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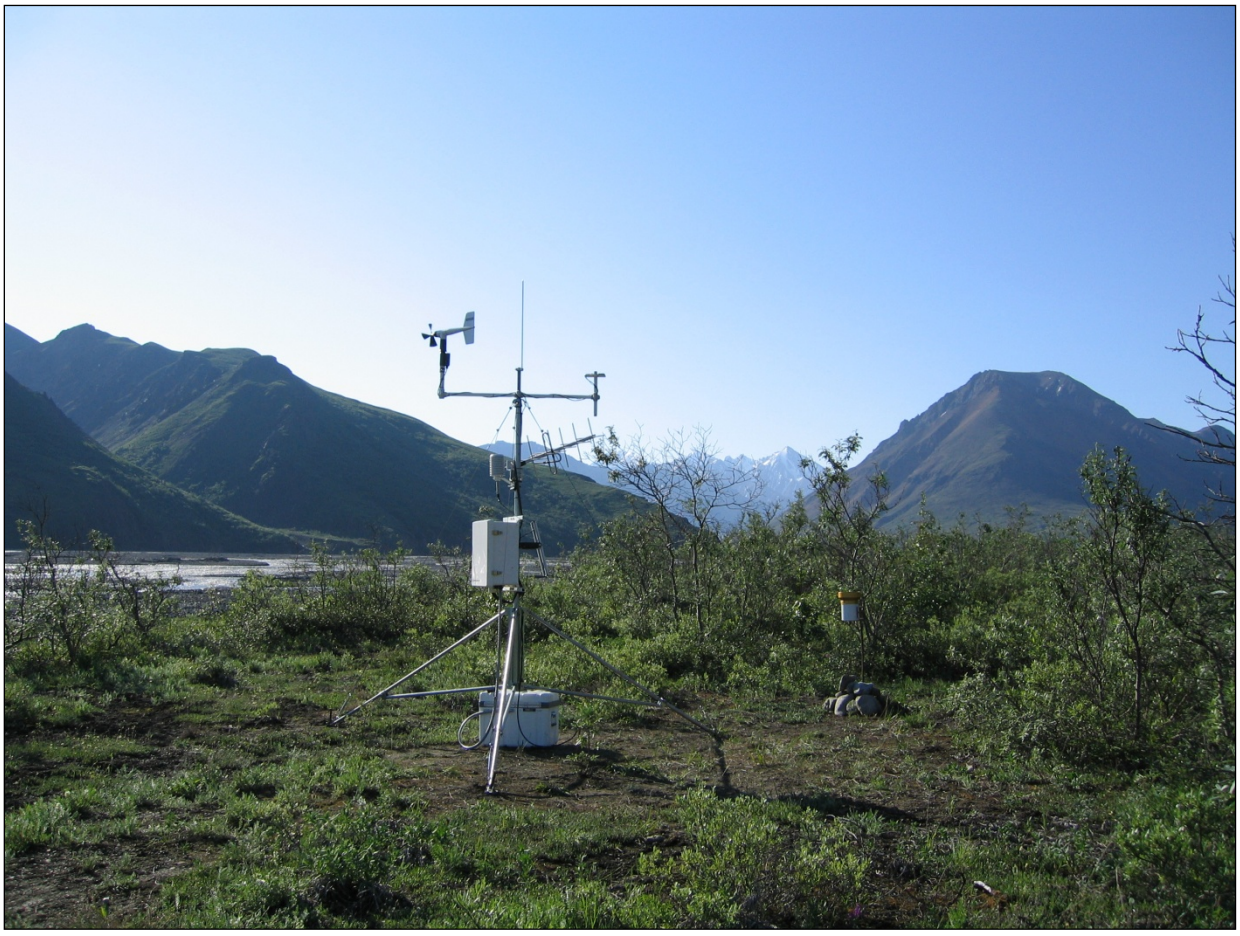
Natural Resource Stewardship and Science

Annual Climate Summary 2011

Central Alaska Network

Natural Resource Data Series NPS/CAKN/NRDS—2013/423



ON THE COVER
Climate station near the Toklat River -Denali National Park and Preserve
Photograph by: NPS Photo by Pam Sousanes

Annual Climate Summary 2011

Central Alaska Network

Natural Resource Data Series NPS/CAKN/NRDS—2013/423

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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 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.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

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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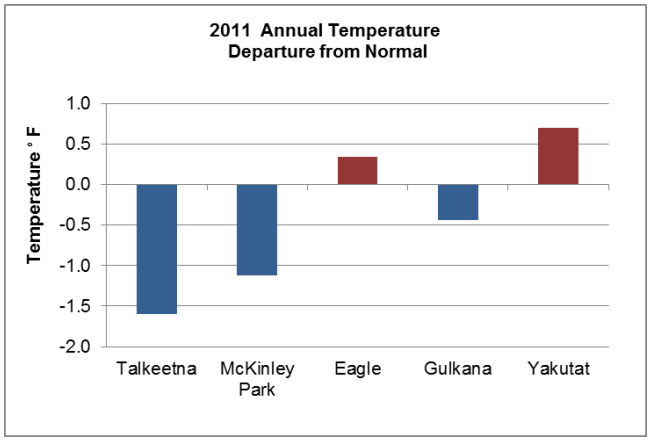
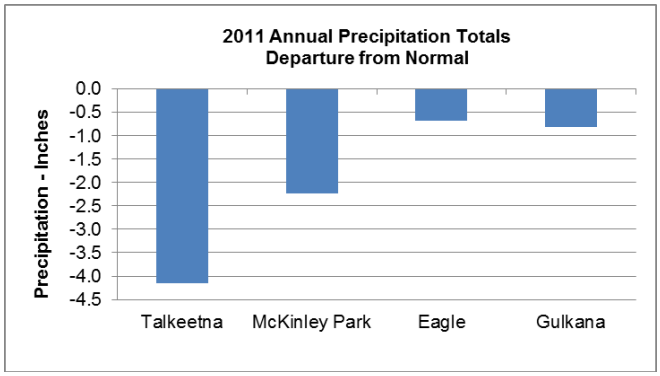
Executive Summary

Using methodologies developed for the Central Alaska Network (CAKN), climate was monitored at existing National Weather Service stations and new CAKN climate stations in and around Denali National Park and Preserve, Wrangell -St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve. A major change occurred in 2011 with the calculation of new "normals". In past reports we have compared current year values with a period of record average for 1971-2000. The National Climatic Data Center updated the new normal period to 1981-2010. A comparison of the two normal periods is included in this report. The 2011 climate statistics are compared with the new normal period.

The CAKN climate records show that on average the Central Alaska region was cooler and drier at most sites compared to normal. The mean annual temperatures at the longer-term sites averaged 0.4 degrees F colder than the 1981-2010 normal. Temperatures were variable across the network from month to month, but the negative temperature departures in March and November stand out; temperatures ranged from 2.3 to 9.9 degrees F below normal in March and from 5.1 to 13.0 degrees F colder than normal in November. Another anomaly occurred in December with monthly average temperatures ranging from 1.0 to 12.5 degrees warmer than the 1981-2010 normal with the strongest departures in the eastern regions of the network. The annual precipitation totals were well below normal at Yakutat. Talkeetna and McKinley Park were 85% of normal and Gulkana and Eagle were just below normal.





Yakutat precipitation is not included due to scaling issues. The 2011 annual total was 121.0 inches, normal is 155.1 inches per year

Introduction

Denali National Park and Preserve, Wrangell–St. Elias National Park and Preserve, and Yukon-Charley Rivers National Preserve make up the Central Alaska Inventory and Monitoring Network (CAKN), covering over 21 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.

The CAKN climate monitoring program deployed sixteen new climate stations between 2003 and 2005, mostly at higher elevations, to capture elevational and latitudinal climate gradients within the parks, and to capture data in areas where there were no baseline references. Climate monitoring protocols for these new stations were developed in 2006 (Sousanes, 2006). The analyses for this annual report are based on the long-term National Weather Service cooperative sites in and around the CAKN parks that have been in operation for 63 to 86 years. The new sites are analyzed for comparison, but long-term trends will take time to develop. This is the seventh in a series of reports for the Central Alaska Network Climate Monitoring Program.

Central Alaska Network Climate Characterization

The central Alaska climate can be characterized by the three major climate regimes that span from the southern boundaries of the network along the coast to the interior. The southern coast of Wrangell-St. Elias is significantly affected by the Gulf of Alaska. The Pacific Ocean moderates the temperature along the coast in both summer and winter, and brings a considerable amount of precipitation to the coastal areas and the southern flanks of the mountain ranges, including the Chugach and St. Elias Ranges that ring the Gulf Coast. Just north of these mountain ranges the precipitation tapers off and seasonal temperatures are more extreme. The winters are cold and the summers can get hot. The CAKN areas farthest north, and the farthest from the coast, are true interior climates characterized by low annual precipitation and large seasonal variation in temperature.

The climate of Alaska is affected by solar radiation, atmospheric gases (volcanic eruptions, CO_2), the water temperature of the Pacific Ocean, and ocean currents. These large scale processes drive changes in atmospheric patterns, like the repositioning of the polar jet stream and the Aleutian low pressure system or the frequency of La Ninas and El Ninos (Papineau, 2003). Each of these can affect the regional patterns of storm tracks, prevailing winds, snowfall amounts, and the extent of sea ice (ACIA, 2005).

There are several large-scale climate patterns and indices that are of particular interest to Alaska, including the Pacific Decadal Oscillation (PDO) which is 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, 2008). The PDO seems 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 has been predominantly negative and air temperatures have been near or below normal – a possible indication of a phase shift from positive to negative. Unfortunately large scale changes such as this take at least a decade 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, 2012). 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 five long-term climate stations with the most complete records nearest the three CAKN parks that represent the major climate regimes in the network (Table 1). These stations have records for a sufficient number of years to compare 2011 data with the latest normal period, 1981-2010. For these sites temperature, precipitation, and snowfall are analyzed. Monthly temperature means and precipitation totals for 2011 are compiled and compared with the new 1981-2010 normal values for each site. A comparison of the normal period values for each of the long term sites is also included in this report, which simply was calculated by subtracting the latest normal period by the previous normal period to find the difference and to determine whether it was a positive or negative departure.

There are fifteen new climate stations (labeled as I&M RAWS) in the three CAKN parks (Figure 1; Table 2). Monthly and annual means and totals were compiled for the newer CAKN stations including, temperature, wind, relative humidity, solar radiation, snow depth, and summer rainfall. Most of the summaries, analyses, charts, and graphs from NOAA and NRCS are in English units; in order to standardize units throughout the report, data are presented in English units. Period of record averages for the long-term sites are available in Appendix A, and extremes and records for these sites are listed in Appendix B.

Table 1. Long-term sites used in CAKN analysis.

Name	Lat	Long	Elev. (ft)	Network	Start	End	Park
Eagle	64.7666	-141.2000	850	COOP	1949	Present	YUCH
McKinley Park	63.7195	-148.9656	2060	COOP	1925	Present	DENA
Talkeetna	62.1800	-150.0600	350	COOP	1949	Present	DENA
Gulkana	62.1502	-145.4500	1580	SAO	1949	Present	WRST
Yakutat	59.5000	-139.6700	30	SAO	1936	Present	WRST

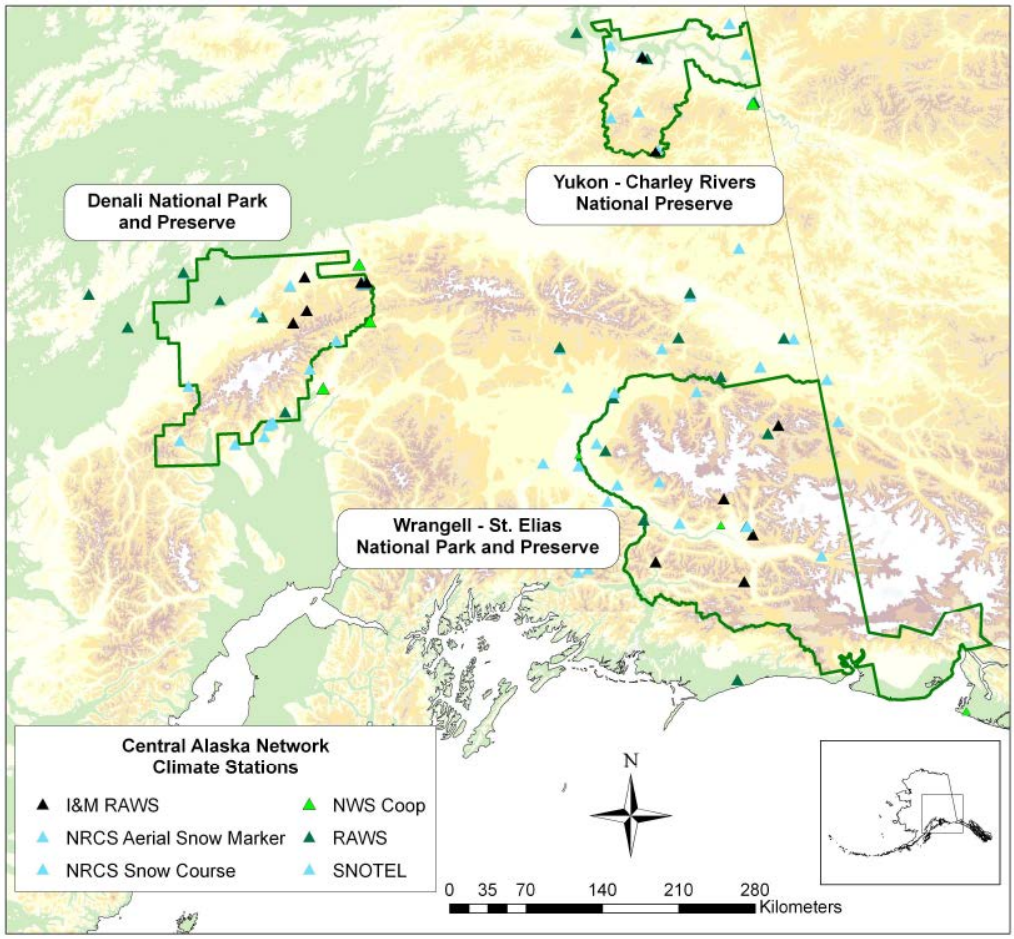


Figure 1. Map of CAKN climate station locations.

Table 2. CAKN and Remote Automated Weather Station (RAWS) sites.

Name	Lat	Long	Elev (ft)	Network	Start	End	Park
Stampede	63.7478	-150.3281	1800	CAKN RAWS	2003	Present	DENA
Toklat	63.5255	-150.0465	2920	CAKN RAWS	2005	Present	DENA
Eielson Visitor Center	63.4307	-150.3102	3730	CAKN RAWS	2005	Present	DENA
Wonder Lake	63.4900	-150.8800	2119	RAWS	1995	Present	DENA
Dunkle Hills	63.2670	-149.5415	2651	CAKN RAWS	2003	Present	DENA
Coal Creek	65.3041	-143.1570	820	CAKN RAWS	2004	Present	YUCH
Upper Charley	64.5169	-143.2023	3654	CAKN RAWS	2005	Present	YUCH
Chicken Creek	62.1240	-141.8473	5260	CAKN RAWS	2004	Present	WRST
Chisana	62.0775	-142.0500	3320	RAWS	1988	Present	WRST
Chititu	61.2735	-142.6209	4554	CAKN RAWS	2004	Present	WRST
May Creek	61.3208	-142.5844	1650	CAKN RAWS	1990	Present	WRST
Gates Glacier	61.6029	-143.0132	4060	CAKN RAWS	2005	Present	WRST
Klawasi	62.1469	-144.9269	3100	RAWS	1991	Present	WRST
Tebay	61.1810	-144.3392	1880	CAKN RAWS	2005	Present	WRST
Tana Knob	60.9080	-142.9013	3739	CAKN RAWS	2005	Present	WRST

Results

Climate Year 2011 Synopsis

The CAKN climate records show that on average the Central Alaska region was cooler and drier at most sites compared to normal (Figure 2). The mean annual temperatures at the longer-term sites averaged 0.4 degrees F colder than the 1981-2010 normal. Temperatures were variable across the network from month to month, but the negative temperature departures in March and November stand out; temperatures ranged from 2.3 to 9.9 degrees F below normal in March and from 5.1 to 13.0 degrees F colder than normal in November. Another anomaly occurred in December with monthly average temperatures ranging from 1.0 to 12.5 degrees warmer than the 1981-2010 normal with the strongest departures in the eastern regions of the network. All of the long-term sites (except for Yakutat) had record breaking temperatures at some point between May 27 and May 30, which is the same week that all the records were set in 2010. The records held for only one year for three consecutive years – this has been the pattern for the past 3 years in a row.

The annual precipitation totals were below normal for all of the sites in CAKN. Talkeetna and McKinley Park had annual totals that were 85% of normal. Eagle was 95% of normal, and Gulkana was 93% of normal. In Yakutat, along the Gulf of Alaska, the annual total was about 34 inches below the normal 155 inches per year, or about 78% of normal. September and October were noticeably dry with all of the long-term sites having negative departures from normal. February snowfall in McKinley Park was higher than normal translating to more precipiation for that month. Talkeetna was wet in August with a total of 8.44 inches of rain, 3.44 inches more than normal. Another notable event was the amount of snowfall the south-central region and north Gulf Coast area received in November. Yakutat had the snowiest November on record with a total of 82.5 inches of snow for the month, with record high daily snowfall totals on November 16, 22, and 23 with a total of 12.3, 12.5, and 4.4 inches respectively. Figure 3 shows the 2011 annual temperatures and total precipitation amounts compared with the 1981-2010 normals.

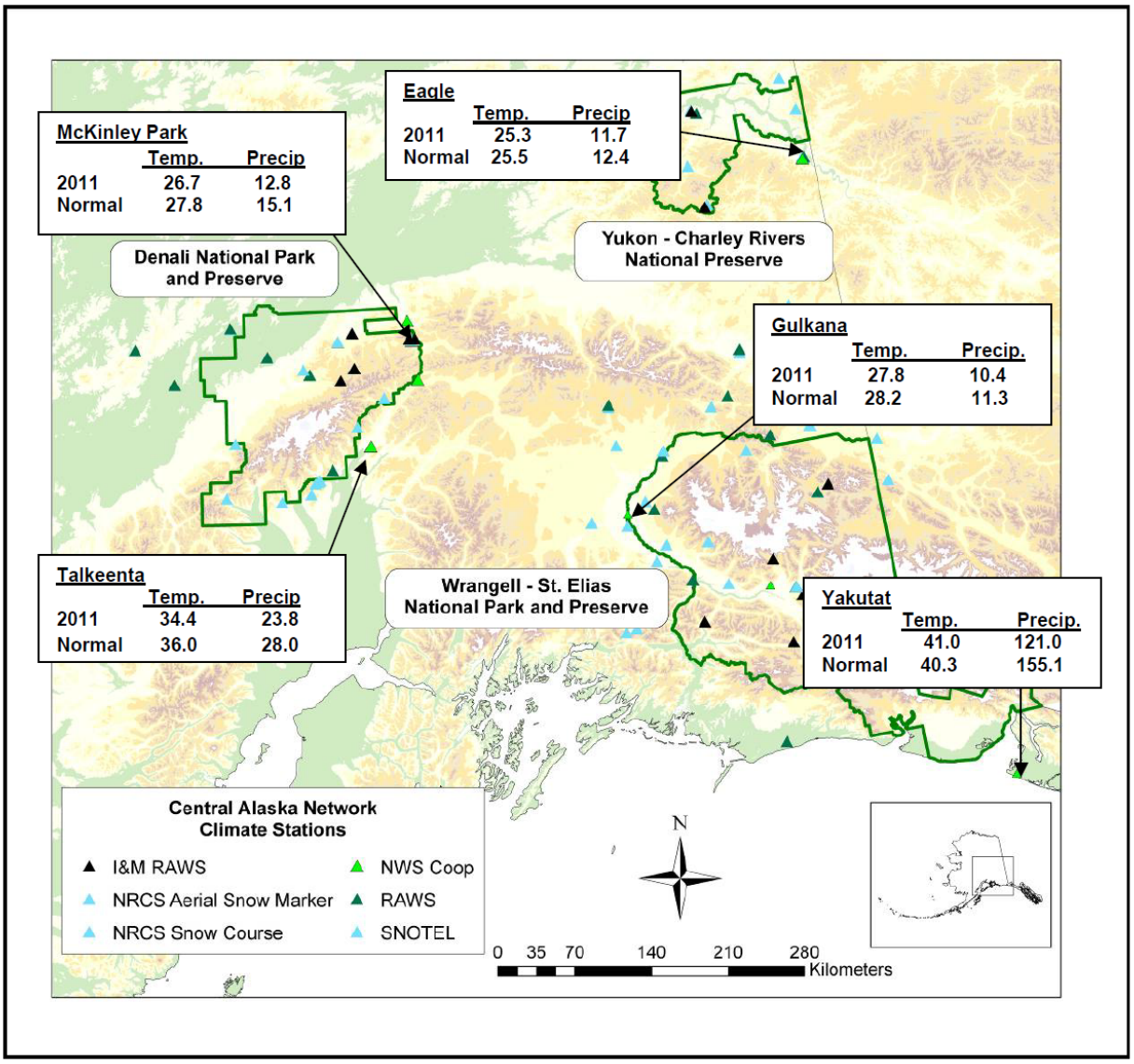


Figure 2. Mean annual temperature and precipitation totals for long-term sites in CAKN for 2011 compared with 1981-2010 normals.

State and National Data

Based on data from January through December, the average annual temperature for the contiguous U.S. was 12.1°C (53.8°F) which is 0.6°C (1.0°F) above the 20th Century average and ranks as the 23rd warmest year on record (NOAA 2012). The temperature trend for the lower 48 states is + 0.07 °C (+0.12°F) per decade. The average precipitation total for the lower 48 states was 9.14 mm (0.36 inches) below the long-term average. The precipitation trend has been ~ 4.57 mm (~0.18 inches) per decade.

The average annual temperature for Alaska was about 0.2 degrees C warmer than normal driven almost entirely by the very warm temperatures in December 2011 (Figure 3). Winter temperatures in 2010-11 which includes December, January and February, were 0.4 degrees F

(0.2 degrees C) below average (this includes December of 2010 and January and February of 2011); spring temperatures were 0.9 degrees F (0.5 degrees C) below average; summer was 0.7 degrees F (0.4 degrees C) below average, and fall was 0.4 degrees F (0.2 degrees C) warmer than the average (Figure 4). Precipitation state wide was just above average (Figure 5). Overall, the winter of 2010-2011 was near normal, spring was dry, the summer season was wetter, and the fall was just below average.

The snowpack once again varied across the state for the 2010 – 2011 season from well above normal in Northwest Alaska and in areas north of the Yukon River, to normal and just below normal in the central region of the state, to well below normal in Southcentral Alaska and along the Kenai Peninsula (Figure 6). Yakutat, and the north Gulf Coast, were well below normal, while the Southeast panhandle was above normal. Yukon Charley had near normal to above normal snowpack for the year with most of the snow accumulating in November and February. The northern regions of Denali were near normal at park headquarters to above normal in the western region. The south side of the Alaska Range was below normal. Wrangell-St. Elias had above normal conditions on the north side of the Alaska Range and near normal conditions in the Wrangell Mountains. The Chugach Range was about 80% of normal.

The snow season started later than normal at the northern sites, the same as 2009-2010. The first persistent snow started around October 25th, almost 2 weeks later than normal. In Wrangell- St. Elias, Chisana in the northeast area of the park had the first persistent snow on October 14th, while the May Creek snowpack started on November 2nd. The snow off dates for the region occurred during the first few weeks of May. Lake Minchumina, Coal Creek, and May Creek still had snow on the ground for the May 1 surveys, these sites are often snow free by the May 1 surveys.

The warm temperatures and low precipitation in May once again sparked an early fire season. The snowpack melted, the ground surface dried out, and convective activity increased. This again is a remarkably similar patter to both 2009 and 2010. Cooler and cloudy conditions were the norm for the rest of the summer season, putting a damper on the fire season. The total area burned in the CAKN parks was 3,766 acres, 2,532 acres in Denali and 1,234 acres in Wrangell-St. Elias. There were no fires in Yukon-Charley this year. The notable larger fires affecting the region were the Moose Mountain and Hastings fir near Fairbanks and the East Volkmar fire near Delta. Statewide there were a total of 515 wild land fires in 2011, with a total of 293,018 acres burned. 377 of the 512 were human cause fires (AICC, 2011).

There was one climatically significant event that occurred during 2011. A powerful storm hit western Alaska in November causing high tides, strong winds in excess of 80 mph, heavy rain, and blizzard conditions (Figure 7). This was one of the strongest storms in decades. The near record high temperatures in the beginning of December caused more headaches with rain topping snow packed roads. Winds in excess of 100 mph slammed into Anchorage and record snowfall events in the region compounded problems for the south-central region.

