Alaska Climate Research Center
The Alaska State Climate Center

ANNUAL REPORT 2022

Severe flooding in Manley Hotsprings, May 18, 2022. Photo: Jessica Cherry.

GEOPHYSICAL INSTITUTE
University of Alaska Fairbanks

KEY OBSERVATIONS

Temperature

Alaska was warmer than the 1991-2020 normal by 0.61°F despite continuous La Niña conditions and a negative PDO phase. Utqiaġvik was the warmest of the selected First Order stations in relative terms with an annual deviation of over +2°F.

Precipitation

2022 saw regionally very dry periods as well as some very wet weather. Annual precipitation sums were near or above average in most areas. A notable spring and early summer drought in the Southwest contributed to the fire season.

Snowfall

Anchorage recorded above average snowfall during the 2022 calendar year, while Fairbanks, Juneau, and Bettles recorded less snow than normal. Notable snow fall events were late season storms in the Interior, which lead to regionally very large end of season snow depth, October storms in the Southeast, and record snow storms in Anchorage in December.

Wildfire season

The 2022 fire season started relatively early and came to a close during the second half of July. The season was short but very intense, especially - and unusually - in the Southwest. A total of over 3.1 million acres burned during the 2022 season.

Sea ice extent

Arctic sea ice extent was below the average of the satellite record for all of 2022. The daily minimum, set on September 18th, 2022, tied with 2017 and 2018 as tenth lowest on record.

General overview and significant weather events

After two cooler than average years, Alaska saw a return to above normal temperatures in 2022. Note that deviations are based on the recent and relatively warm climate normal period 1991-2020. Of the selected First Order stations, only Kotzebue saw a significantly cooler than normal annual temperature. 2022 temperatures rank in the top ten for the respective series at several of the First Order stations (Anchorage, Kodiak, Nome, Utqiaġvik). Numerous new records for daily temperatures were set. The most significant one was perhaps the new record for winter temperature in Utqiaġvik, set on December 5th during a period of extreme warmth.

2022 was a relatively wet year overall, with large regional variations. Shifting weather patterns caused both dry spells with regionally severe drought and weeks of almost continuous rain at other times. A dry spring and early snowmelt in southwestern Alaska contributed to an early start to the fire season, which was unusually intense in this part of the state. High end of season snow depth in parts of the Interior prevented the drought from becoming as severe in these areas. However, spring snow melt caused significant flooding locally. Manley Hotsprings was particularly affected due to an ice jam on the Tanana River in early May. Infrastructure damage in the town was extensive. June and early July were characterised by widespread fire activity. Smoke negatively impacted air quality in much of the state. In mid-July, rainy weather set in and put an end to the drought and the fire season.

The fall season saw multiple ex-typhoons move up to Alaska's western coast. The most impactful storm was former Typhoon Merbok, which arrived on the Bering coast on September 16-17. Merbok was one of the strongest September storms on record for the Northern Bering Sea. In Nome, the water rose to levels not seen since the 1974 flood. Coastal communities suffered extensive damage to houses, roads, protective berms, and fish and hunting camps. In mid-October, storms in the Gulf of Alaska brought intense snowfall in the Southeast, leading to a record start of the snow season in some areas. In December, South-central Alaska was hit by three consecutive storm systems that dropped a record amount of precipitation. December 2022 was the snowiest December since 1955 and set a new precipitation record in Anchorage.

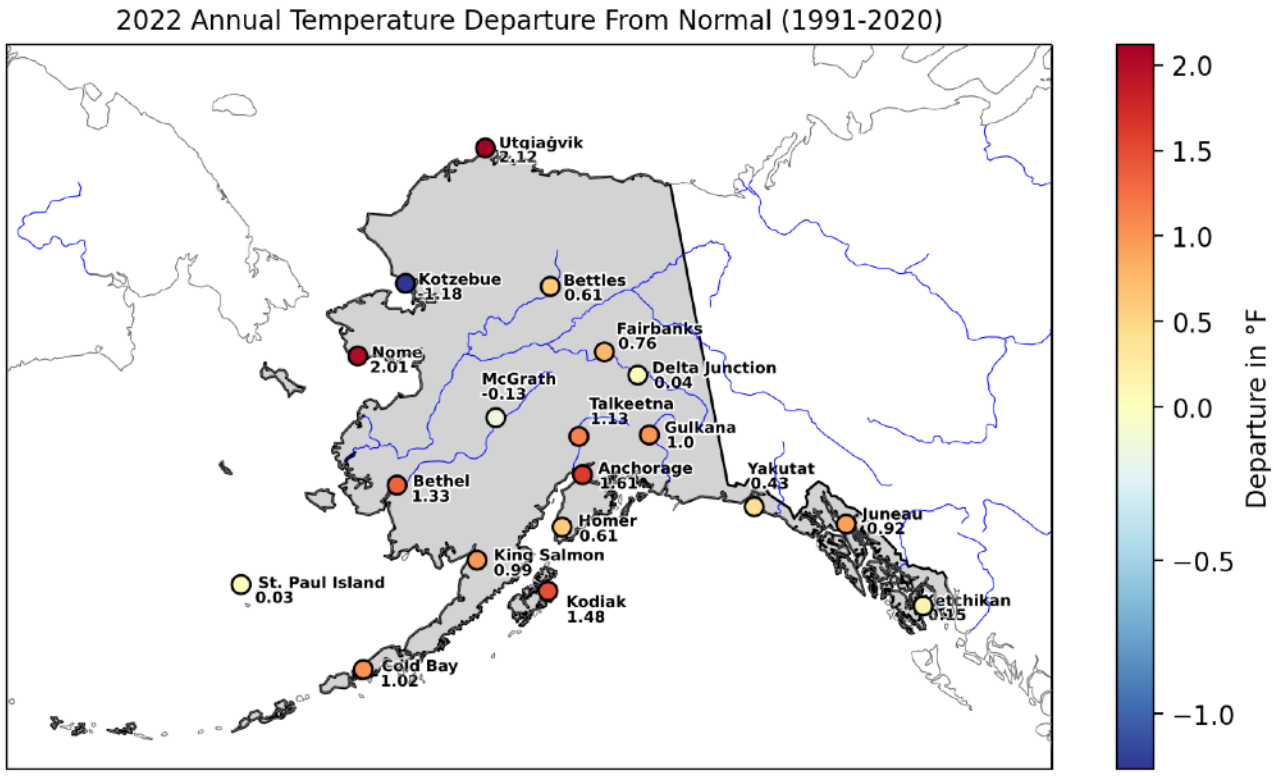

Figure 1. *Mean annual (2022) air temperature deviations (in Fahrenheit) from the normal (1991 - 2020) for selected stations.*

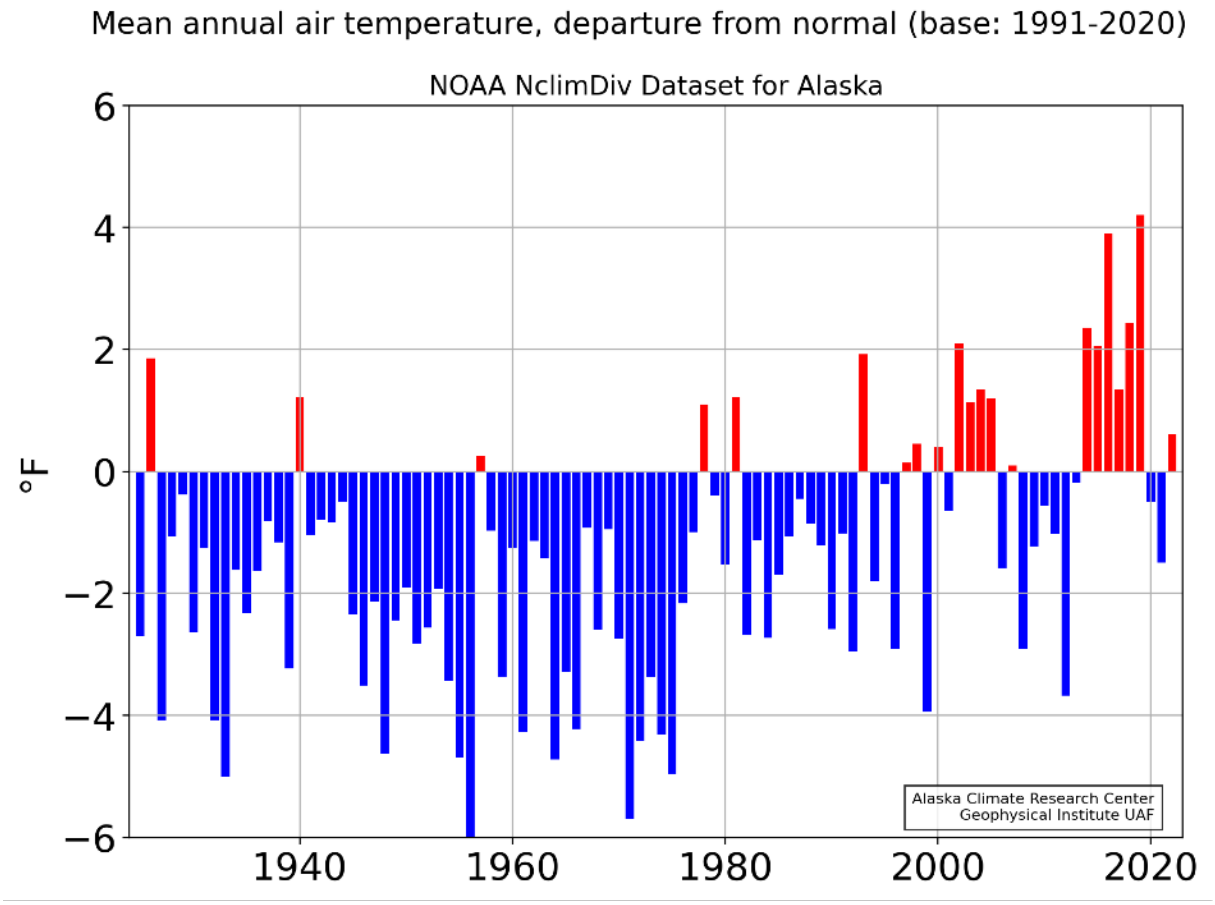

Figure 2. *Mean annual air temperature deviations (in Fahrenheit) from the normal (1991-2020).*

2022 Temperature in Detail

Annual Temperature in Alaska

The majority of Alaska's First Order stations reported warmer than average annual temperatures in 2022 (Figure 1, Table 1). The mean deviation from normal across the 19 selected stations was 0.8°F, with the largest negative departures recorded in Kotzebue (-1.2°F) and the largest positive departures recorded in Utqiaġvik (+2.1°F) and Nome (2.0°F). The statewide mean deviation per the NCEI nClimDiv data set (Vose et al., 2014) was 0.61°F, Figure 2). Individually, all of Alaska's NCEI climate regions were warmer than average. The Cook Inlet & Bristol Bay region had the largest positive deviation from normal with +1.37°F, followed by the West Coast with +0.84°F (Figure 3).

