MAY–OCT 2020

ALASKA CLIMATE DISPATCH

A STATE-WIDE SEASONAL SUMMARY AND OUTLOOK

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WEATHER TERMS AND THE PUBLIC

By Brian Brettschneider, National Weather Service Alaska Region/International Arctic Research Center (IARC), UAF

Every scientific discipline has terms that have specific meaning to its practitioners. When these terms are used in papers or conferences, everyone in the discipline knows what they mean. For example, in the atmospheric sciences, terms like advection, vorticity, lapse rate, and others are straightforward extensions of the English language that are unambiguous to other atmospheric scientists. Weather and climate, however, are shared experiences and common topics of discussion between all members of society. When you step outside, you experience temperature, humidity, precipitation, wind, and solar radiation. Confusion may start to creep in when scientific terms become part of the public vernacular.

Probably everyone reading the Alaska Climate Dispatch has heard terms such as cold front, jet stream, blizzard, thunderstorm, and many others. These terms have formal scientific definitions, but their specific meaning may be misunderstood, especially by the non-specialist. In this article, we take a look at a few terms that are commonly used to describe oceanic or atmospheric phenomenon affecting Alaska. In some cases, you will find that you had the concept spot on; in others, you may learn a thing or two. The terms we will describe are: Atmospheric River, Polar Vortex, The Blob, Ice Fog, El Niño, Climate Normals, and Bomb Cyclone.

ATMOSPHERIC RIVER

In early December 2020, record rainfall was observed in southeast Alaska. Skagway, Haines, Pelican, Juneau, and Ketchikan all had rainfall totals that exceeded or neared all-time records for 1-, 2-, 3-, and 7-day periods. The 3-day rainfall in Skagway had a recurrence interval of nearly 1,000 years. In Haines, destructive landslides tragically took the lives of two residents.

During the event and immediately afterward, the term atmospheric river was heard frequently. What is an atmospheric river? Is this a real term that meteorologists use or is it some made-up term used by the media? On the list of meteorological terms, atmospheric river is one of the newest. It only started appearing in the literature during the 1990s. Prior to this, the term pineapple express was sometimes used.

In short, an *atmospheric river* is a highly anomalous corridor of moisture in the atmosphere that is confined to a relatively narrow spatial extent, but which has a long fetch that often originates deep in the tropics. On satellite imagery, it looks like a river of clouds (Figure 1). In cold climates such as Alaska, the air cannot hold as much moisture compared to the tropics. Under special circumstances that occur several times each year, very moist air from the tropics is funneled to much higher latitudes by weather patterns in the sub-tropics and overcomes the local atmosphere's inability to hold moisture.

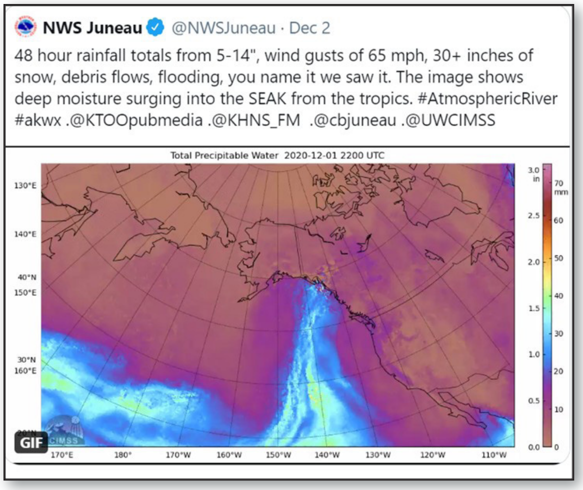
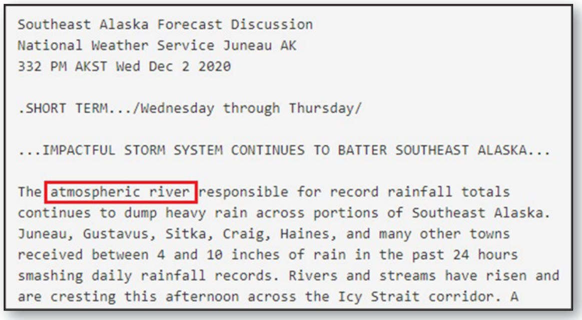


Figure 1. Tweet from National Weather Service in Juneau highlighting the atmospheric river of early December 2020: https://twitter.com/NWSJuneau/status/1334272219791335424.

In this issue


Southeast Alaska Forecast Discussion
National Weather Service Juneau AK
332 PM AKST Wed Dec 2 2020

.SHORT TERM.../Wednesday through Thursday/

...IMPACTFUL STORM SYSTEM CONTINUES TO BATTER SOUTHEAST ALASKA...

The atmospheric river responsible for record rainfall totals continues to dump heavy rain across portions of Southeast Alaska. Juneau, Gustavus, Sitka, Craig, Haines, and many other towns received between 4 and 10 inches of rain in the past 24 hours smashing daily rainfall records. Rivers and streams have risen and are cresting this afternoon across the Icy Strait corridor. A

Figure 2. Area Forecast Discussion (AFD) issued by the National Weather Service in Juneau on Dec 2, 2020.

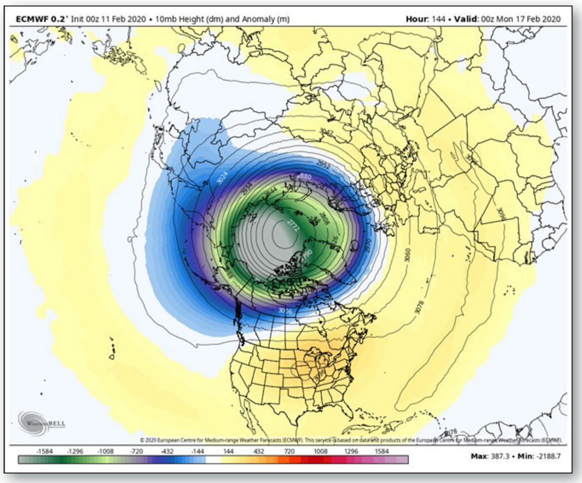


Figure 3. Global Forecast System model forecast of 10 mb pressure heights in February 2020. This represents the approximate height where the stratosphere begins and is the standard marker for identifying the presence or absence of the polar vortex.

Figure 4. Ice fog in Fairbanks at a temperature of -45°F (-43°C). Photo by Rick Thoman.

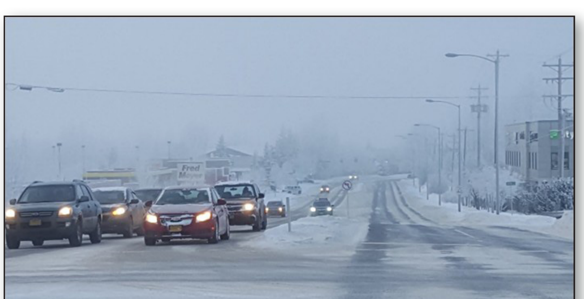


Figure 5. Freezing fog in Anchorage with a temperature of -8°F (-22°C). Photo by Brian Brettschneider.

Meteorologists are always on the lookout for atmospheric rivers due to the high impact of these events. The December 2020 atmospheric river in southeast Alaska was well forecast and advertised for many days by the National Weather Service (Figure 2).

POLAR VORTEX

Perhaps no term has leaped farther from the academic literature to the popular culture than polar vortex. The first use of the term in a science journal was in 1951. By 2014 the term had made its way into the mainstream due to several anomalous cold snaps in the Lower 48, but an ABC News article labeled polar vortex "the most misused weather term of 2014" (see https://abcnews.go.com/US/polar-vortex-misused-weather-term-2014/story?id=26793261).

Even scientists face confusion. The classical polar vortex is a circulation pattern centered near the North Pole in the lower stratosphere—now called the *stratospheric polar vortex*. On maps it is denoted as an area of very cold temperatures above about 40,000 feet (12,000 meters). Figure 3 shows a classic stratospheric polar vortex. The blues, greens, and then grays represent temperature departures from normal for this time of year. The upper air is so cold and dense that the stratosphere boundary (tropopause) is a mile closer to the surface than is typical for the time of the year.

A very reasonable question to ask is why the weather at 40,000 feet matters down at the surface. With no daylight at polar latitudes, and with very cold temperatures high in the atmosphere, the entire atmospheric column can cool off considerably. Since the jet stream is a response to the difference in temperatures between the equator and the poles, a very cold pool of air high in the atmosphere will strengthen the jet stream. When ripples form in the jet stream, the very cold air is dragged southward where the jet stream buckles to the south.

To make matters more confusing, we now talk about a *tropospheric polar vortex* as well. The troposphere is the atmosphere from the surface up to about 40,000 feet (12,000 meters). On shorter time scales (about 3–10 days), pieces of the cold underneath the stratospheric polar vortex can "break off" and make their way into the mid-latitudes. Most discussion in the media about the polar vortex is referring to this short-lived but highly impactful phenomenon—the tropospheric polar vortex.

The American Meteorological Society definition is found here: https://glossary.ametsoc.org/wiki/Polar_vortex.

ICE FOG/FREEZING FOG

If the temperature is below freezing, and it's foggy outside, then you are experiencing ice fog, right? The quick answer is that it depends on the temperature. If the air temperature is warmer than about -35°F (-37°C), you are experiencing mostly regular fog (freezing fog). At temperatures colder than -35°F, you are probably experiencing ice fog (Figure 4). Anyone who is reading this in the Anchorage or Juneau areas, or in any place in the Lower 48, the fog you experienced was not ice fog—at least mostly not ice fog. Even in Fairbanks, pure ice fog is (now) limited to a few days per winter.

