Adapting to Climate Change in the Middle Kuskokwim:

A Collaborative Effort by the Communities of Lower Kalskag, Upper Kalskag, Aniak, Chuathbaluk, Napaimute, Crooked Creek, Georgetown, Red Devil, Sleetmute, and Stony River

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Boats on Stony River.
Photo by Elizabeth Willis

Table of Contents

Introduction

In 2018, the Georgetown Tribal Council received a Bureau of Indian Affairs Tribal Resiliency Program Grant to create a climate vulnerability assessment and adaptation plan for the Middle Kuskokwim region. The Alaska Native Tribal Health Consortium (ANTHC) was contracted to facilitate the climate change adaptation planning process, and develop the final climate change vulnerability assessment and adaptation plan in collaboration with the communities of Lower Kalskag, Upper Kalskag, Aniak, Chuathbaluk, Napaimute, Crooked Creek, Georgetown, Red Devil, Sleetmute, and Stony River.

The observations of environmental change in the Middle Kuskokwim are the foundation of the adaptation strategies outlined in the Middle Kuskokwim Climate Change Adaptation Plan. Middle Kuskokwim residents prioritized the types of environmental change that need to be addressed, and developed five adaption priority areas with associated goals. The Middle Kuskokwim adaptation goals focus on maintaining cultural traditions, ensuring the health and safety of the residents, and continuing a tradition of stewardship toward the land and animals in the region.

The following document includes the climate change vulnerability assessment, and the priority areas for adaptation that were identified by Middle Kuskokwim residents. The vulnerability assessment describes changes to the air, water, land, plants, animals, and people, all inextricably connected. The assessment is based on the observations and comments from the people whose relationship with the lands extend back to time immemorial. Additional information has been integrated from the Alaska Climate Adaptation Science Center, other available agency reports, and observations posted to the Local Environmental Observer (LEO) Network.

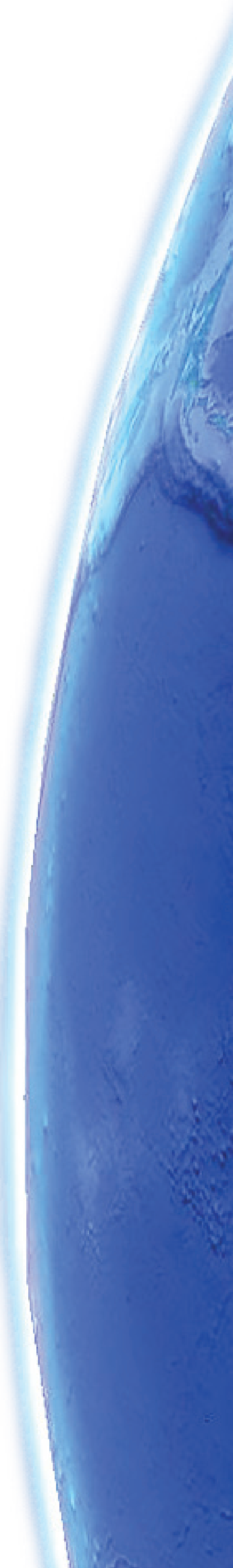
Kuskokwim River summer and winter
Photos by Harvey Hoffman

Fireweed
Photo by Patty Yaska

Region

The Kuskokwim River flows southwest for 540 miles, from the headwaters in the Alaska Range and Kuskokwim Mountains, and drains in to the Bering Sea. As the river moves, it is fed by swift glacial rivers draining from the Alaska Range and clear streams from the Kuskokwim Mountains. The Kuskokwim River basin encompasses 50,000 square miles, and transitions from a mountainous landscape in the east, becoming dotted and streaked by innumerable lakes, streams, and sloughs in the western flats (Brown, 1985). Below the surface of the ground, the Middle Kuskokwim region is mineral rich. The quicksilver mineral cinnabar, along with gold and tungsten, are abundant. These deposits have drawn explorers and miners to the region, shaping the history of Middle Kuskokwim since the early 1900s. Deposits of copper, antimony, silver, tin, and molybdenum also occur, although these have not been commercially mined (Cady et al., 1955).

The vegetation changes based on the moisture content of the soil (United States Forest Service). Higher elevations are dominated by white spruce and birch trees, thickets of willow and alder, and ferns, mosses, and lichens in the undergrowth. Moose, caribou, black bears, and wolverines roam the uplands, while small mammals such as beaver, fox, marten, muskrat, land otter, lynx, weasel, and hare can be found across the region. Farther down river, spruce and birch trees thin and are confined to the riverbanks, interspersed by willow and alders. Nearing the Yukon-Kuskokwim Delta, the soil is moisture heavy and lies above discontinuous, but widespread permafrost. In these poorly drained areas, grasses, sedges, mosses, lichens, scrub willow and alder dominate (Brown, 1985). Migratory waterfowl pass through the delta annually, feeding on the abundant blackfish, whitefish, sheefish, rainbow trout, Arctic char, and Dolly Varden as they travel. All five species of salmon migrate up the Kuskokwim to meet subsistence fishers in each community along the way.




Fairbanks
Anchorage
Middle Kuskokwim
Crooked Creek
Georgetown
Red Devil
Sleetmute
Stony River
Aniak
Upper Kalsag
Lower Kalsag
Chuathbaluk
Napaimute
©Google Earth
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Communities

The Kuskokwim region is often geographically broken in to three sub-regions imposed on Yup'ik and Athabascan traditional homelands. The Lower Kuskokwim region includes the present day communities of Kwethluk, Napaskiak, Napakiak, Kasigluk, Oscarville, Nunapitchuk, Tuntutuliak, Tuluksak, Atmauthluak, Akiak, Akiachak, and Eek. The Middle Kuskokwim communities of Lower Kalskag, Upper Kalskag, Aniak, Chuathbaluk, Napaimute, Crooked Creek, Georgetown, Sleetmute, Stony River and Red Devil. The Upper Kuskokwim includes the communities of Takotna, McGrath, Medfra, and Nikolai.

The 10 Middle Kuskokwim communities are home to over 1,400 people who actively hunt, fish, and gather traditional foods. Each community has a different combination of infrastructure, economies, and services that work together to meet the needs of residents.

In the Middle Kuskokwim, there are no roads. Communities are connected primarily by the air and by river during the summer, and by the ice road and marked snowmachine trails in the winter. When the Kuskokwim River freezes during winter, village transportation crews work together to monitor ice conditions, plow and maintain the road, and mark open water. During the winter of 2017-2018, the ice road extended 250 miles from Kasigluk to Bethel to Crooked Creek. The ice road provides a much more affordable travel option, allowing people to get together for community events, sports, meals, and shopping (DeMarban, 2019).

"No one is just from one village anymore. We move around, our parents were semi-nomadic and we share the same histories." *—Jonathan Samuelson, Georgetown and Red Devil*

Ayumqerryaraq – Lower Kalskag

Central Yup'ik

A distance of 95 river miles from Bethel, Lower Kalskag and Upper Kalskag sit on the north bank of the Kuskokwim River. Prior to European settlement, the area of the Kalskag communities was used as a Yup'ik seasonal fish camp called Kessiglik. Kalskag began as one community, but exists today as two communities connected by a 4-mile dirt road. Residents share many of the same resources, but each community maintains their own separate governing entities.

The City of Lower Kalskag became incorporated in 1969, following the construction of St. Seraphim Russian Orthodox Chapel in 1940, a school built in 1959, a post office in 1962, a sawmill in 1965, and a power plant in 1969. Lower Kalskag is co-governed by the City and the Village of Lower Kalskag, and is currently home to approximately 275 residents ((e) Alaska Community Database Online). Most homes, the school, and the clinic have either piped water and sewer utilizing a community well, or individual septic systems. Electricity is provided by the Alaska Village Electric Cooperative. Healthcare is available at the Crimet Phillips Sr. Clinic ((e) Alaska Community Database Online).

Kessigliq – Upper Kalskag

Central Yup'ik

Upper Kalskag was first settled in 1898 by the Kameroff family. The community grew in 1932 with the construction of a BIA government school that drew in surrounding residents. Soon after, a general store, post office, barge company, and a reindeer herding practice followed. In the 1930's, Russian Orthodox residents of Kalskag left the predominantly Roman Catholic community, and constructed residences in what is now Lower Kalskag. Today, Upper Kalskag is co-governed by the City and Village of Kalskag, and is home to 227 residents ((j) Alaska Community Database Online).

