of Precipitation

### Period of Record Precipitation Averages

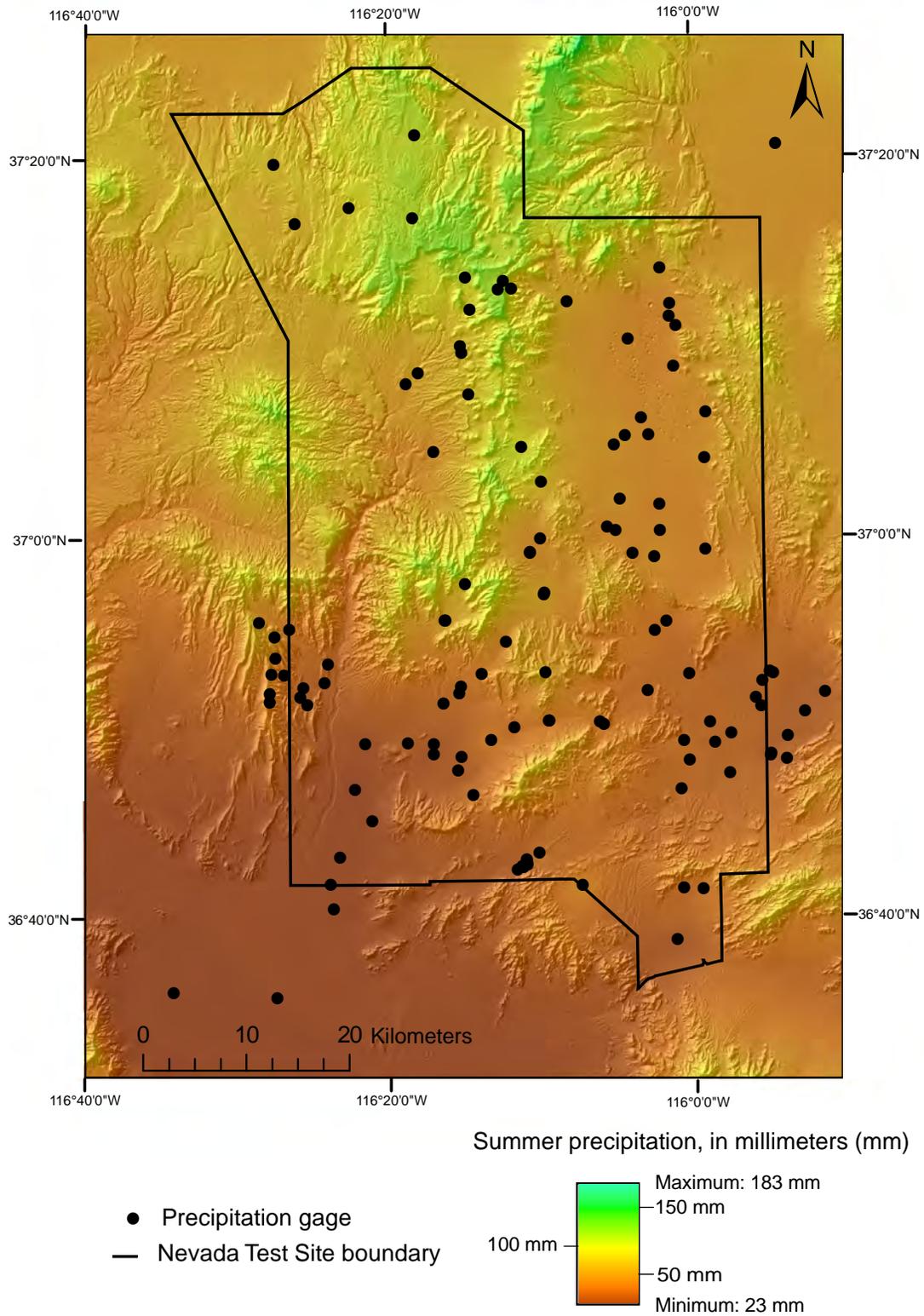
Period of record (POR) climate averages are a common way of characterizing climate at a particular location or over a region (fig. 10). For some areas, POR climate averages may not reflect average conditions at a specific location as some climate events, such as the Pacific Decadal Oscillation, persist for periods of 20 to 30 years (Hereford and others, 2004; 2006). POR average annual precipitation was calculated by averaging interpolated monthly precipitation at each 30-m node over the period 1960 through 2006 for the NTS and vicinity. The smallest POR average annual precipitation occurs in the southwestern portion of the modeling domain in the Amargosa Desert (79 mm); the highest POR average annual precipitation (362 mm) occurs on Rainer Mesa and along the Belted Range on the northern boundary of the model domain (fig. 10). In general, the POR average precipitation reflects topography, which is expected given the strong orographic influences within the climate-station data (fig. 6). For example, Yucca Flat and Frenchman Flats, which are broad flat-lying topographic lows, have lower average annual precipitation than adjacent areas and also have low variability in average annual precipitation. Strong precipitation gradients indicative of the topography are also evident with average annual precipitation increasing from the western to eastern portion of the southern part of the NTS. Lack of such a gradient in the north helps to explain why regressions between annual precipitation and easting (table 2) are not statistically significant.



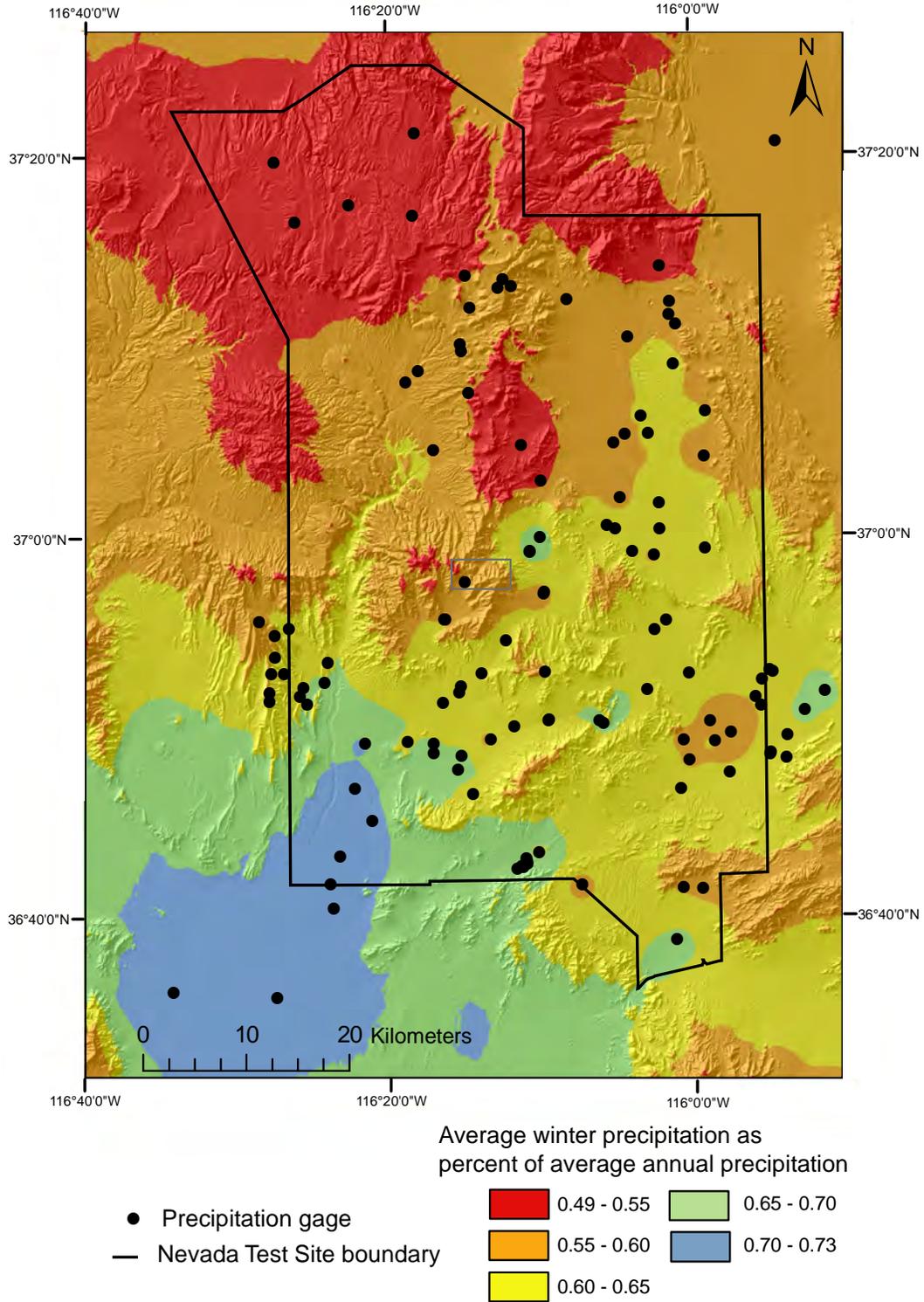
**Figure 10A.** Average annual precipitation over the period from 1960 to 2006 for the Nevada Test Site.



