



WINTER  
2015-16

# ALASKA CLIMATE DISPATCH

## A STATE-WIDE SEASONAL SUMMARY AND OUTLOOK

BROUGHT TO YOU BY THE ALASKA CENTER FOR CLIMATE ASSESSMENT AND POLICY IN PARTNERSHIP WITH THE ALASKA CLIMATE RESEARCH CENTER, SEARCH SEA ICE OUTLOOK, NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION, AND THE NATIONAL WEATHER SERVICE

## THE NEW WINTER SEVERITY INDEX IN ALASKA

By Brian Brettschneider, Borealis Scientific, LLC, Anchorage

Analyses of a broad range of data relating to Alaska climate and weather are available on the Alaska Climate Info Facebook page: <https://www.facebook.com/AlaskaClimateFacts>.

The winter of 2015-16 in Alaska will be remembered as one of the mildest on record. In fact, according to the newly developed Accumulated Winter Season Severity Index (AWSSI), it was the least severe winter on record for many locations in Alaska (Figure 1).

Before delving into this new winter severity index, let's examine how we describe the intensity, or lack thereof, of winter conditions. At the qualitative level, we usually describe winter as being either cold or warm, and either snowy or not snowy.

During the winter of 2015-16, air temperatures were substantially warmer than normal across the entire state, and snowfall was well below normal in most, but not all, places (details pages 16-19). Rivers were slow to freeze up in the fall, and many reported their earliest spring breakup on record—some by large margins. By any number of metrics, this winter was anemic. But just how anemic? Quantifying the winter in a single, numerical index is an elusive goal that is fraught with complications. The easiest way to describe winter is to look at temperatures during the “cold” season. In many applications for Alaska, the cold months are October through the following April. Figure 2 shows the cold season temperatures for all of Alaska based on climate divisions beginning in 1925. The October 2015 through April 2016 temperature was the highest on record by a relatively wide margin. This warmth was spread nearly evenly across the state.

Circumstances beyond our control made it impossible to complete the Autumn and Winter 2015 issues of the Alaska Climate Dispatch on schedule. We apologize to our readers and hope they will enjoy this special 3-season issue, which covers September 2015 to May 2016.

### IN THIS ISSUE

- Winter Severity Index .....pages 1-5
- Weather Impacts .....6-8
- Pacific Ocean and Alaska's Climate .. 9-11
- Autumn Weather Summary ..... 12-15
- Winter Weather Summary ..... 16-19
- Spring Weather Summary .....20-23
- Sea Ice.....24-25
- News and Events.....25

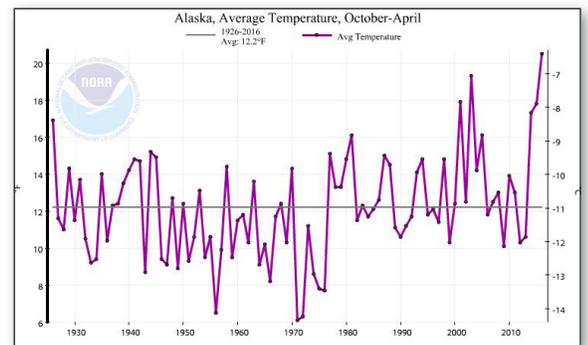
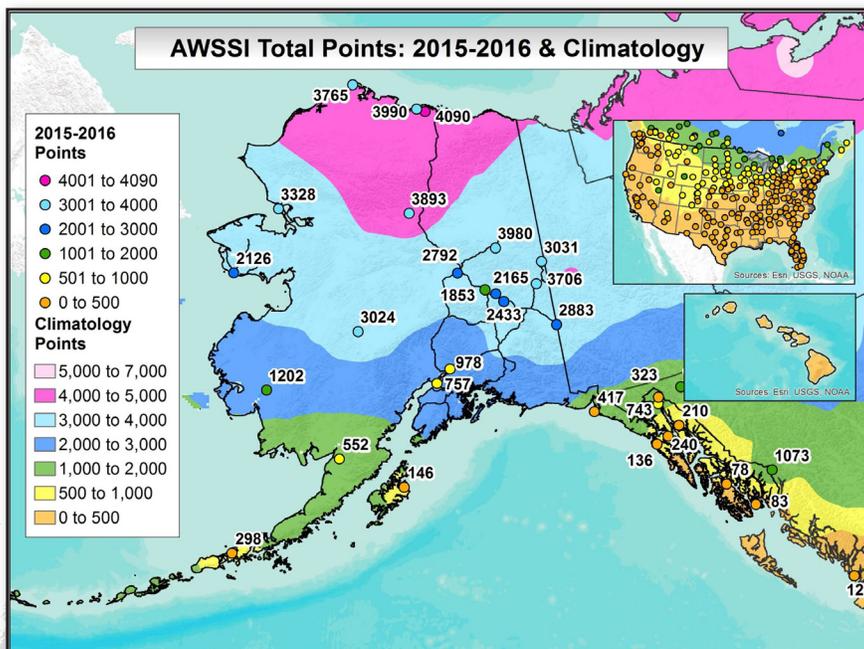


Figure 2, above. Alaska average temperature for all October through April time periods since 1925. <https://www.ncdc.noaa.gov/cag/time-series/us/50/00>

Figure 1, left. Accumulated Winter Season Severity Index (AWSSI) points in Alaska in 2015-16 overlaid on climatological values.

## WINTER SEVERITY INDEX

Unfortunately, using this method to assess Alaska temperatures has a key flaw—namely, October is reliably a winter month in northern and interior Alaska but a fall month in southern Alaska. Therefore, using a single timeframe for the entire state must be viewed with that major caveat.

Of course the other major factor in assessing winter conditions is the amount of new snow that falls and the depth of snow on the ground. But what constitutes severe snow conditions? Is it a lot of snowfall or is it a deep snow pack? Do the two go hand-in-hand? The companion chart for Figure 2 that depicts precipitation during the same time period (not shown) suffers from a key flaw—there is no breakdown between snow and rain. This lack of distinction between winter snow and winter rain presents a significant climate analysis problem for all locations. The October-April 2015-16 precipitation total for Alaska showed near average values for most of the 13 climate divisions in the state with a trend toward very dry conditions along the North Slope and very wet conditions in Southeast. Unfortunately for southeastern Alaska, the very wet conditions did not translate into a lot of snow. In the Interior, the heavy late September snow around Fairbanks was not captured by an October through April assessment. For these reasons (and others), the climate tools from NOAA's National Center for Environmental Information (NCEI) tell only part of the winter severity story.

Daily Points				
Points	Max	Min	New Snow	Snow Depth
1	25 to 32	25 to 32	0.1–0.9	1
2	20 to 24	20 to 24	1.0–1.9	2
3	15 to 19	15 to 19	2.0–2.9	3
4	10 to 14	10 to 14	3.0–3.9	4–5
5	5 to 9	5 to 9		6–8
6	0 to 4	0 to 4	4.0–4.9	9–11
7	-1 to -5	-1 to -5	5.0–5.9	12–14
8	-6 to -10	-6 to -10		15–17
9	-11 to -15	-11 to -15	6.0–6.9	18–23
10	-16 to -20	-16 to -20	7.0–7.9	24–35
11		-20 to -25		
12			8.0–8.9	
13			9.0–9.9	
14			10.0–11.9	
15	< -20	-26 to -35		>35
18			12.0–14.9	
20		< -35		
22			15.0–17.9	
26			18.0–23.9	
36			24.0–29.9	
45			> 29.9	

Table 1. Daily point criteria for AWSSI.

## THE AWSSI

As I personally experimented with various beginning/end dates of winter and assessing winter “severity” over the years, I found the definition problem insurmountable. Is a day with an average temperature of 10°F twice as severe as a day with an average temperature of 25°F? I always felt too much uncertainty regarding the scoring or ranking. Everyone had their own opinion about how to score winter severity.

In 2015, an article in the *Journal of Applied Meteorology and Climatology* set out to address this problem. When I heard about this paper, I was extremely excited—and relieved. Authors Barb Mayes Boustead (NWS Omaha, Nebraska), Steve Hilberg (Midwest Regional Climate Center), Martha Shulski (Nebraska State Climatologist and coauthor of *The Climate of Alaska*), and Ken Hubbard (University of Nebraska—Lincoln) developed a set of criteria that assigns points for high temperature, low temperature, new snow, and snow depth to generate the Accumulated Winter Season Severity Index (AWSSI) <sup>1</sup>.

The AWSSI works by evaluating and assigning points to daily climate summary variables for temperature and snow, based on their “severity.” Every day during winter, a high temperature at or below freezing, a low temperature at or below freezing, measurable snow, and measurable snow depth all accumulate points (Table 1). Adding these four point-equivalent values provides a single number by which to compare winters. At the end of the winter, all the daily points are added up.

Table 1 shows the matrix for assigning points. Importantly, the values are ordinal; meaning a day with a low temperature of -18°F (10 points) is not twice as severe as a day with a low of +8°F (5 points). However, a station with 10 points is always more severe than a station with 5 points—no matter where the stations are located or when the values occurred. Looking at Table 1, a day with a high temperature of 22°F, a low of 12°F, 1" of new snow, and a snow depth of 6" scores 13 total points (2 for the high temperature, 4 for the low temperature, 2 for the new snow, and 5 for the snow depth).

A key criterion for assigning daily points is that they occur during winter—but, as I noted earlier, having a single “winter” period for all of Alaska is not practical. The AWSSI paper solves this problem by using the first of any of these events to define the beginning of winter for each station:

- first day with measurable snowfall,
- first day with a high temperature of 32°F or colder, or
- December 1.

Conversely, the last day of winter is when the last of these occur:

- last day with measurable snowfall,
- last day with a high temperature of 32°F or colder,
- last day with a measurable snow depth, or
- February 28/29.

In the southern part of the Lower 48, winter starts on December 1 and runs through the end of February (90 or 91 days). In interior Alaska, the length of winter is 200 to even 300+ days. Given the possibility of winter conditions occurring well into June, in Alaska we cannot calculate AWSSI until the end of June, so the starting date for analyzing the next winter’s AWSSI point total is July 1.

It is important to note that the AWSSI was created with the Lower 48 in mind. Some of the criteria do not optimally reflect arctic/subarctic conditions. For example, snow depth is generally transient outside of mountain areas in the Lower 48—but near continuous in Alaska. Alaska also receives many small snowfalls throughout the winter due to the low moisture capacity of our cold air masses. A heavier weighting of low snowfall events to reflect the frequency of snowfall would capture Alaska snow conditions more accurately. On the

WINTER SEVERITY INDEX

temperature side of the ledger, the lowest categories for high and low temperature are frequently reached in interior Alaska even during "warm" winters. A few extra categories with colder values would capture extreme low temperature events. Those cold snaps are what stress people and resources.

2015-16 AND CLIMATOLOGY

The map in Figure 1 shows the climatology of total AWSSI points for all winters from 1980-1981 through 2014-15 (shown as solid). Areas from Bettles northward generally average over 4000 AWSSI points annually. Southeast Alaska and the Alaska Peninsula average less than 1200 AWSSI points. The majority of mainland Alaska averages 1800 to 3500 AWSSI points. The normal value for Fairbanks is 3720, for Anchorage is 1820, and for Juneau is 698. In the Lower 48, some examples of AWSSI normal values include: Chicago at 612, New York at 244, Oklahoma City at 151, Seattle at 49, Houston at 14, and Miami at 0.2 points.

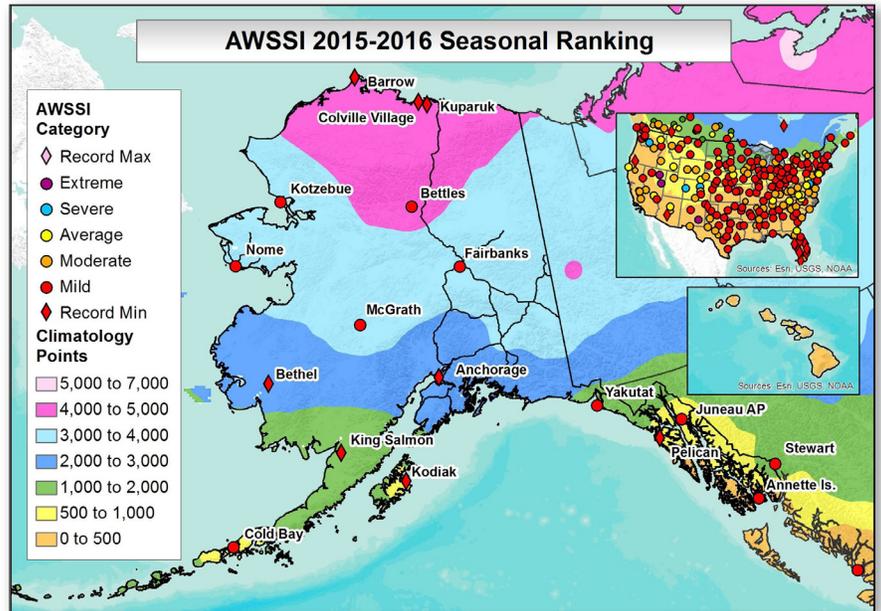


Figure 3. Accumulated Winter Season Severity Index (AWSSI) rankings for the 2015-16 winter season in Alaska overlaid on climatological values.

Station Name	Days in Winter 2015-16	Days in Winter Climatology	Winter Days Deficit	AWSSI Points 2015-16	AWSSI Points Climatology	AWSSI Points Deficit	AWSSI Points Rank
Anchorage	175	190	-15	757	1821	-1064	63 out of 63
Annette Is.	104	140	-36	83	190	-107	59 out of 64
Barrow	303	310	-7	3765	4786	-1021	65 out of 65
Bethel	156	215	-59	1202	2196	-994	65 out of 65
Bettles	226	232	-6	3893	4616	-723	54 out of 56
Cold Bay	158	204	-46	298	672	-374	56 out of 57
Fairbanks	196	212	-16	2792	3720	-928	84 out of 85
Juneau AP	107	150	-43	210	698	-488	63 out of 64
King Salmon	152	199	-47	552	1317	-765	62 out of 62
Kodiak	173	173	0	146	534	-388	58 out of 58
Kotzebue	226	240	-14	3328	3918	-590	54 out of 62
McGrath	193	219	-26	3024	3874	-850	68 out of 71
Nome	205	232	-27	2126	2959	-833	71 out of 75
St Paul	158	205	-47	458	1041	-583	56 out of 58
Yakutat	181	178	3	417	1366	-949	59 out of 61

Table 2. AWSSI climatology values and winter 2015-16 values for selected stations in Alaska.

Table 2 contains AWSSI climatology values for 15 stations across Alaska and their values for the winter of 2015-16. The three green columns show the number of days in the winter of 2015-16 compared to the normal number of winter days as determined by the AWSSI first and last occurrence of winter conditions. Among these stations, this past winter varied from 3 days longer (in Yakutat) to 59 days shorter (in Bethel) than the climatological normal; the statewide average was 26 days shorter! Looking closer at the data, the values for 2015-16 showed no delay for winter's onset (statewide average +0.6 days) but a very early end to the winter season (statewide average -25.2 days). Therefore, Alaska's winter was nearly a month shorter than average when compared to climatology. The start/end values are not shown in Table 2.

Looking at the 2015-16 AWSSI point totals, every Alaska station was substantially below normal. In fact, 5 of the stations reported their lowest AWSSI values on record, and every one but Kotzebue had a winter in the bottom 5 of the 35-year record. As mentioned earlier, the values are ordinal, so a valid mathematical comparison cannot be made between stations. The stated purpose of the AWSSI is to evaluate individual stations' values over time—not to compare one station against another. That being said, the AWSSI does permit a greater than, or less than, comparison. For example, the 2015-16 values indicate that Fairbanks had a more severe winter than Nome. We also note that King Salmon and Yakutat had similar winter severity values in 2015-16—even though the characteristics of their winters were rather different.

A map representation of the station percentile for the winter of 2015-16 is shown in Figure 3. All stations with at least 15 years of climatology and complete values for 2015-16 are displayed as dots and colored by percentile category. The Mild category is the lowest 20<sup>th</sup> percentile. Each additional category higher in the legend represents more winter severity by increments of 20 percentiles. Every station in Alaska shown on Figure 3 is in the lowest 20<sup>th</sup> percentile. The 8 stations marked with red diamonds had their lowest AWSSI value on record. In addition, Cold Bay, Fairbanks, and Juneau had their second lowest values on record. Kotzebue was the "winter winner" in Alaska, as they were only in the bottom 12<sup>th</sup> percentile compared to their own AWSSI history.

# WINTER SEVERITY INDEX

## AWSSI COMPONENTS

The point criteria matrix (Table 1) describes how points are assigned each day based on high and low temperatures and new snow and snow depth. A breakdown of the 2015-16 winter season and the climatological normal values by AWSSI point category is shown in Figure 4 for Barrow, Fairbanks, Anchorage, and Juneau. As you look at Figure 4, remember that the AWSSI total for Barrow and Anchorage was the lowest on record and the values for Fairbanks and Juneau were the second lowest on record.

For places in Alaska that are below 0°F for most of December and January, the two temperature categories are responsible for the majority of AWSSI points. Barrow averages 3400 temperature points per year. Even this past winter, the warmest on record for Barrow, saw over 2700 AWSSI temperature points. On the snow part of the equation, the main drawback in using AWSSI for Alaska appears. Notice the vast disparity between snow and snow depth points on the chart. Since snow generally stays on the ground all winter in Alaska (very different than the Lower 48), snow depth points accumulate rapidly. A snow depth of 6" that persists for 150 days will accumulate 900 snow depth points. However, if a station receives 60" of snow as 20 separate events of 3" each, that only adds up to 120 points. Since cold stations receive frequent light snows, they have relatively few snow points. To recalibrate the AWSSI for Alaska, I would assign snowfalls more points and snow depths fewer points.

