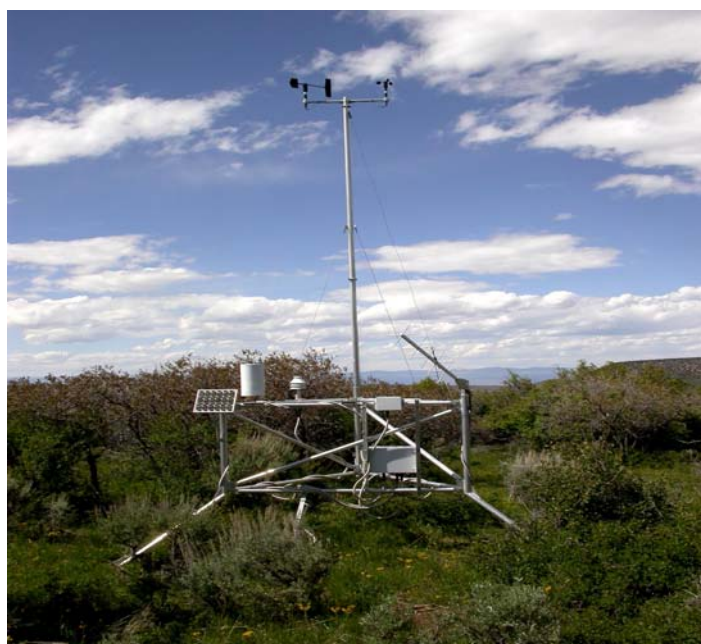


U.S. Department of the Interior
National Park Service
Inventory and Monitoring Program

**Northern Colorado Plateau Network
Climate Monitoring Report: 2005**



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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, as well as 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 be in response to anthropogenic stressors or variation in climatic conditions. Discerning reasons for observed changes that are responsive to mitigation measures (e.g., anthropogenic vs. climate driven) is important to properly inform management decision making. 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. 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. Identify monthly, 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 31 weather stations in NCPN 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 starting in the 1960's, although 1904 is the earliest record and 13 stations were established since 1994 (Appendix A). The NCPN monitoring strategy is to obtain weather observations from agency archives annually, convert observations to 24-hr values where applicable, and store data on the NCPN server for ease of access and use.

This report satisfies the annual reporting requirement of the NCPN Climate Monitoring effort by providing monthly and annual summaries of 2005 observations for weather stations in the Network, and by providing analyses of climate extremes for 2005. The compilation of data to satisfy the two objectives, and expanding the analyses to include the delineation of climatic trends, inherently satisfies the overall goal of this protocol.

Table 1. Overview of climate monitoring programs, and number of weather stations by program in NCPN park units. See Appendix B for definition of park-unit acronyms.

Climate Monitoring Program - Agency	Program Synopsis	No. of weather stations													
		ARCH	BLCA	BRCA	CANY	CARE	COLM	CURE	DINO	FOBU	HOVE	NABR	PISP	TICA	ZION
NWS-Coop (National Weather Service (NWS) Cooperative Observing Program) - National Oceanic and Atmospheric Administration (NOAA)	Observer-based program created in 1890 to define the climate of the United States and to 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	2	1	1	1	2	1	1	1	1	1	1
RAWS (Remote Automated Weather Stations) - National Interagency Wildfire Program (FS, BLM, NPS, et al.)	An inter-agency 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 United States. Data include snow water equivalent, snow depth, precipitation, temperature and other climatic elements at hourly intervals.			1											

Table 1. Cont'd.

Climate Monitoring Program - Agency	Program Synopsis	No. of weather stations													
		ARCH	BLCA	BRCA	CANY	CARE	COLM	CURE	DINO	FOBU	HOVE	NABR	PISP	TICA	ZION
Snow Course – NRCS	An observer-based program that manually measures snow depth and snow-water equivalent along a permanent transect.			1											
SNOWNET (incl. Avalanche network) - MesoWest (Univ.of Utah)	SNOWNET is 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-sec.		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-min). Sensors and site locations are subject to change to accommodate research needs.				2										

Data Acquisition & 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, Coop, RAWS, and SNOTEL observations are acquired from the Western Regional Climate Center (WRCC). Data from SNOWNET stations are provided by MesoWest, located at the Univ. of Utah. Observations of four stations are not archived and processed due to the current lack of an accessible data portal (2 CRN stations), and due to the temporary nature of research weather stations (2 CLIM-MET stations). Quality Assurance and Control (QA/QC) procedures for Coop data are performed by NCDC (National Climate Data Center). Data-quality codes are provided along with the 24-hr observations to WRCC 2-4 months after receipt at NCDC. Codes indicate various features of the data, such as missing records or the use of estimation procedures. WRCC performs QA/QC on SNOTEL data, and provides similar data-quality flags with the 24-hr data. RAWS data are received as 1-hr observations, and translated to 24-hr measures by the NCPN. SNOWNET data are received as 15-min to 1-hr measures and converted to 24-hr values. The 24-hr conversion procedure for RAWS and SNOWNET 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-hr observations is missing or otherwise flagged as suspect, the 24-hr measure is flagged as not valid.

Analyses

Data Completeness

An assessment of data completeness for the four fundamental climate variables - max. temperature, min. temperature, rain precipitation, and snowfall - is provided for each weather station. For the purposes of this report, all 24-hr 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 $\geq 95\%$ valid daily values, with $\geq 85\text{-}95\%$ 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.

Summaries, Extremes, Trend Assessments

All analyses used 24-hr measures. Station-level summaries used all valid, daily data. Analyses using monthly or annual means or totals only used information that was based on ca. 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.

Summaries

Monthly and annual summaries for consistently measured variables are provided on the accompanying CD for each weather station in the NCPN park units. See the **Location of Summary Reports and Graphical Displays on Accompanying CD** section at the end of this report for a description of CD contents.

Climatic Gradient

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

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 the station. Overlaying 2005 observations on these plots highlights extremes of the 2005 climate record where they occur. Numerical deviation of a 2005 monthly mean or total from the corresponding long-term mean is further used to illustrate the historical context of 2005 climate attributes. Resulting graphics from this analysis are available for every NCPN weather station (MS-WORD versions of graphs are contained on the accompanying CD - see the **Location of Summary Reports and Graphical Displays on Accompanying CD** section at the end of this report for a description of CD contents).

For each NCPN weather station, annual means and totals for 2005 were differenced from station long-term means, and differences for all NCPN stations were arrayed by elevation to assess topographic relationships. Data spanning the time of station inception up to the end of 2004 were the basis for long-term means.

Trend Assessments

Annual means and totals for 2005 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. Trend graphs are available for every NCPN weather station (MS-WORD versions of graphs are contained on the accompanying CD - see the **Location of Summary Reports and Graphical Displays on Accompanying CD** section at the end of this report for a description of CD contents).

Regional Perspective

Regional patterns in the departure of 2005 climate from historical conditions were examined using PRISM (Daly et al. 2002) predictions. The PRISM model provides estimates of recent, and long term average annual minimum and maximum temperature, and total precipitation at a 4-km grain. This model is parameterized using surface stations, such as NWS-Coop and SNOTEL, and upper-air measures. Differences between 2005 annual averages or totals and 30-yr means (1971-2000) were mapped to

spatially illustrate departures. PRISM estimates are an average for a 4-km cell, and thus will not match measures from individual weather stations. The intent of this analysis was simply to illustrate the 2005 climate in a historical context at a regional scale.

Results & Discussion

Data Completeness

Coop stations generally have more complete rain and snowfall records than temperature records (Table 2). Exact reasons for missing or invalid records are not obvious from the data-quality flags. However, it is likely that malfunction or mis-reading of temperature instruments is more prevalent compared to the physical measuring of precipitation levels. RAWS stations vary in data completeness. These stations are not necessarily operational in winter. A large proportion of missing records occurred during this season, especially for the two stations in ZION NP. The daily records of the Agua Canyon RAWS station are especially limited in the earlier years. The SNOTEL station at Agua Canyon has numerous estimated values. The 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 has been noticeably inconsistent since 2002.

Climatic Gradient

Climatic attributes recorded in 2005 at NCPN weather stations varied in their relationship with the geographic and elevation gradients. Average annual maximum temperature in 2005 corresponded closely to geographic location, and to elevation which had a dominant affect (Fig. 1A). These relationships were evident, but weaker, for average minimum temperature (Fig. 1B). Total rainfall was statistically invariant of elevation or location (Fig. 2A) when evaluating all possible stations combined. The ZION Coop and ZION-HQ RAWS stations recorded high precipitation levels, but are low elevation sites. Excluding these stations resulted in significant, linear relationships with geographic location and elevation. Total snowfall exhibited an exponential relationship with location and elevation (Fig. 2B). Snowfall levels at the FOBU Coop station, in addition to the low 2005 average minimum temperature (Fig. 1B), highlight the cooler climate of this site relative to other NCPN stations.

Table 2. Summary of data completeness for weather stations in NCPN park units. The triad of numbers under each climate variable is the percentage of years with $\geq 95\%$ valid daily records (top number), $\geq 85\text{--}95\%$ valid daily records, $< 85\%$ valid daily records (bottom number).

