



Annual Climate Summary 2014

Arctic Network

Natural Resource Data Series NPS/ARCN/NRDS—2017/1095



ON THE COVER

Imelyak station in Noatak National Preserve.
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Natural Resource Data Series NPS/ARCN/NRDS—2017/1095

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Executive Summary

The Arctic Network's (ARCN) climate monitoring program has established seventeen remote weather stations to monitor climate in Gates of the Arctic National Park and Preserve, Noatak National Preserve, Kobuk Valley National Park, Cape Krusenstern National Monument, and Bering Land Bridge National Preserve. The main goal of the program is to operate these remote sites for the long term in order to help scientists and park managers understand the climate patterns across these large parks. There are three weather and climate stations (in the villages of Bettles, Kotzebue, and Nome, Alaska) near the parks operated by various state and federal agencies that are used as index sites to compare current climate conditions in the region to the climatological normal—the average weather conditions over a 30-year period. The current normal period is 1981-2010. This report summarizes the annual and monthly temperature and precipitation deviations for the index sites and compiles monthly and annual statistics for the sites with shorter records, including six additional fire weather stations, four SNOTEL stations, and one airport weather site located in or near park boundaries. A brief synopsis of regional, national, and global climate conditions for 2014 is included for climatic context.

The Arctic Alaska region was much warmer than the 1981-2010 normal in 2014. The mean annual air temperatures of 28.4°F in Kotzebue and 31.6°F in Nome were the warmest years on record. 2014 was the 5th warmest year on record in Bettles. Annual precipitation totals at the ARCN index sites varied from 85% of normal in Kotzebue to 117% of normal at Bettles. Bettles recorded 17.45 inches for the year, Kotzebue had 9.61 inches (87% of normal) and Nome received 14.21 inches (85% of normal). Average annual temperatures in 2014 mask the temporal variability experienced at most locations including a very warm January, a cool period in June and July, and a much warmer than normal fall season.

The average annual temperature for Alaska was 4.0°F above the 1981-2000 average making 2014 the warmest year on record. Precipitation statewide was just above average and ranked as the 52nd wettest year on record. Monthly variability was high, however, with a wet January, dry spring, and very wet summer (the third wettest on record for the state). Nationally, the average annual temperature for the contiguous U.S. for 2014 was 52.6°F, 0.5°F above the 20th century average. It was the 34th warmest year over the 120-year record. Globally, 2014 was the warmest year on record since records began in 1880. Over land and ocean combined, 2014 was 1.2°F above the 20th century average of 57.0°F.

Between May and September of 2013, the Arctic Network staff performed annual site maintenance at the sixteen network weather stations, two fire weather stations and one Natural Resources Conservation Service SNOTEL station. The Kugururok site in Noatak National Preserve was installed in July, 2014.

Introduction

Gates of the Arctic National Park and Preserve (GAAR), Noatak National Preserve (NOAT), Kobuk Valley National Park (KOVA), Cape Krusenstern National Monument (CAKR), and Bering Land Bridge National Preserve (BELA) make up the Arctic Inventory and Monitoring Network (ARCN), covering about 19 million acres. The network was established to monitor key components of ecosystems of the parks and to provide that information back to park managers for use in stewardship of park resources. Climate is considered to be the most important broad-scale factor influencing ecosystems and therefore the natural resources of parks. Because global climate models indicate that climate change and variability will be greatest at high latitudes, climate monitoring is critical to understanding the changing conditions of park ecosystems.

There are three National Weather Service (NWS) stations in the ARCN region that have been in operation for 62 to over 100 years and are used as index sites to place current year regional weather conditions into climatological context. Monthly and annual statistics are compared to the latest climate normal period (1981-2010).

The ARCN parks represent a large portion of the mountainous environment of the northern portion of the state of Alaska and therefore provide an opportunity to understand climate gradients that have traditionally been a challenge to instrument and monitor. The ARCN climate monitoring program deployed seventeen climate stations between 2011 and 2014, many at higher elevations, to capture elevational and latitudinal climate gradients within the parks, and to capture data in areas where there are no baseline references. These sites are referred to as ARCN RAWS (remote automated weather stations). This work is being implemented based on the Central Alaska network (CAKN) climate vital sign protocols (Sousanes 2006). The ARCN protocol implementation plan and standard operating procedures are currently in review (Sousanes et al. 2017). There are eleven additional sites that are analyzed in this report including four Snow Telemetry (SNOTEL) sites, six fire RAWS, and one Federal Aviation Administration (FAA) Automated Weather Observing System (ASOS). The SNOTEL sites are within or near the park boundaries and provide representative year-round precipitation measurements. These sites are operated and maintained under an interagency agreement between the National Park Service (NPS) and the Natural Resources Conservation Service (NRCS). The six fire RAWS are located within or near the park boundaries and are part of a much larger national fire program and are maintained under contract with the National Interagency Fire Center. Monthly weather statistics are generated for each of these sites; however, long-term trends will take time to develop.

The 2014 field season marked the fourth year of operational climate monitoring in ARCN parks. Annual maintenance was performed at seventeen climate stations. Maintenance at the climate sites included sensor replacement, troubleshooting, upgrades, data downloads, and sensor calibrations. Station maintenance logs were used to keep track of the climate station inventory for the stations, which includes: sensors, data loggers, towers, solar panels, and batteries. Sensor and power performance was tracked and instrumentation was replaced as necessary. A new station was established at Kugururok in Noatak National Preserve. The Quartz Creek and Hoodoo Hill fire

RAWS stations were also serviced this field season by ARCN staff; maintenance for this site and all other NPS fire RAWS is usually done by the NPS radio shop. A maintenance report is completed after each field season to document the details of the site visits—these reports include the field notes, photos, logistics, and sensor metadata (Hill and Sousanes 2014).

This is the second annual data report that summarizes the annual and monthly weather statistics of the most recent year for the Arctic Network Climate Monitoring Program.

Arctic Network Climate Overview

The Arctic Network encompasses strong climate gradients, from the arctic maritime climates in BELA and CAKR where it borders the Bering and Chukchi seas to the strongly continental climates found in GAAR and eastern NOAT. Arctic network parklands constitute parts of the North Slope, Central Interior, and West Coast climate divisions as defined by Bieniek et al. (2012). A transitional climate region lies between the coast and the interior influenced by major mountain ranges which act not only as the environmental controls to drive climate but also contribute to the highly localized micro climates found in complex mountain terrain. Temperature inversions are common in through much of the year as a result of low water vapor content, extended periods of snow cover, and low solar radiation. The climate gradients are intrinsic to the ecosystem patterns, and vegetative and faunal communities found in ARCN parks. Redmond and Simeral (2010) and Davey et al. (2007) provide a more detailed discussion of the climate of the Arctic Network.

The climate patterns of Alaska are primarily influenced by latitude, continentality, and elevation. The high latitude drives the seasonal pendulum of available solar radiation; areas farther north have limited incoming solar warmth in the winter and an abundance of available light in the summer. Major mountain ranges in the state act as barriers to the moisture spinning off of the Pacific Ocean to the south. The warm, moist air masses deposit precipitation on the windward sides of the mountains, rain at low elevations and snow at higher elevations. Large-scale atmospheric and oceanic circulation patterns influence seasonal and annual weather patterns in the state, like the repositioning of the polar jet stream and the Aleutian low pressure system or the frequency of La Niñas and El Niños (Papineau 2001). Each of these can affect the regional patterns of storm tracks, prevailing winds, snowfall amounts, and the extent of sea ice (ACIA 2004).

There are several large-scale climate patterns and indices that are of particular interest to Alaska, including the Pacific Decadal Oscillation (PDO), an index of sea surface temperatures in the North Pacific Ocean. Typical winter sea surface temperatures during the warm phase of the PDO are warmer off of the Gulf Coast of Alaska moderating air temperatures over Alaska (Hartmann and Wendler 2005, Keen 2013). The PDO appears to cycle through a warm and cool phase every 20-30 years. Temperature trends that have shown climatic warming tend to be strongly biased by a sudden shift in 1976 from the cooler regime to a warmer regime. Since 2005, the index had been predominantly negative and air temperatures have been near or below normal, a possible indication of a phase shift from positive to negative. However, there appears to be more variation in the past few years. Large-scale changes such as this may take a few decades to confirm.

While the north Pacific seems to explain some of the temperature trends in the region, the Arctic Ocean, and in particular the extent of sea ice, will likely influence both temperature and precipitation patterns in Alaska. In recent years, there has been a continued significant reduction in the extent of the summer sea ice cover and the decrease in the amount of relatively older, thicker ice (NSIDC 2015). Models predict that retreating sea ice will affect the temperature and ecosystems of adjacent lands. An increase in the amount of energy absorbed by vegetation and its transfer to the atmosphere will contribute to the further high-latitude amplification of climate warming (Chapin et al. 2005).

Methods

Data were compiled from three index sites: Bettles, Kotzebue, and Nome. These are the nearest stations to the ARCN parks that have long-term climate records and represent the major climate regimes in the network. These stations have records for a sufficient number of years to compare 2014 data with the latest normal period, 1981-2010. Temperature, precipitation, and snowfall were analyzed for the long-term sites. Monthly temperature means and precipitation totals for 2014 are compiled and compared with the 1981-2010 normal values for each site.

Data were also compiled from seventeen ARCN stations in the parks, six additional fire RAWS, four NRCS SNOTEL sites, and one FAA ASOS site in or near the parks (Figure 1, Table 1). During the annual visits at ARCN sites, data were downloaded from each climate station and quality checked. ARCN station data, metadata, quality control flags/notes, and sensor history is managed with Aquatic Informatics software and stored through the NPS Water Resources Division server in Fort Collins, Colorado. Errors or values outside a standard range were flagged and not used in the summary statistics. The quality checked data files were sent to the Western Regional Climate Center in October 2013 for archival purposes; there has been a lag between when these files are sent and when they are updated. All data quality corrections and approvals are stored in the Aquatic Informatics software. Monthly and annual means and totals were compiled for the climate variables measured at each location including, temperature, wind speed and direction, peak wind gust, relative humidity, solar radiation, soil temperatures, snow depth, and summer rainfall. Winter precipitation is not measured at the ARCN stations.

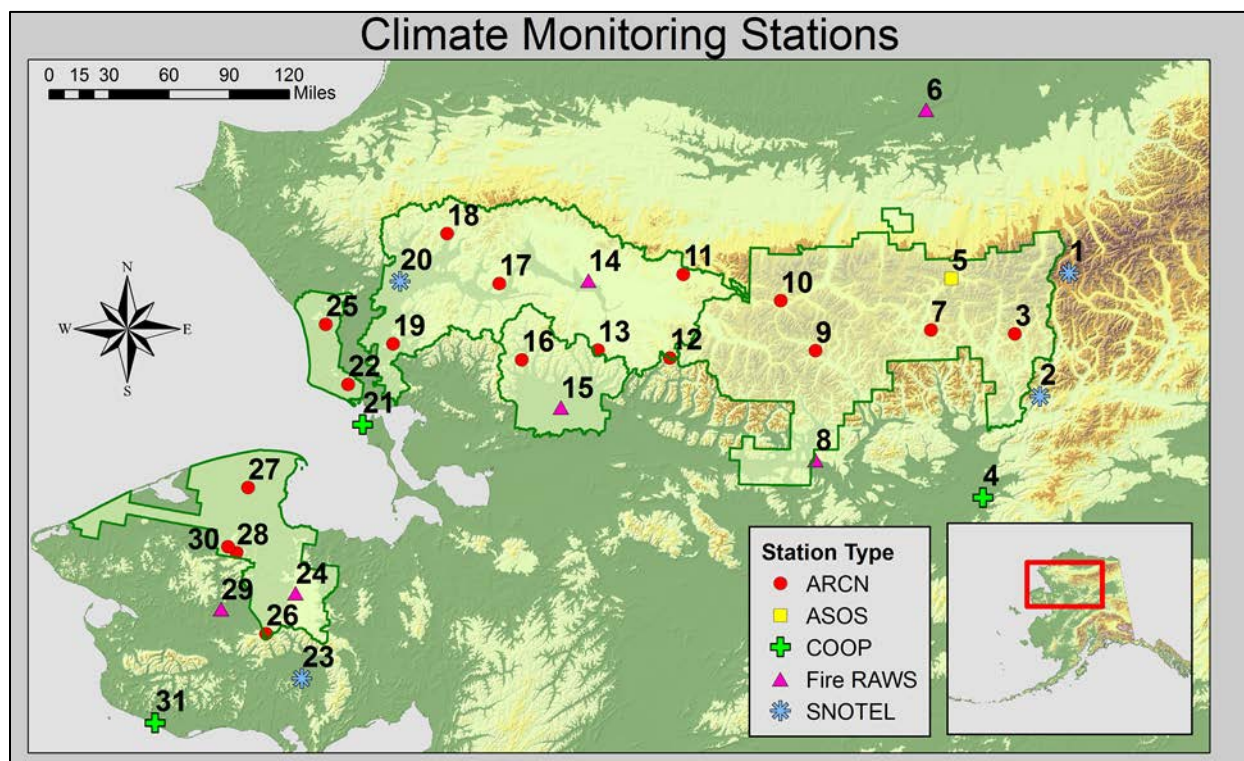


Figure 1. Map of climate station locations. Site numbers are given in Table 1.