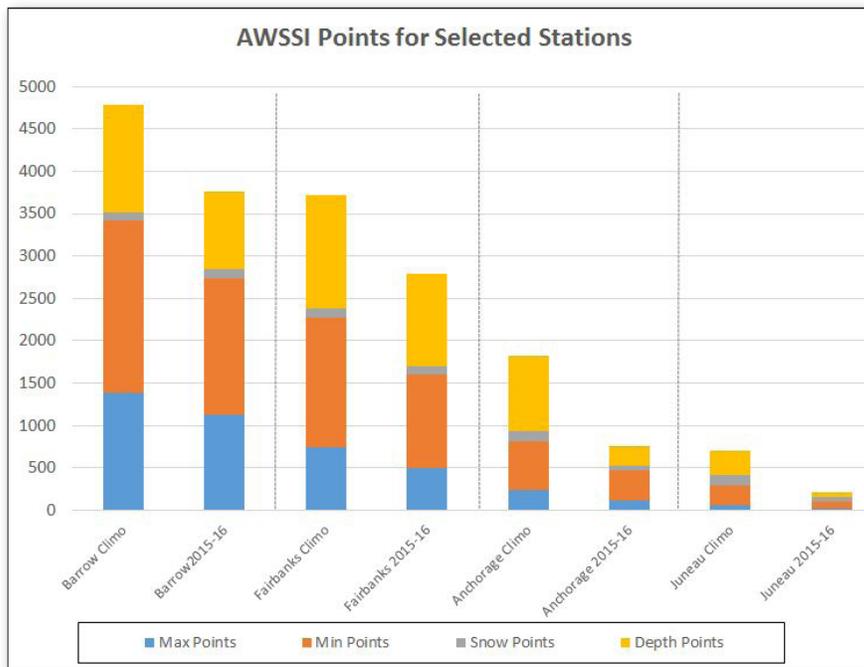


Figure 4. Accumulated Winter Season Severity Index (AWSSI) sub-categories for the 2015-16 winter season for selected stations in Alaska as compared to climatological values.

## AWSSI TRENDS

Most stations in Alaska have seen a steady reduction in total AWSSI points through time, corresponding to the gradual increase in temperatures across Alaska (and globally) through the 20<sup>th</sup> century and particularly since the great PDO shift of 1976-77. Figure 5 shows the AWSSI trend for Anchorage, Barrow, Fairbanks, and Juneau.

For Anchorage, the trend for AWSSI is actually increasing slightly. This is due to an increase in average snow depth over the past 20 years. This snow depth increase offsets a slight temperature increase during the period of record. The AWSSI decrease for Fairbanks is very slight and not statistically significant. For Juneau, and especially Barrow, the decline in winter severity has been dramatic. In the case of Barrow, the reduction is certainly related to the increase in ice-free days in the Beaufort and Chukchi Seas, which raises the temperature in September through November. The long-term decline in Juneau is mostly associated with a reduction in snow depth and a more modest reduction in temperature points. That being said, since Juneau's winter temperatures are never that low in winter, they don't have many temperature point to lose.

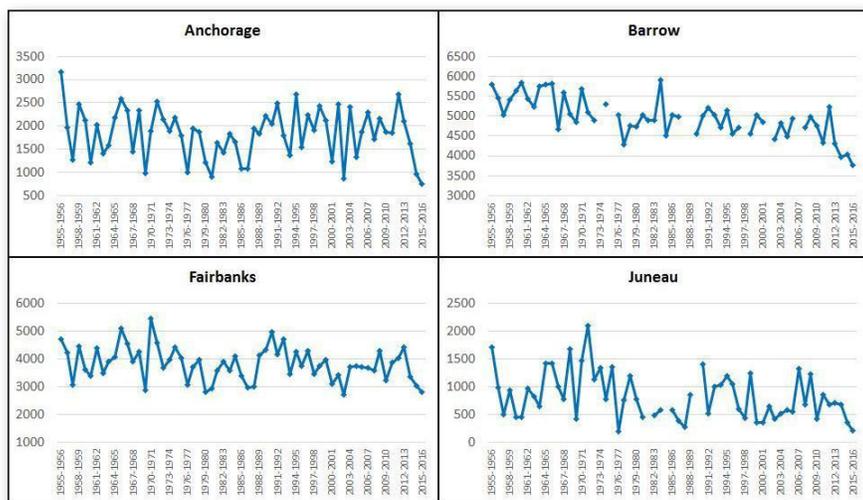


Figure 5. AWSSI total point trend from 1955-1956 to 2015-16 for Anchorage, Barrow, Fairbanks, and Juneau. In this analysis, a season was only included if no more than 3 days between October 1 and April 30 were missing. A few years did not meet that threshold for Barrow and Juneau—hence the gaps in the chart.

At the national level, the trend in AWSSI for most of the U.S. and Canada is strongly negative. Figure 6 shows the long-term percentage change in AWSSI points for consecutive 30-year periods (1985-86 to 2014-15 compared to 1955-56 to 1984-85). Interestingly, the percentage change in Alaska is less than most of the Lower 48. Anchorage, Kodiak, and

## WINTER SEVERITY INDEX

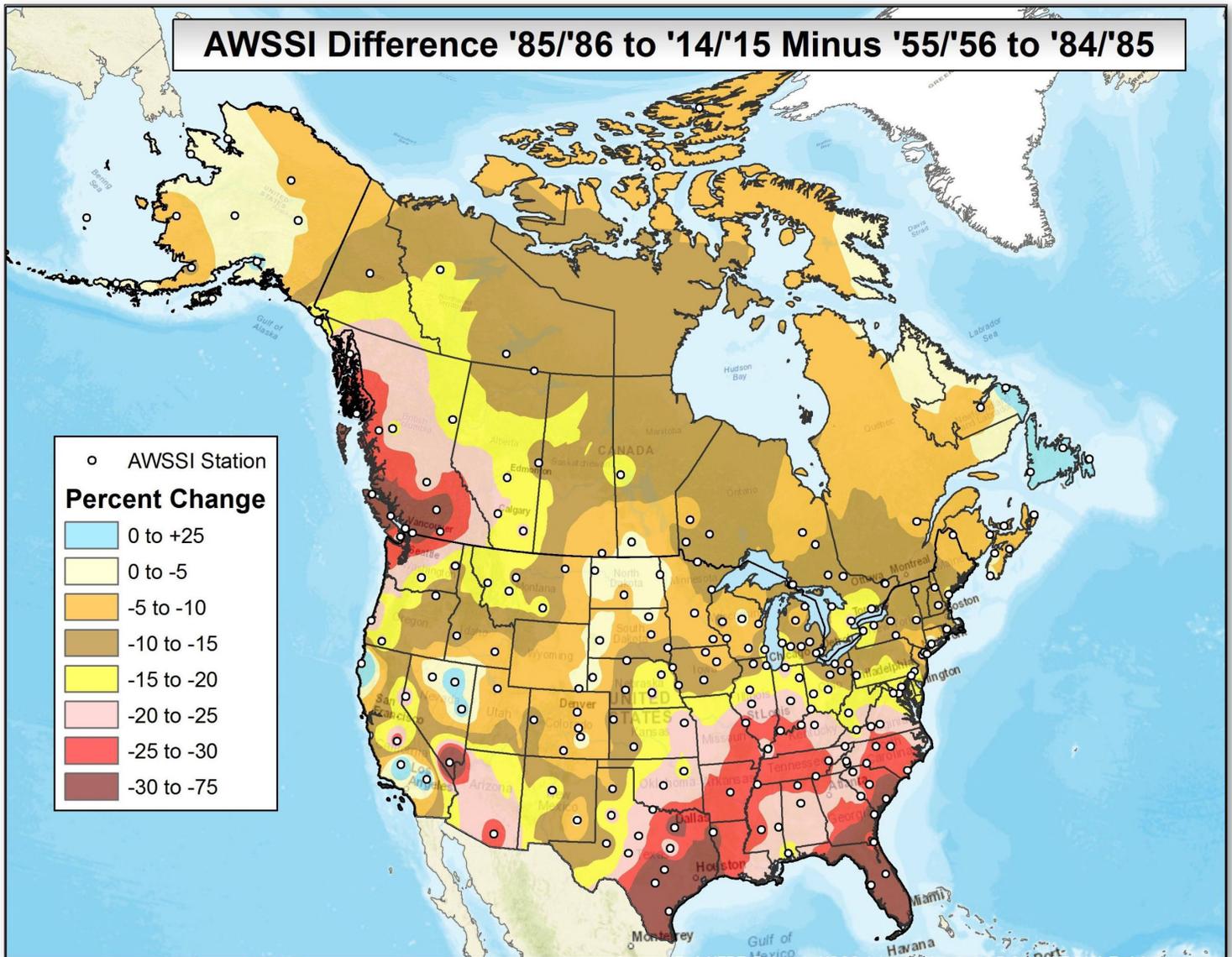


Figure 6. Percent change in AWSSI total points across consecutive 30-year time periods. Included stations have at least 20 years of data in each time period.

Nome actually show very slight positive AWSSI gains over time (under 3%). The region from Juneau down to Seattle saw a precipitous decline in AWSSI.

Why did some Alaska stations show a counter trend in winter severity? This is a difficult question to answer. The stations with an AWSSI increase primarily saw an increase in snow depth, which may have station-specific explanations. For example, the snow measurement site for Anchorage was moved from the airport to the Anchorage Forecast Office—a shaded, sheltered location. Nome and Kodiak may have had similar changes in where snowfall and depth location are measured.

## CONCLUSION

The Accumulated Winter Season Severity Index is a useful tool for gauging the relative difference in winter severity for a particular season compared to climatology. While strict mathematical comparisons are not possible, trends across time and space are visible. The winter 2015-16 point totals were the lowest on record for many locations across Alaska and the Lower 48. Those stations that did not finish in last place were not far from their record lowest totals.

Summarizing winter severity into a single number is an important development in climate communication. All too often, climate descriptions consist of a single climate variable (e.g., temperature, humidity, cloudiness, etc.). Using a single variable to describe the winter is inadequate, but providing multiple climate variable descriptions requires the recipient to synthesize the data and make scientific inferences. The AWSSI performs that function for both the climate scientist and the public.

1. Boustead B., S. Hilberg, M. Shulski, and K. Hubbard. 2015. The Accumulated Winter Season Severity Index (AWSSI). *J. Appl. Met. and Clim.*, Vol. 54, 1693-1712.

# AUTUMN 2015 TO SPRING 2016: WEATHER IMPACTS ACROSS ALASKA

By Rick Thoman, National Weather Service.

This article is based on information from the Alaska Interagency Coordination Center, Alaska Climate Research Center, and National Weather Service. The National Integrated Drought Information System hosts quarterly information on regional climate impacts and outlooks, available at: <https://www.drought.gov/drought/resources/reports>

## SEPTEMBER-NOVEMBER 2015

**Sep 1-2, Prince of Wales Island:** more than 6" of rain closed the road between Throne Bay to Coffman Cove.

**Sep 28-30, Fairbanks area:** record heavy September snow (up to 16") left 21,000 customers without power; in some places outages lasted nearly a week. Schools were cancelled on the 30<sup>th</sup>.

**Oct 1, central Bering Sea:** a strong storm brought high seas and large waves to areas along the Bering Sea coast. At Toksook Bay, west of Bethel, two boats sank and several were damaged as high waves swamped the normally safe shelter area. Boats slamming onshore destroyed property such as fish racks.

**Oct 8, Southeast:** Hurricane Oho, the first eastern Pacific tropical cyclone to approach Southeast Alaska since 1975, brought gusty winds and heavy rain to southern Southeast, with minor flooding in Ketchikan.

**Nov 9, Anchorage:** 1-3" of snow falling on warm pavement turned roads slick, with more than 30 automobile accidents.

**Nov 11, Dutch Harbor:** high winds blew windows out of several buildings, and at least one home suffered structural damage to the roof and garage door. Due to the threat of blowing debris, schools were closed for the day.

**Nov 17-18, Southeast:** a foot of snow in the Juneau area snarled traffic with multiple fender-benders reported. Yakutat picked up almost 11" of snow from the same storm, and up to 10" of snow fell at Pelican and Elvin Cove.

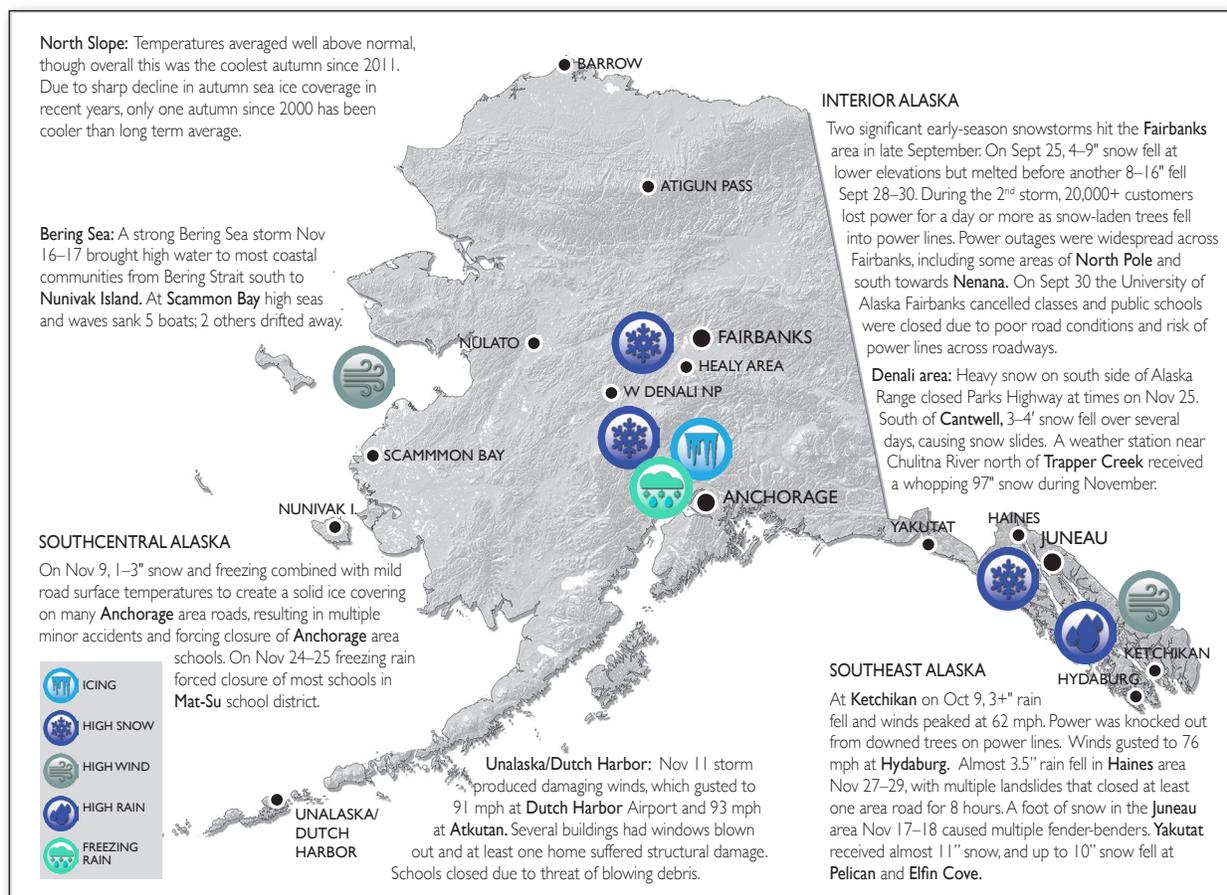


Figure 7. Alaska weather and climate highlights for September-November 2015. More highlights and details are available at [https://accap.uaf.edu/tools/climate\\_highlights#date/2015-09/2015-11](https://accap.uaf.edu/tools/climate_highlights#date/2015-09/2015-11)

## WEATHER IMPACTS

This was the second warmest winter of record for Alaska as a whole. Only the winter of 2000–01 was warmer.

## NORTHERN

**Barrow:** Blizzard Feb 12–13 with 40–50 mph winds produced near-zero visibility and huge snow drifts. Schools closed on the 12<sup>th</sup> and there were no flights in or out on either day. Despite the blizzard, Barrow also had the warmest winter of record.

Lowest temperature reported from any community in Alaska was -47°F at **Arctic Village** Dec 24–25 — the highest statewide minimum temperature for any winter in the past century.

## BERING SEA &amp; ALEUTIANS

Sea ice coverage around Alaska at end of Feb was lowest since 2001. Bering Sea ice edge Feb 28 was not far south of **St. Matthew** and **Nunivak Islands**. Virtually no ice in Bristol Bay and Cook Inlet.

One of the strongest storms of record battered central Aleutians Dec 12–13, producing wind gusts >100 mph and damaging buildings and power lines in **Adak**. Homes in **Atka** were also damaged.

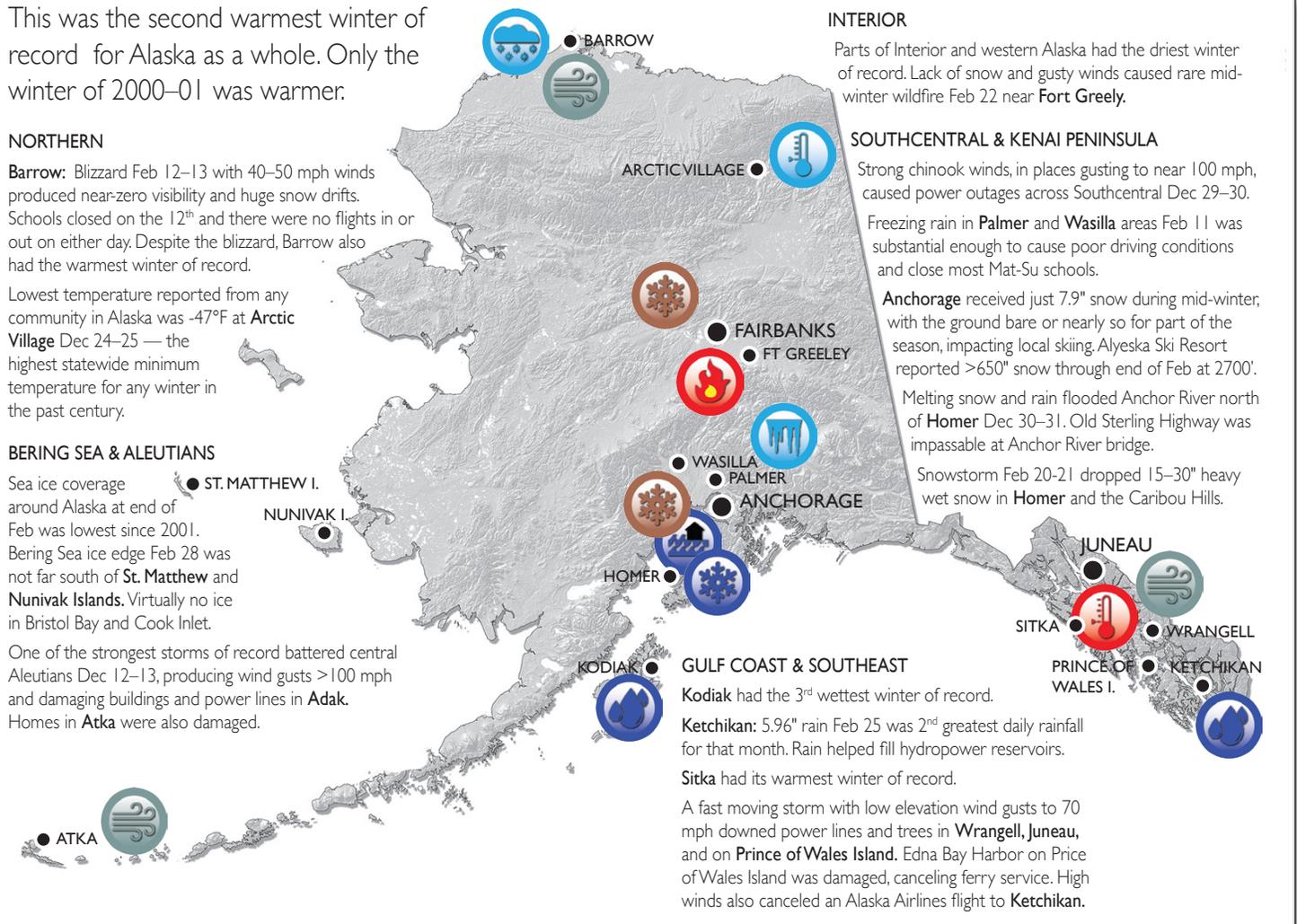


Figure 8. Alaska weather and climate highlights for December 2015-February 2016. More highlights and details are available at [https://accap.uaf.edu/tools/climate\\_highlights#date/2015-12/2016-02](https://accap.uaf.edu/tools/climate_highlights#date/2015-12/2016-02)

## DECEMBER 2015-FEBRUARY 2016

**Dec 12-13, Bering Sea coast:** Adak was battered by one of the strongest storms ever to strike the Bering Sea and adjacent North Pacific. Sustained winds reached 94 mph with gusts to 122 mph. There was damage to homes and power lines. At Atka, about 100 miles northeast of Adak, there was also damage to homes.