A relatively strong phase of La Niña opened the year. La Niña is defined by cooler-than-normal waters in the eastern and central equatorial Pacific Ocean that affects global weather patterns. In the spring of 2011 La Nina conditions moderated in the spring and then reemerged in the fall, lasting through the end of the year. With records of El Nino/La Nina events dating back to 1950,

2011 ranked as the warmest "La Niña year" in the 1950–2011 period of record. Two of the three warmest years on record (2010 and 1998) are "El Niño years" (NOAA 2012). The Pacific Decadal Oscillation, an index of sea surface temperatures in the north Pacific was negative for all of 2011 indicating colder than normal sea surface temperatures off of Alaska's coast (JISAO, 2011) (Figure 8). The strongest negative departure was in November which correlates well with the negative monthly temperature departures experienced across the network for the month. Arctic sea ice extent for September 2011 fell just short of the record low set in September 2007 (NSIDC 2012) (Figure 9).

The year 2011 tied with 1997 as the 11th warmest year since records began in 1880. This value, calculated from the annually-averaged temperature over global land and ocean surfaces, was 0.51°C (0.92° F) above the 20th century average of 13.9°C (57.0°F). The warmest years on record were 2010 and 2005, which were 0.64°C (1.15°F) above average (NOAA, 2012).

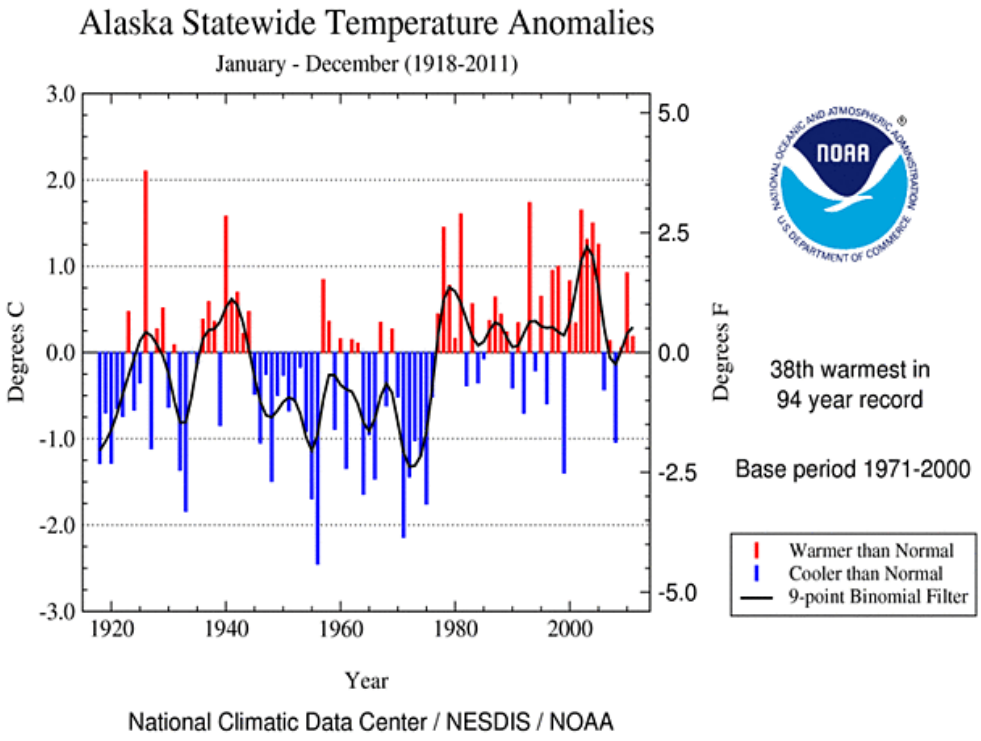


Figure 3. Average temperatures across Alaska were 0.2 °C above the 1971-2000 mean (NOAA 2012). Figure retrieved from http://www.ncdc.noaa.gov/sotc/2012/13.

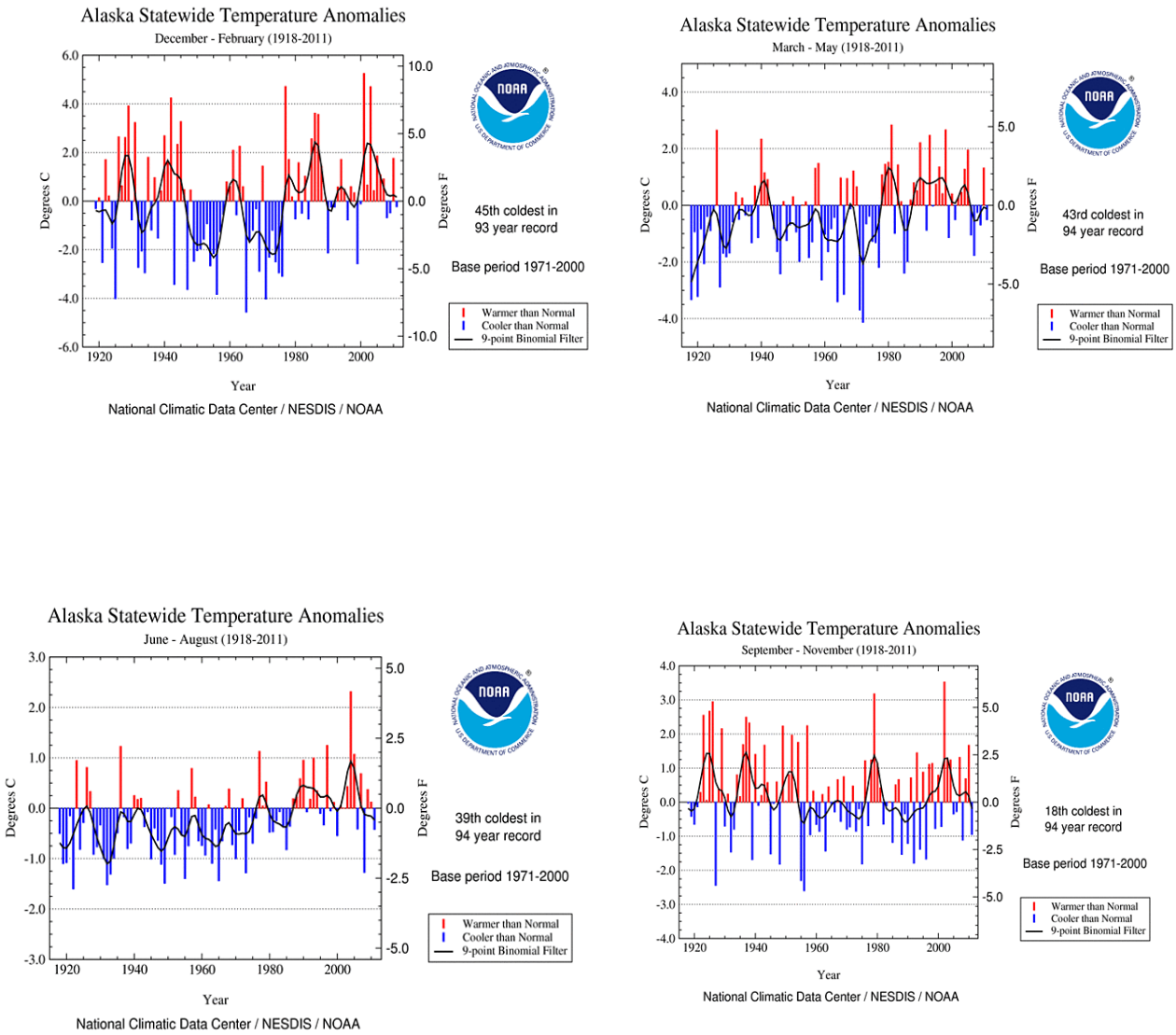


Figure 4. Seasonal statewide temperature anomalies 2011. Figures retrieved from http://www.ncdc.noaa.gov/sotc/national/2011/13.

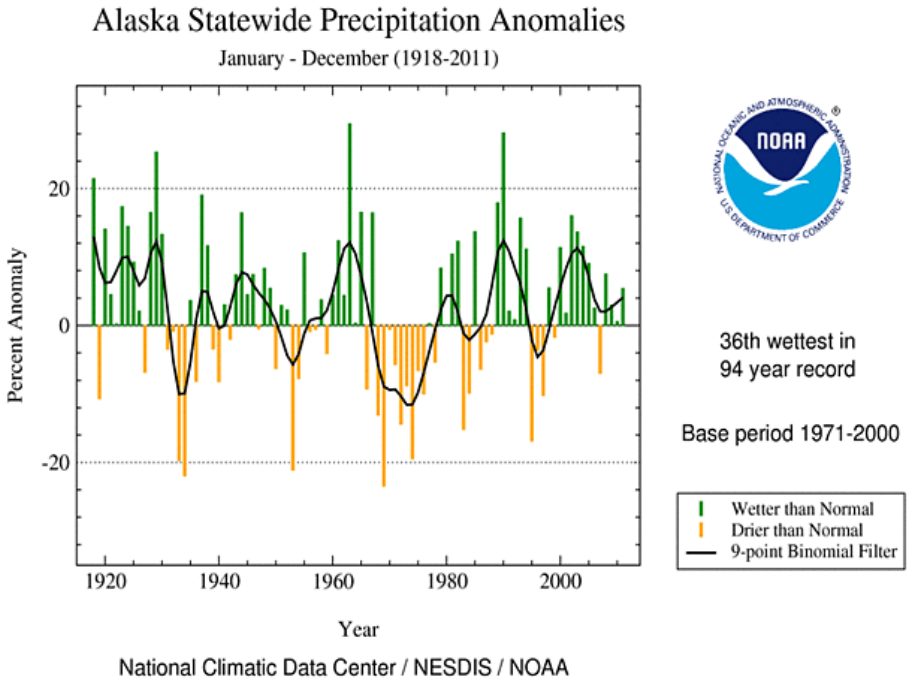


Figure 5. Annual precipitation anomalies 1918-2011. Figures retrieved from http://www.ncdc.noaa.gov/sotc/national/2011/13.

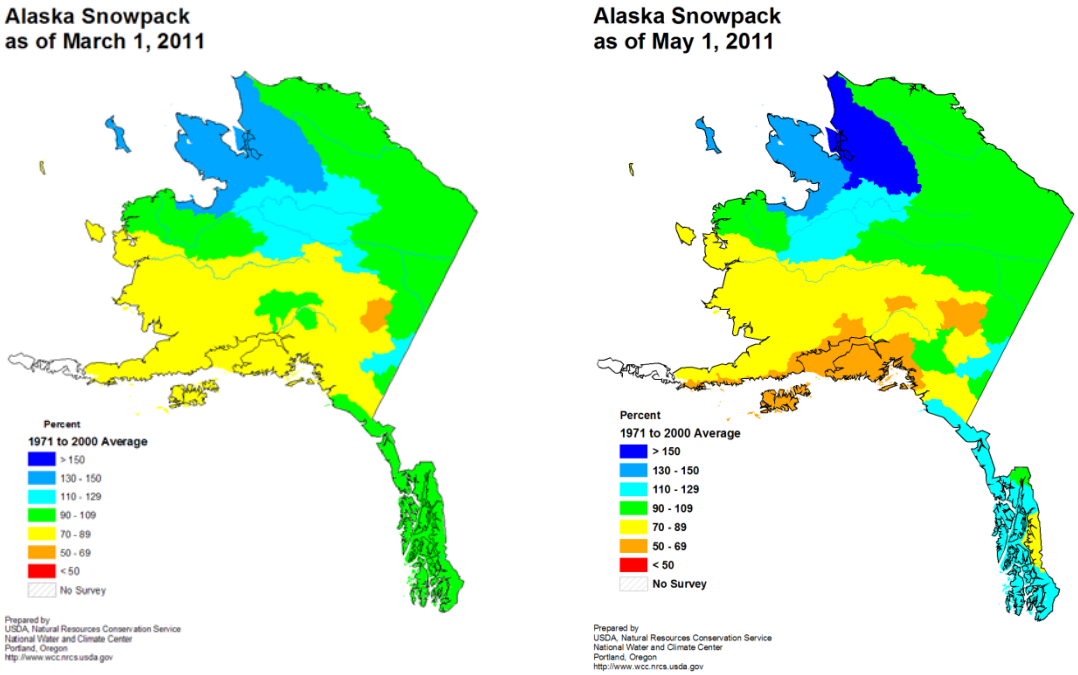


Figure 6. March 1 and May 1 snowpack depths for Alaska 2011 (NRCS 2011).

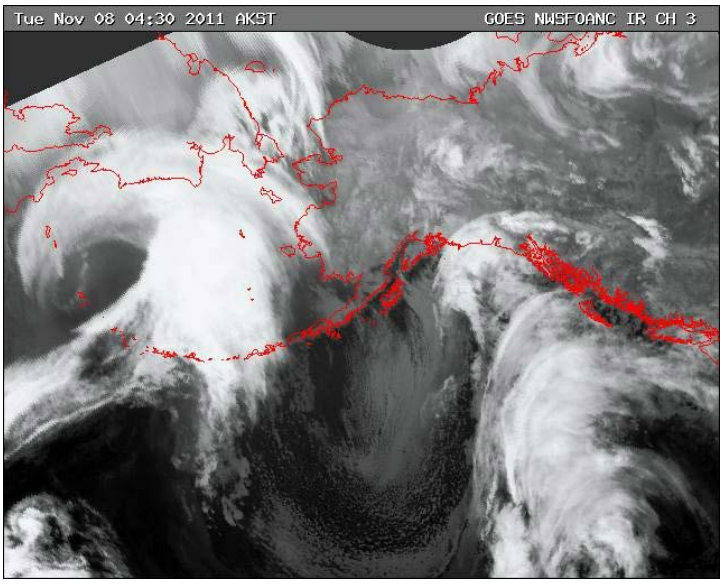


Figure 7. GOES satellite image of the storm that impacted the west coast of Alaska on November 8 and 9, 2011 (Courtesy of NOAA, 2012).

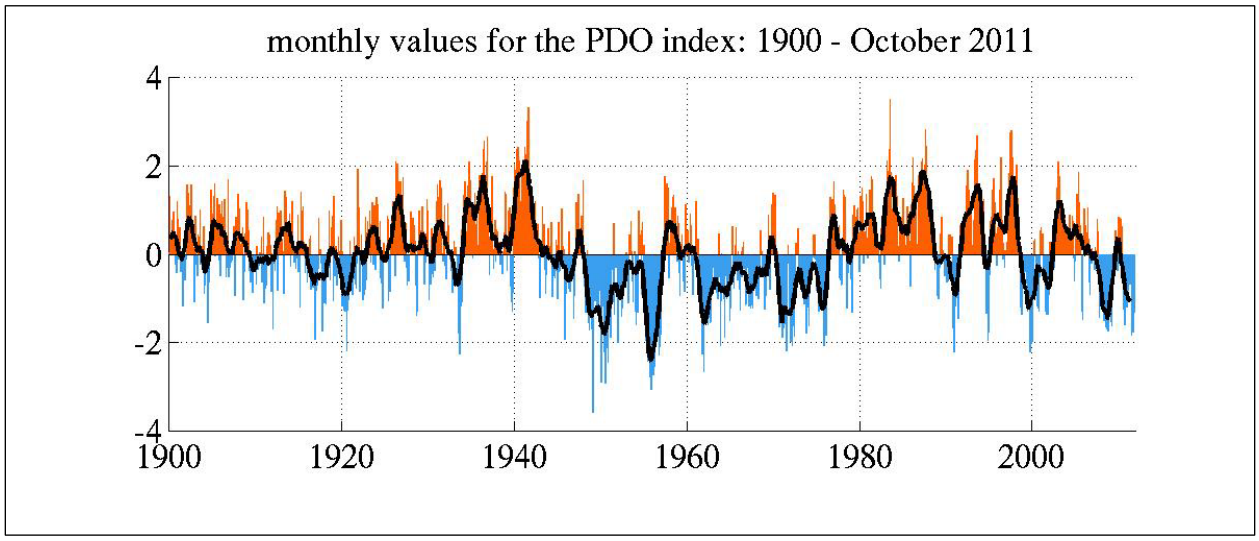


Figure 8. Pacific Decadal Oscillation index. Note the negative departures over the past 5-6 years. Graph retrieved from http://jisao.washington.edu/pdo/ (JISAO 2012).

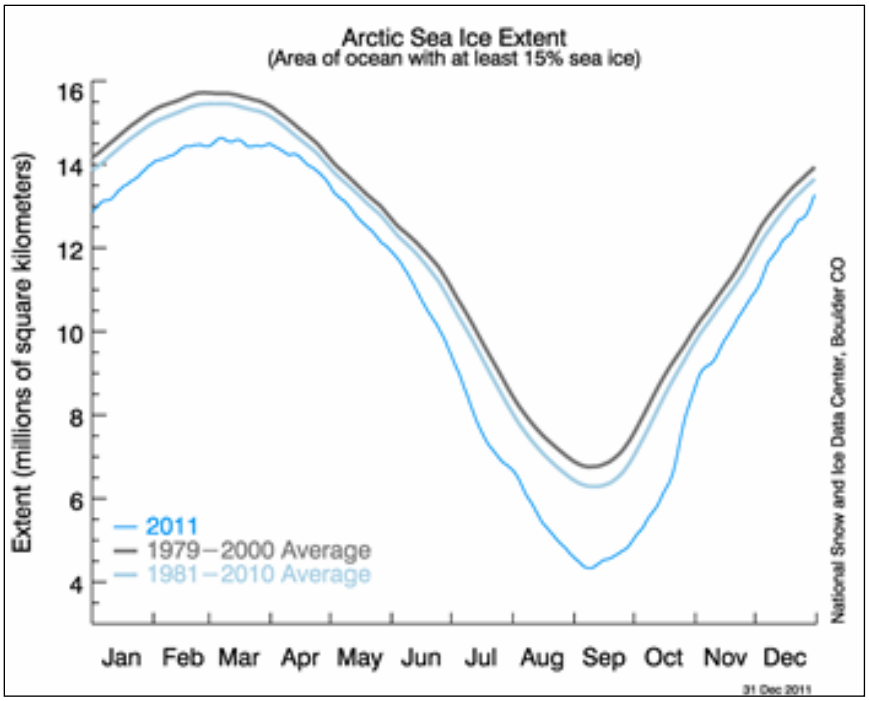


Figure 9. Arctic Sea Ice extent 1979-2011. Graph retrieved from http://nsidc.org/data/seaice_index/images/daily_images/N_stddev_timeseries.png (NSIDC 2012).

Temperature

In 2011, the mean annual temperatures for the long-term sites around the CAKN region averaged -0.4° F below the 1981-2010 normal (Figure 10). The strongest negative departures were in the western region of the network both north and south of the Alaska Range. On the eastern side of the network the site farthest north (Eagle) and the site farthest south (Yakutat) were both warmer than normal for the year, while Gulkana was cooler than normal. The temperatures were variable through the winter, spring and fall seasons, but relatively stable through the summer months. Table 3 shows the departure from the 1981-2010 normal for each month at each of the long term sites around CAKN.

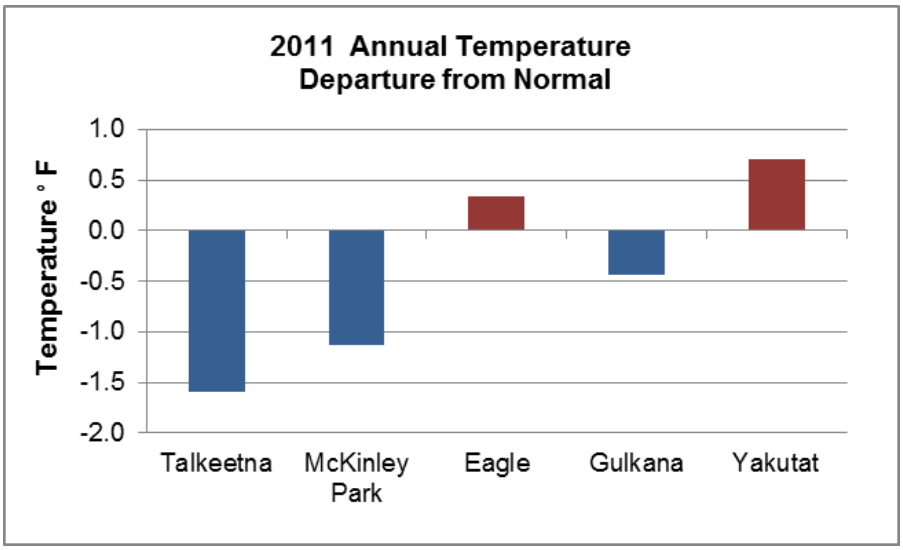


Figure 10. 2011 Mean annual temperature departure from normal (1981-2010) at long-term CAKN sites.

Table 3. 2011 monthly average temperature departure from normal (1981-2010) for long-term sites in CAKN.

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Talkeetna	1.4	-6.0	-1.3	0.1	0.0	-1.0	-2.1	-2.0	0.6	2.0	-10.2	1.0	-1.6
McKinley Park	2.4	-4.5	-4.2	-1.8	0.3	0.2	-2.1	-1.1	3.2	4.8	-13.0	3.0	-1.1
Eagle	-1.3	0.8	-7.0	-3.3	3.5	0.5	-0.5	-1.6	1.7	5.3	-8.5	12.5	0.3
Gulkana	1.3	-4.3	-9.9	1.4	1.4	0.8	-0.6	-1.1	0.1	3.5	-7.0	10.7	-0.4
Yakutat	2.1	-1.1	-2.3	1.4	2.7	2.0	2.8	0.6	1.4	1.8	-5.1	3.0	0.7

January temperatures were just above normal for most sites; Eagle was the only exception with a monthly mean temperature 1.3 degrees F below normal. February and March were cool around the interior, with most sites having below to well-below monthly temperatures for both months with the strongest temperature departures in February. Eagle was again the exception with a February mean temperature that was just above normal.

April was cooler in the northern areas and warm in the southeastern region, including Gulkana and Yakutat. May started out cool and warmed up with some record setting temperatures the last week. The stations near Denali had monthly temperatures that were close to normal for May. June was almost 1 degree F cooler than normal for June in Talkeetna, while the other long-term sites in the interior were just above normal. The monthly average temperature for Yakutat was 2 degrees warmer than normal. July and August were cooler than normal for all of the northern sites. Yakutat proved to be the exception with temperatures in July and August above normal.

The fall temperatures were moderate across the region; temperatures were much warmer than normal in the interior locations. The temperatures plummeted in November with an unusually long cold spell for early season. The temperatures statewide were well below normal. The persistent cold period ended in December; the temperature rose dramatically during the first week of the month and persisted until about the 3rd week. The temperatures slid to well below

normal for the last week of the year. See Appendix A for 'period of record' data for the long-term sites and Appendix B for individual site records and extremes.

The mean monthly temperatures for the long-term site are listed in Table 4 and compared to the two latest normal periods. Figure 11 shows the changes in the annual temperatures between the 1981-2010 period and the 1971-2000 period. Overall there has been more warming than cooling in the latest 30 year normal period (1981-2010). Talkeentna has shown the most warming between the two periods, while Eagle has shown the least warming. The differences between the monthly average temperatures reveal that most of the warming has occurred in the winter months (Figure 12). Winter temperatures have warmed on average by 2.2 degrees F at the long term sites; spring temperatures warmed 0.8 degrees F, summer temperatures averaged 0.5 degrees F warmer, while fall temperatures were 0.3 degrees F warmer for the 1981-2010 normal period.

Table 4. Mean monthly and annual temperatures for 2011 from long-term sites compared with both the 1971-2000 and 1981-2010 normal period.