Monthly Mean Temperatures

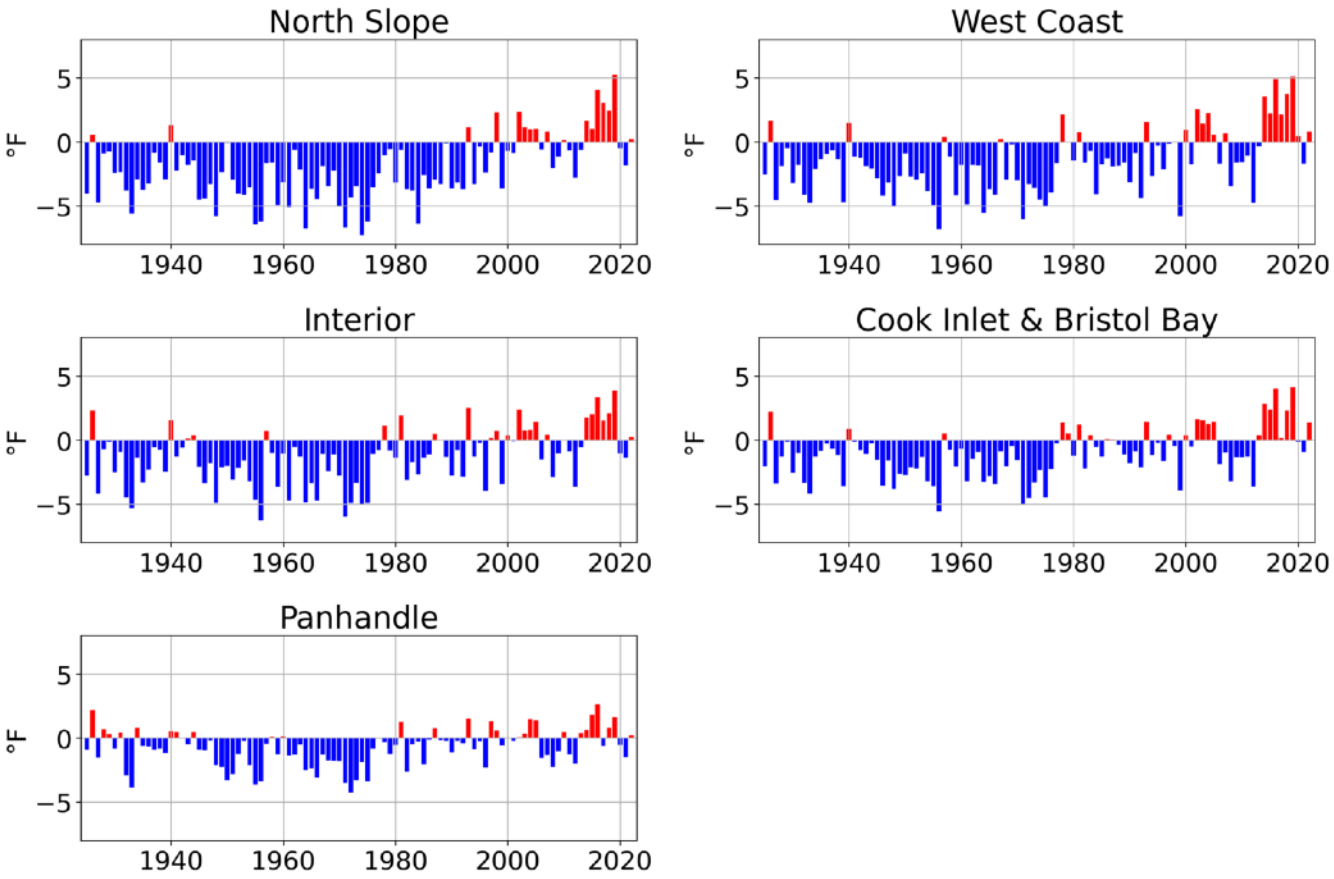

Figure 3. *Time series of annual mean temperature departure from the normal (1991-2020) for the Alaska climate divisions. Data source: NOAA nClimDiv.*

Averaging over the First Order stations, July was the warmest month of 2022 followed by June and August. In terms of deviation from the climatological mean, March was the warmest month (+4°F) and April was the coldest (-1°F). January, May, July, August, and December were also below the long term mean, while all other months were warmer than average. Positive deviations were always 1 or more degrees Fahrenheit above the climatological mean, while negative deviations did not exceed -1°F in any month.

There were considerable variations between individual stations and different regions of Alaska. Most of the selected stations recorded the highest positive deviations in February or March. 7 of the 19 stations reached their highest deviations between October and December. Utqiaġvik in particular stands out with a very high positive deviation of more than 11°F in December. This is also the highest positive monthly deviation for any of the selected stations and any month of 2022. The Utqiaġvik station also set an incredible new daily temperature record with 40°F on December 5th. This is the warmest temperature ever measured at the site during the winter months.

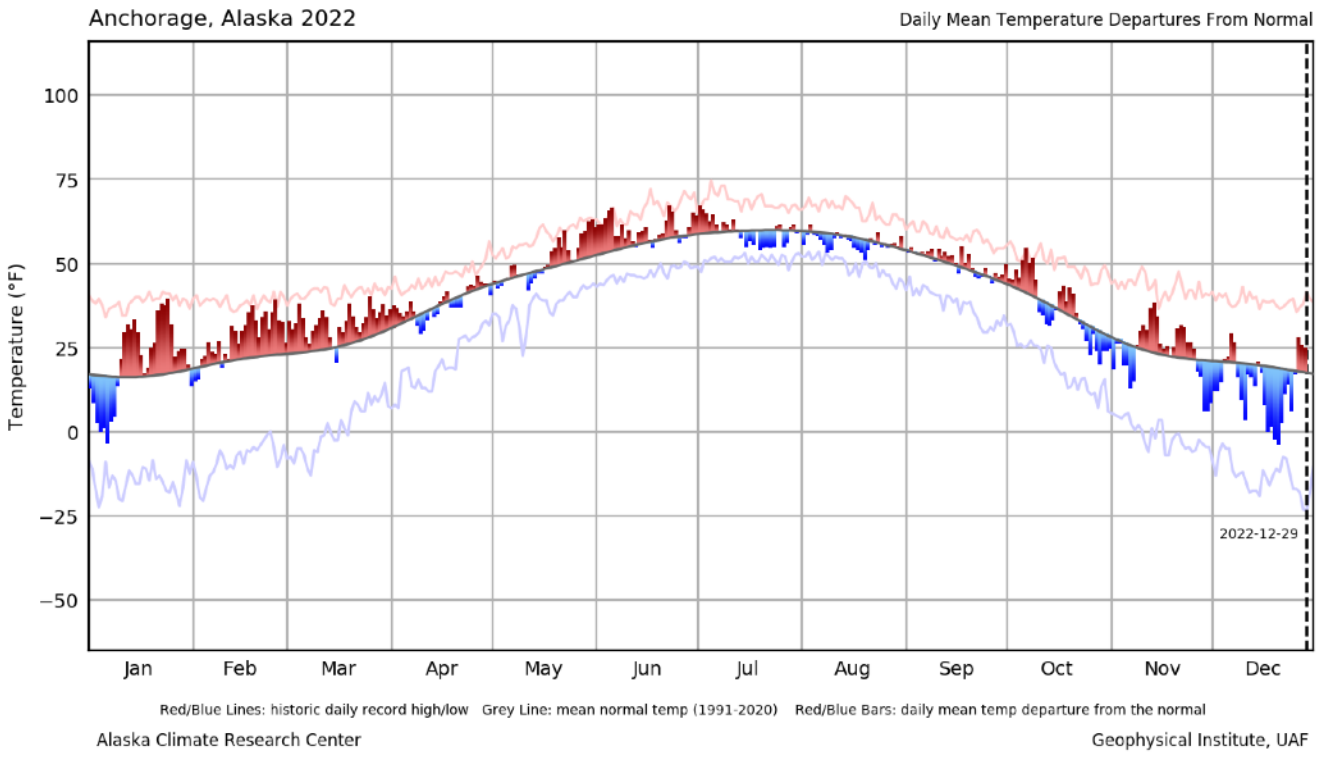

Figure 5. *Mean normal temperature, daily mean departure from normal, and historic daily record minimum and maximum for Anchorage, 2022.*

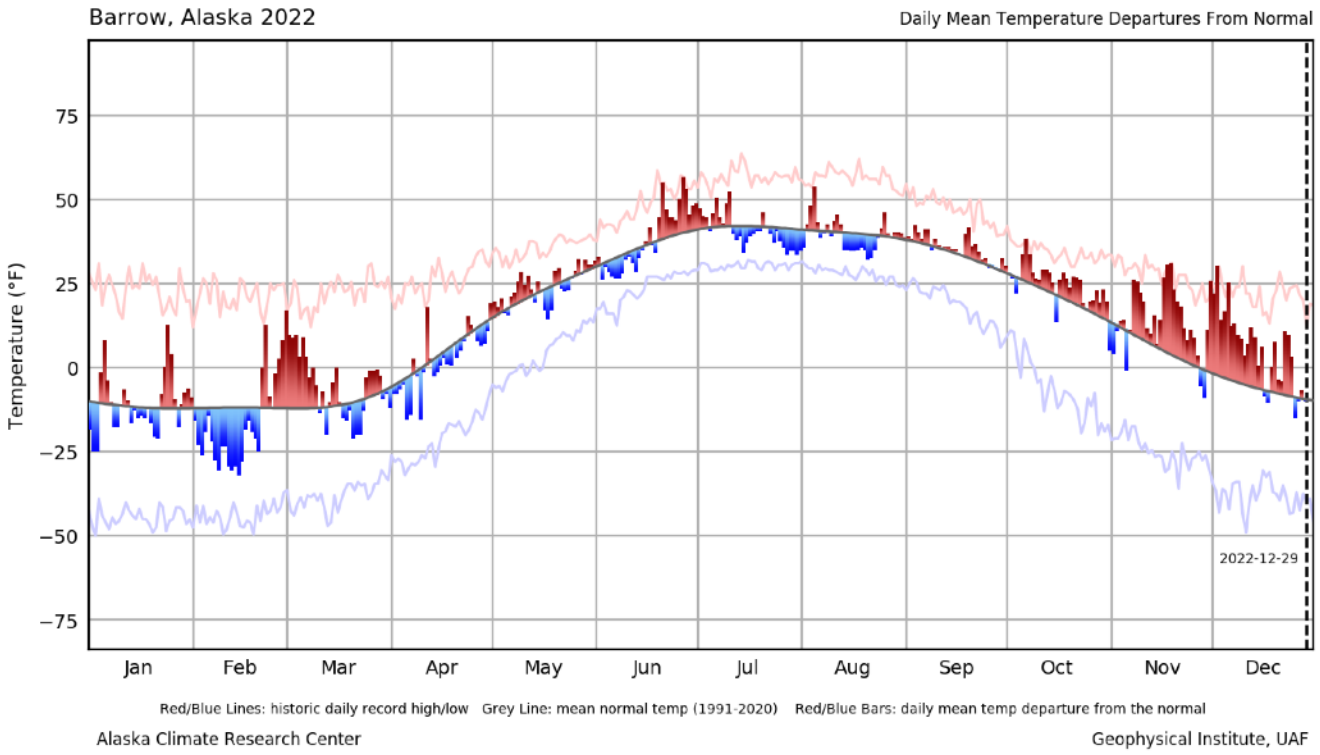

Figure 6. *Mean normal temperature, daily mean departure from normal, and historic daily record minimum and maximum for Utqiaġvik (Barrow), 2022.*