Station	Observation period	Climate variable				Comments
		Max Temp.	Min. Temp.	Rain Precip.	Snowfall	
ARCH Coop	6/1/80 – 12/31/05	92 4 4	69 27 4	92 4 4	73 12 15	
BLCA Coop	10/9/03 – 12/31/05	0 100 0	50 50 0	100 0 0	100 0 0	
CURE Coop	11/1/67 – 12/31/05	28 10 62	28 10 62	87 5 8	72 20 8	Temperature observations not consistently recorded until 1990
BRCA Coop	6/1/59 – 12/31/05	81 17 2	68 28 4	89 9 2	77 17 6	
CANY/ Needles Coop	6/18/65 – 12/31/05	81 12 7	63 32 5	73 15 12	59 10 31	
CANY/Neck Coop	6/17/65 – 12/31/05	78 15 7	73 20 7	88 7 5	78 17 5	
CARE Coop	3/1/67 – 12/31/05	79 11 10	79 15 6	95 3 2	90 8 2	
COLM Coop	8/1/48 – 12/31/05	70 18 12	65 20 15	71 12 17	79 11 10	
DINO/NM Coop	6/1/65 – 12/31/05	76 22 2	85 12 3	88 10 2	85 13 2	
DINO/Quarry Coop	12/1/15 – 12/31/05	40 7 53	42 7 51	43 7 50	41 5 54	Numerous months in early years without valid records
FOBU Coop	8/1/90 – 12/31/05	56 25 19	44 44 12	63 6 31	63 6 31	1-2 of the winter months each year tend to have a handful of missing or expert-system corrected temperature observations
HOVE Coop	4/2/57 – 12/31/05	65 21 14	69 18 13	76 18 6	73 16 11	
NABR Coop	6/17/65 – 12/31/05	70 20 10	71 17 12	93 5 2	91 7 2	
PISP Coop	6/1/63 – 12/31/05	56 33 11	63 26 11	79 16 5	72 19 9	Temperature records are limited since 1998

Table 2. Cont'd.

Station	Observation period	Climate variable				Comments
		Max Temp.	Min. Temp.	Rain Precip.	Snowfall	
TICA Coop	7/1/48 – 12/31/05	65 15 20	67 18 15	80 3 17	73 7 20	
ZION Coop	1/1/1904 – 12/31/05	84 7 9	77 12 11	76 0 24	70 7 23	
BLCA RAWS	6/4/97 – 12/31/05	89 0 11	89 0 11	89 0 11	na	
BRCA/Agua Canyon RAWS	6/4/90 – 12/31/05	44 25 31	44 25 31	44 25 31	na	Early years lack complete set of 1-hr observations each day
BRCA RAWS	1/6/03 – 12/31/05	67 0 33	67 0 33	67 0 33	na	
DINO RAWS	7/29/98 – 12/31/05	75 13 12	75 13 12	75 13 12	na	
ZION/LavaPt RAWS	7/31/95 – 12/31/05	55 9 36	55 9 36	55 9 36	na	Hourly observations are incomplete in winter months
ZION/ZION HQ RAWS	11/5/02 – 12/31/05	50 25 25	50 25 25	50 25 25	na	Hourly observations are incomplete in winter months
BRCA/Agua Canyon SNOTEL	10/7/94- 12/31/05	67 17 16	83 0 17	25 33 42	na	Numerous precipitation records have estimated values
BRCA SnowCourse	1/1/35 – 12/31/05	na	na	na	na	Snow depth measures recorded ca. 1-2 mos. for 98% of the years up to 2003. >2003 data not yet posted on NRCS web site.
CARE SNOWNET	12/15/97- 12/31/05	78 11 11	78 11 11	67 11 22	na	
TICA SNOWNET	12/28/97 – 12/31/05	12 44 44	12 44 44	0 0 100	na	Numerous missing records since 2002; precipitation not regularly reported
ZION/Eastgate SNOWNET	11/2/97 - 12/31/05	78 11 11	78 11 11	56 22 22	na	

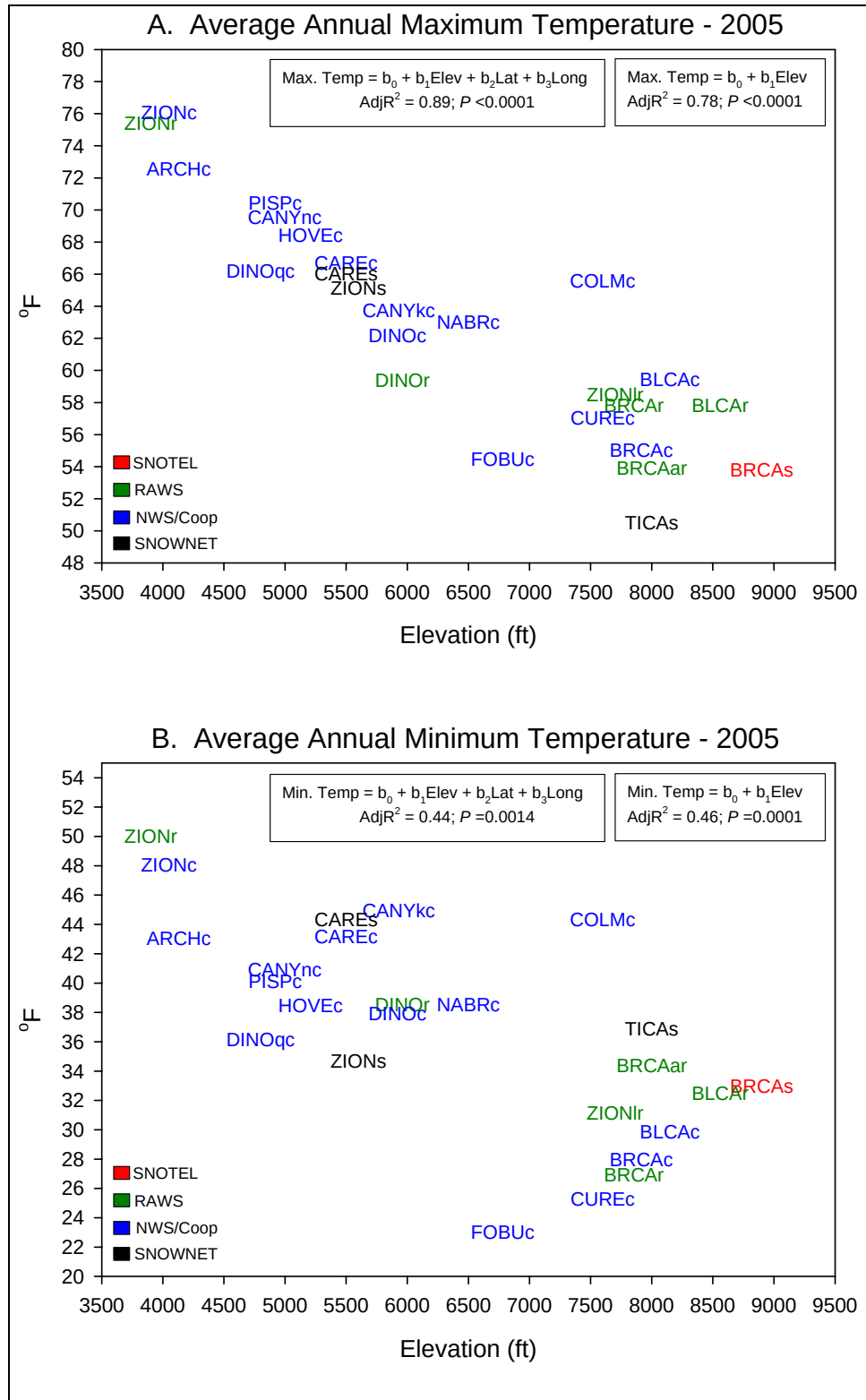


Figure 1. Average annual temperature values arrayed by elevation, and results of regressing values on combinations of elevation, latitude, and longitude. See Table 3 for definition of station codes.