**Dec 30-31, Kenai Peninsula:** melting snow and rain combined to produce flooding on the Anchor River north of Homer. The Old Sterling Highway was impassable at the Anchor River bridge in Anchor Point.

**Jan 1-2, Anchorage:** 2016 got off to an icy start as freezing rain the afternoon of January 1 hit roads, causing dozens of minor accidents. By the morning of January 2, some side streets were so icy that people were ice-skating on the roads.

**Jan 26, Southeast:** a compact but intense storm brought high winds to a large swath of Southeast Alaska. Winds gusted to 71 mph at Ketchikan, 70 mph in downtown Juneau, and 64 mph at Hydaburg. Power lines were downed, trees were knocked onto buildings, and wind debris was kicked up in Wrangell, Juneau, and Prince of Wales Island. Eaglecrest Ski area near Juneau closed

to allow repairs, the Edna Bay Harbor on Prince of Wales Island was damaged, canceling ferry service from Prince of Wales Island to Ketchikan, and an Alaska Airlines flight to Ketchikan was canceled due to high winds.

**Feb 11, Southcentral:** some Mat-Su schools closed due to freezing rain creating treacherous road conditions.

**Feb 12-13, North Slope:** a blizzard all but shut down Barrow and much of the coastal North Slope. Winds gusting 40 to 50 mph produced near-zero visibility and huge snow drifts. Barrow schools were closed on February 12, and there were no flights in or out of Barrow either day. In the Prudhoe Bay and Kuparuk areas, road traffic was halted until ground visibility improved.

## WEATHER IMPACTS

## MARCH-MAY 2016

**Mar 4, Anchorage:** 1-3" of snow, coming on the heels of more than a week of temperatures in the 40s, produced very icy roads that resulted in more than 70 automobile accidents, including a 15-car pile-up on the Glenn Highway. Both the Glenn and Seward Highways were closed for part of the day due to the accidents.

**Mar 5, Anchorage:** limited and patchy snow cover in the Anchorage area forced Iditarod Sled Dog Race officials to shorten the ceremonial start in downtown Anchorage.

**Mar 19, Anchorage area:** the largest one-day snowfall since December 2013, with 6-11" across the city and more than 50 accidents reported.

**Apr 3-22, Barrow:** nearly three weeks of continuous strong east to northeast winds made this the windiest April of record. The winds opened the largest leads in the sea ice early in the season in recent memory and caused

severe drifting snow, with roads needing to be repeatedly plowed open.

**Apr 26, Eagle:** the ice went out on the Yukon River, the second earliest of record. A small jam formed downriver of town that produced high water in front of Eagle, flooding some yards and roads until the early morning of the 29<sup>th</sup>. However, there was no significant flood damage.

**May 11, Deering:** a combination of an ice jam, recent rains, and snow melt pushed the Innachuk River overbank, cutting off the road to the airport. Water subsided enough to reopen the road the following day.

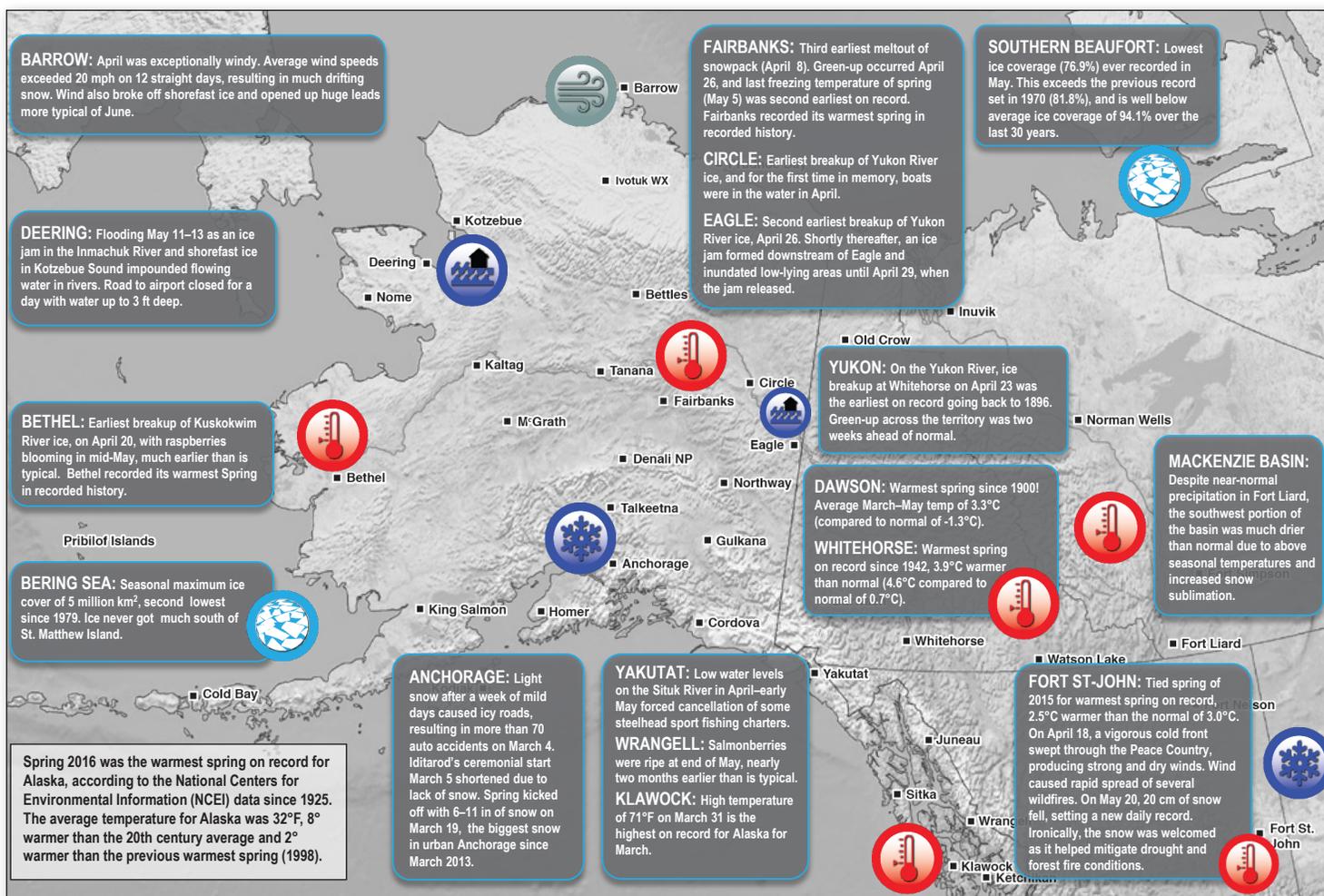


Figure 9. Alaska weather and climate highlights for March-May 2016. More highlights and details are available at [https://accap.uaf.edu/tools/climate\\_highlights#date/2016-03/2016-05](https://accap.uaf.edu/tools/climate_highlights#date/2016-03/2016-05)

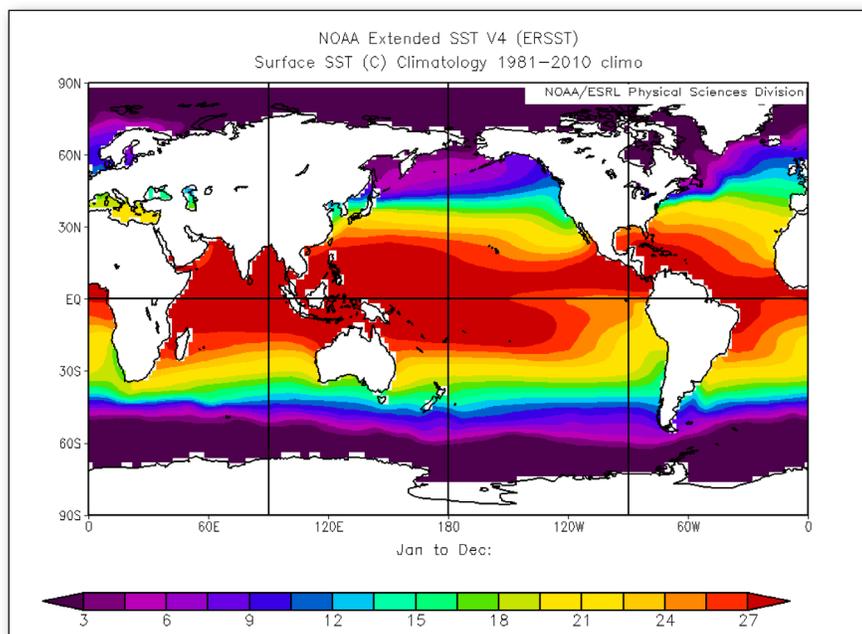
# THE PACIFIC OCEAN AND ALASKA'S CLIMATE

by Rick Thoman, National Weather Service

This article is based on information from NOAA's Climate Prediction Center (<http://www.cpc.ncep.noaa.gov/>) and ACCAP's monthly Alaska Climate Forecast Webinars ([https://accap.uaf.edu/NWS\\_Briefings](https://accap.uaf.edu/NWS_Briefings)).

The Pacific Ocean covers nearly a third of earth's surface, more than all the continents put together, so it is little wonder that the Pacific has a profound influence on the world's weather and climate. For areas washed by Pacific waves, including Alaska, the importance is even greater. The most obvious factor is the ocean surface temperature (Figure 10). Because water is so much denser than air, temperatures change much more slowly in the ocean than the atmosphere. As a result, variations in temperatures on lands adjacent to the ocean (and especially islands) tend to follow the neighboring oceans. This effect is generally confined, however, to coastal margins (although the marine influence is felt farther inland in flat country like the Yukon-Kuskokwim delta, and conversely quite narrowly where big mountains rise up from the ocean, such as in most of Southeast Alaska). On a larger scale, warmer than average ocean temperatures can add extra water vapor to the air above, while cooler than average ocean surface temperatures can limit the amount of water available to the atmosphere.

With these kinds of considerations, climate scientists keep close tabs on what's happening in the Pacific to help understand observed conditions and forecast the future. In general, we're looking for differences in long-term (multiple decades) averages, though it is important to keep in mind that sea surface temperatures (SSTs) and upper ocean heat content over most of the Pacific Ocean are increasing over time. Across the entire basin from Japan to North America north of Hawai'i, the average SST has increased about half a degree Celsius since the early 1900s. This does not sound like much, but it represents a large increase in available moisture and energy, and the full spread of the annual average sea surface temperature in this huge area during the same time period is only about 1.5°C



## HOW SEA SURFACE TEMPERATURES INFLUENCE ALASKA'S CLIMATE

There is a major, and often misunderstood, difference between the tropics and higher latitudes in how ocean temperature anomalies influence the atmosphere. Over the past several decades, with the advent of continuous satellite-based monitoring and much more extensive direct measurement of physical properties of the ocean—both surface and at depth—ocean and climate scientists have developed an understanding of how variations in sea surface temperatures modulate climate. The engine here is the tropical ocean, where huge areas of thunderstorms form and persist. Within about 1000 miles of the equator, ocean surface temperatures warmer than about 28°C allow thunderstorms to grow unless some upper atmosphere process, such as high pressure aloft, suppresses their growth. Tropical thunderstorms are nothing like our tiny Alaska thunderstorms. Complexes of storms regularly cover an area larger than the U.S. and extend 12 or more miles above the ocean surface. These storms pump massive amounts of water and wind into the upper atmosphere, which in turn spiral away from the equator and directly influence the strength and location of the jet stream. The specific locations of these persistent thunderstorms are critical, as this linkage between the tropical oceans and the atmosphere is the mechanism by which modest changes in tropical ocean surface temperatures can influence Alaska's climate.

It's a different story at higher latitudes. Unlike the tropics, where the ocean's connection to massive tropical thunderstorms modifies the atmosphere on a large scale, at higher latitudes the ocean surface temperature anomalies are the cumulative reflection of relatively recent air temperature anomalies (ignoring the impact of anomalous ocean currents). Water has a much higher heat capacity than air, so it takes the ocean surface a while to "catch up" with the air temperature. In climate science we reflect this dichotomy with the maxim "In the tropics, the ocean drives the atmosphere, but elsewhere the atmosphere drives the ocean". But of course it's not that simple, with at least two caveats. First, the ocean is three-dimensional, and the water some distance below the surface can influence physical properties at the surface. This is especially evident in the transition from summer to autumn.

Figure 10. Average annual sea surface temperature, 1981–2010. Figure from NOAA Earth System Research Laboratory.

## PACIFIC OCEAN AND ALASKA'S CLIMATE

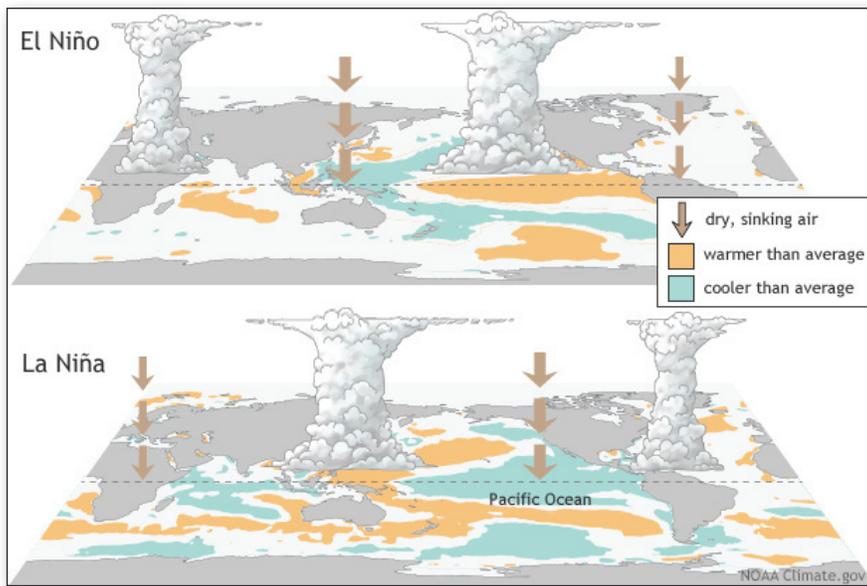


Figure 11. Schematic of the El Niño and La Niña phases of the ENSO. Figure from NOAA Climate.gov

During summer, the lack of storms and relatively calm ocean waters can allow very shallow anomalies (warm or cold) to form at the surface. These tend to “disappear” in the autumn when storm season cranks up and the ocean water is mixed down to a greater depth. Recent work has revealed the second caveat: sea surface temperatures at mid and high latitudes can have subtle (but real) impacts on the overlying atmosphere flow patterns. However, this is evident only over very long time scales and is unlikely to be significant over a single season.

So here’s a rundown of the large-scale variations in Pacific Ocean temperatures that influence Alaska’s seasonal climate:

## EL NIÑO-SOUTHERN OSCILLATION (ENSO)

Sea surface temperatures in the eastern equatorial Pacific vary significantly from year to year. This pattern has been known for centuries, primarily because unusually warm waters near the South American coast adversely affects fish stocks and subsequent fishing success. Typically the warmest Pacific waters are in the far west, from the Solomon Islands to west of the dateline (far southwest of Hawai’i). On an irregular cycle of three to seven years, the very warm waters shift into the central and eastern Pacific. These unusually warm waters typically show up along the South American coast in December, when Christians celebrate the birth of Christ, hence the name “El Niño” (baby boy). This shift in turn weakens the trade winds and moves the focus of thunderstorm activity eastward. When ocean surface temperatures are significantly cooler than average in the central and eastern Pacific, this is called La Niña. La Niña, however, is not the opposite of El Niño (Figure 11). La Niña represents basically an enhanced version of “normal,” with the focus of tropical thunderstorms over the western Pacific in both the “normal” and La Niña cases. El Niño marks a disruption of the typical thunderstorm pattern, while La Niña is more akin to “normal on steroids.” For a couple of decades now, ENSO has been characterized by climate scientists using the ocean surface temperature anomaly in an imaginary box in the central Pacific spanning 5 degrees either side of the equator between 170W and 120W longitude, known for historical reasons as the Niño 3.4 region. Departures of more than 0.5°C from the seasonal average fall into either the El Niño category (half degree or more warmer than average)

or La Niña (half degree or more below average). Temperatures within half a degree of normal are classified as “neutral.”

So what do El Niño and La Niña mean for Alaska seasonal climate, keeping in mind this is just one piece of the climate puzzle? Historically, moderate to strong El Niño conditions tip the odds in favor of mild winter temperatures over the eastern two-thirds of Alaska, while moderate to strong La Niña conditions have a more varied impact on temperatures but increase chances for cold and snowy outbreaks compared to El Niño. Precipitation impacts are complicated by the interaction of large-scale winds with Alaska’s mountains, but overall El Niño conditions tip the odds toward a winter that is dry over mainland Alaska but wet along the northern Gulf Coast. There is little correlation between El Niño and precipitation in Southeast Alaska.