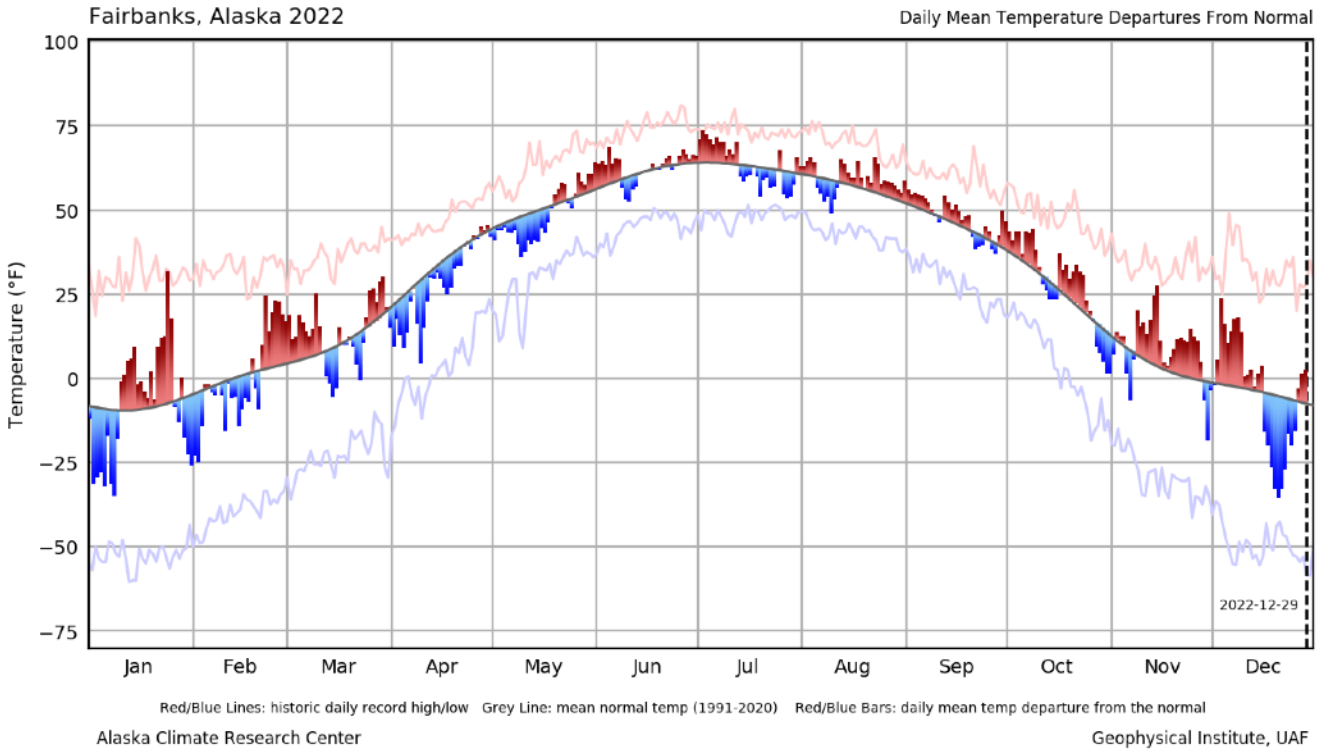

Figure 7. *Mean normal temperature, daily mean departure from normal, and historic daily record minimum and maximum for Fairbanks, 2022.*

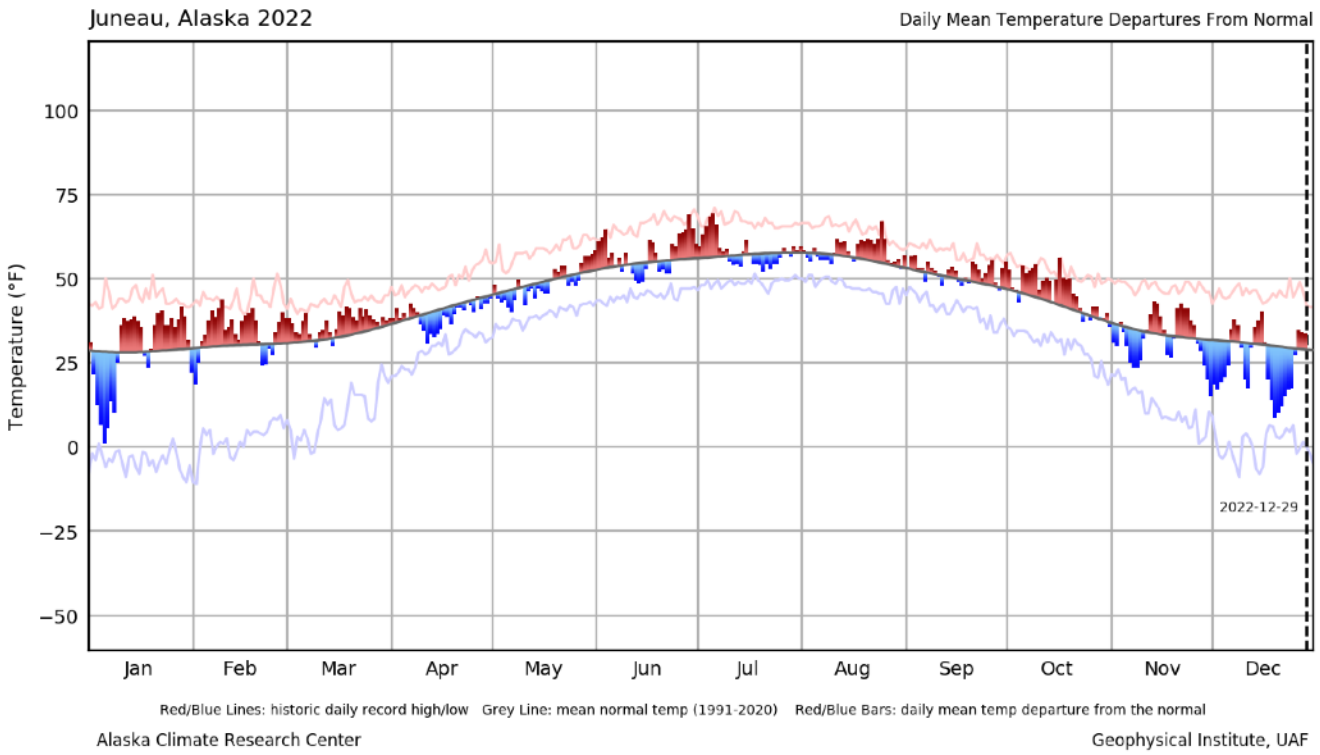

Figure 8. *Mean normal temperature, daily mean departure from normal, and historic daily record minimum and maximum for Juneau, 2022.*

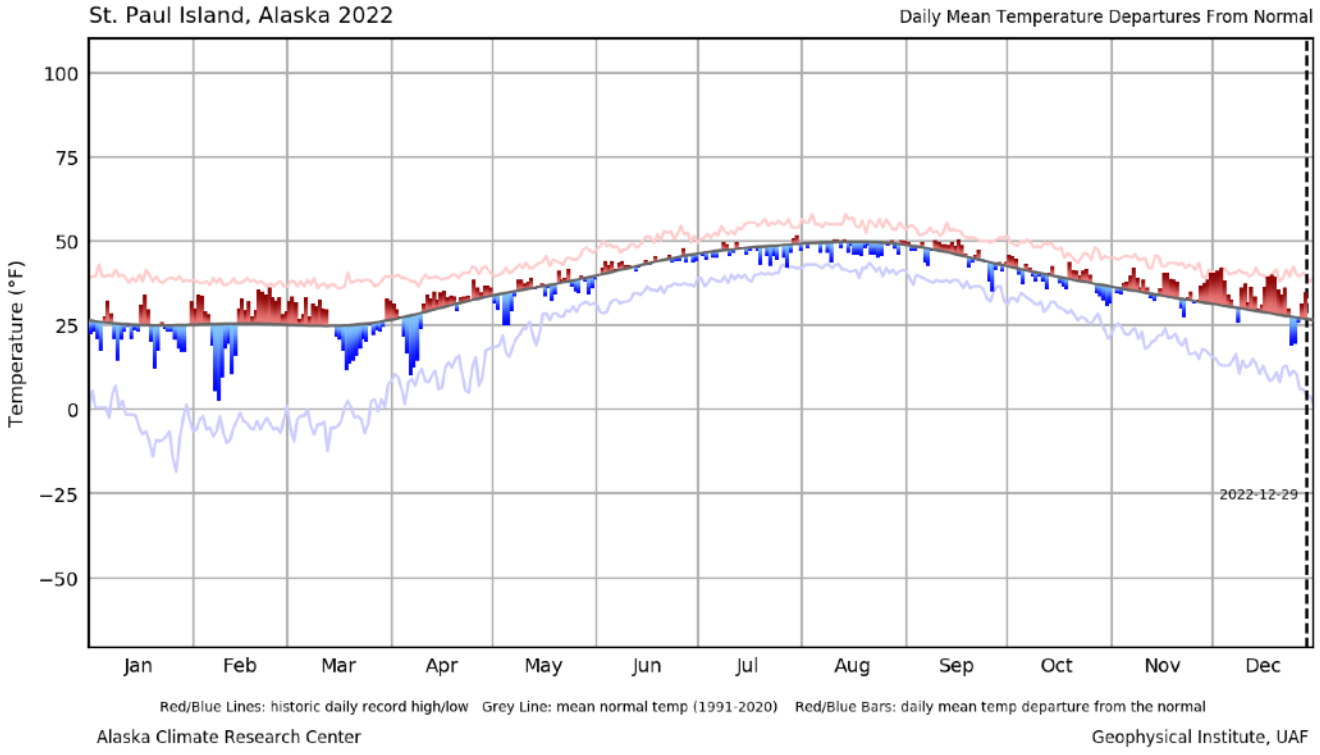

Figure 9. *Mean normal temperature, daily mean departure from normal, and historic daily record minimum and maximum for St. Paul Island, 2022.*

Regional differences are also apparent when considering negative deviations. The Southeast and South-central regions had a notably cold December. In contrast, the western parts of the state mostly had their most negative deviations in January.

Figures 5 through 9 show climographs for, respectively, Anchorage, Utqiaġvik (Barrow), Fairbanks, Juneau, and St. Paul Island, as examples of 2022 temperature deviations in the five main climate regions of Alaska. For a more detailed look at spatial variations across the state, Fig. 10 shows monthly anomaly maps based on ERA5 reanalysis data (Hersbach et al., 2020). January was unusually cold in the west and north of the state, while the southern and eastern areas saw positive anomalies. In February, the split was even more pronounced, with large negative anomalies in the north and a very warm south. March - the warmest month in terms of deviation from normal based on the First Order stations - was warmer than normal in almost all of the state. April - the coldest month - was cold everywhere except on the west coast, where substantial positive deviations were recorded. May saw a warm southwest and a cooler or near normal northeast. June was cool or near normal on the North Slope and warmer than average in the rest of the state. July and August both saw a general pattern of warmth in the east and Interior and cooler temperatures in the western half of the state. September was warm throughout, more so in the north. October and November both saw substantial positive anomalies in much of the state. October was warmest in the southeast, while November saw a cool southeast and extreme warmth on the North Slope. This pattern persisted into December with an even more pronounced split between the extremely warm North and a cool Interior and Southeast.

Temperature connections with Large-Scale Circulations

The large-scale coupling between atmospheric circulation, El Niño-Southern Oscillation (ENSO) and the related Pacific Decadal Oscillation (PDO) also influences the climate of Alaska (Mantua et al. 1997, Hartmann and Wendler 2005). For example, a positive PDO usually leads to above normal temperatures in Alaska. In 2022, the PDO was negative throughout the year, with relatively low values throughout. This continues an ongoing phase of negative PDO that began in fall 2019.