What is the difference? *Ice fog* is fog that consists of ice crystals. *Freezing fog* is composed of supercooled liquid droplets. Even when the temperature is below 0°F (Figure 5), the fog particles are liquid droplets. At times, the liquid droplets will freeze and turn to ice crystals, but the formation process includes a liquid phase. Ice fog, on the other hand, involves atmospheric water vapor completely skipping the liquid phase and going directly to the solid (frozen) form. When the temperature is colder than about -50°F or -55°F, it's hard to prevent ice fog formation, especially in populated areas. Any type of dust, smoke, or exhaust will efficiently serve as the nucleus for an ice fog crystal.

THE BLOB

This one does not have the confusing factor that the terms already discussed have, but many people have heard about The Blob and don't know very much about it. Basically, *The Blob* is (was) a part of the North Pacific Ocean (including the Gulf of Alaska) that became anomalously warm beginning in 2014, and continuing through all of 2016 and remaining warm (to a lesser degree) ever since (Figure 6). Professor Nick Bond of the University of Washington first used "The Blob" to describe the phenomenon (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015GL063306). Since mid-2014, this part of the ocean has been above normal over 90% of the time and represents the largest non-ice covered area with ≥1°C sea surface temperature (SST) anomalies anywhere on Earth.

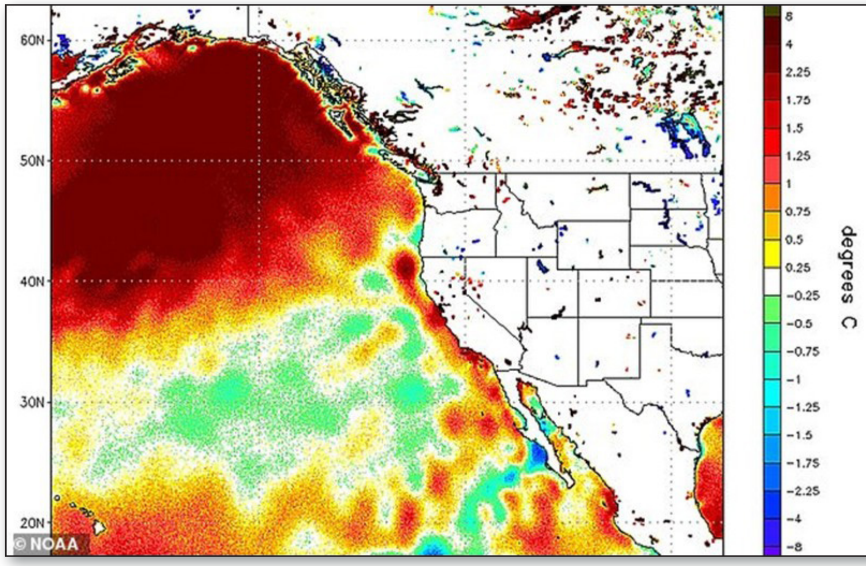


Figure 6. Map of sea surface temperature (SST) anomalies in 2016. The Blob is the large red area in the North Pacific, including the Gulf of Alaska. Figure from NOAA.

There is no consensus as to why The Blob formed or what sustained it. Was it high pressure that allowed more sunlight to warm the ocean? Was it a shift in the storm track that reduced the frequency of stormy conditions that upwell colder water? Did warm water move here from the sub-tropics first and that affected the weather patterns afterward? More research is needed to answer these questions. The impact of the The Blob has been dramatic on the marine ecosystem. The effect on the climate of Alaska were equally pronounced. The Blob was concurrent with the warmest years on record for Alaska.

EL NIÑO

Everyone has heard of El Niño, right? But what do El Niño, La Niña, ENSO, and Niño 3.4 really mean? They are terms related to the fluctuations in surface water temperature in a part of the tropical Pacific Ocean straddling the equator. Specifically, it is the region between 5°N/S latitude and 170°W to 120°W. Even more specifically, the area is referred to as the Niño 3.4 region. Nearly all references to "Niño regions" are referring to the Niño 3.4 region (Figure 7).

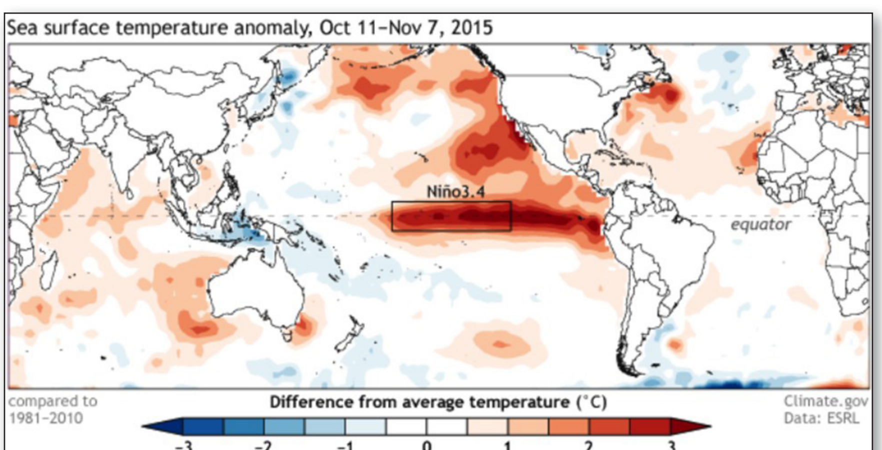


Figure 7. Sea surface temperature (SST) anomaly map from Autumn 2015 showing a classic El Niño pattern of increased temperatures in the Niño 3.4 region. Figure from Climate.gov.

The Niño 3.4 region represents only 1.7% of the total area of the world's oceans. Why then do climate scientists pay such close attention to it? For one, since it is on the equator it is not subject to cold fronts, hurricanes/typhoons, changing currents, or coastal upwelling that affect water temperatures on short time scales. Changes in the water temperature in this region are mostly the result of changing trade winds. Weak trade winds in this part of the Pacific Ocean allow heat to build up while strong trade winds push the warm surface water away and allow cooler water from below to come to the surface. In short, changes to this region only occur when very large-scale pattern shifts occur across the entirety of the Pacific Ocean Basin.

Here are the terms you might hear related to El Niño:

- *El Niño Southern Oscillation (ENSO)*: This is broadly the relationship between sea surface temperatures and air pressure patterns in the tropical Pacific Ocean.
- *El Niño*: a warming of the Niño 3.4 region by at least 0.5°C over the course of 5 consecutive overlapping 3-month periods (Figure 7).
- *La Niña*: a cooling of the Niño 3.4 region by at least 0.5°C over the course of 5 consecutive overlapping 3-month periods.

The changes to sea surface temperatures in the tropical Pacific Ocean have dramatic effects on the distribution of thunderstorms throughout the tropics. Where these thunderstorm form greatly impacts the movement of air from equatorial regions to the mid-latitudes and polar regions. This affects things like the jet stream, the Aleutian Low, and the overall flow of the atmosphere. The flow of air across Alaska is mostly from the south during El Niño winters and mostly from the north during La Niña winters. It is pretty amazing that changes in the tropical Pacific have such widespread effects.

CLIMATE NORMALS

One of the topics that is most misunderstood among people who follow weather and climate is the concept of climate normals. We are used to hearing the person on television or the radio say, "the normal high temperature for today is 40°F," or, "the temperature last week was 5°F below normal."

The short answer to describe *climate normals* is that it is a smoothed average of monthly weather elements, interpolated at a daily time scale, that represents the current state of the climate. While we can use them as a proxy for short-term climate change, they are not designed as a tool to assess global warming.

The widespread use of climate normals began in the 1930s. The World Meteorological Organization (WMO) mandates each member nation to compute 30-year averages of climatological variables, including temperature and precipitation, at least every 30 years but recommends updates each decade, in part to incorporate newer weather stations.

The U.S. follows this recommended decadal schedule, updating the U.S. Climate Normals once every 10 years. We are currently using the 1981–2010 dataset, the latest release from the National Centers for Environmental Information (NCEI). This dataset contains daily and monthly normals of temperature, precipitation, snowfall, heating and cooling degree days, frost/freeze dates, and growing degree days calculated from observations at approximately 9,800 stations operated by NOAA's National Weather Service.

In May or June of 2021, NCEI will publish the 1991–2020 station-based and gridded climate normals for the entire U.S. They use a sophisticated set of algorithms to homogenize data from multiple nearby stations. Afterward, a polynomial equation is fit to the monthly averages so that daily values can be interpolated.

In Figure 8, we see the estimated daily temperature normal and average for Fairbanks for the 1991–2020 period. The daily average, in red, is subject to lots of day-to-day variability. The normal value, in black, is smooth. While is may seem inefficient to calculate daily normals from monthly data when daily data is available, the normals represent the state of the climate. Looking at the red line, for example, there's a sharp rise in January temps around the 10th of the month, and a sharp drop around the 20th. Is that real, or a statistical artifact? Using the black line renders that question moot. The next issue of the Alaska Climate Dispatch will have an article describing the changes that accompany the new 1991–2020 climate normals.