Site	*JAN*	*FEB*	*MAR*	*APR*	*MAY*	*JUN*	*JUL*	*AUG*	*SEP*	*OCT*	*NOV*	*DEC*	*ANN*
Talkeetna													
2011	15.6	12.1	23.6	36.0	47.8	56.0	58.0	54.7	48.1	35.2	9.3	17.0	**34.4**
1971-2000 normal	11.0	15.4	22.6	34.3	45.8	55.3	58.9	55.6	46.2	31.4	17.5	13.0	**33.9**
1981-2010 normal	14.2	18.1	24.9	35.9	47.8	57.0	60.1	56.7	47.5	33.2	19.5	16.0	**36.0**
McKinley Park													
2011	5.5	3.1	9.2	26.1	43.1	53.0	53.5	49.5	43.6	27.7	-4.1	9.9	**26.7**
1971-2000 normal	2.0	4.5	13.1	27.2	42.0	52.2	55.6	50.9	40.5	22.5	9.1	4.9	**27.0**
1981-2010 normal	3.1	7.6	13.4	27.9	42.8	52.8	55.6	50.6	40.4	22.9	8.9	6.9	**27.8**
Eagle													
2011	-10.8	-5.3	0.8	25.5	49.5	58.0	60.3	53.2	44.5	28.6	-6.3	5.7	**25.3**
1971-2000 normal	-11.6	-6.1	7.8	28.8	46.0	57.5	60.8	54.8	42.8	23.3	2.2	-6.8	**25.0**
1981-2010 normal	-9.5	-3.7	7.2	28.9	46.1	57.9	60.4	53.6	41.8	23.0	3.0	-4.0	**25.5**
Gulkana													
2011	-1.6	1.2	5.7	33.2	46.6	55.2	57.0	52.4	43.4	30.1	-1.2	11.1	**27.8**
1971-2000 normal	-4.7	3.2	15.3	31.1	43.9	53.1	57.0	53.1	43.1	26.4	5.5	-1.6	**27.1**
1981-2010 normal	-2.9	5.5	15.6	31.8	45.2	54.4	57.6	53.5	43.3	26.6	5.8	0.4	**28.2**
Yakutat													
2011	30.2	28.6	29.7	39.2	47.4	52.8	57.1	54.4	49.8	42.8	27.2	32.6	**41.0**
1971-2000 normal	25.8	28.4	31.5	37.2	43.6	49.7	53.6	53.3	48.2	41.1	32.4	28.6	**39.5**
1981-2010 normal	28.1	29.7	32	37.8	44.7	50.8	54.3	53.8	48.4	41	32.3	29.6	**40.3**

Yellow – YUCH, Green – DENA, Blue – WRST

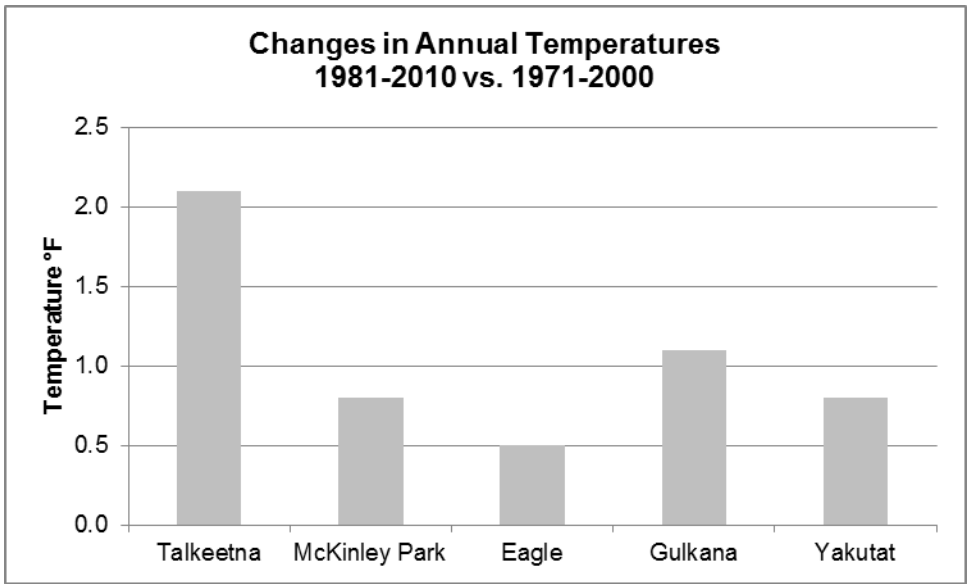


Figure 11. Change in annual temperatures (degrees F) between 1981-2010 and 1971-2000.

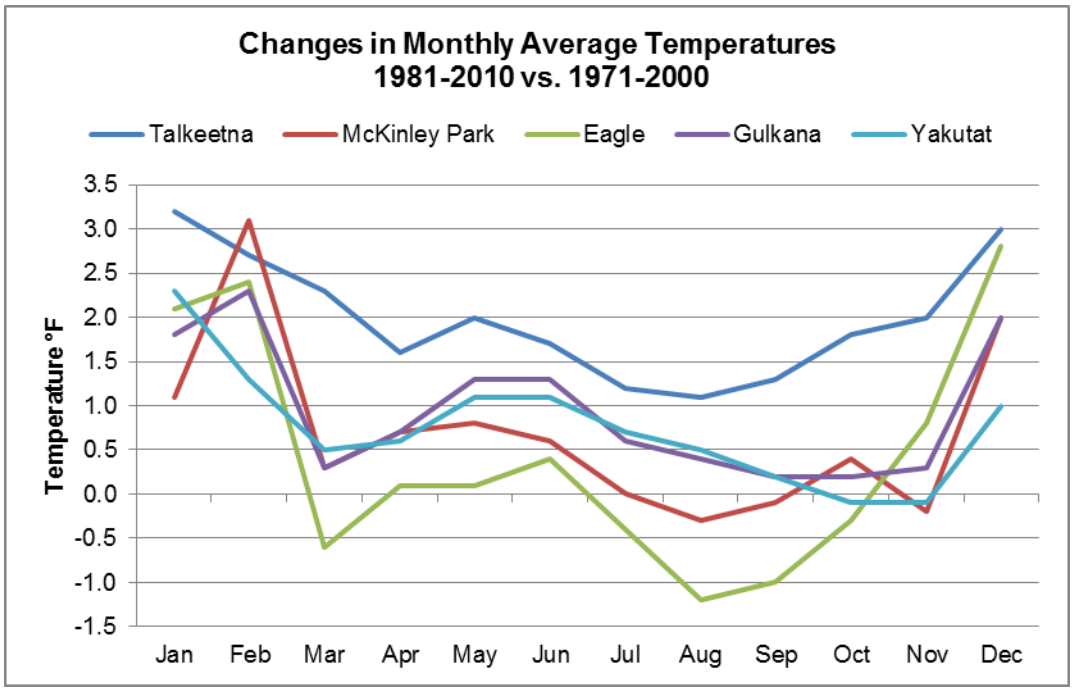


Figure 12. Change in monthly temperatures (degrees F) between 1981-2010 and 1971-2000.

NPS CAKN Sites

Although the new CAKN climate stations and other Remote Automated Weather Stations (RAWS) around the CAKN parks do not have long records, the monthly and annual averages and totals fill in some of the large spatial gaps in the network and offer information on climate patterns related to elevation and topography. Table 5 lists the monthly and annual temperatures

for these sites grouped by park and Figure 13 and 14 shows them graphically. The monthly average temperatures are warmer for the lower elevation interior sites during the summer months, while the winter monthly average temperatures are warmer at higher elevations, effectively smoothing the annual averages. See Appendix C for complete monthly summaries from the CAKN climate sites.

Table 5. Monthly mean temperatures from CAKN stations 2011.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Stampede	-1.3	1.3	5.0	27.0	44.7	52.2	53.3	48.0	42.0	24.3	-9.3	3.9	**24.2**
Toklat	11.5	5.9	8.7	24.9	41.4	48.9	49.8	46.1	41.4	26.6	-1.3	9.6	**26.1**
Eielson VC	20.2	12.7	19.3	26.5	43.0	46.6	47.6	44.8	40.6	27.9	5.4	12.7	**28.9**
Wonder Lake	6.9	3.4	11.2	26.2	45.1	51.6	53.4	48.5	41.9	25.1	-4.0	6.3	**26.3**
Dunkle Hills	11.3	6.4	10.3	25.6	39.9	48.3	50.1	46.1	40.8	26.0	2.4	12.5	**26.6**
Denali VC	-2.2	0.5	6.1	29.9	46.4	55.2	55.9	50.7	44.0	27.5	-6.2	8.0	**26.3**
Coal Creek	0.2	-6.5	1.9	26.1	50.4	55.6	58.5	51.7	43.7	25.1	-12.2	1.9	**24.7**
Upper Charley	1.5	-2.2	7.5	23.3	42.2	48.3	50.9	46.1	39.3	22.4	-4.7	6.6	**23.4**
Chicken Creek	11.4	4.9	6.7	23.5	36.5	43.1	45.7	42.1	36.4	25.0	2.6	15.0	**24.4**
Chisana	-7.5	-4.4	-2.3	27.8	43.0	51.2	53.0	47.1	36.8	18.7	-10.7	4.9	**21.5**
Chititu	15.4	8.1	11.8	26.1	38.1	43.8	46.6	43.2	38.1	28.8	9.0	19.4	**27.4**
May Creek	1.4	3.6	10.3	35.2	47.8	54.9	55.5	50.7	42.2	27.8	2.3	14.3	**28.8**
Gates Glacier	16.3	9.7	13.8	26.5	38.4	43.8	46.6	43.4	38.1	28.9	10.8	19.4	**28.0**
Klawasi	9.8	6.3	10.9	31.2	43.9	50.7	52.8	48.8	42.9	29.7	3.7	19.8	**29.2**
Tebay	6.5	8.5	10.9	30.5	42.4	49.1	52.4	48.6	41.8	31.4	8.3	19.5	**29.1**
Tana Knob	15.9	10.4	13.5	28.7	40.1	45.5	48.8	45.4	39.8	30.8	8.9	20.0	**29.0**

Yellow – YUCH, Green – DENA, Blue – WRST

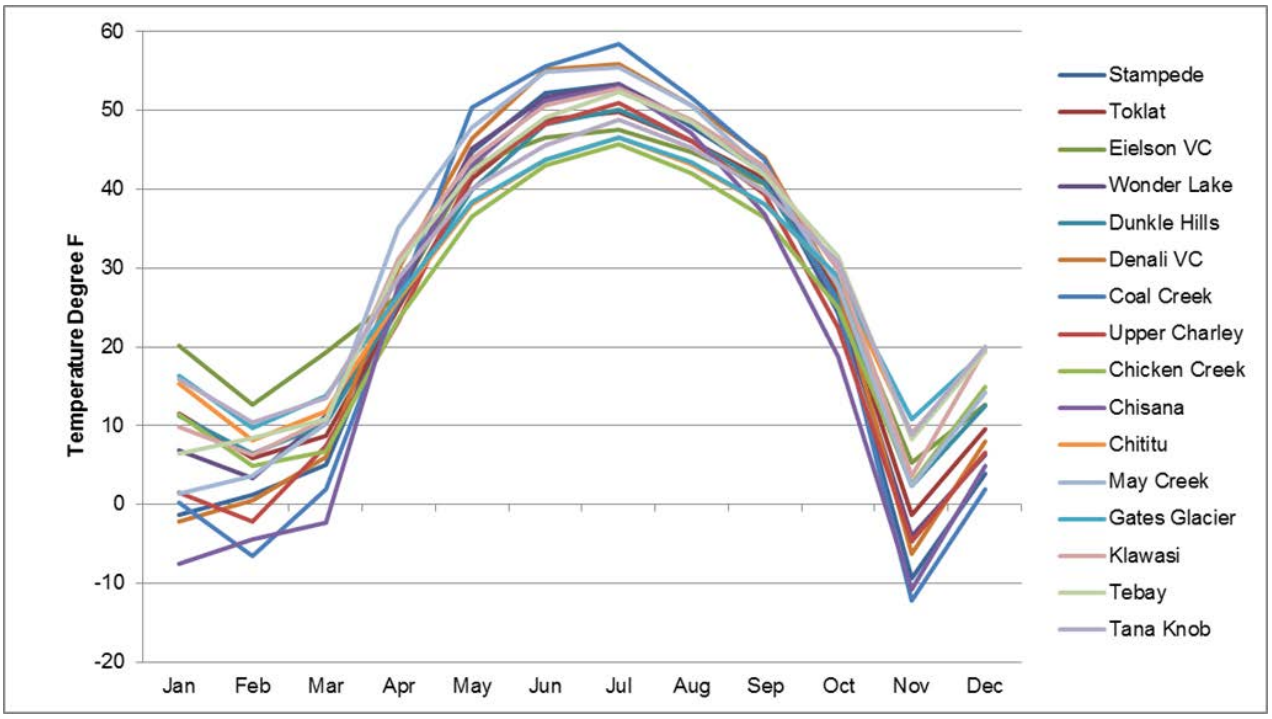


Figure 13. CAKN mean monthly temperatures 2011.

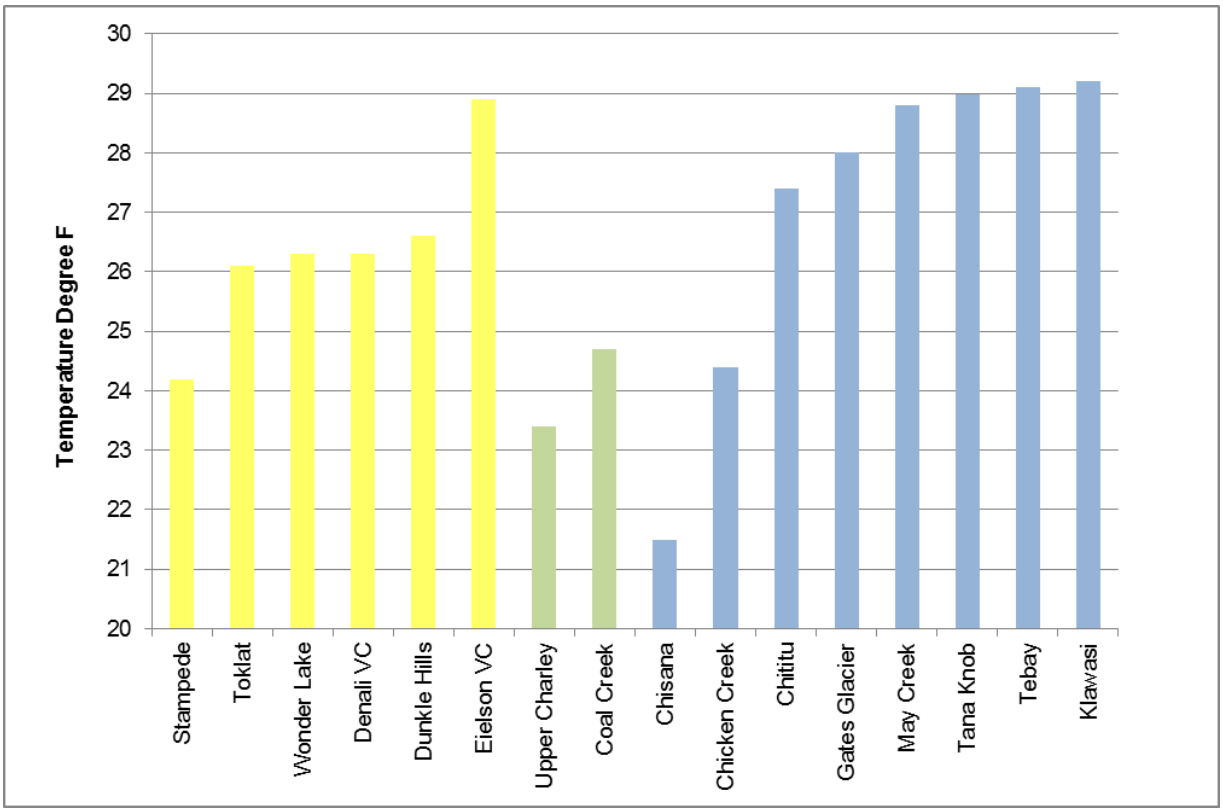


Figure 14. CAKN mean annual temperatures 2011. Yellow sites are DENA, green YUCH, and blue WRST.

One of the objectives of the CAKN climate program was to instrument higher elevation sites to acquire information related to temperature gradients in complex topography. In many cases higher sites were deployed in the vicinity of existing lower elevation sites for comparison. Correlations between the paired high and low elevation sites are best described by monthly means rather than annual means. In the summer, the higher sites tend to be 5 to 10° colder depending on the elevation, but in the winter during cold spells, a persistent inversion can set up and the higher elevations can be 10 to 20° F warmer than the surrounding lowlands. The air is often still in the darker winter months due to the lack of solar radiation that generates the surface winds that are so common in the summer. However, if a storm system moves in from the Gulf of Alaska or Bering Sea, warm maritime winds (known as Chinooks) often funnel through the mountain passes, raising temperatures and mixing the air. The areas just north of these mountain passes often get winds in excess of 40 mph during these events.

The following tables show the monthly and annual variation between low and high elevation sites in the three CAKN parks. Table 6 shows Chicken Creek and Chisana, sites located in the continental interior region of northeastern WRST, north of the Chugach and Wrangell Mountain ranges. The annual temperature was 2.9 degrees F warmer at Chicken Creek, the higher site. Table 6 also shows May Creek and Gates Glacier which are located between the Wrangell Mountain Range to the north and the Chugach Range to the south. The mean annual temperature for 2011 at Gates Glacier was 0.8 degrees cooler than the lower elevation site at May Creek. The higher sites were warmer in the winter and cooler in the summer, but the winter differences were more extreme.

Table 6. Mean monthly temperatures for 2011 at high and low elevation paired sites in WRST.

Month	Chicken Creek Elev. - 5260'	Chisana Elev. – 3320'	Gates Glacier Elev. - 4060	May Creek Elev. – 1600'
Jan	11.4	-7.5	16.3	1.4
Feb	4.9	-4.4	9.7	3.6
Mar	6.7	-2.3	13.8	10.3
Apr	23.5	27.8	26.5	35.2
May	36.5	43	38.4	47.8
Jun	43.1	51.2	43.8	54.9
Jul	45.7	53	46.6	55.5
Aug	42.1	47.1	43.4	50.7
Sep	36.4	36.8	38.1	42.2
Oct	25	18.7	28.9	27.8
Nov	2.6	-10.7	10.8	2.3
Dec	15	4.9	19.4	14.3
Annual	24.4	21.5	28	28.8

Red = warmer temperatures; blue = colder temperatures.

Table 7 shows the high and low elevation sites in DENA and YUCH. In 2011, the lower elevation site at Coal Creek had a warmer overall temperature for the year. The mean annual temperature at Upper Charley, the higher elevation site, was 1.3°F cooler than Coal Creek. The Upper Charley site was on average 4.7 degree F warmer than Coal Creek during the winter months, and 5.5 degrees cooler during the sum for the winter months. In Denali, Eielson Visitor Center is located at a high elevation site just north of the crest of the Alaska Range. This site is compared with Stampede which is located farther north and east, where the topography starts to flatten out. The mean annual temperature at Eielson was 4.7°F warmer than Stampede (Table 7). This site is subject to the warm Chinook winds that come through the passes in the winter; this

site had the warmest annual temperature of the higher elevation interior sites. Figure 15 highlights the differences in seasonal temperatures at both high and low elevation sites.

Table 7. Mean monthly temperatures for 2011 at high and low elevation paired sites in YUCH and DENA

Month	***Upper Charley*** Elev. - 3654'	***Coal Creek*** Elev. - 802'	***Eielson VC*** Elev. - 3730'	***Stampede*** Elev. - 1800'
Jan	1.5	0.2	20.2	-1.3
Feb	-2.2	-6.5	12.7	1.3
Mar	7.5	1.9	19.3	5
Apr	23.3	26.1	26.5	27
May	42.2	50.4	43	44.7
Jun	48.3	55.6	46.6	52.2
Jul	50.9	58.5	47.6	53.3
Aug	46.1	51.7	44.8	48
Sep	39.3	43.7	40.6	42
Oct	22.4	25.1	27.9	24.3
Nov	-4.7	-12.2	5.4	-9.3
Dec	6.6	1.9	12.7	3.9
Annual	23.4	24.7	28.9	24.2

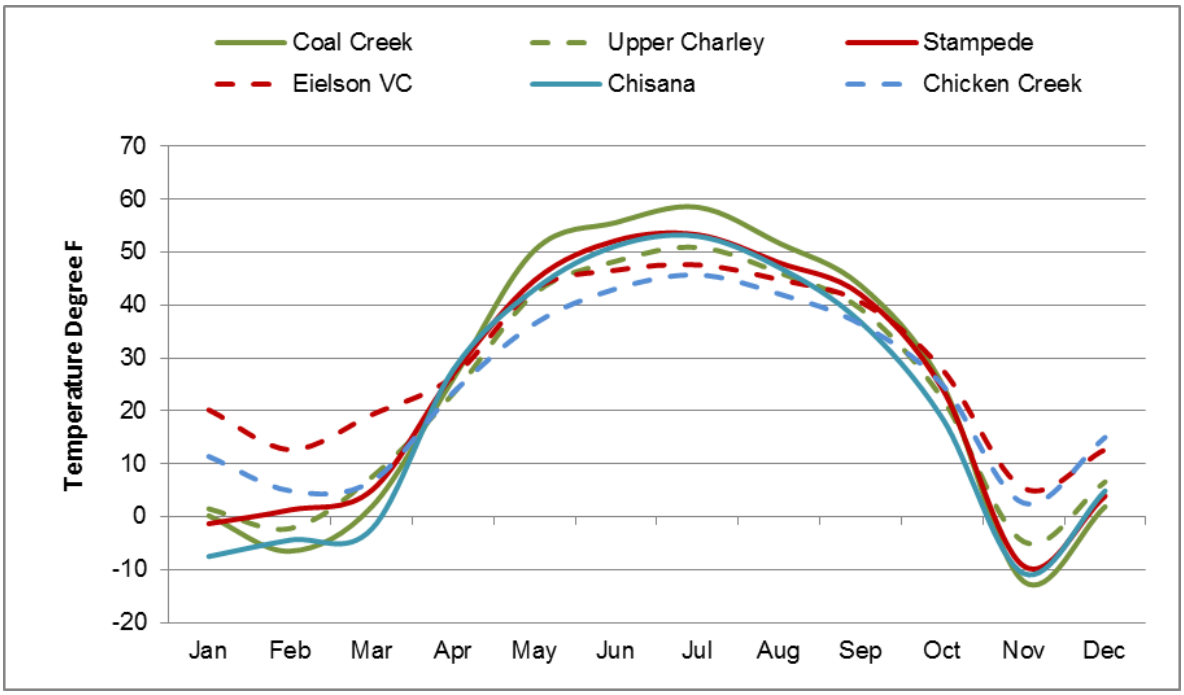


Figure 15. CAKN mean monthly temperatures – Paired high and low elevation sites for 2011.

Precipitation

Annual precipitation totals were below normal for all of the CAKN long-term sites in 2011 (Table 8 and Figure 16). September was particularly dry with the average departure about ~1.7 inches below normal (Figure 17). Annual precipitation for Talkeetna and McKinley Park were 85% of normal. Eagle and Gulkana were 95% and 93% of normal, respectively. The

precipitation amounts for Yakutat are generally five times greater, on average, than the other sites in the network; because of this difference, Yakutat is not included in the figures due to scale issues. Annual precipitation totals for Yakutat were about 78% of normal for 2011; every month was below normal except for August. See Appendix B for records for all long-term sites.

Table 8. Annual precipitation totals 2011 - departure from 1981-2010 normal.

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Talkeetna	-0.2	-0.98	-0.91	0.18	-1.34	-0.95	-0.03	3.44	-3.25	-1.74	-0.51	2.14	-4.15
McKinley Park	-0.28	1.91	-0.37	-0.35	-0.14	-0.2	-0.73	-0.86	-1.43	-0.41	-0.13	0.76	-2.23
Eagle	-0.22	0.25	-0.35	0.08	-0.75	1	1.25	-0.03	-0.74	-0.39	-0.61	-0.17	-0.68
Gulkana	0.45	0.73	0.3	-0.21	-0.34	-0.26	0.16	-0.15	-1.22	-0.65	0.29	0.08	-0.82
Yakutat	-2.73	-1.24	-8.52	-3.95	-5.32	-3.74	-4.02	0.65	-2.33	-4.41	-1.21	2.67	-34.15

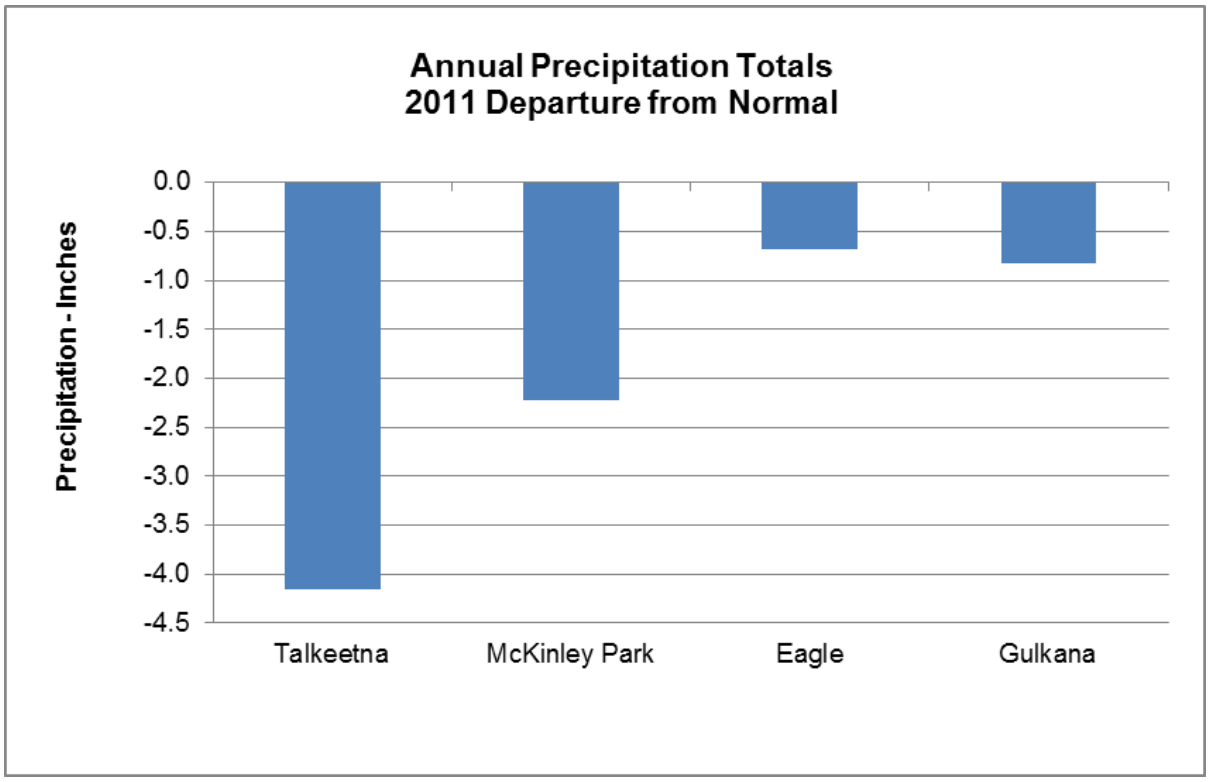


Figure 16. Annual precipitation totals departure from normal for long-term CAKN sites – 2011.