ENSO phases cycle from positive to negative on a much shorter time scale than the roughly decadal time scale of the PDO, with cold and warm phases typically lasting 6-8

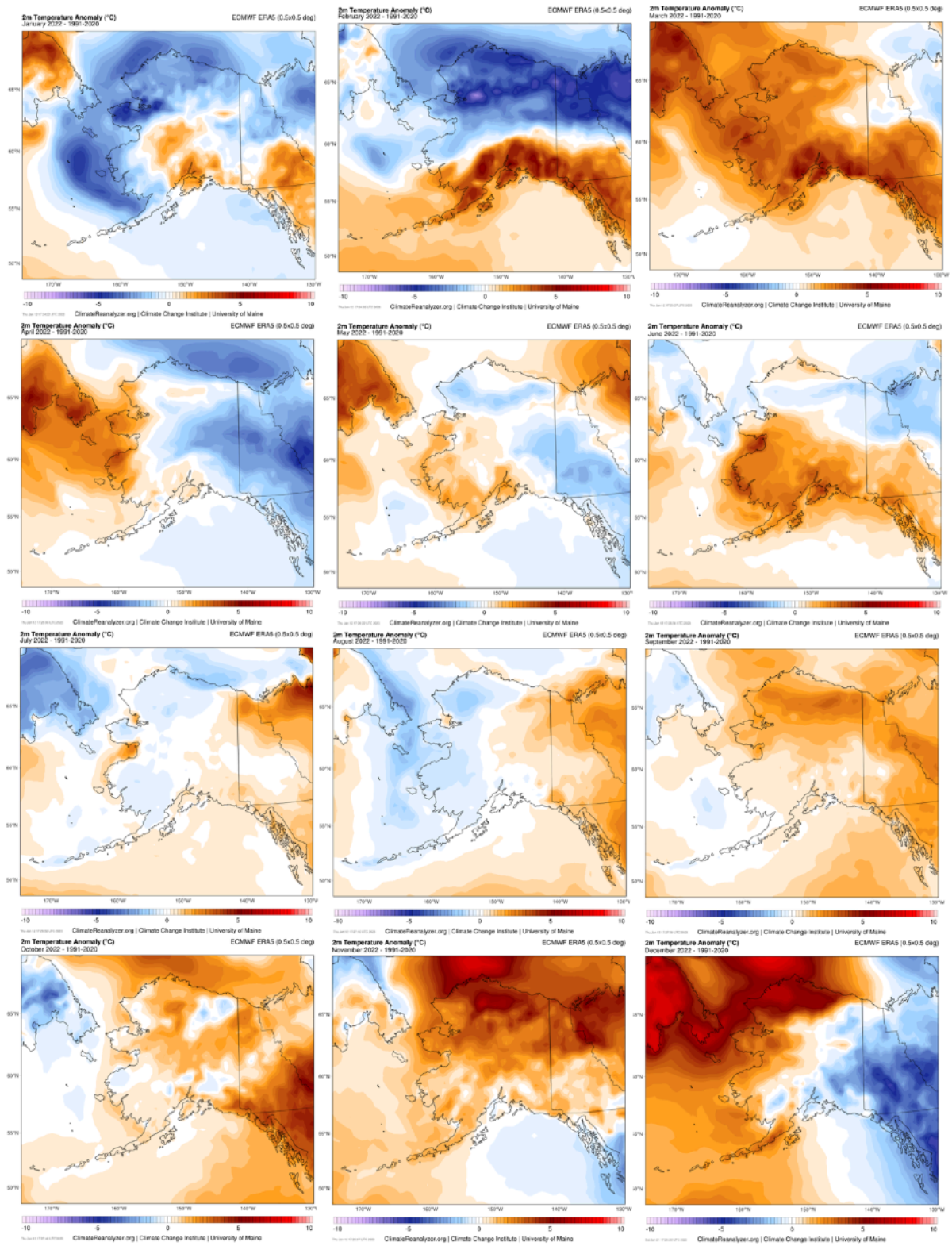

Figure 10. *January - December monthly anomaly maps over Alaska based on ERA5 reanalysis data and the 1991-2020 climatology. Images from ClimateReanalyzer.org.*

months. El Niño winters are characteristically warm and wet over southern Alaska and western Canada, while La Niña winters are often cold and dry over the same areas. 2022 was a La Niña year throughout. 2022 was a relatively warm year despite the cold ENSO and negative PDO phases, which suggests that temperatures may have been dampened by the large-scale teleconnections and might have been even higher in neutral or warm phases.

Station	Observed (ºF)	Normal (ºF)	Departure (ºF)
Anchorage	39.3	37.7	1.6
Bethel	32.9	31.5	1.3
Bettles	24.6	24.1	0.6
Cold Bay	40.4	39.3	1.0
Delta Junction	30.2	30.1	0.0
Fairbanks	29.2	28.4	0.8
Gulkana	29.8	28.4	1.0
Homer	40.8	40.1	0.6
Juneau	43.1	42.2	0.9
Ketchikan	46.2	46.1	0.2
King Salmon	37.5	36.6	1.0
Kodiak	43.8	42.2	1.5
Kotzebue	23.0	24.2	-1.2
McGrath*	29.2	29.0	-0.1
Nome	30.1	28.1	2.0
St. Paul Island	36.0	36.0	0.0
Talkeetna	37.3	36.0	1.1
Utqiaġvik	16.0	13.9	2.1

Station	Observed (ºF)	Normal (ºF)	Departure (ºF)
Yakutat	41.7	41.1	0.4

Table 1. *Mean temperature for 2022, normal temperature (1991-2020) and deviations from the mean for the 19 first-order meteorological stations in Alaska, color-coded to Figure 1. An asterisk (*) marks stations with more than five days of missing data. Missing data are ignored in the computation of the mean.*

2022 Precipitation in Detail

Annual Precipitation

2022 was a wetter than normal year in all AK climate divisions. The Cook Inlet and Bristol Bay region had the lowest positive anomaly with about 6% above normal. The Northslope and Interior were wettest in relative terms at about 18% and 17% above normal, respectively (Fig. 11). At the First Order Stations, Anchorage and Gulkana stand out with a very wet year (174% and 184% above normal, respectively). Juneau, King Salmon, Nome, Talkeetna, and Utqiaġvik all saw between 20% and about 40% more precipitation than usual. Delta Junction, Fairbanks, and McGrath were driest in relative terms. Delta Junction had the lowest value of the year with the 78% of normal (Fig. 12 & 13, Table 2)

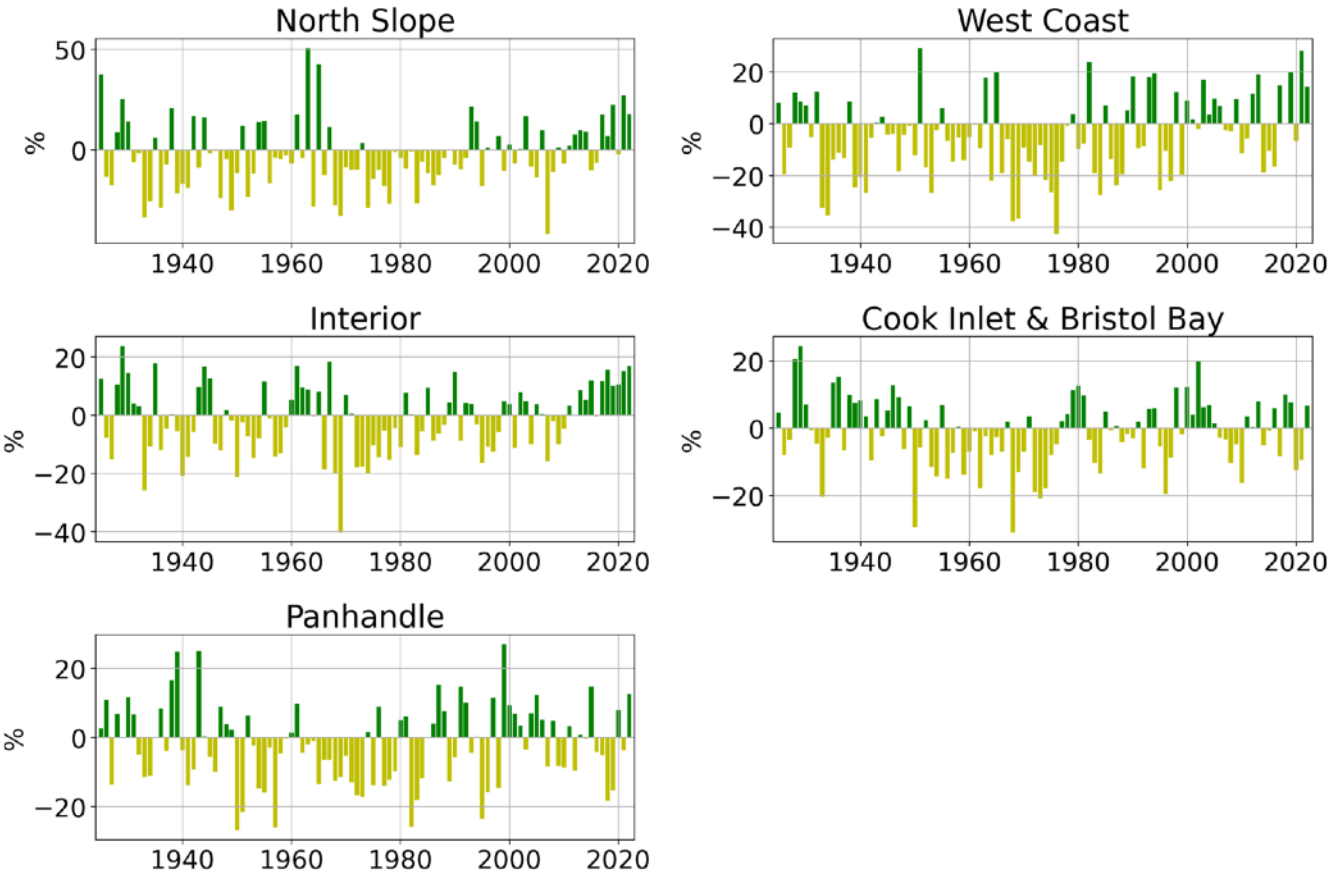

Figure 11. *Time series of annual precipitation sums as percentage departure from the normal (1991-2020) for the Alaska climate divisions. Data source: NOAA nClimDiv.*

Monthly Precipitation

Averaging over the selected stations shows that April, May, and June were drier than normal, while all other months saw positive deviations from normal precipitation. February in particular had a high percentage deviation across the stations. However, when we consider the precipitation maps based on reanalysis (Fig. 14), we see that the north of the state was relatively dry while the southern half was very wet. The North Slope has only one First Order station (Utqiaġvik), so it is underrepresented if we take the average over all stations.

The anomaly maps paint a more detailed picture: January was slightly drier than normal in the west, north, and Interior and wetter in South-central Alaska and the Panhandle. February, as mentioned, was very wet in the southern half of the state. March was again relatively wet though not extremely so in most of the south and very dry in the north. At the Juneau First Order station, a new record for four month precipitation (January,

