



Climate Monitoring in the Northern Colorado Plateau Network

Annual Report 2008

Natural Resource Technical Report NPS/NCPN/NRTR—2009/215



ON THE COVER

Historic weather station, Dinosaur National Monument. National Park Service photo by Melissa Powell.

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Acronyms

CLIM-MET	Climate Impact Meteorological station
COOP	National Weather Service Cooperative Observer Program
CRN	Climate Reference Network
hr	hour
NCPN	Northern Colorado Plateau Network
NP	national park
NPS	National Park Service
QA/QC	quality assurance/quality control
RAWS	Remote Automated Weather Station
SNOTEL	Snowpack Telemetry
WRCC	Western Regional Climate Center

NCPN park units

ARCH	Arches National Park (UT)
BLCA	Black Canyon of the Gunnison National Park (CO)
BRCA	Bryce Canyon National Park (UT)
CANY	Canyonlands National Park (UT)
CARE	Capitol Reef National Park (UT)
CEBR	Cedar Breaks National Monument (UT)
COLM	Colorado National Monument (CO)
CURE	Curecanti National Recreation Area (CO)
DINO	Dinosaur National Monument (CO, UT)
FOBU	Fossil Butte National Monument (WY)
GOSP	Golden Spike National Historic Site (UT)
HOVE	Hovenweep National Monument (CO, UT)
NABR	Natural Bridges National Monument (UT)
PISP	Pipe Spring National Monument (AZ)
TICA	Timpanogos Cave National Monument (UT)
ZION	Zion National Park (UT)

Executive Summary

This report documents the 2008 monthly and annual climate summaries and climatic extremes for weather stations located within park units of the Northern Colorado Plateau Inventory and Monitoring Network (NCPN) and three stations located near park boundaries. In 2008, mean annual maximum and minimum temperatures tended to be below average throughout much of the NCPN region, while snowfall was notably above long-term averages. Differences between long-term means and this year's measures of average minimum and maximum temperature and total precipitation (and snowfall) were not related to the elevation gradient of stations. A general increase over the past 25–50 years in the 4-year composite, moving mean for mean annual minimum temperature is evident for most of the National Weather Service Cooperative Observer (Coop) stations in the NCPN. Conversely, there is evidence for a declining trend in snowfall over the past 20–25 years. Historical records for NCPN Coop stations indicate that annual precipitation has been highly variable, and that a strong unidirectional trend over the observation periods (18–81 years) is not readily evident.

1 Introduction

Climate is a key driver of ecosystem processes, and is one of the four interactive controls in the conceptual model of ecosystem sustainability (Chapin et al. 1996). Long-term patterns in rainfall and temperature provide first-order constraints on potential ecosystem structure and function (Whitford 2002). Secondary constraints are realized from the intensity and duration of individual weather events and, additionally, from seasonality and interannual variability. These constraints influence the fundamental properties of ecological systems, such as soil–water relationships, plant–soil processes, nutrient cycling, and disturbance rates and intensity. These properties, in turn, influence the life-history strategies supported by a climatic regime (Neilson 1987).

Understanding the role of climate as a forcing agent for other vital signs is critical to the efforts of the Northern Colorado Plateau Network (NCPN) Inventory & Monitoring program. Observed changes in other vital signs may occur in response to anthropogenic stressors or variation in climatic conditions. To ensure properly informed management decisionmaking, it is important to discern reasons for observed changes that are responsive to mitigation measures (e.g., anthropogenic vs. climate-driven). Moreover, distinguishing between intrinsic variation and climate-regime shifts provides useful insights into regional environmental change.

The overarching goal of the NCPN climate monitoring protocol is to compile and present climate data in a form that aids in understanding reasons for observed trends in other vital signs. Specific objectives of this protocol are:

1. To provide monthly and annual summaries of climatic parameters in NCPN park units. Fundamental climate variables include air temperature and precipitation. Additional variables include wind speed and direction, solar radiation, fuel temperature, and moisture.
2. To identify monthly and annual extremes for the fundamental climate variables.

The NCPN climate monitoring effort capitalizes on extant climate monitoring programs. Seven climate monitoring programs have a total of 33 weather stations in NCPN park units and 3 additional priority weather stations located nearby park units (Table 1). These programs provide consistent monitoring of weather conditions and, in some cases, provide a long-term climatic record. The majority of stations have observations dating back to the 1960s; the earliest record is from 1904, and 15 stations have been established since 1994 (Appendix A). The NCPN monitoring strategy is to obtain weather observations from agency archives annually, convert observations to 24-hour values where applicable, and store data on the NCPN server for ease of access and use.

This report follows the format and analyses employed in the previous report (Garman 2008), with exceptions. Analyses of 2008 data for CRN, SNOWNET, and Snow Course stations were not available; therefore, they are not included in this report. In order to provide more thorough coverage of the NCPN area, three additional stations were reported on for the first time: (1) the Hans Flat National Weather Service Cooperative Observer (Coop) station, located outside the park at the Hans Flat Ranger Station for the Maze district of Canyonlands National Park (CANY), (2) the Brian Head Coop station, located a few kilometers north of Cedar Breaks National Monument (CEBR), and (3) the Midway Valley SNOTEL site, located a few kilometers south of CEBR. In the future, data access and regional assessments will be enhanced using the tools of the National Park Service weather-data access and analysis system (NPCLime).

Table 1. Overview of climate monitoring programs, and number of weather stations by program in NCPN park units.

Climate monitoring program—Agency	Program synopsis	Number of weather stations															
		ARCH	BLCA	BRCA	CANY	CARE	CEBR	COLM	CURE	DINO	FOBU	GOSP	HOVE	NABR	PISP	TICA	ZION
NWS-Coop (National Weather Service [NWS] Cooperative Observer Program)—National Oceanic and Atmospheric Administration (NOAA)	Observer-based program created in 1890 to define the climate of the United States and help measure extreme weather events, climate variability, and long-term climatic changes. Core observations include 24-hour minimum and maximum temperatures, and 24-hour rain precipitation and snowfall.	1	1	1	3	1	1	1	1	2	1	1	1	1	1	1	1
RAWS (Remote Automated Weather Stations)—National Interagency Wildfire Program (U.S. Forest Service, Bureau of Land Management, NPS, et al.)	An interagency network used by fire-management personnel to estimate a fire-danger rating in support of preventive measures, and to forecast the behavior of wildland fires. RAWS stations consist of automated sensors that record air temperature and relative humidity, precipitation, wind speed and direction, and measures of fuel moisture and temperature every 15–60 minutes.	1	2						1								2
SNOTEL (SNOwpack TELelemetry)—National Resources Conservation Service (NRCS)	A high-elevation network to provide real-time climate data using automated remote sensing from sites in the mountainous regions of the Western U.S. Data include snow water equivalent, snow depth, precipitation, temperature, and other climatic elements at hourly intervals.		1				1										
Snow Course—NRCS	An observer-based program that manually measures snow depth and snow-water equivalent along a permanent transect.		1														
SNOWNET (including avalanche network)—MesoWest (University of Utah)	A collection of automated stations from various networks, and is used by the NWS Forecast Office. Data include air temperature and precipitation, and sometimes snow depth.					1										1	1
CRN (Climate Reference Network)—NOAA	An initiative to provide long-term observations of temperature and precipitation that can be coupled to past long-term observations for the detection of climatic change. High quality, automated stations record air temperature and precipitation, as well as measures of ground-surface temperature, solar radiation, wind speed, and sensor performance ca. every 2 seconds.	1				1			1								
CLIM-MET—USGS Earth Surface Dynamics Program—SW Climate Impacts	A research program of USGS. Data on atmospheric and surficial processes are automatically recorded at regular intervals (ca. 5 minutes). Sensors and site locations are subject to change to accommodate research needs.			2													

All weather stations are located within park units, except for CEBR, which has two weather stations located within 5 km of the park boundary, and CANY, which has one weather station located outside of the park boundary at the Hans Flat Ranger Station.