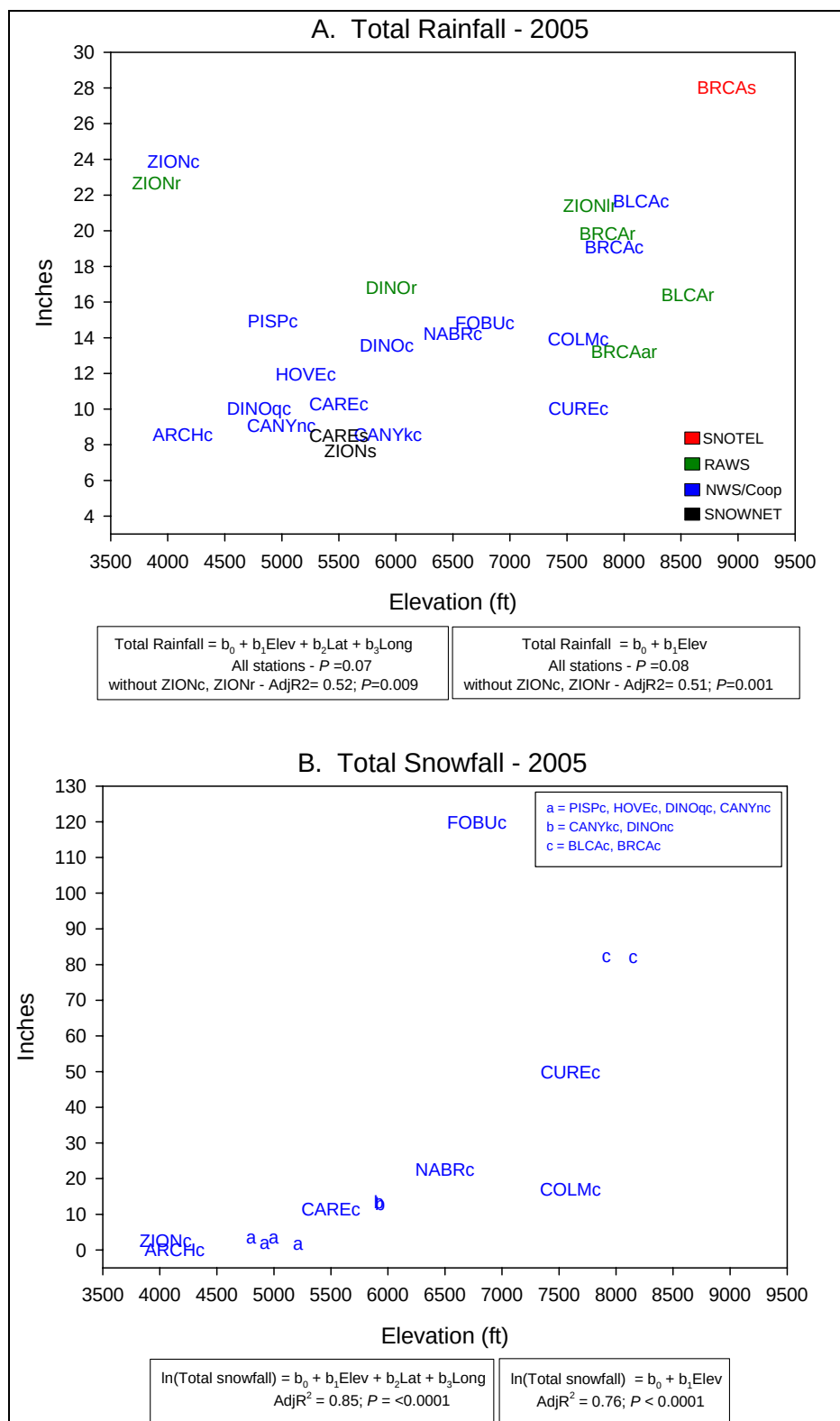


Figure 2. Annual precipitation values arrayed by elevation, and results of regressing values on combinations of elevation, latitude, and longitude. See Table 3 for definition of station codes.

Table 3. Definition of weather-station codes used in Figures 1-2.

Climate Monitoring Program	Figure Code	Park/Station name	Climate Monitoring Program	Figure Code	Park/Station name
SNOTEL	BRCAs	BRCA – Agua Canyon	NWS/Coop	COLMc	COLM
RAWS	BLCAr	BLCA		CUREc	CURE
	BRCAar	BRCA – Agua Canyon		DINOqc	DINO/Quarry
	BRCAr	BRCA – Bryce Canyon		DINOc	DINO/National Monument
	DINOr	DINO		FOBUc	FOBU
	ZIONlr	ZION/Lava Pt.		HOVEc	HOVE
	ZIONr	ZION Headquarters		NABRc	NABR
NWS/Coop	ARCHc	ARCH		PISPC	PISP
	BLCAc	BLCA		TICAc	TICA
	BRCAc	BRCA		ZIONc	ZION
	CANYkc	CANY/ The Neck	SNOWNET	CAREs	CARE
	CANYnc	CANY/ The Needles		TICAs	TICA
	CAREc	CARE		ZIONs	ZION/East Gate

Climatic Extremes

Minimum temperature and rainfall precipitation recorded at NCPN weather stations in 2005 were higher than station long-term averages. About 60% of the stations recorded a greater than average maximum and minimum temperature in January and in July, and greater than average rainfall in the first two months of the year (e.g., Fig. 3). For the suite of NCPN Coop stations, which have the longest (20+ yrs) observation period, 10 stations recorded new maxima or minima in 2005. Record high average minimum temperature was recorded in January or February at nine stations (ARCH, CANY-Neck, COLM, CURE, DINO-Quarry, FOBU, HOVE, NABR, PISP). Record high total rainfall was recorded for at least 1-mo in 2005 at three stations (FOBU, NABR, PISP). The station in CURE (Blue Mesa) recorded record low mean maximum and minimum temperatures in December.

Differences between 2005 annual values and long-term means are shown in Figs. 4-5 for stations with valid 2005 observations, and with at least six valid historical observations (supporting information for Figures is in Table 4). Differences for average annual maximum temperature followed an elevation gradient (Fig. 4A). In general, the 2005 values were higher than average at lower elevations, and lower than average at higher elevations. Differences for average annual minimum temperature tended to decrease with increasing elevation; however, 2005 values were generally higher than average (Fig. 4B). Deviations from the long-term mean for rainfall were invariant of elevation, and 2005 rainfall totals were higher than average for all but three stations (Fig. 5A). Differences for annual snowfall also were invariant of elevation (Fig. 5B). With the exception of the FOBU Coop station, total snowfall in 2005 was below average across the NCPN weather stations.

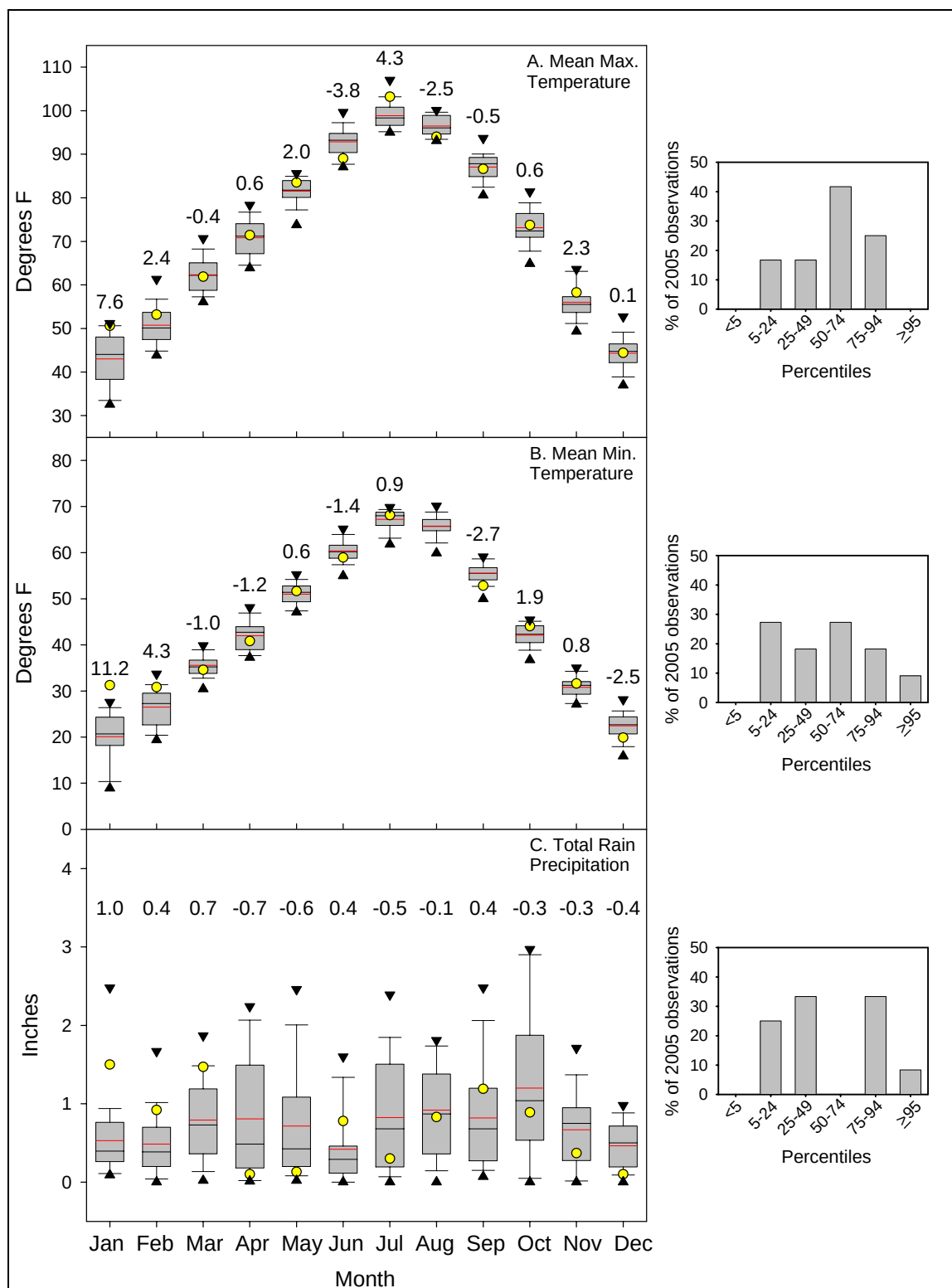


Figure 3. Comparison of 2005 monthly values with historical distributions (6/1/80 – 12/31/04) for ARCH Coop station. Only months with valid data are shown. See Figure 3-Legend for a description of the graph types and information displayed in this figure.