Table 1. Weather stations included in this report. Station start is the earliest date listed in NOAA Applied Climate Information System (ACIS).

Station Name	Latitude	Longitude	Elevation (ft)	Station Type	Start Date	Site No
Anaktuvuk Pass	68.134	-151.743	2103	ASOS	Nov-02	5
Asik	67.475	-162.266	1329	ARCN	Jul-12	19
Atigun Pass	68.130	-149.480	4800	SNOTEL	Jan-83	1
Bettles*	66.540	-151.310	643	COOP	1951	4
Chimney Lake	67.714	-150.585	3700	ARCN	Aug-12	3
Coldfoot	67.250	-150.180	1040	SNOTEL	Mar-95	2
Devil Mtn.	66.296	-164.520	285	ARCN	Aug-11	27
Ella Creek	65.275	-163.820	2318	ARCN	Sep-12	26
Hoodoo Hill	65.595	-163.411	1495	Fire RAWS	Jun-92	24
Howard Pass	68.156	-156.896	2062	ARCN	Jul-11	11
Imelyak	67.545	-157.077	3620	ARCN	Jul-12	12
Kaluich	67.573	-158.432	2411	ARCN	Jul-12	13
Kavet Creek	67.139	-159.044	235	Fire RAWS	Jun-92	15
Kelly Station	67.930	-162.280	310	SNOTEL	Jul-11	20
Killik Pass	67.984	-155.013	4360	ARCN	Aug-12	10
Kotzebue*	66.867	-162.633	30	COOP	1897	21
Kugururok	68.317	-161.492	1020	ARCN	Jul-14	18
Midnight Mtn.	65.820	-164.543	2267	ARCN	Aug-11	28
Mt. Noak	67.141	-162.995	809	ARCN	Jul-11	22
Noatak	68.071	-158.704	985	Fire RAWS	Apr-90	14
Nome*	64.511	-165.440	13	COOP	1907	31
Norutak Lake	66.833	-154.333	800	Fire RAWS	Jun-92	8
Pamichtuk Lake	67.766	-152.164	3135	ARCN	Aug-12	7
Pargon Creek	64.990	-163.100	100	SNOTEL	Oct-00	23
Quartz Creek	65.400	-164.650	321	Fire RAWS	May-98	29
Ram Creek	67.624	-154.345	4100	ARCN	Aug-12	9
Salmon River	67.460	-159.841	1262	ARCN	Jul-11	16
Serpentine	65.852	-164.708	518	ARCN	Aug-11	30
Sisiak	67.995	-160.396	1823	ARCN	Jul-11	17
Tahinichok	67.550	-163.567	966	ARCN	Jul-11	25
Umiat	69.370	-152.136	267	Fire RAWS	Nov-07	6

*Index sites (data values are also in bold).

Most of the summaries, analyses, charts, and graphs included in this report from the National Oceanic and Atmospheric Administration (NOAA) and from the Natural Resources Conservation Service (NRCS) are in standard units; for consistency all data are presented in standard units.

Air Temperature Correction October 2015

During a datalogger and programming change in 2013, dataloggers began recording values from the secondary air temperature sensor on site at ARCN stations (Table 1). A thermistor manufactured by Therm-X provides the primary air temperature measurement at each site, while a Vaisala air temperature and relative humidity sensor provides a secondary air temperature measurement. Prior to 2013 only the primary air temperature sensor value was logged. After 2013, a discrepancy between the two air temperature sensor measurements led to further investigation. It was discovered that the programming used for the thermistor was based on a linear equation obtained from the SNOTEL network. An extensive review of the SNOTEL network by Oyler et al. (2015) revealed a potential non-linear bias in their sensors.

In collaboration with NOAA Climate Reference Network Oak Ridge Air Resources Laboratory, four ARCN thermistors were tested in calibration baths and compared against National Institute of Standards and Technology (NIST) reference sensors. The relationship between the average millivolt output from the four test sensors and the reference temperature was calculated as a ninth order polynomial relationship, rather than the linear fit used in the datalogger program. Comparing the four test sensors to the reference temperature, errors ranged from -0.1°C to $+0.1^{\circ}\text{C}$ using the polynomial, which is better than the specifications provided by the manufacturer. The successful calibration allowed all historical ARCN data to be corrected by first back-calculating the measured voltage from station sensors, and then recalculating the temperature using the polynomial fit (Figure 2). The uncorrected temperatures displayed a warm bias for temperatures ranging from -16°F to $+50^{\circ}\text{F}$. The warm bias peaked near 2°F at observed temperatures near 12°F . Observed temperatures colder than -16°F or warmer than $+50^{\circ}\text{F}$ displayed a cold bias. The Western Regional Climate Center is in the process of updating all of the archived air temperature data with the correction for all the ARCN sites. Details of the correction will be posted on each station's individual web page. Additionally, all changes are stored in the Aquatic Informatics software.

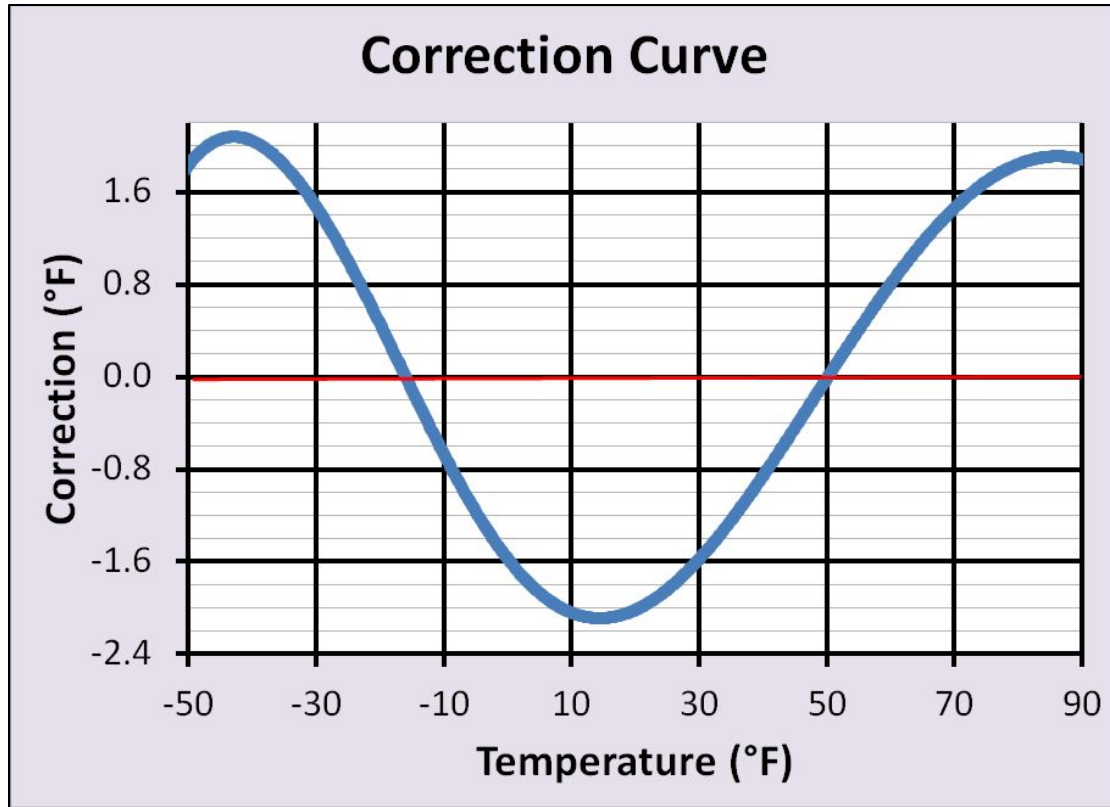


Figure 1. Correction curve for ARCN air temperature thermistors.

The ninth order polynomial equation that is being used to correct the data is as follows:

$$f(x) = p1 \cdot x^9 + p2 \cdot x^8 + p3 \cdot x^7 + p4 \cdot x^6 + p5 \cdot x^5 + p6 \cdot x^4 + p7 \cdot x^3 + p8 \cdot x^2 + p9 \cdot x + p10$$

where equation coefficients for ninth order polynomial equation are:

Coefficient	Ninth Order Coefficient
p1	610558.2264
p2	-2056177.655
p3	2937046.429
p4	-2319657.129
p5	1111854.338
p6	-337069.8833
p7	66105.70159
p8	-8386.783206
p9	824.8180218
p10	-86.73210068

Results

ARCN RAWS

Temperature

The ARCN climate stations installed from 2011-2014 are providing new information for areas that previously had little to no climate observations. These measurements are filling in some of the large spatial gaps in the network and provide information on climate patterns related to elevation and topography. Table 2 lists the monthly and annual temperatures for these sites. Additional parameters including wind speed, wind direction, solar radiation, snow depth, relative humidity, and soil temperature are archived by the NOAA Western Regional Climate Center and by network staff. Due to their short record, deviations or departures from normal cannot be calculated for these sites at this point.

Table 2. Monthly and annual mean temperatures (°F) from ARCN stations 2014^{1, 2}.

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Asik	16.4	8.3	13.0	23.7	33.0	46.7	49.5	52.8	39.4	21.5	21.0	8.7	27.9
Chimney Lake	11.1	5.1	11.5	17.2	31.4	43.8	45.7	45.0	31.6	14.8	15.9	9.3	23.6
Devil Mtn.	13.4	4.0	5.6	18.8	32.7	40.7	47.8	53.5	41.2	25.5	19.1	6.6	25.9
Ella Creek	14.4	5.3	6.4	20.7	28.9	41.2	44.7	50.3	37.0	19.0	21.1	7.8	24.8
Howard Pass	7.3	-3.5	6.2	15.1	31.5	43.6	47.8	45.3	34.7	15.5	15.5	-6.0	21.2
Imelyak	15.4	6.0	12.0	18.4	28.3	40.6	44.0	45.8	32.2	14.7	21.0	9.9	24.1
Kaluich	7.4	-2.2	7.1	15.6	30.7	43.5	47.0	47.2	35.1	14.7	15.8	-3.5	21.7
Killik Pass	7.7	-0.8	7.3	14.1	27.0	39.1	43.0	42.2	28.2	10.5	14.4	2.8	19.8
Kugururok*	–	–	–	–	–	–	–	52.8	39.0	21.9	18.2	5.5	–
Mt. Noak	15.3	7.4	11.0	23.4	33.9	46.1	50.5	54.3	41.4	23.4	20.0	8.5	28.1
Pamichtuk Lake	9.8	0.2	10.4	16.6	33.6	45.9	48.9	48.6	34.5	14.4	16.6	5.8	23.9
Ram Creek	M	M	M	16.6	30.0	42.1	46.0	45.4	31.1	12.4	15.3	6.1	M
Salmon River	12.5	4.9	11.9	M	M	M	M	53.2	39.8	21.4	17.0	4.3	M
Serpentine	15.9	6.2	6.8	18.2	35.9	44.3	49.7	54.0	42.4	25.6	22.6	7.7	27.6
Sisiak	9.2	2.0	7.7	16.6	31.4	45.9	49.0	49.3	36.2	17.6	15.4	0.2	23.5
Tahinichok	14.3	6.7	10.0	21.5	32.8	45.6	49.2	53.4	40.0	22.5	19.4	7.1	27.0

¹ Please note that the monthly values for individual sites may differ from those in the seasonal weather summaries –real-time transmitted data are used to generate the summaries, which may have some data gaps;

² M=Missing due to wildlife damage; *Kugururok station installed July 2014.