ARCH = Arches National Park; BLCA = Black Canyon of the Gunnison National Park; BRCA = Bryce Canyon National Park; CANY = Canyonlands National Park; CARE = Capitol Reef National Park; COLM = Colorado National Monument; CURE = Curecanti National Recreation Area; DINO = Dinosaur National Monument; GOSP = Golden Spike National Historic Site; HOVE = Hovenweep National Monument; NABR = Natural Bridges National Monument; PISP = Pipe Spring National Monument; TICA = Timpanogos Cave National Monument; ZION = Zion National Park

2 Methods

2.1 Data acquisition and quality control

Acquisition of weather station observations and data processing details are provided in the NCPN Climate Monitoring Protocol (Garman et al. 2004). In short, RAWS (Remote Automated Weather Stations) and SNOTEL (Snowpack Telemetry) observations are acquired from the Western Regional Climate Center (WRCC). Data for National Weather Service Coop stations are now accessible in NPCLime on the National Park Service (NPS) Intranet (www1.nrintra.nps.gov/NPCLime), which is tied to a national database of weather-station data. Data from SNOWNET stations are provided by MesoWest, located at the University of Utah. Observations for six stations were not archived and processed due to the current lack of an accessible data portal (4 CRN [Climate Reference Network] stations), and due to the temporary nature of research weather stations (2 CLIM-MET [Climate Impact Meteorological] stations). A goal of the NPCLime system is to provide access to all major weather-station networks; however, access to CRN data is not yet available.

Quality Assurance and Control (QA/QC) procedures are provided by external agencies. QA/QC for Coop data are performed by the National Climate Data Center. Data-quality codes indicate missing records or the use of estimation procedures. The WRCC performs QA/QC on SNOTEL data, and provides similar data-quality flags with the 24-hour (hour) data. RAWS data are received as 1-hour observations, and translated to 24-hour measures by the NCPN. SNOWNET data are received as 15-min–1-hour measures and converted to 24-hour values. The 24-hour conversion procedure for RAWS data involves data-quality checks following guidelines provided by MesoWest (see Garman et al. 2004). Additionally, if less than 85% of the 15-min or 1-hour observations is missing or otherwise flagged as suspect, the 24-hour measure is flagged as invalid.

2.2 Analyses

2.2.1 Data completeness

An assessment of data completeness for the four fundamental climate variables (maximum and minimum temperature, total precipitation, and snowfall) is provided for each weather station.

For purposes of this report, all 24-hour measures that were estimated or flagged as not valid (i.e., missing values or based on incomplete records) were excluded. For each station, the percentage of years with >95% valid daily values, with >85–95% valid daily values, and with <85% valid daily values were tallied for each climate variable. Reasons for noticeable data incompleteness were ascertained by general inspection of the data.

2.2.2 Parameters

All analyses used 24-hour measures. Station-level summaries used all valid daily data. Analyses using monthly or annual means or totals only used information based on 85% valid records. For monthly means, this required ca. ≥ 26 valid daily records. For annual means and totals, 310 valid daily records were required. Annual values were based on the calendar year. Monthly and annual summaries for consistently measured variables for each weather station in the NCPN park units are provided on the accompanying CD. See Section 4.2 of this report for a description of CD contents.

2.2.2.1 Climatic gradient

Using all NCPN weather stations, the relationship between annual means and totals and geographic (latitude) and elevation gradients was evaluated with least-squares regression.

2.2.2.2 Climatic extremes

Monthly means and totals were compared to the historical distribution of values using a variety of methods. Box-whisker plots show percentiles, minima, and maxima of monthly observations since the inception of each station. Overlaying 2008 observations on these plots highlighted extremes of the 2008 climate record where they occurred. Numerical deviation of a 2008 monthly mean or total from the corresponding long-term mean was further used to illustrate the historical context of 2008 climate attributes. Resulting graphics from this analysis are available for NCPN weather stations (MS-Word versions of graphs are contained on the accompanying CD).

For each NCPN weather station, annual means and totals for 2008 were differenced from station long-term means, and differences for stations were arrayed by elevation to assess topographic relationships. Data spanning the time of station inception up to the end of 2007 were the basis for long-term means.

2.2.2.3 Trend assessments

Annual means and totals for 2008 were combined with the historical record to evaluate trends. A moving mean based on the average of the three previous years plus the value of the year was generated to smooth trends. A cumulative or running mean illustrated the long-term mean at

points in time. Temporal trends for the four fundamental climate variables were evaluated with least-squares regression using the corresponding moving mean for stations with at least 10 years of valid data. Trend graphs are available for NCPN weather stations (MS-Word versions of graphs are contained on the accompanying CD).

3 Results

3.1 Data completeness

National Weather Service Coop stations generally have more complete rain and snowfall records than temperature records (Table 3.1; tables and figures appear at the end of this chapter). Exact reasons for missing or invalid records are not obvious from the data-quality flags. However, it is likely that malfunction or misreading of instruments is more common with temperature than with precipitation levels, which use physical measurement. Numerous Coop stations have missing records in winter months, notably Bryce Canyon National Park (BRCA), CEBR/Brian Head, both Dinosaur National Monument (DINO) stations, and Timpanogos Cave National Monument (TICA). RAWS stations vary in data completeness. The daily records of the BRCA/Agua Canyon RAWS station are especially limited from its earlier years. The SNOTEL stations at BRCA/Agua Canyon and CEBR/Midway Valley have numerous estimated precipitation values. SNOWNET stations tend to have more complete temperature than rainfall records. The lack of winter-time maintenance of rain-recording tipping buckets likely limits the overall completeness of the annual record for these stations. Observations at the TICA SNOWNET station have been notably inconsistent since 2002, and absent since February 2006.

3.2 Climatic gradient

Climatic attributes recorded at NCPN weather stations in 2008 generally followed expected patterns in their relationship with the geographic and elevation gradients. Average annual maximum and minimum temperature and snowfall were related to latitude and elevation in 2008 (Figure 3.2A, B, and D). Total precipitation was related to elevation, but the relationship was weak (Figure 3.2C).

3.3 Climatic extremes

Relative to the historical monthly record, the majority of NCPN weather stations recorded below-average monthly maximum and minimum temperatures from January to June and in December (Figure 3.3-1). All stations experienced a period of below-average precipitation sometime between March and October, although wetter months within this time period varied by region. Higher-than-average precipitation occurred in

December at all stations but two.