**Figure 10B.** Average winter season (November through April) precipitation over the period from 1960 to 2006 for the Nevada Test Site.



**Figure 10C.** Average summer season (May through October) precipitation over the period from 1960 to 2006 for the Nevada Test Site.



**Figure 10D.** Average winter season (November through April) precipitation as a percent of average annual precipitation over the period from 1960 to 2006 for the Nevada Test Site.

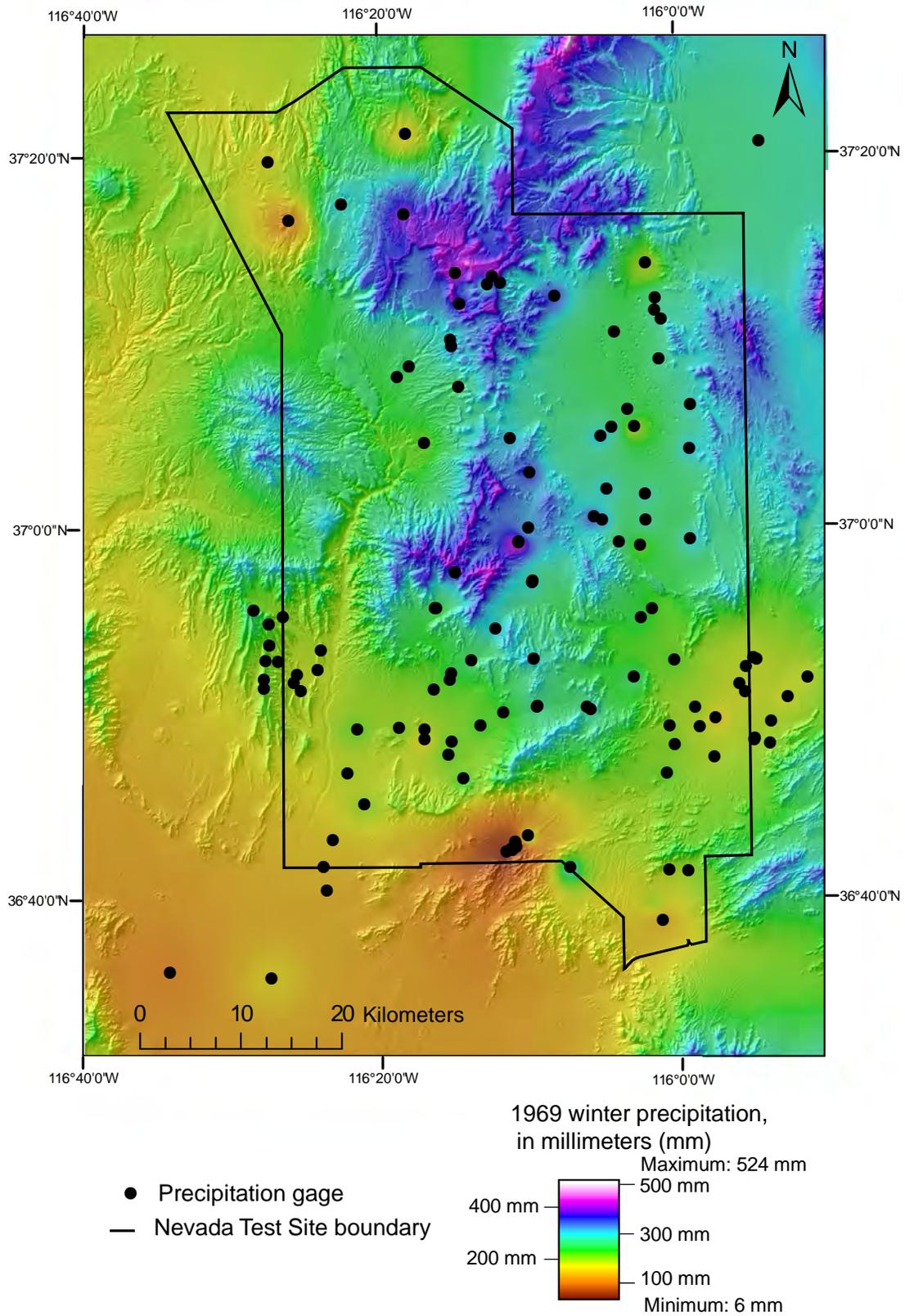
Like annual average precipitation, both average winter and summer precipitation are strongly dependent on elevation for the period of record. Most precipitation on the NTS occurs during the winter, and average winter precipitation ranges from 56 to 199 mm (fig. 10B) over the model domain. The average summer rainfall has less geographic variation and ranges from 23 to 183 mm (fig. 10C). In the lower elevations, or southwestern portion of the model domain, particularly in the area south of Yucca Mountain, winter precipitation accounts for most of the average annual precipitation (about 70 to 73 percent) (fig. 10D). In contrast, winter precipitation accounts for only about 50 to 55 percent of average annual precipitation at higher elevations on Pahute Mesa in the northwestern portion of the model domain.

### **Seasonal Precipitation for 1969, 1989, and 1998**

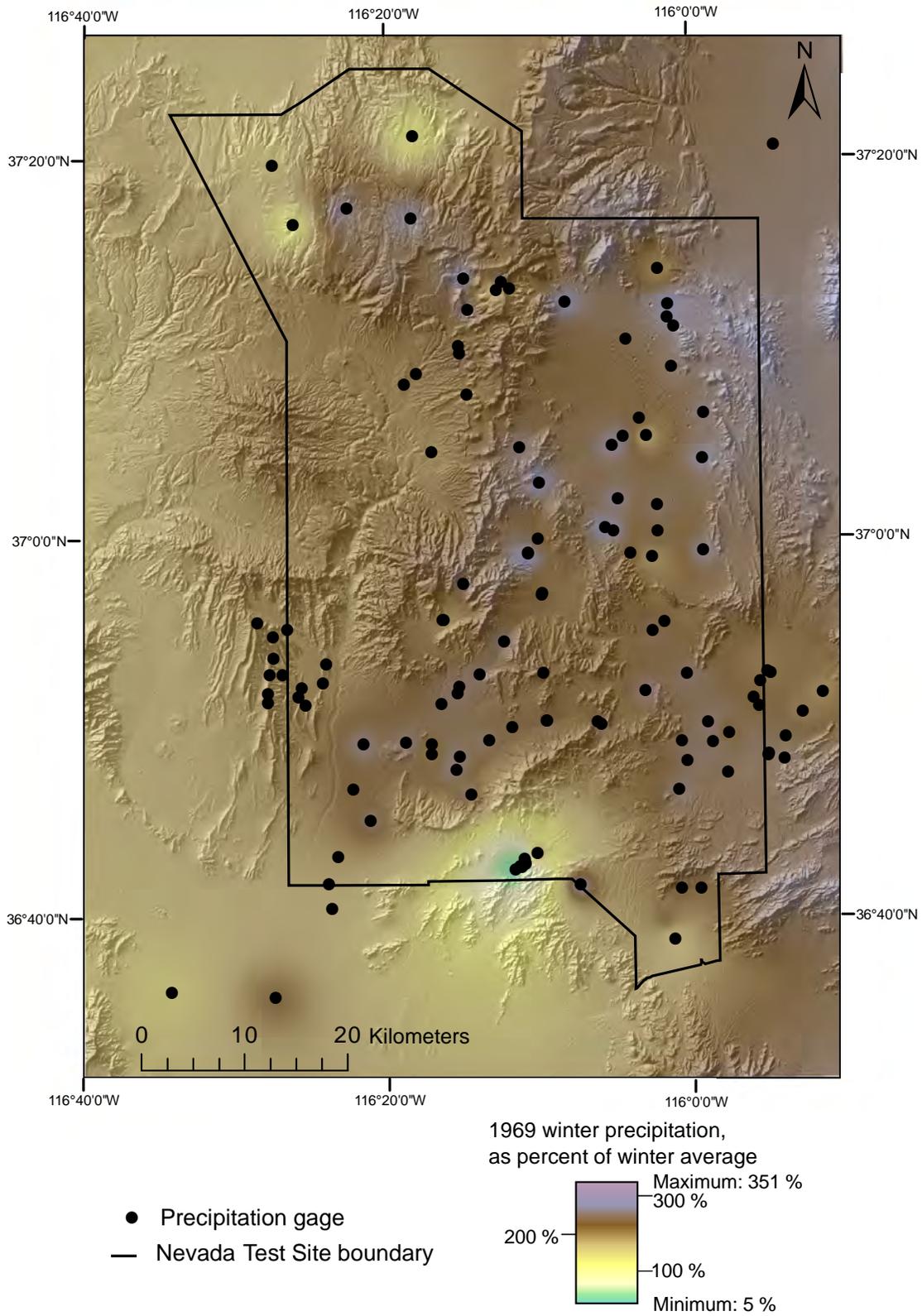
We also examined the spatial variability of seasonal precipitation on the NTS for select years during which precipitation was atypical for the period of record. Winter precipitation was evaluated for 1969 and 1998, both years having above average precipitation (the 3rd and 4th wettest years during the period of record). A major drought occurred on the NTS from 1989 to 1991; therefore, we created a map of annual precipitation for 1989 as an example of the spatial distribution of precipitation during such a drought.