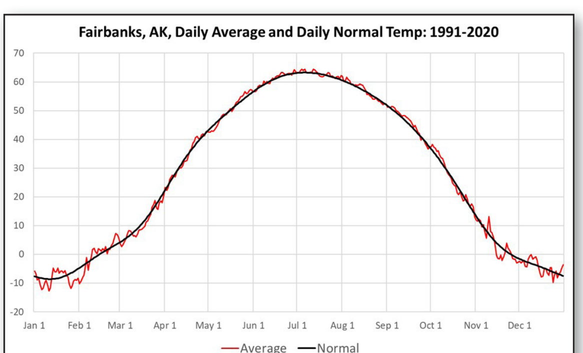


Figure 8. Daily average (high + low ÷ 2) and estimated daily normal temperature for Fairbanks, Alaska, during the 1991–2020 period.

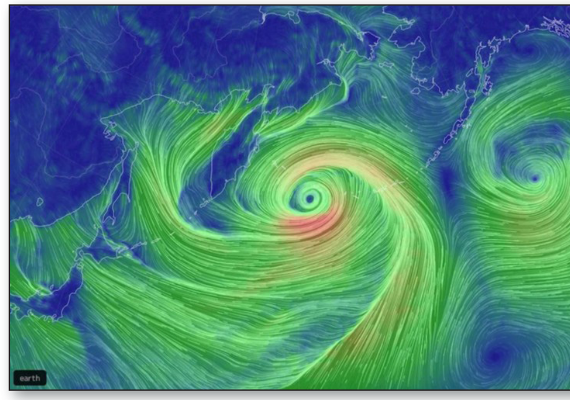


Figure 9. Computer model view of the late December bomb cyclone in the Bering Sea, showing wind direction and speed. Image from Earth.nullschool.net.

BOMB CYCLONE

On December 31, 2020, a new record low pressure was set for Alaska. The automated station at Shemya recorded a sea level pressure of 924.8 mb (27.20"), slightly exceeding the previous record low pressure recorded aboard the ship "Vigilant" docked at Dutch Harbor on Oct 25, 1977 (925.1 mb).

Many news outlets described it as a "Bomb Cyclone" (see Figure 9). A *bomb cyclone* is a relatively new term (since the 1980s) to describe a storm whose central air pressure falls by at least 24 mb in a 24-hour period at 60° latitude. This is also called "explosive deepening". South of 60° latitude, the criteria is a little less than 24 mb. North of 60°, the criteria is a little more than 24 mb. In the Bering Sea and Gulf of Alaska, perhaps a dozen storms per year meet this criteria, so the term has the potential for overuse. According to the readings from Shemya, the December 31 storm deepened by 66.5 mb in the 24 hours prior to the record low pressure reading, although the lowest pressure was likely over Attu Island, where no measurements were taken.

Is it a bomb? No, but a number of meteorological terms also use battlefield references; e.g., fronts, battling airmasses, etc. We describe a storm as deepening explosively, so a natural extension of that is to call it a bomb, I suppose.

FINAL THOUGHTS

We communicate our understanding of the world though language. The language of scientific disciplines are often full of technical terms, jargon, and completely new words. Too often, this creates a barrier to conveying new knowledge to the public and decision makers. Every so often, new terms break through and reach the public. Understanding what these terms mean and how to interpret their meanings benefits both the scientific community and the general public alike.

CLIMATE AND WEATHER SUMMARY: MAY-OCTOBER 2020

By Rick Thoman, Alaska Center for Climate Assessment and Policy, UAF

May through October 2020 was overall quite mild for Alaska as a whole. The six-month average temperature was nowhere near as warm as the same time last year, but still ranked as the ninth warmest since 1925 (2019 was the warmest). The major exception was the Panhandle, where overall, temperatures finished up close to normal. As is usually the case, precipitation was much more variable. Much of west and southwest Alaska were quite dry during the summer and early autumn, including areas around Kotzebue and Kodiak that were in moderate drought for part of the season. In contrast, parts of the eastern Interior were unusually wet. This was especially the case in June and early July, which helped keep wildfire activity to a minimum. Southeast Alaska saw frequent rain, and August was especially soggy in the southern Panhandle.

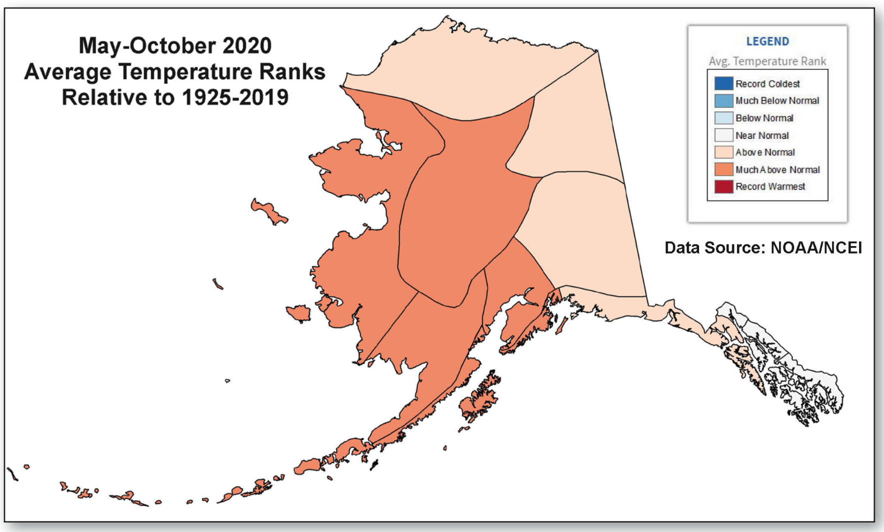
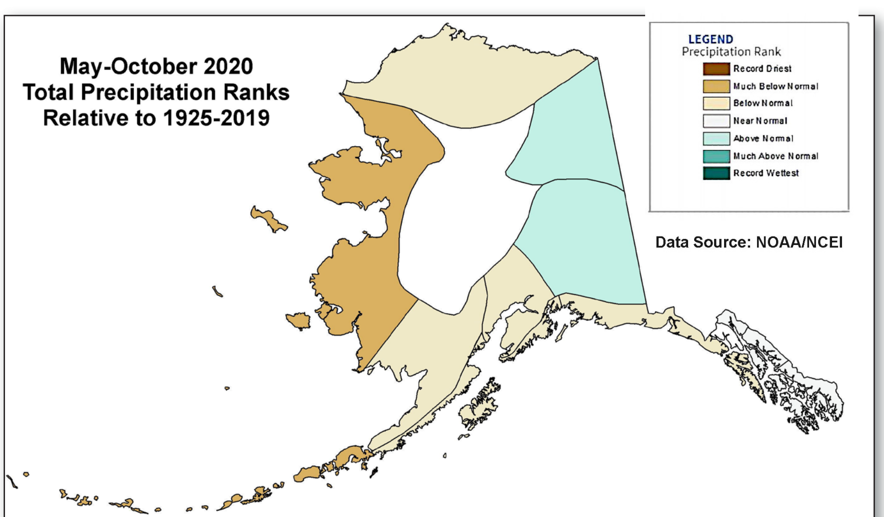


Figure 1. Alaska regional average temperature ranks for May–October 2020, relative to 1925–2019. Figure by Rick Thoman.



MAY 2020

May was mild across all of the state, but especially so over western Alaska. Most notably, Nome had by far the mildest May on record, with an average temperature of 45.7°F. Bethel had the second warmest May with an average temperature of 48.5°F, just behind the May 2016 average of 49.0°F. In the eastern Interior, Northway had its third warmest May with an average of 51.5°F. A short-lived but notable period of unseasonably warm weather over much of mainland Alaska May 9–11 set several temperature records. Gulkana Airport saw new daily records set on May 9 and 10. The high on the 10th of 75°F is the earliest in the year it's been so warm. Talkeetna also set a daily record high on the 10th of 72°F. While the high of 82°F on May 10 at Fairbanks was not a daily record, this would be the highest temperature of the summer. Another round of very warm weather occurred in western Alaska at the end of May. Bethel reached 76°F on the 30th, and Kotzebue hit 72°F on May 31, which tied for second highest temperature on record in May. Unusually for recent times, the North Slope was the region closest to normal in May, mostly 1–3°F above the 1981–2010 normal. At Utqiaġvik, four days in early May saw temperatures drop below 0°F, the most subzero days in May there since 2012.

In a big change from March and April, most areas had near to significantly below normal precipitation. The major exceptions were the Copper River basin and the upper Susitna Valley, where May was wetter than average. Parts of the Gulf of Alaska had a dry spring (March through May) overall, including Kodiak, where the 7.59" precipitation total was low enough to make this was the driest spring since 1972. Thunder is not usually widespread in May, but this year brought a significant outbreak at the end of the month, with thunderstorms from the Seward Peninsula and Kuskokwim Delta to the eastern Interior (Fig. 3). There was no significant snowfall at low elevations in May.

Figure 2. Alaska regional average precipitation ranks for May–October 2020, relative to 1925–2019. Figure by Rick Thoman.