Table 9. Total monthly precipitation at long-term CAKN sites for 2011 compared with both the 1971-2000 and 1981-2010 normals

Site	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Talkeetna													
2011	1.16	0.47	0.14	1.47	0.28	0.97	3.36	8.55	1.07	1.16	1.12	4.07	**23.82**
1971-2000 normal	*1.45*	*1.28*	*1.26*	*1.22*	*1.64*	*2.41*	*3.24*	*4.53*	*4.35*	*3.06*	*1.78*	*1.96*	***28.18***

1981-2010 normal	*1.36*	*1.45*	*1.05*	*1.29*	*1.62*	*1.92*	*3.39*	*5.11*	*4.32*	*2.9*	*1.63*	*1.93*	***27.97***
McKinley Park													
2011	0.35	2.45	0.02	0.05	0.73	1.95	2.49	1.85	0.27	0.37	0.62	1.68	**12.83**
1971-2000 normal	*0.7*	*0.54*	*0.38*	*0.27*	*0.67*	*2.22*	*3.09*	*2.62*	*1.76*	*1.05*	*0.78*	*0.89*	***14.97***
1981-2010 normal	*0.63*	*0.54*	*0.39*	*0.4*	*0.87*	*2.15*	*3.22*	*2.71*	*1.7*	*0.78*	*0.75*	*0.92*	***15.06***
Eagle													
2011	0.31	0.72	0.03	0.34	0.35	2.64	3.68	1.89	0.57	0.56	0.12	0.52	**11.73**
1971-2000 normal	*0.44*	*0.47*	*0.31*	*0.3*	*1.17*	*1.78*	*2.13*	*1.85*	*1.17*	*0.97*	*0.67*	*0.75*	***12.01***
1981-2010 normal	*0.53*	*0.47*	*0.38*	*0.26*	*1.1*	*1.64*	*2.43*	*1.92*	*1.31*	*0.95*	*0.73*	*0.69*	***12.41***
Gulkana													
2011	0.91	1.24	0.6	0.03	0.31	1.14	1.97	1.65	0.36	0.36	1.01	0.86	**10.44**
1971-2000 normal	*0.45*	*0.52*	*0.36*	*0.22*	*0.59*	*1.54*	*1.82*	*1.8*	*1.44*	*1.02*	*0.67*	*0.97*	***11.4***
1981-2010 normal	*0.46*	*0.51*	*0.3*	*0.24*	*0.65*	*1.4*	*1.81*	*1.8*	*1.58*	*1.01*	*0.72*	*0.78*	***11.26***
Yakutat													
2011	10.93	9.62	2.52	5.24	2.89	2.65	3.86	14.72	18.78	17.57	13.24	18.95	**120.97**
1971-2000 normal	*13.18*	*10.99*	*11.41*	*10.8*	*9.78*	*7.17*	*7.88*	*13.27*	*20.88*	*24*	*15.17*	*15.85*	***160.4***
1981-2010 normal	*13.66*	*10.86*	*11.04*	*9.19*	*8.21*	*6.39*	*7.88*	*14.07*	*21.11*	*21.98*	*14.45*	*16.28*	***155.1***

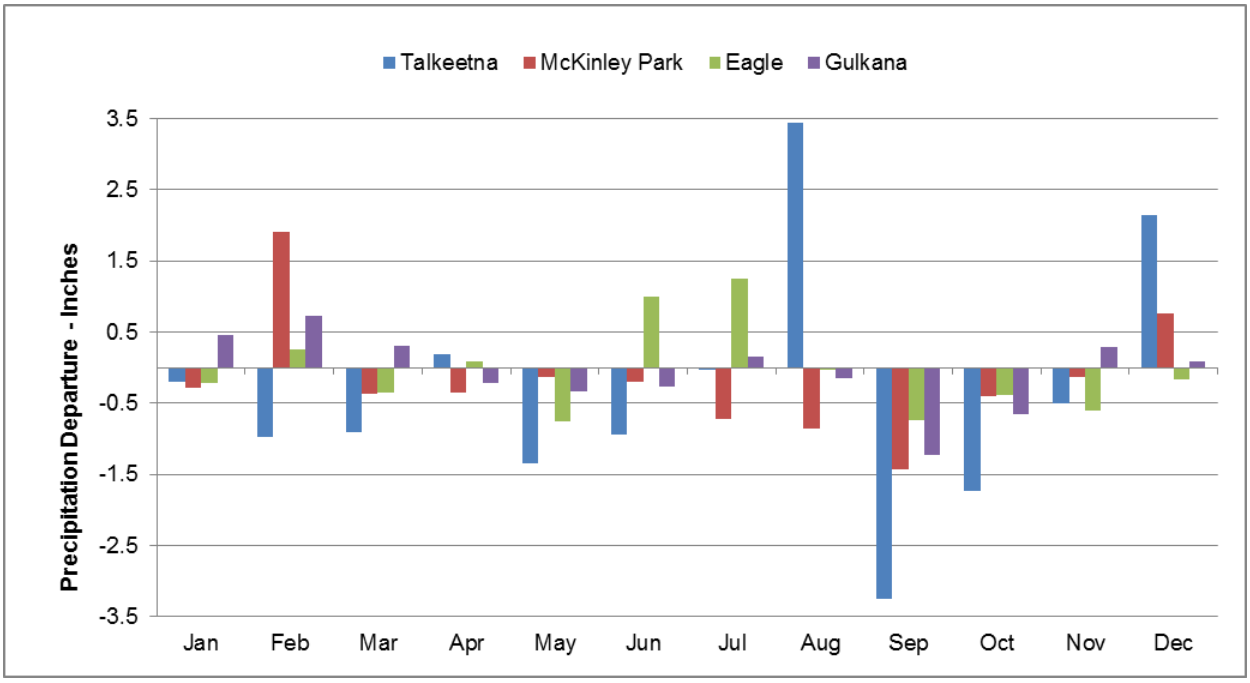
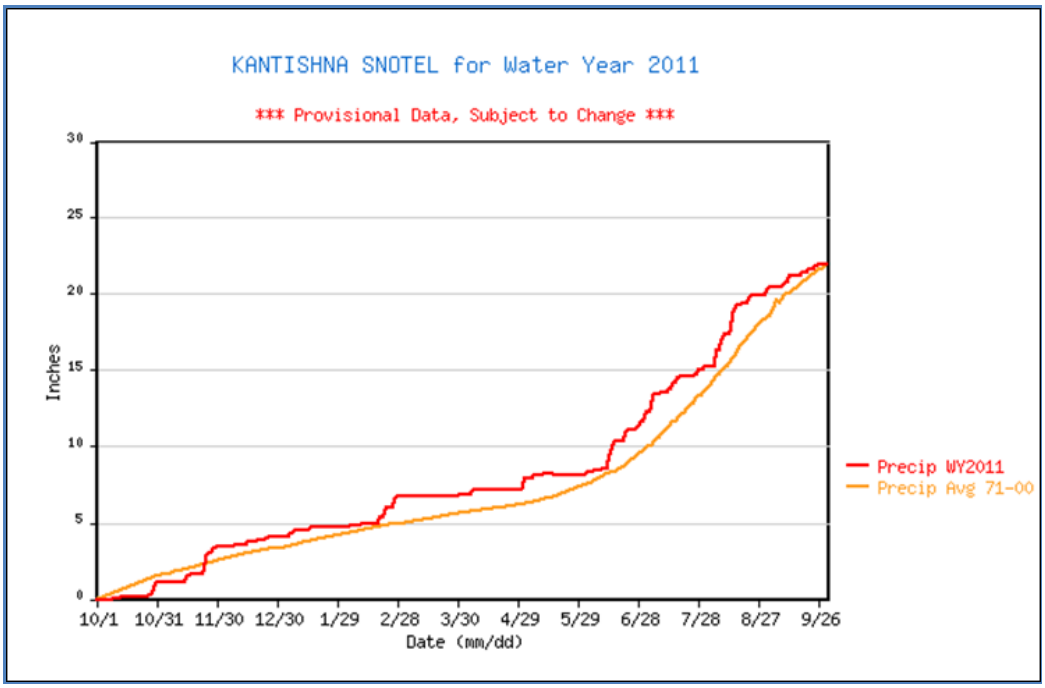


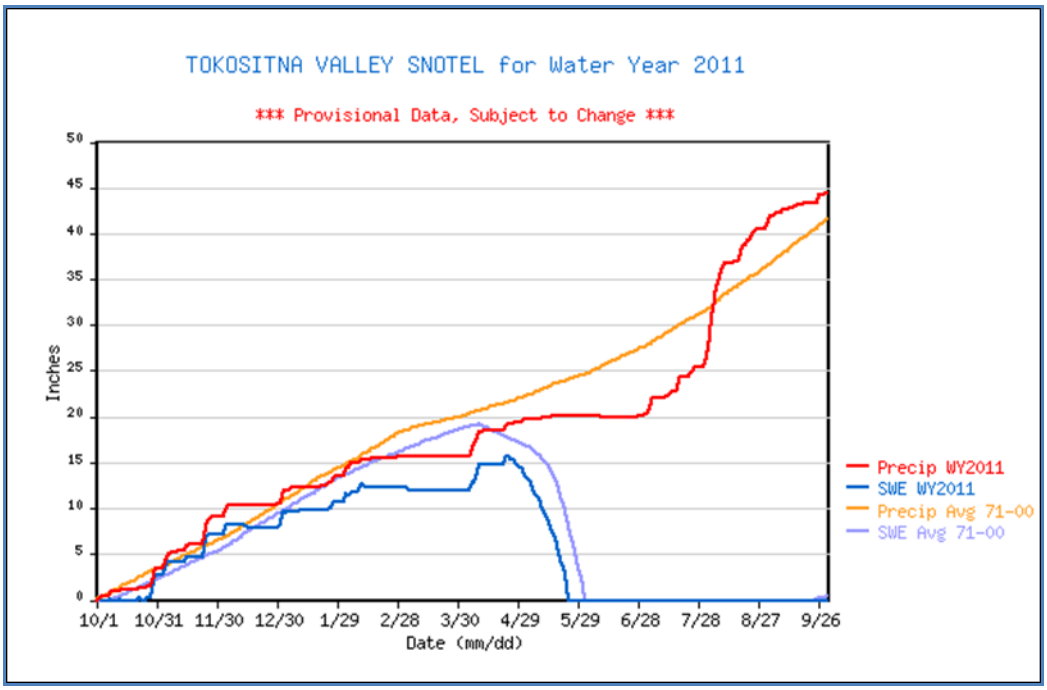
Figure 17. Monthly precipitation totals departure from normal for 2011.

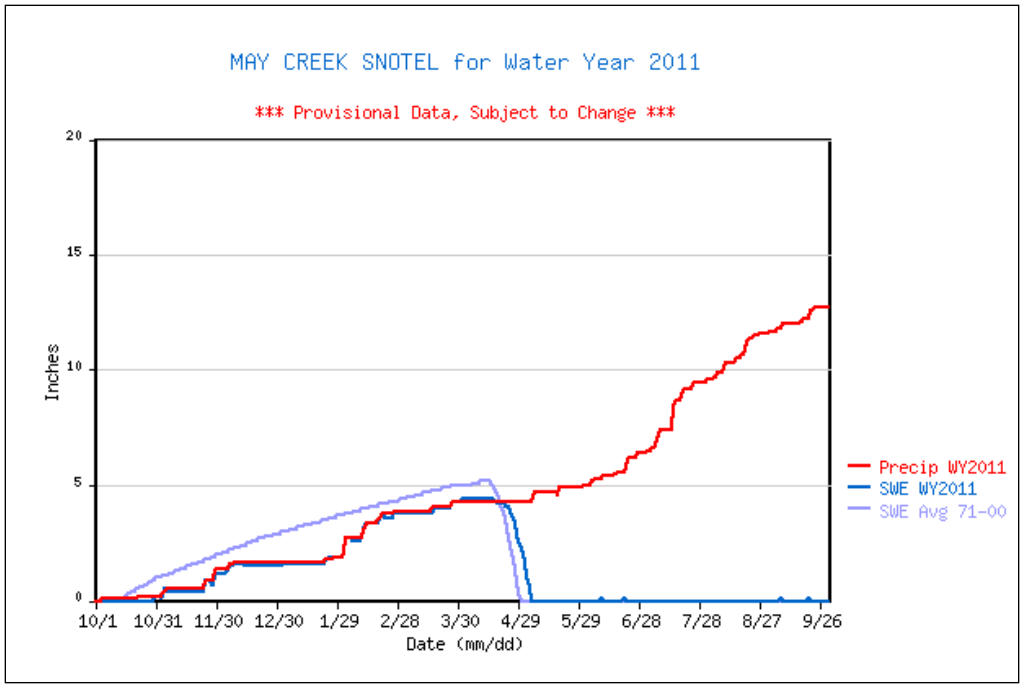
Year round precipitation is recorded at the new snow telemetry (SNOTEL) sites deployed in Denali and Wrangell-St. Elias as part of the CAKN climate and snow program. The Mission Creek SNOTEL near Eagle was destroyed in the Yukon River flood in May 2009. The new American Creek SNOTEL site was installed in summer of 2011 and will start reporting for the upcoming water year. 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, along with the snow courses and aerial markers, surveyed monthly throughout the winter season, are based on the 'water year' running from October 1 through September 30. An annual report summarizing the snow and precipitation data from snow courses, aerial markers, and SNOTEL sites around the network is produced in the late fall of each year (Sousanes, 2012).

The Kantishna SNOTEL site recorded 7.3 inches of total winter precipitation (snow water equivalent) from October 1, 2010 through May 1, 2011, 118% of average. The total annual precipitation for the site was 22.0 inches; the winter snow accounted for 33% of the total annual precipitation. The precipitation gage at Tokositna Valley on the south side of the Alaska Range recorded 21.5 inches of precipitation from October 1, 2010 through May 1, 2011, which is 0.6 inches below the 1971-2000 normal. This is 48% of the total annual precipitation of 44.4 inches for the 2011 water year. Note that normal have not been calculated for the latest 1981-2010 normal period for the SNOTEL sites.

The SNOTEL site at May Creek, between the Chugach and Wrangell Mountain Ranges in Wrangell-St. Elias, reported precipitation, snow water equivalent, and cumulative precipitation. There was 4.3 inches of snow water equivalent on May 1st; the annual total precipitation was 12.7 inches, so the winter snowfall accounted for 33% of the total precipitation for the year. The SNOTEL site at Chisana recorded 3.3 inches of snow water equivalent as of May 1st; the annual precipitation total was 12.3 inches. The winter snowfall accounted for 27% of the total annual precipitation. Cumulative precipitation graphs for the four SNOTEL sites are presented in Figure 18 (note the differences in scale). The average for 1971-2000 is included in the graphs as a reference to normal if the records for the individual sites are long enough.


KANTISHNA SNOTEL for Water Year 2011
*** Provisional Data, Subject to Change ***
Inches
30
25
20
15
10
5
0
10/1 10/31 11/30 12/30 1/29 2/28 3/30 4/29 5/29 6/28 7/28 8/27 9/26
Date (mm/dd)
Precip WY2011
Precip Avg 71-00


TOKOSITNA VALLEY SNOTEL for Water Year 2011
*** Provisional Data, Subject to Change ***
Inches
50
45
40
35
30
25
20
15
10
5
0
10/1 10/31 11/30 12/30 1/29 2/28 3/30 4/29 5/29 6/28 7/28 8/27 9/26
Date (mm/dd)
Precip WY2011
SWE WY2011
Precip Avg 71-00
SWE Avg 71-00



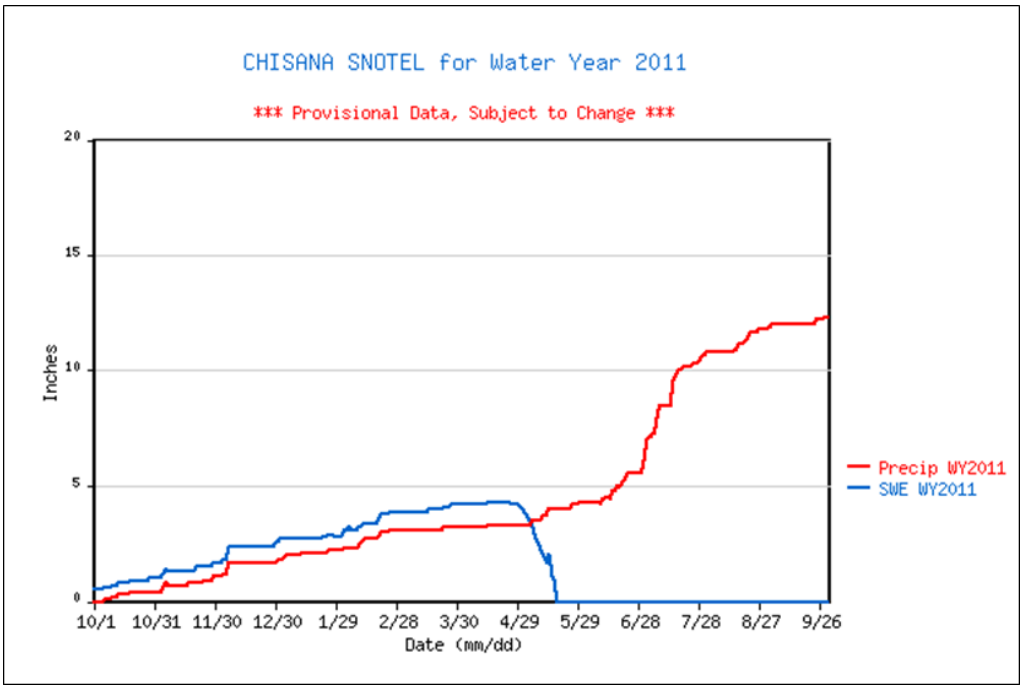


Figure 18. Cumulative precipitation for Water Year 2011 (Oct. 1 – Sep.30) for four SNOTEL sites.

Summary

The climate data for 2011 was compiled and summarized using CAKN data from the NPS sites and from index sites around the region. On average the Central Alaska region was cooler and drier at most sites compared to normal. The data from long-term sites are available at the Western Regional Climate Center (http://www.wrcc.dri.edu/CLIMATEDATA.html) and the National Climatic Data Center (http://www.ncdc.noaa.gov/oa/climateresearch.html). The CAKN climate stations transmit data via satellite and are available on the web at http://www.wrcc.dri.edu/NPS.html. Data products that are available include daily and monthly summaries, time series graphs, wind rose graphs, data inventories, and station metadata for all of the automated stations. The data are downloaded from the stations each year and are QA/QC by network staff and sent to WRCC to fill in any gaps from missed satellite transmissions. The raw data are also available for download through the 'data lister' tool on the WRCC website. These data are also ingested by multiple other networks and agencies and displayed in various formats. The University of Utah provides a well-organized link to all of the Alaska data on their web site at http://mesowest.utah.edu/index.html.

The 2011 field season marked the fifth year of operational climate monitoring within CAKN. Annual maintenance was performed on all climate and snow monitoring instruments in the three CAKN parks. Maintenance included sensor replacement, troubleshooting, upgrades, data downloads, and sensor calibrations. Station maintenance logs were used to keep track of the climate station inventory for DENA, WRST, and YUCH which includes; sensors, data loggers, towers, solar panels, and batteries. Sensor and power performance was tracked and instrumentation was replaced as necessary.

An interagency agreement is in place for the maintenance, data archiving, and data dissemination for the four SNOTEL sites in the network. The data from the stations are transmitted hourly via meteor burst communication and are on-line at http://www.ak.nrcs.usda.gov/snow/.

This annual report provided a climate summary for the CAKN region in 2011 with brief references to the Alaska regional climate and the global climate. For a graphic display of worldwide significant climate anomalies for 2011 see Appendix D.