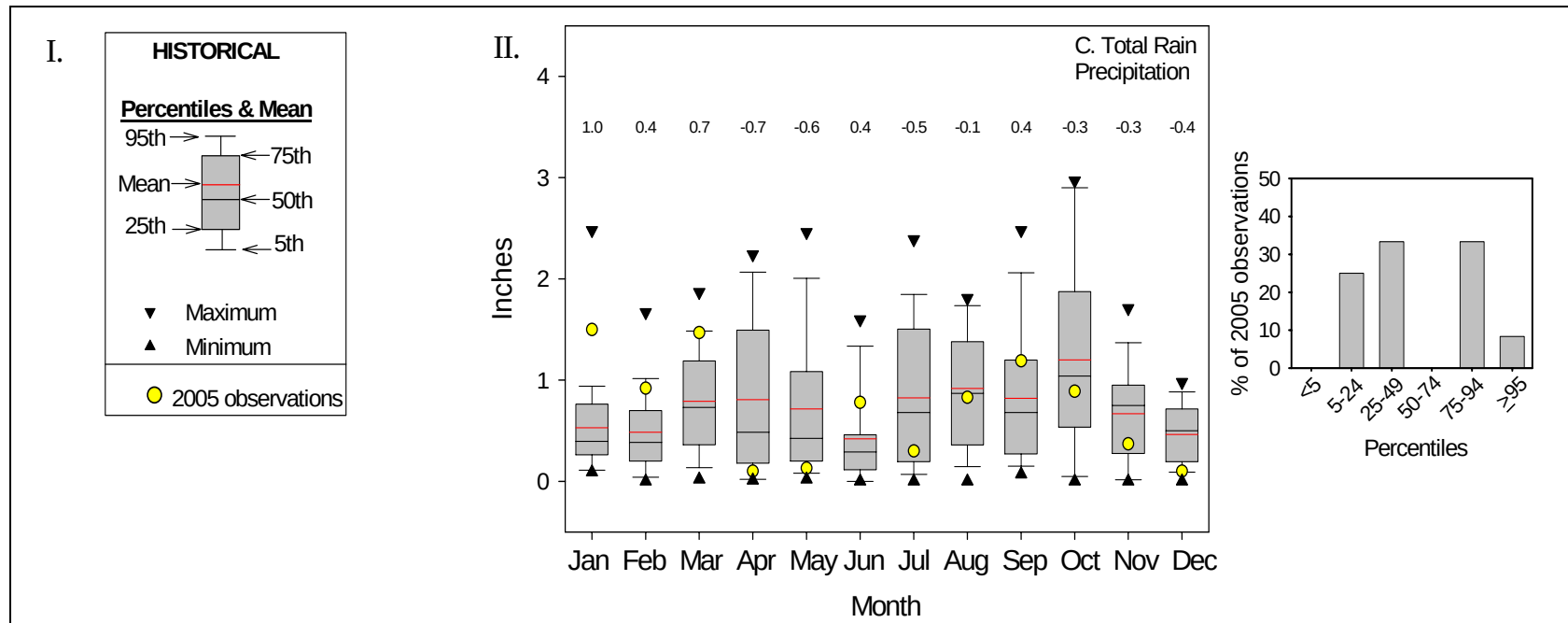


Figure 3-Legend. Description of information contained in Box-Whisker plots and supporting graphs. Plots are used to illustrate valid, monthly 2005 observations in an historical context for minimum, maximum air temperature, and total rainfall precipitation. Gradations of a Box-Whisker bar and other symbols are shown in I. Valid 2005 observations are plotted on top of the historical distribution shown by the Box-Whisker plots (II). Numbers above each bar are the deviation between 2005 monthly values and the historical mean. The right-hand side bar chart in II shows the percentage of monthly 2005 observations by historical-based percentile class. E.g., in the above example, three (25%) of the 2005 monthly values - April, May, December - were between the 5th and 24th percentiles of the historical distribution for these months.

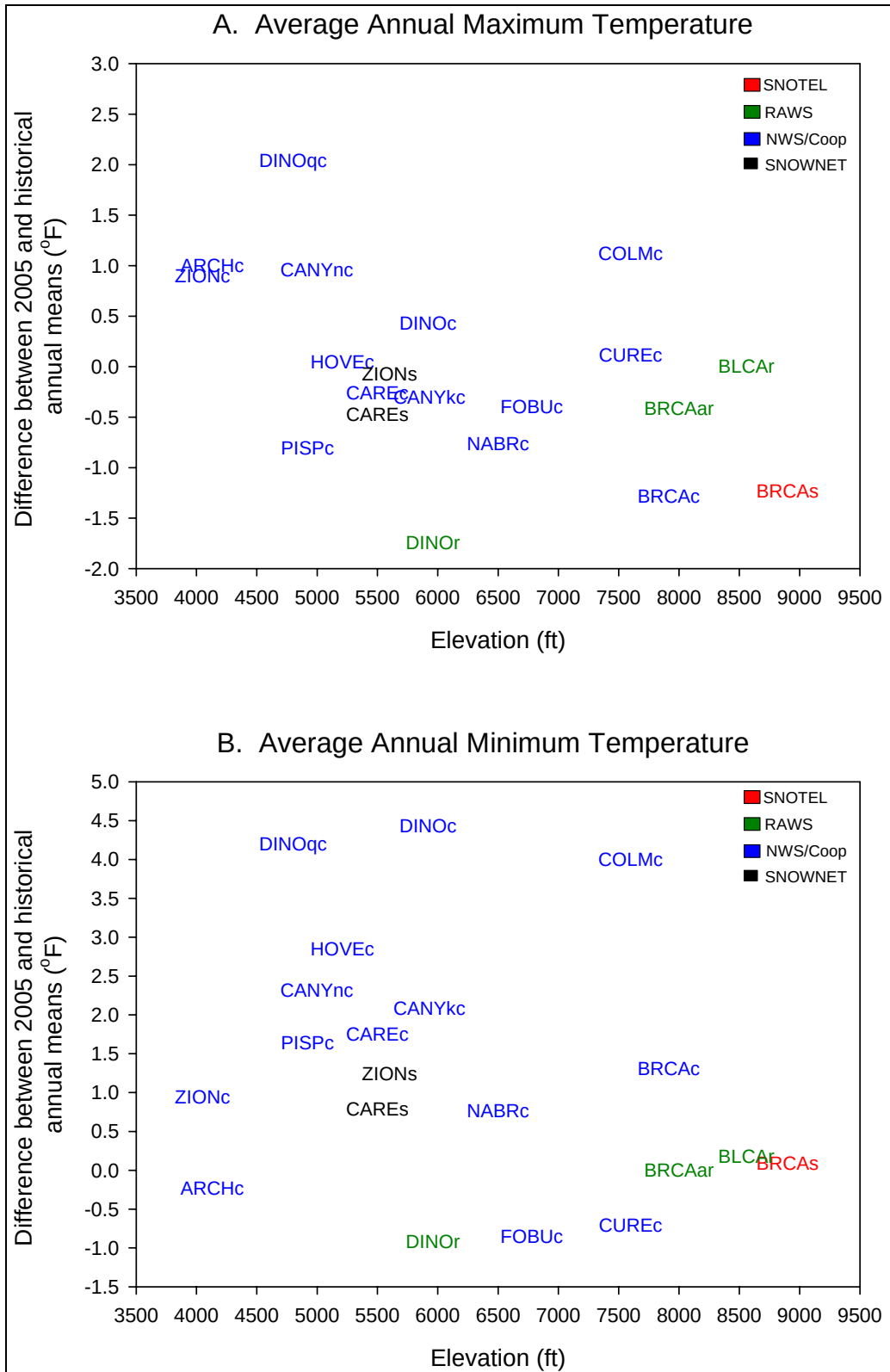


Figure 4. Differences between 2005 average annual temperature values and long-term means, arrayed by elevation. See Table 4 for supporting information.