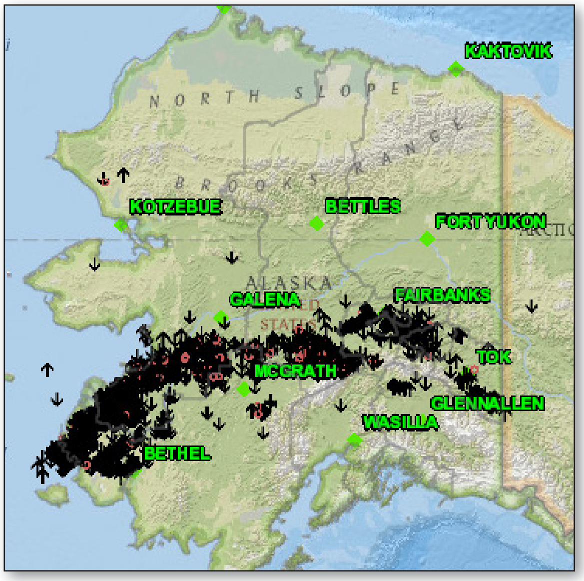


Figure 3. More than 2900 lightning strikes were recorded in Alaska on May 31, 2020. The lightning ignited more than 15 fires. Image from akfireinfo.com, BLM Alaska Fire Service data.

JUNE 2020

June was uncommonly rainy over a large part of Alaska. In the Panhandle, both Juneau (7.30") and Ketchikan (13.60") had the second wettest June on record, and Petersburg fifth wettest. In the Interior, Northway, Delta Junction, and Fairbanks all had a top five wettest June. At Fairbanks Airport, 2.14" of rain fell June 19–21, by far the greatest three-day rain total in June on record, leading to some flooding on area rivers. Thunder was unusually frequent and widespread over mainland Alaska. For the first time on record (since 1953), Anchorage Airport reported thunder on three consecutive days. Fairbanks Airport had nine days in the month with thunder, and some places in the Fairbanks area had as many as 12 days with thunder. Western Alaska also had more than its usual share of thunderstorms. The Nome Airport saw a thunderstorm move through on the 19th, making this the first time since 1990 that Nome reported thunder in both May and June. Parts of Southwest Alaska and a small area in the northern Interior were drier than normal in June.

Temperatures in June were notably mostly for the lack of any hot weather. The highest official temperature in the state was only 85°F at Eagle. Anchorage Airport failed to reach 70°F for the first time since 2011. Western Alaska started off June very mild, with Nome having the warmest first three weeks of June on record. Cooler weather the last week of the month took the edge off the warmth, but nearly all of western Alaska finished up 2–4°F above average, which is a significant departure for a summer month. Thanks in part to the frequent rain, the southeast quarter of mainland and most of the Panhandle were slightly cooler than normal. Wildfires increased early in the month but then largely fizzled out the last week of June with wet and cool weather. Notable were several fires northwest of Bethel that were started by lightning the last day of May (Fig 3). The 12,000 acre Manokinak River Fire burned to within 25 miles of the Bering Sea, apparently the largest wildfire on record to burn so close to the ocean in this region of Alaska.

JULY 2020

July was cooler than normal over most of the Interior, North Slope, and northwest regions, but warmer than normal in southcentral and southwest Alaska and most of the Panhandle. The central and eastern North Slope and northeast Interior were particularly cool. On the flip side, Cold Bay reported the fourth warmest July on record with an average temperature of 54.0°F. Kodiak also had the fourth warmest July with an average temperature of 58.8°F. Southeast Alaska started July off quite warm, with the Juneau Airport seeing record high temperatures on the 1st (78°F) and 2nd (81°F). On the 2nd an offshore wind pushed the temperature up to a daily record of 83°F at Sitka Airport. Late in the month a short-lived but intense heatwave struck parts of the Panhandle. Most notably, the Sitka Airport rose to 88°F on the 31st, equaling the highest temperature on record there, first set on July 30, 1976. This remarkable heat was immediately followed by rare summer evening thunderstorms across parts of the Panhandle, including at Sitka and Petersburg. The absence of any really warm weather in Interior and northern Alaska was unusual. At Utqiaġvik, the highest temperature in July was 53°F, the second lowest July high temperature in the past century. At Fairbanks Airport the highest temperature for the month was 79°F, making this the first time since 1981 that the temperature failed to reach the 80s in July.

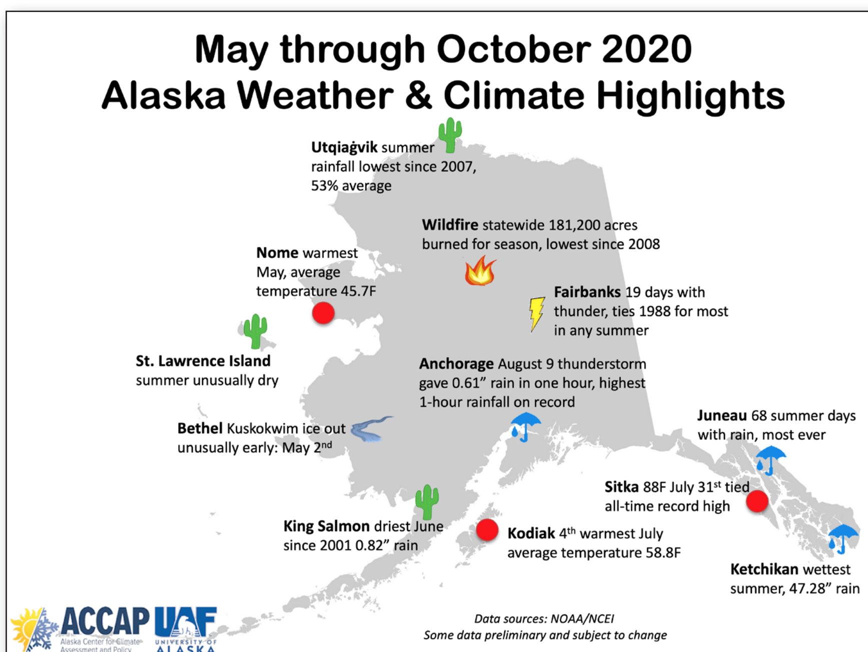


Figure 4. Alaska weather and climate highlights for May–October 2020. More highlights and details are available at http://highlights.accap.uaf.edu/tools/climate_highlights.

Rainfall was generally closer to normal in July than it was in June. Much of the Interior had a bit less rain than normal, except for a band from the Yukon-Tanana uplands southwest into the Denali Park area. Southeast Alaska also had above normal rainfall. In contrast, rainfall deficits were significant in northwestern Alaska, on Kodiak Island, and on parts of the western Gulf of Alaska coast. The far northeast Interior was also quite dry. Thunderstorm activity overall was not as frequent as in June, but Anchorage Airport recorded two days with thunder, bringing the seasonal total to five. In a typical year, Anchorage has just one day with thunder.

The Aftermath, a boat belonging to Unalaska fishing charter Keepin' It Reel, sustained damage during a strong early season storm on August 31. Photo by Hope McKenney/KUCB.

AUGUST 2020

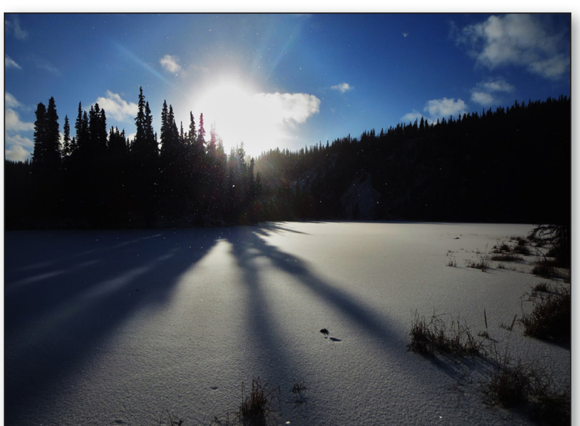
August was warmer than the long term normal over most of Alaska except for the Panhandle. No records were set, but Fairbanks (average temperature of 59.7°F) and Anchorage (58.8°F) both had a "top ten" mildest August. In contrast, thanks to frequent rain, Southeast saw temperatures average slightly below normal. However, in a carryover from the end of July, Hyder reported a high temperature of 93°F for August 1, which wound up being the highest official temperature in the state for 2020.

Overall, August in Southeast Alaska was another unusually wet month. Rainfall amounts of one and one half to three times normal were widely reported and capped off a very damp summer. At Ketchikan, the total summer rainfall came to just under four feet (47.28"), which is the most in any summer in more than a century of climate observations. At Juneau Airport, 68 of the 92 days in June through August had measurable rain (0.01" or more), which was also a record. In sharp contrast, northwest Alaska was quite dry in August. Kotzebue received only a third of an inch of rain (16% of normal) in what is typically the wettest month of the year, and the total summer rainfall was only half of normal, making this the driest summer since 1977. Comparatively dry conditions also continued on Kodiak Island, and the last week of the month the U.S. Drought Monitor indicated moderate drought there, the first moderate drought analyzed anywhere in Alaska since mid-January. Early in the month one of the most extreme rainfalls in Alaska away from the ocean drenched parts of the central Interior, including western Denali National Park. An automated weather station along the McKinley River northwest of Wonder Lake reported 5.35" rain in 24 hours on August 1–2. This appears to be the highest 24-hour rainfall on record in Interior or northern Alaska. Anchorage also had a bout of record heavy rain. A thunderstorm on the 9th (the sixth of the season) produced 0.61" rain in one hour at Anchorage Airport, which is the highest 1-hour rainfall on record there. Fairbanks Airport reported thunder on six days during August, the most for any August on record. This brought the season total to 19 days with thunder, which equals the highest total. The last days of the month brought an unseasonably strong summer storm to southwest Alaska (photo this page). The rapidly deepening storm produced widespread damage at Unalaska, where winds gusted to 84 mph at the airport and as strong as 120 mph near the top of a large crane at the harbor.