In Upper Kalskag, a piped gravity sewage system serves over 60 households and facilities, augmenting the individual well and septic systems that were established for most homes in 1997 (The Kuskokwim Corporation). Upper Kalskag receives electricity from the Alaska Village Electric Cooperative. Healthcare is available at the Catherine Alexie Health Clinic (The Kuskokwim Corporation). Delivery services are provided by barge and airplane. During the summer, fuel and supplies arrive on the barge. Daily air service, utilizing a state-owned airstrip, transports additional goods, people, and the mail. Additional trails are marked in the winter, directing people to Aniak and Russian Mission ((j) Alaska Community Database Online).

Historic photo provided by Dan Gillikin

Anyaraq – Aniak

Central Yup'ik: "The Place Where it Comes Out"
(referring to the mouth of the Aniak River)

Aniak is on the south bank of the Kuskokwim River, 25 river miles from Kalskag. In 1832, Russian fur traders built Lukeen's Fort at the confluence of the Kuskokwim and Aniak rivers. It was destroyed, and replaced by Kolmakof's Redoubt a few miles downriver from Sleetmute (Cady et al., 1955) where a mercury deposit was discovered (Kurtak et al., 2010). In 1908, gold was discovered, and later silver, copper, and other minerals (The Kuskokwim Corporation, Cady et al., 1955). A store and post office opened in 1914, a territorial school in 1936, and an airstrip was built in 1939. At one point in history, Yup'ik families left the Aniak area, but returned when Willie Pete and Sam Simeon returned with their families (The Kuskokwim Corporation). The gold rush brought additional prospectors, new infrastructure, and an increased population. Aniak is co-governed by the City of Aniak, which was incorporated in 1972, and the Aniak Traditional Council.

Aniak is the largest community in the Middle Kuskokwim, home to 485 residents ((a) Alaska Community Database Online), and serves as the regional hub, offering groceries from three stores and a sub-regional clinic.

The majority of homes receive water from either individual wells, or a more recently constructed central well, and are served by piped sewer. Although some homes still have individual septic, drainage is a problem because of underlying permafrost. Plans are in place to transition all homes to piped sewer. Electricity is provided by privately-owned Aniak Light and Power. The Clara Morgan Sub-Regional Clinic provides a wide range of physical, mental, and emergency health care services (The Kuskokwim Corporation). The barge arrives in the summer with goods, but transportation and cargo is also available through air service. A state-owned, lighted, asphalt runway is able to accommodate larger commercial and charter planes.

Aniak
Photo by Harvey Hoffman

Curarpalek – Chuathbaluk

Central Yup'ik: "Hills where Big Blueberries Grow" or "Provided with Big Blueberries"

On the north bank of the river, 11 river miles from Aniak and with the Kilbuck-Kuskokwim Mountains in view, is Chuathbaluk. The area was long used by Deg Xit'an people as a fish camp. In 1894, the St. Sergius Mission was built by the Russian Orthodox Church, and residents from the downriver community of Kukuktuk took up residence there. After an influenza epidemic in 1900, the site was deserted, except for the services that were still held at the mission. Residents from Crow Village, Aniak and Crooked Creek moved to Chuathbaluk in the early 1950's after the church was rebuilt. In the 1960's a state school opened, and the City became incorporated in 1975, now co-governing the community with Chuathbaluk Traditional Council (The Kuskokwim Corporation).

Approximately 111 people live in Chuathbaluk ((b) Alaska Community Database Online). Homes in Chuathbaluk receive piped water from a community well, and electricity is provided by the Middle Kuskokwim Electric Cooperative. North of the community is a state-owned airstrip that provides scheduled air service year round, supplemented by winter travel on the ice road after the river freezes ((b) Alaska Community Database Online).

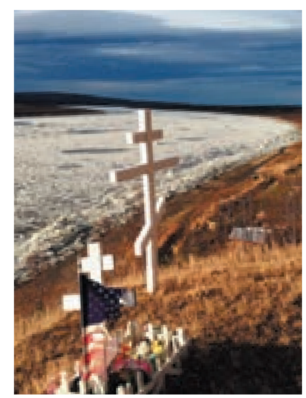
Kuskokwim River
Photo by Patty Yaska

Blueberries
Photo by Elizabeth Willis

Napaimute

Central Yup'ik: "Spruce Tree Village" or "Forest People"

Moving 20 river miles up the Kuskokwim from Chuathbaluk, Napaimute sits on the north bank of the river. At one time, the area of Napaimute was called "Hoffman's," after George Hoffman who established a trading post in 1906. The population established around the trading post grew. Two schools were constructed between 1920 and 1926, but by the early 1950's, many residents had moved elsewhere as mining, fur, and reindeer herding declined. Despite the out-migration, Napaimute holds significant importance as an ancestral home for many people. In 1994, the Native Village of Napaimute (NVN) received federal recognition as one of Alaska's Native Tribes. Over the years, tribal membership has grown, as have efforts to revitalize the community. Although there is currently one year-round resident, the Napaimute Traditional Council has begun to build community infrastructure, including a council-owned airstrip, community building, tribal office, and rental cabins. NVN also provides fuel service, runs a small store, and operates a sawmill (Native Village of Napaimute). In the summer, mail and supplies are delivered by barge ((f) Alaska Community Database Online).

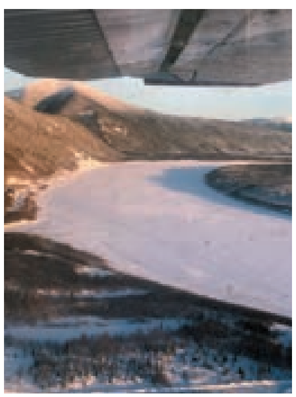


Freeze up, Napiamute
Photo by Dan Gillikin

Qipcarpak - Crooked Creek

Central Yup'ik

Around several bends in the river, Crooked Creek appears on the north bank of the river, 35 river miles from Napimute. The area has been known as "Kvikchagpak," Yup'ik for "great bend," and as "Khottylno," Deg Xinag for "sharp turn." Historically used as a fish camp by residents of Kwigiumpainukamuit, permanent infrastructure was built to service the Flat and Iditarod mining camps, an industry which continued to influence life in the village until the 1980s. In 1914, a trading post built by Denis Parent established the "upper village," some distance away from homes in the "lower village." Those area distinctions are still used today. The community is governed solely by the Native Village of Crooked Creek, as there is no incorporated city. The 94 residents of Crooked Creek ((d) Alaska Community Database Online) haul water from a central well and washeteria, although the school and store have individual wells. Electricity is provided by the Middle Kuskokwim Electric Cooperative (The Kuskokwim Corporation). Health care is available at the Crooked Creek Health Clinic. Air service is provided during the weekdays utilizing a state-owned airstrip, and cargo is delivered by barge and skiff in the summer ((d) Alaska Community Database Online).



Crooked Creek
Photo by Rebecca Wilmarth

Georgetown

Following the Kuskokwim upriver from Crooked Creek as it bends to the southeast, is Georgetown. Prior to the discovery of gold in 1909, the area was known as Keledzhichagat and was used as a fish camp by the residents of nearby Kwigiumpainukamiut. The community of Georgetown was named after three traders, George Hoffman, George Fredericks, and George Morgon, who established a community of 300 prospectors near the confluence of the Kuskokwim and George rivers. In 1911, a fire destroyed the majority of structures. The community relocated to the east side of the George River, and a school was constructed in 1965, but only operated for five years as the mining industry declined ((a) Koopman, 2017, (d) Alaska Community Database Online).

Georgetown Tribal Council (GTC) maintains good working relationships with the neighboring communities, and is in the process of planning a new settlement on the south bank of the Kuskokwim. There are no permanent residents currently living in Georgetown, however GTC envisions a future with homes, seasonal cabins, and a community center that will provide space for people to gather and engage in traditional and subsistence activities. Georgetown community leadership is young, and energetic, actively utilizing knowledge from Georgetown Elders to help plan for the future.

Georgetown
Photo by Rebecca Wilmarth

Red Devil

Named after the Red Devil Mine, operating from 1921-1971

Sixteen miles southwest of Georgetown, Red Devil spans both banks of the Kuskokwim River. In 1921, mercury was discovered in the Kilbuck-Kuskokwim Mountains, and by 1933 the Red Devil Mine was in full operation. In 1957, a post office opened, followed by a school in 1958. After the mine closed operations in 1971, residence in the community declined and the school was closed in 2009. The 16 current residents ((g) Alaska Community Database Online) are working to revive the Red Devil tribal council and develop a city government that could provide access to funds for additional community development.

Four homes in Red Devil are fully plumbed and connected to individual wells, while residents of the remaining 13 homes haul water from the still-accessible school well. Electricity is provided by the Middle Kuskokwim Electric Cooperative. A state-owned airstrip is still maintained by community members. There is currently no clinic in Red Devil, but community members hope to purchase the school building from the state, and open a community center and clinic (Shallenberger, 2019).