Among the ARCN stations, mean annual air temperatures (MAAT) ranged from 19.8°F at Killik Pass to 28.1°F at Mt. Noak (Table 2, Figure 3). February was the coldest month in 2014 at most ARCN stations. At 7:00 a.m. on February 16, an air temperature of -38.3°F and a sustained wind speed of 83.4 mph produced a wind chills at Howard Pass of -93.8°F. This event damaged the anemometer and produced the coldest wind chill of the year. The coldest monthly mean temperature was recorded at Howard Pass with an average temperature of -6.0°F in December. Stations were particularly warm in January throughout ARCN and especially in the western regions. Asik, at an elevation of 1,823

feet, was the warmest station in January with a mean monthly temperature of 16.4°F. On average across ARCN sites, January was 8.7°F warmer than February and 3.3°F warmer than March despite increasing sunlight.

April was warmest in western NOAT, with monthly means in the lower 20s at Asik, Tahinichok, and Mt. Noak. With longer daylight hours, temperature inversions began to breakdown in April and stations at higher elevations (e.g., Killik Pass, Chimney Lake, Pamichtuk) were among the coldest stations. Unlike 2013, temperatures in May warmed rapidly and nearly all ARCN stations had monthly mean temperatures above freezing for the month. Average summer (June-August) temperatures ranged from 41.4°F at Killik Pass at the northwest corner of GAAR to 50.3°F at Mt. Noak in CAKR. October is a transition month in the Arctic when temperatures drop well below freezing and snow begins to accumulate. The average monthly temperature for October 2014 was 18.4°F.

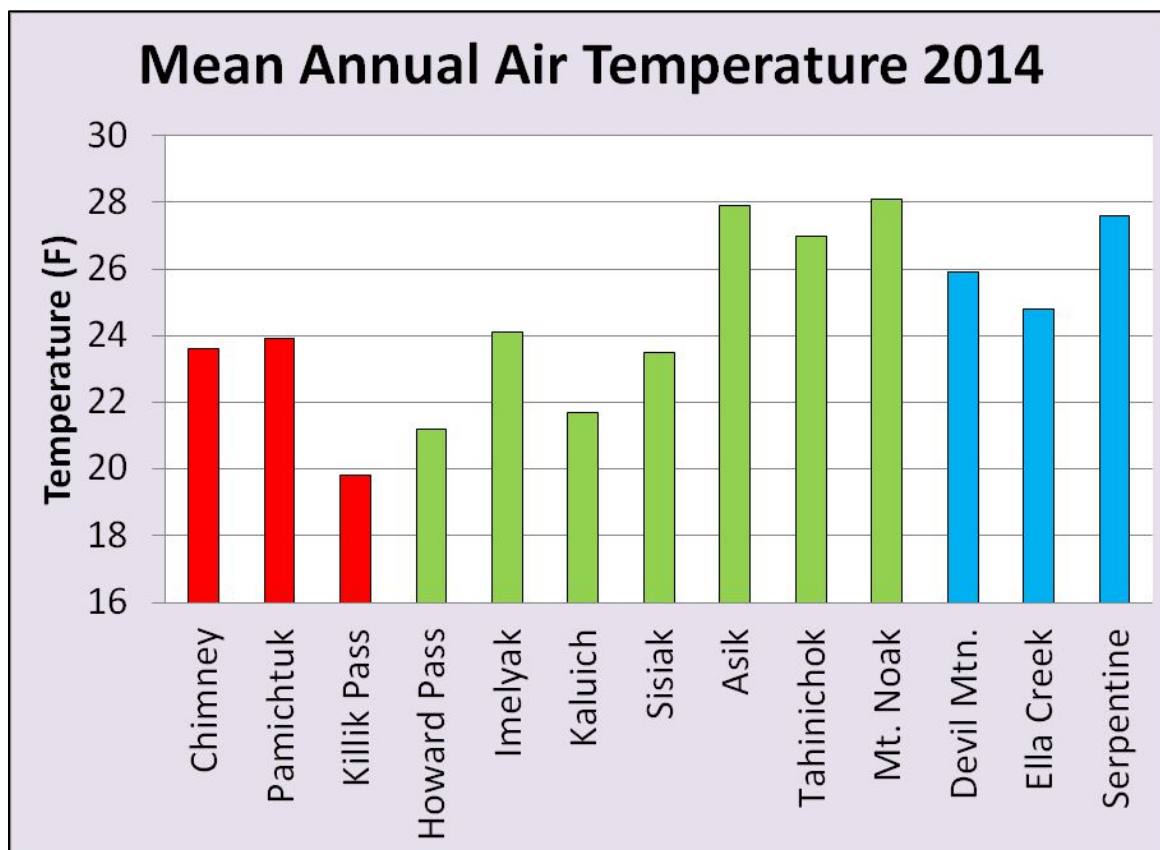


Figure 3. ARCN 2014 mean annual air temperatures. Red sites are GAAR, green Western Arctic Parklands (WEAR), and blue BELA.

Summer Precipitation

ARNC stations measure rainfall with a standard tipping bucket. Due to logistical constraints, ARCN rain gages are currently not shielded from wind and therefore measurements may underestimate precipitation at exposed locations. NRCS SNOTEL sites in or near the park boundaries provide a

robust precipitation measurement in both summer and winter for comparison with ARCN stations. Table 3 summarizes summer rainfall measurements at ARCN and SNOTEL stations.

Table 3. Rainfall (inches) from ARCN and SNOTEL stations in 2014^{1, 2}.

Station Name	Station Type	June	July	August	September	Summer (June-August)
Asik	ARCEN	1.0	4.2	3.2	2.8	8.4
Chimney Lake	ARCEN	3.4	5.9	2.6	1.2	11.9
Devil Mtn.	ARCEN	0.5	3.1	0.6	2.0	4.2
Ella Creek	ARCEN	0.3	4.7	3.8	2.8	8.8
Howard Pass	ARCEN	1.3	2.8	1.2	1.0	5.3
Imelyak	ARCEN	2.5	8.2	2.8	1.0	13.5
Kaluich	ARCEN	2.1	2.8	2.7	1.4	7.6
Killik Pass	ARCEN	2.0	3.0	0.9	0.5	5.9
Kugururok*	ARCEN	–	–	1.5	1.5	M
Mt. Noak	ARCEN	M	M	1.6	3.4	M
Pamichtuk Lake	ARCEN	3.0	3.3	1.3	1.3	7.6
Ram Creek	ARCEN	M	1.9	2.2	0.9	M
Salmon River	ARCEN	M	M	1.4	1.8	M
Serpentine	ARCEN	0.1	3.2	1.6	2.4	4.9
Sisiak	ARCEN	1.7	3.1	0.8	1.2	5.6
Tahinichok	ARCEN	M	M	1.5	3.8	M
Atigun Pass	SNOTEL	5.4	6.7	4.0	2.3	16.1
Coldfoot	SNOTEL	2.9	6.4	3.4	2.8	12.7
Kelly Station	SNOTEL	1.0	2.3	1.3	3.0	4.6
Pargon Creek	SNOTEL	0.6	4.0	2.3	0.7	6.9

¹ Please note that the monthly values for individual sites may differ from those in the seasonal weather summaries; real-time transmitted data are used to generate the seasonal summaries, which may have some data gaps.

²M=Missing due to wildlife damage. *Kugururok station installed July 2014.

Summer (June-August) rainfall measurements were highly variable in 2014 and ranged from 4.2 inches at Devil Mountain to 16.1 inches at Atigun Pass (Table 3, Figure 4). The highest monthly total was 8.2 inches recorded at Imelyak in July. Over four inches fell from July 12 to 14. Localized (convective) summer rain showers are common in mountainous regions and likely explain the high degree of spatial and temporal variability. July was the rainiest month at all stations with over three inches recorded at most sites. In summer 2014, rainfall decreased from east to west at stations in or near GAAR with over 16 inches at Atigun Pass and less than six inches at Killik Pass. In WEAR and BELA, the highest-elevation sites (Imelyak 13.5 inches, Ella Creek 8.8 inches) recorded the most rainfall and the lowest-elevation sites (Kelly 3.0 inches, Devil Mtn. 4.2 inches) recorded the least rainfall. A longer period of record is necessary to determine if these regional patterns in ARCN are typical over a longer timescale.

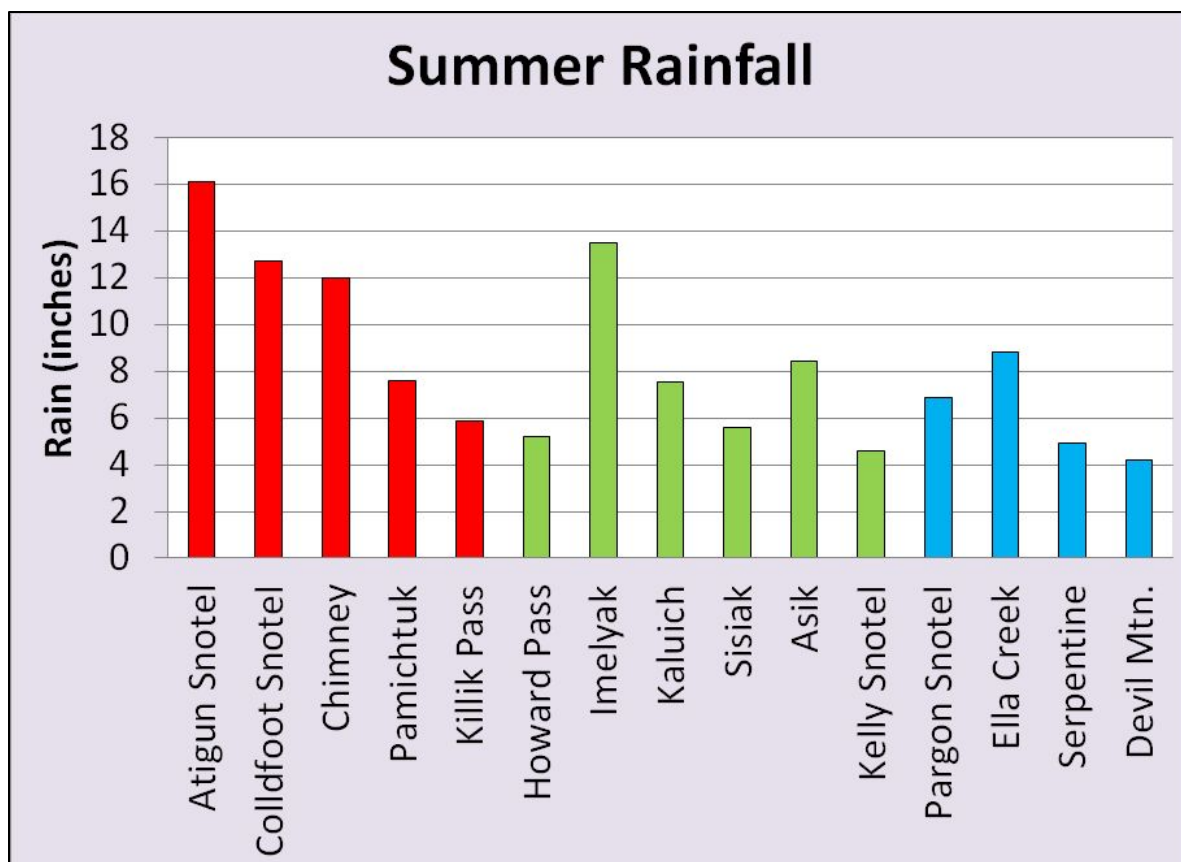


Figure 4. ARCN summer precipitation. Red sites are in or near GAAR, green WEAR, and blue BELA.

Snow and Precipitation (2013-2014 Season)

SNOTEL Sites

Year-round precipitation is recorded at the SNOTEL at Coldfoot, Atigun Pass, Kelly Station, and Pargon Creek (Table 4). Kelly Station is the only site located within NPS boundaries. The Coldfoot station is located along the Dalton Highway south of the Brooks Range at 1,040 feet and Atigun Pass is located at 4,800 feet where the Dalton Highway passes through the Brooks Range (Figure 1). Kelly Station is located on the Noatak River approximately 75 miles upriver from Kotzebue. Pargon Creek is located on the Seward Peninsula, southeast of Bering Land Bridge National Preserve. The SNOTEL sites provide an accurate representation of winter snow water equivalent at remote sites as well as summer rainfall. The data from these sites are based on the water year from October 1 through September 30.

For water year 2014, the Coldfoot SNOTEL site recorded 8.9 inches of total winter precipitation (snow water equivalent, SWE) from October 1, 2013 through May 1, 2014, which is 122% of the 1981-2010 normal. The total annual precipitation for the site was 23.4 inches; the winter snow accounted for 38% of the total annual precipitation. The period of continuous snow was from September 23 to May 14. Peak snow depth was 30 inches on April 13 with a SWE of 7.6 inches of water. Peak SWE occurred near the same time with 7.7 inches on April 17 (Figure 5).