Differences between annual values for 2008 and long-term means along the elevation gradient are shown in Figure 3.3-2 for stations with valid 2008 observations and at least five valid observations (supporting information for figures is in Table 3.3). In general, differences between 2008 and historical averages were unrelated to elevation gradient. This differs from 2005, when annual and historical-mean differences in annual maximum temperature varied with elevation (higher than average at lower elevations, lower than average at higher elevations). The majority of stations experienced lower-than-average mean annual maximum temperature (Figure 3.3-2A). Though many stations experienced lower-than-average mean annual minimum temperatures (Figure 3.3-2B), a clear pattern was less evident. Many stations experienced lower-than-average total precipitation (Figure 3.3-2C), but the stations that deviated most greatly from long-term means have relatively short historic records (<15 years). In addition, the majority of stations experienced higher-than-average snowfall (Figure 3.3-2D).

3.4 Trend assessments

3.4.1 Average annual maximum temperature

Trends were evident for all of the fundamental climate attributes. Seventeen stations had a significant ($P < 0.05$) linear slope for average annual maximum temperature (Table 3.4). The majority of significant relationships indicated an increase in mean annual maximum temperature. The CANY/Hans Flat Coop, ZION/Lava Pt. RAWS, and CEBR/Midway Valley SNOTEL (Figure 3.4A) stations exhibited a strong linear trend ($\text{Adj}R^2 > 0.70$), but the ZION (Zion National Park) station had only 10 years of data.

3.4.2 Mean annual minimum temperature

A trend in the 4-year composite for mean annual minimum temperature was prevalent among NCPN climate stations, with 13 of the 16 significant relationships indicating an increase in temperature (e.g., Figure 3.4B). The eight models that explained a high level of variance and had a positive slope (Coop: CEBR/Brian Head, BRCA, CANY/Hans Flat, CARE, DINO/NM, NABR, PISP; SNOTEL: BRCA/Agua Canyon) indicated, on average, an annual increase over the past 29 yrs of 0.12°F in the 4-year composite mean for mean annual minimum temperature. A general increase

in temperature has been noted in other western U.S. regions (e.g., Yellowstone River basin; Davey et al. 2006) since the 1970s, and, since the 1990s, in Alaska (Corell 2004).

3.4.3 Total precipitation

Only six stations exhibited a significant slope for total precipitation; however, the variance explained by three of the models was relatively low ($\text{AdjR}^2 < 0.6$), and the other three models had low sample sizes (≤ 8). The record for most stations clearly indicated the drought conditions of 1999–2002 (e.g., Figure 3.4C), which were recorded throughout the region (USGS 2003). In general, annual precipitation is variable through time, and there is no strong trend (negative or positive) in this attribute among the weather stations analyzed.

3.4.4 Snowfall

Thirteen of the 17 stations with snowfall data had a significant, negative slope (see Table 3.4), but only the NABR Coop station exhibited a strong, linear trend (Figure 3.4D). Closer inspection of snowfall records indicated a notable decline in snowfall at many NCPN stations since 1985–1990. The variability prior to this time period contributed to the relatively low amount of explained variance in models using the full observation period. For models with an $\text{AdjR}^2 < 0.40$ (see Table 3.4), models based on only 1985–2008 data explained about twice the variance. These results strongly suggest that a majority of the 17 stations considered have experienced a declining trend in snowfall over the past 20–25 yrs.

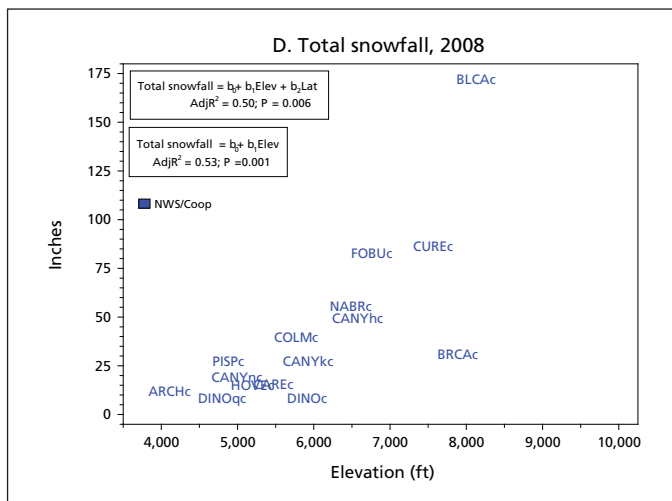
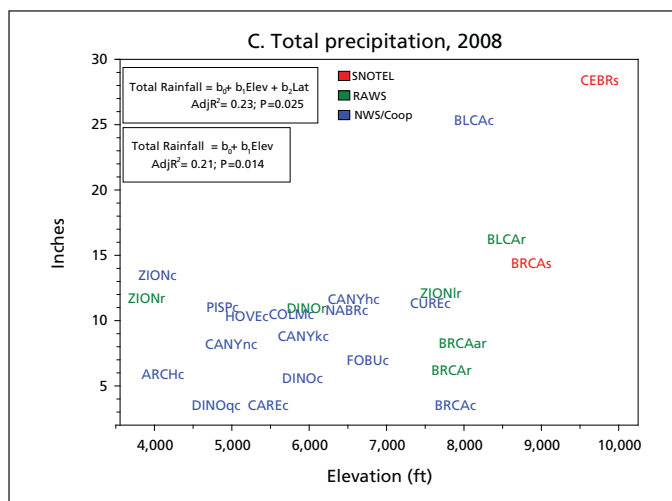
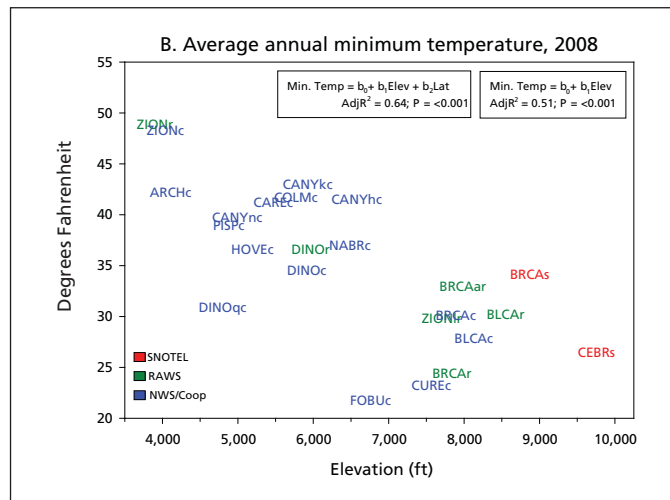
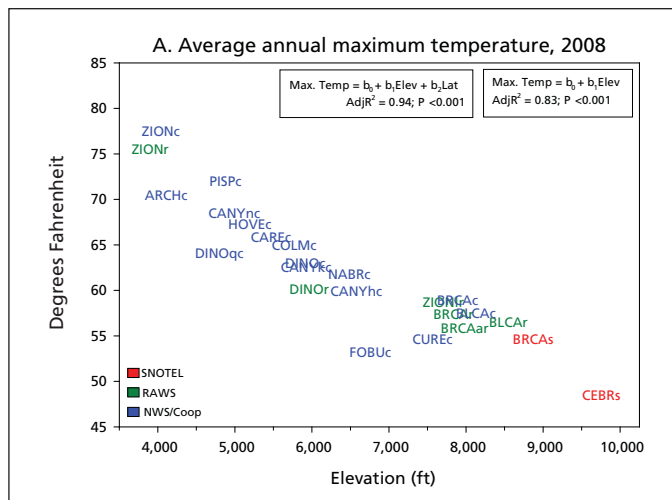
3.4.5 Limitations of NCPN climate record