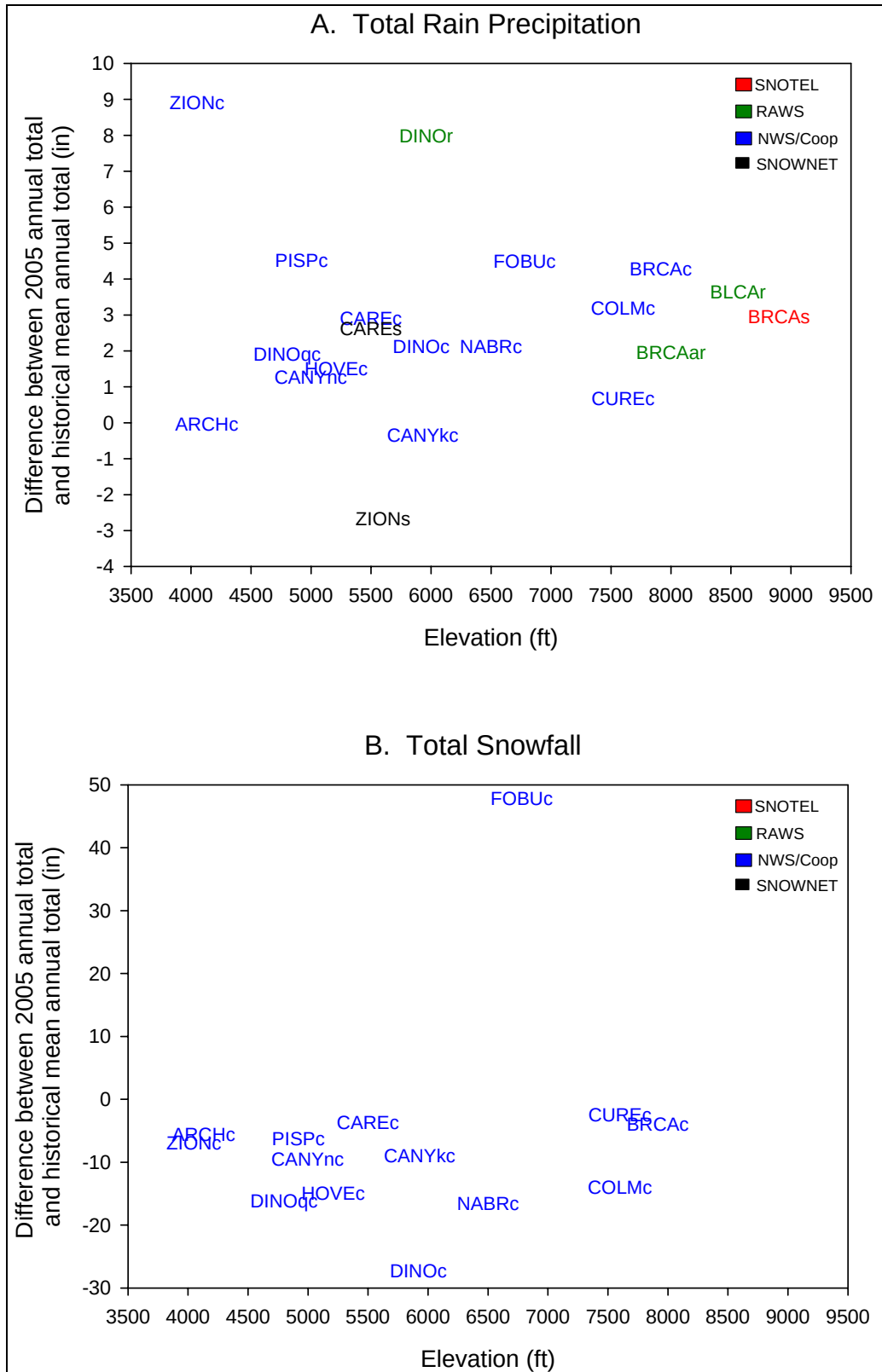


Figure 5. Differences between 2005 annual total precipitation values and long-term means, arrayed by elevation. See Table 4 for supporting information.

Table 4. Weather stations with valid 2005 annual averages and totals, and no. of years comprising the historical record, by climate variable.

			No. of years comprising long-term mean or total			
Climate Monitoring Program	Station Code in Figures 4, 5.	Park/Station name	Mean Annual Max. Temp.	Mean Annual Min. Temp.	Annual Precipitation	Annual Snowfall
SNOTEL	BRCA _s	BRCA – Agua Canyon	9	9	8	na
RAWS	BLCA _r	BLCA	7	7	7	na
	BRCA _{ar}	BRCA – Agua Canyon	11	11	11	na
	DINO _r	DINO	6	6	6	na
NWS-Coop	ARCH _c	ARCH	24	24	24	23
	BRCA _c	BRCA	45	44	45	43
	CANY _{kc}	CANY/ The Neck	38	37	39	39
	CANY _{nc}	CANY/ The Needles	38	38	37	33
	CARE _c	CARE	35	37	37	37
	COLM _c	COLM	60	59	55	59
	CURE _c	CURE	17	17	35	35
	DINO _{qc}	DINO/Quarry	41	45	46	44
	DINO _c	DINO/National Monument	39	39	39	39
	FOBU _c	FOBU	13	13	10	10
	HOVE _c	HOVE	42	43	46	46
	NABR _c	NABR	36	35	39	39
	PISP _c	PISP	37	37	41	39
	ZION _c	ZION	93	92	77	77
SNOWNET	CARE _s	CARE	7	7	6	na
	ZION _s	ZION/East Gate	7	7	6	na

“Long-term” Trends

Trends were evident for the fundamental climate attributes recorded at NCPN Coop stations. Thirteen of the 15 stations examined had a significant linear slope for average annual maximum temperature (Table 5). The majority of significant relationships exhibited an increase in mean maximum temperature. Only the ARCH Coop station (Fig. 6A), however, exhibited a strong linear trend ($\text{AdjR}^2 > 0.70$). A trend in average annual minimum temperature was prevalent among the NCPN climate stations, with 11 of the 12 significant relationships indicating an increase in temperature (e.g., Fig. 6B). The four models which explained a high level of variance (CARE, DINO-NM, NABR, PISP) indicate, on average, an increase in mean annual minimum temperature of 0.08°F per year over the past 34 years. A general increase in temperature since the 1970's has been noted in other western US regions (e.g., Yellowstone River basin; Davey et al. 2006), and since the 1990's in Alaska (Arctic Climate Impact Assessment, 2004). Only six stations exhibited a significant slope for rainfall precipitation. However, three of these stations had very limited data (Lava Pt RAWS, Agua Canyon SNOTEL, ZION SNOWNET), and for stations with larger sample sizes, the variance explained by the linear model was relatively low ($\text{AdjR}^2 < 0.4$). The record for most stations clearly indicates the drought conditions of 1999-2002, especially the limited rainfall in 2002 (e.g., Fig. 6C). Precipitation in 2002 has been described as a record low throughout the Plateau region (USGS 2003).

Eleven of the 15 stations with snowfall data had a significant, negative slope (Table 5), but only the NABR Coop station exhibited a strong, linear trend (Fig. 6D). Closer inspection of snowfall records indicated a noticeable decline since 1985-90 at many NCPN stations. The variability prior to this time period contributed to the relatively low amount of explained variance in models using the full observation period. For full-data models with an $\text{AdjR}^2 < 0.40$ (see Table 5), models based on only 1985-2005 data explained about twice the variance. These results strongly suggest that a majority of the 15 stations considered have experienced a declining trend in snowfall over the past 20-25 yrs.

Inherent climatic oscillations operate over long time frames (e.g., 50-60 yrs; Mantua et al., 1997). The 25-45 yr 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 100-yr observation period of the ZION Coop station, however, affords an interesting perspective of climate variability and trends (Fig. 7). Similar to the majority of Coop stations, the ZION station recorded increases in mean maximum and minimum temperature 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 rainfall values fail to exceed historical maxima. Trend assessments with the moving mean did indicate increasing temperature and declining snowfall over this extended time period (Table 5), but trends were relatively weak and models explained much less of the variance than those based on a shorter duration.

Table 5. Results of trend analyses of climatic variables based on least-squares regression of the moving mean over time. P values correspond to the significance of the regression model and of the slope. AdjR^2 is the Coefficient of Determination. Bold values are significant ($P < 0.05$) with a high (> 0.70) AdjR^2 .

Station	Average Annual Max. Temp. (F)				Average Annual Min. Temp. (F)				Total Rain Precipitation (in)				Total Snow Fall (in)			
	df	P	AdjR^2	slope	df	P	AdjR^2	slope	df	P	AdjR^2	slope	df	P	AdjR^2	slope
ARCH Coop	21	<0.0001	0.87	0.202	21	0.64	-	-	21	0.0012	0.39	-0.123	21	0.79	-	-
BRCA Coop	42	0.015	0.11	-0.022	41	<0.0001	0.69	0.055	42	0.14	-	-	40	0.92	-	-
CANY-Neck Coop	35	0.07	-	-	34	0.0001	0.34	0.070	36	0.39	-	-	36	0.015	0.13	-0.134
CANY-Needles Coop	35	<0.0001	0.51	0.050	35	<0.0001	0.56	0.110	34	0.78	-	-	30	0.25	-	-
CARE Coop	32	<0.0001	0.48	-0.056	34	<0.0001	0.72	0.068	34	0.32	-	-	34	<0.0001	0.37	-0.367
COLM Coop	57	0.0015	0.15	0.030	56	0.27	-	-	52	0.55	-	-	56	<0.0001	0.36	-0.404
CURE -Blue Mesa Coop	14	0.99	-	-	14	0.91	-	-	33	0.0007	0.28	-0.080	33	0.0003	0.31	-0.880
DINO-NM Coop	36	<0.0001	0.36	0.079	36	<0.0001	0.72	0.118	36	0.53	-	-	36	<0.0001	0.64	-1.068
DINO-Quarry Coop	38	<0.0001	0.32	0.070	42	0.0032	0.17	0.045	43	0.14	-	-	41	0.0002	0.28	-0.327
FOBU Coop	10	0.0054	0.55	0.138	10	0.12	-	-	7	0.06	-	-	7	0.56	-	-
HOVE Coop	39	<0.0001	0.42	0.059	40	0.005	0.17	0.035	43	0.82	-	-	43	<0.0001	0.32	-0.311
NABR Coop	33	0.0173	0.14	-0.029	32	<0.0001	0.83	0.088	36	0.173	-	-	36	<0.0001	0.74	-1.109

Table 5. Cont'd.