Winter precipitation during 1969 was more than 450 mm on the higher-elevation terrain in the north-central parts of the NTS (fig. 11A) and was well above average throughout the modeling domain, mostly ranging from 2 to 3 times that of average (fig. 11B). Winter precipitation during 1969 was highest in the eastern one-third of the NTS, where it typically was greater than 250 percent of the average winter precipitation. The difference between winter season precipitation during 1969 and average winter precipitation was largely independent of elevation; precipitation extremes occurred both in higher-elevation areas (west of the Belted Range) and in the low-elevation areas (e.g., Frenchman Flats).

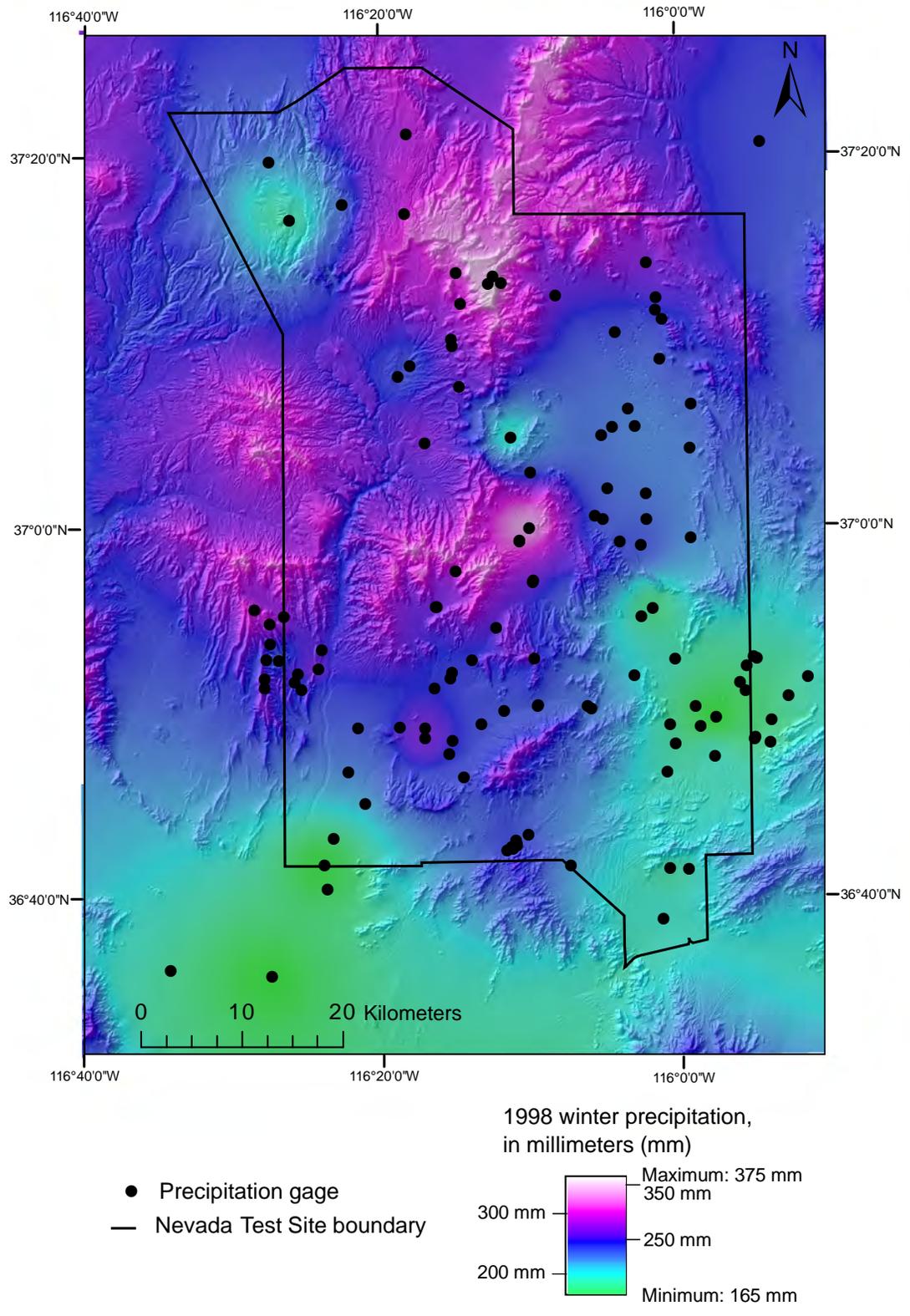
The distribution of precipitation during the winter seasons of 1969 and 1998 are significantly different due to a difference in storm types during the highest rainfall periods. For example, in February 1998, a procession of strong frontal systems crossed southern Nevada, leading to a relatively uniform coverage of precipitation across the NTS (<http://docs.lib.noaa.gov/rescue/dwm/1998/19980202-19980208.djvu>). In contrast, during February 1969, a series of cutoff low-pressure systems with a few frontal systems crossed southern Nevada, leading to more spatially patchy precipitation across the NTS. During the winter of 1998, precipitation was as much as 375 mm at higher elevations, or less than what occurred in 1969, and generally 165-200 mm at lower elevations, which was more than what occurred during 1969 (fig. 12A). The intermediate-elevation areas, including Jackass Flats and the area to its west and also in intermediate-elevation areas west of Buckboard Mesa, were mostly between 280 and 350 percent of the average winter precipitation (fig. 12B). By looking at 1998 winter precipitation as a percent of winter average (fig. 12B), it is evident that many of the high-elevation areas, particularly on Rainer Mesa and on the Belted Range, received less precipitation relative to the surrounding areas than would normally occur. The smallest increase in above normal winter season precipitation during 1998 occurred northwest of Frenchman Flats and west of Yucca Flat, which are low- and intermediate-elevation areas, respectively, in the central and southeastern portion of the NTS.