Inherent climatic oscillations operate over long time frames (e.g., 50–60 years; Mantua et al. 1997). The 25–50-year observation period characteristic of the majority of NCPN stations illustrates general, common trends among stations, but is of insufficient length to begin to discern climatic-regime shifts. The 104-year observation period of the ZION Coop station, however, affords an informative perspective of climate variability and trends (Figure 3.4.5). Similar to the majority of Coop stations, the ZION station recorded increases in mean annual maximum and minimum temperatures over the past 2–3 decades, and in rainfall in the recent past. However, periods of similar increases are evident in this historical record, and recent temperature and precipitation values fail to exceed historical maxima. Trend assessments with the moving mean did indicate slightly increasing temperature and declining snowfall over this extended time period (see Table 3.4), but models generally explained much lower amounts of the variance than those based on a shorter duration.

Table 3.1. Summary of data completeness for weather stations in NCPN park units.

Station	Observation period	Percentage of years with valid daily records												Comments
		Max. temp.		Min. temp.		Rain precip.		Snowfall						
		< 95%	> 85-95%	< 95%	> 85-95%	< 95%	> 85-95%	< 95%	> 85-95%	< 95%	> 85-95%	< 95%	> 85-95%	
NWS-COOP														
ARCH	6/1/80-12/31/08	93	3	3	66	31	3	93	3	3	76	10	14	
BLCA	10/9/03-12/31/08	60	40	0	80	20	0	100	0	0	100	0	0	
BRCA	6/1/59-12/31/08	76	18	6	64	28	8	84	10	6	74	16	10	
CANY/Hans Flat	10/1/80-12/31/08	90	7	3	90	7	3	90	7	3	83	10	7	
CANY/Neck	6/17/65-12/31/08	80	14	7	73	21	7	89	7	5	80	16	5	
CANY/Needles	6/18/65-12/31/08	82	11	7	61	34	5	75	14	11	61	9	30	
CARE	3/1/67-12/31/08	76	14	10	81	14	5	95	2	2	88	10	2	
CEBR/Brian Head	2/1/91-12/31/08	83	0	17	83	0	17	83	0	17	83	0	17	Numerous missing records since 2007
COLM	8/1/48-12/31/08	68	19	13	64	19	17	71	13	16	78	12	10	
CURE (Blue Mesa)	11/1/67-12/31/08	29	14	57	31	12	57	83	10	7	71	21	7	Temperature observations not consistently recorded until 1990
DINO/NM	6/1/65-12/31/08	71	23	7	82	11	7	84	9	7	82	11	7	
DINO/Quarry	12/1/15-12/31/08	59	12	30	62	12	26	64	12	25	61	10	30	Numerous months in early years without valid records
FOBU	8/1/90-12/31/08	58	26	16	47	42	11	68	5	26	68	5	26	1-2 of the winter months tend to have a handful of missing or expert-system corrected temperature observations
HOVE	4/2/57-12/31/08	67	19	14	71	17	12	77	17	6	75	15	10	
NABR	6/17/65-12/31/08	68	23	9	68	21	11	93	5	2	91	7	2	
PISP	6/1/63-12/31/08	59	30	11	65	24	11	80	15	4	72	20	9	
TICA	7/1/48-12/31/08	62	14	24	64	18	19	76	3	21	70	6	24	
ZION	1/1/1904-12/31/08	85	7	9	77	12	11	77	0	23	69	7	25	
RAWS														
BLCA	6/4/97-12/31/08	92	0	8	92	0	8	92	0	8	-	-	-	
BRCA/Agua Canyon	6/4/90-12/31/08	47	26	26	47	26	26	52	21	26	-	-	-	Early years lack complete set of 1-hr observations each day
BRCA	1/6/03-12/31/08	83	0	17	83	0	17	83	0	17	-	-	-	
DINO	7/29/98-12/31/08	82	9	9	82	9	9	82	9	9	-	-	-	
ZION/LavaPt	7/31/95-12/31/08	64	7	29	64	7	29	64	7	29	-	-	-	Hourly observations are incomplete in winter months
ZION/ZION HQ	11/5/02-12/31/08	57	29	14	57	29	14	57	29	14	-	-	-	Hourly observations are incomplete in winter months

Table 3.1. Summary of data completeness for weather stations in NCPN park units, cont.												
Station	Observation period	Percentage of years with valid daily records								Comments		
		Max. temp.		Min. temp.		Rain precip.		Snowfall				
		<95%	>85–95%	<95%	>85–95%	<95%	>85–95%	<95%	>85–95%			
SNOTEL												
BRCA/Agua Canyon	10/7/94–12/31/08	67	20	13	82	7	13	22	40	40	-	Numerous precipitation records have estimated values
CEBR/Midway Valley	10/1/81–12/31/08	54	11	36	57	4	39	61	14	25	-	Numerous precipitation records have estimated values since 2002
Snow Course												
BRCA	1/1/35–12/31/08	-	-	-	-	-	-	-	-	-	-	>2003 data not yet posted on NRCS web site.
SNOWNET												
CARE	12/15/97–12/31/05	-	-	-	-	-	-	-	-	-	-	>2005 data not available
TICA	12/28/97–12/31/05	-	-	-	-	-	-	-	-	-	-	>2005 data not available
ZION/East Gate	11/2/97–12/31/05	-	-	-	-	-	-	-	-	-	-	>2005 data not available