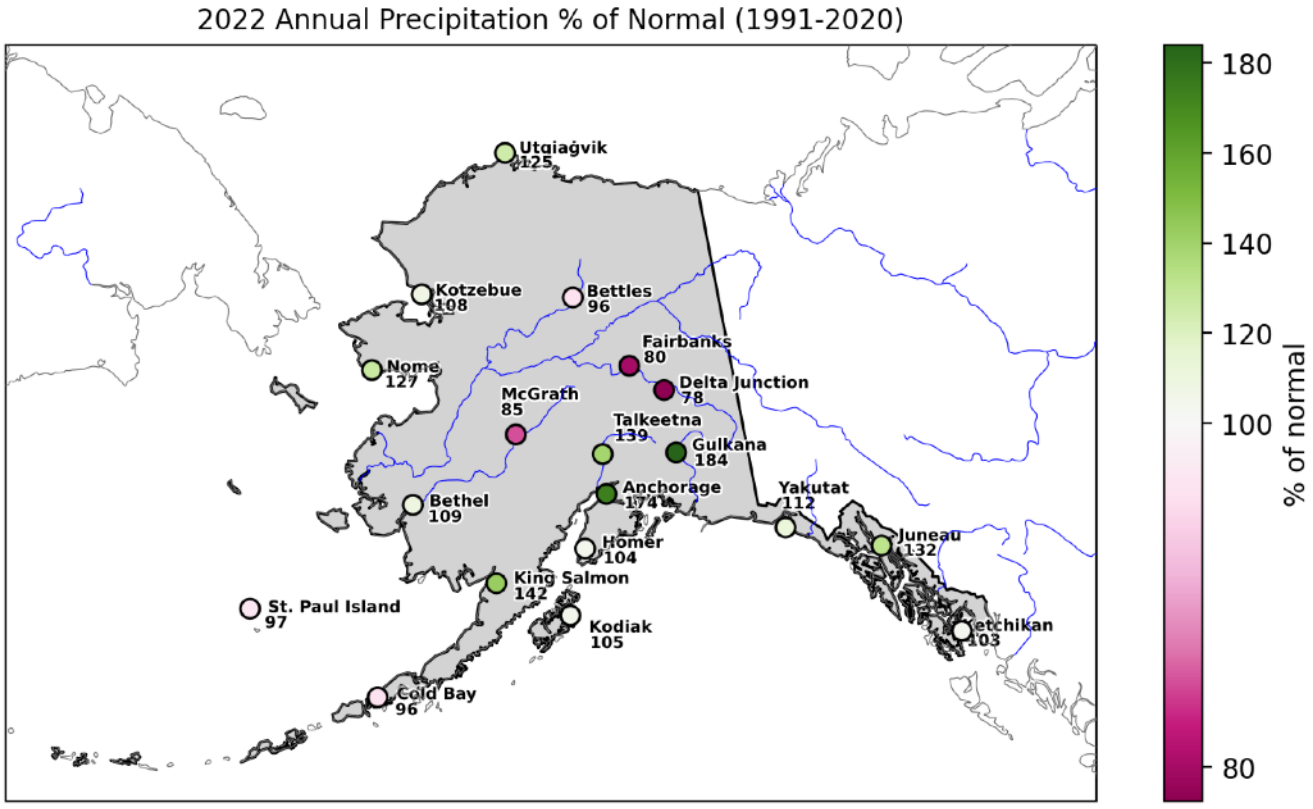

Figure 12. *2022 precipitation deviation (%) from the normal (1991-2020) for the selected stations.*

February, March, April) was set. January and February both set new monthly records at this station, while March 2022 was the second wettest March on record. A dry period for most of the state began in April. May saw values close to normal in the north and east and continued dry conditions elsewhere. June again was very dry in much of Alaska. July and August rains brought relief from the dry and fire prone conditions. Utqiaġvik set a notable new record for all time daily precipitation at the site on July 26 (1.42 inches). August was

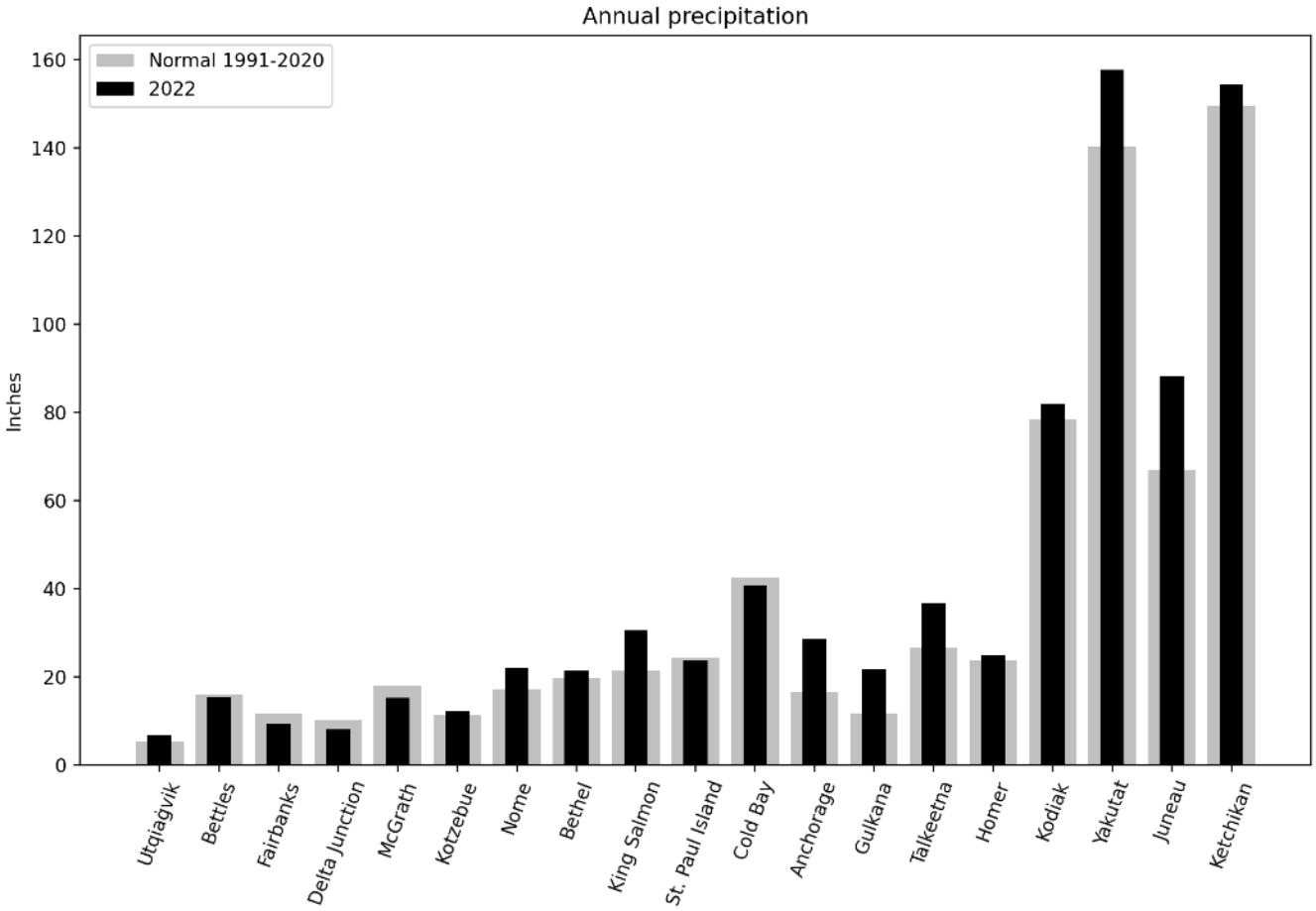

Figure 13. *Precipitation sums (in inches) for 2022 and corresponding normal values at the selected stations (1991-2020) for the selected stations.*

particularly wet in South-central: Anchorage recorded precipitation on almost every day of the month. September was relatively dry on the North Slope and wetter than normal in most other areas with relatively large regional variations. October was very wet in roughly the southern half of the state, again with quite large regional variations. Gulkana set a new monthly record for October with 3.86 inches of precipitation. November saw a wet

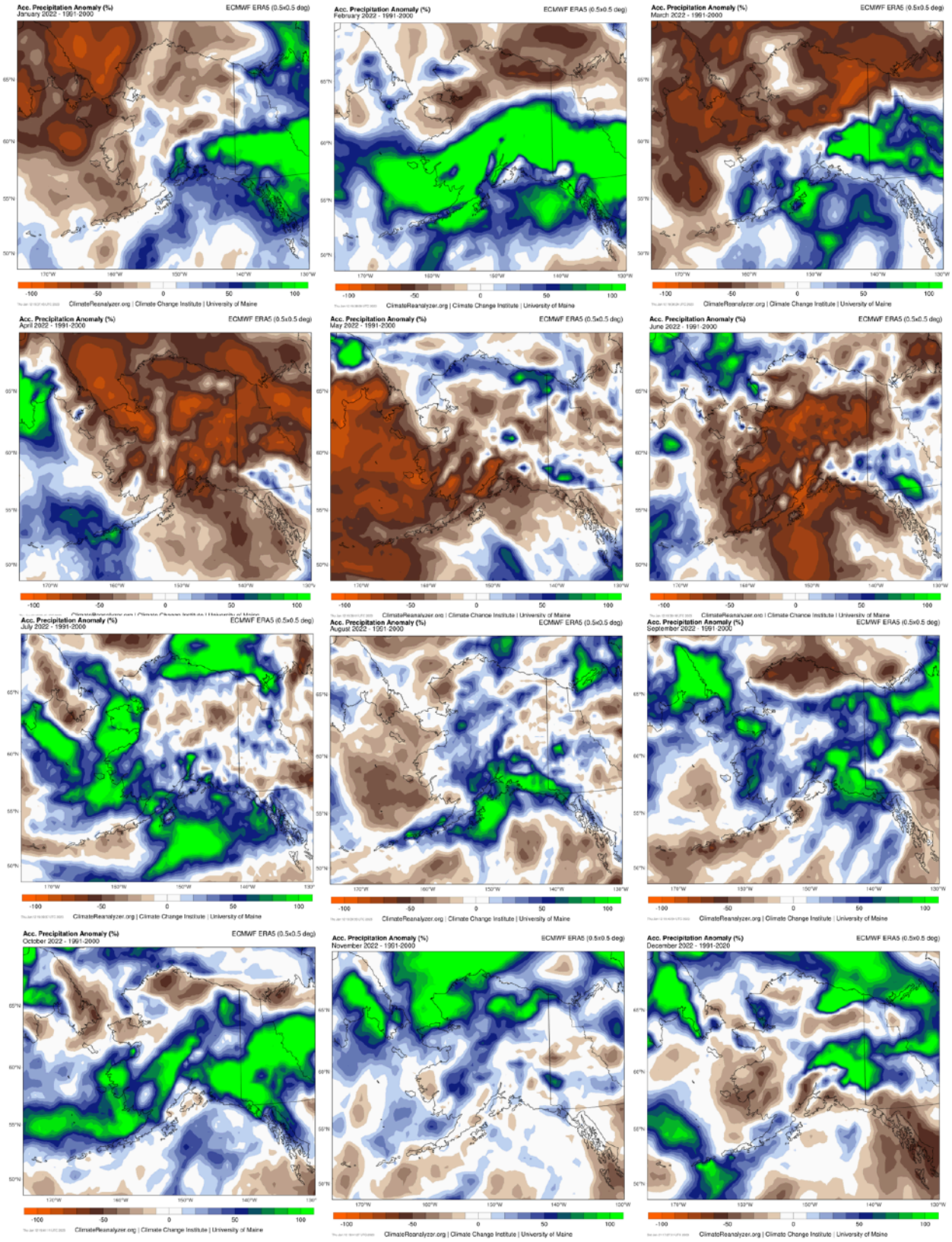

Figure 14 *January - December monthly anomaly maps over Alaska based on ERA5 reanalysis data and the 1991-2020 climatology. Images from ClimateReanalyzer.org.*

northern coast and near normal conditions elsewhere. December was very wet in parts of South-central with near record snowfall and a new monthly precipitation record in Anchorage.