Red Devil
Photo by Kattie Wilmarth

Cellitemiut – Sleetmute

Central Yup'ik: "Whetstone Village" or "Whetstone People"

On the east bank of the river, 20 river miles upriver from Red Devil is the community of Sleetmute. Prior to Russian exploration, the community was originally established by Deg Xit'an people. In 1906, a trading post was built, followed by a school in 1921 and a post office in 1923. There is no city government, and the community of 86 residents ((h) Alaska Community Database Online) is governed by the Sleetmute Traditional Council (The Kuskokwim Corporation).

Water is provided to each house by a hand-pumped gravity storage tank, connected to either the central well, or individual household wells. Electricity is provided by the Middle Kuskokwim Electric Cooperative, and health care is available at the Sleemute Clinic (The Kuskokwim Corporation). Barges deliver goods and provide transportation in the summer, along with air service utilizing a state-owned airstrip.

Gidighuyghatno' Xidochagg Qay - Stony River

Deg Xinag

An additional 20 river miles up the Kuskokwim River, the community of Stony River sits on an island that borders the north bank. Stony River was originally the site of a trading post until the 1960's, when construction of a school drew families from the surrounding area. Stony River is unincorporated, and governance for the 42 residents ((I) Alaska Community Database Online) is provided by the Village of Stony River (The Kuskokwim Corporation). There are regular community-wide activities for litter prevention, yard clean up, and road maintenance that bring the community together and improves community health.

Homes are not plumbed in Stony River, but water is provided by individual household wells and a washeteria. Electricity is provided by the Middle Kuskokwim Electric Cooperative and health care is provided by the Stony River Clinic (The Kuskokwim Corporation). Weekday air service is provided using a state-owned airstrip, and the barge delivers cargo and fuel during the summer ((I) Alaska Community Database Online).

Stony River council building with new roof.
Photo by Elizabeth Willis

Changing Climate

Climate Summary Points:

- Annual temperatures are projected to rise between 5.8° F and 8° F depending on the time frame and emissions scenario.
- Winter temperatures are projected to rise between 4° F and 12° F depending on the time frame and emissions scenario.
- Average annual precipitation is expected to increase, and the increase is expected to be larger than historical variability in all seasons.
- During the winter, the majority of precipitation will still fall as snow rather than rain. However, closer to the coast, snow will fall later in the year and melt earlier.

"We had early break-up, early melts, more rain than last few summers, few bumble bees, early ducks and geese, and more dandelions."

—Barbara Askoak, Lower Kalskag.
LEO Network Post, 2016

The climate of western Alaska is considered transitional, influenced by both maritime and continental characteristics. Maritime climate in Alaska is influenced by the Bering Sea, and the fluctuation of sea ice coverage. Continental climate is influenced less by the ocean, and more by the geographic features affecting storm tracks. For the Middle Kuskokwim, these influences have historically led to long, cold, winters and shorter summers.

Average annual temperatures in the Middle Kuskokwim are changing, becoming warmer. Average annual temperatures in the period before rapid warming (calculated between 1961 and 1990) range from 23-28.4 degrees Fahrenheit. In the summer, temperatures have historically ranged from 46.4 – 51.8 degrees Fahrenheit, transitioning to -4-4.1 degrees Fahrenheit in the winter ((b) Koopman, 2017). Between 1970 and 2019, the average temperature rose 1 degree per decade. During 2017 and 2019, the average annual temperate was above freezing for the first time on record (Markon et al., 2018). Average annual precipitation in the Middle Kuskokwim (calculated between 1961 and 1990) ranges between 14.6 and 16.5 inches. The majority of precipitation occurs from May to September, when an average of 9.4 and 12.1 inches falls. In the winter months, an average of 3.5-5 inches of precipitation falls as snow ((b) Koopman, 2017).

Fire, Stony River
Photo by Elizabeth Willis

Residents of the Middle Kuskokwim communities are already observing the impacts of a warming climate. The weather changes more quickly than it has in the past, and is challenging to predict, but overall, residents agree that annual temperatures are rising. Temperatures are warmer during every season, making the winters warm and the summer hot. During warm winters, snow will fall as rain and it takes longer for adequate snow cover to form. Warm winters require less wood for home heating, but when conditions are colder, changing ice and snow conditions make it difficult for people to travel to gather firewood. More precipitation is falling as rain on top of the snow, causing widespread ice. After a winter with low snow, the water levels in the river are observed to be lower, especially when the spring, summer, and fall months are warmer than usual.

Child drives through snow melt February 2019, Aniak.
Photo by Dave Cannon

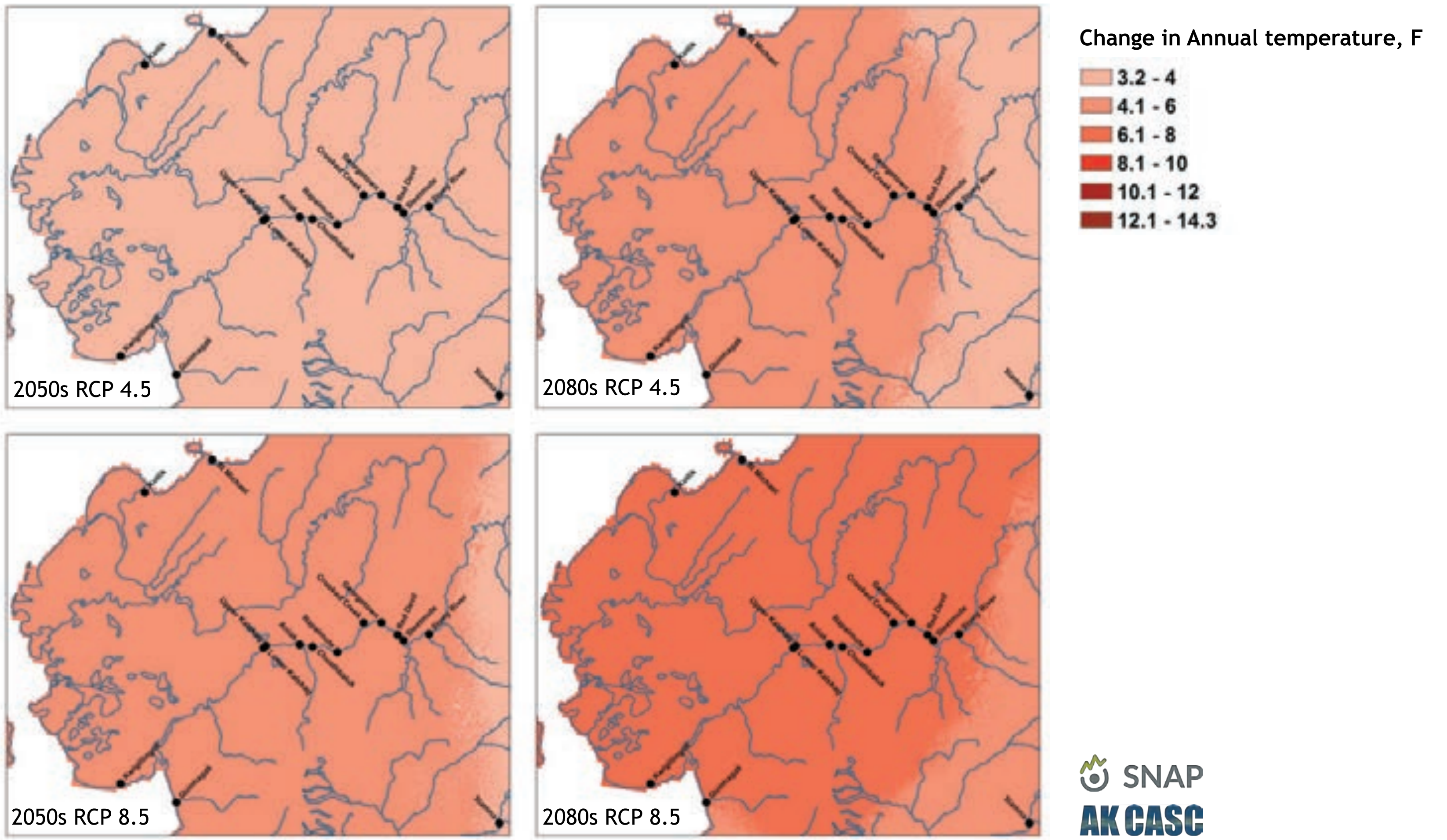
Projections for temperature and precipitation, and all following climate projections, were created by the Scenarios Network for Arctic and Alaska Planning (SNAP) and provided with interpretations by the Alaska Climate Adaptation Science Center. These projections are dependent on future emissions scenarios called Representative Concentration Pathways (RCPs). These scenarios demonstrate what the future climate may look like if emissions of carbon dioxide and other greenhouse gases were reduced (lower emissions scenario) on a global scale and result in less warming (RCP 4.5), and the current emissions scenario resulting in more warming (RCP 8.5 or higher emissions scenario).