Table 4. Precipitation and snow summary statistics for SNOTEL stations in 2014¹.

Site	Winter Precip. ² (normal)	Annual Precip. (normal)	Peak Spring Snow Depth Inches (Date)	Peak SWE ³ Inches (Date)	Snow On	Snow Off
Coldfoot	8.9 (122%)	23.4 (144%)	30 (Apr. 13)	7.7 (April 17)	9/23/13	5/14/14
Atigun Pass	5.4 (81%)	24.3 (120%)	42 (May 29)	--	8/20/13	6/24/14
Kelly Station	8.9 () ⁴	16.3 () ⁴	21 (April 14)	4.8 (April 16)	11/9/13	5/4/14
Pargon Creek	9.2 (137%)	17.3 (149%)	9 (Mar. 21)	--	1/7/14	4/21/14

¹Standard procedure for NRCS sites is to summarize by water year (October 1- September 30).

²The winter season is defined as October 1 - May 1.

³Snow water equivalent (SWE) is not measured at Atigun Pass or Pargon Creek.

⁴1981-2010 normals are not calculated at Kelly Station due to the short duration of the record.

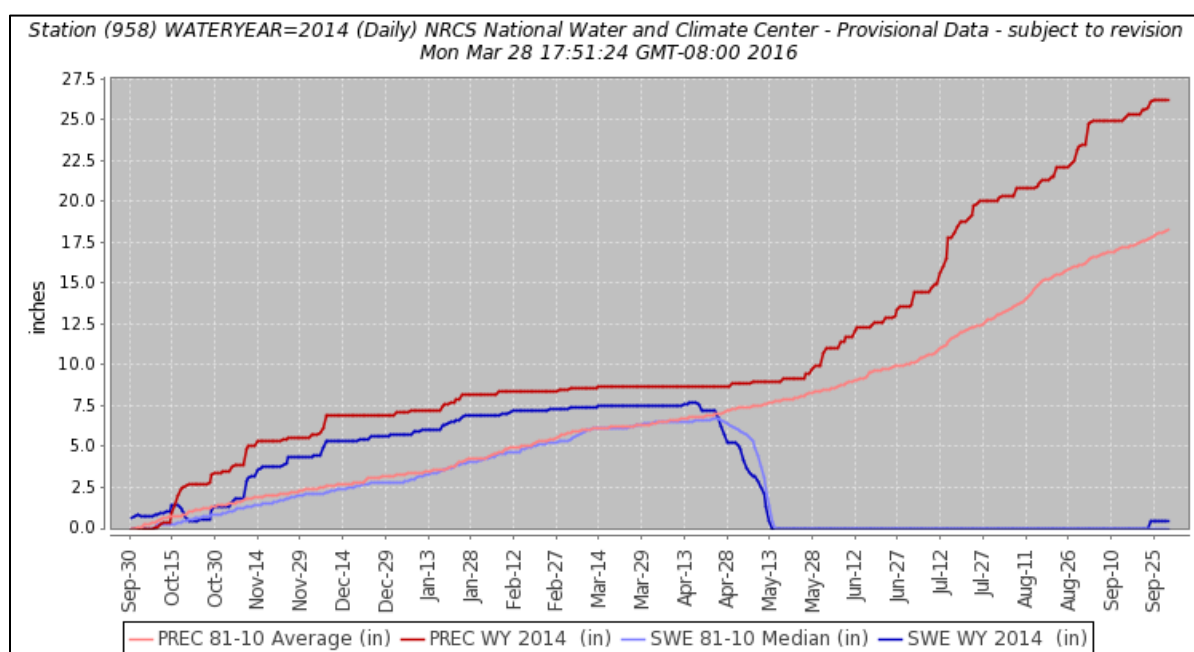


Figure 5. Cumulative precipitation and SWE for water year 2014 (October1, 2013 – September 30, 2014) at Coldfoot. Graph generated from NRCS (NRCS 2014b).

The precipitation gage at Atigun Pass recorded 5.4 inches of precipitation from October 1, 2013 through May 1, 2014. This is only 22% of the total annual precipitation (24.3 inches) for the 2014 water year. The annual precipitation was 120% of normal due to a wetter than normal summer season. The period of continuous snow at Atigun Pass was more than 10 months long, starting on August 20 and persisting through June 24 (Figure 6).

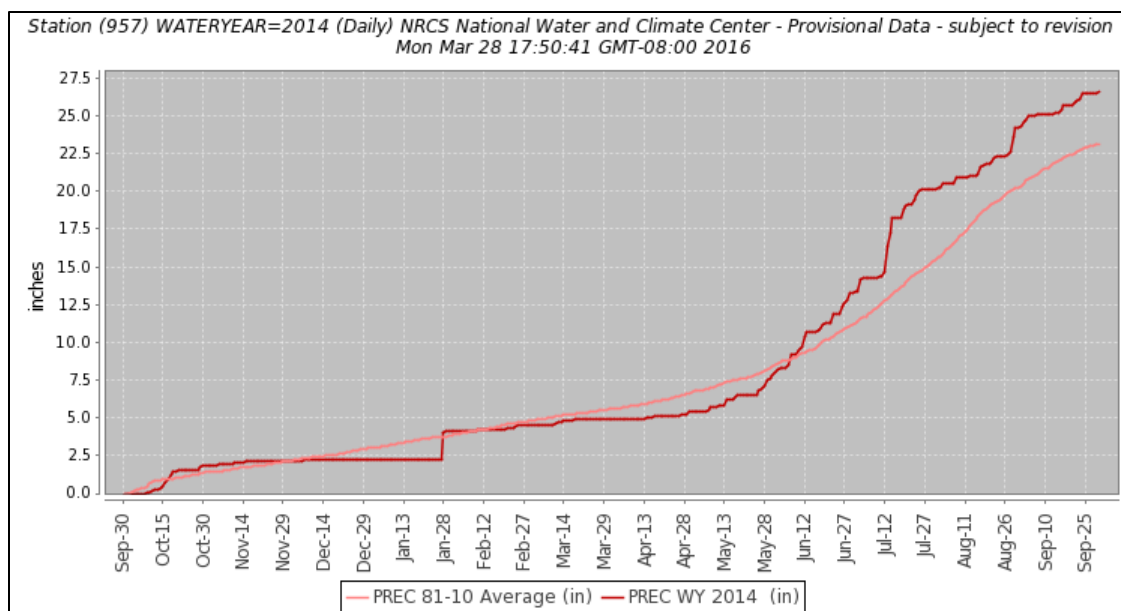


Figure 6. Cumulative precipitation for water year 2014 (October 1, 2013 - September 30, 2014) at Atigun Pass. Graph generated from NRCS (NRCS 2014b).

Kelly Station was the driest of the four SNOTEL sites analyzed with 8.9 inches of winter precipitation in the 2014 water year, about 55% of the annual total (16.3 inches). Snow depth reached its maximum of 21 inches on April 14 with a peak water content of 4.8 inches. Snow cover persisted at Kelly from November 9 to May 4 (Figure 7).

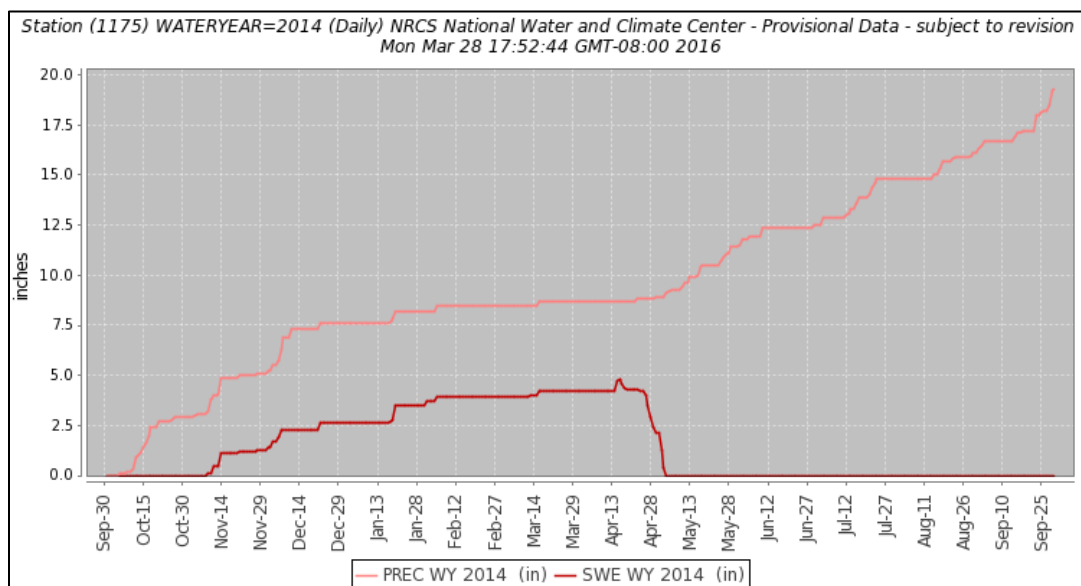


Figure 7. Cumulative precipitation and SWE for water year 2014 (October 1, 2013 - September 30, 2014) at Kelly Station. Graph generated from NRCS (NRCS 2014b).

Pargon Creek received 9.2 inches of winter precipitation and 17.3 inches of annual precipitation. Peak snow depth was much shallower and earlier than other sites with 9 inches on March 21. Continuous snow cover was not established until January 7. Melt-out also occurred earliest at Pargon Creek, on April 21 (Figure 8).

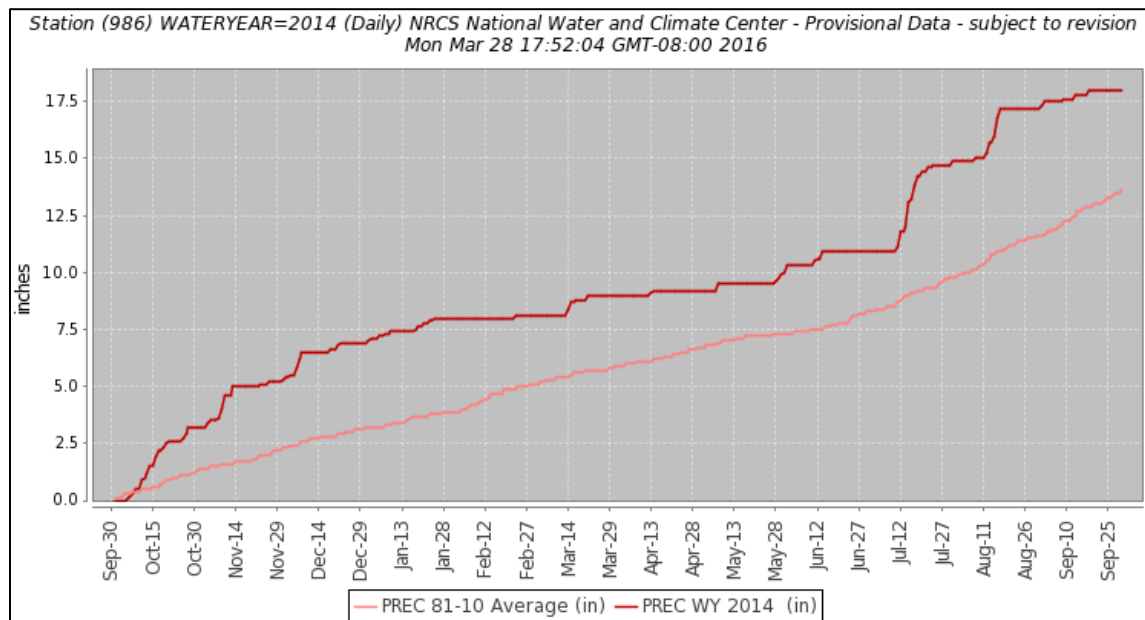


Figure 8. Cumulative precipitation for water year 2014 (October 1, 2013 - September 30, 2014) at Pargon Creek. Graph generated from NRCS (NRCS 2014b).

Remote Sensing of Snow Cover

Swanson (2014) analyzed seasonal snow cover in ARCN using MODIS satellite data for the 2000-2013 time period. Compared to normal, the end of the continuous snow season (CSS) in ARCN varied across space. The end of CSS in ARCN was later than normal in higher elevations of the Brooks Range. However, melt-out in western NOAT, CAKR, and BELA occurred two weeks earlier than normal in many locations, with snow disappearing before May 1 (Figure 9).