Station	Observed (ºF)	Normal (ºF)	Departure (ºF)
Anchorage	28.6	16.4	174.2
Bethel	21.4	19.7	108.9
Bettles	15.4	16.0	96.1
Cold Bay	40.8	42.7	95.5
Delta Junction	8.0	10.3	78.1
Fairbanks	9.3	11.7	79.7
Gulkana	21.6	11.8	183.9
Homer	24.9	23.9	104.3
Juneau	88.3	67.0	131.8
Ketchikan	154.4	149.5	103.2
King Salmon	30.5	21.4	142.4
Kodiak	82.0	78.3	104.8
Kotzebue	12.2	11.4	107.7
McGrath*	15.3	18.0	84.8
Nome	21.9	17.2	127.4
St. Paul Island	23.7	24.3	97.3
Talkeetna	36.8	26.5	138.7
Utqiaġvik	6.7	5.4	124.7

Station	Observed (ºF)	Normal (ºF)	Departure (ºF)
Yakutat	157.7	140.4	112.3

Table 2. *Annual precipitation (inches) for 2022, normal precipitation (inches) (1991-2020), and deviations from normal (%) for the 19 first- order stations. Shades of purple and green correlate with Figure 12. An asterisk (*) marks stations with more than five days of missing data. Missing data are ignored in the computation of the mean.*

2022 Snowfall

Snowfall for 2021/22 was above average in the four First Order stations with long term snowfall records, Fairbanks, Juneau, Anchorage, and Bettles (Fig. 15 & 16, Table 3). These are the only four of the selected stations that continuously report snowfall. For Bettles, Fairbanks, and Juneau, much of this positive deviation was due to lots of snow in December 2021. In 2022, intense rain in Juneau strongly reduced the near record snowpack. February stands out as especially snowy at all four stations. The spring months mostly saw less snow than usual at the four First Order stations mentioned above, although May snowfall in Bettles and Fairbanks was above average. In general, many regions of the state recorded high snow depth and snow water equivalent (SWE) values in spring. Extreme weather events fuelled by bands of tropical moisture resulted in heavy snowfall across the Interior late in the season, leading to high snowfall values in May and further contributing to regionally far above average SWE and snow depth. SWE values were especially high across the Tanana River basin through the beginning of May, ranging

2022 Snow (calendar year)			
	Snow (in)	**Normal (in)**	**Deviation (%)**
Anchorage	114.3	77.9	146.7
Bettles	33.4	97.9	34.1
Fairbanks	59.3	64.6	91.8
Juneau	65.1	87.6	74.3
2021/22 Snow (September 2021-May 2022)			
	Snow (in)	**Normal (in)**	**Deviation (%)**
Anchorage	89.3	77.9	114.6
Bettles	109.4	97.9	111.7
Fairbanks	95.3	64.6	147.5
Juneau	113.4	87.6	129.5

Table 3. *Snowfall sums for the 2022 calendar year and the 2021/2022 winter season, normal snowfall (1991-2020), and deviations from normal (%) for the selected stations that report snowfall.*

from 260 to 337% of normal, and snow depth was much above normal (172 to 314%). The

snowpack across other basins similarly remained near or above normal through the beginning of May. For two SNOTEL stations, the peak SWE for the 2021-2022 snow season was the highest ever recorded during the more than 30 year period of record. See our blog post on the 2021/22 snow season for details. Snowmelt occurred quickly in many areas due to high temperatures in late spring. Snowmelt in the regions with a deep late spring snowpack attenuated the drought conditions that were spreading elsewhere in the state by May.

After some flurries and early storms at high elevations during August, the new 2022/23 snow season started in earnest in September and October. At the end of October, seasonal snow cover was present in almost all of the state. The Southeast saw large snowfalls in mid-October as storm systems moved through the Gulf of Alaska. At some stations in the Wrangells a record start of the season was recorded due to these storms. SWE values reached up to 10 times the normal amount for the time of year. November was relatively dry in the Interior, with low snowfall in Bettles. In contrast, Juneau had a

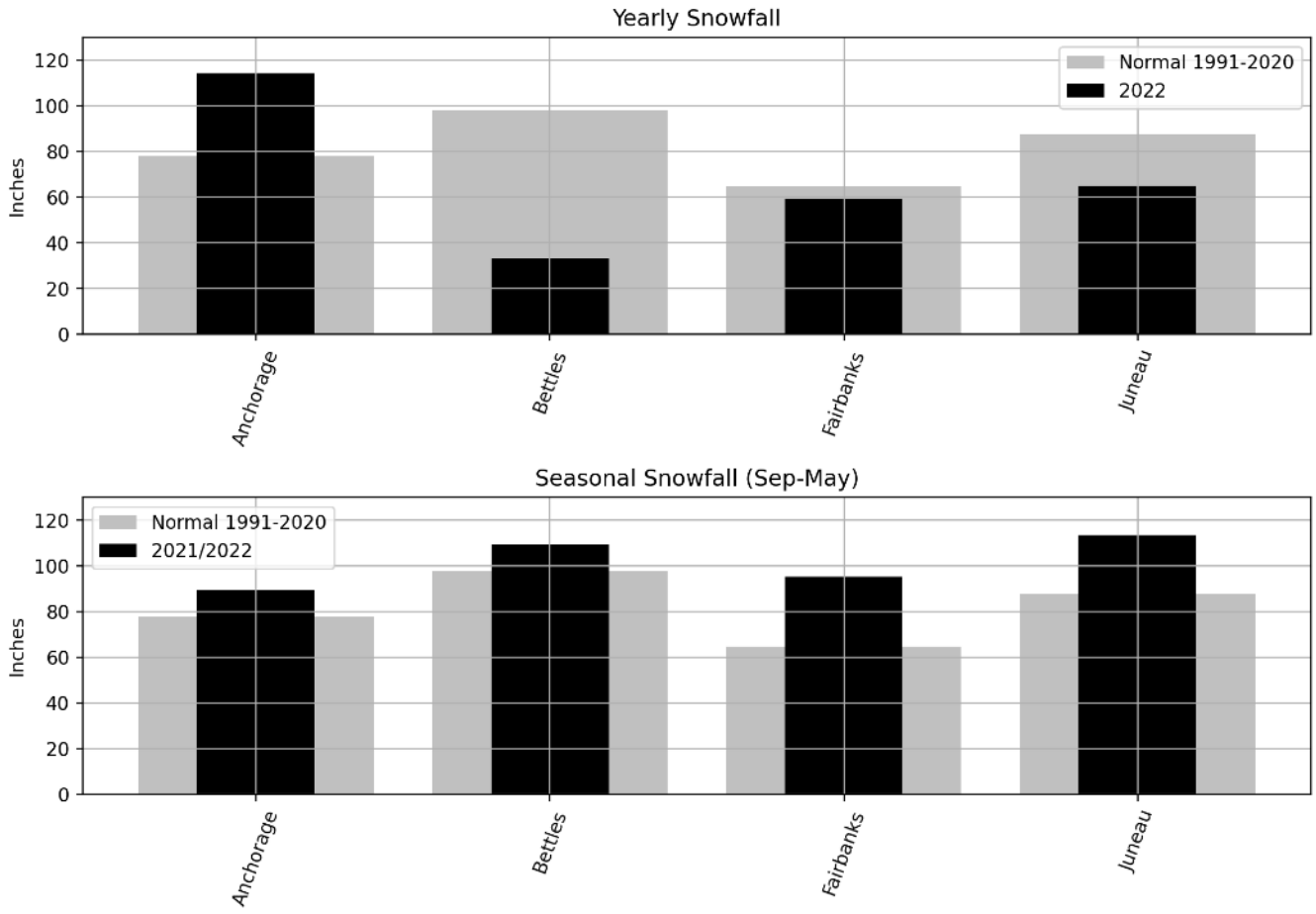

Figure 15. *Annual snowfall averaged over four of the selected stations. 2022 values (black) compared to the normal for 1991-2020 (gray). Top panel shows values for the 2022 calendar year, bottom panel for the 2021/22 winter season.*

close to normal month in terms of precipitation while snowfall was unusually low. This indicates that precipitation fell as rain rather than snow. Anchorage saw a significant snow event early in November, bringing snow depth to above average values before warm temperatures subsequently led to a decrease in snow depth. Fairbanks ended November with near average snow depth values thanks to a series of smaller snow fall events. December was a very notable snow month in South-central. Three major storm systems dropped near record amounts of snow on Anchorage and the surrounding areas. December 2022 was the snowiest December in Anchorage since 1955.

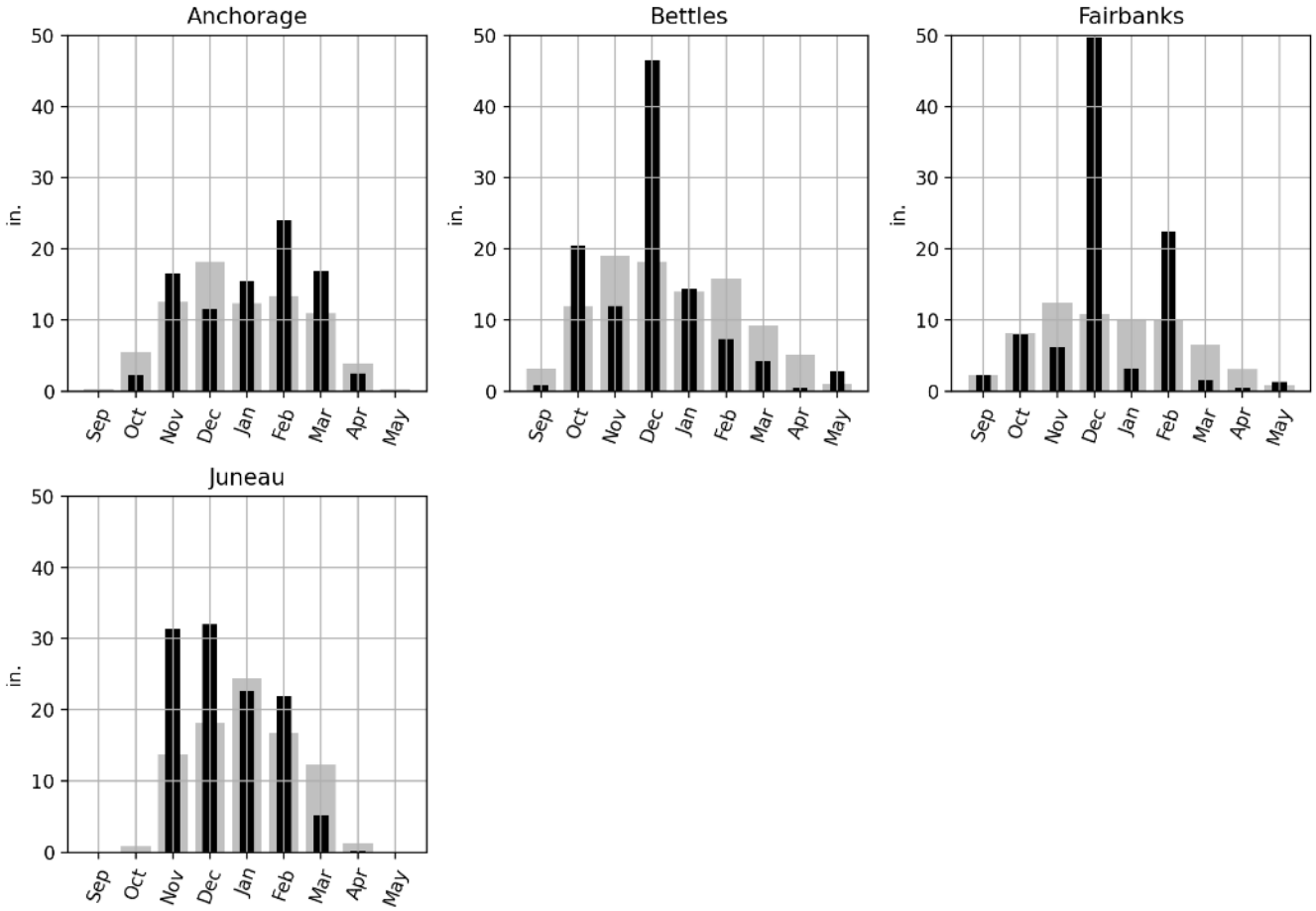

Figure 16. *Monthly snowfall in inches for selected stations in 2021/2022 (black bars), compared to the 1991-2020 normal (gray bars).*

2022 Arctic Sea Ice

Arctic sea ice, particularly the development of sea ice in the Bering and Chukchi Sea, is a key driver for Alaska's climate. In 2022, Arctic sea ice extent was below the average of the satellite record for the entire year. Despite continuous below average conditions, no new negative records were set. The daily minimum, set on September 18th, 2022, tied with 2017 and 2018 as tenth lowest on record. At the monthly scale, the September 2022 average extent tied with 2010 as 11th lowest on record. Sea ice growth in the fall months in the Bering and Chukchi Sea was impeded by a number of strong storms that brought southerly winds and high temperatures. Ice growth during the last weeks of the year was particularly slow and December extent was the fourth lowest on record. A time series of daily Arctic sea ice extent can be seen in Figure 17.