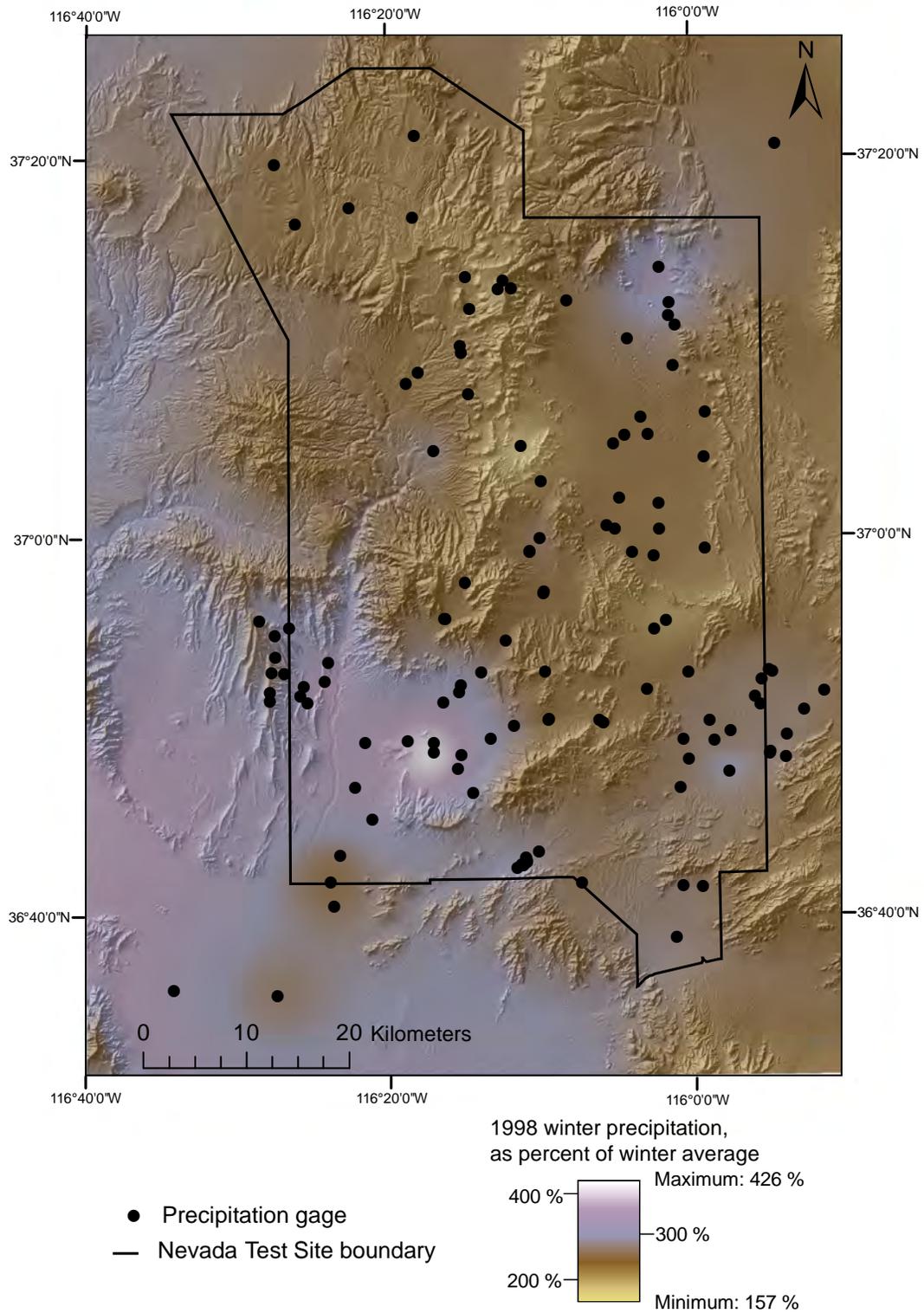
**Figure 11A.** Winter season (November through April) precipitation for 1969, a wet year on the Nevada Test Site.



**Figure 11B.** Winter season (November through April) precipitation, as a percent of average winter precipitation, for 1969, a wet year on the Nevada Test Site.



**Figure 12A.** Winter season (November through April) precipitation for 1998, a wet year for the Nevada Test Site.



**Figure 12B.** Winter season (November through April) precipitation for 1998, expressed as a percent of average winter precipitation, for the Nevada Test Site.

The drought of 1989 was pervasive, covering most of the NTS (fig. 13A), and particularly affecting winter precipitation. The drought was pronounced in the southwestern portion of the modeling domain. Low-elevation areas such as the Amargosa Desert and Crater Flat (fig. 1) received as little as 10 mm of annual precipitation. Parts of Yucca Mountain, at intermediate elevations, also experienced extreme drought with as little as 5 mm of annual precipitation. During this drought year, areas at lower elevations and further east than Yucca Mountain, such as Frenchman Flats, received about 26 mm of annual precipitation.

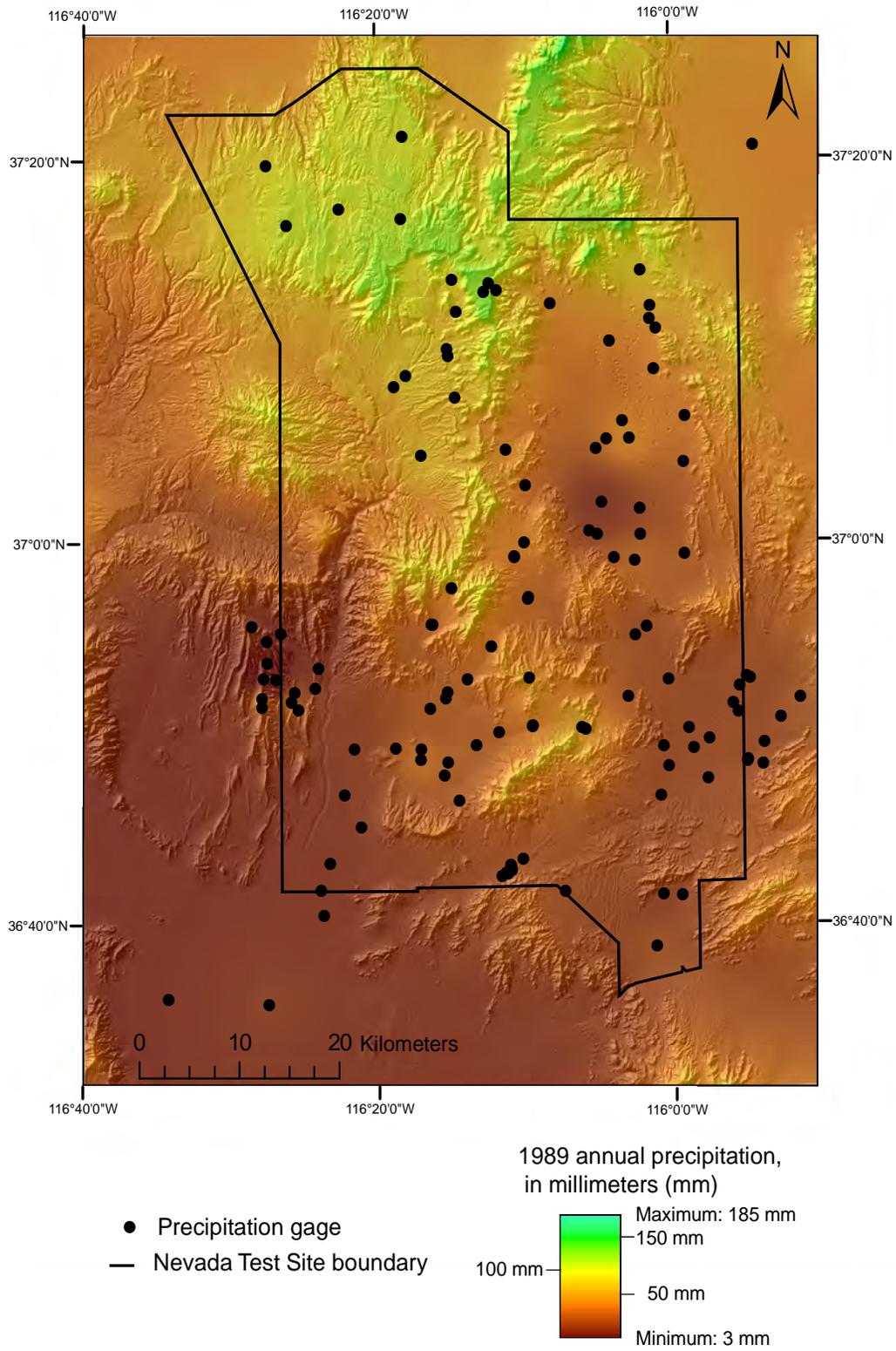
Differences between annual precipitation during 1989 and average precipitation were strongly dependent on elevation. Annual precipitation for 1989 varied between 2 and 71 percent of average annual precipitation (fig. 13B). The greatest precipitation deficit, which resulted in precipitation that was about 5 to 10 percent of average annual precipitation, occurred in the vicinity of Yucca Mountain and west of Jackass Flats in the southwestern part of the NTS. Precipitation was closest to normal at higher-elevation areas in the northern part of the NTS, including Pahute Mesa, where precipitation was about 50 percent of normal.