## PACIFIC DECADAL OSCILLATION (PDO)

The Pacific Decadal Oscillation (PDO) was identified about 20 years ago in an effort to understand variations in salmon returns in the Pacific Northwest. The PDO is ultimately about the pattern of ocean surface temperature anomalies (departures from normal) in the north Pacific roughly north of Hawai’i. The stereotypical positive PDO pattern features warmer than average temperatures in a horseshoe shape extending from the Bering Sea and Gulf of Alaska, southward along the west coast of North America and then hooking back towards Hawai’i, while at the same time an area of cooler than average water extends eastward from Japan into the central North Pacific (Figure 12). Unlike ENSO, a negative PDO pattern is the mirror image of the positive pattern. Early work on PDO indicated a 20 to 30 year cycle of North Pacific SST anomalies that was largely independent of the tropics. Recent work (and 20 plus years of additional data) have demonstrated several nuances to this story. We now know that atmospheric response to a given PDO pattern has changed over the past century, that the PDO almost certainly indirectly reflects tropical SST variations to some extent, and that time scales for changes in the PDO phase can be much shorter than a couple of decades.

So what does this mean for Alaska? It was almost immediately noticed that the PDO change from an overall cold (negative) phase to a warm phase in 1976 corresponded with a dramatic increase in seasonal to annual scale temperatures across Alaska. Since the late 1980s, however, Alaska temperatures have shown weaker correlation with PDO, and this

## PACIFIC OCEAN AND ALASKA'S CLIMATE

has been especially dramatic in some seasons and some regions (for example, Southeast Alaska in the late winter and spring).

In general, however, the warmest winters are strongly favored to occur during positive PDO while the coldest winters are strongly favored in negative PDO conditions. PDO is a useful tool for seasonal scale climate forecasting for Alaska because of the “memory” built into sea surface temperatures and because dynamic climate models have some skill in forecasting the basic pattern of SST anomalies several months in advance. However, we always need to keep in mind that, except in the most maritime climates, SST configurations are just one factor influencing our day to day weather.

## NORTH PACIFIC MODE (NPM), ALSO KNOWN AS “THE BLOB”

Thanks to the power of social media, “The Blob” burst into our collective consciousness during the winter of 2013-14, when a strong warm anomaly in SSTs developed in the northeast Pacific. The overall “blob” pattern, called the North Pacific Mode (NPM), had actually been known for some time and found comparable to PDO in capturing observed North Pacific surface temperature anomalies. The typical pattern (Figure 13) looks something like PDO, but with both warm and cold anomalies centered farther south and lacking much connection to the tropics. The NPM is more variable in the short term than the PDO but at least as persistent in the multi-year time range.

The “blob” was cited in the media as a cause of recent dry winters in the western U.S. (and by implication the mild weather in much of Alaska), but, as you now know, this confused the co-occurrence of warm SSTs in the northeast Pacific with the cause. The “blob” was the product of the same atmospheric feature (persistent high pressure aloft—also known as the Ridiculously Resilient Ridge) that brought drought to the western states. From a climate system viewpoint, the magnitude of the blob's SST anomalies were as large or larger than previously seen, and because of the three dimensional nature of the ocean, the warmth of 2013-14 has now extended well below the surface, with excess heating through the upper 300 meters of the northeast Pacific Ocean.

How about using the NPM in forecasting? The correlation of the NPM pattern over Alaska is somewhat different than the PDO, with moderate to strong positive and negative NPM values tilting the odds toward warmer winters (colder winters occur more frequently when the NPM is not too far from zero). Traditionally the NPM has not been used in

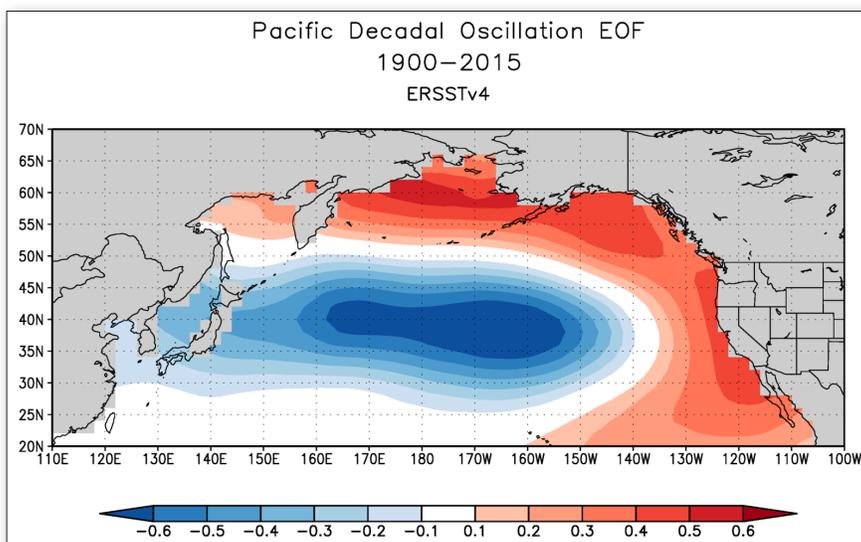


Figure 12. Schematic of SST anomalies in the positive phase of the Pacific Decadal Oscillation (PDO) Figure courtesy Richard James, Prescient Weather.

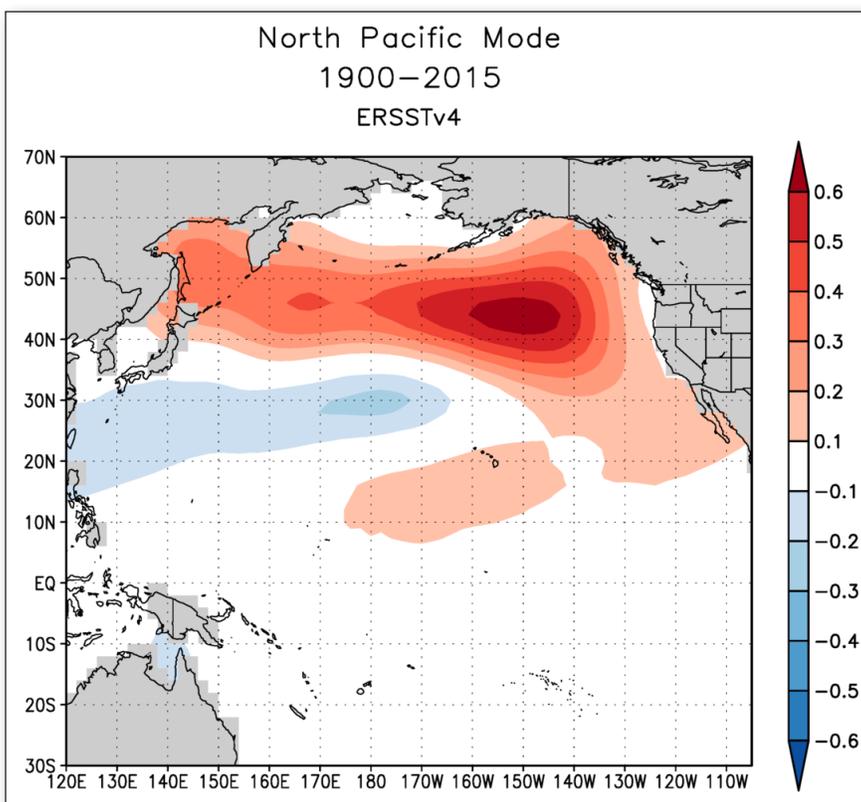


Figure 13. Schematic of SST anomalies in the positive phase of the Pacific Mode (NPM) Figure courtesy Richard James, Prescient Weather.

seasonal forecasting, in part because of its higher variability compared to the PDO over shorter (1-6 month) time scales, but mostly because it is just not as well known among climate scientists.

# AUTUMN 2015 WEATHER CONDITIONS IN ALASKA

By Gerd Wendler, Blake Moore, and Kevin Galloway  
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This article presents a climate summary of autumn 2015 (September, October, November), concentrating on temperature and precipitation from the 19 first-order meteorological stations operated by National Weather Service (NWS) meteorologists in Alaska. The deviations from the long-term average are based on the new normal of 1981–2010. Additional information, including temperature and precipitation records, is available at the Alaska Climate Research Center, <http://akclimate.org>. All figures and tables are provided by the Alaska Climate Research Center, except as noted.

## TEMPERATURE

Temperatures in Alaska in autumn 2015 were noticeably warmer than normal (Figure 14). All 19 first order stations reported above normal temperatures for the season, for a mean deviation of 2.9°F, close to autumn 2014's deviation of 3.0°F. While this is not a large value for a single station or month, it is notable as a mean of 19 stations spread over an area as large as Alaska for a whole season. Western Alaska, including McGrath (6.0°F) and King Salmon (5.3°F), showed the highest positive deviations (>5°F for the season). Cold Bay had the lowest, but still positive, deviation with a seasonal value of +0.9°F. Coastal areas recorded lower deviations than the Interior (Figure 14). Table 3 lists each autumn month's temperature data, deviations, and seasonal means. September was relatively cold with a deviation of -1.3°F, while October (+5.5°F) and November (+4.4°F) reported temperatures far above normal.

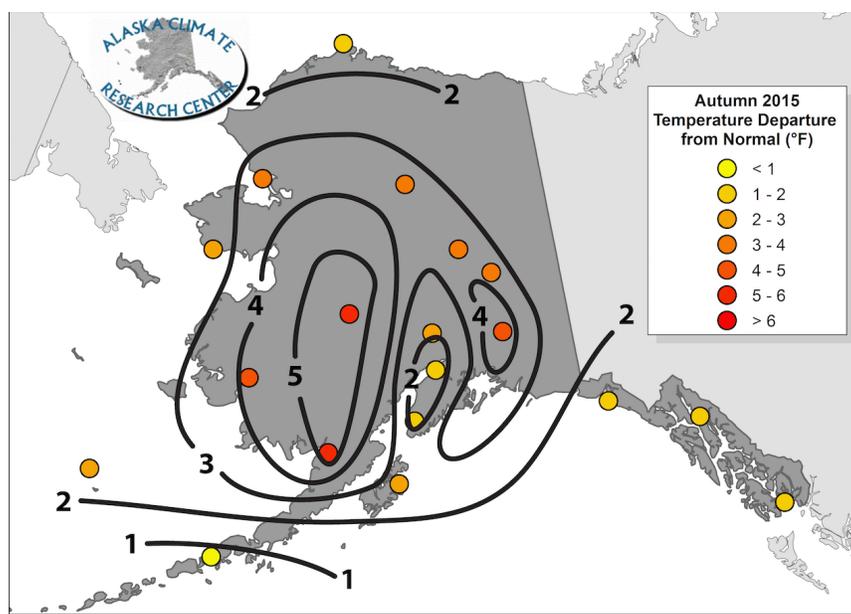
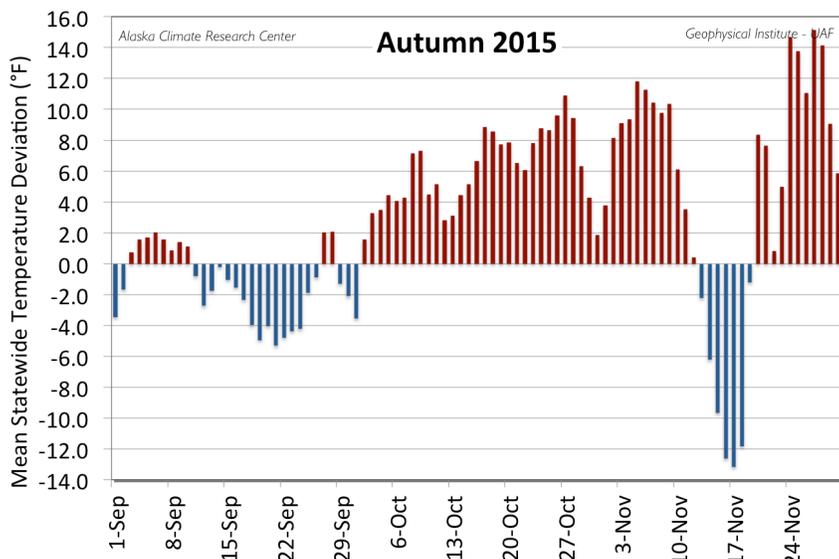


Figure 14. Autumn 2015 isotherm map of the deviation in temperature (°F) from the 30-year normal (1981–2010) based on all first-order meteorological stations in Alaska.

Figure 15. Time series of the mean Alaska temperature deviations (°F) for autumn 2015.



Statewide monthly temperatures had been consistently above normal since July 2014, but **September** broke this 14-month trend with a monthly mean temperature of 44.3°F, 1.3°F below the 30-year normal and 3.5°F below the September 2014 mean of 47.8°F. 16 of the 19 first-order stations reported below normal mean temperatures (Table 3), and 20 days of the month were below the 30-year normal (Figure 15). The peak warm deviation (+2.1°F) occurred on the 28<sup>th</sup>, while the coldest deviation of -5.3°F occurred on the 21<sup>st</sup>. Bettles reported the greatest negative deviation at 3.7°F below its long-term mean of 40.6°F. Talkeetna (-3.2°F), Nome (-2.8°F), Delta Junction (-2.6°F), Fairbanks (-2.5°F), and Anchorage (-2.2°F) also reported negative deviations equal to or exceeding 2.0°F. St. Paul Island had the greatest positive deviation at 1.7°F.

## AUTUMN WEATHER SUMMARY

Station	Temperature (°F)							
	September		October		November		Seasonal	
	Mean	Dev	Mean	Dev	Mean	Dev	Mean	Dev
<b>Anchorage</b>	<b>46.4</b>	<b>-2.2</b>	<b>40.5</b>	<b>5.7</b>	<b>23.8</b>	<b>1.6</b>	<b>36.9</b>	<b>1.7</b>
<b>Annette</b>	<b>53.0</b>	<b>-0.8</b>	<b>51.3</b>	<b>4.6</b>	<b>41.1</b>	<b>1.1</b>	<b>48.5</b>	<b>1.7</b>
<b>Barrow</b>	<b>31.1</b>	<b>-1.0</b>	<b>20.6</b>	<b>3.4</b>	<b>2.9</b>	<b>2.2</b>	<b>18.2</b>	<b>1.5</b>
<b>Bethel</b>	<b>44.0</b>	<b>-1.6</b>	<b>37.5</b>	<b>7.2</b>	<b>24.5</b>	<b>7.1</b>	<b>35.3</b>	<b>4.2</b>
<b>Bettles</b>	<b>36.9</b>	<b>-3.7</b>	<b>25.2</b>	<b>6.3</b>	<b>7.4</b>	<b>8.4</b>	<b>23.2</b>	<b>3.7</b>
<b>Cold Bay</b>	<b>48.6</b>	<b>0.5</b>	<b>42.5</b>	<b>2.1</b>	<b>34.7</b>	<b>0.2</b>	<b>41.9</b>	<b>0.9</b>
<b>Delta Junction</b>	<b>41.3</b>	<b>-2.6</b>	<b>31.9</b>	<b>7.8</b>	<b>11.8</b>	<b>5.6</b>	<b>28.3</b>	<b>3.6</b>
<b>Fairbanks</b>	<b>42.4</b>	<b>-2.5</b>	<b>31.8</b>	<b>7.6</b>	<b>9.1</b>	<b>6.5</b>	<b>27.8</b>	<b>3.9</b>
<b>Gulkana</b>	<b>42.6</b>	<b>-0.7</b>	<b>32.4</b>	<b>5.8</b>	<b>13.4</b>	<b>7.6</b>	<b>29.5</b>	<b>4.3</b>
<b>Homer</b>	<b>46.2</b>	<b>-1.9</b>	<b>42.9</b>	<b>4.8</b>	<b>32.3</b>	<b>2.8</b>	<b>40.5</b>	<b>1.9</b>
<b>Juneau</b>	<b>49.2</b>	<b>-0.8</b>	<b>44.6</b>	<b>2.2</b>	<b>36.1</b>	<b>2.7</b>	<b>43.3</b>	<b>1.4</b>
<b>King Salmon</b>	<b>46.8</b>	<b>-0.8</b>	<b>42.8</b>	<b>9.3</b>	<b>30.3</b>	<b>7.4</b>	<b>40.0</b>	<b>5.3</b>
<b>Kodiak</b>	<b>50.3</b>	<b>0.9</b>	<b>45.5</b>	<b>5.0</b>	<b>36.3</b>	<b>2.4</b>	<b>44.0</b>	<b>2.7</b>
<b>Kotzebue</b>	<b>40.8</b>	<b>-1.5</b>	<b>30.5</b>	<b>6.2</b>	<b>14.8</b>	<b>5.7</b>	<b>28.7</b>	<b>3.5</b>
<b>McGrath</b>	<b>43.6</b>	<b>-1.0</b>	<b>33.8</b>	<b>8.7</b>	<b>16.0</b>	<b>10.5</b>	<b>31.1</b>	<b>6.0</b>
<b>Nome</b>	<b>40.0</b>	<b>-2.8</b>	<b>34.3</b>	<b>5.6</b>	<b>21.5</b>	<b>4.6</b>	<b>31.9</b>	<b>2.4</b>
<b>St. Paul Island</b>	<b>47.0</b>	<b>1.7</b>	<b>41.6</b>	<b>3.0</b>	<b>35.8</b>	<b>2.8</b>	<b>41.5</b>	<b>2.5</b>
<b>Talkeetna</b>	<b>44.3</b>	<b>-3.2</b>	<b>39.6</b>	<b>6.4</b>	<b>22.7</b>	<b>3.2</b>	<b>35.5</b>	<b>2.1</b>
<b>Yakutat</b>	<b>47.7</b>	<b>-0.7</b>	<b>44.0</b>	<b>3.0</b>	<b>34.7</b>	<b>2.4</b>	<b>42.1</b>	<b>1.5</b>

Table 3. Autumn 2015 means and deviations in temperature (°F) from the 30-year normal (1981–2010) for all first-order stations for each autumn month and for the season.

**October** 2015 temperatures were decidedly above normal across the state and through most of the month. The monthly mean temperature was 37.5°F, a substantial 5.5°F above the normal of 32.0°F and 5.2°F above the October 2014 mean of 32.3°F. Mean temperatures were above normal for all 19 stations (Table 3) and for every day in October, with the exception of the 1<sup>st</sup> of the month, which was below normal by 3.6°F (Figure 15); the peak warm deviation, an extreme +10.9°F, occurred on the 27<sup>th</sup>. King Salmon reported the greatest positive deviation for October with 9.3°F above its long-term monthly mean of 33.5°F. McGrath (8.7°F), Delta Junction (7.8°F), Fairbanks (7.6°F), and Bethel (7.2°F), all stations in Interior Alaska, also reported deviations exceeding 7.0°F.