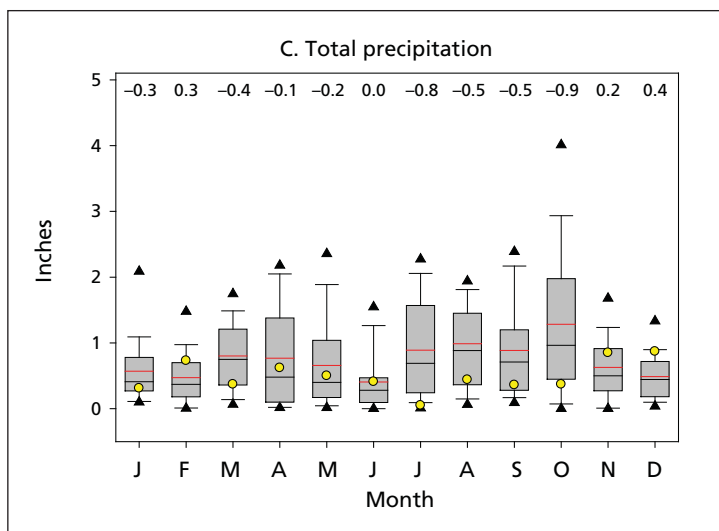
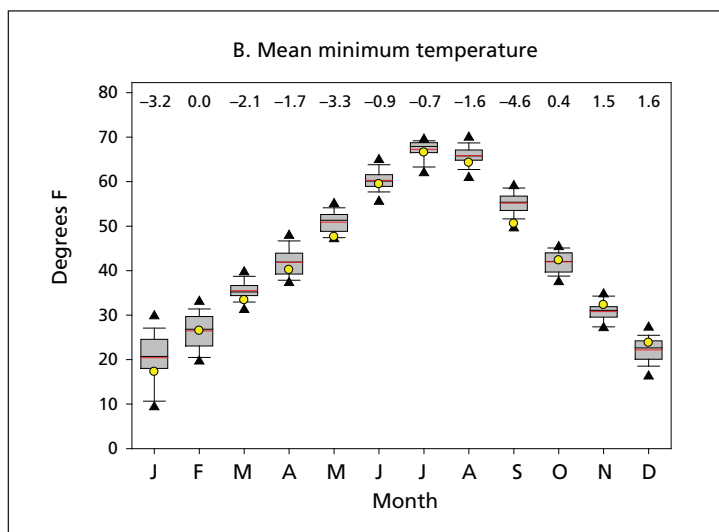
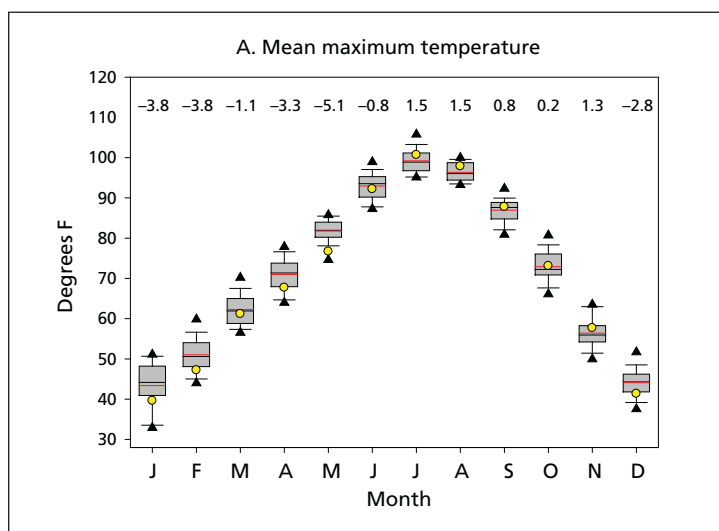
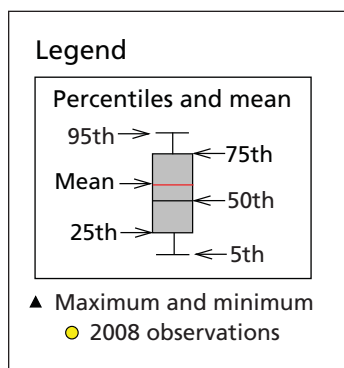


Station codes

Climate monitoring program	Figure code	Park/Station name
NWS/Coop	ARCHc	ARCH
	BLCac	BLCA
	BRCAc	BRCA
	CANYhc	CANY/Hans Flat
	CANYkc	CANY/Neck
	CANYnc	CANY/Needles
	CAREc	CARE
	COLMc	COLM
	CUREc	CURE
	DINOc	DINO/National Monument
	DINOqc	DINO/Quarry
	FOBUc	FOBU
	HOVEc	HOVE
	NABRc	NABR
	PISPC	PISP
	ZIONc	ZION
RAWs	BLCAr	BLCA
	BRCAar	BRCA/Agua Canyon
	BRCAr	BRCA/Bryce Canyon
	DINOr	DINO
	ZIONlr	ZION/Lava Pt.
	ZIONr	ZION/Headquarters
SNOTEL	BRCAs	BRCA/Agua Canyon
	CEBRs	Midway Valley

Figure 3.2. Average annual maximum temperature (A), minimum temperature (B), total precipitation (C), and total snowfall (D) for each park unit, arrayed by elevation, with results of regressing values on combinations of elevation and latitude.

Figure 3.3-1. Comparison of 2008 monthly values with historical distributions (6/1/80–12/31/08) for ARCH Coop station. Numbers across top of graphs are the deviation between the monthly mean in 2008 and the historical monthly mean.