In Alaska, five models that combine historical weather data and future global climate are used to estimate local future temperature and precipitation. The information in this report is an average of those five models. These models are compared to averages calculated between 1970 and 1999 and are represented in degrees Fahrenheit (shown as °F).

River willows
Photo by Mary Peltola

Under a lower emissions scenario (RCP 4.5), annual temperatures are projected to rise between 3.2 and 4° F above average between 2040 and 2069. Between 2070 and 2099, annual temperatures are projected to rise 4-6° F. Under a high emissions scenario (RCP 8.5), annual temperatures are projected to rise between 4.1 and 6°F above average during the years 2040 to 2069. Between 2070 and 2099, annual temperatures are projected to rise between 6.1-8°F.

Figure 1: Change in Annual Average Temperature over the Yukon-Kuskokwim Delta

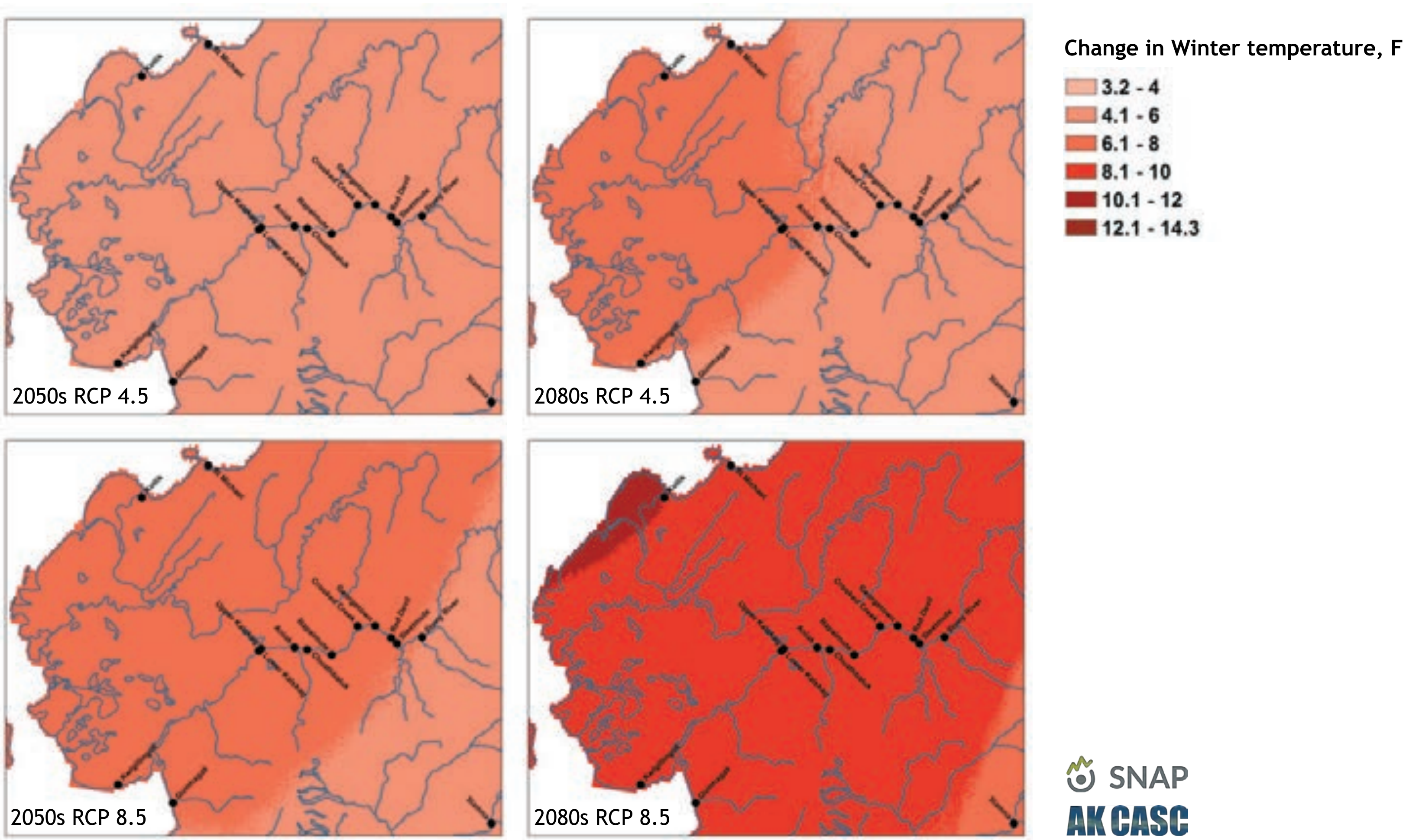


SNAP
AK CASC

Walsh et al., 2018

Winter temperatures will warm more drastically than summer temperatures. Under a lower emissions scenario (RCP 4.5), winter temperatures are projected to rise between 4-6° F above average between 2040 and 2069. Closer to the coast, winter temperatures are expected to rise 6.1-8° F during the years 2070-2099. Under a high emissions scenario (RCP 8.5), winter temperatures are projected to rise between 6.1 and 8°F above average during the years 2040 to 2069. Between 2070 and 2099, winter temperatures are projected to rise between 8.1 and 12°F.

Figure 2: Change in Winter Average Temperature over the Yukon-Kuskokwim Delta



SNAP
AK CASC

Walsh et al., 2018

The ice road is an important link between communities that provides a more cost effective method of travel compared to flying. Warmer temperatures make travel on the ice road dangerous during the winter. Ice conditions are becoming unpredictable, and in places are forming as "needle ice" or thawing and refreezing in ways that appear safe but are not. In recent years, residents have noticed that the lower river near the coast has broken up earlier.

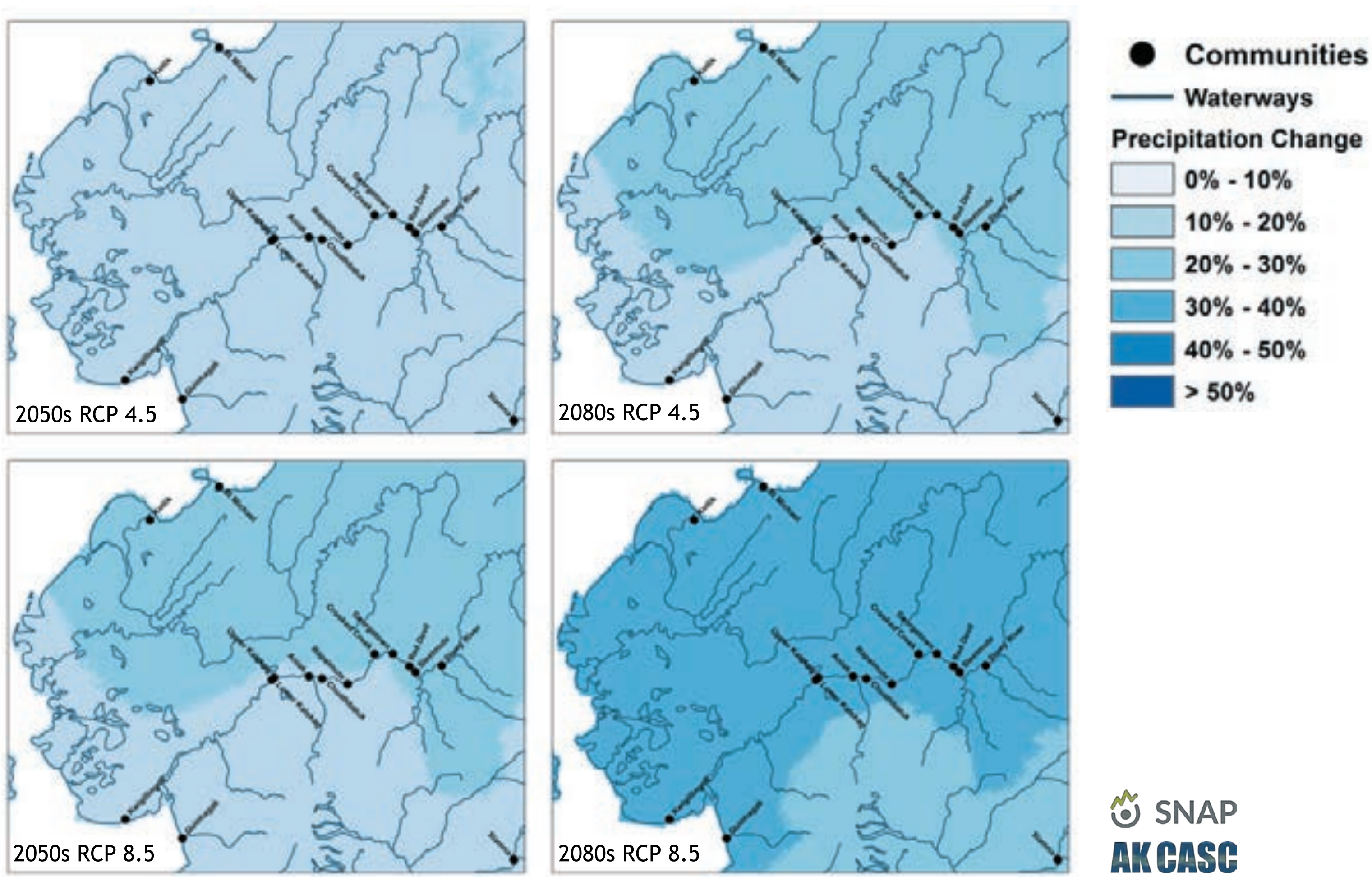
Ice road, overland trail
Photo courtesy of the Native Village of Napaimute