**November** continued the above normal trend both across the state and through much of the month. The monthly mean temperature was 23.6°F, 4.4°F above the normal of 19.2°F and 2.6°F below the extremely warm November 2014 mean of 26.2°F. These high temperatures were caused in part by positive values of the Pacific Decadal Oscillation (PDO), which is derived from Pacific water temperatures north of 20°N (page 10). Mean November temperatures were above normal for all 19 stations (Table 3), and only one week (November 13–19) had mean temperatures below the 30-year normal (Figure 15). The peak warm deviation, an extreme 15.2°F, occurred on the 27<sup>th</sup>, while the coldest deviation of -13.2°F occurred on the 17<sup>th</sup>. McGrath reported the greatest positive deviation from normal with a high value of 10.5°F above its long-term November mean of 5.5°F. Gulkana (7.6°F), King Salmon (7.4°F), and Bethel (7.1°F) also reported positive deviations exceeding 7.0°F.

## PRECIPITATION

Autumn precipitation showed a positive deviation of 28%. 13 stations reported above normal values, while 6 stations reported lower than normal precipitation. Every day of the season had measureable precipitation at at least one of the 19 stations. Fairbanks (144%), Anchorage (84%), and Talkeetna (82%) reported the greatest surplus, while Delta Junction (-54%) and Barrow (-27%) experienced a deficit in precipitation. For details, see Figure 16 and Table 4.

Looking at the autumn months separately, September was wetter than normal, October was close to normal, while November had a great surplus of precipitation (Table 4).

**September** was notably wet, with 12 of 19 stations reporting above normal values and an overall deviation of +28%. This is wetter than September 2014, which was 4% above normal. On a monthly basis, Fairbanks had the greatest positive deviation, with a total of 3.74", or 240% above the normal amount of 1.10". Anchorage (158%), Talkeetna (110%) and Bethel (107%) also reported precipitation greater than 100% above normal. The leading station with lower than normal precipitation was Kodiak with just 29% of normal. Kotzebue (38%) and Gulkana (45%) also reported less than half of their normal precipitation. Yakutat had the maximum monthly precipitation total at 21.46" and the highest daily total of 3.77" on the 29<sup>th</sup>, a new record for that day. Fairbanks reported the highest total snowfall at 20.9", its second highest September total on record. Fairbanks also reported the highest one-day snowfall at 11.2" on the 29<sup>th</sup>, a new daily record, as well as the highest snow depth at 11", also on the 29<sup>th</sup>. It should be noted that September is early in the winter season, and most stations have little, if any, snowfall and seldom have an established snowpack.

**September** 2015 set an extensive number of daily precipitation records, nearly half of which occurred during the very wet last four days of the month (see <http://akclimate.org> for specifics). It was the wettest September on record for Anchorage with 7.71" of precipitation, breaking the old 2004 record of 7.61". Using the climate record since 1929, it was also the wettest September in Fairbanks at 3.74", breaking the 1960 record of 3.05". Further, the record snowfall on the 29<sup>th</sup> of 11.2" was a new daily record for any day in September for Fairbanks (photo next page). Juneau continued its exceptionally wet year—every month in 2015, except May, has had above normal precipitation. Figure 17 presents daily precipitation deviations from normal for the season; the storm periods bringing lots of moisture into Alaska are clearly evident.

AUTUMN WEATHER SUMMARY

**October** was slightly drier than normal, with the overall precipitation calculated as 4% below normal. This is wetter than October 2014, which had a precipitation deviation of 25% below normal. Kodiak had the greatest positive deviation from normal, with a total of 13.80", or 67% above the expected amount of 8.26"; it was the fifth wettest October for Kodiak. The only other station with precipitation greater than 50% above normal was Nome (53%). Delta Junction was the driest station with just 20% of normal precipitation. The only other station with less than half its normal precipitation was Bethel (35%).

Yakutat had the highest **October** precipitation total at 15.55", while Kodiak reported the highest daily total of 3.10" on the 27<sup>th</sup>, a new record for that date. Bettles reported the highest total snowfall at 8.1". Anchorage reported the highest one-day snowfall at 3.1" on the 30<sup>th</sup>. Fairbanks reported the highest snow depth at 9" on the 1<sup>st</sup>, a result of the record snowfall at the end of September. Again, October is early in the winter season, and the more southerly stations have little, if any, snowfall, and seldom have established a snowpack.

**November** was significantly wetter than normal across the state, with overall precipitation 74% above normal. 16 of the 19 stations reported above normal values. It was much wetter than November 2014, which had a precipitation total 18% below normal. King Salmon reported the greatest positive deviation from normal, with a total of 4.84", or 248% above the normal amount of 1.39". McGrath (194%), Bettles (170%), Fairbanks (166%), and Talkeetna (165%) also had precipitation totals greater than 150% above normal. Like October, Delta Junction continued as the driest station with just 57% of normal.

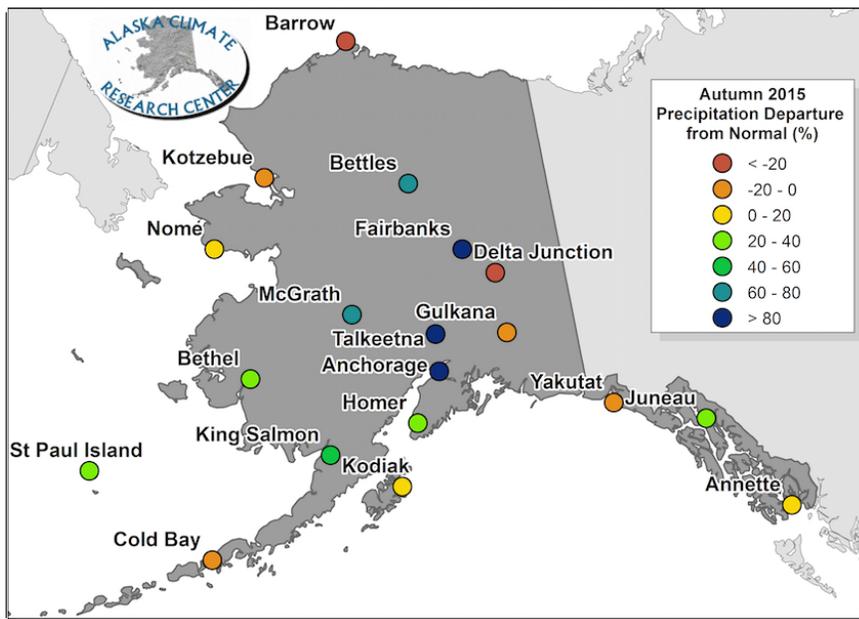


Figure 16. Autumn 2015 map of the precipitation departures (%) from the 30-year normal (1981–2010) based on all first-order meteorological stations in Alaska.

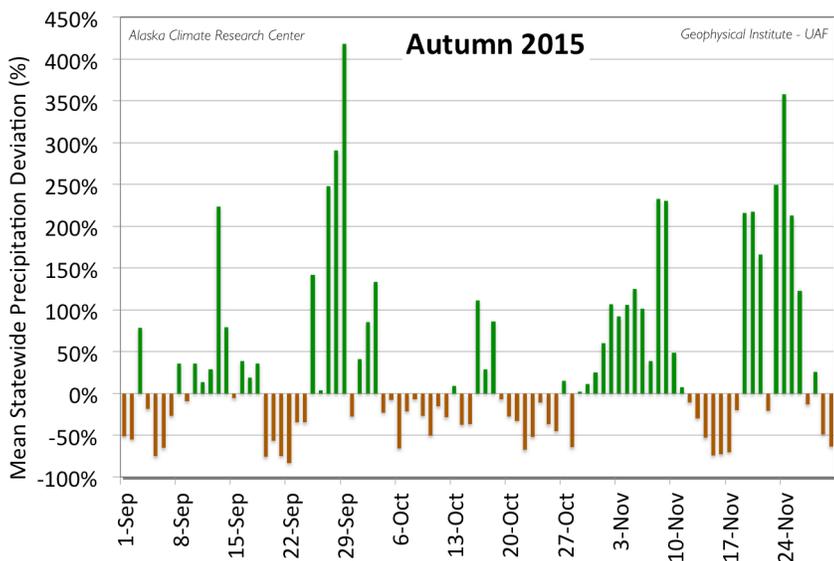


Figure 17. Time series of the mean Alaska precipitation deviations (%) for autumn 2015.

Station	Snowfall (in)		
	Seasonal		
	Total	Normal	Deviation
Anchorage	19.7	21.4	-8%
Annette	0.9	3.6	-75%
Barrow	12.4	19.2	-35%
Bethel	9.4	17.9	-47%
Bettles	68.2	31.0	120%
Cold Bay	5.3	12.6	-58%
Fairbanks	50.1	25.8	94%
Juneau	16.6	13.9	19%
King Salmon	13.1	9.8	34%
Kodiak	1.6	7.5	-79%
Kotzebue	21.5	17.4	24%
McGrath	47.0	31.0	52%
Nome	18.2	17.3	5%
St. Paul Island	12.0	10.3	17%
Yakutat	22.8	20.7	10%

Table 5 Seasonal snowfall for autumn 2015 (September, October, November) for the 15 first-order stations in Alaska that report snow.

## AUTUMN WEATHER SUMMARY



## Storm Total Snowfall September 28 - 30



College Hills	16.9"
South Fox	15.5"
3 Mile Chena Hot Springs Rd	15.0"
Upper McGrath Road	14.5"
Midtown Fairbanks	13.6"
UAF	13.0"
Keystone Ridge	13.0"
East Farmers Loop	12.9"
University West	11.1"
North Pole	10.0"
Trims Camp	12.0"
Denali Park Headquarters	11.8"
Nenana	8.5"
Eagle	6.0"





Snowfall totals recorded across Interior Alaska after the September 28-30 snowstorm. Image courtesy of Alaska National Weather Service.

Yakutat reported the maximum November precipitation total with 16.23", as well as the highest daily total of 2.09" on the 20<sup>th</sup>, a new record for that date. Bettles reported the highest total snowfall at 50.6", a new monthly record. McGrath reported the highest one-day snowfall at 10.8" on the 23<sup>rd</sup> and the highest snow depth at 30".

Juneau remained on track to set a new annual precipitation record. From January to the end of November Juneau received 82.54" of precipitation, beating the old record for the same time period of 75.83" from 1991. The normal precipitation for that time period is 56.43".

Finally, we all know that precipitation can fall in liquid (rain) or solid (snow) form. The end of September with its precipitation and cool temperatures brought snowfall into Interior Alaska, at a time when rain is more commonly observed. Table 5 shows about twice as much snowfall at both Bettles and Fairbanks as would normally be expected, although much of the early autumn snowfall in Interior regions melted or sublimated well before the following spring.

Station	Precipitation (in)							
	September		October		November		Seasonal	
	Total	Dev	Total	Dev	Total	Dev	Total	Dev
Anchorage	7.71	158%	1.97	-3%	1.69	46%	11.37	84%
Annette	11.36	16%	15.41	11%	10.33	-16%	37.10	3%
Barrow	0.45	-38%	0.27	-34%	0.26	24%	0.98	-27%
Bethel	5.70	107%	0.58	-65%	1.97	23%	8.25	38%
Bettles	3.20	68%	1.11	7%	2.46	170%	6.77	75%
Cold Bay	3.94	-17%	4.72	-1%	4.87	-2%	13.53	-6%
Delta Junction	0.62	-40%	0.16	-80%	0.36	-43%	1.14	-54%
Fairbanks	3.74	240%	0.83	0%	1.78	166%	6.35	144%
Gulkana	0.71	-55%	0.71	-30%	1.78	147%	3.20	-3%
Homer	5.42	64%	3.01	17%	3.28	18%	11.71	35%
Juneau	11.51	33%	7.21	-16%	12.02	101%	30.74	32%
King Salmon	3.25	2%	1.57	-25%	4.84	248%	9.66	45%
Kodiak	2.16	-71%	13.80	67%	6.93	1%	22.89	2%
Kotzebue	0.60	-62%	1.03	2%	1.32	71%	2.95	-12%
McGrath	2.83	14%	1.93	34%	4.14	194%	8.90	67%
Nome	1.49	-39%	2.46	53%	1.95	60%	5.90	12%
St. Paul Island	4.21	41%	3.88	25%	3.64	26%	11.73	30%
Talkeetna	9.07	110%	2.73	-6%	4.32	165%	16.12	82%
Yakutat	21.46	2%	15.55	-29%	16.23	12%	53.24	-7%

Table 4. The deviation in precipitation (%) from the 30-year normal (1981–2010) is presented for the first-order stations for each autumn month and for the autumn 2015 season.

# WINTER 2015-16 WEATHER CONDITIONS IN ALASKA

By Gerd Wendler, Blake Moore, and Kevin Galloway  
Alaska Climate Research Center, Geophysical Institute, UAF

This article presents a climate summary of winter 2015-16 (December, January, February), concentrating on temperature and precipitation from the 19 first-order meteorological stations operated by National Weather Service (NWS) meteorologists in Alaska. The deviations from the long-term average are based on the new normal of 1981–2010. More information, including temperature and precipitation records, is available at the Alaska Climate Research Center, <http://akclimate.org>. All figures and tables are provided by the Alaska Climate Research Center.

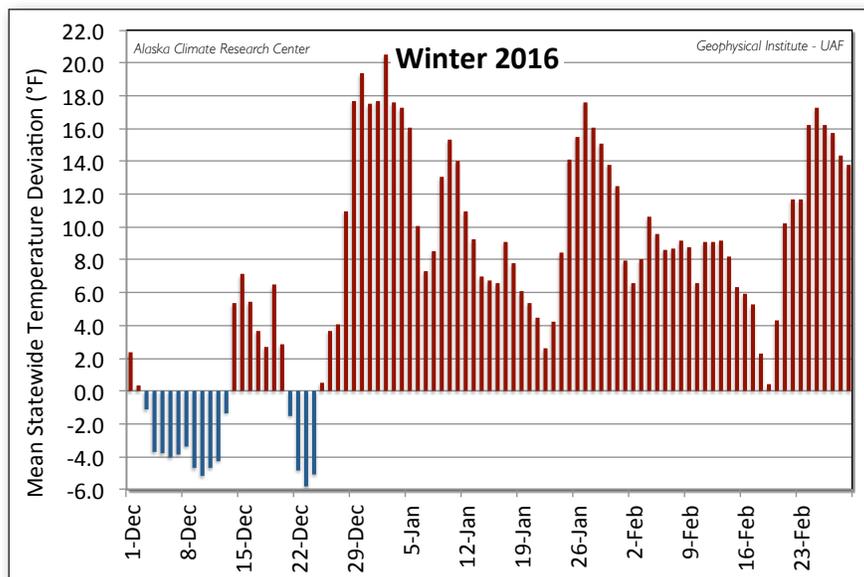


Figure 19. Time series of the mean Alaska temperature deviations (°F) for winter 2015-16.

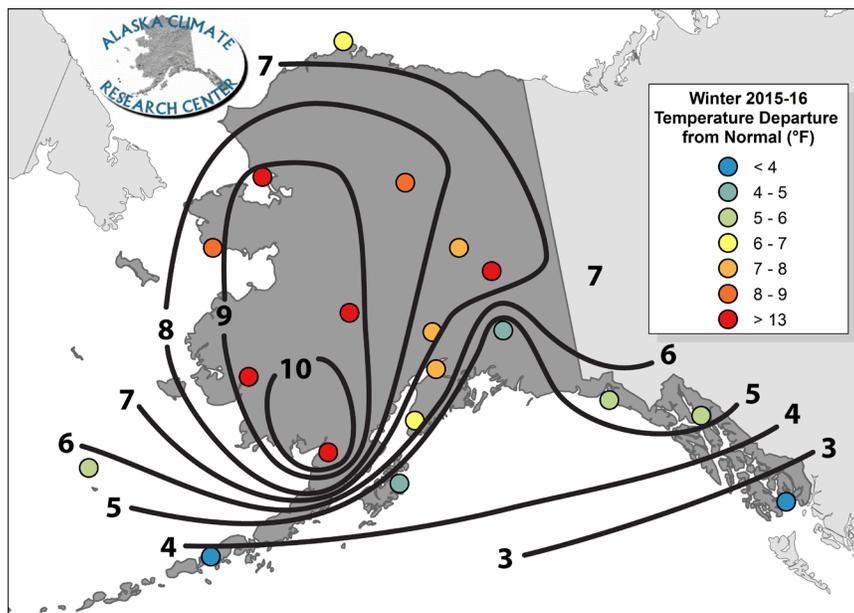


Figure 18. Winter 2015-16 isotherm map of the deviation in temperature (°F) from the 30-year normal (1981–2010) based on all first-order meteorological stations in Alaska. Values from Delta Junction are not included, because frequent Chinook events led to excessively high temperature deviations. Delta Junction, in the foothills on the northern side of the Alaska Range, experiences fairly frequent winds with a southerly flow. When the moist air is elevated on the south side of the mountain range, it rains or snows, hence it is cooled moist adiabatically, however, when it descends on the north side, it warms at the higher dry adiabatic rate.

## TEMPERATURE

Midwinter temperatures were far above normal, due in part to the continued strongly positive phase of the Pacific Decadal Oscillation (PDO, page 10). All 19 first-order stations in Alaska measured temperatures above the long-term mean (Figure 18). The seasonal statewide mean temperature was 20.5°F, the second highest winter temperature in Alaska since 1949, and just 0.3° cooler than the winter of 2001. Table 6 lists the mean temperatures and temperature deviations from the 30-year normal (1981-2010) for the 19 first-order stations by month and for the winter season. Figure 19 shows the daily mean deviation in temperature for the average of the 19 stations. King Salmon, in southwestern Alaska, recorded the season's largest deviation from the long-term mean at +12.2°F, while Annette in southeast Alaska recorded the lowest, but still positive, deviation at +2.2°F.

It was the warmest winter on record for the following stations:

- King Salmon (30.1°F, topping 29.3°F from 2001),
- Barrow (-5.0°F, breaking -4.7°F from 2014),
- Sitka (41.3°F, just topping 41.2°F from 1977; not a first-order station).

It was the second warmest winter for:

- Anchorage (26.1°F, after 29.1°F set in 1977),
- Bettles (1.3°F, after 2.9°F from 2001),
- McGrath (6.6°F, after 8.5°F from 2001),
- Kotzebue (8.8°F, after 11.6°F from 2001; not a first-order station),
- Kenai (27.1°F, after 27.6°F from 1977; not a first-order station).