### **Seasonal Coefficients of Variations**

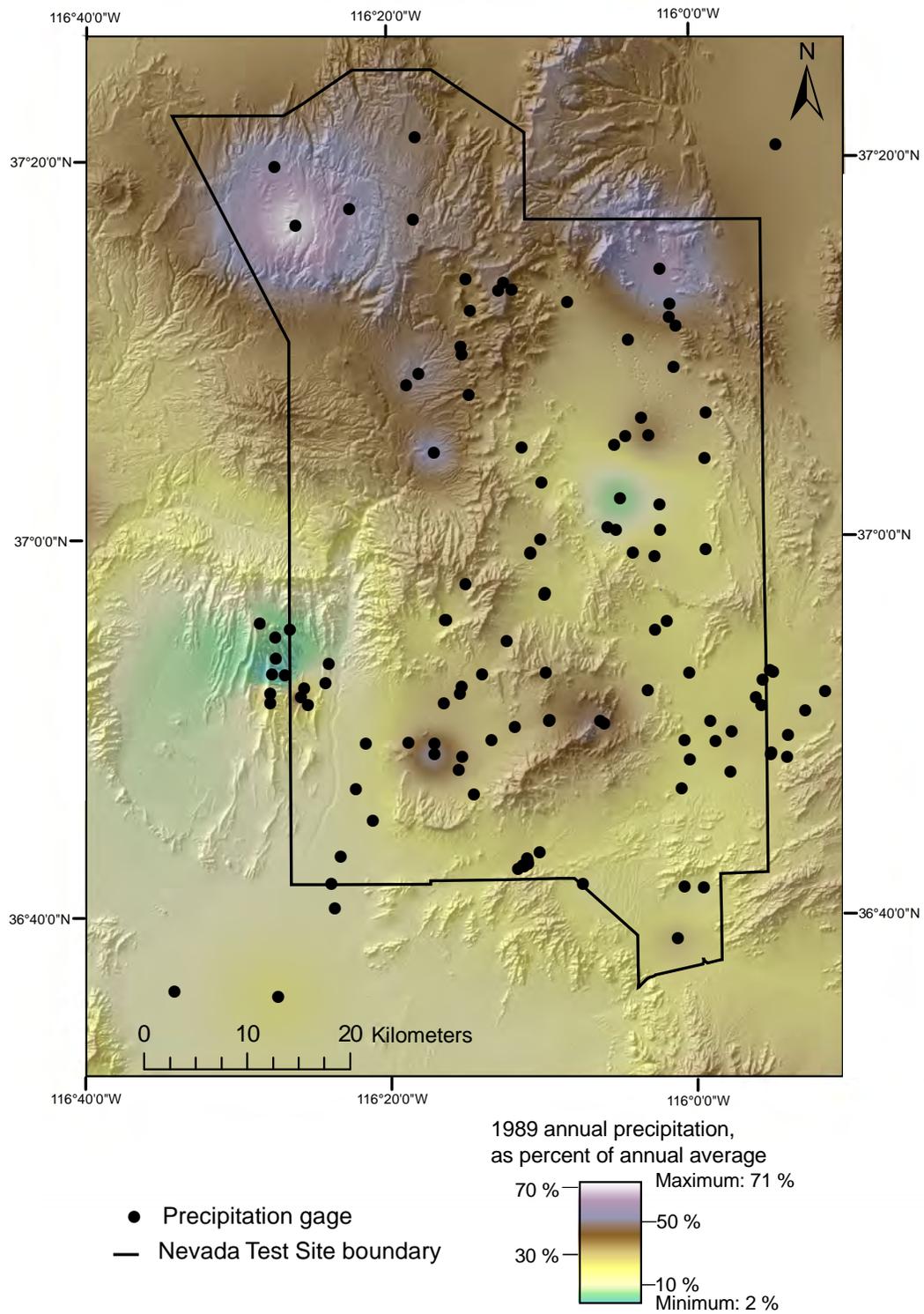
We examined temporal variability in precipitation by producing maps of the coefficient of variation (CV) for the winter and summer seasons (fig. 14) based on interpolated precipitation from 1960 to 2006. The CV, defined as the standard deviation of a sample population divided by the mean of the sample, is one way of providing a meaningful comparison between sample populations (in this instance, precipitation at different locations). The CV is a useful statistic for comparing the degree of variation from one data series to another, even if the means of the data series are significantly different.

For winter precipitation, the CV generally was lower in the northwest (generally higher elevation) and higher in the southeast (lower elevation; fig. 14A). Other than the general pattern, local elevation gradients seem relatively unimportant for the winter season rainfall CV. A large radial gradient, or “bullseye,” indicates an outlier precipitation gage located on Pahute Mesa. The winter season CV near the gage was significantly higher than the CV of surrounding areas. For winter season CV, most values ranged between 0.42 and 0.65 (95 percent confidence interval).

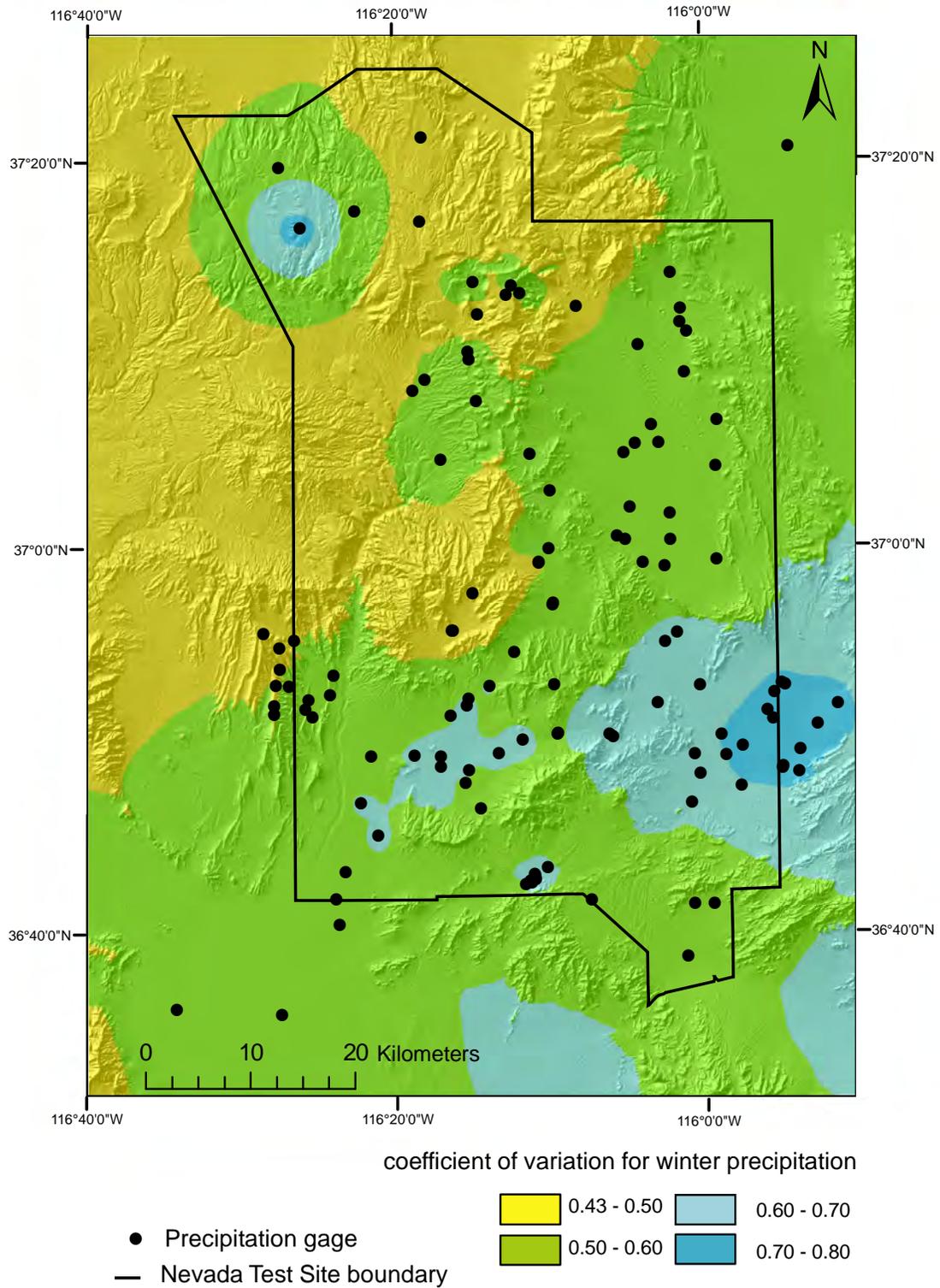
Average summer season CV was equal to winter season CV with mean values of 0.54. However, summer season CV was more variable across the model domain as indicated by the larger 95 percent confidence interval of 0.36 to 0.71. Summer precipitation had a stronger northwest-southeast gradient with lower CVs in the northwest and higher CVs in the south and southeast (fig. 14B). Although local elevation gradients influence the summer season CV, there were also low relief areas with significant variability in CV. For example, there was a large gradient (0.56 to 1.04) for the summer season CV in the Amargosa Desert although there was little variation in elevation (less than 100 m) in this area. Note that the outlier precipitation gage for the winter season CV, which was located on Pahute Mesa, was not an outlier for the summer season CV. This indicates that the outlier was not likely due to a systematic problem such as an incorrect station elevation but rather a reflection of the winter season precipitation data at this station.