Ice road, ice monitor
Photo courtesy of the Native Village of Napaimute

Overland ice road
Photo courtesy of the Native Village of Napaimute

Overall, annual precipitation is expected to increase in the region. However, each year is different and there will be some years with wetter summers, and some with drier summers. A modest increase in precipitation, combined with a greater increase in temperature, will likely leave less water in the soil and lead to drier conditions.

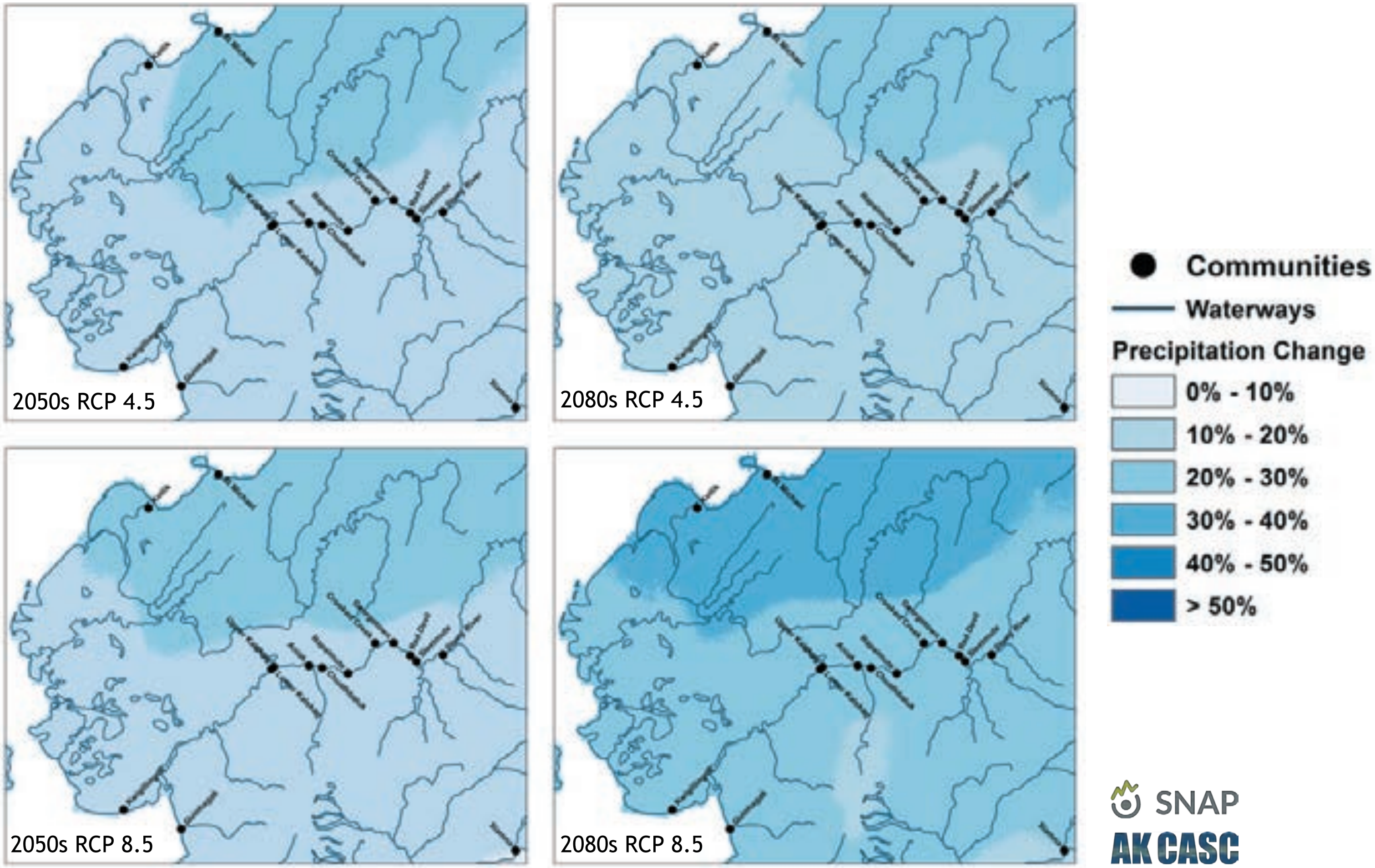
Figure 3: Change in Average Precipitation over the Yukon-Kuskokwim Delta



Walsh et al., 2018

Under a low emissions scenario, annual precipitation is projected to increase by 10%-20% during the years 2040-2069 and increase 20%-30% between 2070 and 2099. Under a higher emissions scenario, precipitation is projected to increase by 20%-30% between 2040 and 2069 and by 30%-40% between 2070 and 2099.

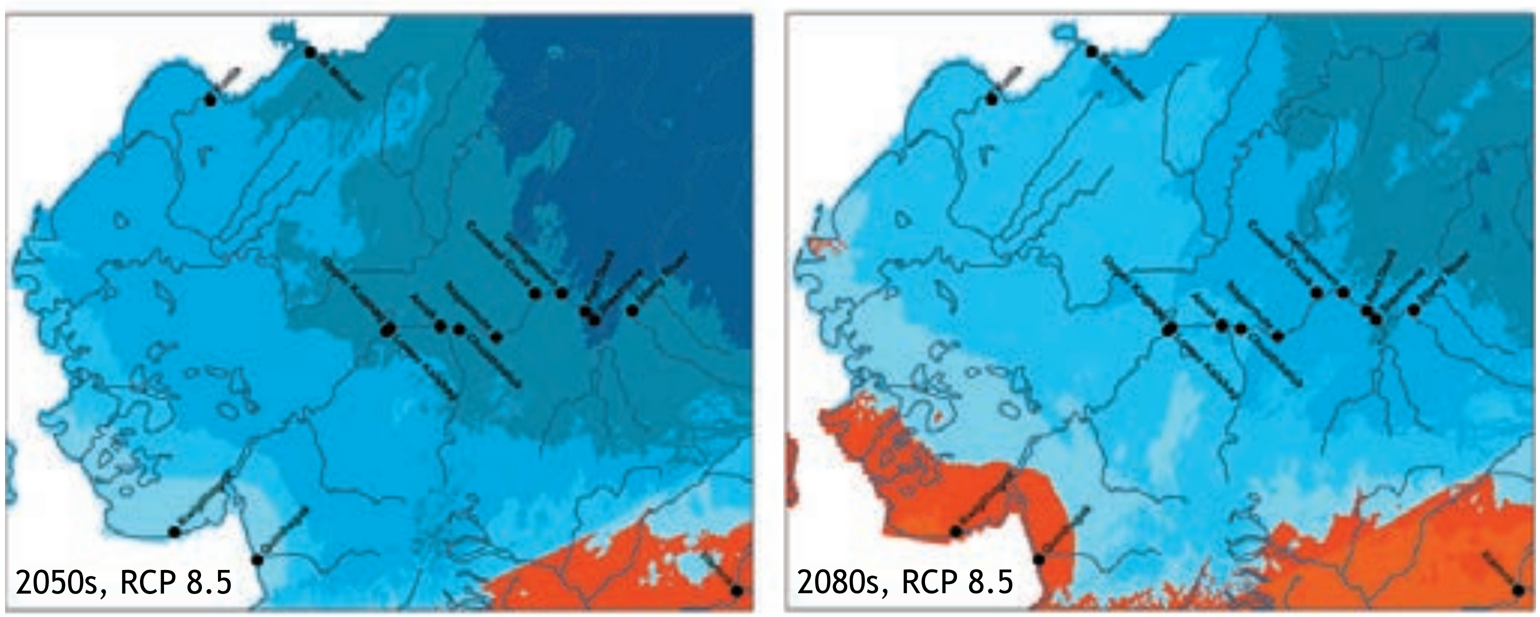
Figure 4: Change in Summer Average Precipitation over the Yukon-Kuskokwim Delta