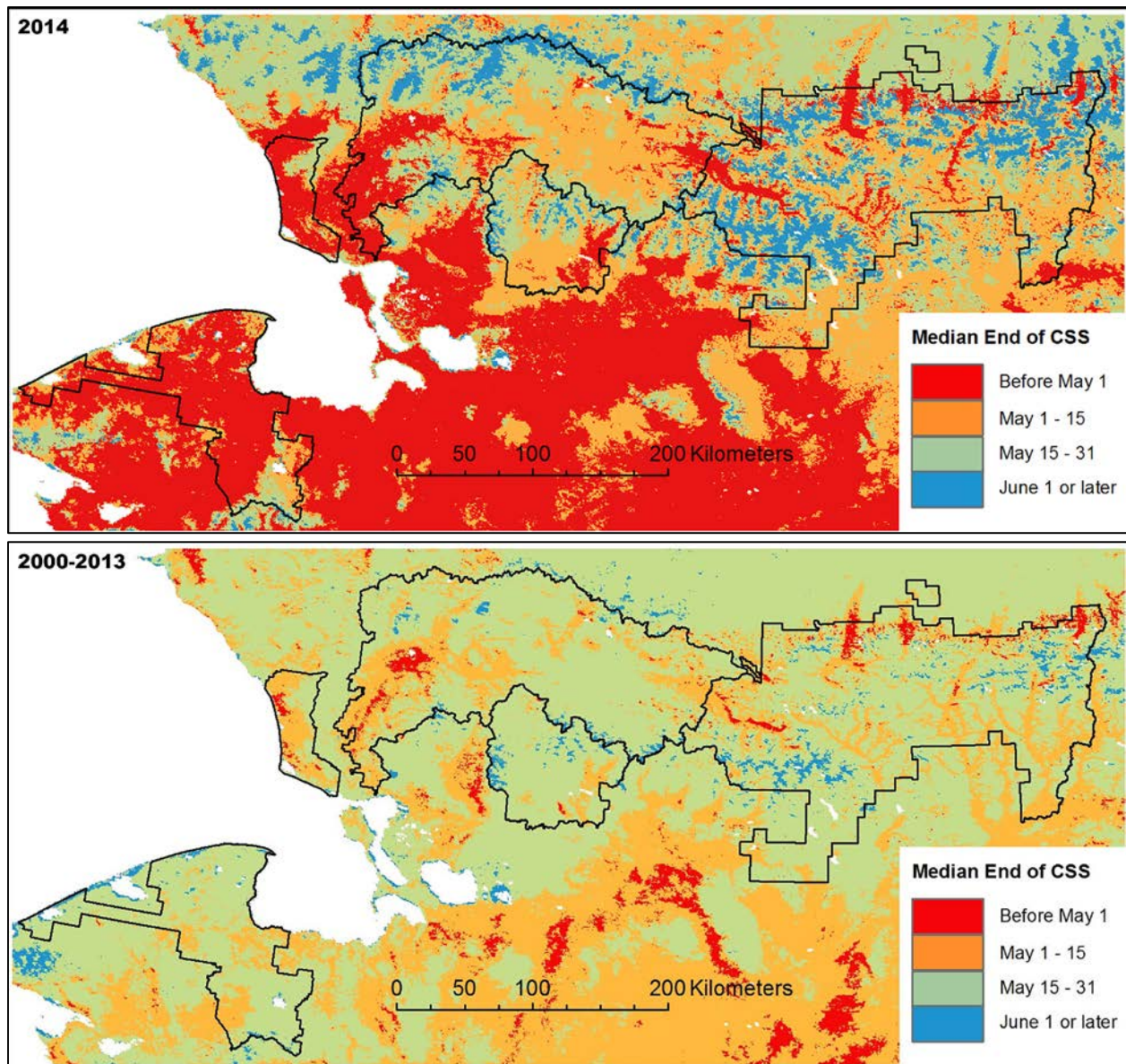


Figure 9. Maps of ARC showing the dates of the end of the continuous snow season (CSS) in 2014 (top) and the median date for the 2000-2013 time periods (bottom). Figures based on Swanson (2014).

Index Sites (Bettles, Kotzebue, Nome)

Temperature

Bettles, Kotzebue, and Nome had mean annual air temperatures well above the long-term normal for 2014 (Table 5). The mean annual air temperatures of 28.4°F in Kotzebue and 31.6°F in Nome were the warmest years on record. In Bettles, 2014 was the 5th warmest year on record. Temperatures were variable across index sites from month to month, but the positive temperature departures in January and November, and cooler than normal temperatures in June and July, stand out across the region (Table 5, Figures 10-13).

Table 5. 2014 monthly mean temperature and departures from 1981-2010 normal (parentheses) for index sites in ARCN (°F).

Station Name	Station ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Bettles	500761	3.5	-5.8	8.7	24.0	43.5	53.9	55.9	54.3	40.4	21.6	6.5	3.8	25.9
		(+13.5)	(-0.8)	(+4.3)	(+0.7)	(-0.9)	(-4.6)	(-3.8)	(+1.8)	(-0.2)	(+2.7)	(+7.5)	(+9.5)	(+2.5)
Kotzebue	505076	14.3	5.3	7.8	22.0	36.2	44.2	53.6	58.4	45.7	26.7	19.3	7.8	28.4
		(+17.1)	(+6.1)	(+6.7)	(+8.7)	(+4.3)	(-1.5)	(-1.0)	(+6.7)	(+3.4)	(+2.4)	(+10.2)	(+5.5)	(+5.7)
Nome	506496	21.3	13.6	12.3	28.4	35.1	45.8	51.1	55.7	45.3	29.1	26.2	15.6	31.6
		(+16.1)	(+6.2)	(+2.0)	(+7.9)	(-1.7)	(-2.0)	(-1.1)	(+5.6)	(+2.5)	(+0.4)	(+9.3)	(+6.1)	(+4.3)

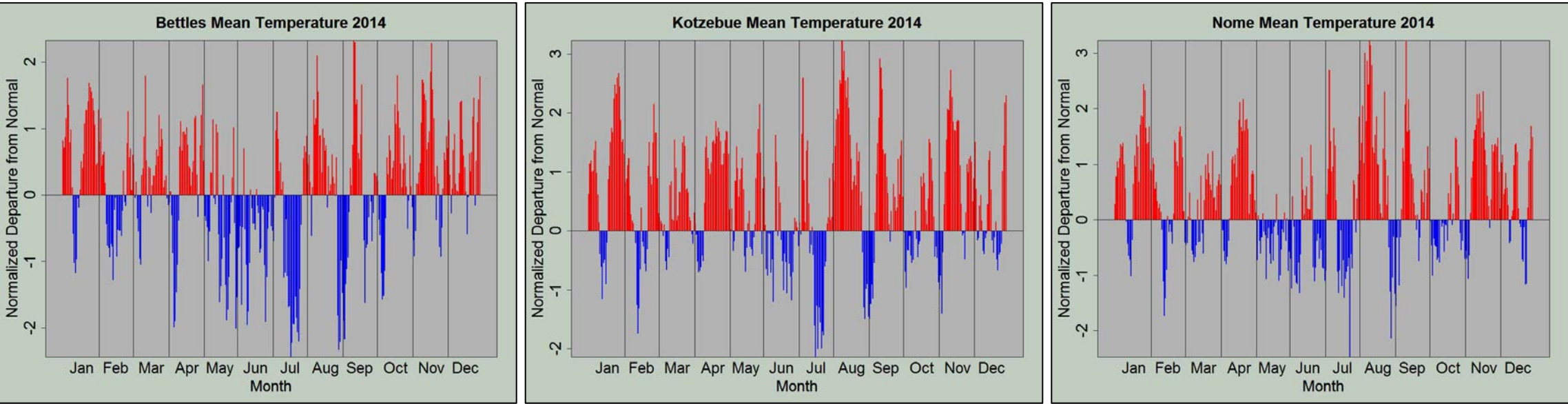


Figure 10. Standardized anomaly time series plots for Bettles, Kotzebue, and Nome. Daily departures from normal were calculated by $Departure\ from\ Normal = \frac{T_{obs} - T_{mean}}{SD}$ where T_{obs} = observed daily mean temperature, T_{mean} = mean daily temperature for 1981-2010 normal period, and SD = standard deviation of observations.

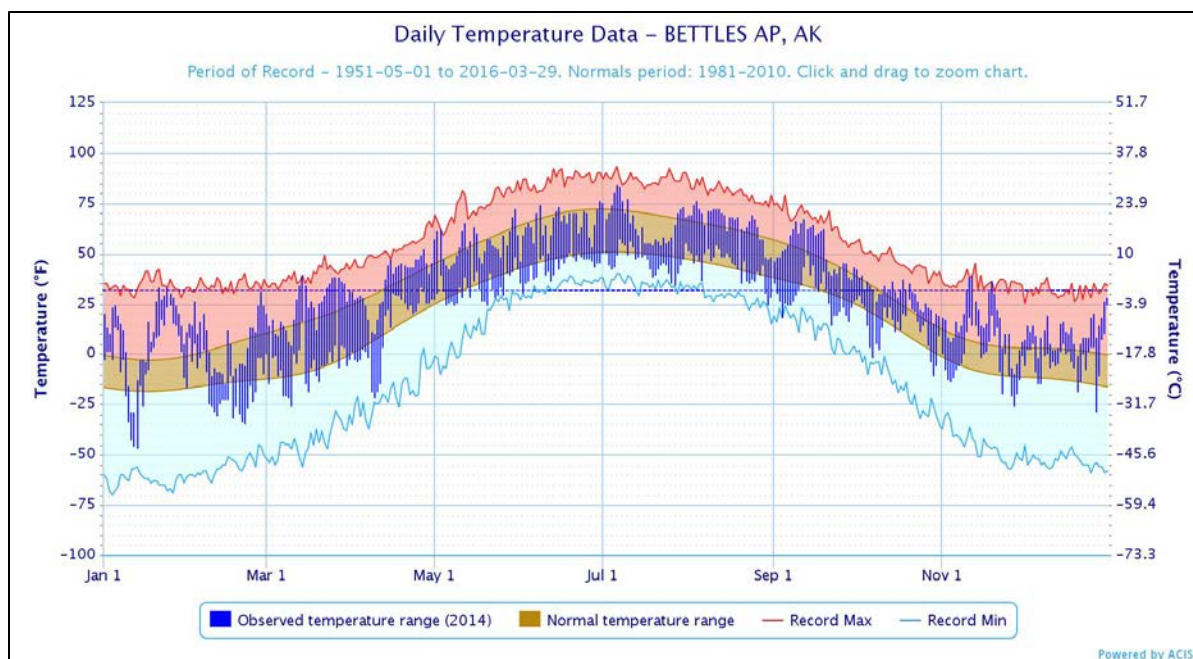


Figure 11. Bettles daily temperature time series. The normal temperature range is shown in brown, record high temperatures outlined in red, and record minimums in light blue. 2014 observed temperatures are shown in dark blue. Figure generated from the NOAA xMACIS system at xmacis.rcc-acis.org.

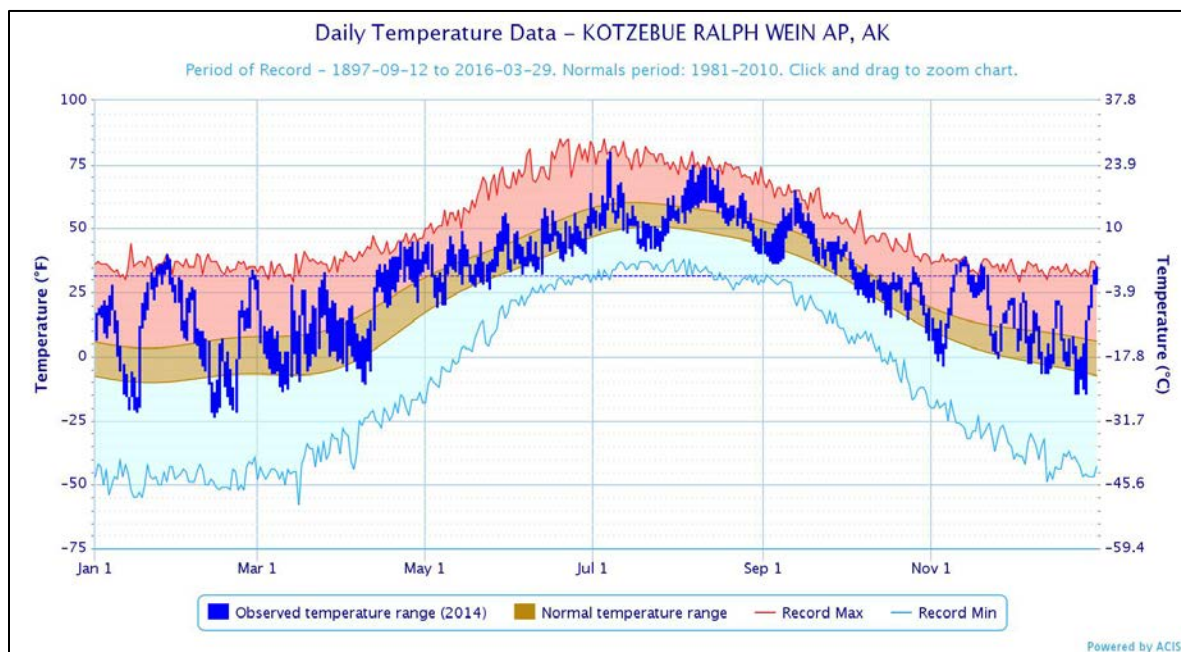


Figure 12. Kotzebue daily temperature time series. The normal temperature range is shown in brown, record high temperatures outlined in red, and record minimums in light blue. 2014 observed temperatures are shown in dark blue. Figure generated from the NOAA xMACIS system at xmacis.rcc-acis.org.