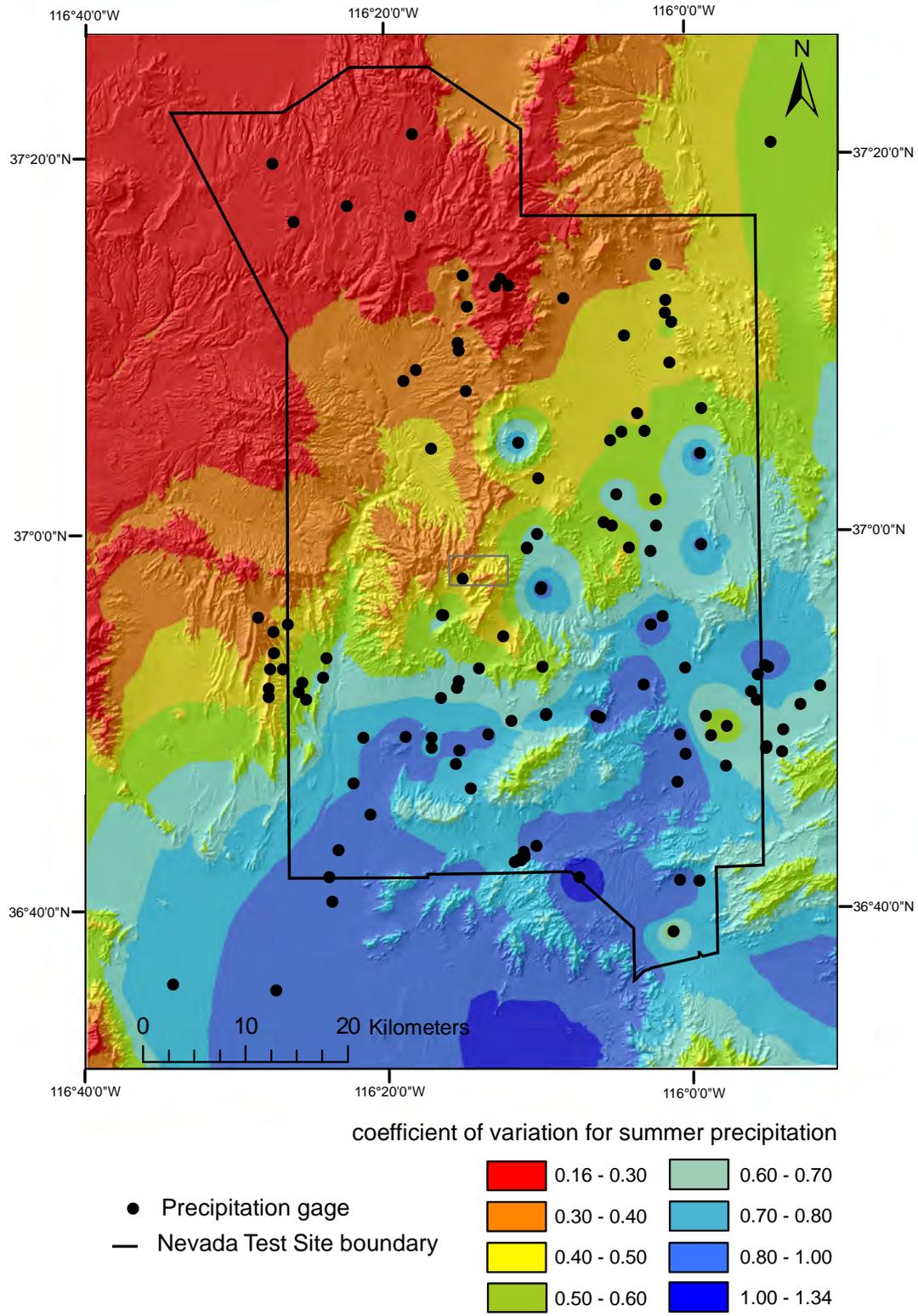
**Figure 13A.** Annual precipitation for 1989, a year of severe drought, for the Nevada Test Site.



**Figure 13B.** Annual precipitation for 1989, expressed as a percent of average annual precipitation, for the Nevada Test Site.



**Figure 14A.** The coefficient of variation (CV) of winter season (November through April) precipitation for the Nevada Test Site.



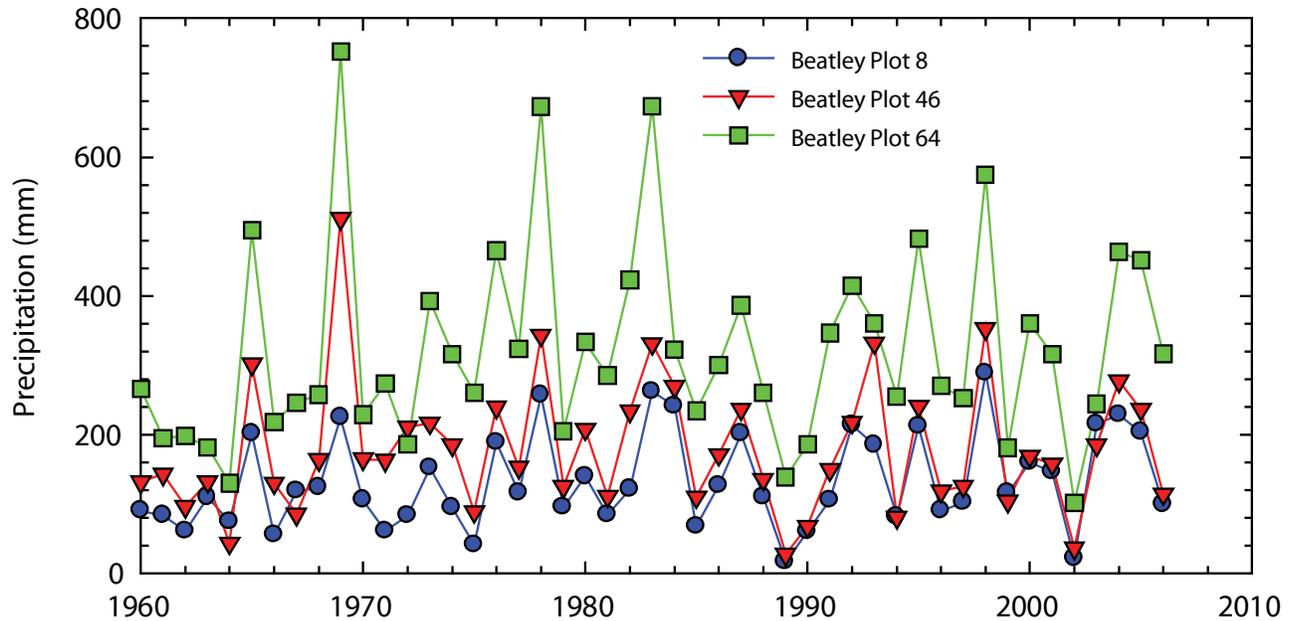
**Figure 14B.** The coefficient of variation (CV) of summer season (May through October) precipitation for the Nevada Test Site.

## Time Series at Specific Sites

Permanent ecological study plots on the NTS have been measured at irregular intervals from 1963 through 2006 (Webb and others, 2003). The plots established by Janice Beatley had storage rainfall gages that recorded between 1963 and 1973, but for most plots, no precipitation data is available after 1973, requiring that precipitation be estimated from other sites. We used our interpolation technique to create time series of precipitation at three Beatley plots—plots 8, 46, and 64 (fig. 1)—that span the elevation range of NTS to show the usefulness of this technique in understanding the potential for climatic influence on vegetation. As shown in figure 15, these three plots, which range in elevation from 961 to 2,274 m, generally show the same interannual variability; all three plots show the same pattern of above- and below-average annual precipitation, although the relative amounts exhibit a high amount of inter-annual variability.

For the NTS in general, 1978 is the wettest winter on record by a wide margin (fig. 8), but 1978, 1983, and 1998 have similar high annual precipitation (fig. 7). A similar pattern also occurs on the three Beatley plots (fig. 15), where 1969, 1978, and 1983 have the highest annual precipitation, followed closely by 1998. At Beatley plots 46 and 64, annual precipitation in 1969 is the largest annual precipitation on record. In contrast, when all stations in the network were averaged, 1969 is the 4<sup>th</sup> wettest year on record. By comparing the observed and simulated precipitation at Beatley plot 64 with the adjacent active precipitation gage on Rainer Mesa, located within a distance of 1 km, it is evident that precipitation recorded during the winter of 1969 at Beatley plot 64 was much greater than that of the adjacent station. The simulated annual precipitation at Beatley plot 64 was 752 mm while a gage (100013) at a similar elevation of 2,283 m, located on the eastern side of the ridge between the two gages, recorded 480 mm of precipitation. Monthly precipitation was recorded at Beatley plot 64 for each month of 1969 with the exception of February. Based on 11 months of precipitation data, the recorded annual precipitation at Beatley plot 64 was at least 670 mm.