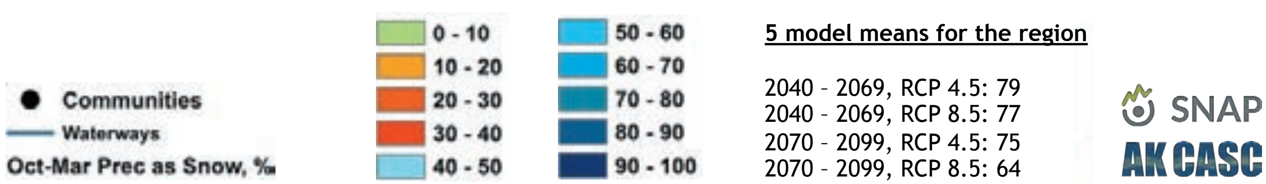
Walsh et al., 2018

Despite changing temperatures, runoff in the Middle Kuskokwim watershed is expected to still be dominated by snowmelt rather than rain. However, the amount of precipitation that falls as snow during October to March is expected to decrease. Snow cover is expected later in the year, and is expected to melt earlier. Between 2040 and 2099 in both emissions scenarios, the coastal areas south of the Middle Kuskokwim are expected to see more rain during the winter months, and are projected to experience longer snow-free periods.

Figure 5: Change in Snow Dominance over the Yukon-Kuskokwim Delta

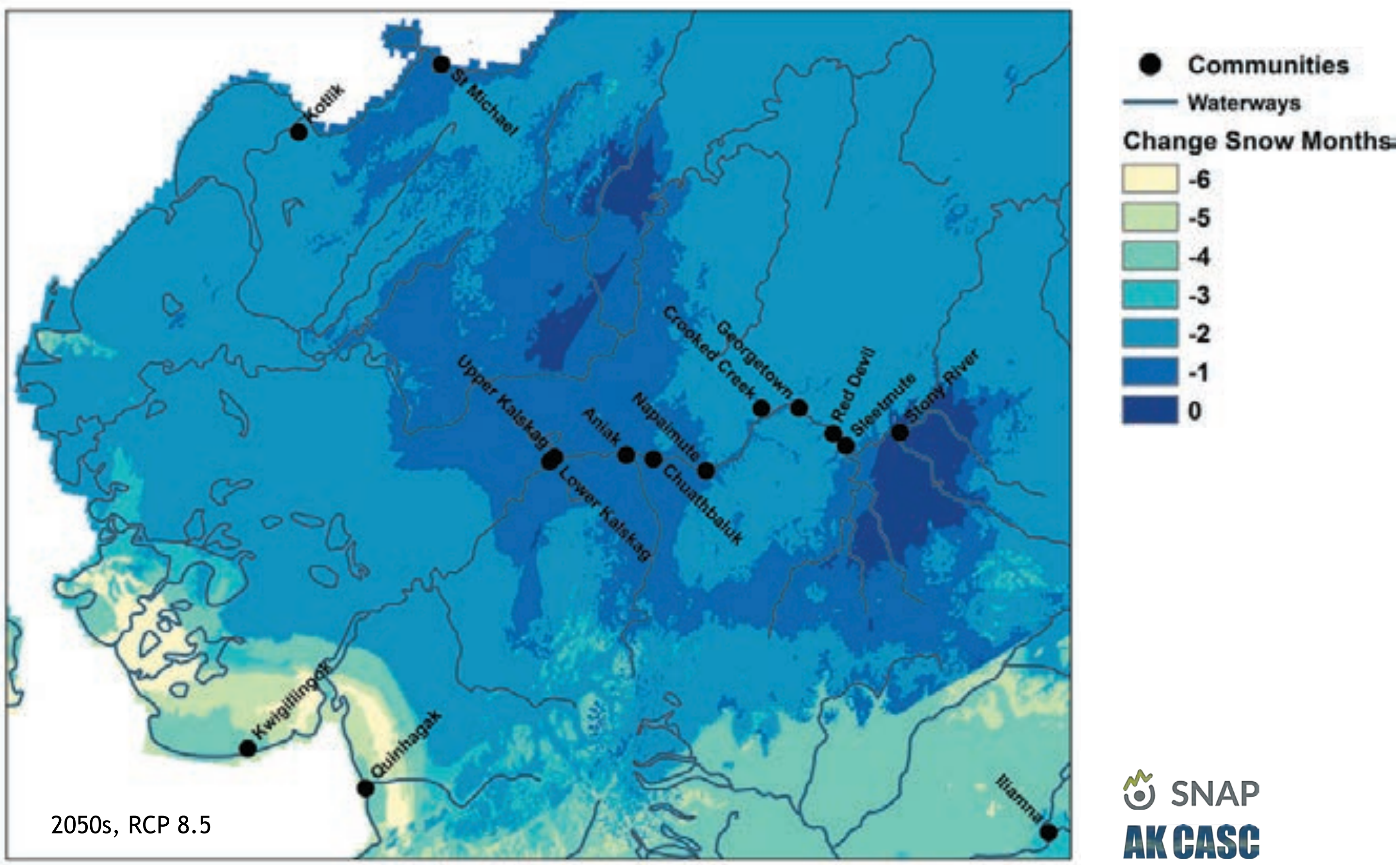


Littell et al., 2018



Snow is an important factor in overland travel during the winter. Travel in to the mountains is a common activity during the winter. When there is not enough snow, people cannot travel out on snowmachines. Additionally, successful trapping seasons are dependent on snow cover. Trapping provides an opportunity for people to get outside during winter, and is a source of income in the region. Under a warmer emissions scenario (RCP 8.5), most of the region will lose 1 to 2 months of reliable snow cover. During these months, of the days when precipitation falls, 7 out of 10 days will have snowfall and 3 of 10 will be rain or mixed rain and snow.

Figure 6: Change in Number of Months with Reliable Snow Cover Between 2040-2069



Littell et al., 2018

Changing Environment

River

Climate Summary Points:

- The river is freezing later, and breaking up earlier. Ice conditions throughout the winter are becoming more variable.
- Under a high emissions scenario, reductions in the amount of water contained in the April 1st snowpack is projected to be reduced by up to 10% between 2040-2069 and 10%-20% between 2070-2099.

"The river is our biggest resource. We alter our lives around the freeze and thaw."

—Elizabeth Willis, Stony River

Photo courtesy of the Native Village of Napaimute

River Ice

Warming temperatures are already having a noticeable impact on the quality of ice along the Kuskokwim ice road. Historically, the river begins to freeze in early October, and break-up occurs in May. Many residents of the Middle Kuskokwim note that the Kuskokwim River is freezing later than usual, experiencing mid-winter thaw and re-freeze, and breaking up earlier. In some areas, the river no longer freezes completely. In a LEO Network post from Chuathbaluk submitted on April 17th, 2016, Patricia Yaska wrote that the river ice near the community went out earlier than usual following an extremely warm winter (Yaska, 2016). Longer ice-free periods on the river are allowing residents to travel by boat earlier in the spring, and later in the fall. In 2017, Patricia posted to the LEO Network again, saying that 2017 was the second year in a row that people were able to travel the Kuskokwim River by skiff in November (Yaska, 2017).

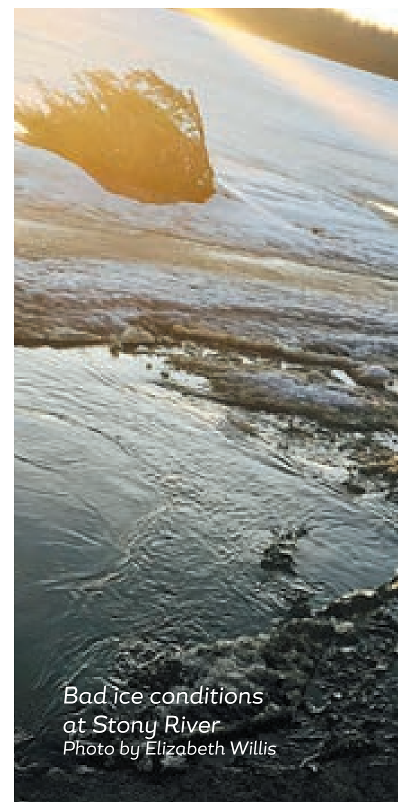
Mid-winter thaws may lead to flooding in some areas as the water pools on top of the ice before re-freezing. Eroding riverbanks has brought the floodwaters closer to infrastructure in some communities ((a) United States Army Corps of Engineers). In a LEO Network post submitted from Lower Kalskag in early May of 2012, John Parka writes that the ice began to move on May 7th, but stopped and water levels began to rise, causing residents to worry about the safety of the dumpsite, sewage lagoon, and personal property (Parka, 2012).