## WINTER WEATHER SUMMARY

Station	Temperature (°F)							
	December		January		February		Seasonal	
	Mean	Dev	Mean	Dev	Mean	Dev	Mean	Dev
Anchorage	21.5	2.5	27.0	9.9	29.9	9.7	26.1	7.3
Annette	35.9	-1.2	40.9	3.9	41.6	3.9	39.5	2.2
Barrow	-10.6	-2.8	-0.3	13.1	-4.1	10.1	-5.0	6.8
Bethel	13.8	3.4	21.5	14.9	21.8	10.7	19.0	9.6
Bettles	-7.9	-2.2	5.0	15.0	6.9	11.9	1.3	8.2
Cold Bay	32.6	1.5	32.8	4.6	34.3	5.3	33.2	3.8
Delta Junction	2.9	0.8	15.7	16.7	18.1	13.2	12.2	10.2
Fairbanks	-2.2	1.9	3.5	11.4	7.9	9.2	3.1	7.5
Gulkana	-1.2	-1.6	6.1	9.0	11.3	5.8	5.4	4.4
Homer	27.9	0.8	33.9	9.1	35.4	9.2	32.4	6.4
Juneau	32.0	2.1	34.9	6.6	37.6	7.5	34.8	5.4
King Salmon	23.2	4.6	32.4	16.2	34.8	16.0	30.1	12.2
Kodiak	34.6	3.4	36.4	5.9	36.0	5.2	35.7	4.9
Kotzebue	1.9	-0.4	13.8	16.6	10.6	11.4	8.8	9.2
McGrath	1.1	4.3	8.5	15.0	10.2	8.8	6.6	9.4
Nome	11.5	2.0	20.2	15.0	16.1	8.7	15.9	8.5
St. Paul Island	31.8	2.9	30.8	5.7	32.9	8.5	31.8	5.7
Talkeetna	17.3	1.3	25.1	10.9	29.0	10.9	23.8	7.7
Yakutat	31.8	2.2	35.9	7.8	37.1	7.4	34.9	5.8

Table 6. The winter 2015-16 means and deviations in temperature (°F) from the 30-year normal (1981–2010) for all first-order stations for each winter month and for the season.

It was the third warmest winter for Bettles, Delta Junction, and Talkeetna. Yakutat experienced its fourth warmest winter, while it was the fifth warmest in Cordova, Dutch Harbor, and Nome.

Looking at the winter months separately, December 2015 temperatures continued the overall above normal trend from October and November 2015. December's mean temperature was 15.7°F, 1.4°F above the 30-year normal of 14.3°F. The monthly mean temperatures were above normal for 14 of the 19 stations and on 16 days of the month. Two cold spells, from December 2-13 and 21-24, saw mean temperatures below the long-term mean (Figure 19). The peak warm deviation, an extreme 19.3°F, occurred on the 30<sup>th</sup>, while the coldest deviation of -5.8°F occurred on the 26<sup>th</sup>. King Salmon recorded the greatest positive deviation with a value of 4.6°F above its long-term mean of 18.6°F. Other stations with December deviations exceeding 3.0°F were McGrath (4.3°F), Bethel (3.4°F), and Kodiak (3.4°F). Barrow had the greatest negative deviation at -2.8°F, followed by Bettles with a value of -2.2°F. Annette reported the highest December temperature of 50°F on both the 5<sup>th</sup> and 6<sup>th</sup> and the highest monthly mean temperature at 35.9°F. Bettles recorded the month's lowest temperature (-40°F at on the 24<sup>th</sup>), while Barrow reported the lowest December mean temperature at -10.6°F.

January 2016 temperatures continued consistently above normal. Alaska's monthly mean temperature was 22.3°F, 10.9°F above the normal of 11.4°F and 7.3°F above the January 2015 mean of 15.0°F. January mean temperatures remained above normal for all 19 stations and on all 31 days of the month. The peak positive deviation for the month, an extreme +20.5°F, occurred on the 2<sup>nd</sup>. Delta Junction reported January's greatest positive deviation with a significant value of 16.7°F above its long-term mean of -1.0°F. Kotzebue (16.6°F), King Salmon (16.2°F), Bettles (15.0°F), McGrath (15.0°F), and Nome (15.0°F) all reported deviations equal to or exceeding 15.0°F. The highest temperature in January was 52°F at Annette on both the 10<sup>th</sup> and 11<sup>th</sup> of the month. Annette also had the highest mean temperature for the month at 40.9°F. The lowest temperature was -32°F at Bettles on the 22<sup>nd</sup>. Barrow reported the lowest mean temperature at -0.3°F, making 2016 Barrow's second warmest January, below

the record of 5.6°F set in 1930. It was the fourth warmest January for Kotzebue, Delta Junction, and Northway. It was the fifth warmest for King Salmon and Bettles.

February 2016 was the fifth month in a row with above normal temperatures in Alaska. The monthly mean temperature was 23.5°F, 9.1°F above the normal of 14.4°F and 4.0°F above the February 2015 mean of 19.5°F. As in January, February mean temperatures were above normal for all 19 stations and every day of the month (Figure 19). Positive deviations peaked on the 25<sup>th</sup> at +17.2°F. King Salmon reported the greatest positive deviation with 16.0°F above its long-term mean of -1.0°F. Delta Junction (13.2°F), Bettles (11.9°F), Kotzebue (11.4°F), Talkeetna (10.9°F), Bethel (10.7°F), and Barrow (10.1°F) also reported deviations exceeding +10.0°F.

Annette reported the highest February temperature of 59°F on the 9<sup>th</sup> and the highest monthly mean at 41.6°F. The lowest temperature was -22.0°F at Bettles on the 17<sup>th</sup>, while Barrow reported the lowest mean monthly temperature at -4.1°F.

It was the second warmest February on record at the following stations:

- King Salmon (34.8°F, after 35.6°F from 2003),
- Juneau (37.6°F, after 40.1°F from 1977),
- Kenai (31.2°F, after 31.3°F from 2003; not a first-order station),
- Sitka (42.8°F, after 50.0°F from 1977; not a first-order station).

It was the third warmest February for Barrow, Bettles, Kotzebue, Talkeetna, and Ketchikan. It was the fourth warmest February for Bethel and Anchorage and the fifth warmest for Delta Junction and Homer.

WINTER WEATHER SUMMARY

PRECIPITATION

Most of Alaska experienced a precipitation deficit for winter 2015-16. Twelve of the 19 stations reported below normal seasonal precipitation, while 7 stations reported values above normal; there were no days during the season without any measureable precipitation at all of the 19 stations. In some cases the deficits were very substantial. For example, Fairbanks received only 0.13" water-equivalent, which is 8% of its expected precipitation for the whole winter. Other stations with notable deficits were Delta Junction and McGrath, both with 20% of their normal amounts, followed by Talkeetna at 23% and Anchorage at 32%. Barrow had the greatest surplus of precipitation at 190%, but because precipitation in northern Alaska is generally light, the actual seasonal total was only 1.19" (Table 7).

It was the driest winter on record for Fairbanks, which received about a third of the amount from the next driest winter of 1936 (0.35"). McGrath had its second driest winter with a total of 0.67", after the 0.45" from 1961. It was the third driest winter in Anchorage and Talkeetna. At the other end of the spectrum, it was the third wettest winter at Kodiak and the fourth wettest winter in Homer.

Looking at the months separately, **December** precipitation was notably lower than expected, with the statewide mean 19% below normal. 21 days of the month reported below normal values (Figure 20). It was also drier than December 2014, which had a precipitation total just 2% below normal. The greatest daily deviation of 147% occurred on the 28<sup>th</sup>, driven by a strong Bering Sea storm impacting the western, southcentral, and interior areas of

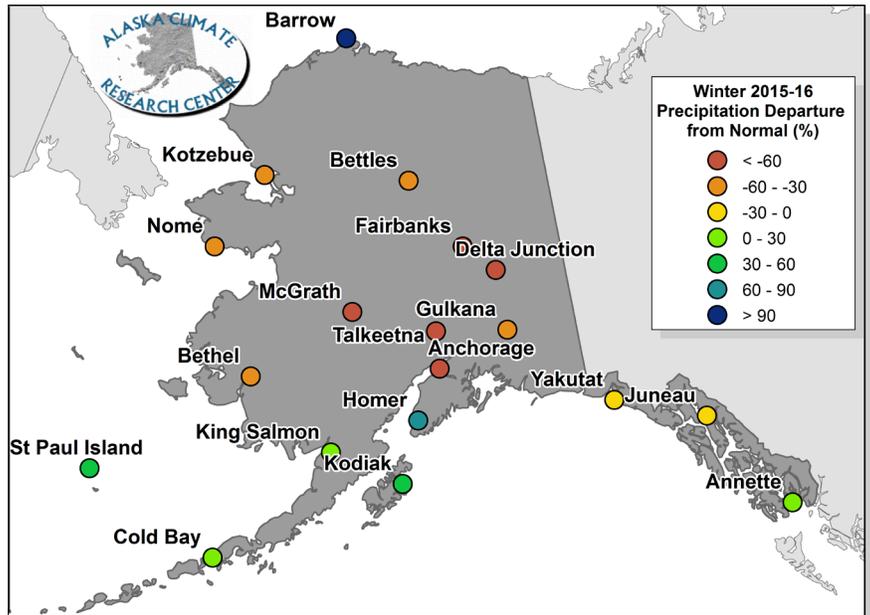


Figure 20. Winter 2015-16 map of the precipitation departures (%) from the 30-year normal (1981–2010) based on all first-order meteorological stations in Alaska.

the state. Fairbanks reported December's greatest negative deviation, with a total of 0.07", or just 11% of the normal amount of 0.64". Delta Junction (18%), Anchorage (21%), Talkeetna (29%), and Barrow (29%) also had precipitation totals less than 30% of normal. St. Paul Island had December's greatest positive deviation with 106% of normal, due to repeated Bering Sea storms. Kodiak reported the maximum December precipitation with 12.28", while Yakutat reported the highest daily total of 2.10" on the 30<sup>th</sup>, a new record for that day.

It was the third driest **December** for McGrath, the fourth driest for Anchorage, and the fifth driest for Fairbanks. Juneau entered December on track to set a calendar year precipitation record (page 15), but the station recorded a relatively dry month. From January 2015 to the end of December 2015, Juneau received 84.96" of precipitation, second to its record annual total of 85.15" set in 1991. Normal annual precipitation for Juneau is 62.27".

Station	Precipitation (in)							
	December		January		February		Seasonal	
	Total	Dev	Total	Dev	Total	Dev	Total	Dev
Anchorage	0.23	-79%	0.28	-62%	0.30	-58%	0.81	-68%
Annette	6.93	-35%	9.50	-11%	15.54	113%	31.97	11%
Barrow	0.04	-71%	0.30	131%	0.85	507%	1.19	190%
Bethel	1.24	11%	0.23	-71%	0.16	-78%	1.63	-38%
Bettles	0.83	-10%	0.33	-59%	0.24	-72%	1.40	-46%
Cold Bay	7.27	63%	4.49	42%	2.00	-33%	13.76	30%
Delta Junction	0.07	-82%	0.05	-84%	0.07	-75%	0.19	-80%
Fairbanks	0.07	-89%	0.01	-98%	0.05	-88%	0.13	-92%
Gulkana	0.61	-22%	0.24	-48%	0.11	-78%	0.96	-45%
Homer	4.00	30%	4.50	71%	5.20	204%	13.70	85%
Juneau	2.42	-59%	6.53	22%	3.26	-21%	12.21	-20%
King Salmon	2.35	91%	0.48	-53%	0.96	26%	3.79	26%
Kodiak	12.28	41%	10.41	26%	12.88	110%	35.57	54%
Kotzebue	0.46	-39%	0.38	-39%	0.34	-48%	1.18	-42%
McGrath	0.47	-64%	0.08	-93%	0.12	-87%	0.67	-80%
Nome	0.78	-28%	0.53	-44%	0.50	-46%	1.81	-39%
St. Paul Island	4.63	106%	1.61	2%	1.20	-8%	7.44	45%
Talkeetna	0.56	-71%	0.35	-74%	0.18	-88%	1.09	-77%
Yakutat	9.95	-39%	14.42	6%	10.87	0%	35.24	-14%

January was a little drier than normal, with overall precipitation 23% below normal. 12 of the 19 stations and 23 days of the month reported below normal values. This contrasts with the wet January of 2015, which had 66% more precipitation than normal. The greatest daily deviation of 71% occurred on the 28<sup>th</sup>. Fairbanks continued its dry trend from December into January with the month's greatest negative deviation, a total of 0.01", or just 2% of the normal 0.58". McGrath (7%), Delta Junction (16%), Talkeetna (26%), and Bethel (29%) also reported January precipitation totals less than 30% of normal. Barrow recorded the greatest

Table 7. The deviation in precipitation (%) from the 30-year normal (1981–2010) is presented for the first-order stations for each winter month and for the winter 2015-16 season.

## WINTER WEATHER SUMMARY

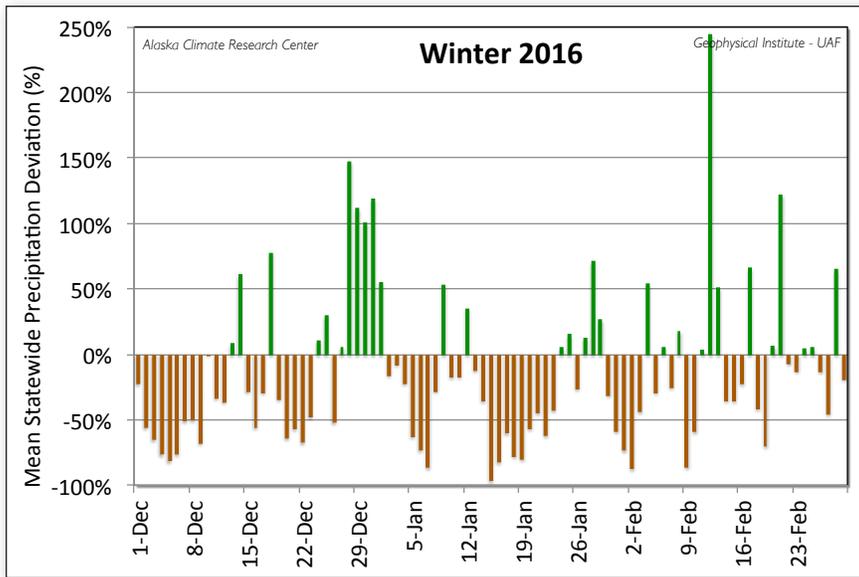


Figure 21. Time series of the mean Alaska precipitation deviations (%) for winter 2015-16.

positive deviation with 131% above normal. Yakutat reported the greatest January precipitation total with 14.42", while Annette reported the highest daily total of 2.07" on the 25<sup>th</sup>, a new record for that date.

In **January**, McGrath received a total of 0.08" of precipitation, the lowest on record. The previous record low total was 0.10" from 1961. Fairbanks tied its record low January precipitation of 0.01", set in 1966. The total precipitation in Fairbanks from December 1, 2015, to February 29, 2016, was 0.08", the lowest amount for this time frame, breaking the previous record of 0.10" from 1969-70.

Unsurprisingly, **January** snowfall was also light, with 13 of the 15 stations that measure snowfall reporting below normal amounts. The overall deviation from the normal was 60% of the expected amount. Snowpack averaged about 70% of normal. St. Paul matched its normal of 12.6", and Barrow reported 73% above normal. With a total of 0.0", Yakutat reported the greatest negative deviation at -31.9". Juneau and Annette also reported 0.0" of snow.

**February** precipitation was higher than expected, with overall precipitation 9% above normal. 5 stations and 12 days of the month reported above normal values. It was also wetter than February 2015, which had precipitation 8% below normal. The greatest daily deviation of 244% occurred on the 12<sup>th</sup>, driven by Barrow's record water equivalent snowfall of 0.57", which dwarfs its February mean precipitation normal of 0.01". Barrow also had February's greatest positive deviation with 507% above normal, followed by Homer at 204%. Continuing its dry trend for the winter, Fairbanks reported February's greatest negative deviation with a total of 0.05", or just 12% of its normal amount of 0.42". Talkeetna tied Fairbanks with just 12% of normal also. McGrath (13%), Bethel (22%), Gulkana (22%), Delta Junction (25%), and Bettles (28%) also reported precipitation totals less than 30% of normal. Annette had the maximum monthly precipitation total with 15.54", as well as the highest daily total of 2.09" on the 8<sup>th</sup>, a new record for that specific day.

**February** 2016 was the second wettest February on record at:

- Kodiak (12.88", after 16.64" from 1947),
- Ketchikan (24.88", after 25.60" from 1954; not a first-order station), and
- At the other end of the state, Barrow, (0.85", after 0.95" from 1917).

It was the fourth wettest February at Homer, and the fifth wettest at Annette.

Snowfall continued light in **February**, with the overall deviation 49% below expected and 14 of the 15 stations that measure snowfall reporting below normal. Snowpack averaged about 30% of normal. Barrow was the only station to report an above normal total. Like January, Yakutat reported the highest negative deviation in snowfall amount at -26.4" with an actual total of 2.2".

Barrow reported the highest **February** snowfall at 8.9", and the highest one-day snowfall at 5.7" on the 12<sup>th</sup>, a new daily record for Barrow, breaking the 1.2" record from 1989, and setting a new record for any February day at Barrow, breaking the old record of 4.0" from February 27, 1916. By February 20, Anchorage had gone 37 winter days without snowfall, a new record for consecutive days in winter. With just a trace of snow, Annette tied for its second lowest February snowfall; the February 1997 record is no snowfall at all. Barrow had its fourth snowiest February on record, while Kodiak reported its fourth least snowy February.

Fairbanks experienced its lowest seasonal snowfall on record in winter 2015-16 with just 2.5", less than half the previous low record of 6.5" from 1953. It was also the lowest seasonal snowfall in Anchorage, with 7.9", breaking the old record of 8.7" from 1982. It was the fourth least snowy winter for Juneau and fifth for McGrath. The very low seasonal snowfall totals for the first-order stations are presented in Table 8.

In summary, the winter of 2015-16 was remarkably warm and dry, which is at least partly in agreement with the global trend. February 2016 was the warmest February on planet Earth since observations began.

Station	Snowfall (in)		
	Seasonal		
	Total	Normal	Deviation
<b>Anchorage</b>	<b>7.9</b>	<b>38.9</b>	<b>-80%</b>
<b>Annette</b>	<b>4.1</b>	<b>22.9</b>	<b>-82%</b>
<b>Barrow</b>	<b>16.7</b>	<b>8.7</b>	<b>92%</b>
<b>Bethel</b>	<b>17.1</b>	<b>27.9</b>	<b>-39%</b>
<b>Bettles</b>	<b>24.7</b>	<b>43.5</b>	<b>-43%</b>
<b>Cold Bay</b>	<b>36.6</b>	<b>39.6</b>	<b>-8%</b>
<b>Fairbanks</b>	<b>2.5</b>	<b>30.5</b>	<b>-92%</b>
<b>Juneau</b>	<b>18.3</b>	<b>60.1</b>	<b>-70%</b>
<b>King Salmon</b>	<b>21.5</b>	<b>25.7</b>	<b>-16%</b>
<b>Kodiak</b>	<b>16.0</b>	<b>41.9</b>	<b>-62%</b>
<b>Kotzebue</b>	<b>23.9</b>	<b>30.2</b>	<b>-21%</b>
<b>McGrath</b>	<b>17.1</b>	<b>49.0</b>	<b>-65%</b>
<b>Nome</b>	<b>24.1</b>	<b>39.4</b>	<b>-39%</b>
<b>St. Paul Island</b>	<b>28.8</b>	<b>34.7</b>	<b>-17%</b>
<b>Yakutat</b>	<b>26.4</b>	<b>83.7</b>	<b>-68%</b>

Table 8. Seasonal snowfall for winter 2015-16 (December, January, February) for the 15 first-order stations in Alaska that report snow.