Station	Average Annual Max. Temp. (F)				Average Annual Min. Temp. (F)				Total Rain Precipitation (in)				Total Snow Fall (in)			
	df	P	AdjR ²	slope	df	P	AdjR ²	slope	df	P	AdjR ²	slope	df	P	AdjR ²	slope
PISP Coop	34	<0.0001	0.53	0.076	34	<0.0001	0.81	0.079	38	0.35	-	-	36	<0.0001	0.50	-0.496
TICA Coop	45	0.0044	0.15	0.029	47	0.014	0.10	-0.022	46	0.24	-	-	45	<0.001	0.57	-1.535
ZION Coop	90	<0.0001	0.19	0.023	89	0.0005	0.12	0.015	74	0.034	0.05	0.026	74	<0.0001	0.21	-0.115
BLCA RAWS	4	0.16	-	-	4	0.06	-	-	4	0.14	-	-	-	-	-	-
BRCA - AGUA Canyon - RAWS	8	0.24	-	-	8	0.001	0.77	0.175	8	0.62	-	-	-	-	-	-
DINO RAWS	3	0.32	-	-	3	0.94	-	-	3	0.28	-	-	-	-	-	-
ZION - Lava Pt RAWS	4	0.11	-	-	4	0.47	-	-	4	0.0096	0.90	-1.161	-	-	-	-
BRCA - AGUA SNOTEL	6	0.64	-	-	6	0.06	-	-	5	0.0324	0.65	-0.078	-	-	-	-
CARE SNOWNET	4	0.67	-	-	4	0.19	-	-	3	0.32	-	-	-	-	-	-
ZION - East Gate SNOWNET	4	0.44	-	-	4	0.17	-	-	3	0.021	0.94	-2.498	-	-	-	-

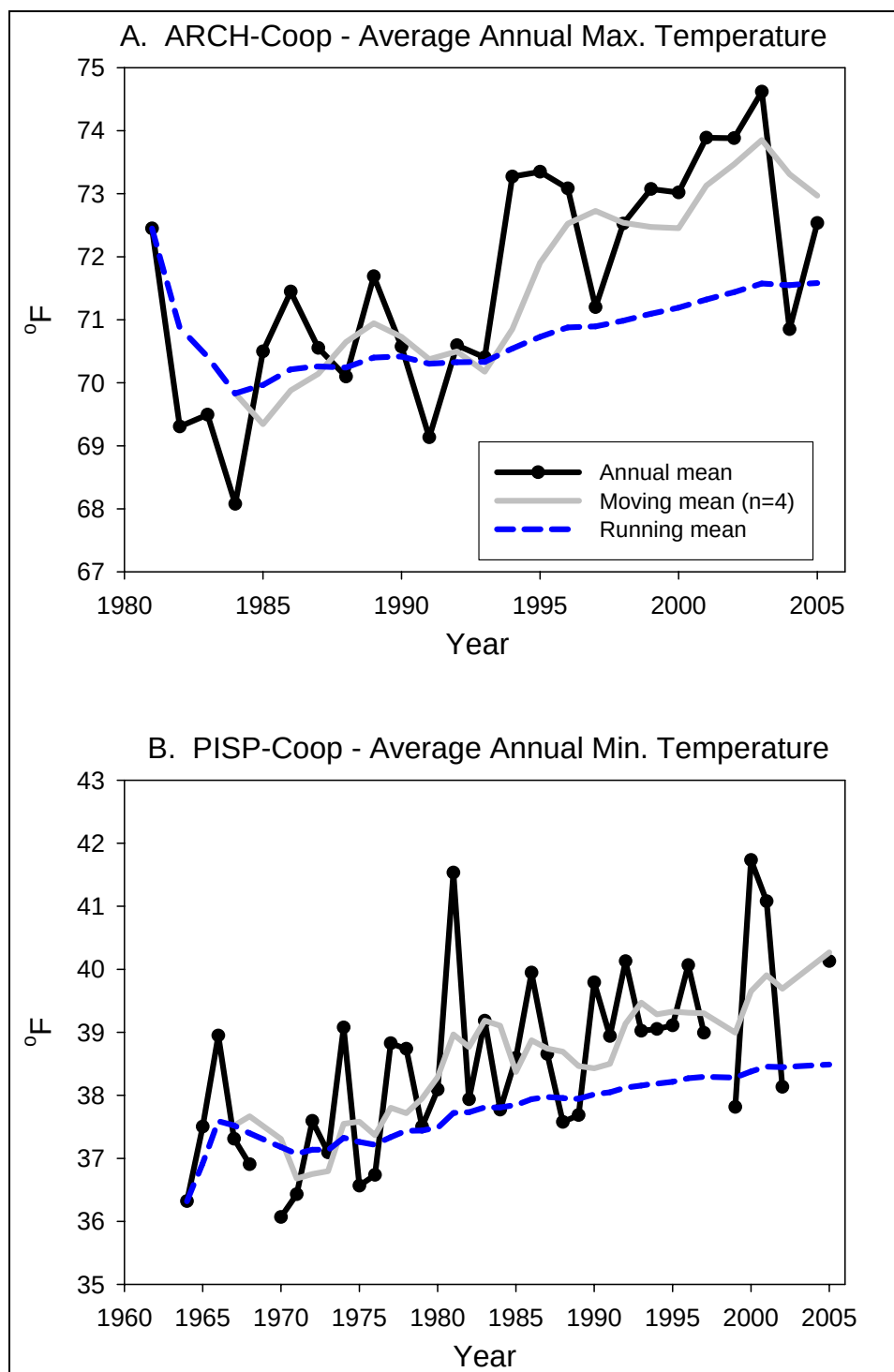


Figure 6. Long-term trends for selected stations and climate variables. Breaks in the Annual line indicate years with limited or missing data. Moving mean is the average of valid values from the previous 3 yrs and the year of the estimate. The running mean is a cumulative mean.