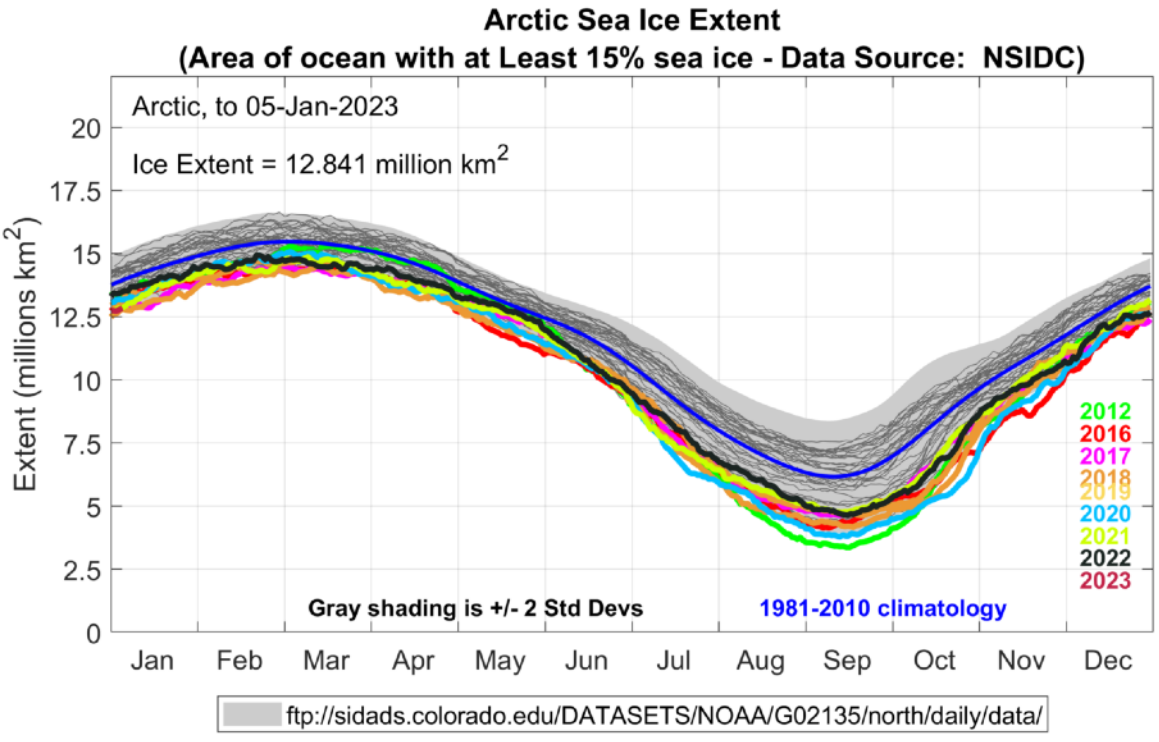

Figure 17. *Time series of daily Arctic sea ice extent. This year's data (2022), seen in black, are updated through January 5, 2023. The median sea ice extent for the 1981-2010 reference period is depicted in dark blue. Plot compiled by: Howard J. Diamond, PhD; Climate Science Program Manager at NOAA's Air Resources Laboratory Data Source: National Snow & Ice Data Center (nsidc.org/).*

2022 Wildfire Season

The unusual 2022 wildfire season started in April with a fire near Kwethluk in southwestern Alaska that burned roughly 10,000 acres. By the end of May, 150 wildfires had burned over 13,000 acres. The season intensified significantly in June: By June 19th, over 1 million acres had burned. By July 2, the tally was at over 2 million and by July 21, 3 million acres had burned (Fig. 18). The 3 million mark was only reached in 7 previous years (2022, 2015, 2005, 2004, 1990, 1969, 1957) since accurate reporting began in 1950. The steep increase in burned area in June and July was due to a combination of strong lightning activity and dry fuel conditions. The season came to a relatively abrupt end in the second half of July as weather patterns shifted and brought widespread precipitation throughout the state. The wet weather continued in August and September and the fire season did not pick up again significantly. As of September 30, the total number of fires stood at 590, 288 of which were human caused according to the AICC. The total number of acres burned was 3.1 million. The vast majority of the burned acreage was due to lightning sparked fires. Human caused fires burned just under 12 000 acres.

The regional distribution of fires is also noteworthy: Over a third of the total affected area was in the Southwest fire management zone (see map), an area not typically known to be very fire prone. The Southwest zone recorded well over 1 million acres burned. It has not been previously recorded crossing this threshold. On the other hand, management zones in the Interior, which see intense fire seasons relatively often, recorded a moderate season in 2022 with no new records. Fires in the Upper Yukon and other Interior zones drove the state-wide acreage tally in the record years 2004 and 2005. 2022 was similar to 2015 in terms of the relatively large contribution to total acreage burned from the Southwest zone. Climate change affects the tundra vegetation in the Southwest, which likely plays a role in changing fuel availability and fire patterns in this part of the state.

2022 Drought Conditions

Due to below normal precipitation, abnormally dry conditions expanded in May in southwest Alaska and the northern Cook Inlet region. Dry, warm weather persisted and by June, drought conditions had developed in most of the state, with severe drought in the northern Cook Inlet. Mid-July rain significantly eased the drought. Parts of South-central and Interior Alaska remained abnormally dry, but widespread precipitation during the

second half of July brought an end to drought conditions in most regions. Abnormally dry conditions persisted a while longer locally around Fort Yukon but Alaska remained drought free through the rest of the year. The May and June drought conditions were a key contributing factor to the early start of the fire season and intense June fire activity.

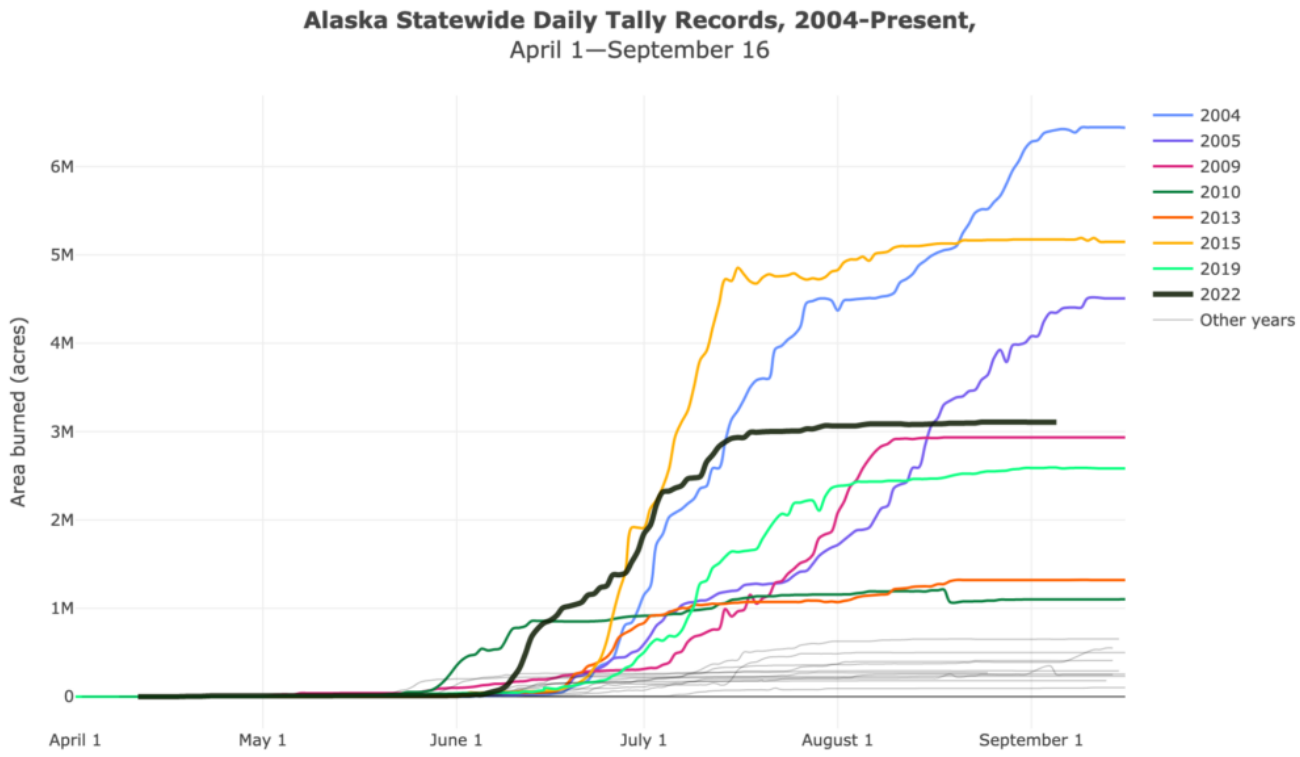

***Figure 18**. Daily acreage burned, cumulative sum through Sept. 16. Plot produced by the Scenarios Network for Alaska and Arctic Planning (SNAP). Data: AICC*

Newsworthy Information

January: Volcano eruption near Tonga: Early on January 15, many Alaskans heard mysterious booming sounds. These were later attributed to the eruption of an undersea volcano near Tonga in the South Pacific. Check out our blog post about the eruption's shockwave.

Scientists aim to improve sea ice predictions: As the amount of sea ice in the Arctic declines and becomes more mobile, accurate forecasts are becoming even more vital for things like fisheries and resource development, shipping, subsistence activities and wildlife management.

The Alaskan Layered Pollution and Chemical Analysis project, or ALPACA, seeks to improve understanding of how pollution behaves in cold and dark conditions and how the layered atmosphere affects pollution events. Experts gathered at UAF in January to work on ALPACA.

February: Ocean heat waves trigger 'squid bloom' along Pacific Northwest coast: Marine heatwaves driven by climate change have fuelled a dramatic increase in market squid along the Washington and Oregon coast over the past two decades, which could disrupt the existing ecosystem.

Nova episode explores Arctic methane explosions and follows several scientists from the University of Alaska Fairbanks as they seek to understand these holes, which are openings created by underground methane explosions.

The Loss through Auroral Microburst Pulsations (LAMP) experiment will study pulsating aurora, which will help scientists learn about how space weather changes atmospheric chemistry.

March: Heavy snow in Interior Alaska this winter led to bison hanging out on plowed roads and digging up farmland. Deep snow prompted more bison to move onto plowed roadways in the Delta Junction area, leading to an increased number of collisions with vehicles.

Heavy snowpack in several Alaska river basins raised concerns of possible spring flooding. The Yukon, Tanana, Koyukuk, Kuskokwim, and Susitna basins all had more snowpack than usual, with some well above normal.

April: As Alaska warms, birch tree tappers in Talkeetna wrestle with erratic seasons. Sap runs are getting earlier and less predictable, trending towards an earlier and shorter window for ideal conditions.

George Divoky spent his 48th consecutive summer on Cooper Island studying the black guillemot, a bird that has become a symbol of a warming planet.

Study finds: Precipitation helped drive distribution of Alaska dinosaurs. Precipitation, more than temperature, influenced the distribution of herbivorous dinosaurs in what is now Alaska, according to new research.

May: Denali's historic, lingering snow season affected the park's wildlife. Denali National Park melted out slowly from its snowiest winter season in 99 years of record keeping. The unusually heavy, lingering snow was challenging for park wildlife.