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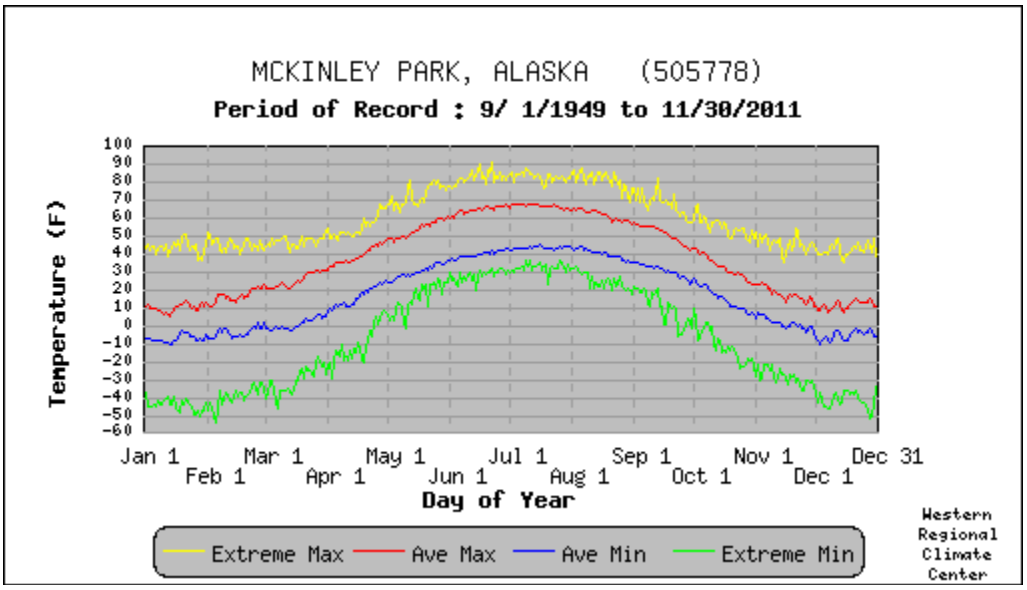
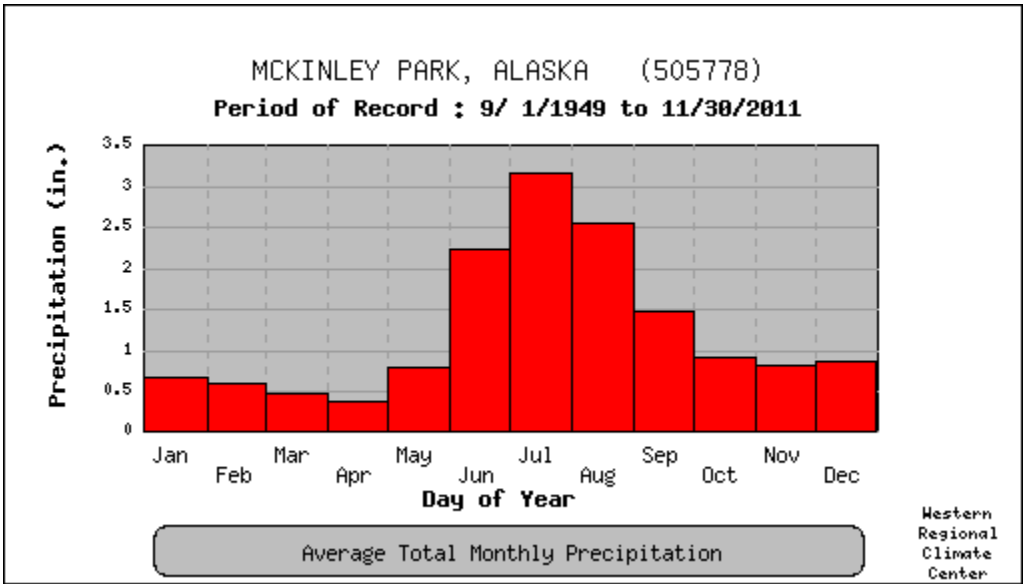
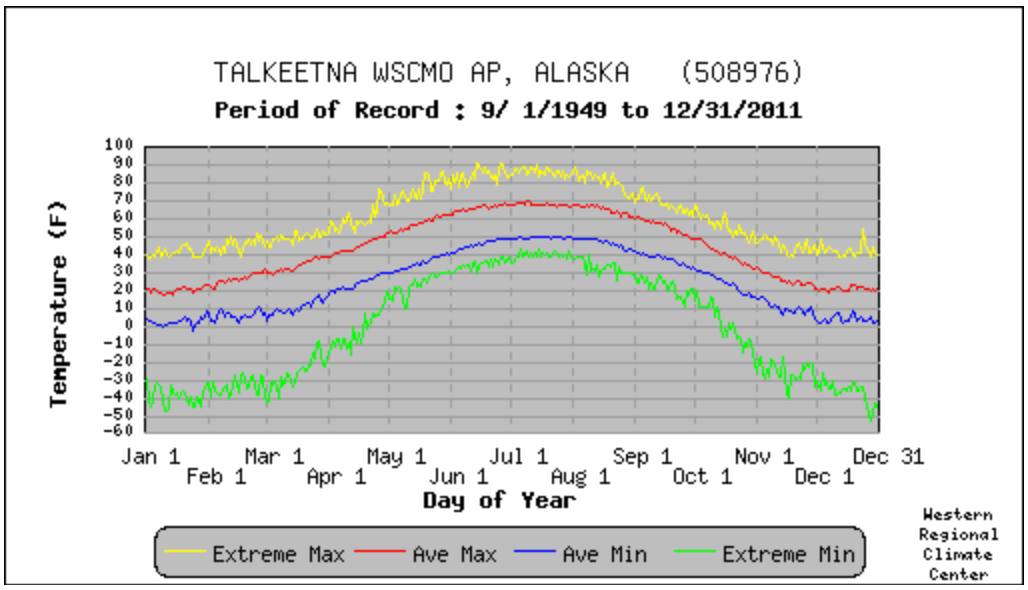
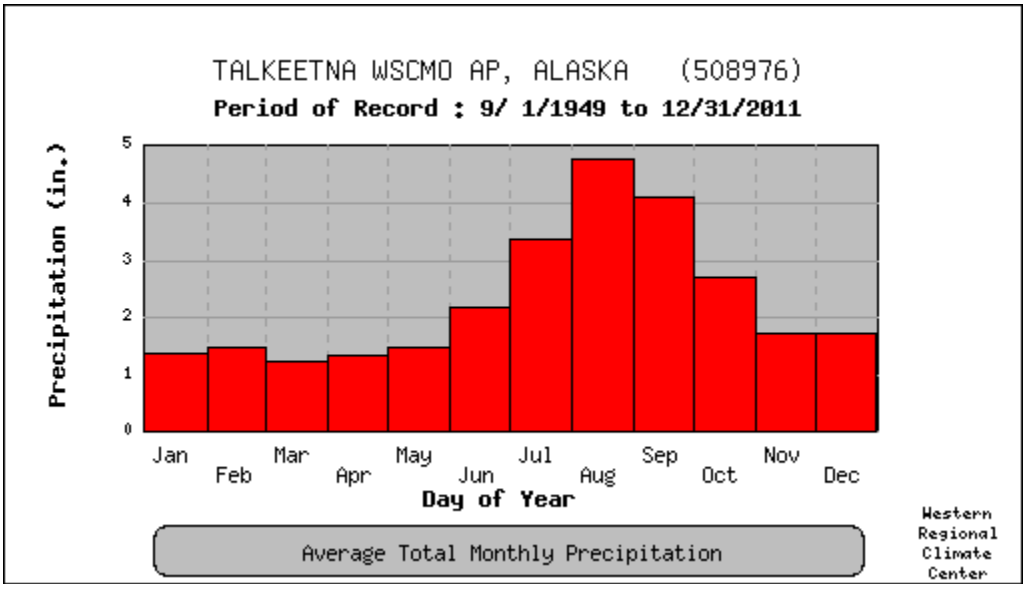
Appendix A. Period of Record Means at Long-term Sites

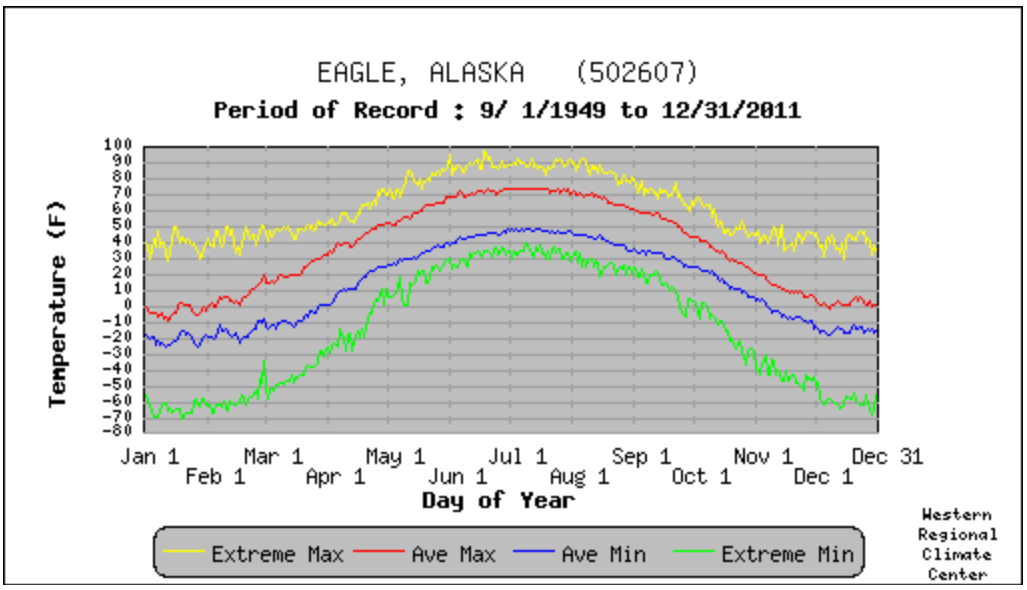
Annual summary stats retrieved from http://www.wrcc.dri.edu/summary/Climsmak.html.

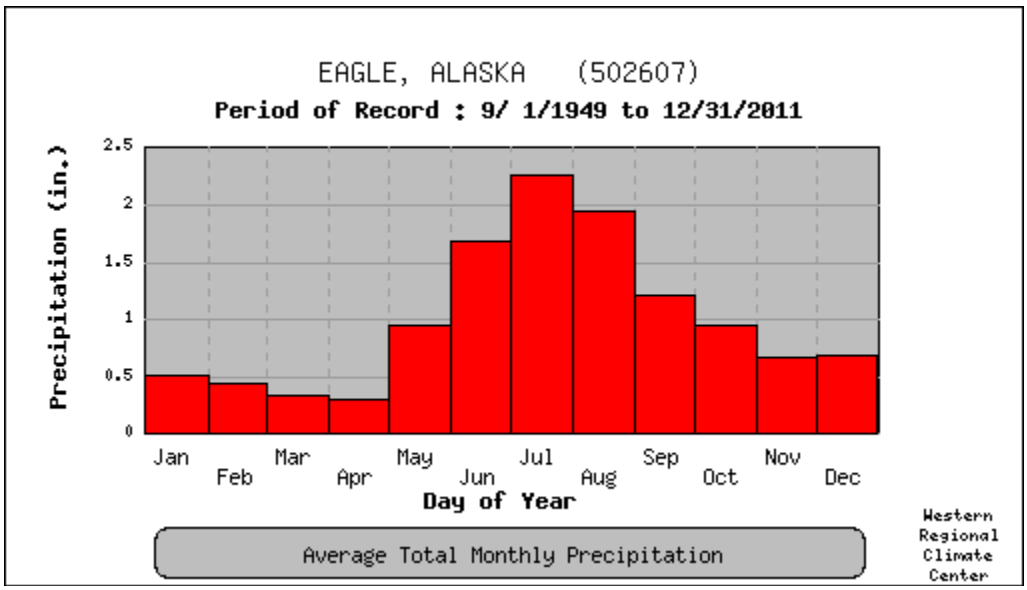


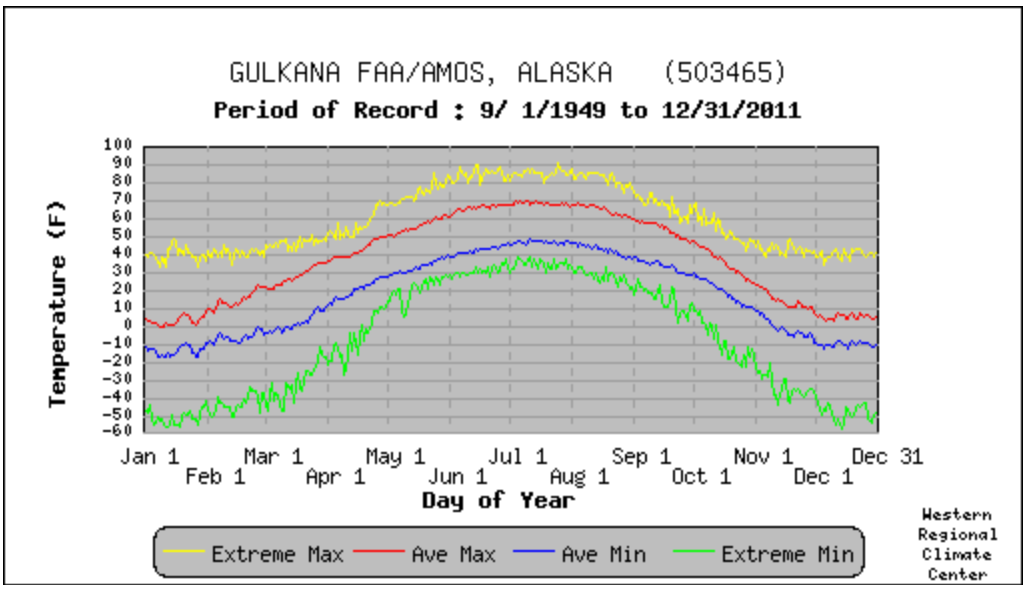


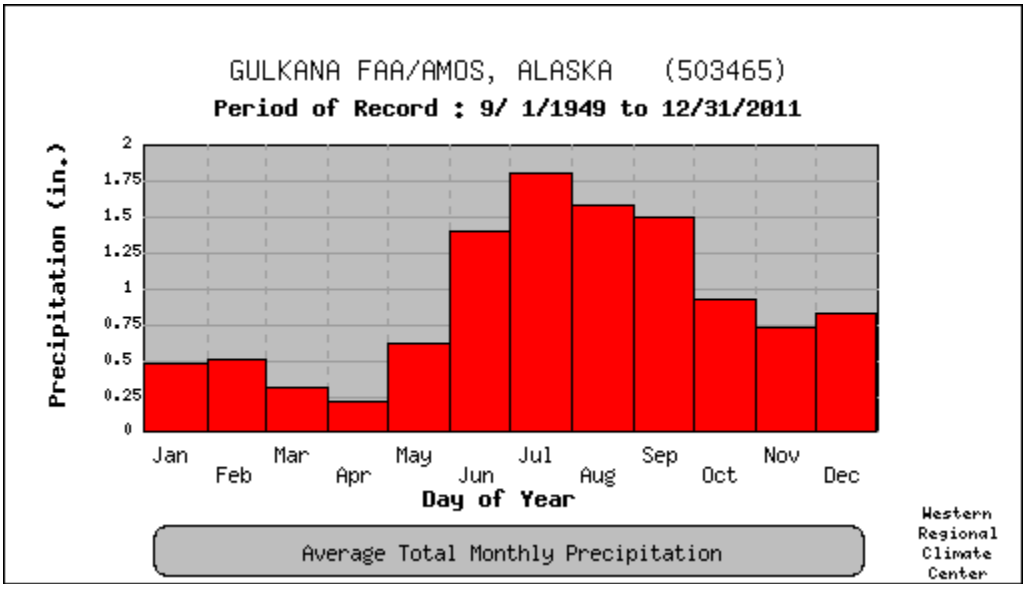

TALKEETNA WSCMO AP, ALASKA (508976)
Period of Record : 9/ 1/1949 to 12/31/2011
Temperature (F)
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Dec 31
Day of Year
Extreme Max
Ave Max
Ave Min
Extreme Min
Western Regional Climate Center

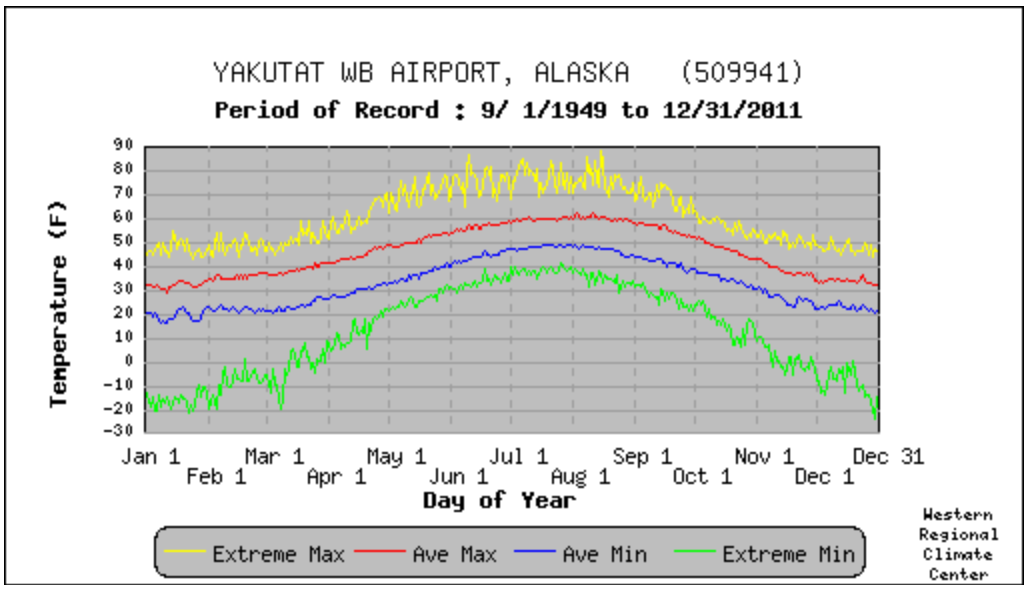

TALKEETNA WSCMO AP, ALASKA (508976)
Period of Record : 9/ 1/1949 to 12/31/2011
Precipitation (in.)
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Day of Year
Average Total Monthly Precipitation
Western Regional Climate Center

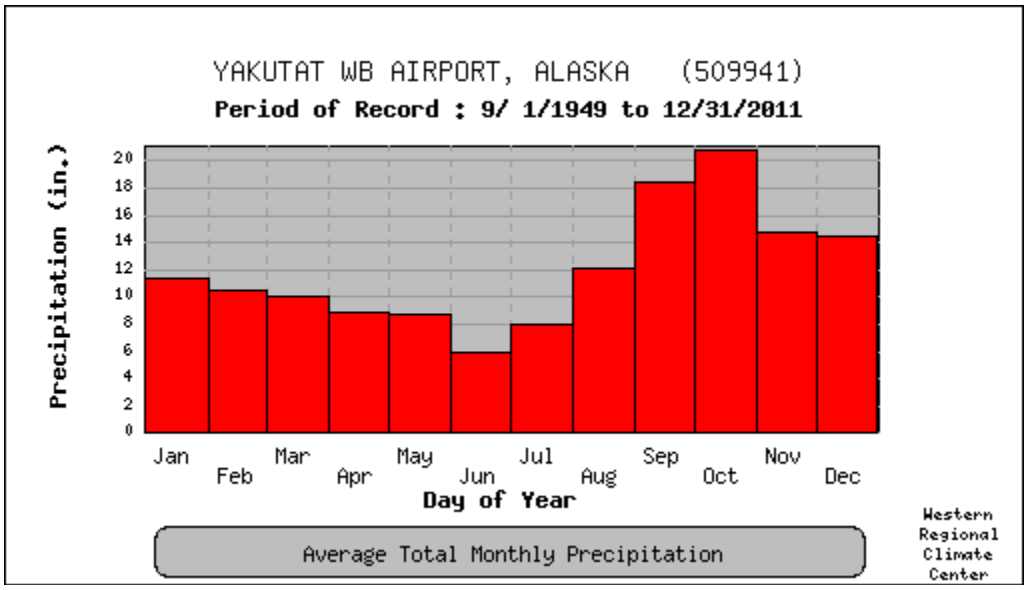

EAGLE, ALASKA (502607)
Period of Record : 9/ 1/1949 to 12/31/2011
Temperature (F)
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Dec 31
Day of Year
Extreme Max
Ave Max
Ave Min
Extreme Min
Western Regional Climate Center


EAGLE, ALASKA (502607)
Period of Record : 9/ 1/1949 to 12/31/2011
Precipitation (in.)
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Day of Year
Average Total Monthly Precipitation
Western Regional Climate Center


GULKANA FAA/AMOS, ALASKA (503465)
Period of Record : 9/ 1/1949 to 12/31/2011
Temperature (F)
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Dec 31
Day of Year
Extreme Max
Ave Max
Ave Min
Extreme Min
Western Regional Climate Center


GULKANA FAA/AMOS, ALASKA (503465)
Period of Record : 9/ 1/1949 to 12/31/2011
Precipitation (in.)
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Day of Year
Average Total Monthly Precipitation
Western Regional Climate Center


YAKUTAT WB AIRPORT, ALASKA (509941)
Period of Record : 9/ 1/1949 to 12/31/2011
Temperature (F)
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Dec 31
Day of Year
Extreme Max
Ave Max
Ave Min
Extreme Min
Western Regional Climate Center


YAKUTAT WB AIRPORT, ALASKA (509941)
Period of Record : 9/ 1/1949 to 12/31/2011
Precipitation (in.)
20
18
16
14
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Day of Year
Average Total Monthly Precipitation
Western Regional Climate Center

Appendix B. 2011 Climate Extremes at Long-term Sites

Daily summary stats retrieved from:
http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ak5778

Monthly summary stats retrieved from:
http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ak5778

McKinley Park - 2011 Records – 87 years

Record High Temperatures °F	78	May 29
Record Low Temperatures °F	-32, -30	Nov 21, 22
Record precipitation - inches	0.35, 0.66	Feb 21, 25
Record snowfall - inches	11, 13.2	Feb 21, Feb 25
	2.6	Sep 29
	3.5	Nov 11

Talkeetna – 2011 Records – 62 years

Record High Temperatures °F	37, 38, 40	Jan 2,3, and 4
	40	Jan 11
	41	Feb 2
	84	May 27
Record precipitation - Inches	0.76	Aug 7
	1.28	Dec 4

Eagle – 2011 Records -56 years

Record High Temperatures °F	30	Jan 4
	51	Mar 31
	74, 79, 79, 79,	May 18, 19, 20, 22
	86, 85, 86	May 28, 29, 30
	67, 74	Sep 13, 14
Record low temperatures °F	-43	Nov 19
Record Snowfall – in.	3.0	Nov 8

Gulkana 2011 records – 61 years of data

Record high temperatures °F	80, 78, 78	May 27, 28, 29
	67	Sep 13
	46	46
Record low temperatures °F	35	July 20
	-35	Nov 20
Record precipitation – Inches	0.64	Feb 11
	0.72	Aug 19

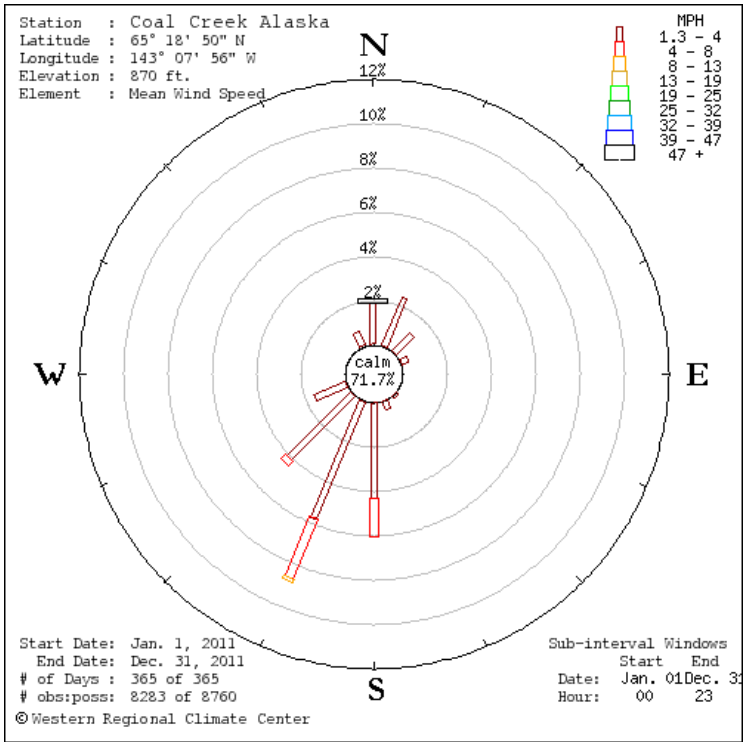
Yakutat 2011 records – 62 years of data

Record high temperatures °F:	45, 44	Feb 2,3
	52	Mar 28
	59	Oct 11
	-3	Mar 11
	2.92	Dec 4
Record snowfall – Inches	12.3	Nov 16
	12.5, 4.4	Nov 22, 23
Record snow depth - Inches	27	Nov 20
	50, 44, 37	Nov 28, 30 Dec 1

Appendix C. 2011 CAKN Climate Station Monthly Data

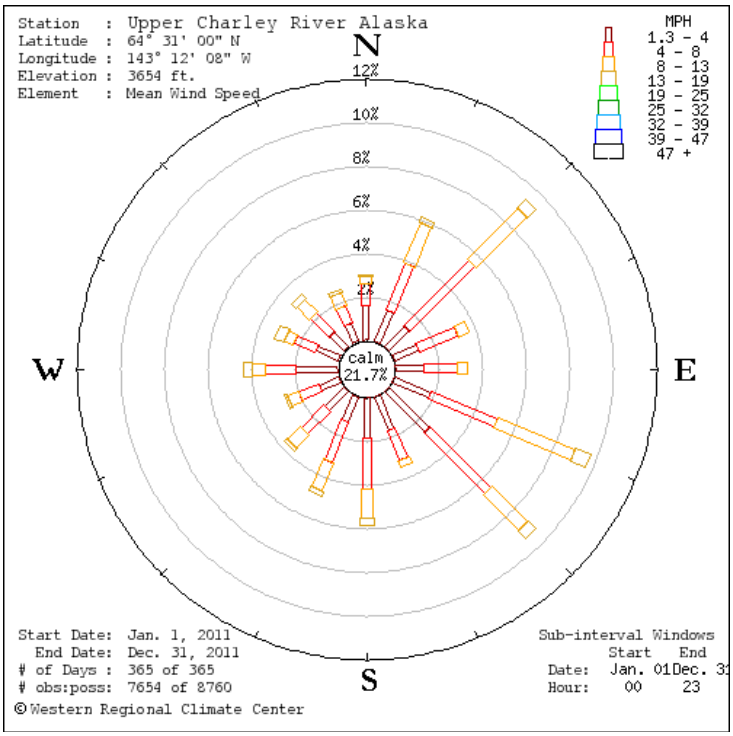
Coal Creek Alaska

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Average Soil Temperature Inches			Relative Humidity	Snow Depth	Summer Precip*
Date	ly	mph	Deg	mph	Deg F			Deg F			%	in	in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	10 cm	20 cm	50 cm	Ave.	Ave.	Total
Jan-11	27	1	138	8	0	32	-47	15	28	29	84	20	
Feb-11	901	1	161	25	-6	38	-49	10	22	23	73	22	
Mar-11	5510	1	168	9	2	48	-42	15	19	21	66	24	
Apr-11	10472	2	176	9	26	54	-11	23	23	23	63	21	
May-11	13250	2	167	12	50	83	22	36	29	28	54	2	
Jun-11	11647	1	180	11	56	82	34	44	30	30	71	1	4.57
Jul-11	11330	1	180	9	58	81	38	49	31	31	73	1	2.55
Aug-11	8739	1	174	8	52	77	32	44	33	31	80	1	2.38
Sep-11	4756	1	169	8	44	72	25	37	32	31	80	1	
Oct-11	1711	1	137	7	25	50	-7	30	31	31	86	2	
Nov-11	132	1	152	10	-12	31	-43	18	31	31	77	6	
Dec-11	43	1	169	12	2	38	-35	20	31	30	80	10	