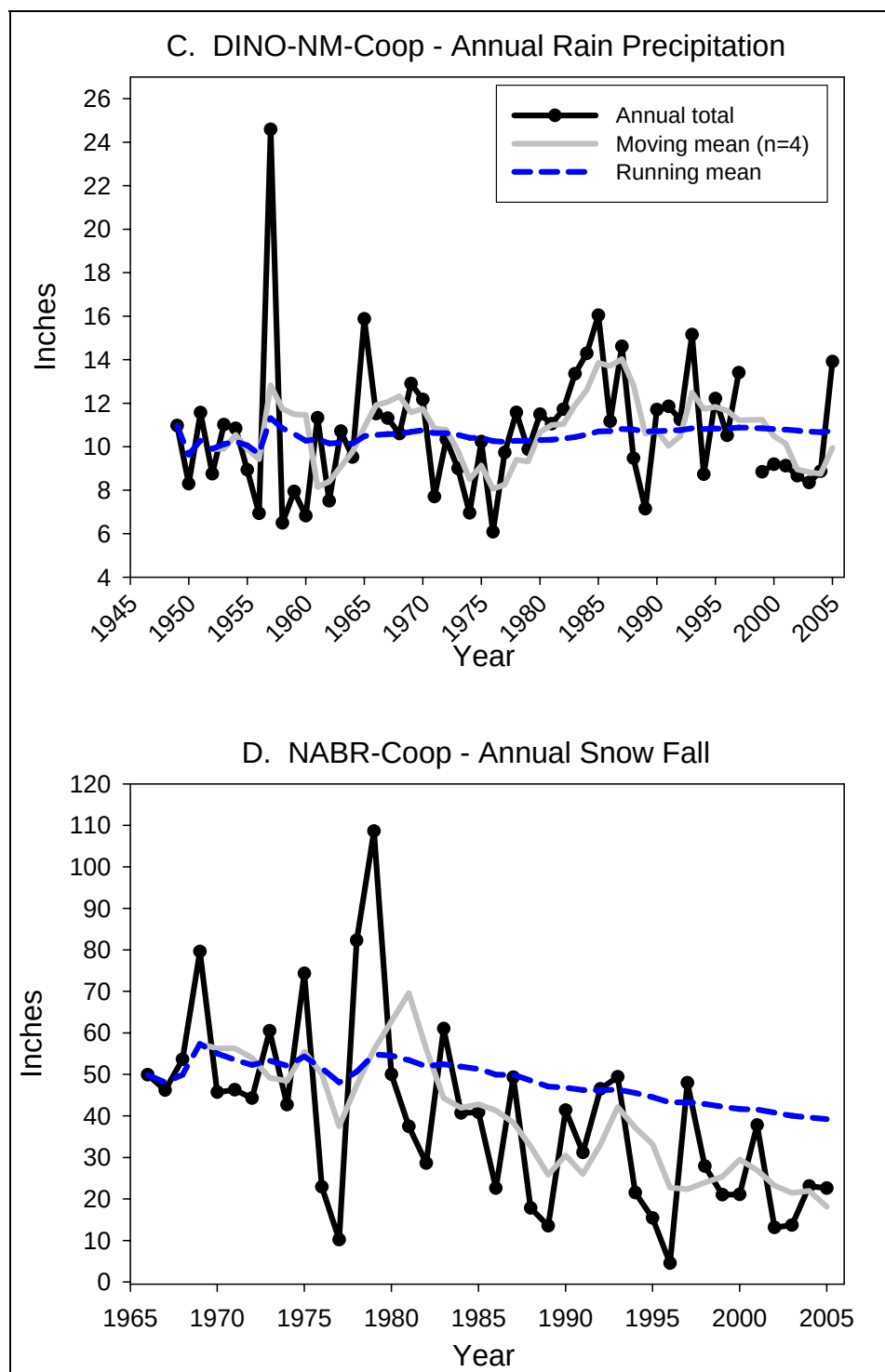


Figure 6. Cont'd.

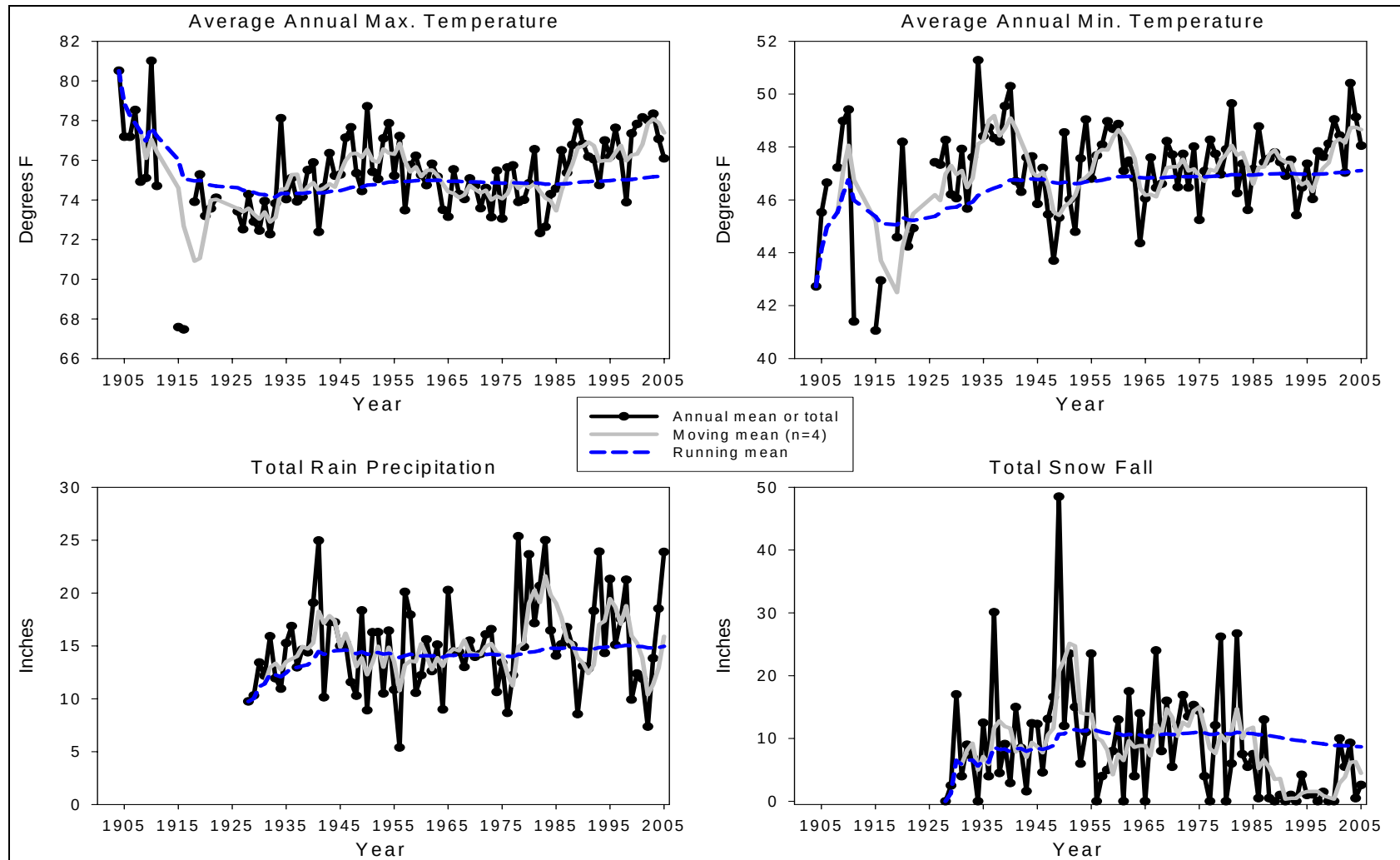


Figure 7. Long-term trends for ZION Coop station. Breaks in the Annual line indicate years with limited or missing data. Moving mean is the average of valid values from the previous 3 yrs and the year of the estimate. The running mean is a cumulative mean.

Regional Perspective - Assessment of PRISM Predictions

For the selected geographic area shown in Fig. 8, 2005 average annual maximum and maximum temperatures and annual precipitation were, on average, higher than 30-yr means (Table 6). Precipitation tended to be noticeably higher in the upper central portion of UT, SW UT, and west-central CO. Departure from the long-term minimum temperature mean was especially noticeable in central and east-central UT, and throughout west-central CO. Only a few areas shown in Fig. 8 experienced below average conditions. Precipitation in 2005 was below average in northeast of FOBU in addition to the region southeast of CURE. The NW fringe of UT experienced below mean values for average annual maximum temperature.

Generalizing to the NCPN park environs, the SW portion of the NCPN (area encompassing ZION, CEBR, and BRCA) experienced higher than average precipitation but about average temperature in 2005. Excluding the area around BLCA, CURE, and FOBU, the remainder of the NCPN region experienced elevated mean annual minimum temperature of 2-4 °F, and elevated precipitation of 2-4 inches in 2005 compared to average conditions. For areas around BLCA, CURE, and FOBU, precipitation levels varied from average to lower than average, but mean annual minimum temperatures were average.

Table 6. Average difference for temperature and precipitation between PRISM estimates for 2005 and long-term means (1971-2000) for the geographic area shown in Figure 8.

Climate variable	Mean difference (1 SD) [2005 value – long-term mean]	Range of difference values
Average Annual Max. Temperature (°F)	0.39 (0.747)	-4, 6
Average Annual Min. Temperature (°F)	2.009 (1.029)	-1, 6
Annual Precipitation (in)	0.26 (0.637)	-6, 24