SEPTEMBER 2020

September was a mild month for most of state, though not dramatically so. The only areas with slightly below average temperatures overall were parts of western and southwest Alaska. Several notable temperature records were set during the month. At Cold Bay, the temperature dropped to 29°F on September 4. This was not only a daily record but is also the second earliest "first autumn freeze" on record. At King Salmon, the low of 23°F on September 12 was the lowest temperature so early in the autumn. On the warm side, the Sitka Airport rose to 70°F on the 30th. This easily exceeded the daily record of 63°F set in 2018 and is also the latest date in the year when the temperature has reached 70°F or higher. Most parts of mainland Alaska away from the ocean saw the temperature drop to freezing or below at least once in September. At Fairbanks Airport, the first frost occurred on the 13th, ending the growing season at 130 days, the seventh longest on record. In the Panhandle some places had an unusually early frost, including Juneau Airport, where the temperature dipped to 30°F on the 15th, about two weeks earlier than the long-term average and the earliest first freeze since 2006.

Precipitation was much more variable than temperatures. Parts of the North Slope and northwest Interior saw rainfall totals more than twice normal, while following an excessively wet August, Southeast Alaska was unusually dry. At the same time, generally dry weather persisted into mid-month, with Kodiak Island and the Kotzebue area rated as in moderate drought by the U.S. Drought Monitor in early September. During the second half of September several storms impacted the western Gulf of Alaska, which produced copious rain for the Kodiak area and ended the drought. On the 22nd, Kodiak Airport reported 3.26" of rain, the greatest calendar day precipitation total there since October 2014. There was little to no snow except in the mountains and on the North Slope during the month. At Fairbanks there was no snow at all, making this the third straight September with zero snow in the month. In the 90 years of Weather Bureau/National Weather Service observations, this the first time that has happened.



These two pictures were taken at Horseshoe Lake in Denali National Park and Preserve just one week apart (top October 9, lower October 16). The area received nearly 20" of snow in the last 2 weeks of October. NPS photos/Jessica Drain.

OCTOBER 2020

As sometimes happens in October, much of Alaska saw a rapid transition from mild autumn weather at the start of the month to winter-like cold and snow by Halloween. Overall though, it was another mild month for nearly all of the state except for Southeast and a small portion of the southeast mainland. The largest departures from normal were along the northwest North Slope and the West Coast, where the collapse of autumn sea ice in the past 25 years has profoundly impacted the climate of these regions. The average temperature at Utqiaġvik of 25.9°F was more than 8°F above the 1981–2010 normal and the fourth warmest of any October since 1920. Nome reported an October average of 35.0°F, the seventh warmest since 1907. The month started off with unusually mild conditions over nearly all the state. Fairbanks Airport topped out at 68°F on the 1st, the third highest October temperature in the past 117 years. Much of the Panhandle had an unusually dry and crisp two weeks in the middle of the month. Frequent clear skies allowed for some chilly overnight temperatures, including a record lows of 24°F on the 21st at the Juneau Airport and 28°F at Sitka Airport on the 24th. The month ended with positively wintery temperatures in the Interior and Brooks Range as temperatures fell below 0°F across much of the region.

Precipitation totals for October were quite variable. Much of the state was significantly drier than average but with pockets of above normal precipitation (rain plus melted snow). Most significantly, Ketchikan reported just 8.20" of rain for the month, the second lowest October total on record. The above normal precipitation areas included most of the North Slope, the Alaska Range, and parts of the southeast Interior. According to the U.S. Drought Monitor, only the Kotzebue area remained in moderate drought at the end of the month. In the Interior, the sharp descent into wintery conditions occurred mid-month. Fairbanks did not have any snow at all, not even a flake, until October 14, more than three weeks later than average and the third latest “first autumn snow” on record. But just five days later the first inch of snow fell, and that established the permanent winter snowpack. For October as a whole, Fairbanks finished with 8.8" of snow, making this the 13th straight October with snowfall below the 1981–2010 normal snowfall of 10.8". Some areas near the Alaska Range and upper Tanana Valley actually had above normal snow, including Denali National Park Headquarters, where the 20.2" of snow was the most in any October since 1997 (photos this page). Other areas saw snowfall near or below normal, including Anchorage with only 0.9" for the month, compared to the normal of 7.9".

THE WATER COLUMN: EXPANDING OUR USE OF SATELLITES FOR HYDROLOGY

By Jessica Cherry, Alaska-Pacific River Forecast Center, National Weather Service

For a number of reasons, use of satellite data in the workflow at the Alaska-Pacific River Forecast Center (APRFC) has increased in recent years. In winter, USGS gages measuring river stage and discharge work poorly due to ice effects. Our homegrown sonic sensors for stage can only be deployed at sites with bridges. In communities where we have manual observers, most of these individuals are Elders; it is not clear that we can recruit the next generation to take river measurements, as young people leave for opportunities in the cities. In some communities, we can't find a willing observer at all. While we are continuing to test new *in situ* approaches, satellite data have obvious advantages. Coverage is consistent and reliable, and many products are available at no direct cost to our Center. Here I will discuss several of these products and their advantages and disadvantages, as well as new products under development. The APRFC receives dozens of satellite products that characterize precipitation rates and cloud properties, but here I will focus on imagery that characterizes water and land surfaces (Table 1, page 11).

OPTICAL AND NEAR INFRARED IMAGERY

The longest operating satellite series is Landsat. We still use Landsat 8 Operational Land Imager (OLI) imagery (15–30 m) for detecting ice and flood conditions on Alaska's widest rivers. The repeat time of 16 days is one downside of this product, but combined with Landsat 7, that time goes down to 8 days. Landsat 7 is corrupted by a sensor failure, but still somewhat useable. False color, natural color, and water-mapped Red Green Blue (RGB) images are helpful for detecting river ice and flood conditions in clear sky conditions, but the higher resolution (15m) panchromatic is even more informative. Landsat 9 is scheduled to launch in 2021. Another disadvantage of Landsat is that right now, scenes must be downloaded from USGS and analyzed in GIS, and latency can be more than 24 hours. Possible solutions exist in Google Earth Engine but require some development effort. Figure 1 shows a scene from the Kuskokwim River during 2020 breakup.

The Moderate Resolution Imaging Spectroradiometer (MODIS) instrument is still flying on the Terra and Aqua platforms, providing daily data over Alaska at 250–500m resolution depending on the band. Even at this moderate resolution, this imagery provides useful information about snow and ice cover in cloud-free conditions. New derived products are being developed for MODIS imagery, even though in 2021, the sensors are far beyond their design life span. The frequent repeat time and moderate resolution strike a balance that makes the imagery helpful, though possibly underutilized. MODIS products including mosaics are available to the APRFC through UAF's Geographic Information Network for Alaska (GINA) and the direct broadcast communication link to the National Weather Service (NWS). These include RGB products mapped for specific purposes (i.e., differentiating snow and clouds) as well as general false and natural color mosaics and multispectral composites and channel differencing. No special downloading or image projection is necessary to quickly review MODIS imagery in the NWS Advanced Weather Interactive Prediction System (AWIPS) system, and latency is minimal. This is a big advantage for operational users.

The European Space Agency's Sentinel 2 has become one of our newer workhorses. The optical sensor flying on the 2a and 2b platforms has a repeat time of about 5 days in Alaska and a spatial resolution of 10 m in the visible wavelengths. Latency is about a day. The data are not available in AWIPS, but they are on a convenient web-based platform and do not require downloading. The long period between repeat collection is not ideal, but when we do get cloud-free conditions, the imagery is very helpful for assessing river ice conditions and phenomena like glacial dammed lake (GDL) releases. For the latter, we may see a pulse of water on a river gage without precipitation, which may be indicative of a GDL release; the imagery from Sentinel 2 is of ideal resolution to see these lakes and so long as we have passes before and after the release, we can confirm which lake released. Timeliness is ideal, but not essential for attributing these releases after they occur.

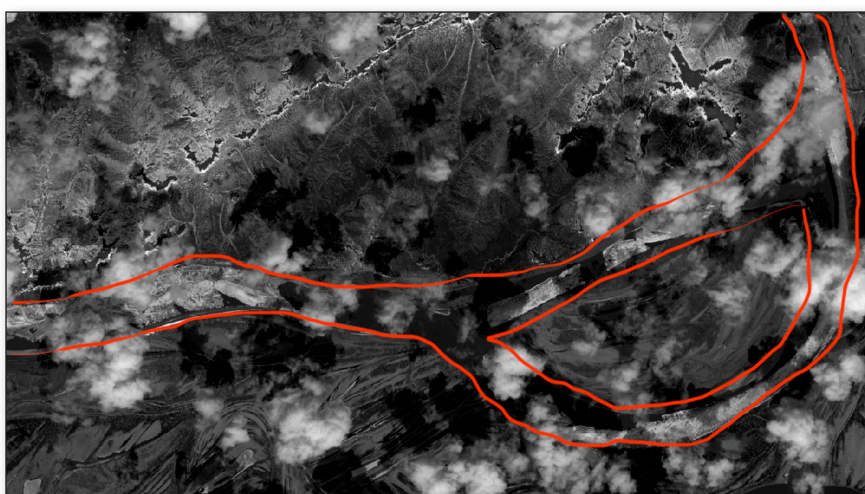


Figure 1. Landsat 8 Operational Land Imager (OLI) imagery on May 5, 2020, showing ice conditions on the Kuskokwim River (outlined in red) during breakup.