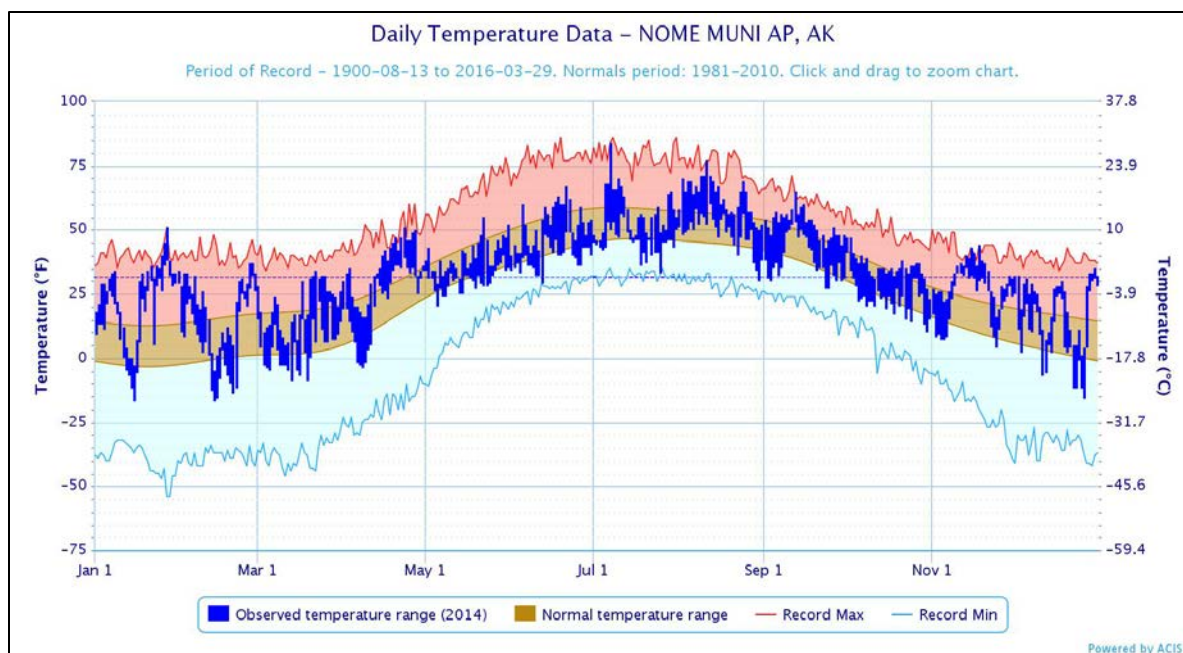


Figure 13. Nome daily temperature time series. The normal temperature range is shown in brown, record high temperatures outlined in red, and record minimums in light blue. 2014 observed temperatures are shown in dark blue. Figure generated from the NOAA xmACIS system at xmacis.rcc-acis.org.

The calendar year started with warm temperatures; January was warmer than normal at each index site in the network. January temperatures on average were an astonishing 15.6°F warmer than normal among the three index sites. A persistent high pressure system in late January produced record setting temperatures across the region. February was colder than normal in Bettles, but warmer than average in Kotzebue and Nome.

Warm temperatures persisted into March and April, with the strongest warm anomalies continuing on the western coast sites of Nome and Kotzebue. In May, Bettles and Nome were near normal, but Kotzebue remained well above normal. It was the 4th warmest spring on record in Kotzebue.

Overall, the average summer season (June-August) temperature was cooler than normal at Bettles (2.2°F), and warmer than normal in Kotzebue (+1.4°F), and Nome (+0.8°F). It was the 4th coldest June on record in Bettles. Kotzebue and Nome were also below normal for the month. The cool pattern continued into July for all three sites, with an average temperature anomaly of -2.0°F for the three index sites. Warmer than normal temperatures returned in August, most notably at Kotzebue (+6.7°F) and Nome (+5.6°F).

September was near normal at Bettles, and warmer than normal in Kotzebue and Nome. The average monthly temperature was 40.4°F in Bettles, 45.7°F in Kotzebue, and 45.3°F in Nome. October was warmer than average at all three index sites. November was exceptionally warm in Kotzebue and Nome, the second warmest November on record for both locations. Warm temperatures continued into December with anomalies of +9.5°F, +5.5°F, and +6.1°F at Bettles, Kotzebue, and Nome respectively.

Precipitation

Annual precipitation totals at the ARCN index sites varied from 85% of normal in Nome to 117% of normal at Bettles (Table 6). January was a particularly wet month at both Bettles (190%), and Nome (167%). Warm, moist air was transported by the jet stream into the region in late January.

Precipitation was below normal at all sites for February through April (Figure 14). May was near normal at Bettles with 0.83 inches of precipitation. At the coastal index sites however, May precipitation was well above normal with 0.99 inches in Kotzebue and 1.32 inches in Nome.

June and July were very wet at Bettles with 3.54 inches and 5.18 inches of rain respectively. The combined June-July total of 8.54 inches broke the old record of 7.05 inches set in 1963. In contrast, Kotzebue (0.38 inches) and Nome (0.22 inches) were both well below normal for precipitation in June. Measureable precipitation was only measured on five days in Nome in June. July was wet at the coastal sites, but August was drier than normal. Overall, Kotzebue was 106% of normal for the summer season (June-August) and Nome was 72% of normal.

Overall, all three index sites were below normal for fall (September-November) precipitation. At Bettles, October (0.39 inches; 38%) and November (0.23 inches; 25%) were particularly dry. Kotzebue was similarly dry with 0.43 inches in October and 0.28 inches in November. October was also dry in Nome, 39% of normal. Unlike the other index sites, however, November precipitation at Nome was above normal, with 1.44 inches recorded.

Table 6. Monthly and annual precipitation (inches) and departures from normal (%) for 2014.

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Bettles	1.54 (190%)	0.29 (34%)	0.12 (21%)	0.38 (63%)	0.85 (97%)	3.54 (253%)	5.18 (219%)	2.00 (76%)	1.34 (70%)	0.39 (38%)	0.23 (25%)	1.59 (173%)	17.45 (117%)
Kotzebue	0.55 (89%)	0.17 (26%)	0.34 (77%)	0.21 (39%)	0.99 (241%)	0.38 (66%)	2.59 (179%)	1.51 (69%)	1.81 (115%)	0.43 (43%)	0.28 (36%)	0.35 (46%)	9.61 (87%)
Nome	1.57 (167%)	0.60 (65%)	0.53 (82%)	0.45 (59%)	1.32 (153%)	0.22 (22%)	2.62 (124%)	1.71 (53%)	2.58 (105%)	0.63 (39%)	1.44 (118%)	0.54 (50%)	14.21 (85%)

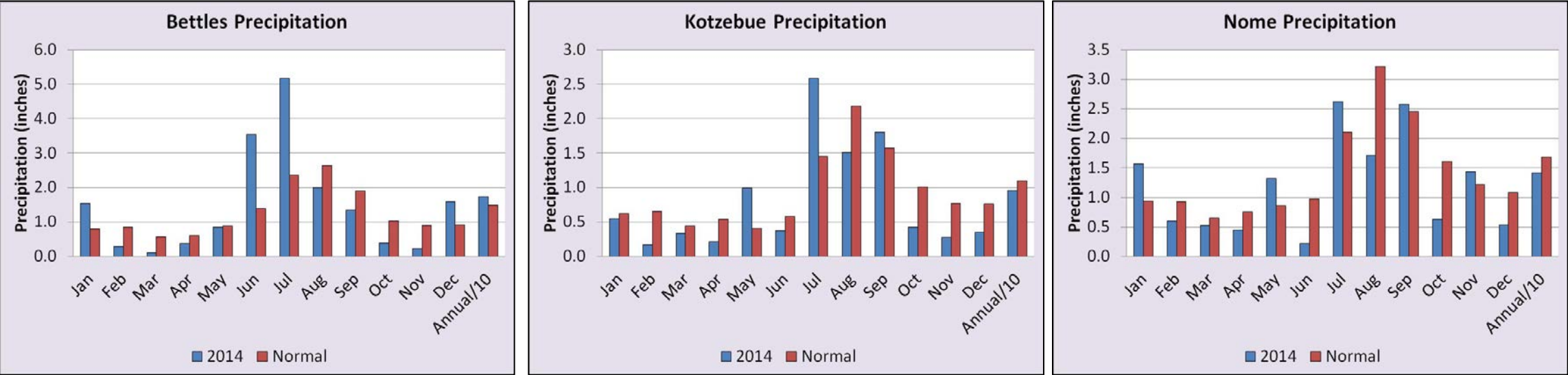


Figure 14. Monthly precipitation totals - departure from normal for 2014.

Snow

For the 2013-2014 snow season (standard time period is August-July for NWS stations) total annual snowfall ranged from 31.7 inches in Kotzebue to 87.5 inches in Bettles (Table 7). Over three feet of snow fell in Bettles in November, more than 225% of normal. It was by far the snowiest month of the snow season. Besides a few storms in early January, the rest of the snow season in Bettles was below normal.

In Kotzebue, The 2013-2014 snowfall was 31.7 inches, which is 54% of normal. Almost all precipitation in October came as rain, rather than snow; only two years on record had less October snowfall. November was near normal, but December through February only totaled 13.3 inches; normal is 30.2 inches.

Total snowfall in Nome was 71.2 inches for the season, 95% of normal. Similar to Kotzebue, October snowfall was well below normal due to warm temperatures. December was the snowiest month in Nome with 18.4 inches which is 121% of normal. March snowfall was above normal with 12.3 inches.

Table 7. Monthly and annual snowfall (inches) and departures from normal (inches) August 2013 - July 2014.

Station Name	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Year
Bettles	0 (0.0)	6.9 (+4.4)	12.4 (0.0)	37.8 (+21.7)	5.4 (-10.2)	23 (+9.1)	4.8 (-9.2)	2.3 (-7.0)	1.6 (-14.7)	0.2 (-1.1)	0 (0.0)	0 (0.0)	87.5 (-11.4)
Kotzebue	0 (0.0)	0.4 (-0.4)	0.5 (-5.6)	10.7 (+0.2)	7.2 (-4.3)	4.9 (-4.2)	1.2 (-8.4)	6.8 (+0.9)	0.4 (-4.7)	0 (-1.2)	0 (0.0)	0 (0.0)	31.7 (-27.3)
Nome	0 (0.0)	1.1 (+0.5)	0.5 (-4.1)	13 (+0.9)	18.4 (+3.9)	12.2 (-0.5)	9.1 (-3.1)	12.3 (+3.4)	3.1 (-4.4)	2.6 (+0.3)	0 (-0.3)	0 (0.0)	71.2 (-3.9)

Alaska Statewide

Temperature

According to the National Climatic Data Center's (NCDC) State of the Climate Report for 2014 (NOAA 2014a), the average annual temperature for Alaska was 4.0°F above the 1971-2000 average making 2014 the warmest year on record (Figure 15). The average annual temperature deviations for the twenty First Order (professionally maintained by the National Weather Service) stations in Alaska are shown in Figure 15. Based on the mean monthly temperature departures from normal, the warmest months of 2014, in decreasing order, were January (+12.8°F), December (+7.5°F), and November (+7.0°F), while June was the coldest month with a mean monthly temperature deviation of -1.3°F (Figure 16).