# SPRING 2016 WEATHER CONDITIONS IN ALASKA

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This article presents a climate summary of spring 2016 (March, April, May), concentrating on temperature and precipitation from the 19 first-order meteorological stations operated by National Weather Service (NWS) meteorologists in Alaska. The deviations from the long-term average are based on the new normal of 1981–2010.

Additional information, including temperature and precipitation records, is available at the Alaska Climate Research Center, <http://akclimate.org>. All figures and tables are provided by the Alaska Climate Research Center.

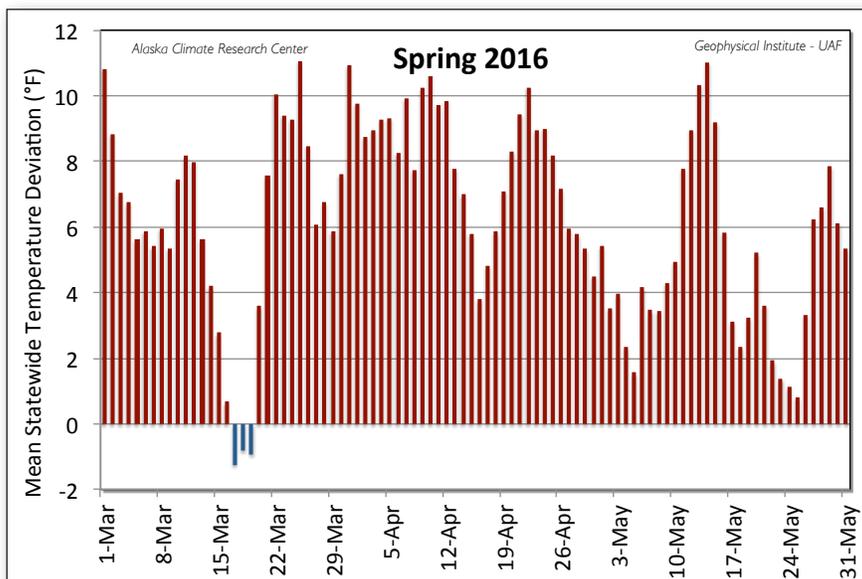


Figure 23. Time series of the mean Alaska temperature deviations (°F) for spring 2016.

## TEMPERATURE

Spring 2016 temperatures substantially and uniformly above the 30-year mean (Figure 22) continued the overall warm trend of the previous year. The mean deviation of the 19 stations for the season was +6.2°F, a very high deviation for a statewide seasonal value. Indeed, at 37.1°F, the statewide spring mean temperature is the highest observed in Alaska since 1949 (the period of record for these stations) and surpasses the second highest value, observed in 1981, by a considerable 1.9°F. All 19 stations reported positive temperature deviations

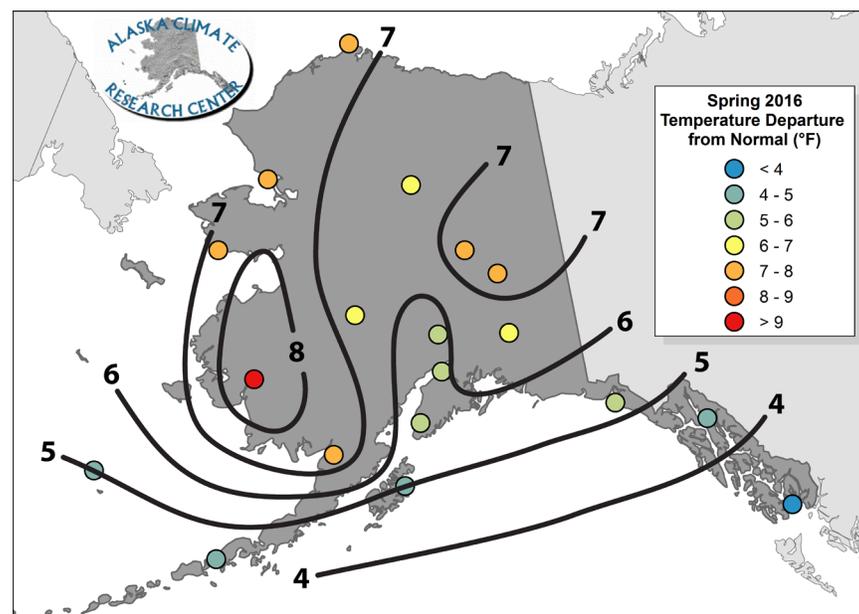


Figure 22. Spring 2016 isotherm map of the deviation in temperature (°F) from the 30-year normal (1981–2010) based on all first-order meteorological stations in Alaska.

for the season, and 9 of the 19 set new seasonal temperature records (Tables 9 and 10). Bethel reported the spring's largest deviation at +9.2°F. In general, the deviations were higher in northern and central Alaska, with lower values in southern areas with maritime influence, especially in Southeast. Annette reported the lowest but still substantial deviation of +3.0°F.

Table 9 presents monthly and seasonal means and deviations. Not a single station in any of the 3 spring months recorded a negative deviation. April had the highest mean monthly deviation with +7.8°F, followed by March (+5.9°F) and May (+4.8°F).

Looking at the daily temperature deviations from the long-term mean (Figure 23), only 3 days (March 16–18) of the 92 days of the spring season had temperatures below the expected value, and these deviations were minor (less than -2°F). On the other side of the coin, 9 days had positive deviations over +10°F, and 27 exceeded +8°F. Large positive deviations were observed in all 3 spring months.

A number of stations set or matched their record high mean season temperatures (Figure 24 and Table 10). In addition, it was the second warmest spring on record for 6 of the 19 first-order stations:

- Yakutat (43.4°F, after 44.1°F from 1936),
- Gulkana (37.6°F, after 42.6°F from 1917),
- McGrath (35.6°F, after 36.1°F from 1917),
- Nome (29.6°F, after 29.8°F from 1981),
- Kotzebue (23.1°F, after 23.7°F from 1998),
- Barrow (10.6°F, after 10.7°F from 1998)
- Nenana (36.1°F, after 36.4°F from 2015; not a first-order station).

## SPRING WEATHER SUMMARY

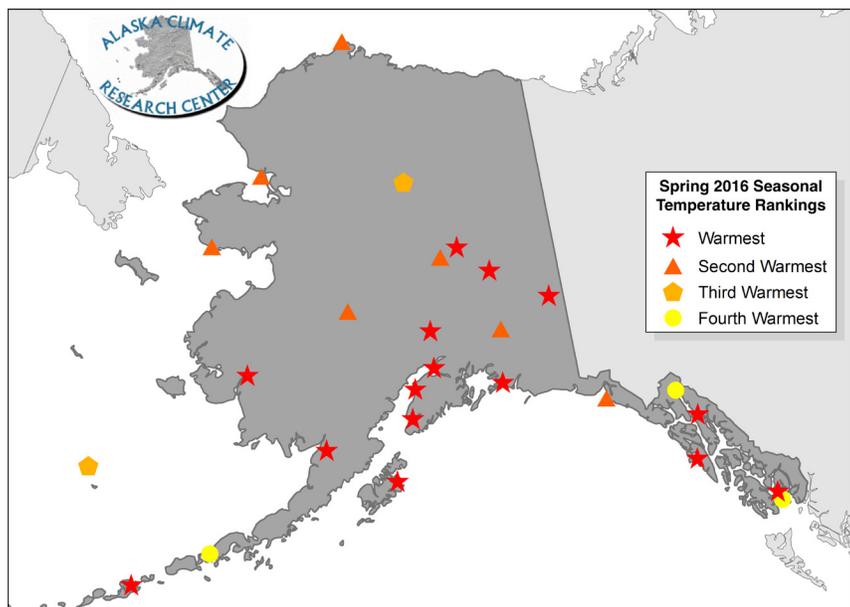


Figure 24. Spring 2016 map of the mean seasonal temperature rankings for select stations in Alaska.

Spring 2016 was the third warmest for the remaining 4 first-order stations: St. Paul Island, Cold Bay, Bettles, and Annette, while it was the fourth warmest for Haines (not a first-order station).

Looking at the 3 months independently, **March** 2016 was the sixth month in a row where temperatures were above normal in Alaska. The monthly mean temperature was 25.4°F, 2.9°F above the March 2015 mean of 22.5°F. All 19 stations reported above normal monthly means. The highest positive deviation of +11.0°F occurred on the 25<sup>th</sup>, while the greatest negative deviation occurred on both the 17<sup>th</sup> and 19<sup>th</sup> at -1.1°F. Delta Junction reported the greatest positive deviation with a significant value of +9.8°F above its long-term mean of 14.1°F. King Salmon (8.8°F), Fairbanks (8.4°F), Gulkana (8.3°F), Bettles (7.4°F) and Homer (7.3°F) also reported deviations exceeding +7.0°F for March.

Annette reported the month's highest daily temperature at 60°F on **March** 31 and the highest mean temperature at 42.5°F. Barrow recorded the lowest daily temperature of -28°F on March 17, as well as the lowest March mean at -7.2°F.

Stations set or tied many daily temperature records in **March**, and like the previous 3 months, all were highs (see <http://akclimate.org> for specifics). The daily high in Anchorage of 53°F on the 31<sup>st</sup> was a daily record and the highest temperature for any March day in Anchorage. Sitka set or tied its daily high on 11 days in March 2016, which is quite a feat. Yakutat set 8 record highs, and Juneau and Haines each set 6.

Table 9. Mean and temperature deviations (°F) from the 30-year normal (1981-2010) are presented for all first order stations for each spring month and for the spring 2016 season. Asterisks indicate a station had its warmest spring on record (see Table 10 for details)

Station	Temperature (°F)							
	March		April		May		Seasonal	
	Mean	Dev	Mean	Dev	Mean	Dev	Mean	Dev
<b>Anchorage*</b>	33.4	6.8	43.5	6.7	52.0	4.2	43.0	5.9
<b>Annette</b>	42.5	2.8	45.6	1.4	55.0	4.8	47.7	3.0
<b>Barrow</b>	-7.2	5.5	10.3	8.5	28.7	7.6	10.6	7.2
<b>Bethel*</b>	21.1	5.9	41.5	14.6	49.0	7.1	37.2	9.2
<b>Bettles</b>	11.8	7.4	30.5	7.2	48.6	4.2	30.3	6.3
<b>Cold Bay</b>	32.8	2.7	39.9	5.9	44.4	4.1	39.0	4.2
<b>Delta Junction*</b>	23.9	9.8	41.7	9.5	50.4	2.8	38.7	7.4
<b>Fairbanks*</b>	19.8	8.4	42.4	9.9	53.4	4.0	38.5	7.4
<b>Gulkana</b>	23.9	8.3	39.2	7.4	49.7	4.5	37.6	6.7
<b>Homer*</b>	37.2	7.3	43.0	6.0	48.6	4.1	42.9	5.8
<b>Juneau*</b>	39.9	6.1	44.9	4.1	51.8	3.2	45.5	4.4
<b>King Salmon*</b>	32.9	8.8	43.2	9.5	49.0	4.8	41.7	7.7
<b>Kodiak*</b>	39.3	6.5	42.2	4.6	48.2	3.9	43.2	5.0
<b>Kotzebue</b>	3.3	2.2	25.5	12.2	40.6	8.7	23.1	7.7
<b>McGrath</b>	17.2	5.6	39.0	9.3	50.6	3.9	35.6	6.3
<b>Nome</b>	11.6	1.3	34.3	13.8	42.9	6.1	29.6	7.1
<b>St. Paul Island</b>	28.5	3.7	36.1	6.9	40.8	4.6	35.1	5.0
<b>Talkeetna*</b>	31.2	6.3	42.4	6.5	52.0	4.2	41.9	5.7
<b>Yakutat</b>	39.0	7.0	42.5	4.7	48.7	4.0	43.4	5.2

Station	Seasonal High Temperature Records			
	New Record	Old Record	Difference	Year of old Record
Sitka	48.1	46.1	2.0	2005
<b>Juneau</b>	45.5	44.7	0.8	2005
Cordova	42.8	42.8	0.0	1981
<b>Kodiak</b>	43.2	42.9	0.3	1983
<b>Homer</b>	42.8	42.8	0.0	2015
Kenai	41.2	40.6	0.6	1983
<b>Anchorage</b>	43.0	41.6	1.4	1984
<b>Talkeetna</b>	41.9	40.6	1.3	1926
<b>King Salmon</b>	41.7	40.1	1.6	1993
<b>Bethel</b>	37.2	36.6	0.6	1981
Dutch Harbor	40.5	39.8	0.7	1996
<b>Fairbanks</b>	38.5	37.3	1.2	1993
<b>Delta Junction</b>	38.7	37.8	0.9	2005
Northway	35.9	33.2	2.7	2015

Table 10. Select stations with record high seasonal temperatures for Spring 2016. First-order stations in bold font.

The very mild **March** in Southeast Alaska was reflected in new high monthly average temperatures. March 2016 was the warmest on record for:

- Juneau, at 39.9°F (above 39.6°F from 1984),
- Ketchikan, at 43.8°F (43.5°F from 1915; not a first-order station),
- Sitka, with 45.1°F (42.5°F from 1984; not a first-order station), and
- Haines, at 39.6°F (39.1°F from 1915; not a first-order station).

It was the second warmest March on record in:

- Kodiak (39.3°F, after 40.4°F from 1983),
- Homer (37.2°F, after 38.0°F from 1977).

It was the fourth warmest **March** for Cordova and Bettles and the fifth warmest for Anchorage.

The monthly mean temperature in Alaska in **April** was 38.3°F, a significant 7.8°F above the normal of 30.5°F and 4.9°F above the April 2015

## SPRING WEATHER SUMMARY

Station	April 2016 Monthly High Temperature Records			
	New Record	Old Record	Difference	Year of old Record
<b>Anchorage</b>	43.5	40.7	2.8	2015
<b>Bethel</b>	41.5	39.8	1.7	1940
<b>Delta Junction</b>	41.7	40.3	1.4	1993
<b>Gulkana</b>	39.2	36.5	2.7	1980
<b>Homer</b>	42.9	41.9	1.0	2015
<b>Juneau</b>	44.9	44.4	0.5	1993
Kenai	42.3	40.5	1.8	1904
<b>King Salmon</b>	43.2	42.0	1.2	1940
<b>Kotzebue</b>	25.5	24.9	0.6	2004
<b>McGrath</b>	39.0	38.8	0.2	2007
Northway	39.4	37.5	1.9	1995
Sitka	46.9	46.0	0.9	1993
Skagway	45.3	45.1	0.2	1958
<b>Talkeetna</b>	42.4	40.7	1.7	1940

Table 11. Select stations with record high monthly temperatures for April 2016.

mean of 33.4°F. All 30 days of the month were above normal. The peak positive deviation for the month, a remarkable 11.1°F, occurred on the 10<sup>th</sup>. Bethel reported the greatest positive deviation from normal with an extreme value of 14.6°F above its long-term mean of 14.1°F. Nome (13.8°F), Kotzebue (12.2°F), Fairbanks (9.9°F), Delta Junction (9.5°F), King Salmon (9.5°F), and McGrath (9.3°F) also recorded deviations exceeding 9.0°F. Note that the 3 stations with the highest deviations are located in Alaska's western coastal area.

Fairbanks reported the highest daily temperature in April with 67°F on the 25<sup>th</sup>. Annette had April's highest mean temperature at 45.6°F. Barrow recorded the lowest temperature with -22°F on the 1<sup>st</sup> and the lowest mean monthly temperature at 10.3°F. Stations set or tied a number of daily temperature records, and like the last 4 months, all were highs. Bethel reported 11 daily high records in April, which is quite notable. King Salmon and St. Paul each had 10 record highs, while Juneau had 8 (see <http://akclimate.org> for specifics). The exceptional warmth is also demonstrated in the number of new record high April mean temperatures: 10 of the 19 first-order stations set new monthly record highs (Table 11). St. Paul tied its monthly high for April with 36.1°F, originally set in 1979.

It was the second warmest April on record at 4 first-order stations:

- Fairbanks (42.4°F, after 43.7°F from 1940),
- Nome (34.3°F, after 35.6°F from 1940),
- Cold Bay (39.9°F, after 40.8°F from 1979),
- Kodiak (42.2°F, after 44.1°F from 1979),
- Ketchikan (47.3°F, after 48°F from 1940; not a first-order station),
- Dutch Harbor (40.6°F, after 40.7°F from 2003; not a first-order station).

It was the third warmest April for Barrow and Cordova, and the fourth warmest for Yakutat. Haines and Bettles each had their fifth warmest Aprils on record.

May 2016 marked the eighth month in a row with temperatures above normal in Alaska. The monthly mean temperature was 47.6°F, 4.8°F above the normal of 42.8°F and 0.2°F below the May 2015 mean of 47.8°F. Monthly mean temperatures (Table 9) were above normal for all 19 first-order stations and on all 31 days of the month (Figure 23). The peak positive deviation for the month, a notable 11.0°F, occurred on the 14<sup>th</sup>. Kotzebue reported the greatest positive deviation from normal with a significant value of 8.7°F above its long-term mean of 40.6°F. Barrow (7.6°F), Bethel (7.1°F), and Nome (6.1°F) also recorded deviations exceeding 6.0°F. Note that the four stations with the highest deviations are located in Alaska's northern and western coastal areas.

Fairbanks recorded the highest daily temperature in May with 82°F on the 14<sup>th</sup>, a new daily record. Annette had the highest mean temperature for the month at 55.0°F. The lowest temperature was -14°F at Barrow on the 7<sup>th</sup> and 8<sup>th</sup>, and Barrow also reported the lowest May mean monthly temperature with a value of 28.7°F.

Once again in May, stations set or tied quite a number of daily temperature records, and like the last five months, all were high events (see <http://akclimate.org> for specifics). Most occurred around the very warm middle of the month. Barrow reported 4 new and 2 tied daily high records in May. Bethel and King Salmon each had 4 record high events.