The Visible Imaging Infrared Radiometer Sensor (VIIRS) sensors on both the Suomi National Polar-orbiting Partnership (SNPP) and NOAA-20 platforms are another key source of products for the APRFC and make use of sensors in both the visible and near infrared wavelengths. The two derived products that we use the most are the River Ice and Flood product and the River Ice Concentration product. These products are even more valuable than the RGB imagery because the pixels have been categorized for quick interpretation: ice, no ice, water over ice, and percent of pixel that is flooded or percent coverage of ice (Figure 2). Between SNPP and NOAA-20, we receive a satellite pass every few hours into the NWS data platform with almost no latency. The resolution of these products is limited by the Near IR band (used in the algorithm) to 375m. Like all of the other optical products, it only works in cloud-free conditions during daylight hours. In the middle of the winter, most of the optical data here are not acquired nor processed above about 60° N. By the time breakup season comes around in April and May, there is plenty of sunlight for image acquisition; however, in autumn, which can also be quite cloudy, complete freezeup may not happen until December, when virtually no imagery is available. This can make it challenging or impossible to detect freezeup flooding this way. Luckily, the sites most susceptible to freezeup flooding in the historical record have been in southcentral Alaska, so there is some hope there.

The Geostationary Operational Environmental Satellite-17 (GOES-17) is the latest NOAA geostationary satellite parked in the western half of the United States. Its excellent temporal resolution (10 min) and moderate spatial resolution (500 m) make it an ideal for the western contiguous U.S., but its geostationary position and extreme look angle makes it unusable for Alaska hydrologic applications. Through various partnerships, the APRFC will also sometimes gain access to high-resolution commercial satellite imagery such as Worldview, but the higher value comes from products that can be reviewed on a daily basis.

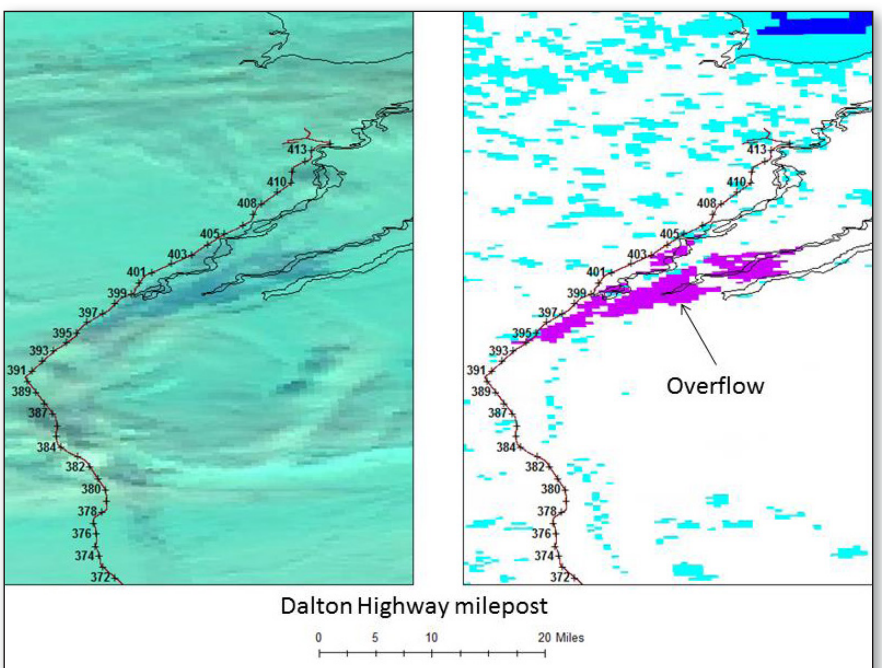


Figure 2. VIIRS RGB (left) and River Ice and Flood product (right) both showing overflow conditions on the Sagavanirktok River in the spring of 2015. Overflow flooding caused millions of dollars of damage and economic hardship when it shut down the only road access to the Prudhoe Bay oil fields (see Alaska Climate Dispatch March-May 2015).

MICROWAVE

In the microwave part of the spectrum, the APRFC has used Synthetic Aperture Radar (SAR) for almost two decades, starting with Radarsat-1 (1995–2013). Because free data from Radarsat-2, which launched in 2007, was denied to the U.S. agencies, use of SAR trailed off until ESA's Sentinel-1 series was launched starting in 2014. These data are conveniently served through several different web portals with various post-processing capabilities. The repeat cycle is 6 days because of the two different platforms, and most data are 20 m resolution. The challenge of SAR has been asking staff to interpret the microwave signals on the fly during forecast shifts. This challenge was addressed by the development of a classification product by scientists at the National Water Center (NWC). Like the VIIRS-derived classification products, this has helped the data become much more valuable (Figure 3). It no longer requires APRFC staff to be SAR analysts because the classified product already designates water as open water, mixed ice/water, and low or high confidence of river ice. Figure 3 shows an example of the NWC Sentinel-1 classification product. In terms of the future outlook for SAR, the NISAR mission will launch in 2022 and provide additional SAR coverage over Alaska.

The other microwave-based products the APRFC looks at are estimates of snow water equivalent (SWE) sitting in the snowpack. NOAA's Microwave Integrated Retrieval System (MIRS) is an umbrella of product generation for a handful of different sensors flying on different platforms. For example, there are separate SWE products generated from the microwave sensors onboard the NOAA (19 and 20), MetOp (Meteorological Operational A and B), DMSP (Defense Meteorological Satellite Program F17 and F18), NPP, and GPM (Global Precipitation Mission) platforms. The SWE products generated from MIRS probably work best in areas of little or no tree canopy and shallow snowpacks (like the North Slope). The microwave signal attenuates and is less accurate in deeper snow and complex tree canopies. There is another microwave-based SWE product from Japan's Advanced Microwave Scanning Radiometer-2 (AMSR-2) sensor that seems to work better. Still, use of these sensors for SWE is highly experimental.

ALTIMETRY

Laser and radar altimetry are new, emerging tools for the APRFC. We are designated end users for a research effort funded by NASA to estimate river discharge from space. Space altimetry was largely developed for the oceanographic community and

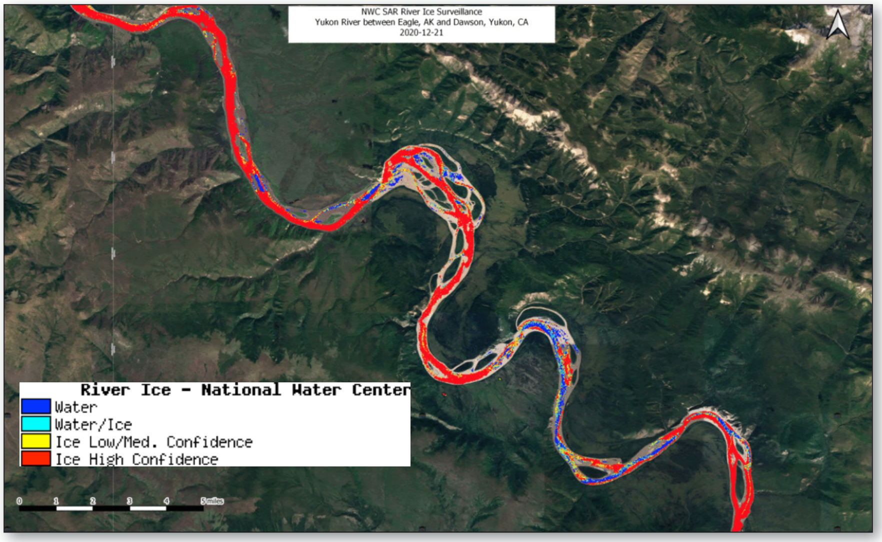


Figure 3. National Water Center processed an image from a Sentinel-1A swath in support of APRFC to classify open water and river ice on the last unfrozen reach of the Yukon River. The Yukon River between Eagle and Forty Mile appears to be almost entirely closed in this December 21, 2020, Sentinel-1A image.

then applied to the study of ice sheets on Greenland and Antarctica. Researchers at USGS and NASA are now using that same technology—with its vertical accuracy of cm—and other remote sensing products like change in surface water extent from optical or microwave products to calculate stage and discharge. Rather than swath-based observations which can be mosaicked together, altimeters have a much narrower observation pathway. Figure 4 shows some of those paths for the Fairbanks area, for several available sensors. The points those paths cross the Tanana River are marked in circles. Exact repeat tracks for altimeters can be upwards of ~90 days in some locations, but the sensor will pass over the same river in different locations with much higher frequency than that.

The launch of the new Surface Water and Ocean Topography (SWOT) mission in 2022 will have a similar focus. Already, we can see that these altimetry approaches may be helpful for identifying the start of a glacial dammed lake outburst, if the timing is just right. Individual altimeters such as Jason-3 have repeat times of 10 days or so, but there are more and more altimetry missions (ICESat-2, SWOT, Sentinel 3, etc.) such that combined coverage will soon be every couple of days in Alaska. In the long term, the APRFC could also benefit from updating glacier states in our models every few years; a combination of altimetric and optical satellite sensors may help estimate changes in mass balance. We know these glaciers are changing fast. The level of effort required to develop these types of products is significant, though, and would require partnerships with researchers and other operational centers.