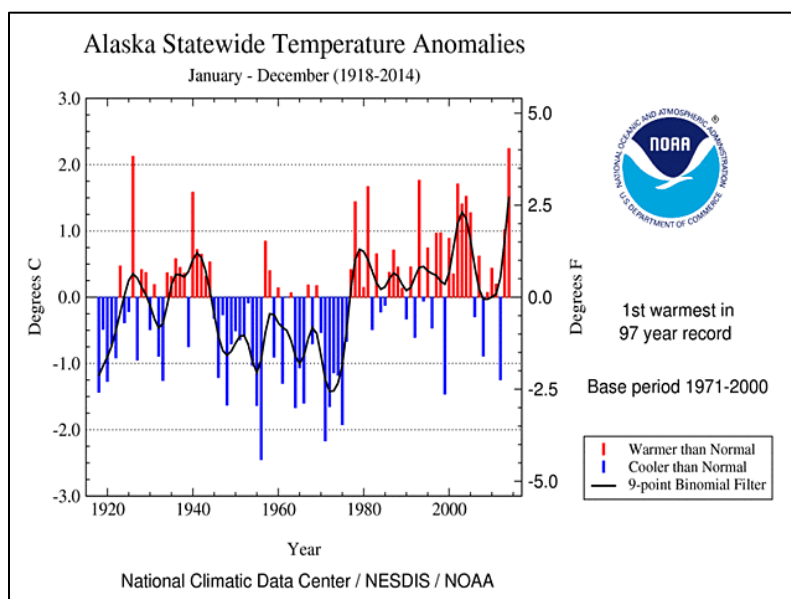


Figure 15. Average temperatures across Alaska in 2014 were 4.0°F above the 1971-2000 mean. Graph courtesy of NOAA (NOAA 2014a).

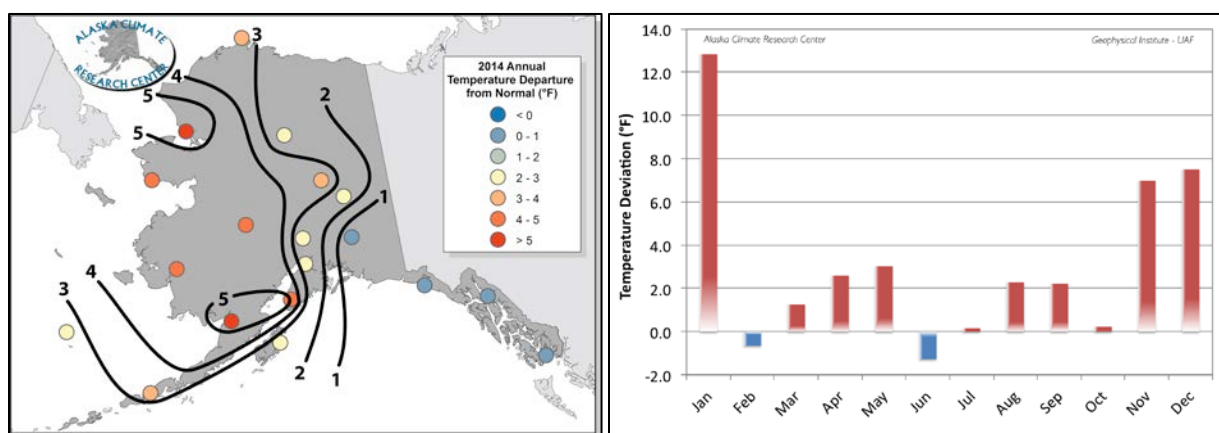


Figure 16. Statewide temperature departures for 2014 (left) and mean monthly temperatures deviation for the 20 First Order stations in Alaska by month for 2014 (right). Graphs courtesy of the Alaska Climate Research Center (ACRC 2014).

Precipitation and Snow

Statewide precipitation was just above average and ranked as the 52nd wettest year on record (Figure 17). January was wet around the state approximately 60% above average. Spring precipitation statewide was approximately 10% below average; the summer of 2014 was the third wettest on record in June and July with record summer rainfall totals for Fairbanks and Juneau. Both the fall season and December were drier than normal at 90% and 81% of normal, respectively (NOAA 2015, Figure 18). Note that the NCDC uses 1971-2000 as the normal base period for Alaska statistics. The snowpack was less than 50% of normal in many locations in the western and southwestern areas of the state, while the interior and the Arctic slope areas had closer to normal snowpack for March diminishing through May1 (Figure 19).

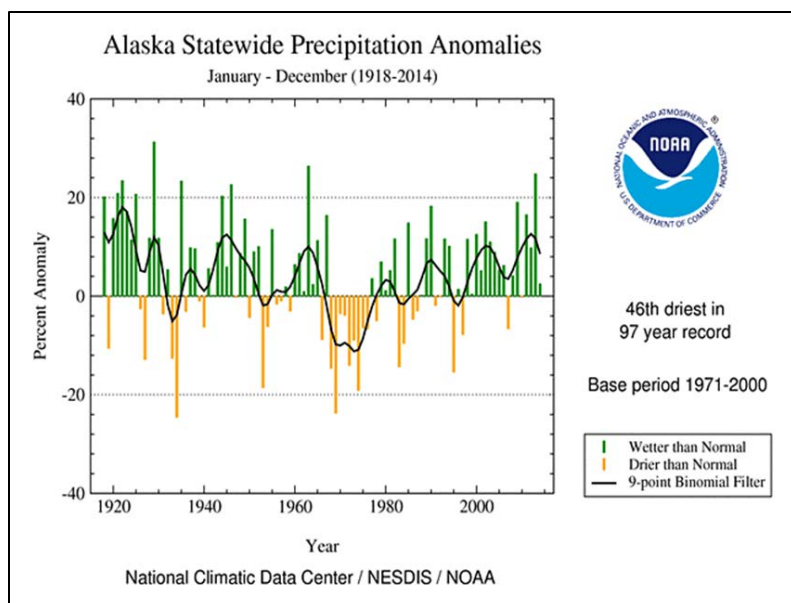


Figure 17. Annual precipitation anomalies 1918-2014. Graph courtesy of NOAA (NOAA 2014a).

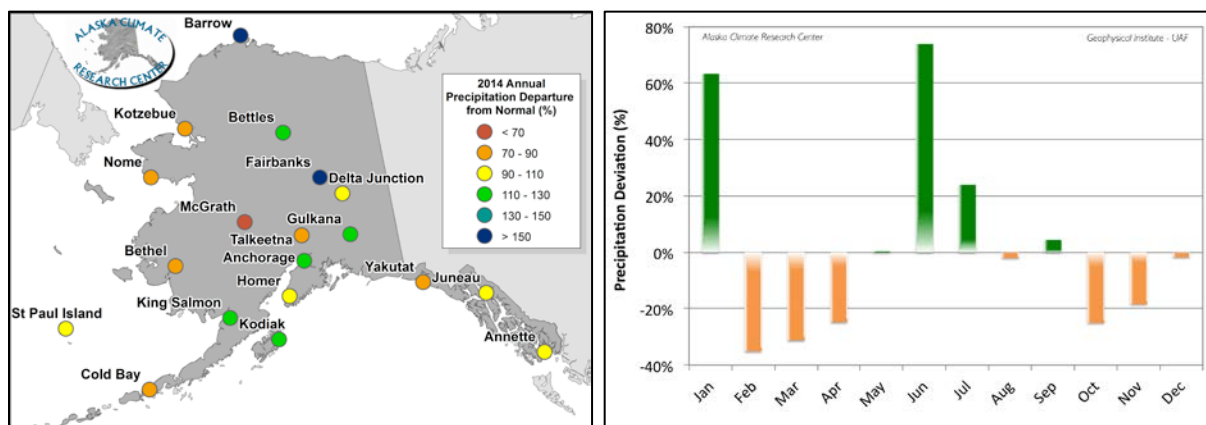


Figure 18. Annual precipitation departures from normal for 2014 (left) and monthly deviations (right) for the 20 First Order climate stations in Alaska. Graphs courtesy of the Alaska Climate Research Center (ACRC 2014).

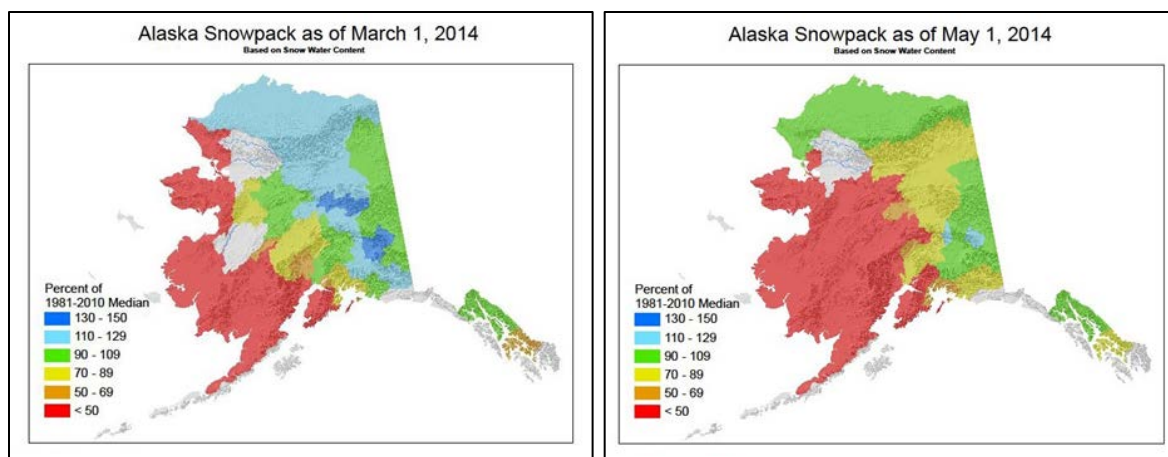


Figure 19. March 1 and May 1 snowpack percent of average for Alaska 2014 (NRCS 2014a).

Fire

The summer of 2014 will go down in history as one of the wettest summers ever recorded in Alaska. Summer (June-August) precipitation totals broke records in both Fairbanks and Juneau. Although the spring was dry and melt out was earlier than normal, the summer rains kept fire starts and spreads to a minimum. Statewide there were a total of 393 wildland fires in 2014, with a total of 233,529 acres burned. Human-caused fires accounted for 339 of the 393 fires. The total area burned in the ARCNP was 752 acres this year from two wildfires in NOAT (AICC 2015).

National and Global Synopsis

Based on data from January through December, the average annual temperature for the contiguous U.S. for 2014 was 52.6°F, 0.5°F above the 20th century average. It was the 34th warmest year over the 120-year record (NOAA 2014a). The temperature trend for the lower 48 states is +0.13°F per decade since records began in 1895. The average precipitation total for the lower 48 states in 2014 was 30.76 inches, 0.82 inches above average, making it the 40th wettest year on record. The precipitation trend for the contiguous U.S. has increased by about 0.14 inches per decade over the past 120 years.

Globally, 2014 was the warmest year on record (Figure 20). Over land and ocean combined, 2014 was 1.2°F above the 20th century average of 57.0°F. Including data from 2014, the Earth is warming at a rate of 0.11°F per decade since 1880 and at a rate of 0.28°F per decade since 1970. Nine out of ten of the warmest years on record have occurred in the 21st century. Precipitation, globally, was near average, but varied from region to region (NOAA 2015c).

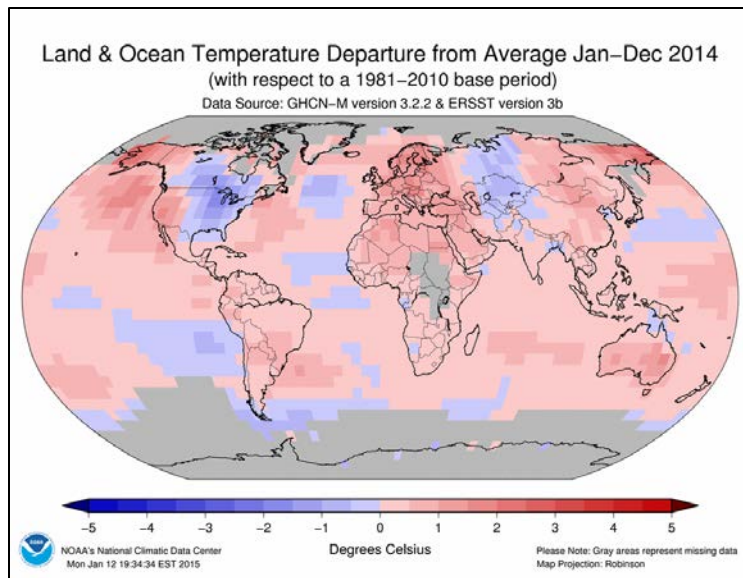


Figure 20. 2014 State of the Climate Land and Ocean Temperature Departures in 2014 compared to the 1981-2010 average. Graph courtesy of NOAA (2014a).