The drought of 1989-1991 is striking for these three plots; no other year in the record has as low an annual precipitation with as little variability with elevation as occurred in 1989, and the 3-year period is unprecedented in the 47-year interpolated record. This type of data provides support for the contention that the nature of the 1989-1991 drought, which had devastating effects on some plant species on the NTS (Webb and others, 2003), is unique to the historical record of precipitation on the NTS. Another significant drought occurred during 2002. Like the drought of 1989-1991, lower than average precipitation occurred at low, mid, and high elevations on the NTS during 2002.



**Figure 15.** Time series of annual precipitation from 1960 to 2006 for a high elevation (2,274 m, Beatley plot 64), an intermediate elevation (1,245 m, Beatley plot 46), and a low elevation (961 m, Beatley plot 8) permanent ecological study plot on the Nevada Test Site.

## Study Limitations

The quality of the spatial interpolation of precipitation described in this report is strongly dependent on the accuracy of the precipitation data at individual gages and on the density of the gage network. Data were collected by different groups using different measurement devices, frequencies of data collection, data-collection protocols, and quality assurance procedures. Due to data gaps and changes in the number and location of actively recording precipitation gages, the density of the gage network changes both temporally and spatially. The density of the gage network was insufficient to accurately represent small-scale thunderstorms with the exception of the high density network around Yucca Mountain. While the accuracy and reliability of the precipitation estimates presented in this report are dependent on the quality of the precipitation data, they are also dependent on the interpolation schemes we used. In general, interpolation tends to produce smoothed estimates of precipitation. In addition to the precipitation data, the accuracy of the interpolation scheme also depends on the resolution of the DEM; as the DEM resolution increases, the elevation of the DEM becomes more accurate, which improves the precipitation estimates. A simple interpolation scheme was employed in this report. A more detailed interpolation scheme could consider the location and direction of the precipitation gage relative to areas with significant local relief.

## Conclusions

High-resolution spatial models for interpolating precipitation are highly useful in the intermountain western United States, where networks of climate stations provide only sparse spatial coverage. A statistically robust technique was used to estimate annual and seasonal precipitation on the Nevada Test Site (NTS) at 30-m resolution, which is sufficient to allow reconstruction of

climate at specific sites of interest, including permanent ecological study plots where climatic records are discontinuous. Using this technique, one can evaluate both the spatial variation of precipitation during a given year as well as a time series of precipitation over a region. An added benefit is the ability to calculate spatially distributed coefficients of variation, which give a measure of the variation in reliability of precipitation over a region.

This technique allows us to evaluate different types of years that might otherwise be thought of as “wet years” and “dry years.” As shown in our graphical maps, wet years can vary significantly in the magnitude of above-average precipitation, with some parts of the NTS with near-normal precipitation whereas others have greatly above-average amounts. The same is true of drought years, where near-normal precipitation can occur at the highest elevations while extreme drought occurs at lower elevations. With respect to evaluation of the causes of change in ecological study plots, one application of this technique—the high-resolution precipitation maps—can help to explain regional variation in response; for example, why higher-elevation sites may not change as much in response to a drought period as lower-elevation sites.

Finally, this technique changes the relative value of short-term climate data. For stable calculation of mean annual precipitation and its interannual variance, climate records of relatively long duration are preferred. For regional interpolation, short-term climate stations provide important information for specific periods of time that help to decrease the amount of uncertainty within that region. Therefore, this technique increases the importance of short-term data, which may provide poor temporal coverage but enhances the sparse spatial coverage within the intermountain West.

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[http://www.sord.nv.doe.gov/climate/Climatology\\_of\\_The\\_Nevada\\_Test\\_Site.Soule.pdf](http://www.sord.nv.doe.gov/climate/Climatology_of_The_Nevada_Test_Site.Soule.pdf).
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# Appendix

**Table A1.** Metadata for precipitation stations on or adjacent to the Nevada Test Site, Nye County, Nevada. The only data used were from January 1, 1960, through December 31, 2006.

[Station ID is either the NCDC number or our uniquely assigned numbers. The data sources are ARL-SORD, Air Resource Laboratory Special Operations Research Division (<http://www.sord.nv.doe.gov/arl-sord-1.htm>); BEATLEY, unpublished data collected by Janice C. Beatley (Webb and others, 2003); BECAMP, unpublished data in the files of the Basic Environmental Compliance And Monitoring Program archives, NTS (also see Soulé, 2006); F&D, Flint and Davies, 1997; NDFF, Nevada Desert FACE (Free Air Carbon dioxide Enrichment) Facility ([https://www.unlv.edu/Climate\\_Change\\_Research/NDFF/](https://www.unlv.edu/Climate_Change_Research/NDFF/)); NCDC, National Climatic Data Center (see <http://www.wrcc.dri.edu/summary/Climsmnv.html>); YMMM, Yucca Mountain Meteorological Monitoring (<http://www.ymp.dri.edu/index.html>). Many stations have isolated month(s) of missing data.]

Station ID	Station Name	UTM NAD 27 Z11 easting	UTM NAD 27 Z11 northing	Elevation (meters)	Period of Record	Data Source
100001	40 Mile Canyon North	563357	4100361	1,469	February 1960- January 2007	ARL-SORD
100002	Area 06 (South)	586028	4083950	1,131	February 1997- January 2007	ARL-SORD
100003	Buster Jangle	584239	4102053	1,241	February 1960- January 2007	ARL-SORD
100004	Cane Springs	579559	4074210	1,219	September 1964- January 2007	ARL-SORD
100005	Desert Rock	587109	4053082	991	October 1963- January 2007	ARL-SORD
100006	E Tunnel	570906	4116230	1,905	December 1996- January 2007	ARL-SORD
100007	Jackass Flats	563452	4071024	1,043	January 1958- January 2007	ARL-SORD
100008	Little Feller 2	561843	4107992	1,561	August 1976- January 2007	ARL-SORD
100009	Mercury	587728	4058111	1,149	April 1962- October 1963, March 1971 - January 2007	ARL-SORD
100010	Mid Valley	573706	4091939	1,421	September 1964- January 2007	ARL-SORD
100011	Pahute Mesa 1	549887	4122427	1,997	January 1964- January 2007	ARL-SORD
100012	PHS Farm	585309	4118275	1,392	October 1964- January 2007	ARL-SORD
100013	Rainier Mesa	569649	4116158	2,283	January 1960- January 2007	ARL-SORD
100014	Rock Valley	572170	4060062	1,036	March 1963- January 2007	ARL-SORD
100015	Tippipah Spring 2	571899	4100860	1,518	May 1960- January 2007	ARL-SORD

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100016	Well 5B	592307	4073198	939	October 1962- January 2007	ARL-SORD
100017	Yucca Dry Lake	584801	4090255	1,196	January 1960 – January 2007	ARL-SORD
200001	Beatley Plot 01	586161	4055122	1,020	May 1962- December 1972	BEATLEY
200002	Beatley Plot 02	577878	4058342	1,082	May 1962- December 1972	BEATLEY
200003	Beatley Plot 03	572505	4060647	1,035	May 1962- December 1972	BEATLEY
200004	Beatley Plot 04	573690	4061459	1,049	May 1962- December 1972	BEATLEY
200005	Beatley Plot 05	567230	4067091	1,114	May 1962- December 1972	BEATLEY
200006	Beatley Plot 06	565813	4069462	1,075	May 1962- December 1972	BEATLEY
200007	Beatley Plot 07	557463	4064520	979	June 1962- December 1972	BEATLEY
200008	Beatley Plot 08	555765	4067591	961	June 1962- December 1972	BEATLEY
200009	Beatley Plot 09	556740	4071993	1,009	July 1962- December 1972	BEATLEY
200010	Beatley Plot 10	560870	4072134	1,051	July 1962- December 1972	BEATLEY
200011	Beatley Plot 11	565918	4076930	1,202	July 1962- December 1972	BEATLEY
200012	Beatley Plot 12	566076	4077556	1,245	July 1962- December 1972	BEATLEY
200013	Beatley Plot 13	568086	4078781	1,297	July 1962- December 1972	BEATLEY
200014	Beatley Plot 14	570454	4081948	1,465	July 1962- December 1972	BEATLEY
200015	Beatley Plot 15	566131	4070745	1,149	August 1962- December 1972	BEATLEY
200016	Beatley Plot 16	568975	4072384	1,177	August 1962- December 1972	BEATLEY
200017	Beatley Plot 17	571227	4073658	1,269	May 1962- December 1972	BEATLEY
200018	Beatley Plot 18	564538	4084008	1,452	July 1962- December 1972	BEATLEY
200019	Beatley Plot 19	564472	4084019	1,442	August 1962- December 1972	BEATLEY
200020	Beatley Plot 20	587439	4067689	1,005	June 1962- December 1972	BEATLEY
200021	Beatley Plot 21	588286	4070491	982	August 1962- December 1972	BEATLEY
200022	Beatley Plot 22	587730	4072357	1,001	July 1962- December 1972	BEATLEY
200023	Beatley Plot 23	590275	4074238	979	September 1962- December 1972	BEATLEY
200024	Beatley Plot 24	588227	4078898	1,048	May 1962- December 1972	BEATLEY
200025	Beatley Plot 25	584174	4077240	1,116	July 1962- December 1972	BEATLEY