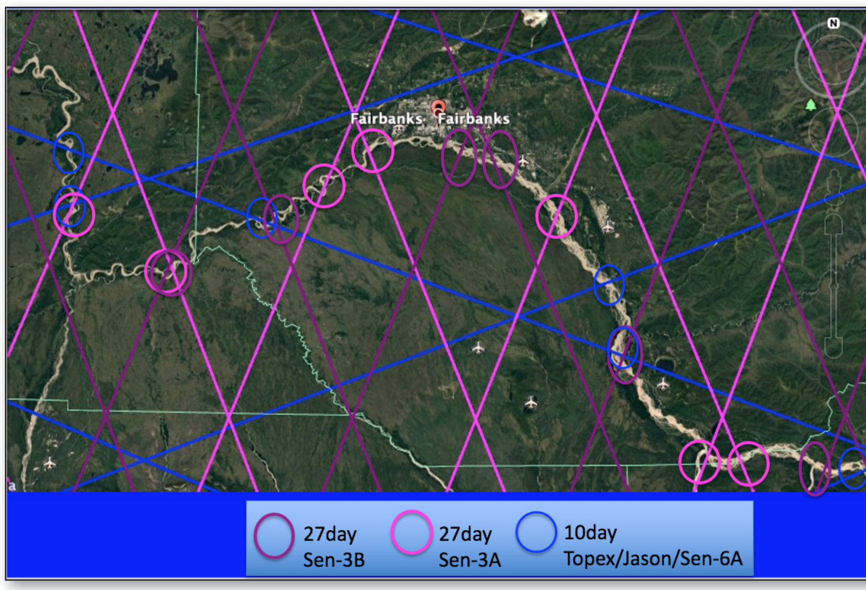


Figure 4. Altimeter coverage on Tanana River near Fairbanks as part of a remotely sensed discharge product in development by partners at USGS and NASA. Repeat times over various points on the river are indicated for existing and future missions. Image provided by product developer Charon Birkett, NASA.

Platform/Sensor	Data Type	Spatial Resolution	Temporal Resolution	Latency
Landsat OLI	Optical	15–30m	16 days	24 hrs
Aqua/Terra MODIS	Optical	250–500m	Daily	1 hr
Sentinel 2a,b	Optical	10m	5 days	24–48 hrs
VIIRS on SNPP, NOAA-20	Optical and NIR	375m	Sub-daily	1 hr
Sentinel 1a,b	Microwave	20m	6 days	24–48 hrs
MIRS various	Microwave	15–35km	Sub-daily	24 hrs

Table 1. Satellite products currently being used by the APRFC for operational hydrology.

SEA ICE: SUMMER AND AUTUMN 2020

by John Walsh and Rick Thoman, Alaska Center for Climate Assessment and Policy, UAF

The Arctic-wide sea ice cover reached its minimum extent for 2020 in mid-September. The September average ice extent, approximately 3.92 million square kilometers, was the second lowest (after 2012) of the post-1979 satellite period of record (Figure 1). The 2020 September extent was about 9% less than the previous (2019) September value of 4.32 million square kilometers and was below the linear trend line plotted in Figure 1. The trend line depicts a loss of about 43% relative to the first few years of the record. A remarkable feature of Figure 1 is that the 14 years with the lowest September sea ice extent are the most recent 14 years, 2007–2020. No year prior to the past 14 years had less sea ice than the year (2014) with the greatest ice extent among the past 14 years.

As shown in Figure 2, open water in the Alaskan sector of the Arctic Ocean was once again extensive in September of 2020, especially in the Chukchi Sea, where the open water area was the largest on record. On the other hand, an area of sea ice persisted through the summer in the Beaufort Sea, where the open water area was less extensive than in 2019. This asymmetry between the Beaufort and Chukchi seas was consistent with the earlier freeze-up in the Beaufort relative to the Chukchi Sea (see below). Figure 2 also shows that the Northern Sea Route offshore of Russia was even more open than in 2019, but that some ice remained in the various straits comprising the Northwest Passage in the Canadian Archipelago. The extreme retreat of sea ice offshore of Russia followed an unusually warm spring and summer in the Siberian region, where record high temperatures were reached during several periods within the ice melt season. On the Atlantic side of the Arctic, there was actually more sea ice east of Greenland than in mid-September of 2019, although the ice edge was farther north of Svalbard in 2020 than in 2019.

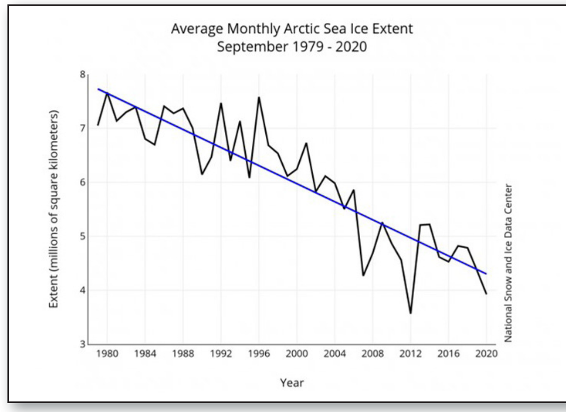
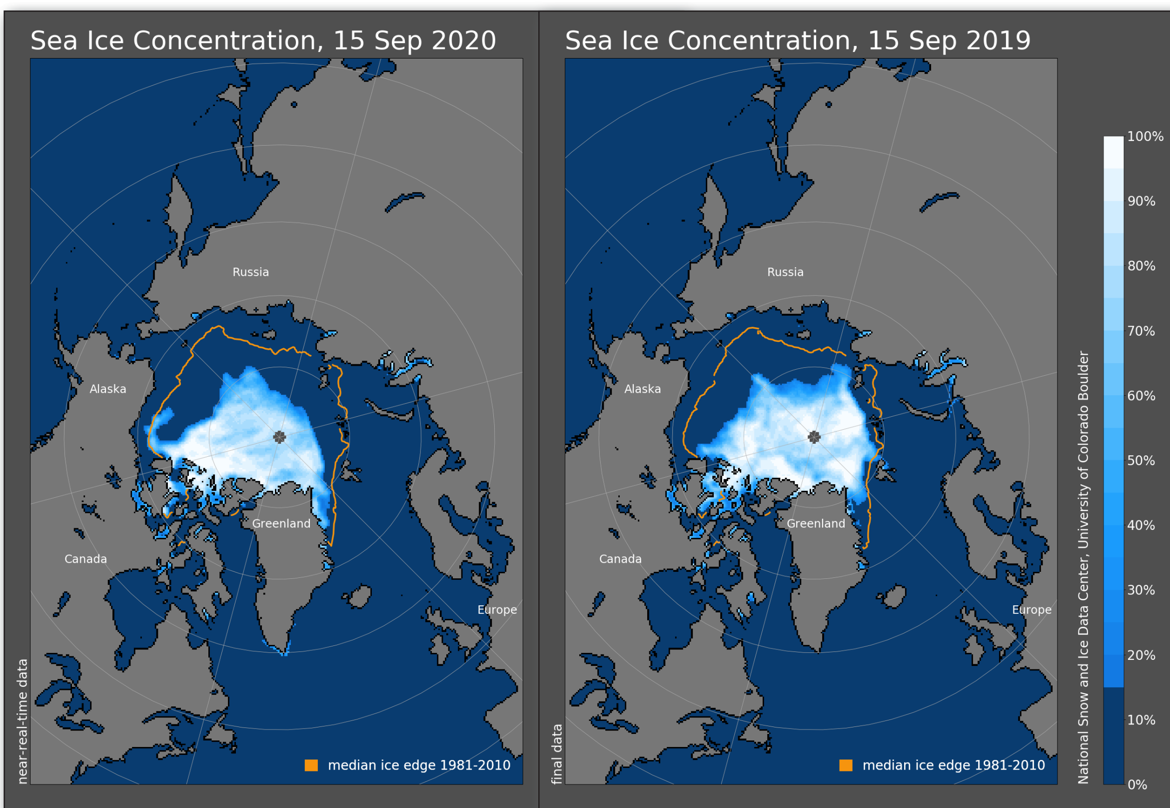


Figure 1. Average monthly sea ice extent for September, 1979–2020. Source: National Snow and Ice Data Center, http://nsidc.org/arcticseaicenews/2020/10/.

Figure 2. Sea ice concentrations on September 15 of 2020 (left panel) and 2019 (right panel). As shown by color scale to right of each panel, concentrations range from 0% (deep blue) to 100% (bright white). Orange lines are median positions of the ice edge for the 1981–2010 reference period. Source: National Snow and Ice Data Center, ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/north/daily/images/.



The extreme warmth of the Arctic Ocean during spring and summer of 2020 is apparent in Figure 3, which shows the ranks of the each month's air temperatures averaged over 70–90°N. According to this metric, 2020 was the warmest of the 1979–2020 period in May, July, and August. June was the second warmest, September the third warmest, and April the sixth warmest on record. The remarkable warmth in the earlier portion (April–June) of the melt season undoubtedly contributed to the early and extensive loss of sea ice during these months, while the warmth of the later months (July–September) was likely enhanced by the absence of sea ice in parts of the Arctic Ocean that have historically been ice-covered. In this respect, the evolution of the Arctic's sea ice and temperatures during 2020 are a manifestation of the temperature-albedo feedback that is a key process in the Arctic Amplification of global temperature variations.