River ice, Stony River
Photo by Elizabeth Willis

"I remember growing up in Chuathbaluk, and in Aniak, and by the end of October, and by Thanksgiving, we were traveling between the two villages (Aniak & Chuathbaluk) on the "ice road". This day and age, we cannot do that. We are still traveling to Aniak for groceries with a boat, in an ice-free river."

—*Patricia Yaska, Chuathbaluk. LEO Network, 2017.*

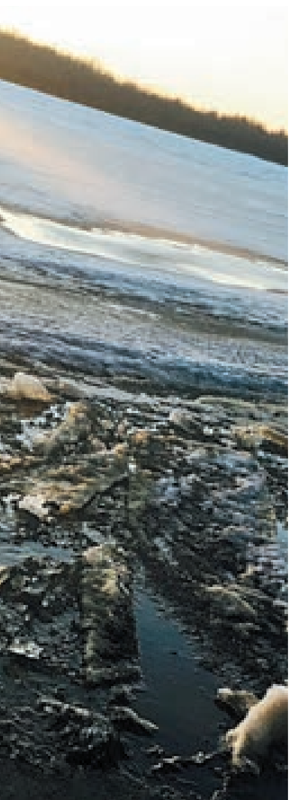
Photo courtesy of the Native Village of Napaimute



Bad ice conditions at Stony River
Photo by Elizabeth Willis

The importance of the Kuskokwim River ice road to the region cannot be understated. It provides a cost effective travel option during the winter. However, changes in freeze/thaw timing, depth of ice, and frequency of open water, increase the risk of accidents and injury during travel. Traditional paths along the ice have changed, and trails are marked in different areas than what is usual based on where the ice is the most stable. In uncertain conditions, it takes longer to travel using the ice road, and travel delays can impact activities such as traveling for work, gathering wood, shopping, traveling to see family, or to visit a health facility. The ability to travel safely is important for maintaining relationships between people, families, and communities in the region.

Village transportation crews, and Bethel Search and Rescue, are actively adapting to changing conditions and working to provide residents with the information they need to travel safely. River conditions are surveyed using ice radar and aerial imagery from drones. Transportation crews take ice core samples at regular intervals along the ice road, and use trail markers and willow limbs to mark dangerous areas in the ice. Updates on current conditions are distributed in the Bethel Search and Rescue River Reports. These reports are widely distributed to residents through radio and social media, and are also shared with scientists at the NOAA River Forecast Center and the Alaska Center for Climate Assessment and Policy at the University of Alaska Fairbanks.



Bad ice conditions at Stony River
Photo by Elizabeth Willis

River Water

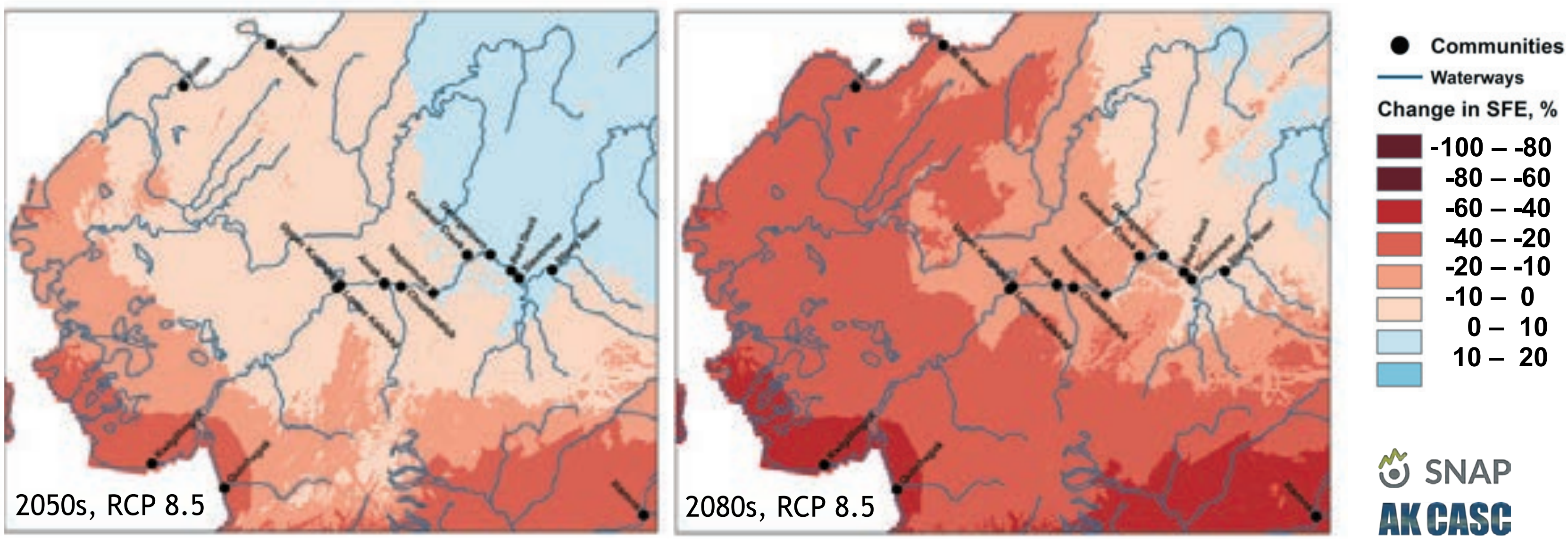
The Kuskokwim River provides food, water, and transportation for communities in the region. Healthy water quality and adequate water levels are important to maintaining that quality of life. The Middle Kuskokwim is considered "snow dominant", which means that the majority of precipitation falls as snow rather than rain during the winter. The Middle Kuskokwim region is projected to remain snow dominant, but in future climate scenarios, less precipitation is projected to be contained in the April 1st snowpack. The amount of snow still on the ground on April 1st can provide an estimate of how much water will melt from the snow, feeding the rivers, lakes, and groundwater as seasonal temperatures warm.

Bank erosion
Photo by Elizabeth Willis

Erosion covered by vegetation, Bethel
Photo by Mary Peltola

Under both low (RCP 4.5) and high (8.5 RCP) emissions scenarios, the amount of water in the April 1st snowpack decreases closer to the coast, where less snow is projected to fall in the future. Under a low emissions scenario, some areas may show an increase in the amount of water contained in the snowpack because of an increase in the amount of precipitation. Under a high emissions scenario, the amount of water in the April 1st snowpack is reduced for much of the Middle Kuskokwim region. During 2070-2099, reductions of 20-60% are projected near the coast, and reductions of 10-20% are expected near the Middle Kuskokwim communities.

Figure 7: Change in the Amount of Water Entrained in April 1st Snowpack over the Yukon-Kuskokwim Delta



Littell et al., 2018

Residents of the Middle Kuskokwim are seeing connections between changing snowpack and the health of salmon runs. There are many factors that impact the abundance of salmon, but the potential for change in river flow and river water temperatures are of particular concern to residents. The Kuskokwim River is an important salmon migration corridor, while the gravel beds in smaller streams and tributaries provide important spawning and rearing habitat. Residents have observed that some smaller streams have dried up, and can no longer support spawning salmon. Young salmon depend on riverbank vegetation to rest and avoid predators, but some salmon streams in the region have also become completely grown in as the water flow is reduced over time. Cold river water is an important cue for king (Chinook) salmon to begin running upriver (Sauter et al., 2001). Residents are concerned that changes in the timing of breakup and snowmelt might cause the fish to miss this cue, leading to smaller runs. Increasing air temperatures during the summer cause the river water temperature to fluctuate and create additional pressure on fish species. Warm water holds less oxygen for fish, and can also allow parasites and water-borne diseases, to thrive.

The amount of water that flows in to the Kuskokwim River also impacts the ability of residents to travel between communities. During the summer, travel by boat is more cost effective than travel by plane or ATV, but low water levels can make travel by boat difficult.

In May, after the ice breaks up and the river begins to thaw, the daily river discharge (the volume of water that flows through the Kuskokwim River channel) increases. The daily river discharge decreases slightly in June, remains steady until the rains come in August and September, and the river begins to freeze in October ((b) United States Army Corps of Engineers). Changes in river discharge due to snowmelt typically do not occur past July 1st. Average river water flows, measured between July 1st and September 30th at Crooked Creek, show a detectable decline between 1952 and 2015.