Upper Charley River Alaska

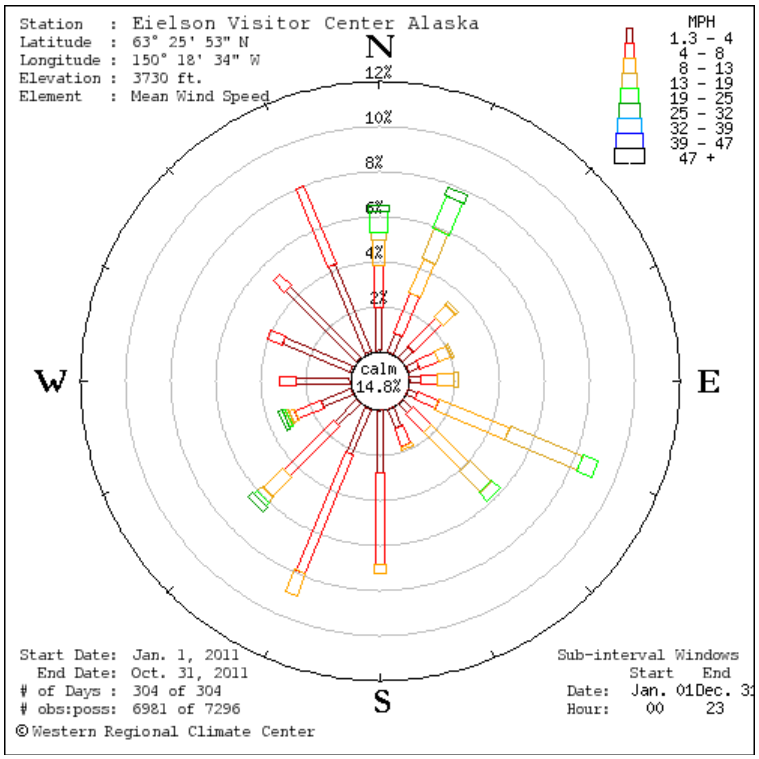
	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Average Soil Temperature			Relative Humidity	Snow Depth	Summer Precip
Date	ly	mph	Deg	mph	Deg F			Deg F			%	in	in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	10 cm	20 cm	50 cm	Ave.	Ave.	Total
Jan-11	1574	0	12	0	2	24	-28	17	21	20	89	20	
Feb-11	9687	4	124	41	-2	31	-34	15	19	18	83	20	
Mar-11	7134	5	110	26	7	39	-17	14	17	14	64	24	
Apr-11	12108	5	178	21	23	49	-1	21	21	20	68	23	
May-11	14920	6	160	25	42	70	19	36	30	29	58	13	
Jun-11	11143	5	180	23	48	71	35	47	39	38	73	0	m
Jul-11	10952	4	193	22	51	70	39	50	44	44	74	0	m
Aug-11	8583	5	152	24	46	64	33	46	43	43	75	0	m
Sep-11	9349	6	136	22	39	61	21	39	38	38	77	0	
Oct-11	4106	4	144	21	22	41	1	29	32	32	89	0	
Nov-11	653	4	164	23	-5	14	-28	20	26	25	85	3	
Dec-11	110	5	155	34	7	32	-16	19	22	21	91	7	



Eielson Visitor Center

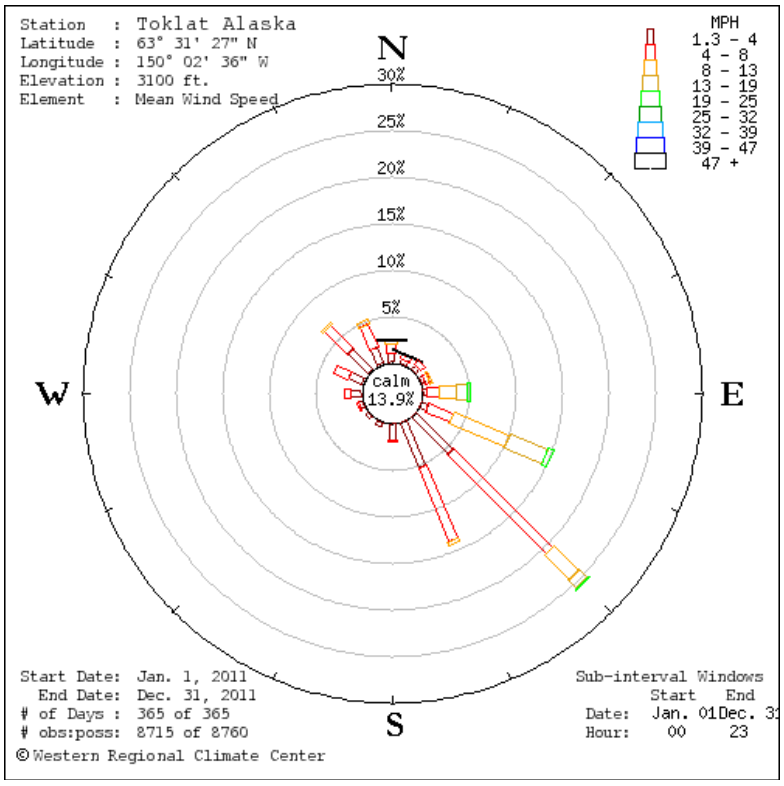
	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Relative Humidity	Summer Precip
Date	ly	mph	Deg	mph	Deg F			%	In.
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	Ave.	Total
Jan-11	532	9	183	48	20	42	-16	M	
Feb-11	1891	6	244	42	13	44	-23	M	
Mar-11	8249	9	155	30	19	39	-4	M	
Apr-11	12424	6	191	37	26	45	-5	M	
May-11	11013	7	162	25	43	68	17	42	
Jun-11	12370	5	184	27	47	63	33	72	2.85*
Jul-11	11301	4	196	24	48	65	34	78	8.04
Aug-11	9172	5	179	25	45	60	32	77	6.54
Sep-11	6551	6	169	32	41	60	23	69	
Oct-11	3129	5	175	30	28	42	3	68	
Nov-11	832	6	223	39	5	30	-29	64	
Dec-11	167	8	208	47	13	44	-25	69	

- June precip total from NWS gage at same location



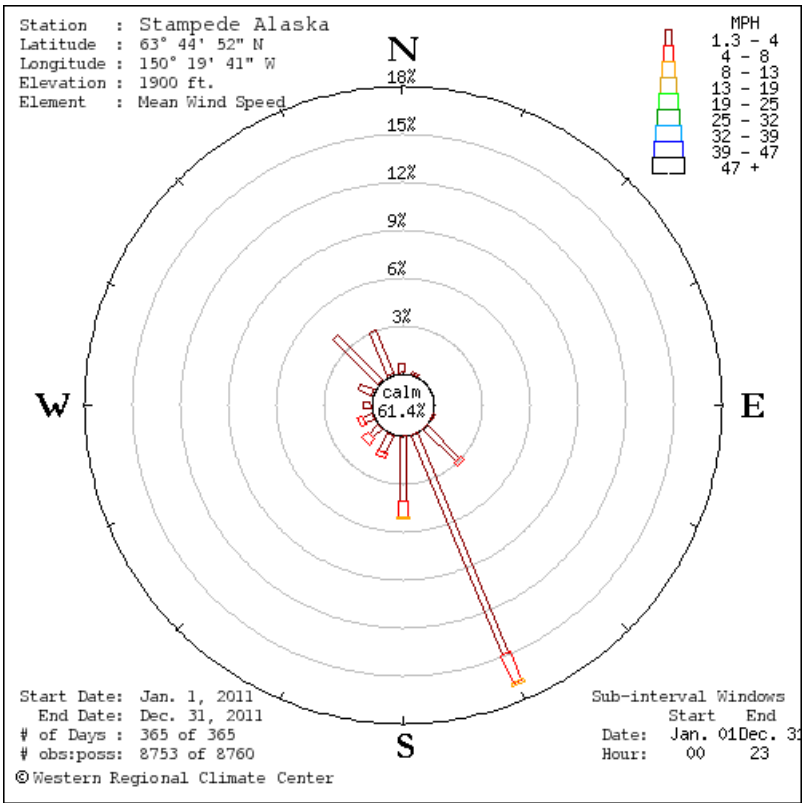
Toklat Alaska

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Average Soil Temperature			Relative Humidity	Snow Depth	Summer Precip
Date	ly	mph	Deg	mph	Deg F			Deg F			%	in	in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	10cm	20cm	50cm	Ave.	Ave.	Total
Jan-11	429	6	165	34	11	39	-27	17	18	20	66	4	
Feb-11	1480	6	170	31	6	37	-35	21	22	23	70	8	
Mar-11	6597	5	172	24	9	37	-25	23	24	24	61	12	
Apr-11	10465	6	180	34	25	43	-15	29	29	29	67	9	
May-11	15800	6	172	24	41	70	17	47	42	40	53	1	
Jun-11	12419	5	191	26	49	66	33	55	53	50	68	4	3.11
Jul-11	10521	4	202	23	50	67	35	55	54	52	74	5	2.67
Aug-11	8596	5	186	24	46	62	31	48	48	47	75	5	3.51
Sep-11	5494	6	175	25	41	57	25	42	41	41	71	3	
Oct-11	2684	5	170	28	27	44	-9	30	30	31	76	3	
Nov-11	645	5	145	33	-1	31	-35	23	25	26	71	6	
Dec-11	148	6	157	38	10	42	-38	27	27	28	76	8	



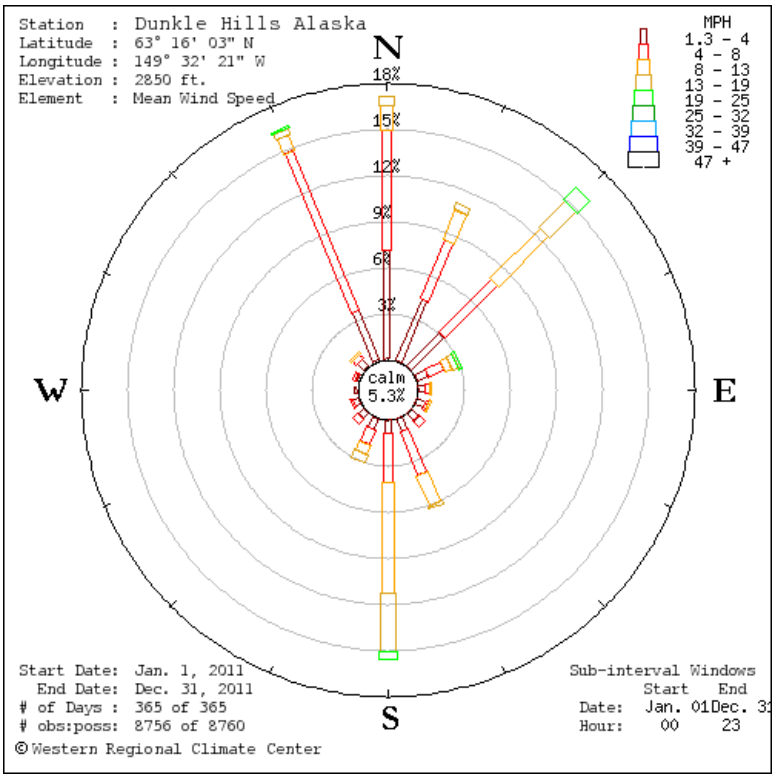
Stampede Alaska

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Average Soil Temperature			Relative Humidity	Snow Depth	Summer Precip
Date	ly	mph	Deg	mph	Deg F			Deg F			%	in	
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	10cm	20cm	50cm	Ave.	Ave.	
Jan-11	280	1	209	20	-1	44	-39	14	17	18	81	9	0
Feb-11	401	2	221	18	1	36	-38	16	17	18	81	16	0
Mar-11	6647	2	170	10	5	42	-36	17	18	19	65	21	0
Apr-11	11133	2	165	11	27	52	-10	24	24	24	65	17	0
May-11	16078	2	154	18	45	75	17	45	43	37	53	1	0
Jun-11	13417	1	163	13	52	75	33	55	54	48	69	1	2.31
Jul-11	11616	1	152	8	53	73	33	57	56	52	73	1	1.65
Aug-11	9193	1	143	11	48	67	30	50	51	49	81	1	2.62
Sep-11	5542	1	141	12	42	65	21	42	43	43	78	1	1.22
Oct-11	1992	1	173	12	24	52	-10	28	31	33	85	2	0
Nov-11	194	1	173	12	-9	31	-40	21	24	27	78	9	0
Dec-11	59	1	158	19	4	47	-45	23	25	26	82	14	0



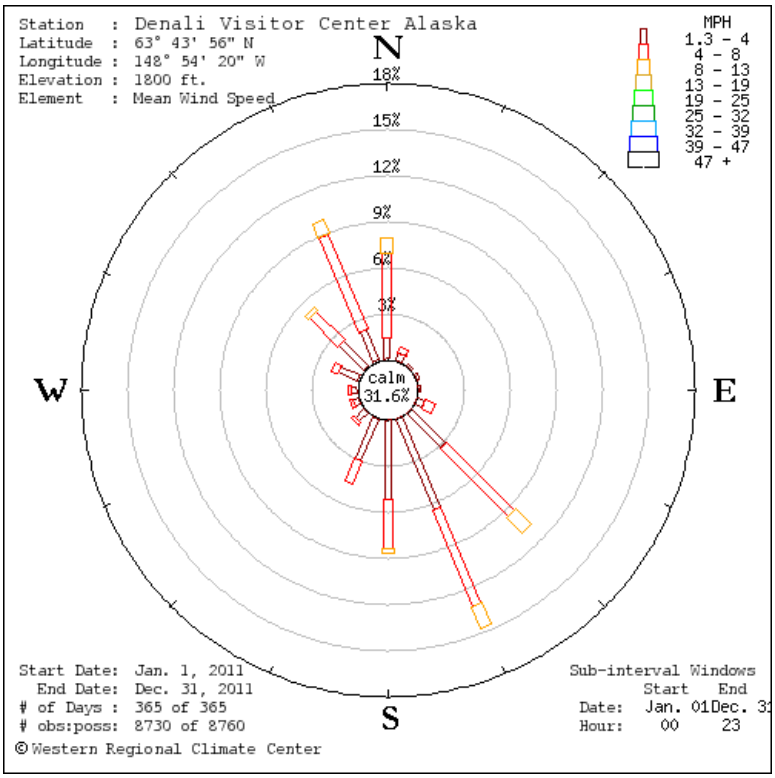
Dunkle Hills

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Average Soil Temperature			Relative Humidity	Snow Depth	Summer Precip
Date	ly	mph	Deg	mph	Deg F			Deg F			%	in	in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	10cm	20cm	50cm	Ave.	Ave.	Total
Jan-11	670	7	164	34	11	44	-27	23	23	30	72	16	
Feb-11	2372	10	124	38	6	35	-19	22	22	28	71	20	
Mar-11	8435	7	159	29	10	36	-18	18	18	24	63	12	
Apr-11	12685	7	187	26	26	51	-6	24	24	26	76	19	
May-11	17656	7	197	26	40	74	18	35	34	30	61	6	
Jun-11	14168	8	185	25	48	71	32	49	47	35	73	0	0.91
Jul-11	12555	7	174	24	50	69	33	52	51	41	77	0	2.89
Aug-11	8804	7	168	27	46	62	31	48	47	43	84	0	3.88
Sep-11	6024	6	173	28	41	62	18	41	42	m	79	0	
Oct-11	2891	4	162	23	26	44	-1	32	33	m	82	6	
Nov-11	1006	7	156	32	2	30	-21	29	30	m	73	12	
Dec-11	198	7	165	45	12	33	-21	28	28	m	87	18	



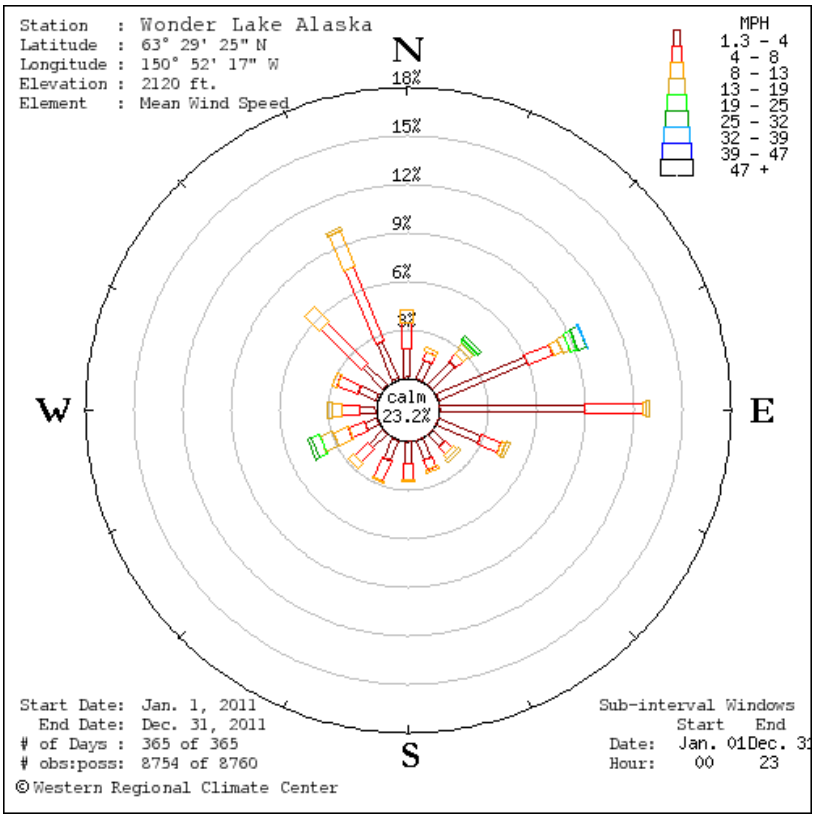
Denali Visitor Center

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Fuel Temp			Relative Humidity			Precipitation
Date	ly	mph	Deg	mph	Deg F			Deg F			%			in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Total
Jan-11	144	2	167	29	-2	42	-43	-3	39	-40	75	100	24	
Feb-11	732	4	159	28	0	36	-46	8	29	-26	75	100	33	
Mar-11	7381	3	156	23	6	47	-41	11	31	-23	60	98	15	
Apr-11	12041	4	155	24	30	54	-20	29	63	1	61	100	19	
May-11	17544	4	353	25	46	84	14	46	93	8	51	100	14	
Jun-11	15177	3	159	24	55	82	30	55	92	24	62	97	21	2.12
Jul-11	12812	3	166	27	56	81	32	56	93	25	67	98	18	2.00
Aug-11	8565	3	169	24	51	74	27	50	81	21	73	98	24	1.77
Sep-11	5806	3	165	24	44	67	22	42	74	15	69	97	25	
Oct-11	2138	3	165	29	28	52	-10	26	59	-15	75	96	34	
Nov-11	265	3	174	24	-6	32	-41	-8	32	-42	73	89	33	
Dec-11	45	3	163	31	8	43	-43	8	41	-31	77	95	54	



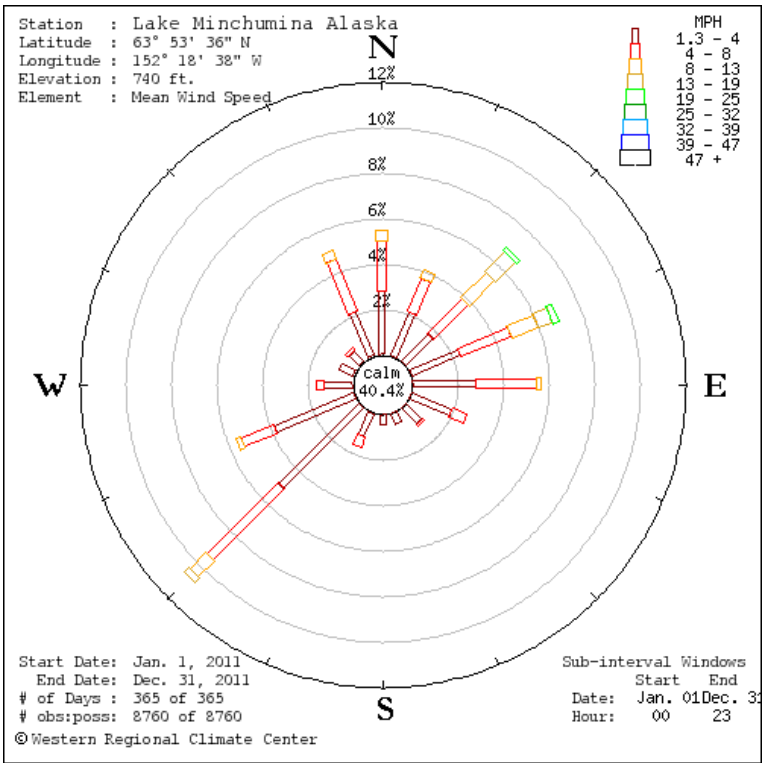
Wonder Lake Alaska

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Fuel Temp			Relative Humidity			Precipitation
Date	ly	mph	Deg	mph	Deg F			Deg F			%			in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Total
Jan-11	476	5	69	48	7	40	-32	6	39	-32	59	100	23	
Feb-11	2178	5	71	51	3	35	-35	4	40	-37	66	100	24	
Mar-11	8255	5	36	44	11	44	-19	12	52	-20	46	86	19	
Apr-11	14141	4	24	30	26	56	-8	27	66	-10	56	100	21	
May-11	18970	5	98	31	45	77	17	47	87	15	47	100	15	
Jun-11	14399	4	6	30	52	71	32	53	82	31	72	100	27	1.87
Jul-11	12648	4	359	25	53	75	35	55	85	34	75	100	27	2.47
Aug-11	9196	4	7	27	48	68	33	49	77	31	78	96	33	4.33
Sep-11	5756	4	40	34	42	64	18	42	69	17	75	95	27	
Oct-11	2687	4	63	37	25	51	-12	25	59	-14	75	95	30	
Nov-11	558	4	80	41	-4	29	-32	-5	31	-34	71	88	34	
Dec-11	128	5	80	46	6	50	-37	5	47	-39	72	96	39	



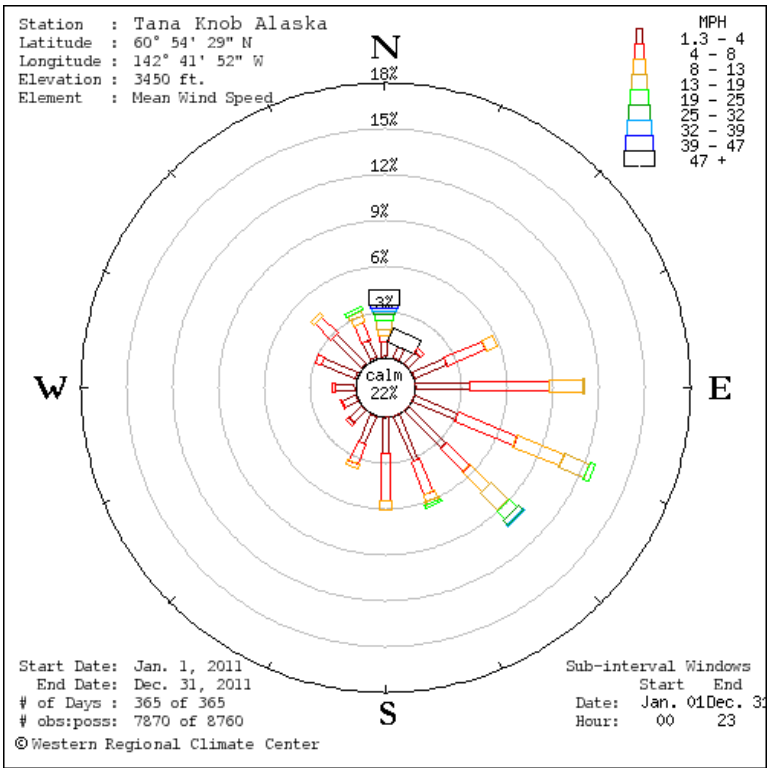
Lake Minchumina

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Fuel Temp			Relative Humidity			Precipitation
Date	ly	mph	Deg	mph	Deg F			Deg F			%			in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Total
Jan-11	410	4	351	49	-1	24	-30	2	22	-23	70	97	27	
Feb-11	913	3	313	38	0	36	-37	7	26	-20	69	100	32	
Mar-11	7506	6	36	41	15	42	-17	18	28	-1	44	87	15	
Apr-11	12304	3	72	20	31	58	-8	30	69	12	53	100	18	
May-11	17026	3	52	26	51	86	22	53	99	16	46	100	13	
Jun-11	13351	3	232	23	58	83	35	59	94	32	65	100	19	1.22
Jul-11	12072	2	237	19	58	83	38	59	98	35	71	100	24	1.71
Aug-11	8324	2	297	23	53	71	33	53	82	30	84	100	36	2.6
Sep-11	5608	3	24	36	47	67	29	46	76	24	77	100	36	
Oct-11	2637	3	345	20	29	51	8	28	59	2	87	100	52	
Nov-11	247	3	17	26	-3	28	-35	-5	28	-38	81	97	57	
Dec-11	74	3	318	33	5	36	-40	6	34	-30	86	98	59	