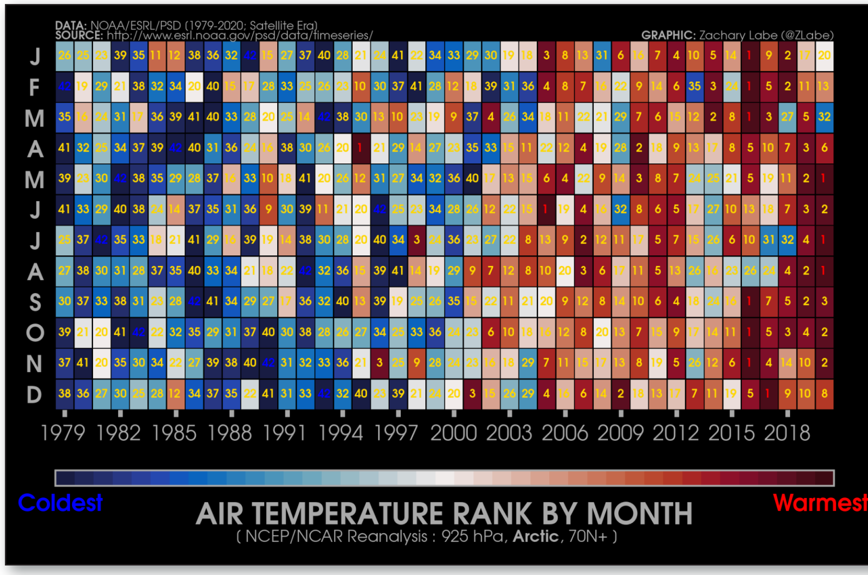


Figure 3. Monthly ranks of Arctic air temperature from 1979–2020 averaged over 70–90°N. Dark reds indicate warmest months (ranks 1, 2, …); dark blues indicate coldest months (ranks …40, 41, 42). Temperatures are for 925 hPa (500–1000 m above the surface) and are from the NCEP/NCAR reanalysis. Source: Zack Labe, Colorado State University.

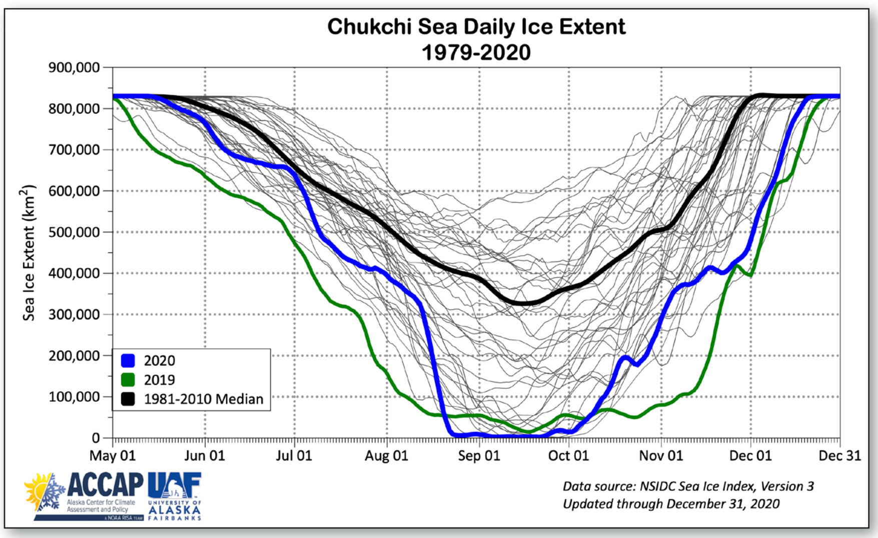


Figure 4. Daily sea ice extent in the Chukchi Sea during each year, 1979–2020. The most recent years are highlighted in color, with 2019 in green and 2020 in blue. Thick black line is the median of the extents for 1981–2010. Source: Rick Thoman, ACCAP.

In the Alaskan sector of the Arctic, sea ice extent in the Chukchi Sea was at a record low from late August through early October (Figure 4). Outside of this late-summer time window, the Chukchi Sea's ice extent exceeded that of 2019, although it still was among the lowest several years of the 1979–2020 period for much of the spring and autumn. The extreme low extents of the past two summers contrast with the median extent for the 1981–2010 period (black line in Figure 4), which remained above 300,000 square kilometers throughout the melt season. For perspective on the recent years' departures from the 1981–2010 median ice extent during the late summer, only 5 of the 50 states in the U.S. have areas larger than 300,000 square kilometers.

The extremely large area of open ocean north of Alaska allowed for the warming of the surface water by the absorption of solar radiation during the summer and early autumn. Sea surface temperatures in parts of the Chukchi Sea were more than 5°F warmer than normal during the late summer. The storage and gradual release of this heat delayed the autumn freeze-up, resulting in the persistence of open water far longer than was typical of the past. Figure 4 shows that much of the Chukchi Sea remained open even into December, although coastal ice had begun to form along the shores of the Chukchi and Bering seas.

Finally, Figure 5 shows the progression of the sea ice freeze-up into the Bering Sea during 2020 in comparison with 2019. Consistent with a generally earlier freeze-up of the Chukchi Sea in 2020 compared to 2019, there was more sea ice south of Bering Strait in mid-December of 2020 than in 2019. The greater ice coverage was especially apparent along the southwest coast, where the coastal ice extended as far south as Bristol Bay. However, the freeze-up is still later than the historical averages. Consequently, Bering Sea ice is younger and thinner than in the past, making it vulnerable to storm activity. Storminess will be a key to the evolution of the Bering ice extent over the remainder of the 2020–21 winter.

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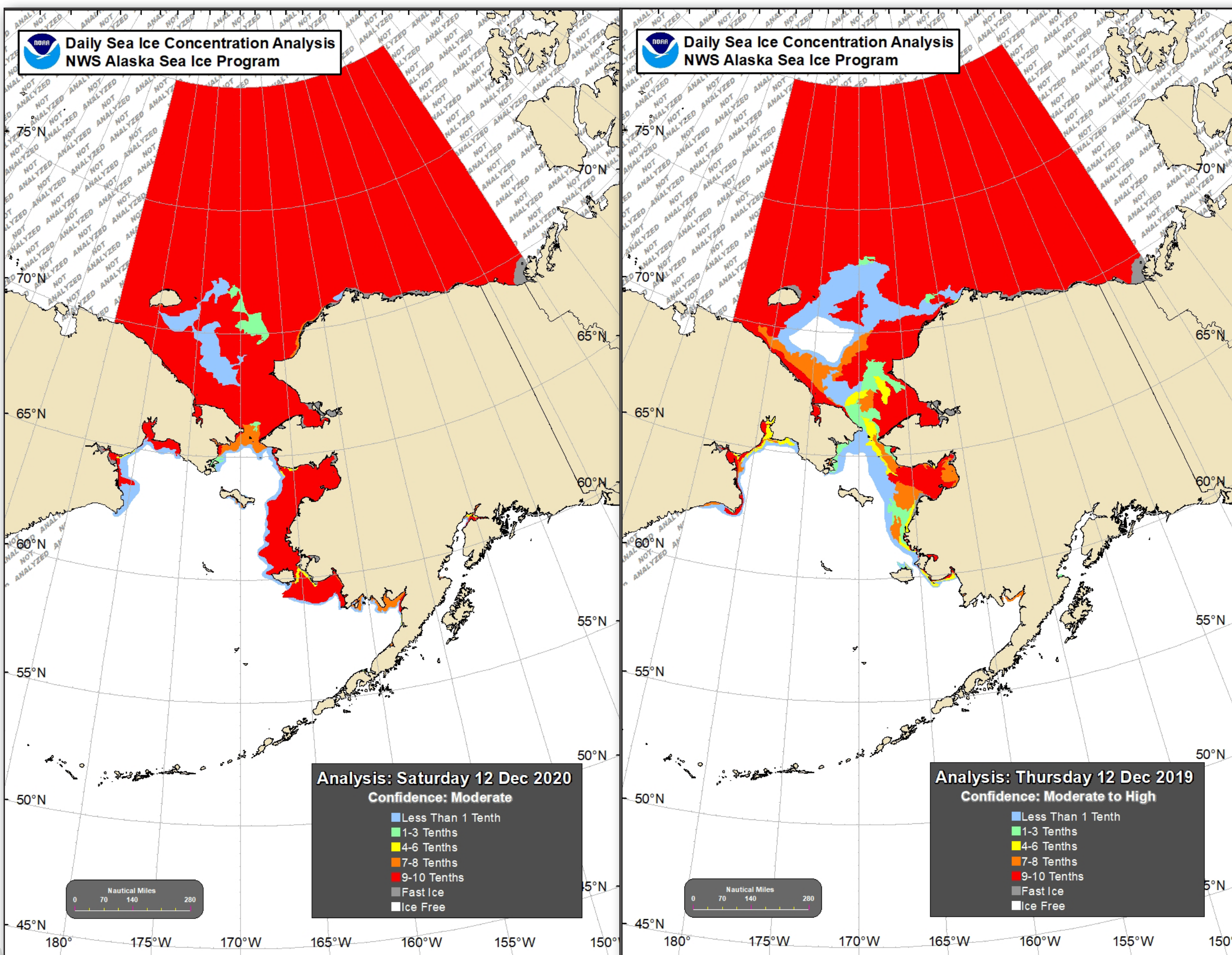
https://www.frames.gov/afsc/alaskas-changing-wildfire-environment

Figure 5. Sea ice coverage on December 12, 2020 (left), and December 12, 2019 (right). As indicated by legend, red denotes essentially complete ice coverage, while gray areas have low concentrations. Source: NWS Alaska Region Sea Ice Program.



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