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200026	Beatley Plot 26	579921	4073999	1,232	July 1962- December 1972	BEATLEY
200027	Beatley Plot 27	584859	4083111	1,132	July 1962- December 1972	BEATLEY
200028	Beatley Plot 28	596375	4079026	1,007	July 1962- December 1972	BEATLEY
200029	Beatley Plot 29	596029	4079195	987	July 1962- December 1972	BEATLEY
200030	Beatley Plot 30	594676	4076565	957	September 1962- December 1972	BEATLEY
200031	Beatley Plot 31	595205	4075785	954	July 1962- December 1972	BEATLEY
200032	Beatley Plot 32	601437	4077160	1,031	September 1962- December 1972	BEATLEY
200033	Beatley Plot 33	599466	4075291	1,009	September 1962- December 1972	BEATLEY
200034	Beatley Plot 34	597801	4072852	935	August 1962- December 1972	BEATLEY
200035	Beatley Plot 35	597718	4070719	1,015	August 1962- December 1972	BEATLEY
200036	Beatley Plot 36	596154	4071024	935	August 1962- December 1972	BEATLEY
200037	Beatley Plot 37	596205	4071199	953	October 1962- December 1972	BEATLEY
200038	Beatley Plot 38	590727	4072254	959	August 1962- December 1972	BEATLEY
200039	Beatley Plot 39	574144	4086703	1,467	October 1962- December 1972	BEATLEY
200040	Beatley Plot 40	574111	4086567	1,467	August 1962- December 1972	BEATLEY
200041	Beatley Plot 41	572760	4090653	1,538	July 1962- December 1972	BEATLEY
200042	Beatley Plot 42	572741	4090564	1,538	November 1962- December 1972	BEATLEY
200043	Beatley Plot 43	582700	4090610	1,274	July 1962- December 1972	BEATLEY
200044	Beatley Plot 44	581064	4092802	1,257	September 1962- December 1972	BEATLEY
200045	Beatley Plot 45	580226	4093124	1,284	September 1962- December 1972	BEATLEY
200046	Beatley Plot 46	581490	4095855	1,245	September 1962- December 1972	BEATLEY
200047	Beatley Plot 47	573852	4097457	1,472	September 1962- December 1972	BEATLEY
200048	Beatley Plot 48	580904	4101103	1,283	September 1962- December 1972	BEATLEY
200049	Beatley Plot 49	581946	4101986	1,258	September 1962- December 1972	BEATLEY
200050	Beatley Plot 50	583510	4103740	1,337	September 1962- December 1972	BEATLEY
200051	Beatley Plot 51	576317	4114983	1,535	September 1962- December 1972	BEATLEY
200052	Beatley Plot 52	586286	4114822	1,359	September 1962- December 1972	BEATLEY

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200053	Beatley Plot 53	586246	4113580	1,431	September 1962- December 1972	BEATLEY
200054	Beatley Plot 54	586853	4112702	1,362	September 1962- December 1972	BEATLEY
200055	Beatley Plot 55	586661	4108742	1,330	October 1962- December 1972	BEATLEY
200056	Beatley Plot 56	589772	4104270	1,339	September 1962- December 1972	BEATLEY
200057	Beatley Plot 57a	589658	4099870	1,271	September 1962- December 1972	BEATLEY
200058	Beatley Plot 58	585317	4095326	1,200	September 1962- December 1972	BEATLEY
200059	Beatley Plot 59	585367	4092811	1,195	September 1962- December 1972	BEATLEY
200060	Beatley Plot 60	589802	4090961	1,216	September 1962- December 1972	BEATLEY
200061	Beatley Plot 61	566068	4109952	1,746	August 1962- December 1972	BEATLEY
200062	Beatley Plot 62	565982	4110613	1,749	August 1962- December 1972	BEATLEY
200063	Beatley Plot 63	566441	4117269	2,001	August 1962- December 1972	BEATLEY
200064	Beatley Plot 64	570131	4116946	2,274	August 1962- December 1972	BEATLEY
200065	Beatley Plot 65	566790	4105957	1,697	December 1962- December 1972	BEATLEY
200066	Beatley Plot 66	574614	4074332	1,294	August 1963- December 1972	BEATLEY
200067	Beatley Plot 67	574566	4074243	1,294	August 1963- December 1972	BEATLEY
200068	Beatley Plot 68	566887	4114217	1,846	March 1964- December 1972	BEATLEY
260150	Amargosa Farms Garey <sup>1</sup>	548226	4047300	747	December 1965 – January 2007	NCDC
260714	Beatty <sup>1</sup>	522348	4085464	1,007	July 1948 – November 1972	NCDC
260718	Beatty 8 N <sup>1</sup>	525146	4094158	1,082	December 1972 – January 2007	NCDC
263980	Indian Springs <sup>1</sup>	617873	4049258	952	July 1948 – June 1964	NCDC
264457	Lathrop Wells <sup>1</sup>	553710	4056018	814	July 1948 – January 1963	NCDC
264473	Lathrop Wells 16 SSE <sup>1</sup>	558353	4030168	665	November 1973 – August 1977	NCDC
300001	ADA 27	554319	4061008	866	March 1965- September 1969	BECAMP
300002	CETO Building Mercury	589605	4058071	1,165	March 1973- June 1995	BECAMP
300003	GMX	595349	4078255	969	August 1976- April 1980	BECAMP
300004	Little Feller 1	560666	4106905	1,573	August 1976- May 1984	BECAMP
300005	Lookout Peak	574240	4078970	1,720	August 1962- February 1967	BECAMP

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300006	Pahute Mesa 2	547858	4128209	1,933	September 1964- December 1969	BECAMP
300007	Pahute Mesa 3	555124	4124032	1,978	September 1964- December 1969	BECAMP
300008	Pahute Mesa 4	561338	4123089	2,103	September 1964- December 1969	BECAMP
300009	Pahute Mesa 5	561477	4131041	2,058	September 1964- December 1969	BECAMP
300010	PU 13	596584	4130355	1,396	August 1976- April 1984	BECAMP
300011	Schultz Ranch	538173	4047887	727	March 1964- December 1969	BECAMP
300012	Shoshone Basin	566446	4087565	1,725	August 1962- December 1969	BECAMP
300013	Station 353	582221	4111402	1,329	August 1962- September 1964	BECAMP
300014	Rock Valley Plot A	571586	4059846	1,018	October 1969- February 1976	BECAMP
300015	Rock Valley Plot B	571994	4060169	1,050	October 1969 – April 1976	BECAMP
300016	Rock Valley Plot C	572549	4060354	1,020	October 1969- July 1979	BECAMP
300017	Rock Valley Plot D	572425	4060844	1,035	October 1969 – March 1975	BECAMP
400001	NTS-60	550772	4077380	1,143	December 1985- January 2006	YMMM
400002	Yucca Mountain	547644	4078749	1,478	January 1989- January 2006	YMMM
400003	Coyote Wash	548883	4078694	1,279	January 1989- January 2006	YMMM
400004	Alice Hill	553111	4079767	1,235	February 1990- January 2006	YMMM
400005	Gate 510	553418	4058384	838	January 1993- January 2006	YMMM
400006	WT-6	549377	4083103	1,315	July 1992- January 2006	YMMM
400007	Sever Wash	552801	4077854	1,081	July 1992- January 2006	YMMM
400008	Knothead Gap	551154	4075780	1,131	July 1992- January 2006	YMMM
500001	Nevada Desert FACE Facility	592223	4069284	965	October 1996- January 2007	NDFP
880001	WX-1	550424	4076521	1,163	January 1988- September 1995	F&D
880002	WX-2a	564332	4075931	1,154	May 1987- December 1989	F&D
880003	WX-2b	563430	4071986	1,055	January 1990- September 1995	F&D
880004	WX-3	548038	4080316	1,351	August 1987- September 1994	F&D
880005	WX-4a	547504	4076856	1,498	January 1988- December 1990	F&D
880006	WX-4b	547481	4075990	1,489	January 1991- September 1995	F&D

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880007	WX-5a	546453	4083775	1,789	July 1988- December 1993	F&D
880008	WX-5b	547984	4082370	1,563	January 1994- September 1995	F&D

<sup>1</sup>Station records both precipitation and snowfall.