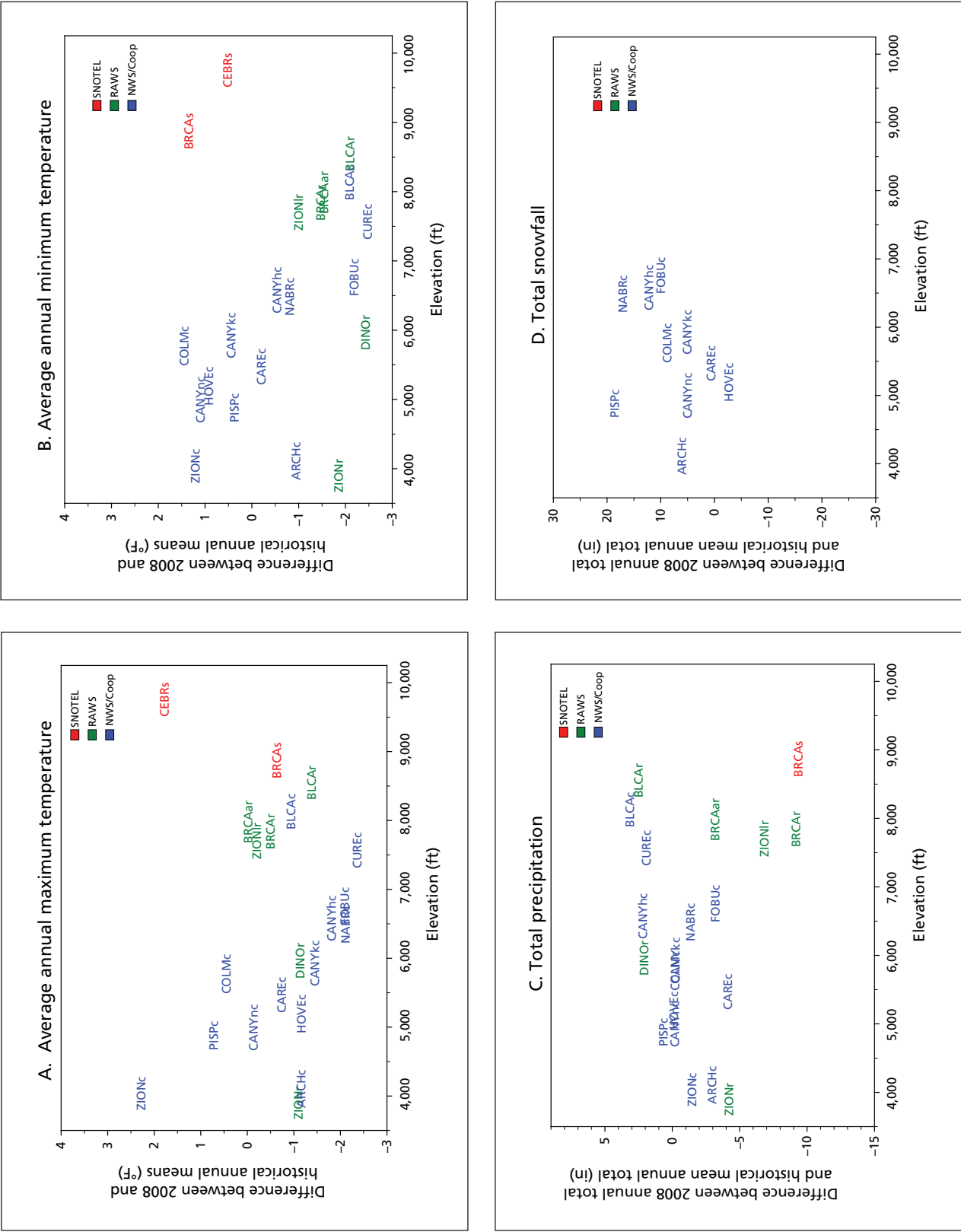


Figure 3.3-2. Differences between 2008 averages and long-term means for maximum annual temperature (A), minimum annual temperature (B), total annual precipitation (C), and total annual snowfall (D), arrayed by elevation.

Table 3.3. List of weather stations with valid 2008 annual averages and totals (and an observational record of at least 5 years), and number of years the historical record comprises, by climate variable.

Climate monitoring program	Station code	Park/Station name	No. of years comprising long-term mean or total			
			Mean annual max. temp.	Mean annual min. temp.	Annual precipitation	Annual snowfall
NWS-Coop	ARCHc	ARCH	28	28	28	25
	BLCAc	BLCA	5	5	5	5
	CANYhc	CANY/Hans Flat	28	28	28	27
	CANYkc	CANY/Neck	41	41	42	42
	CANYnc	CANY/Needles	42	42	39	31
	CAREc	CARE	38	40	41	41
	COLMc	COLM	60	57	58	62
	CUREc	CURE	18	18	39	39
	FOBUc	FOBU	16	17	14	14
	HOVEc	HOVE	46	47	49	47
	NABRc	NABR	40	39	42	42
	PISPC	PISP	41	41	44	42
	ZIONc	ZION	96	67	81	-
RAWS	BLCAr	BLCA	11	11	11	na
	BRCAar	BRCA–Agua Canyon	14	14	14	na
	DINOr	DINO	10	10	10	na
	ZIONlr	ZION–Lava Pt.	10	10	10	na
	ZIONr	ZION–Headquarters	6	6	6	na
SNOTEL	BRCAs	BRCA–Agua Canyon	13	13	9	na
	CEBRs	Midway Valley	18	17	-	na

Table 3.4. Results of trend analyses of climatic variables based on a least-squares regression of the moving mean over time.

Station	Max. temp. (F)			Min. temp. (F)			Total precipitation (in)			Total snowfall (in)		
	df	P	AdjR ²	Slope	df	P	AdjR ²	Slope	df	P	AdjR ²	Slope
ARCH Coop	24	<0.001	0.70	0.152	24	0.101	-	-	24	0.050	-	-
BRCA Coop	43	0.007	0.14	-0.024	42	<0.001	0.71	0.055	43	0.138	-	-
CANY/Hans Flat Coop	24	<0.001	0.74	0.126	24	<0.001	0.86	0.246	24	0.183	-	-
CANY/Neck Coop	37	0.231	-	-	37	<0.001	0.44	0.076	38	0.249	-	-
CANY/Needles Coop	38	<0.001	0.54	0.050	38	<0.001	0.61	0.105	35	0.632	-	-
CARE Coop	34	<0.001	0.44	-0.048	36	<0.001	0.78	0.068	37	0.123	-	-
CEBR/Brian Head Coop	11	<0.001	0.69	0.246	11	<0.001	0.89	0.109	11	0.069	-	-
COLM Coop	56	<0.001	0.26	0.035	53	0.414	-	-	54	0.585	-	-
CURE/Blue Mesa Coop	14	0.012	0.35	0.104	14	0.437	-	-	35	0.021	0.12	-0.049
DINO/NM Coop	37	<0.001	0.37	0.074	37	<0.001	0.74	0.122	37	0.407	-	-
DINO/Quarry Coop	39	<0.001	0.37	0.075	41	<0.001	0.23	0.057	42	0.089	-	-
FOBU Coop	12	<0.001	0.69	0.114	13	0.122	-	-	10	0.253	-	-
HOVE Coop	42	<0.001	0.35	0.047	43	<0.001	0.31	0.049	45	0.786	-	-
NABR Coop	36	0.049	-	-	35	<0.001	0.77	0.077	39	0.558	-	-
PLSP Coop	37	<0.001	0.49	0.064	37	<0.001	0.78	0.071	40	0.194	-	-
TICA Coop	45	0.004	0.15	0.030	47	0.014	0.11	-0.022	46	0.243	-	-
ZION Coop	92	<0.001	0.32	0.030	90	<0.001	0.18	0.020	77	0.015	0.06	0.029
BLCA RAWS	7	0.801	-	-	7	<0.001	0.84	-0.131	7	<0.001	0.86	0.899
BRCA/AGUA Canyon/RAWS	10	0.495	-	-	10	0.834	-	-	10	0.084	-	-
DINO RAWS	6	0.053	-	-	6	0.017	0.65	-0.230	6	0.001	0.87	0.823
ZION/Lava Pt RAWS	6	0.007	0.76	0.219	6	0.678	-	-	6	0.780	-	-
BRCA/Agua Canyon SNOTEL	9	0.581	-	-	9	<0.001	.75	0.188	5	0.162	-	-
CEBR/Midway Valley SNOTEL	14	<0.001	0.92	0.326	13	0.062	-	-	16	<0.001	0.57	-1.639

P-values correspond to the significance of the regression model and of the slope. AdjR² is the coefficient of determination. Bold, shaded values are significant ($P < 0.05$) with a high (> 0.70) AdjR². Only observational years with >85% valid records (days) were used in analyses.

df = degrees of freedom.