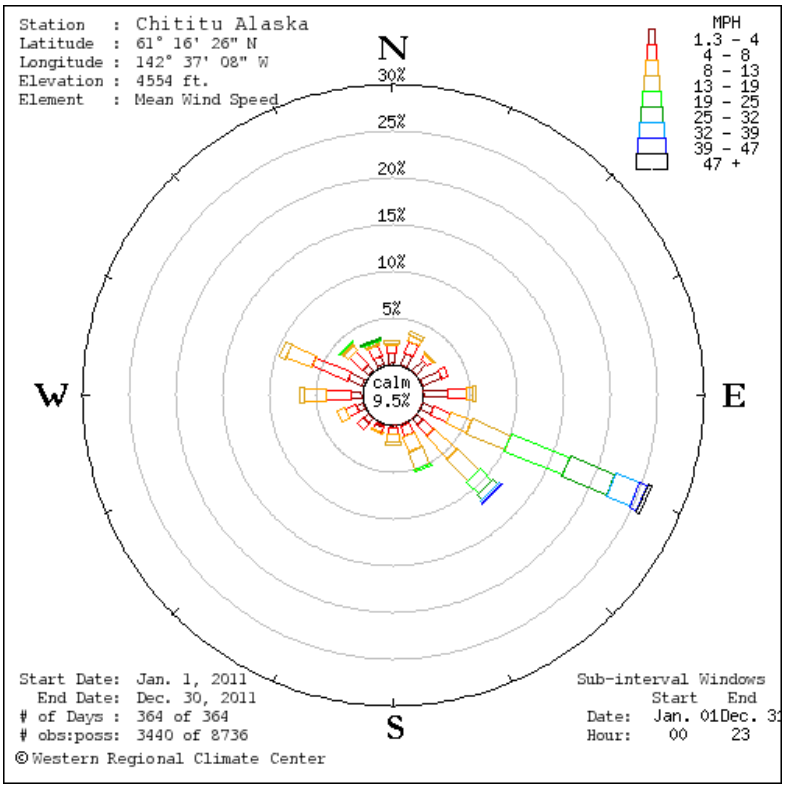
Tana Knob

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Average Soil Temperature			Relative Humidity	Snow Depth
Date	ly	mph	Deg	mph	Deg F			Deg F			%	in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	10cm	20cm	50cm	Ave.	Ave.
Jan-11	538	8	187	51	16	37	-28	30	31	m	74	25
Feb-11	2265	7	189	60	10	36	-19	31	31	m	80	46
Mar-11	6328	3	182	37	14	43	-8	24	25	m	62	17
Apr-11	15833	5	161	36	29	45	18	27	28	m	67	23
May-11	17346	4	201	32	40	64	28	35	32	m	62	13
Jun-11	10042	4	162	17	46	66	35	53	49	m	70	5
Jul-11	9998	4	160	15	49	66	38	55	53	48	77	0
Aug-11	7336	4	151	24	45	58	37	47	48	46	77	0
Sep-11	3949	4	132	32	40	56	28	38	40	42	75	0
Oct-11	1851	4	147	33	31	45	17	31	32	35	78	4
Nov-11	487	4	186	36	9	30	-19	29	31	33	89	13
Dec-11	118	10	133	50	20	38	0	30	31	32	93	52



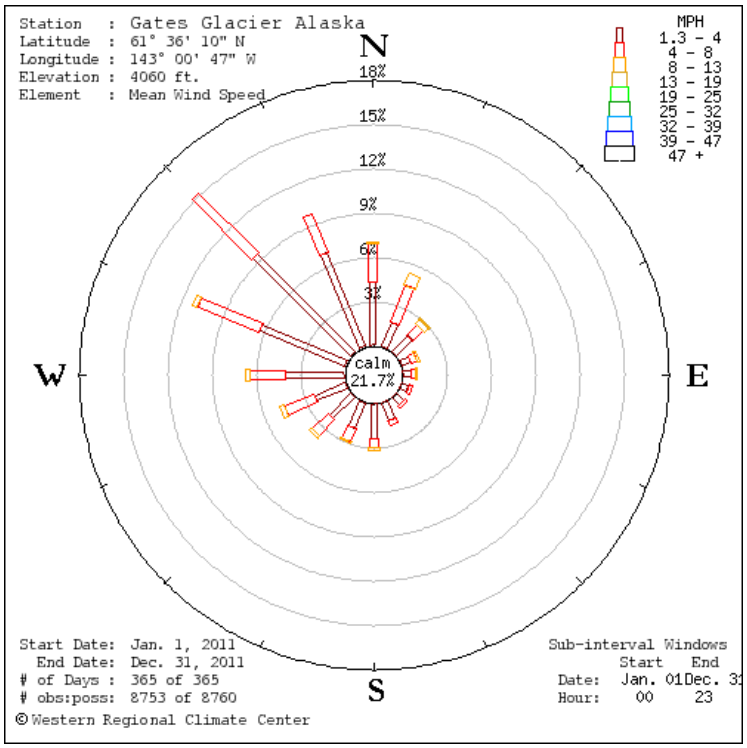
Chititu

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Average Soil Temperature			Relative Humidity	Snow Depth	Summer Precip
Date	ly	mph	Deg	mph	Deg F			Deg F			%	in	in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	10cm	20cm	50cm	Ave.	Ave.	Total
Jan-11	9594	14	163	50	15	35	-28	12	17	15	m	5	
Feb-11	19738	12	194	65	8	36	-20	14	19	16	m	6	
Mar-11	77713	7	176	34	12	37	-13	8	m	10	m	5	
Apr-11	118927	10	187	53	26	43	16	24	m	21	m	6	
May-11	156001	8	201	35	38	65	21	38	m	31	m	7	
Jun-11	122701	6	220	27	44	62	33	47	42	37	84	6	1.67
Jul-11	115751	6	215	33	47	67	36	50	44	41	82	0	3.4
Aug-11	88716	9	171	37	43	55	35	45	42	43	82	0	2.13
Sep-11	57935	11	146	51	38	56	26	37	37	42	74	12	
Oct-11	29775	12	144	56	29	41	16	29	31	38	71	18	
Nov-11	7876	11	148	54	9	30	-19	22	24	29	80	20	
Dec-11	3428	21	128	74	19	39	0	18	20	24	71	17	



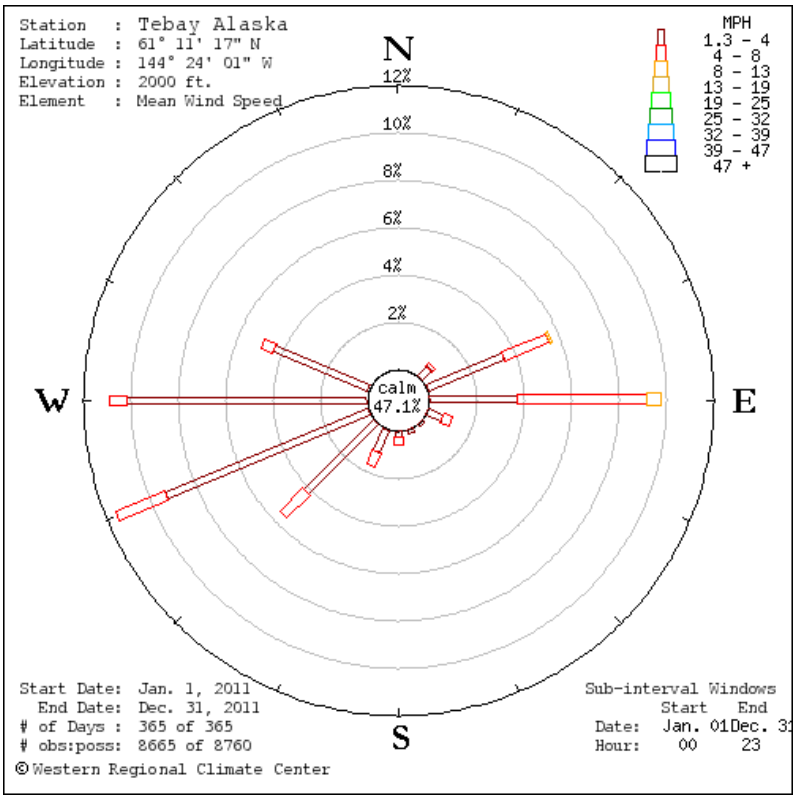
Gates Glacier

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Average Soil Temperature			Relative Humidity	Snow Depth	Summer Precip
Date	ly	mph	Deg	mph	Deg F			Deg F			%	in	in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	10cm	20cm	50cm	Ave.	Ave.	Total
Jan-11	796	4	262	35	16	37	-24	30	31	33	m	33	
Feb-11	1771	3	198	37	10	39	-17	30	31	32	m	55	
Mar-11	7814	2	275	32	14	37	-9	30	31	32	m	60	
Apr-11	12301	3	239	24	27	50	16	31	31	32	m	62	
May-11	17052	3	223	19	38	62	25	31	31	32	m	47	
Jun-11	14316	3	207	20	44	63	33	50	48	41	m	10	2.11
Jul-11	13168	2	214	14	47	63	35	54	53	48	78	0	3.86
Aug-11	8722	3	229	16	43	55	33	46	47	46	74	0	5.65
Sep-11	5401	3	220	25	38	57	26	37	40	42	70	0	
Oct-11	3101	3	239	18	29	42	14	30	32	35	70	9	
Nov-11	642	3	261	22	11	32	-17	30	32	34	78	24	
Dec-11	432	5	220	33	19	38	1	31	31	33	78	54	



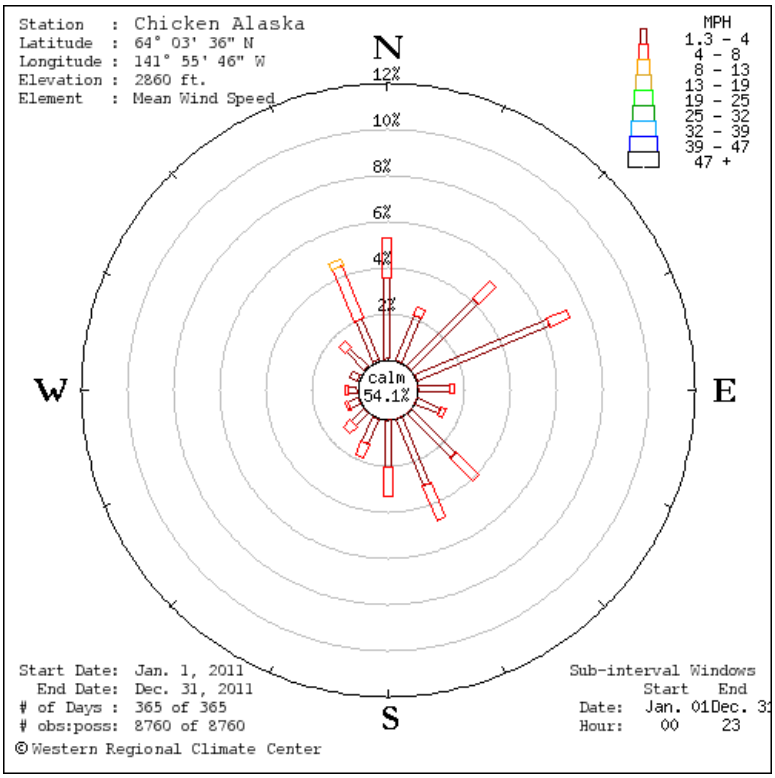
Tebay

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Average Soil Temperature			Relative Humidity	Snow Depth	Summer Precip
Date	ly	mph	Deg	mph	Deg F			Deg F			%	in	in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	10cm	20cm	50cm	Ave.	Ave.	Total
Jan-11	124	1	109	13	6	35	-31	30	30	31	86	34	
Feb-11	1977	3	120	17	8	35	-24	30	30	31	81	54	
Mar-11	7418	2	127	15	11	45	-22	28	29	30	67	49	
Apr-11	11854	2	205	11	30	51	4	30	30	31	75	45	
May-11	17368	2	226	9	42	72	27	34	34	32	68	13	
Jun-11	15207	3	253	11	49	71	30	51	50	43	70	0	m
Jul-11	9789	2	235	11	52	70	36	54	53	48	78	0	2.27
Aug-11	8168	2	226	11	49	68	34	51	51	49	84	0	2.14
Sep-11	4892	1	190	9	42	62	23	45	45	45	86	5	
Oct-11	2369	1	144	9	31	49	15	34	34	36	87	2	
Nov-11	326	2	90	12	8	35	-19	32	32	33	84	20	
Dec-11	63	1	132	19	19	36	-9	31	32	32	95	55	



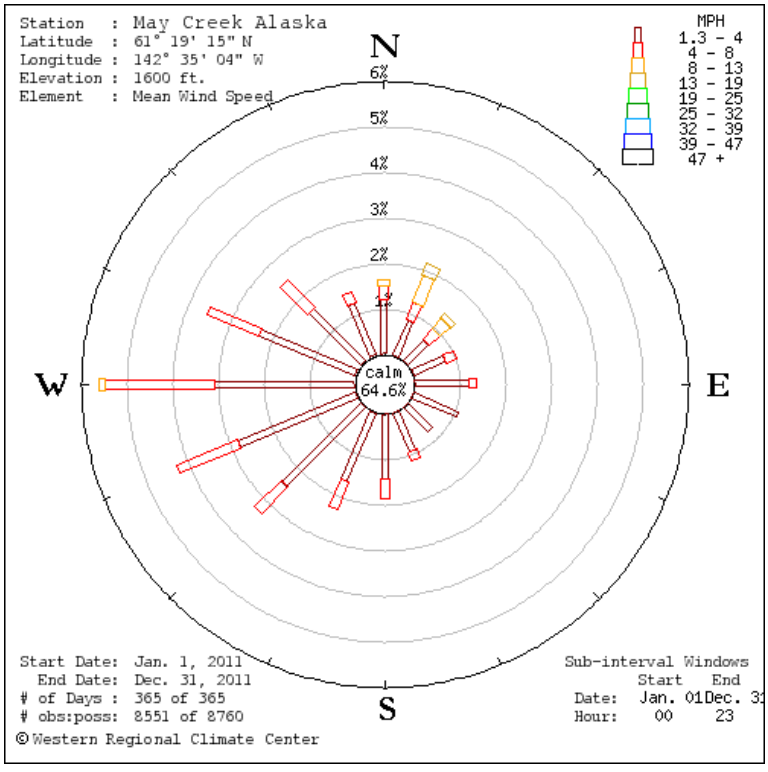
Chicken Creek

	Solar Radiation	Wind Speed	Wind Direction	Wind Gust	Air Temperature			Average Soil Temperature			Relative Humidity	Snow Depth	Summer Precip
Date	ly	mph	Deg	mph	Deg F			Deg F			%	in	in
	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	10cm	20cm	50cm	Ave.	Ave.	Total
Jan-11	1003	3.616	61	28	11	34	-30	18	16	19	73	3	
Feb-11	2230	3.737	49	48	19	33	-26	17	16	18	63	6	
Mar-11	8659	1.691	73	12	15	34	-18	10	7	12	64	6	
Apr-11	13125	3.454	71	29	26	39	10	20	19	18	61	6	
May-11	15426	4.347	58	27	39	59	18	31	30	27	56	3	
Jun-11	12338	5.21	318	24	42	57	32	41	40	34	76	0	1.4
Jul-11	12683	4.499	337	25	48	61	35	47	45	40	66	0	4.82
Aug-11	9959	4.642	65	23	46	53	34	42	42	40	70	0	2.31
Sep-11	6982	3.863	86	29	36	54	22	34	36	36	73	0	
Oct-11	3480	3.362	95	22	24	39	10	29	29	31	69	1	
Nov-11	1038	3.26	67	37	17	26	-26	19	16	23	70	3	
Dec-11	343.8	5.585	74	37	2	41	-3	19	17	19	75	5	



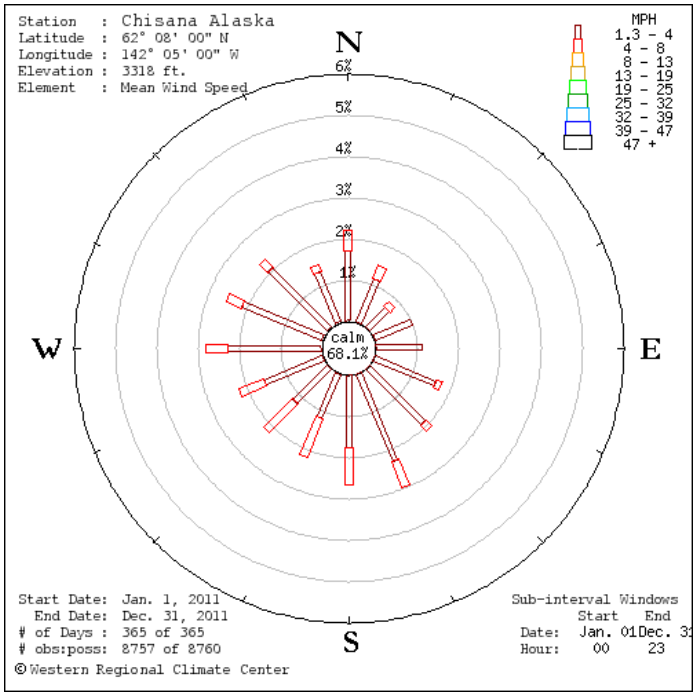
May Creek

	Solar Radiation	Mean Wind Speed	Mean Wind Direction	Maximum Wind Gust	Average Air Temperature			Ave Fuel Temp			Average Relative Humidity			Snow Depth	Precipitation
Date	ly	mph	Deg	mph	Deg F			Deg F			%			in	in
mm/yyyy	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Total
Jan-11	512	2	159	40	1	38	-44	1	28	-47	80	99	30		
Feb-11	1318	1	191	35	4	39	-41	7	26	-26	78	99	29		
Mar-11	8402	2	189	29	10	51	-35	11	31	-11	60	99	22		
Apr-11	12046	2	196	20	35	59	7	33	65	8	59	99	22		
May-11	16556	2	215	30	48	81	19	49	92	18	58	99	10		
Jun-11	15198	2	230	18	55	80	27	57	91	26	63	99	21		0.75
Jul-11	10477	1	222	24	56	81	33	57	93	33	71	99	24		1.89
Aug-11	10411	1	188	24	51	73	26	52	86	25	73	96	28		1.91
Sep-11	6863	1	204	29	42	69	16	42	80	15	72	95	29		
Oct-11	3557	1	182	16	28	52	-1	27	63	-3	75	93	28		
Nov-11	522	1	206	48	2	41	-37	0	47	-43	74	92	25		
Dec-11	175	1	208	22	14	43	-19	14	36	-21	78	93	35		



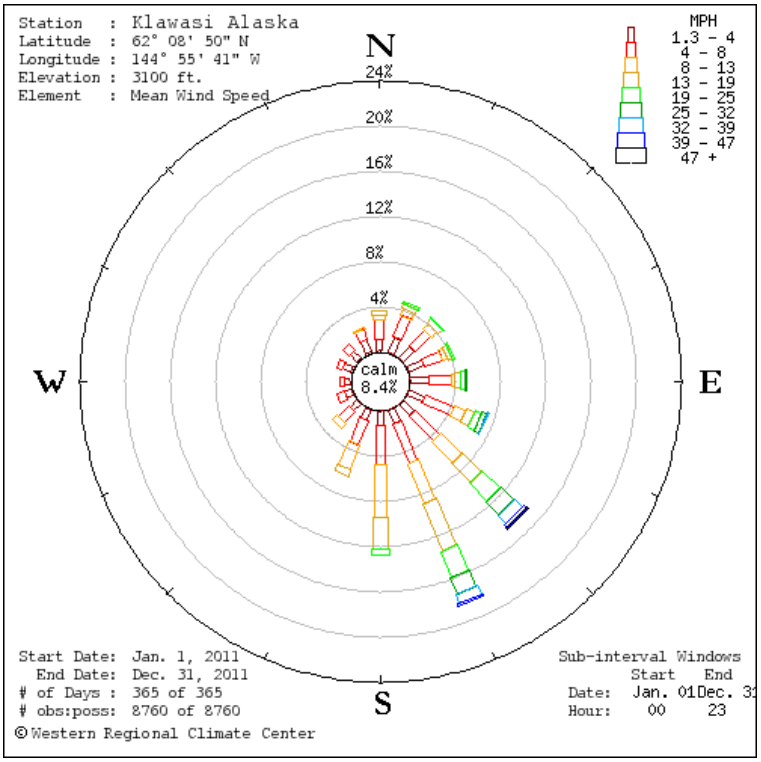
Chisana

	Solar Radiation	Mean Wind Speed	Mean Wind Direction	Maximum Wind Gust	Average Air Temperature			Ave Fuel Temp			Average Relative Humidity			Snow Depth	Precipitation
Date	ly	mph	Deg	mph	Deg F			Deg F			%			in	in
mm/yyyy	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Total
Jan-11	199	0	119	16	-8	35	-50	-5	28	-26	73	93	47	21	
Feb-11	566	1	304	19	-4	38	-43	-1	28	-26	66	94	31	15	
Mar-11	7873	1	168	9	-2	45	-44	0	30	-25	52	82	16	16	
Apr-11	13712	2	130	17	28	53	-7	28	68	-5	56	93	20	12	
May-11	16148	2	155	19	43	74	17	46	88	12	58	100	15	1	
Jun-11	15994	2	102	18	51	73	24	54	89	20	64	100	16	0	1.9
Jul-11	15268	2	150	19	53	77	30	56	94	28	72	100	21	0	4.17
Aug-11	12593	2	128	18	47	70	21	49	87	18	69	100	22	0	0.97
Sep-11	7869	1	131	18	37	69	10	38	86	6	67	100	21	0	
Oct-11	2730	1	120	14	19	49	-9	18	65	-14	74	98	22	1	
Nov-11	165	1	154	11	-11	24	-43	-12	31	-47	68	93	42	6	
Dec-11	134	1	111	31	5	50	-31	1	36	-37	75	99	34	10	



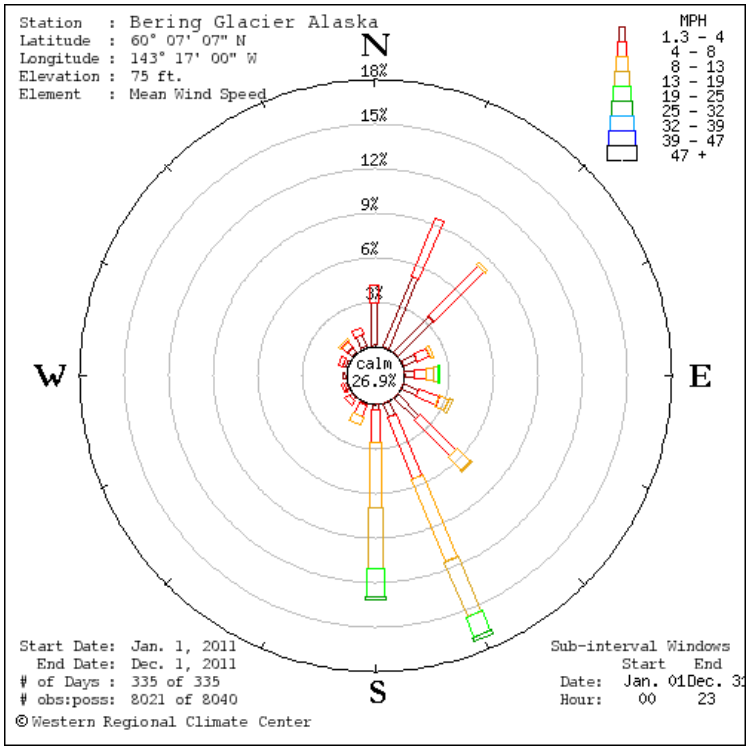
Klawasi

	Solar Radiation	Mean Wind Speed	Mean Wind Direction	Maximum Wind Gust	Average Air Temperature			Ave Fuel Temp			Average Relative Humidity			Precipitation
Date	ly	mph	Deg	mph	Deg F			Deg F			%			in
mm/yyyy	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Total
Jan-11	1090	7	127	58	10	41	-25	13	30	-9	68	88	37	
Feb-11	2613	8	105	55	6	40	-23	21	29	4	68	88	32	
Mar-11	8311	5	124	33	11	43	-17	17	25	9	57	89	28	
Apr-11	13376	12	151	74	31	46	13	30	53	24	57	88	29	
May-11	18037	9	167	37	44	72	22	47	99	19	54	89	16	
Jun-11	15516	10	180	39	51	72	34	54	106	31	61	89	21	1.54
Jul-11	13991	8	160	36	53	74	39	54	88	34	67	99	23	2.94
Aug-11	11875	11	100	52	49	66	34	49	74	29	65	96	32	3.77
Sep-11	7880	11	122	44	43	63	21	42	70	17	58	95	29	
Oct-11	3311	8	114	57	30	45	8	28	51	1	65	93	26	
Nov-11	867	6	140	55	4	35	-23	2	35	-27	72	90	38	
Dec-11	418	15	142	71	20	45	-5	18	43	-10	65	92	33	