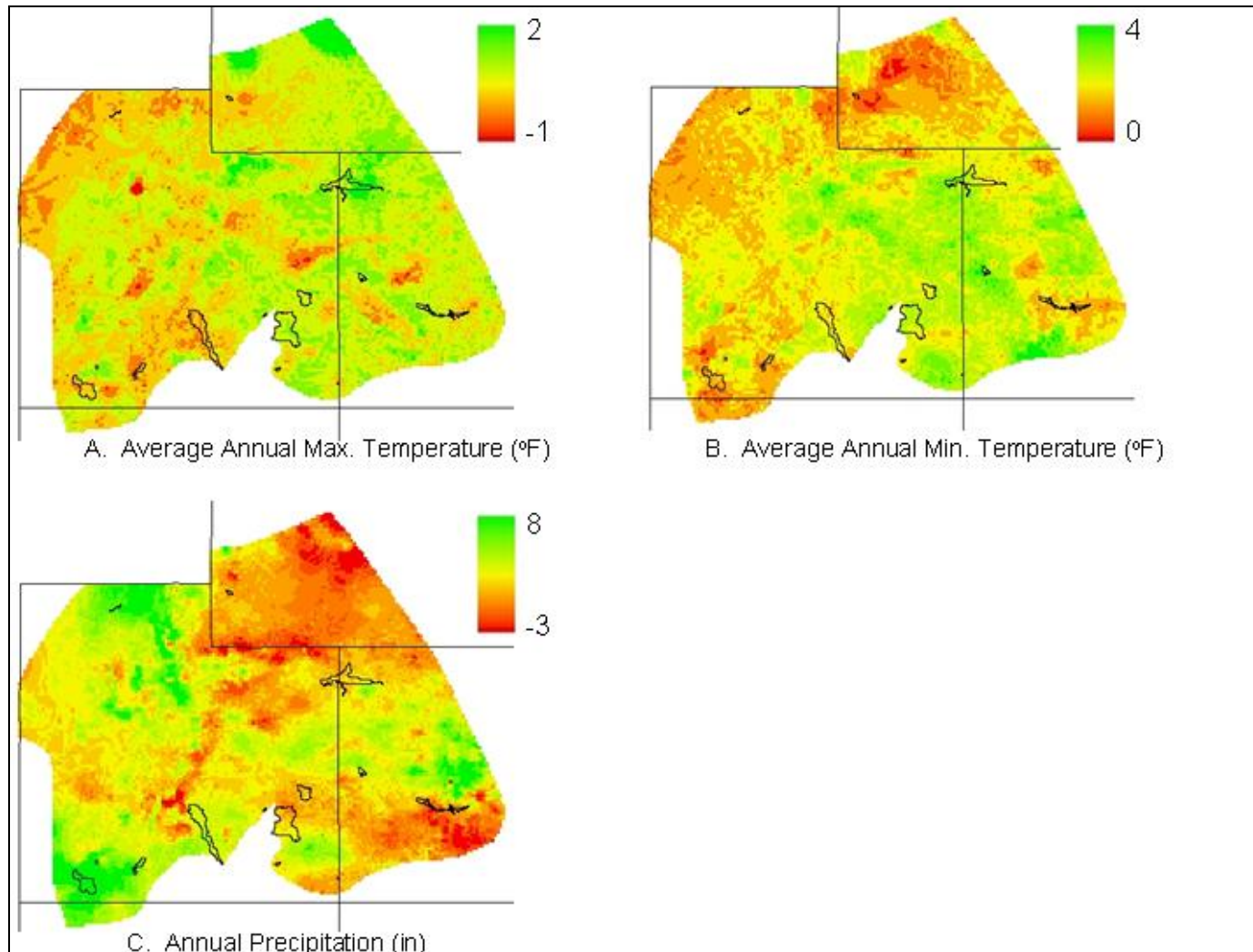


Figure 8. Differences between PRISM (Daly et al. 2002) estimates of 2005 annual averages (annual total for precipitation) and 30-yr means (1971-2000) for the NCPN environ. A positive difference indicates that a 2005 value was greater than the long-term mean.

Conclusions

- 1) Average annual minimum temperature and annual rainfall precipitation tended to be above average in 2005 throughout much of the NCPN region. Nine of the 16 NCPN Coop stations experienced a record high average monthly minimum temperature in January or February.
- 2) For the NCPN weather stations examined, differences between 2005 average annual maximum temperature and long-term means tended to follow an elevation gradient, with difference from the long-term average decreasing with increasing elevation.
- 3) With the exception of the FOBU Coop station, snowfall recorded in 2005 at NCPN weather stations tended to be well below average.
- 4) A general increase in annual mean minimum temperature over the past 25-45 yrs is evident for most of the NCPN Coop stations. Conversely, these records show evidence of a declining trend in snowfall over the past 20-25 yrs. Historical records for NCPN Coop stations indicate that annual rainfall has been highly variable, and that a strong unidirectional trend over the observation periods is not evident.

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 25-45 yr 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+ yrs) observation periods. Additionally, the number of weather stations in a NCPN park is nominal, with generally only 1-3 stations, and stations do not span the full environmental range of a park. For especially 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 environ. Ongoing coordinated efforts between I&M WASO, the Intermountain Region of I&M networks and 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 climate analyses and reports to provide a more comprehensive interpretation of climatic conditions of park units.

Location of Summary Reports and Graphs on CD

Summary reports (e.g., Fig. 9), and monthly distributions and trend graphs for each NCPN weather station are included on the accompanying CD, and are organized by park, by climate-monitoring program, by report or graph type. Park acronyms are used to indicate the park unit. Monitoring programs are COOP, SNOTEL, RAWs, SNOWNET, and SNOWCOURSE. Report type is either Summary_Tables or Historical. Monthly and annual summaries are contained under Summary_Tables, and contain the term monthly or annual in the file name.

Monthly Climate Summary

FOBU COOP, Station No. 483582 (FBMW4) - 01/2005

Day	Air Temperature (°F)			Precipitation (inches)		
	Minimum	Maximum	Average	Rainfall	SnowFall	SnowDepth
1	-	-	-	-	1	-
2	5	29	17	-	1	8
3	6	30	18	0	0.2	8
4	17	27	22	0.01	1	9
5	5	22	13.5	0.02	0.5	9
6	1	19	10	0.02	1	10
7	5	20	12.5	0	0	10

Annual Climate Summary

BRCA Coop, Station No. 421008 (BRYU1) – 2005

Minimum Air Temperature (F)	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Min	-9	-3	3	9	26	31	40	35	28	19	3	-9	14.4
Max	30	28	27	35	41	47	59	54	50	46	38	29	40.3
Average	15.5	13.6	17.7	23.6	33.4	38.1	48.5	44.8	35.4	28.3	20.9	11.8	27.6
Number of days													
<=0F	2	2	0	0	0	0	0	0	0	0	0	6	10
<=32F	27	23	29	23	14	4	0	0	13	25	29	29	216
% of days with valid records	87.1	82.1	93.5	86.7	93.5	90	90.3	100	96.7	90.3	100	93.5	92.1

Maximum Air Temperature (F)	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Min	22	26	26	34	42	50	69	65	57	40	16	19	38.8

Figure 9. Examples of Monthly and Annual Climate Summary reports.

E.g., the monthly report for the ARCH Coop station is ARCH\COOP\Summary_Tables\arch_Coop_monthly_2005.doc. The annual summary is the same path but the file is named arch_Coop_annual_2005.doc. Plots showing monthly means in the context of the historical record (e.g., Fig. 3) and long-term trends (e.g., Fig. 7) are included as WORD documents under the Historical subdirectory. E.g., the plot of recent and historical monthly means for the SNOTEL station is BRCA\SNOTEL\Historical\agua_Snotel_monthcomparison_2005.doc. The long-term trend plot is the same path, but the file is called agua_Snotel_trend_2005.doc.

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Appendix A. Location, elevation, and observational period for the major weather stations within NCPN park units. BLCA and CURE stations are in UTM zone 13; other stations are in UTM zone 12.

Climate Monitoring Program/ Park	Location: UTM Northing Easting	Elevation ft (m)	Period of record	Climate Monitoring Program/ Park	Location: UTM Northing Easting	Elevation ft (m)	Period of record
<u>NWS-COOP</u>				<u>RAWS</u>			
ARCH	4275204 620212	4130 (1259)	6/1/80 – present	BLCA	4269462 265823	8560 (2609)	6/4/97 - present
BLCA	4270811 265847	8150 (2484)	10/9/03 - present	BRCA/ Agua Canyon	4153565 387677	8000 (2438)	6/4/90 - present
BRCA	4166638 396948	7915 (2412)	6/1/59 - present	BRCA	4166704 396581	7855 (2394)	1/6/03 - present
CANY - Neck	4256408 603257	5930 (1807)	6/17/65 - present	DINO	4486307 677030	5960 (1816)	7/29/98 - present
CANY- Needles	4223196 609524	4998 (1523)	6/18/65 - present	ZION/Lava Pt	4140273 319512	7700 (2347)	7/31/95 - present
CARE	4237285 476677	5500 (1676)	3/1/67 - present	ZION/ HQ	4119415 324488	3901 (1189)	11/5/02 - present
COLM	4330319 696008	7600 (2316)	8/1/48 - present	<u>SNOTEL</u>			
				BRCA/ Agua Canyon	4152946 387992	8900 (2712)	10/7/94 - present
CURE (Blue Mesa)	4259937 311146	7600 (2316)	11/1/67 - present	<u>Snow Course</u>			
DINO- Quarry	4477485 643976	4800 (1463)	12/1/15 - present	BRCA	4166517 396775	8000 (2438)	1/1/35 - present
				<u>SNOWNET</u>			
DINO - NM	4456830 672502	5920 (1804)	6/1/65 - present	CARE	4238083 477085	5500 (2438)	12/15/97 -present
FOBU	4631297 519374	6780 (2066)	8/1/90 - present	TICA	4476899 440086	7999 (2438)	12/28/97 -present
HOVE	4139559 669972	5210 (1588)	4/2/57 - present	ZION/East Gate	4123976 333923	5600 (1707)	11/2/97 - present
				<u>CRN</u>			
NABR	4163770 589724	6500 (1981)	6/17/65 - present	BLCA	4269509 265237	8398 (2559)	7/04 - present
PISP	4080598 345012	4920 (1500)	6/1/63 - present	DINO	4456876 672864	6063 (1848)	9/04 - present
				<u>CLIM-MET</u>			
TICA	4477940 440642	5640 (1719)	7/1/48 - present	CANY/Needles	4224489 608979	4910 (1497)	7/98 - present
				CANY/Virginia Park	4216970 601707	5630 (1716)	7/98 - present
ZION	4119827 323929	4050 (1234)	1/1/1904 - present				

Appendix B. Acronyms of NCPN park units.

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