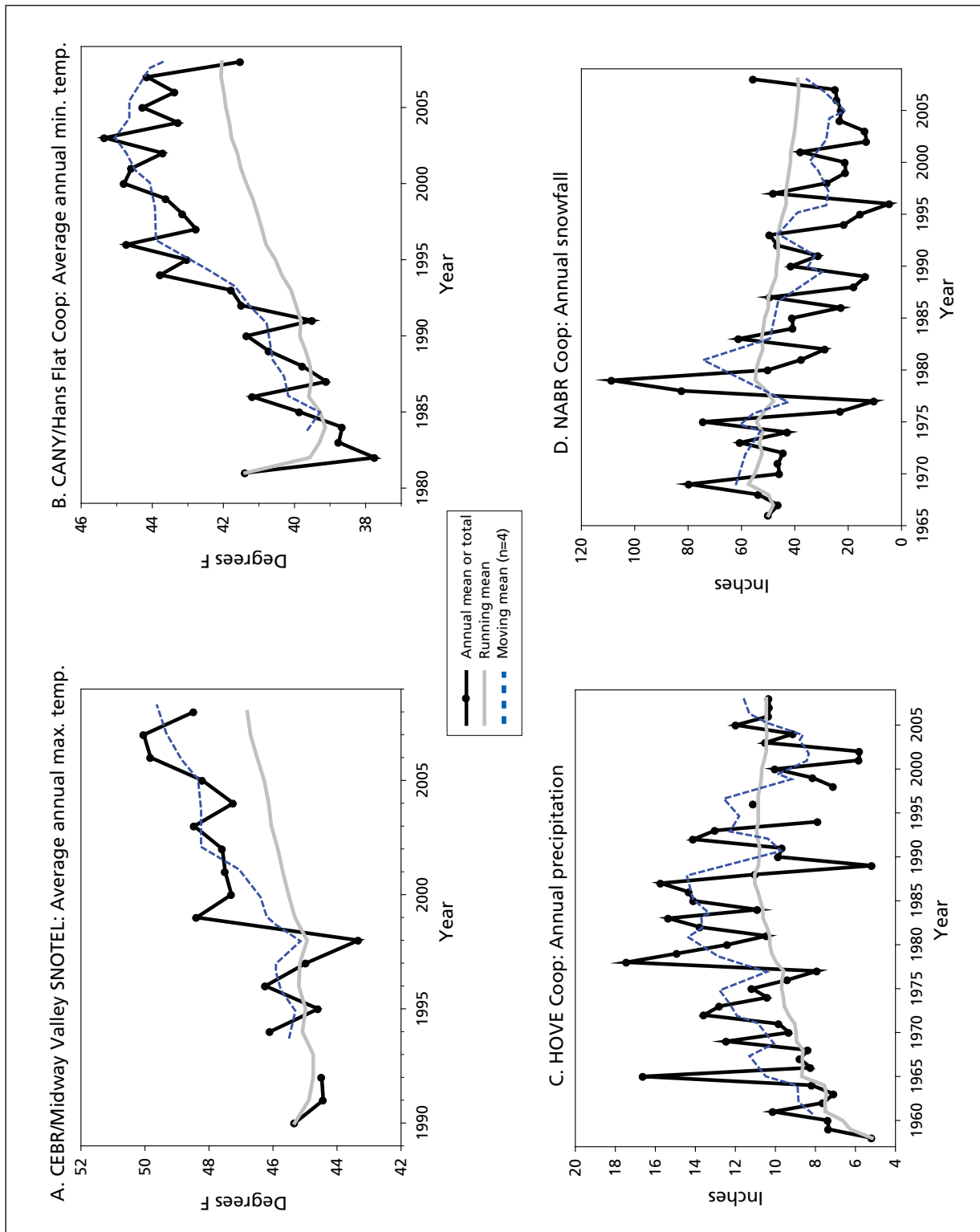


Figure 3.4. Long-term trends for selected stations and climate variables. Breaks in the annual line indicate years with limited or missing data. Moving mean is the average of valid values from the previous three years and the year of the estimate. The running mean is a cumulative mean.

ZION Coop station, observational period 1/1/1904 to 12/31/08

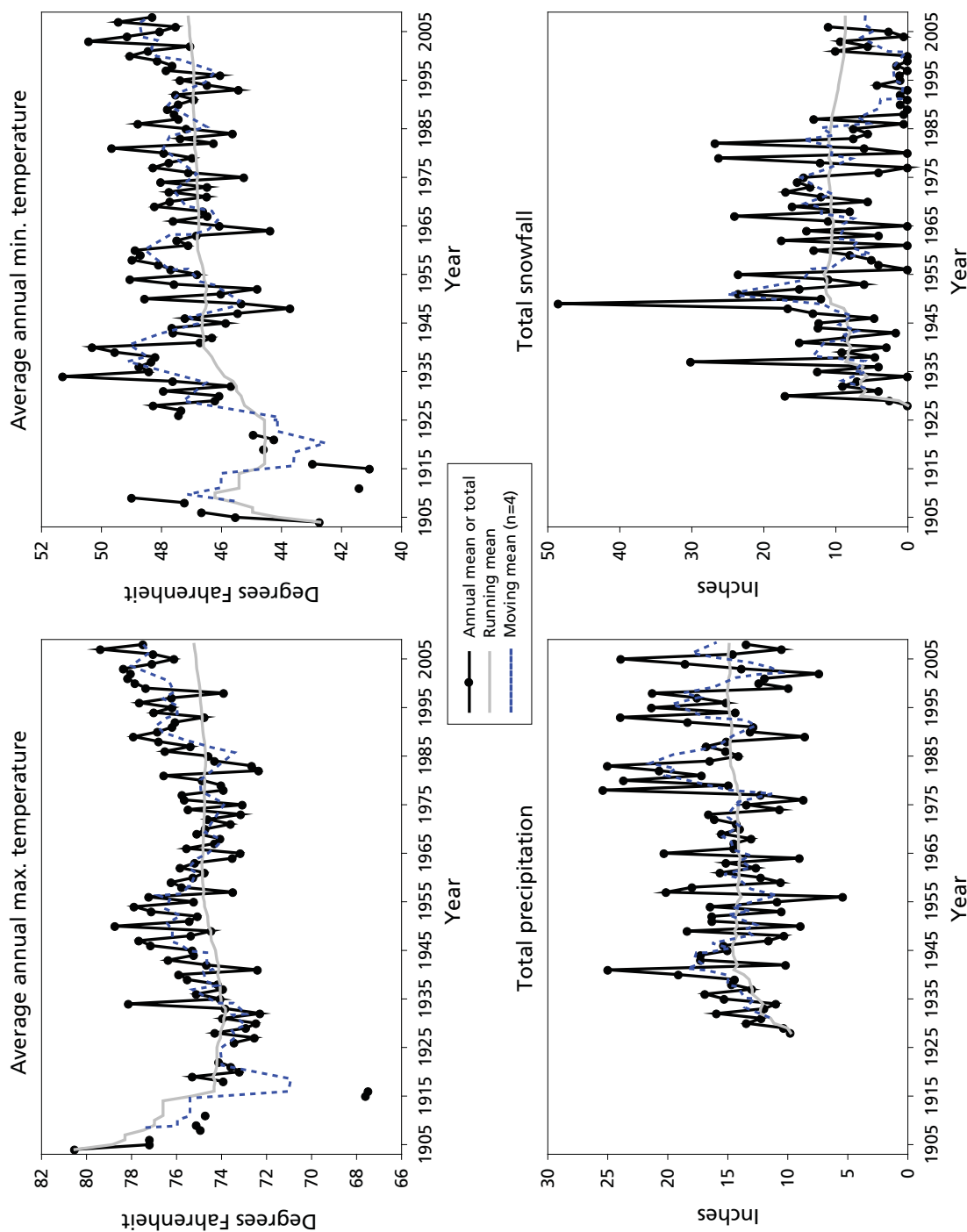


Figure 3.4.5. Long-term trends for ZION Coop station. Breaks in the annual line indicate years with limited or missing data. Moving mean is the average of valid values from the previous three years and the year of the estimate. The running mean is a cumulative mean.