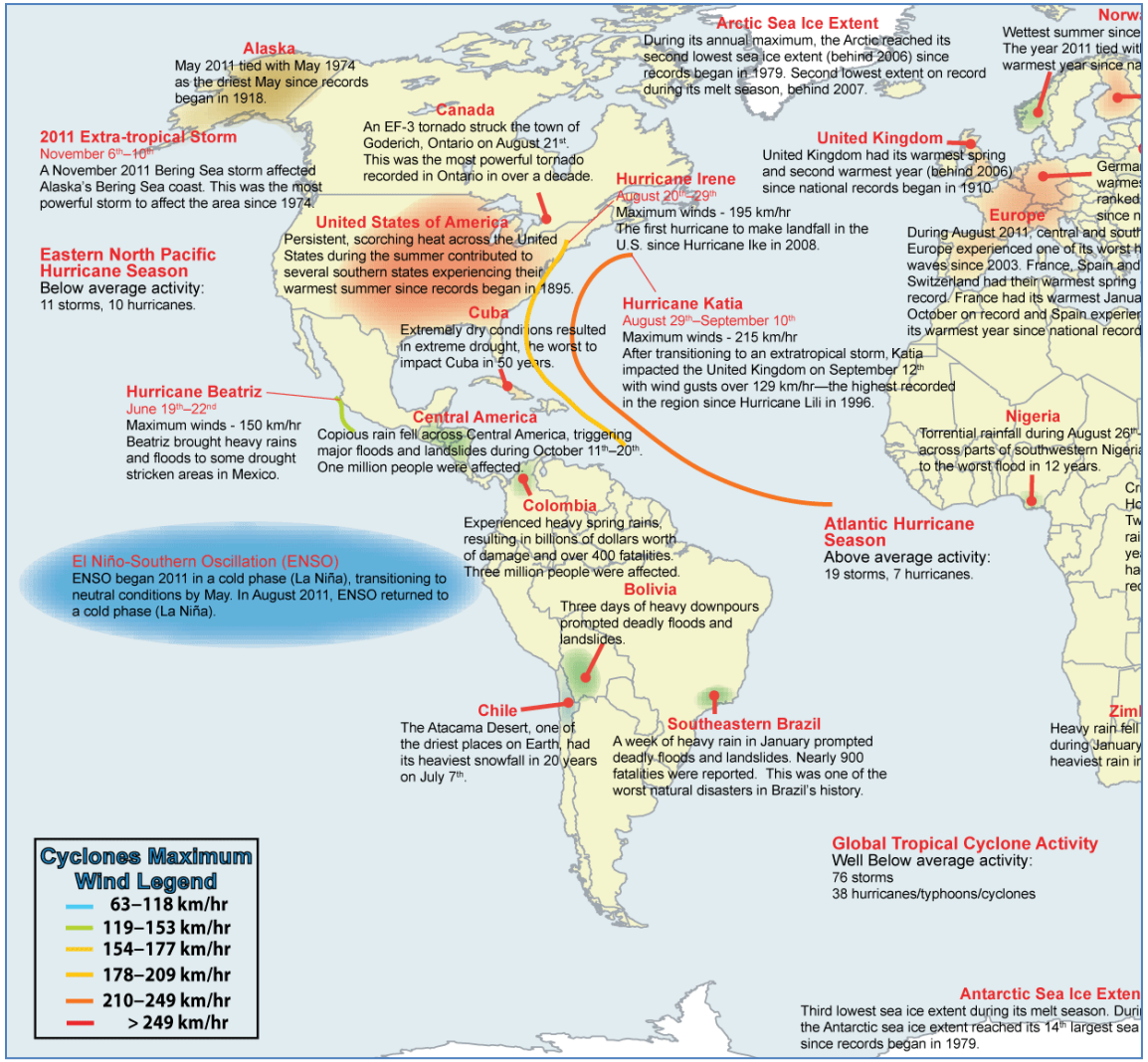


Bering Glacier

	Solar Radiation	Mean Wind Speed	Mean Wind Direction	Maximum Wind Gust	Average Air Temperature			Ave Fuel Temp			Average Relative Humidity			Precipitation
Date	ly	mph	Deg	mph	Deg F			Deg F			%			in
mm/yyyy	Total	Ave.	Ave.	Max.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Total
Jan-11	1163	6	149	199	26	43	-5	23	40	-12	86	100	23	
Feb-11	2340	7	120	194	26	43	-1	25	43	-9	79	100	20	
Mar-11	5040	4	108	187	28	47	-7	25	61	-15	75	100	19	
Apr-11	5518	6	150	199	38	53	22	39	72	16	90	100	49	
May-11	7851	5	65	191	44	63	27	48	81	22	88	100	34	m
Jun-11	7515	3	26	182	45	59	30	49	81	28	90	100	57	m
Jul-11	7160	3	22	171	46	62	31	51	82	29	91	100	60	m
Aug-11	3973	6	105	188	48	64	31	50	83	30	96	100	55	
Sep-11	2837	8	148	199	46	65	28	46	73	24	96	100	59	
Oct-11	1991	8	157	191	40	53	24	39	63	20	94	100	50	
Nov-11	883	7	130	185	28	44	-1	28	46	-8	90	100	29	
Dec-11	323	8	152	197	31	41	11	30	38	3	97	100	54	



Appendix D. Worldwide Significant Climate Anomalies



Graph courtesy of the National Oceanic and Atmospheric Administration (NOAA). Retrieved from http://www.ncdc.noaa.gov/sotc/service/global/significant-extremes/201113.gif

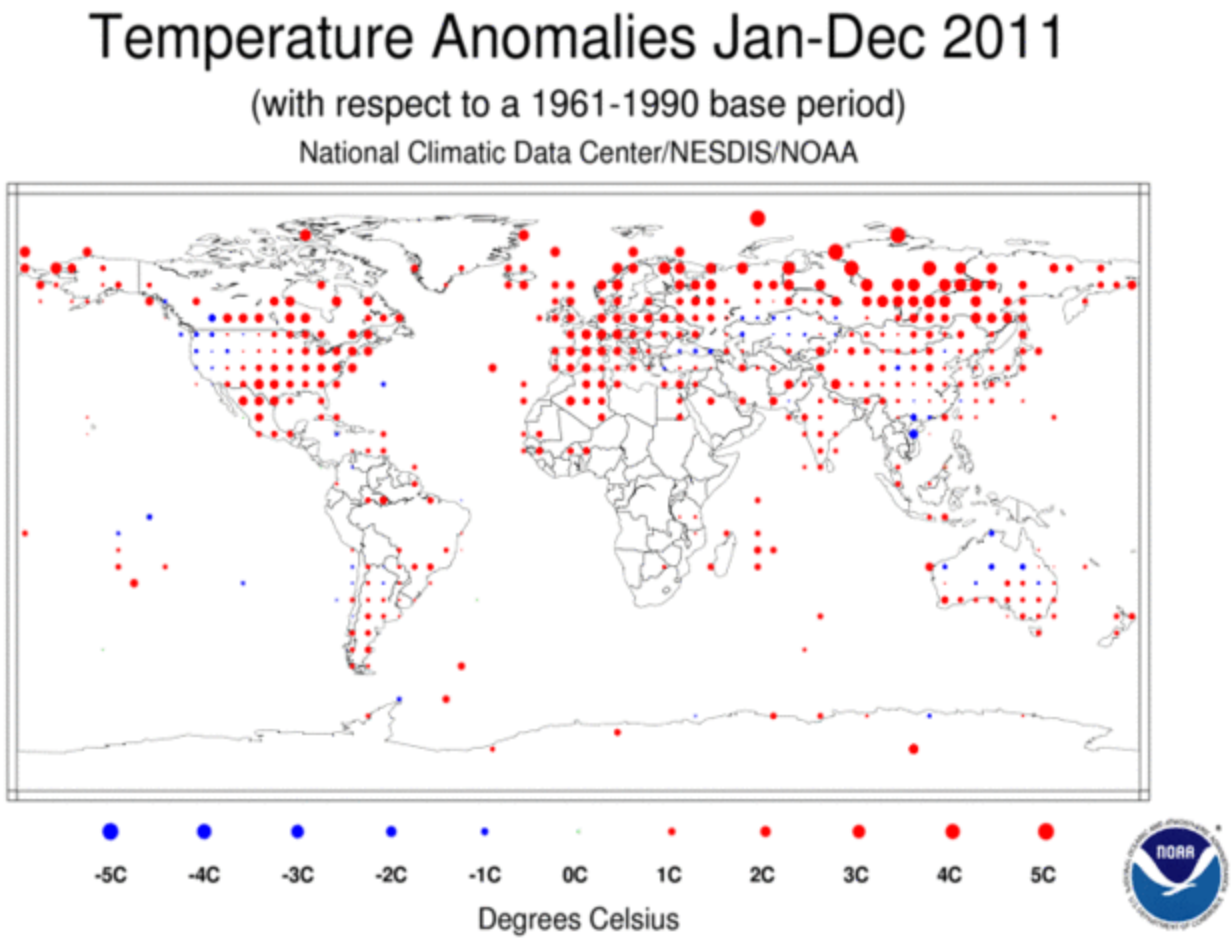


Figure courtesy of NOAA. Retrieved from http://www.ncdc.noaa.gov/sotc/service/global/map-land-sfc-mntp/201101-201112.gif

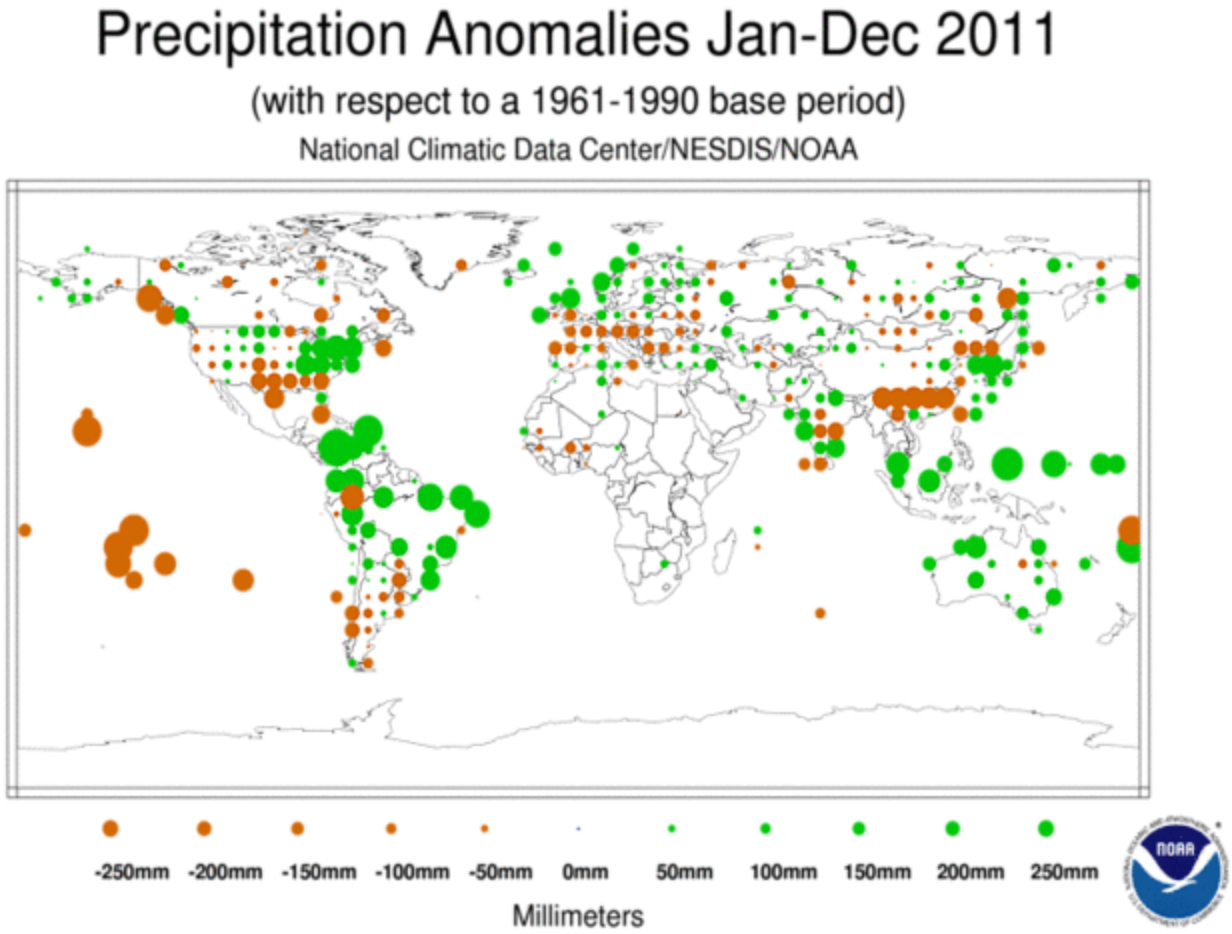
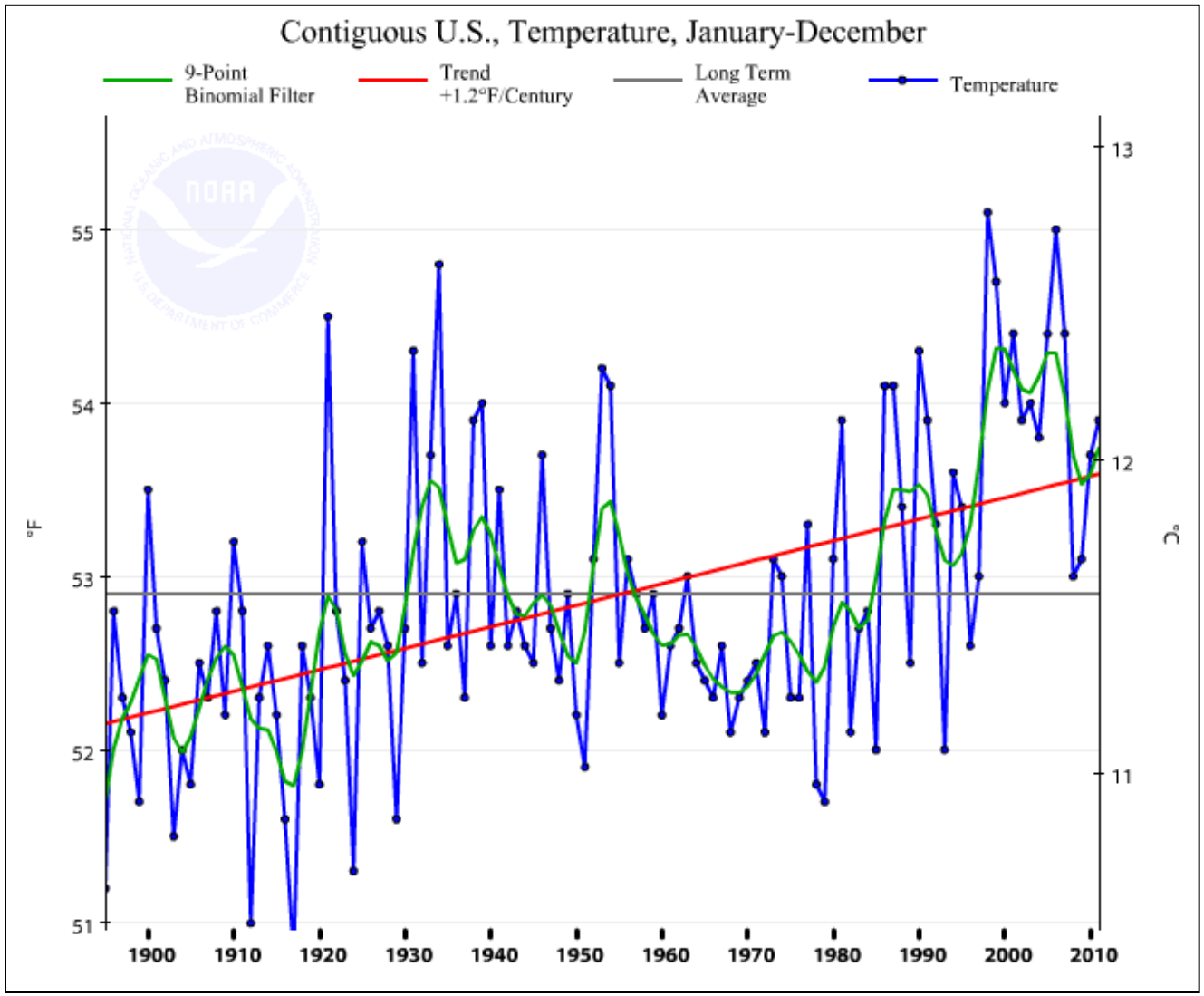


Figure courtesy of NOAA. Retrieved from http://www.ncdc.noaa.gov/sotc/global/2011/13.



http://www.ncdc.noaa.gov/temp-and-precip/time-series/

Preliminary Significant U.S. Weather and Climate Events for 2011

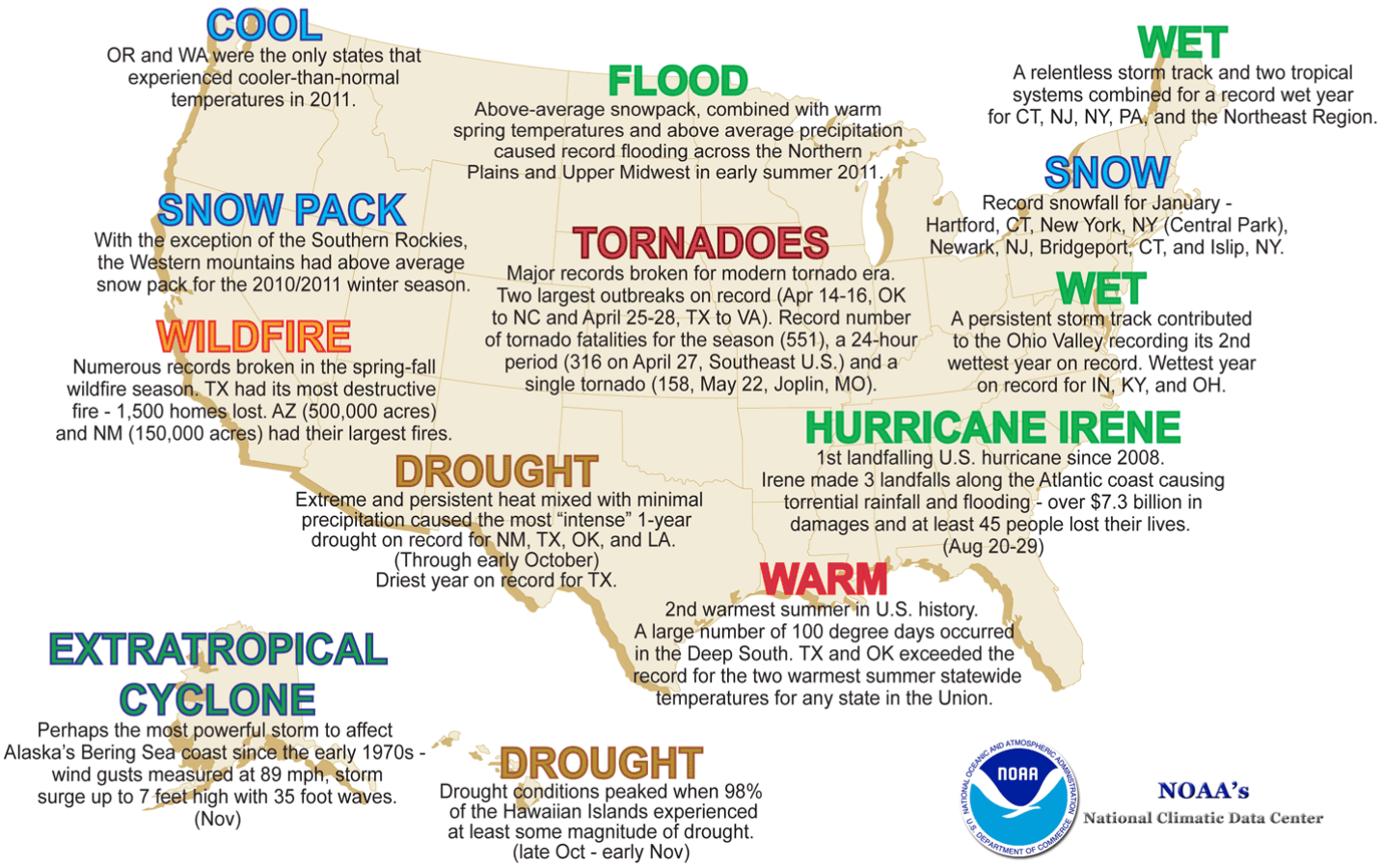
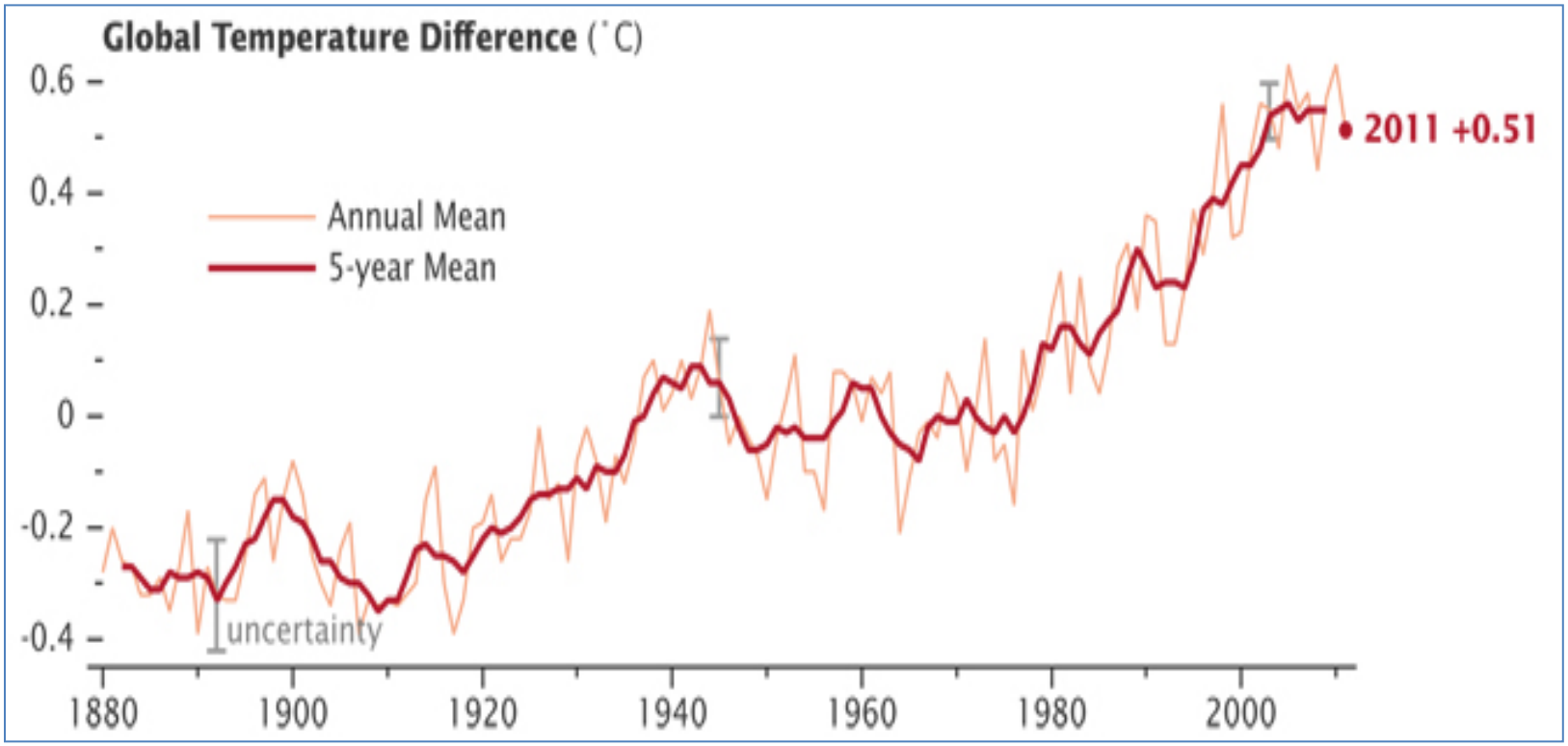


Figure courtesy of NOAA. Retrieved from http://www.ncdc.noaa.gov/oa/climate/research/2011/sig-events-2011.html.



The analysis produced at NASA's Goddard Institute for Space Studies (GISS) shows temperatures around the globe in 2011 compared to the average global temperature between 1951 to 1980. This three-decade period functions as a baseline for the analysis. Graph courtesy of NASA Goddard Institute for Space Studies (GISS). Retrieved from http://www.giss.nasa.gov/research/news/20120119/