It was the warmest May on record for:

- Barrow, at 28.7°F (28.0°F from 1991),
- Bethel, at 49.0°F (48.1 from 1981),
- Kotzebue, at 40.6°F (40.3°F from just last year),
- St. Paul, at 40.8°F (40.6°F from 1979),
- King Salmon, at 49.0°F (48.9°F from 2014),
- Talkeetna, at 52.0°F (51.5°F from 2004).

It was the second warmest May on record for:

- Anchorage (52.0°F, after 53.0°F from 2014),
- Kodiak (48.2°F, after 52.4°F from 2014)
- Kenai (48.7°F, after 49.1°F from 1983; not a first-order station).

It was the third warmest May for Cold Bay and Yakutat and the fourth warmest for Sitka, Homer, and Nome.

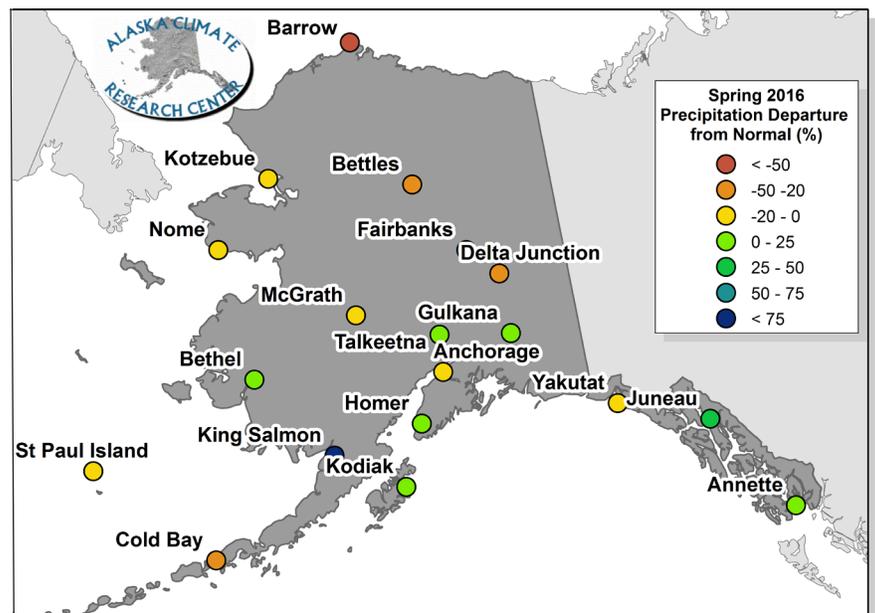


Figure 25. Spring 2016 map of the precipitation departures (%) from the 30-year normal (1981–2010) based on all first-order meteorological stations in Alaska.

## SPRING WEATHER SUMMARY

## PRECIPITATION

Overall precipitation for Alaska in spring 2016 was close to normal with a small positive deviation of 6%. The northern half of the state and Bering Sea region reported deficits in precipitation, while the southern and southwestern regions measured above normal values (Figure 25). At least one of the 19 first-order stations reported some measureable precipitation every day during the spring.

All 3 spring months showed positive precipitation deviations (Table 12), which were relatively large in March 2016 (+17%) but closer to normal in April (+3%) and May (+3%). King Salmon reported the highest positive deviation of +104%. The only other station with a positive deviation exceeding 50% was Fairbanks with a value of +58%. Barrow was the driest station, with a deficit of -58%.

Looking at the 3 months separately, March precipitation was higher than expected, with the overall precipitation 17% above normal. Nine of the 19 stations reported above normal values. Nome had the greatest negative deviation, with a total of 0.04", or just 6% of its normal amount of 0.65". King Salmon had the greatest positive deviation with 179% above normal. Talkeetna had 172% above normal, while Gulkana observed 147% above normal.

Station	Precipitation (in)							
	March		April		May		Seasonal	
	Total	Dev	Total	Dev	Total	Dev	Total	Dev
Anchorage	1.23	105%	0.02	-96%	0.33	-54%	1.58	-12%
Annette	6.37	-21%	12.04	78%	6.29	13%	24.70	21%
Barrow	0.04	-56%	0.07	-56%	0.07	-61%	0.18	-58%
Bethel	0.75	6%	0.67	-9%	1.45	27%	2.87	11%
Bettles	0.45	-22%	0.43	-28%	0.54	-39%	1.42	-31%
Cold Bay	1.19	-56%	3.04	26%	1.70	-35%	5.93	-23%
Delta Junction	0.08	-56%	0.13	-43%	0.71	-21%	0.92	-30%
Fairbanks	0.53	112%	0.52	68%	0.78	30%	1.83	58%
Gulkana	0.74	147%	0.23	-4%	0.52	-20%	1.49	25%
Homer	1.09	-34%	1.88	76%	0.69	-16%	3.66	3%
Juneau	2.17	-43%	5.16	76%	5.67	67%	13.00	28%
King Salmon	1.95	179%	0.85	-12%	3.17	154%	5.97	104%
Kodiak	7.34	33%	8.90	53%	3.25	-42%	19.49	15%
Kotzebue	0.14	-68%	0.60	11%	0.65	59%	1.39	0%
McGrath	1.02	26%	0.42	-43%	1.17	7%	2.61	-1%
Nome	0.04	-94%	0.80	5%	1.22	42%	2.06	-9%
St. Paul Island	1.11	4%	1.20	11%	0.80	-29%	3.11	-5%
Talkeetna	2.86	172%	0.40	-69%	1.62	0%	4.88	23%
Yakutat	9.63	-13%	9.90	8%	6.74	-18%	26.27	-8%

Table 12. Total precipitation (in) and deviation (%) from the 30-year normal (1981-2010) are presented for the first order stations for each spring month and for the Spring 2016 season.

April precipitation was slightly higher than normal, with an overall deviation of +3%. This is considerably drier than April 2015, which had a deviation of +28%. Ten of the 19 stations and 15 days of the month reported above normal values. The greatest daily deviation of 171% occurred on April 1. Annette reported the greatest positive deviation with 78% above normal. Homer and

Juneau both measured 76% above normal, while Anchorage was the relatively driest station with just 4% of its normal precipitation. This is the third lowest precipitation for April in Anchorage on record, while it was the fifth wettest April on record for Juneau.

With an overall deviation of 3% above normal, May precipitation was marginally higher than expected and the same as May 2015. Eight of the 19 stations and 16 days of the month reported above normal values, 10 reported below normal precipitation, and Talkeetna matched its normal of 1.62". King Salmon reported the greatest deviation with 154% above normal. Juneau reported 67% above normal, while Barrow was the relatively driest station at just 39% of normal precipitation observed. This is the third wettest May on record for King Salmon and Nome.

Looking at snowfall, all stations except Kotzebue (+17%) reported negative deviations, far exceeding those of the total precipitation (Table 13). This is of course due to the unseasonably warm conditions of spring 2016, which made more precipitation fall as rain rather than snow.

Station	Snowfall (in)		
	Seasonal		
	Total	Normal	Deviation
Anchorage	10.7	14.2	-25%
Annette	0.0	8.4	-100%
Barrow	3.1	8.0	-61%
Bethel	2.9	16.0	-82%
Bettles	16.3	16.9	-4%
Cold Bay	8.2	20.9	-61%
Fairbanks	7.4	8.7	-15%
Juneau	0.0	12.7	-100%
King Salmon	4.0	11.1	-64%
Kodiak	3.6	19.5	-82%
Kotzebue	14.3	12.2	17%
McGrath	14.9	17.3	-14%
Nome	6.6	18.7	-65%
St. Paul Island	11.8	14.8	-20%
Yakutat	0.7	39.0	-98%

Table 13. Seasonal snowfall for spring 2016 (March, April, May) for the 15 first-order stations in Alaska that report snow.

## SEA ICE: WINTER-SPRING 2016

By John Walsh, Chief Scientist, International Arctic Research Center, UAF

Sea ice in the Bering Sea was thin and sparse during the winter and spring of 2015-16. The maximum extent, reached in late March, was the second lowest of the post-1979 period of satellite records. Only the preceding winter, 2014-15, had less ice in the Bering Sea. Figure 26 shows the end-of-season (June) ice cover of the past 5 years, illustrating the early disappearance of Bering Sea ice during the past two spring seasons in comparison with previous springs, especially the heavy ice year of 2012.

Thin ice and an early breakup characterized the 2016 sea ice regime along the entire west coast of Alaska. Figure 27A shows that the Bering Sea during May 2016 was largely ice-free, with only patches of ice lingering in the northern offshore regions. By contrast, sea ice normally covers much of the northern Bering Sea in May, as shown by the pink line depicting the typical position of the May ice edge (median for 1981-2010).

The early retreat of sea ice continued into the summer months, as shown in Figure 27B. Much of the southern Chukchi Sea was open by early July 2016, as was the southern Beaufort Sea. Large negative departures from normal sea ice coverage were also apparent in the North Atlantic sectors of the Arctic, especially the Barents Sea and the waters east and west of Greenland. The rapid early-season retreat of sea ice is consistent with estimates of winter ice thickness, which indicate that the late-winter ice was considerably thinner than a year ago. Figure 28 shows that the ice north of Alaska was only 1 to 2 meters thick in February 2016, while a band of 3-meter thick ice was present in February 2015. The ice offshore of the Canadian Archipelago was also noticeably thinner in 2016 than in 2015.

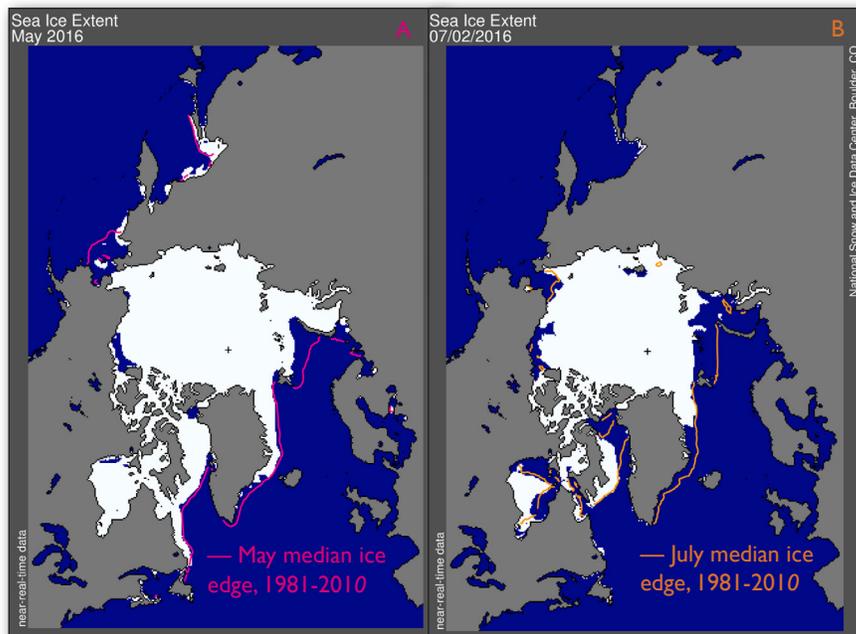


Figure 27. Sea ice extent in 2016 (A) averaged over May and (B) on July 2, 2016. Pink and orange lines depict median positions of the ice edge in May and July respectively over the post-1979 period of satellite passive microwave data. Source: National Snow and Ice Data Center.

## OUTLOOK FOR SUMMER 2016

The low thicknesses and early retreat of the ice cover in 2016 are factors considered by many members of the Sea Ice Prediction Network, which collects and distributes contributions to the September Sea Ice Outlook, as discussed in past issues of the Alaska Climate Dispatch. The Sea Ice Outlook for 2016 is a synthesis of 30 different sea ice predictions for September 2016 (<https://www.arcus.org/sipn/sea-ice-outlook/2016/june>). These predictions for minimum sea ice extent, contributed by various arctic research and operational groups, range from 3.4 to 5.2 million km<sup>2</sup>, with a median value of 4.28 million km<sup>2</sup>. These values compare to the observed 2012 extreme minimum value of 3.6 million km<sup>2</sup>. 23 of the 30 predictions called for a smaller September ice extent than the 4.63 million km<sup>2</sup> observed in 2015. By contrast, the September average for 1981-2010 was 6.5 million km<sup>2</sup>.

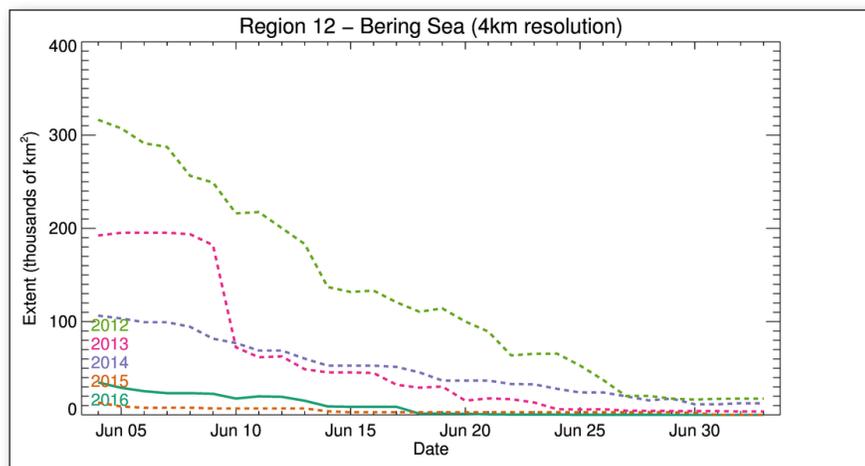


Figure 26. Ice extent in the Bering Sea during June and early July of the past five years, 2012 (dashed green) through 2016 (solid green). Since the heavy ice year of 2012, there has been a trend towards much less ice cover in the Bering Sea. Source: National Snow and Ice Data Center, Multisensor Analyzed Sea Ice Extent (MASIE).

# SEA ICE THICKNESS

FEBRUARY 2016

FEBRUARY 2015

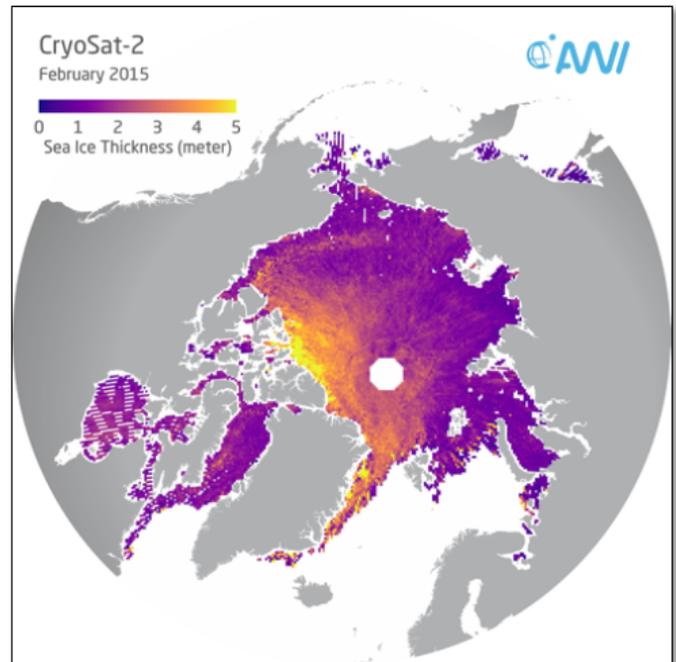
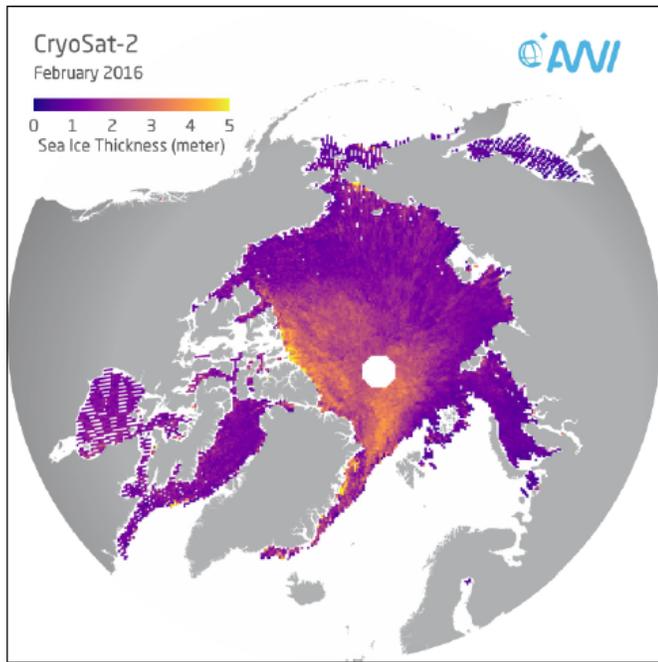


Figure 28. Sea ice thickness (meters) in February of 2016 (left panel) and 2015 (right panel) based on measurements from CryoSat-2. Darkest purple indicates thinnest ice. Source: Alfred Wegener Institute.

## NEWS + EVENTS

### UPCOMING ACCAP WEBINARS

★ **Dynamical Downscaling for Alaska: What is It and How to Use It?**  
*Peter Bieniek and Rick Lader (International Arctic Research Center, UAF)*  
Tuesday, September 20, 2016 at 10:00 AM AKDT  
<https://accap.uaf.edu/downscaling>

Register for monthly webinars and browse our webinar archives, 2007–present

[www.accap.uaf.edu/webinars](http://www.accap.uaf.edu/webinars)

★ **Monthly National Weather Service Alaska Climate Forecast Briefing**  
*Rick Thoman (National Weather Service)*  
Friday, September 23, 2016 at 12:00 PM AKDT  
[https://accap.uaf.edu/NWS\\_briefings](https://accap.uaf.edu/NWS_briefings)

★ **Climate Prediction Applications Science Workshop (CPASW) 2017**  
*May 2-4, 2017 in Anchorage, AK*  
<https://accap.uaf.edu/cpasw>

### NEW PUBLICATIONS

★ **Climate Change and Alaska Fisheries.** *Terry Johnson.* Supported by an ACCAP minigrant, this book summarizes knowledge of North Pacific climate change and its anticipated effects on Alaska fisheries through the middle of the 21<sup>st</sup> century.  
<https://seagrant.uaf.edu/bookstore/pubs/MAB-67.html>

★ **Climate in Context: Science and Society Partnering for Adaptation.** *Adam Parris et al, eds.* ACCAP contributed a chapter to this state-of-the-art synthesis that reflects lessons learned by RISA programs in how to help scientists and stakeholders work together to “co-produce” climate science knowledge, policy, and action.  
<http://www.wiley.com/WileyCDA/WileyTitle/productCd-1118474791.html>



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