Climate Teleconnections

The El Niño Southern Oscillation index remained in a neutral state during all of 2014. Ocean heat content in the North Pacific did warm from 2013 to 2014, especially south of the Alaska Peninsula. Climatologists are closely watching the Pacific to see if this pattern combined with warming in the equatorial Pacific could indicate a transition toward a positive (warm) phase of the PDO. The PDO index was negative for the first couple months of 2014, positive for the spring period, near neutral during the summer months, and the fall and early winter had the largest positive deviations (NOAA 2015b, Figure 21). The Arctic Sea Ice extent in September 2014 was the sixth lowest extent in the satellite record (NSIDC 2015, Figure 22).

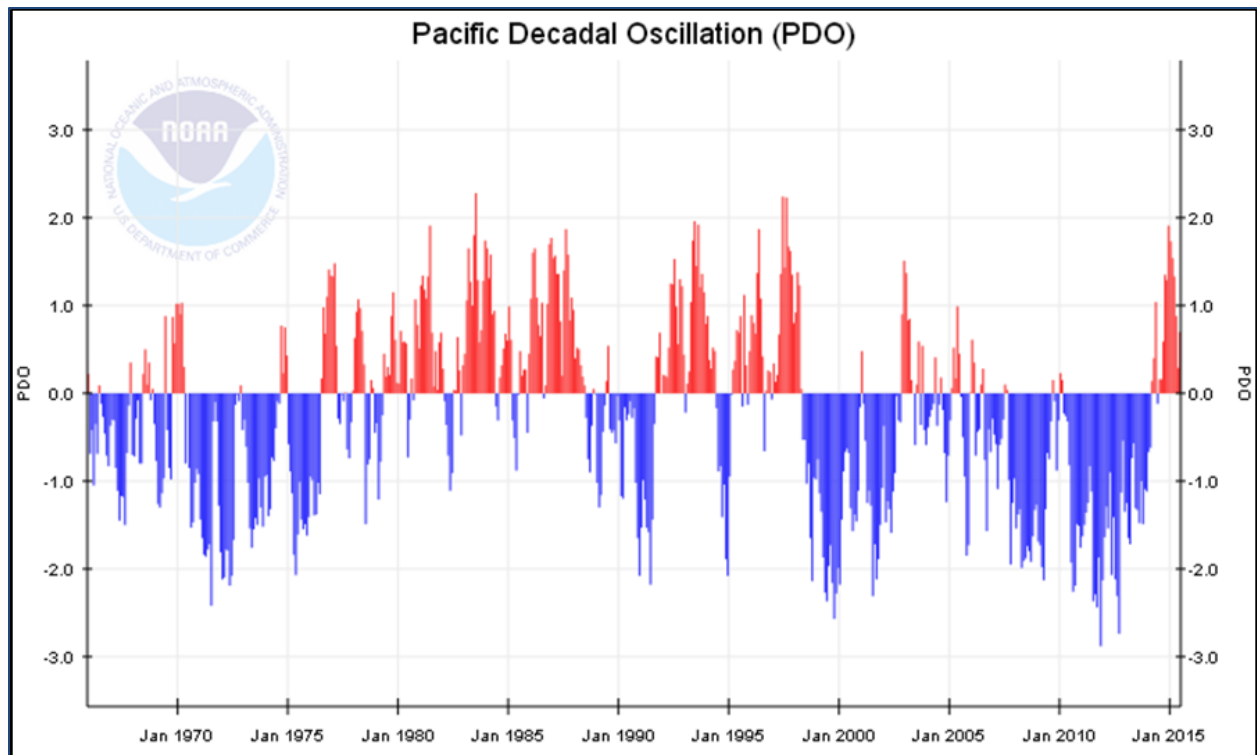


Figure 21. Pacific Decadal Oscillation index based on NOAA's extended reconstruction of SSTs (ERSST Version 3). Graph retrieved from <http://www.ncdc.noaa.gov/teleconnections/pdo.php> (NOAA 2013b).

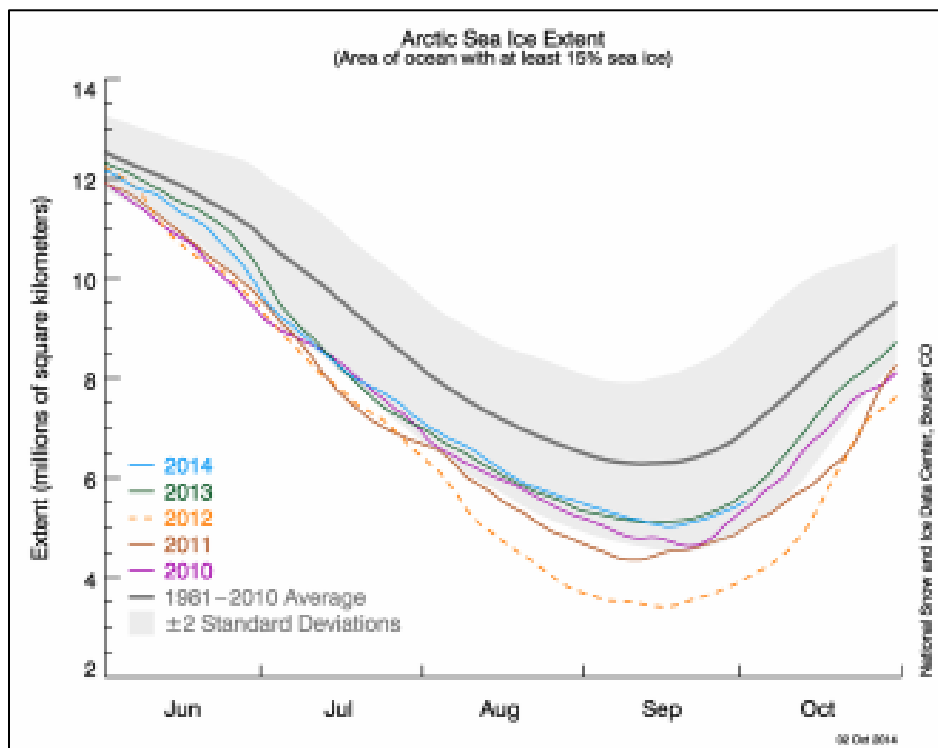


Figure 22. Arctic Sea Ice extent 1979-2014. 2014 was the sixth lowest seasonal minimum extent on record (NSIDC 2015).

Discussion

Status of Climate Monitoring in Network Parks

In an attempt to better understand climate variation as well as long-term changes in park ecosystems, seventeen climate stations have been installed in the five ARCN parks. The objective of the climate monitoring program is to monitor and record weather conditions at representative locations throughout ARCN in order to identify long and short-term trends, provide reliable climate data to other researchers, and to participate in large-scale climate monitoring and modeling efforts beyond park boundaries. A critical element of the program is annual station maintenance. During the 2014 field season, one new I&M climate station was installed at Kugururok and sixteen existing I&M stations were maintained. A summary of all maintenance work is described in detail in a separate report (Hill and Sousanes 2014).

Data Management, Quality Control, and Reporting

The data from NWS index sites are available from the [National Climate Data Center](#). An interagency agreement is in place for the maintenance, data archiving, and data dissemination for the SNOTEL sites in the network. The data from the stations are transmitted hourly and available on-line at the [National Water and Climate Center](#). The ARCN climate stations transmit via satellite and transmitted data are available on the web from [MesoWest](#) and the [Western Regional Climate Center \(WRCC\)](#). Products that are available include daily and monthly summaries, time series graphs, wind rose graphs, data inventories, and station metadata. The raw data are also available for download through the data lister tool on the WRCC website. Additionally transmitted data are utilized by multiple other networks and agencies and displayed in various formats. Because satellite transmissions are not 100% successful, station data are downloaded each year during field visits. Manual QA/QC procedures are performed on each downloaded dataset annually and corrections are compiled and stored in the Aquatic Informatics software. Table 8 summarizes issues affecting data quality at ARCN stations in 2014.

Table 8. Issues affecting data quality at ARCN stations in 2014. Acronyms are as follows: air temperature (AT), rain gage (RG), relative humidity (RH), snow depth (SD), soil temperature (ST), wind speed/wind direction (WS-WD).

Station	Date Begin	Date End	Issue
All stations	1/1/2013	12/31/2013	Erroneous SD values removed.
Asik	7/17/2014	6/6/2015	Solar panel disconnected. Battery not charging.
Chimney Lake	8/28/2013	6/12/2014	ST-10 cm, ST-50 cm sensors damaged.
Chimney Lake	11/21/2014	7/1/2015	RG damaged. Radiation shield damaged for 109 AT sensor.
Devil Mtn.	10/1/2014	6/2/2015	RG out of level at 2015 field visit. Begin date estimated.
Ella Creek	12/31/2014	6/3/2015	Wind sensor damaged.
Ella Creek	9/3/2014	6/3/2015	Radiation shield damaged for HMP-45 AT-RH sensor.
Howard Pass	2/16/2014	7/25/2014	WS-WD sensor damaged.
Howard Pass	12/8/2014	7/20/2015	WS-WD sensor damaged.
Imelyak	5/31/2014	7/25/2014	WS-WD sensor damaged.
Imelyak	7/20/2012	7/25/2014	SD sensor failed.
Kaluich	7/21/2013	7/25/2014	RH sensor failed.
Mt. Noak	7/15/2013	7/15/2014	RG damaged by wildlife.
Mt. Noak	7/9/2013	7/15/2014	RH sensor damaged.
Mt. Noak	6/29/2013	7/15/2014	SD sensor suspect.
Pamichtuk Lake	5/28/2013	6/22/2015	ST-10 cm suspect. Placed at surface.
Ram Creek	8/9/2013	6/10/2014	Station damaged by wildlife. All sensors affected.
Ram Creek	6/10/2014	2/8/2015	SD sensor suspect. Offset incorrect.
Salmon River	8/27/2013	4/6/2014	Transmitted data only. Datalogger failed.
Salmon River	4/6/2014	7/24/2014	Station damaged by wildlife. All sensors affected.
Tahinichok	5/28/2014	7/15/2014	RG, SD out of level. RH sensor damaged.

Significant changes in data archiving, quality control, and reporting methods are expected over time. All NPS Inventory and Monitoring networks monitor climate and a national protocol is being developed to provide guidance for data management and reporting. Currently, cleaned datasets are sent to WRCC for archiving and are also available on request by network staff.

Conclusion

The climate data for 2014 was compiled and summarized using ARCN data from the NPS sites and from index sites around the region. The results presented in this report identify anomalous weather patterns among long-term climate variability. Overall, 2014 was the warmest year on record in Kotzebue and Nome. It ranked as the 5th warmest year in Bettles. The largest monthly warm anomalies were in January and November. Precipitation ranged from 85 to 117% of normal at the three index sites. Bettles and Nome were much wetter than normal in January. The old record of 7.05 inches of rainfall for the June-July period in Bettles was broken with 8.54 inches in 2014. In contrast, Nome and Kotzebue were much drier than normal for June. November was a record-breaking month for snowfall in Bettles, with over 50 inches. Due to a very dry spring, however, annual snowfall ended up below-normal. For the 2013-2014 winter Kotzebue only received about half of the expected total snowfall due to a combination of both warm temperatures and low precipitation.

The 17th ARCN climate station was installed at Kuguruk in 2014 and no additional installations are planned at this time. This young station network is providing key climate and weather information for areas that previously have had little to no observations. Mean annual air temperatures ranged from 19.8°F at Killik Pass to 28.1°F at Mt. Noak. February was the coldest month at most ARCN stations and January was exceptionally warm, consistent with long-term records from Bettles, Kotzebue, and Nome. Summer rainfall measurements were highly variable and ranged from 4.2 inches at Devil Mountain on the Seward Peninsula, to 16.1 inches at Atigun Pass in the Central Brooks Range. Localized convective rain is common throughout the network and likely explains the spatial and temporal variability observed. Data management techniques for climate station observations continue to evolve and improve. The most significant development for the ARCN network is the implementation of quality control procedures within the Aquatic Informatics software.

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