4 Discussion

Average annual maximum and minimum temperatures tended to be below average throughout much of the NCPN region in 2008, especially during the first half of the year. Differences between annual averages for maximum and minimum temperature, total precipitation, and total snowfall were not related to an elevation gradient when compared to long-term means. Snowfall in 2008 was noticeably above long-term averages for all but two of 10 stations with valid snowfall totals. The pattern in total precipitation over the region was less clear, with somewhat less precipitation than the long-term averages at many of the weather stations. A general increase in the 4-year, composite moving mean for average annual minimum temperature over the past 28–48 years is evident for most of the NCPN stations with long observation periods (i.e., Coop stations). Conversely, there is evidence for a declining trend in snowfall over the past 20–25 years. Historical records, especially for the NCPN Coop stations, indicate that annual precipitation has been highly variable, and that a strong unidirectional trend over the observation periods (20–40 years) is not readily evident.

4.1 Cautionary note

NCPN station-level assessments of trends and average conditions should be viewed in the context of the available temporal and spatial record. The 25–48-year observation period characteristic of the majority of NCPN weather stations provides an adequate basis for delineating trends over the recent past, but this period is too short for discerning shifts in climatic regimes. Departures from historical averages are likely only meaningful for stations with longer (30+ years) observation periods. Additionally, the number of weather stations in any NCPN park is nominal, with generally only 1–3 stations, and stations do not span the full environmental range of a park. Especially for the larger units, station-level trends and extremes do not necessarily characterize climatic conditions of a park.

Assessments involving a spatially distributed network of weather stations in and around park lands are key to understanding climatic extremes, trends, and regimes of a park's environs. Ongoing efforts among the NPS Inventory & Monitoring Program's Washington-area Support Office, the WRCC, and the Wyoming State Climate Center are aimed at addressing how best to delineate such a network, and the nature of assessments to achieve this understanding. Approaches developed in these efforts will be employed in future NCPN climatic analyses and reports to provide a more comprehensive interpretation of climatic conditions of park units.

4.2 Location of summary reports and graphs on CD

Summary reports (e.g., Figure 4.2), and monthly distributions and trend graphs for each NCPN weather station are included on the accompanying CD, and are organized by park, climate-monitoring program, report, or graph type. Park acronyms are used to indicate the park unit. Monitoring programs are COOP, SNOTEL, or RAWS. Report type is either Summary_Tables or Historical. Monthly and annual summaries are contained under Summary_Tables, and the term monthly or annual is included in the file name. Summary reports are distributed as MS-Excel spreadsheets.

Monthly Climate Summary

FOBU COOP Station 483582 (FBMW4)–01/2008

Day	Air temperature (°F)			Precipitation (inches)		
	Minimum	Maximum	Average	Total	Snowfall	Snow depth
1	-	-	-	-	-	-
2	-20	17	-1.5	0	0	12
3	-14	19	2.5	0	0	12
4	9	39	24	0	0	12
5	10	32	21	-	-	-
6	-9	22	6.5	-	-	20
7	-12	20	4	0.03	0.5	20

Annual Climate Summary

BRCA Coop, Station No. 421008 (BRYU1)–2008

Variable	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Minimum air temperature (F°)													
Min.	-	-	1	10	13	-	37	45	32	20	11	7	19.6
Max.	-	-	31	36	31	-	60	60	54	49	44	35	44.4
Average	-	-	13.9	17.3	23.3	-	43.9	51.6	39.7	32.2	29.1	20	30.1
# of days <0°F	-	-	0	0	0	-	0	0	0	0	0	0	0
# of days <32°F	-	-	26	28	9	-	0	0	1	16	22	21	123
% of days with valid records	0	0	83.9	100	29	0	61.3	100	100	100	100	71	62.5
Maximum air temperature (F°)													
Min.	-	-	25	34	38	-	70	66	62	38	31	21	42.8

Figure 4.2. Examples of monthly and annual climate summary reports.

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Appendix A. Location, elevation, and observational period for the major weather stations within NCPN park units

Climate monitoring program/Park	UTM location		Elevation ft (m)	Period of record
	Northing	Easting		
NWS-COOP				
ARCH	4275204	620212	4,130 (1,259)	6/1/80–present
BLCA	4270811	265847	8,150 (2,484)	10/9/03–present
BRCA	4166638	396948	7,915 (2,412)	6/1/59–present
CANY/Hans Flat	4234460	571744	6,581 (2,006)	10/1/80–present
CANY/Neck	4256408	603257	5,930 (1,807)	6/17/65–present
CANY/Needles	4223196	609524	4,998 (1,523)	6/18/65–present
CARE	4237285	476677	5,500 (1,676)	3/1/67–present
CEBR/Brian Head	4173391	337166	9,750 (2,972)	2/1/91–present
COLM	4330319	696008	7,600 (2,316)	8/1/48–present
CURE/Blue Mesa	4259937	311146	7,600 (2,316)	11/1/67–present
DINO/NM	4456830	672502	5,920 (1,804)	6/1/65–present
DINO/Quarry	4477485	643976	4,800 (1,463)	12/1/15–present
FOBU	4631297	519374	6,780 (2,066)	8/1/90–present
HOVE	4139559	669972	5,210 (1,588)	4/2/57–present
NABR	4163770	589724	6,500 (1,981)	6/17/65–present
PISP	4080598	345012	4,920 (1,500)	6/1/63–present
TICA	4477940	440642	5,640 (1,719)	7/1/48–present
ZION	4119827	323929	4,050 (1,234)	1/1/1904–present
RAWS				
BLCA	4269462	265823	8,560 (2,609)	6/4/97–present
BRCA/Agua Canyon	4153565	387677	8,000 (2,438)	6/4/90–present
BRCA	4166704	396581	7,855 (2,394)	1/6/03–present
DINO	4486307	677030	5,960 (1,816)	7/29/98–present
ZION/Lava Pt.	4140273	319512	7,700 (2,347)	7/31/95–present
ZION/HQ	4119415	324488	3,901 (1,189)	11/5/02–present
SNOTEL				
BRCA/Agua Canyon	4152946	387992	8,900 (2,712)	10/7/94–present
CEBR/Midway Valley	4159317	338088	9,800 (2,987)	10/1/81–present
Snow Course				
BRCA	4166517	396775	8,000 (2,438)	1/1/35–present
SNOWNET				
CARE	4238083	477085	5,500 (2,438)	12/15/97 -present
TICA	4476899	440086	7,999 (2,438)	12/28/97 -present
ZION/East Gate	4123976	333923	5,600 (1,707)	11/2/97–present
CRN				
BLCA	4269509	265237	8,398 (2,559)	7/04–present
CARE	4239445	474333	6,211 (1,893)	10/07–present
DINO	4456876	672864	6,063 (1,848)	9/04–present
GOSP	4608354	371223	4,938 (1,505)	8/07–present
CLIM-MET				
CANY/Needles	4224489	608979	4,910 (1,497)	7/98–present
CANY/Virginia Park	4216970	601707	5,630 (1,716)	7/98–present

Stations in BLCA and CURE are UTM zone 13; otherwise, coordinates are UTM zone 12.

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