The Nenana Ice Classic tripod, set up on the river ice March 5, tipped on the morning of May 1 but stayed in place. The current finally pushed the ice around the tripod at 6:47 pm Alaska Standard Time May 2.

Flooding in Manley Hot Springs displaced residents and caused power outages. An ice jam formed on the Tanana River on May 7, resulting in the second- worst flood on record for the community.

June: Amid Alaska's permafrost areas, more soil is staying thawed year-round, UAF scientists find. Warmer winters and thicker layers of insulating snow are spurring creation of more taliks, sections of ground that doesn't freeze even in winter.

July: Flash flooding in the Alaska Range caused damage and road wash-outs at multiple creeks along the Richardson Highway on July 11. The road remained closed from July 11 to July 17 when it was reopened for one lane traffic. More information: Alaska DOT.

A strong wind event on July 24-26 led to damage to the power grid due to downed trees and widespread outages in South-central and the Interior. Damage was particularly extensive in and around Fairbanks. Around 30.000 outages were registered on the Golden Valley Electric Association outage map. The Fairbanks Communications Center temporarily lost power, causing an about 45 minute breakdown of 911 services across much of the Interior. More information: AK Public Media.

August: The annual State of the Climate report was published in late August as a supplement to the Bulletin of the American Meteorological Society. Several UAF scientists contributed to the chapter on climate in the Arctic. Summarising 2021 climatic developments, the report finds that temperatures across mainland Alaska were near or below average during 2021, while the eastern Canadian Arctic and Greenland were warmer. Glaciers throughout the Arctic and particularly in Alaska and Canada lost significant ice during the 2020-2021 ablation season. Vegetation productivity was lower in 2021 than in the previous years.

September: Ex-typhoon Merbok caused severe and widespread damage along Alaska's west coast from September 16 to September 19. Coastal communities the Kuskokwim delta to Norton Sound and the Bering Strait reported major flood and wind related impacts. Residents were forced to evacuate their homes and shelter in schools or seek higher ground, e.g., in Golovin, Hooper Bay, and Newtok. Flooding led to extensive infrastructure damage including washed out roads, flooded air fields, inundated homes, and destroyed berms and boats. Several homes reportedly floated off their foundations and numerous hunting and fishing camps - essential for subsistence - were destroyed. Merbok was one of the strongest September storms on record for the Northern Bering Sea. Nome reported a water level of 10.5 feet above the low tide level, the highest value since an extremely strong storm in November 1974.

October: Utqiaġvik and other communities on the Chukchi and western Arctic coast saw substantial flooding from the storm surge associated with a powerful storm system in the Chukchi Sea that arrived on Alaskan coasts around October 7 and 8. Water levels were lower than those during ex-typhoon Merbok in September, although not by much. The Bering Coast, which suffered widespread damage from Merbok, was not strongly affected by this October storm.

Landslides caused multiple road closures this month. Haines Highway was hit on October 1st and cleared soon after. Edgerton Highway was blocked by a slide on October 17th and again on October 19 at a different location. On October 31st, a slide occurred near Petersburg on the Miktof Highway.

Many Alaskan rivers began to freeze. Unseasonable ice jams caused elevated river levels on the Tanana near Fairbanks and the Kuskokwim near McGrath. If ice forms during high water levels and the water under the ice later drains, the remaining ice can be dangerously unstable. The figure below shows the extreme jump in gage height at the Tanana in Fairbanks in late October.

November: River ice was slow to form in many regions due to the high temperatures throughout much of the month. Bethel Search and Rescue reports too much open water on the Kuskokwim River for safe travel.

Takawangha volcano in the western Aleutians was given "elevated alert" status after a series of small earthquakes that indicate increased volcanic activity. John Lyons of the Alaska Volcano Observatory said there is currently no cause for concern. It is not unusual to have multiple volcanos under elevated alert status.

Thick fog affected the Fairbanks area on several days during November. In cold conditions, for example during strong temperature inversions, power plants can produce large plume clouds that contribute to reduced visibility and fog formation downwind of the power plants. The webcam image below shows plumes spreading near UAF on November 28.

December: The early December warmth on the North Slope, the period of intense snow fall in Anchorage and surrounding areas, and the sustained cold spell shortly before Christmas were the defining weather events of the month and received coverage by various media outlets in and outside of Alaska.

Impactful winter weather throughout the state General winter weather impacted driving conditions throughout the state all through December. Clearing the record amounts of snow from Anchorage streets and side walks took some time and residents struggled to get around during the storms. Winter Storm Watches and Warnings were repeatedly

issued by the NWS for affected areas. The western coastal areas saw multiple Bering Sea storm systems move up the coast, accompanied at times by whiteout and blizzard conditions.

Tanana Valley Jet: During the cold spell from about December 19th until Christmas, strong pressure gradients along the AK-Canada border switched on the Tanana Valley Jet, a local weather phenomenon that produces high wind speeds around Delta Junction and in the Tanana Flats. Due to temperature and pressure gradients, cold near surface air is funnelled through the topography of the Upper Tanana Valley. The air is “pushed” down valley through constrictions in the terrain and picks up speed, leading to gusty, windy conditions and potentially dangerous wind chill.

Sources:

Hartmann, B. and Wendler, G., 2005. The Significance of the 1976 Pacific Climate Shift in the Climatology of Alaska. Journal of Climate, 18, 4824-4839. https://doi.org/10.1175/JCLI3532.1

Hersbach, H, Bell, B, Berrisford, P, et al. The ERA5 global reanalysis. *Q J R Meteorol Soc*. 2020; 146: 1999– 2049. https://doi.org/10.1002/qj.3803

Mantua, N., Hare, S., Zhang, Y., Wallace, J., and Francis, R. 1997. A pacific interdecadal climate oscillation with impacts on salmon production. BAMS, 78, 1069-79.

Vose, R.S., Applequist, S., Squires, M., Durre, I., Menne, M.J., Williams, C.N., Fenimore, C., Gleason, K. and Arndt, D., 2014. Improved Historical Temperature and Precipitation Time Series for U.S. Climate Divisions. Journal of Applied Meteorology and Climatology, 53(5): 1232–1251. https://doi.org/10.1175/JAMC-D-13-0248.1.

Appendix

	J	F	M	A	M	J	J	A	S	O	N	D
Anchorage	20.65	28.11	32.34	37.95	50.87	60.1	59.44	56.13	50.28	36.73	23.72	14.6
Bethel	4.6	12.61	20.58	32.23	44.76	57.33	55.24	52.31	46.83	33.08	21.55	11.98
Bettles	-11.76	-9.46	9.45	24.05	44.92	58.25	58.74	53.03	43.83	22.9	5.5	-5.9
Cold Bay	28.13	34.62	30.03	34.78	40.79	48.22	50.9	51.27	49.82	42.73	38.45	34.55
Delta Junction	-0.27	4.66	16.32	28.22	45.55	60.85	60.94	56.6	45.83	29.05	12.42	-0.47
Fairbanks	-7.63	-0.12	13.37	28.28	48.71	62.62	63.37	58.98	47.8	28.34	9.12	-4.45
Gulkana	-2.48	15.73	19.94	28.6	45.4	58.48	57.82	53.03	45.15	27.9	10.15	-9.67
Homer	22.92	33.18	35.18	38.0	46.18	54.18	56.31	55.15	50.02	40.55	31.1	25.33
Juneau	28.98	34.34	36.74	39.0	48.47	57.27	58.05	58.1	51.97	45.92	32.22	25.42
Ketchikan	35.16	38.21	40.02	41.75	48.29	56.77	59.79	61.74	55.83	49.58	36.52	30.73
King Salmon	14.48	30.32	27.98	35.03	46.34	55.42	54.6	54.23	47.68	36.82	27.17	20.26
Kodiak	30.74	36.89	36.29	38.18	47.44	55.8	56.44	57.35	51.57	44.24	35.77	33.31
Kotzebue	-12.68	-6.84	5.97	18.12	31.08	45.7	51.89	49.08	44.93	26.6	13.17	7.03
McGrath	-3.0	5.98	14.6	28.02	49.48	59.7	59.1	53.27	47.25	33.07	8.72	-6.08
Nome	0.98	8.73	16.42	27.78	38.5	50.67	52.15	50.03	46.58	32.02	21.33	14.37
St. Paul Island	22.97	26.14	24.92	30.08	35.32	43.58	46.58	47.79	45.7	38.97	36.12	33.58
Talkeetna	16.39	24.95	30.85	35.68	48.68	60.4	58.63	55.56	47.72	34.31	19.97	11.66
Utqiaġvik	-10.81	-16.32	-6.03	2.0	23.97	38.23	40.5	39.35	35.42	24.53	13.88	4.71
Yakutat	27.21	33.04	35.52	37.13	44.24	53.87	56.05	55.9	50.63	44.79	32.94	27.05

Table A1: Monthly mean temperature (in °F) at the 19 selected stations. The highest and lowest monthly means are colored in red and blue, respectively.

	J	F	M	A	M	J	J	A	S	O	N	D
Anchorage	3.8	6.85	6.54	0.45	2.73	4.21	-0.12	-1.33	0.98	0.38	0.13	-4.81
Bethel	-2.35	-0.71	6.09	3.17	1.71	4.03	-1.05	-1.59	0.77	0.92	3.0	1.98
Bettles	-1.11	-6.07	5.75	-0.5	0.21	-0.34	-1.06	0.38	2.64	1.55	5.21	0.1
Cold Bay	-0.32	4.38	0.13	-0.21	-0.21	1.16	-0.65	-1.38	1.41	1.43	3.2	3.81
Delta Junction	0.67	-2.7	2.17	-5.63	-2.73	2.4	0.23	1.0	0.99	2.24	4.27	-2.82
Fairbanks	0.67	-0.31	2.63	-5.37	-1.63	1.61	0.47	1.99	2.04	2.08	5.02	-0.1
Gulkana	0.87	10.13	5.25	-3.72	-0.39	3.58	-0.09	-0.51	1.51	0.8	3.34	-9.78
Homer	-2.48	4.87	5.08	-0.69	0.17	2.19	0.16	-0.15	0.51	0.35	-0.09	-2.33
Juneau	0.54	4.2	3.85	-1.8	-0.48	2.67	1.0	2.1	1.87	3.72	-1.53	-4.89
Ketchikan	-0.44	2.01	2.02	-1.76	-1.81	1.47	0.94	2.75	2.22	3.38	-3.13	-5.68
King Salmon	-2.16	8.22	4.49	-1.02	0.68	2.62	-2.15	-1.43	-0.96	0.42	2.12	1.71
Kodiak	-0.4	4.55	3.1	-0.96	1.63	4.45	0.28	0.81	0.9	2.09	0.07	1.41
Kotzebue	-10.73	-8.23	4.43	1.81	-2.07	-1.81	-3.41	-3.07	1.83	-0.3	2.42	4.63
McGrath	2.38	1.36	2.69	-4.18	0.87	0.99	-1.67	-2.38	1.3	1.27	0.72	-3.82
Nome	-4.62	-0.31	6.82	5.14	1.25	2.37	0.14	-0.17	3.49	1.58	3.09	5.27
St. Paul Island	-2.33	0.84	-0.24	-0.02	-1.29	0.49	-1.32	-1.76	-0.3	-0.48	2.22	4.68
Talkeetna	2.79	6.14	7.34	-0.52	0.97	3.36	-1.43	-0.94	0.21	0.15	-0.61	-3.92
Utqiaġvik	0.7	-4.43	4.47	-2.05	1.27	2.23	-1.15	-0.45	1.72	3.33	8.19	11.02
Yakutat	-1.39	2.39	3.6	-1.46	-1.42	1.97	0.65	1.25	1.23	2.94	-0.87	-3.7

Table A2: Monthly temperature deviations (in °F) from normal at the 19 selected stations. The highest and lowest deviations are colored in red and blue, respectively.