Shallow water in the rivers and tributaries prevents people from traveling up to camps, which have great cultural and emotional importance. When the river levels are low, the barge carrying fuel cannot reach some communities. This drives up the price of an already expensive commodity.

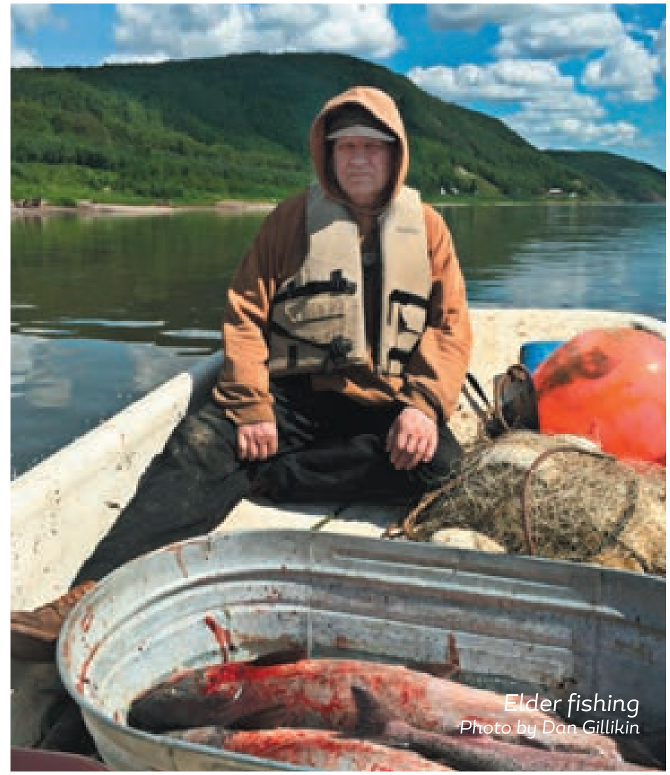
Several communities along the Middle Kuskokwim experience riverbank erosion, which increases the amount of sediment and debris in the river, and increase the risk of grounding even when the river discharge is strong enough to support barge travel ((b) United States Army Corps of Engineers).


Red Devil
Photo by Kattie Wilmarth

Residents of the Middle Kuskokwim are also seeing connections between changing snowpack and the health of salmon runs. There are many factors that impact the abundance of salmon, but cold river water is an important cue for Chinook salmon to begin running upriver (Sauter et al., 2001). Residents are concerned that changes in breakup timing and water temperature might make the fish miss this cue, leading to smaller runs. Water temperatures are fluctuating, which impacts salmon health. Warm water holds less oxygen for fish, and can also allow parasites and water-borne diseases, to thrive.

Middle Kuskokwim communities have partnered to monitor water quality. Water quality monitoring is important to understand changes in the mineral content of river water. In the Middle Kuskokwim region, the soil contains naturally occurring mercury, antimony, gold, silver, and polymetallic deposits (Matz et al., 2017) which may flow in to the water due to erosion, permafrost thaw, mining, and mobilization of methylmercury from wildfire (Taylor, 2007, Kelly et al., 2006). These deposits naturally flow in to the water as the river banks erode, but tailings from previous mining operations may also increase contaminant levels in the water. Tailings from Red Devil mine, containing mercury, arsenic and

Water quality testing, July 2015, Aniak
Photo by Harvey Hoffman



Elder fishing
Photo by Dan Gillikin

antimony, were found to be leaching in to Red Devil Creek after the Red Devil mine closed in 1971. The Bureau of Land Management provided a temporary solution by re-grading the largest tailing piles and building a retention basin in Red Devil Creek, and is expected to develop a permanent method of stabilizing the site (Bureau of Land Management, Shallenbarger, 2019). However, concerns about water quality are heightened due to the proposed Donlin Gold Mine near Crooked Creek, and due to the increased rate of river bank erosion due to permafrost thaw.

In particular, mercury has the potential to concentrate in fish used for subsistence, which may then be transferred to the people who eat the fish. In certain amounts, mercury can present a health risk (Kossover et al, 2016). To date, the Alaska Department of Health and Social Services (DHSS) have not found any cases of unsafe mercury exposures that are the result of consuming Alaska fish. However, measurements of mercury levels found in pike and burbot (lush) from the Middle Kuskokwim were used by DHSS to create region-specific consumption guidelines. DHSS advises women who are, or may become, pregnant, to eat smaller, younger, fish. These fish generally have lower mercury levels (Kossover et al., 2016). Otherwise, the cultural importance, and nutrition, of subsistence foods in Alaska is greater than that of store-bought foods, and consumption should still be encouraged.

Residents of Upper and Lower Kalskag, Aniak, Napaimute, collect surface water samples to monitor changes in temperature and pH (how acidic/basic the water is). Residents of Chuathbaluk sample surface water to monitor changes in Volatile Organic Compounds[1] (VOCs), Semi-Volatile Organic Compounds[2] (SVOC), and nitrates[3] in addition to monitoring pH and temperature. Sites at Georgetown sample for VOCs, SVOCs, temperature, pH and metals. Sleetmute samples for pH and nitrates, as well as for alkalinity[4], salinity[5], and turbidity[6]. The last monitoring site is at Telida, where samples are taken to monitor temperature, pH, turbidity, conductivity[7], metals, and nitrates. Between 2012 and 2017, water temperatures reached 59°F during peak salmon run months of May – August. Metals were also detected in concentrations higher than the Alaska Department of Environmental Conservation standards. These measurements provide important baseline information as the environment changes. Long term monitoring will help determine what impact these changes have on the health of the Kuskokwim River ecosystem (Witte). Results of water quality testing can be found in the online Kuskokwim Tribal Baseline Water Quality Data GIS database, maintained by Georgetown Tribal Council.

Lush Fishing
Photo by Megan Leary

1 Volatile Organic Compounds (VOCs) are chemicals that can dissolve in water or vaporize in the air. They are found in petroleum products such as gasoline or diesel fuel, as well as paints and solvents (USGS).

2 Semi-Volatile Organic Compounds (SVOCs) are found in many of the same products as VOCs, but are more persistent, meaning they are more difficult to remove from the environment.

3 Nitrates are a form of nitrogen and can be found in wastewater treatment plants, failing septic systems, and industrial discharge. Nitrates are an essential nutrient for plants, but in excess can affect fish and animal health (EPA).

4 Alkalinity of water is dependent on the presence of other chemicals that either allow, or do not allow, water to neutralize acids and bases and maintain a stable pH (USGS).

5 Salinity is a measure of how much salt is in the water.

6 Turbidity is a measure of how much sediment is in the water.

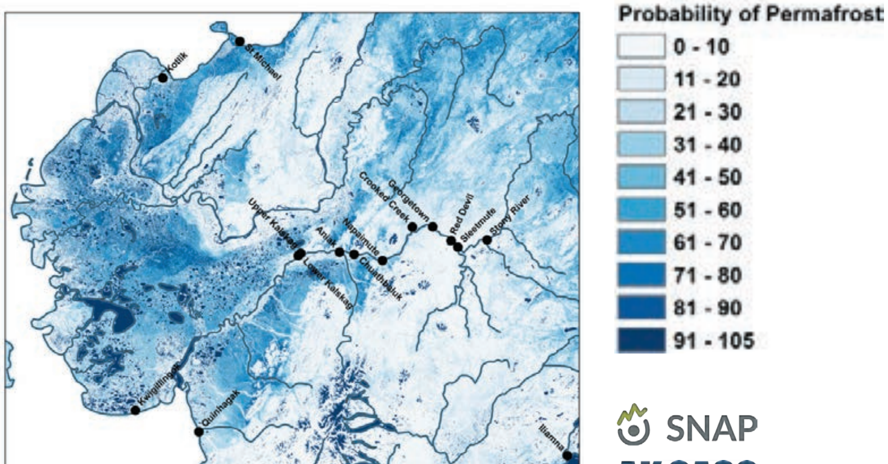
7 Conductivity is a measure of inorganic dissolved solids in the water that either allow, or do not allow, the water to pass an electrical current (EPA)

Landscape

Climate Summary Points:

- In Western Alaska, permafrost occurs closer to the coast and becomes discontinuous (more sporadic) inland. As temperatures warm, the Middle Kuskokwim is projected to be nearly free of permafrost between 2040 and 2099.
- A slight increase in the number of wildland fires is expected to occur by 2099. This increase may also lead to a slight increase in the rate of vegetation change, but the area is still expected to support spruce forest.

Figure 8: Current Probability of Permafrost



Pastick et al., 2015

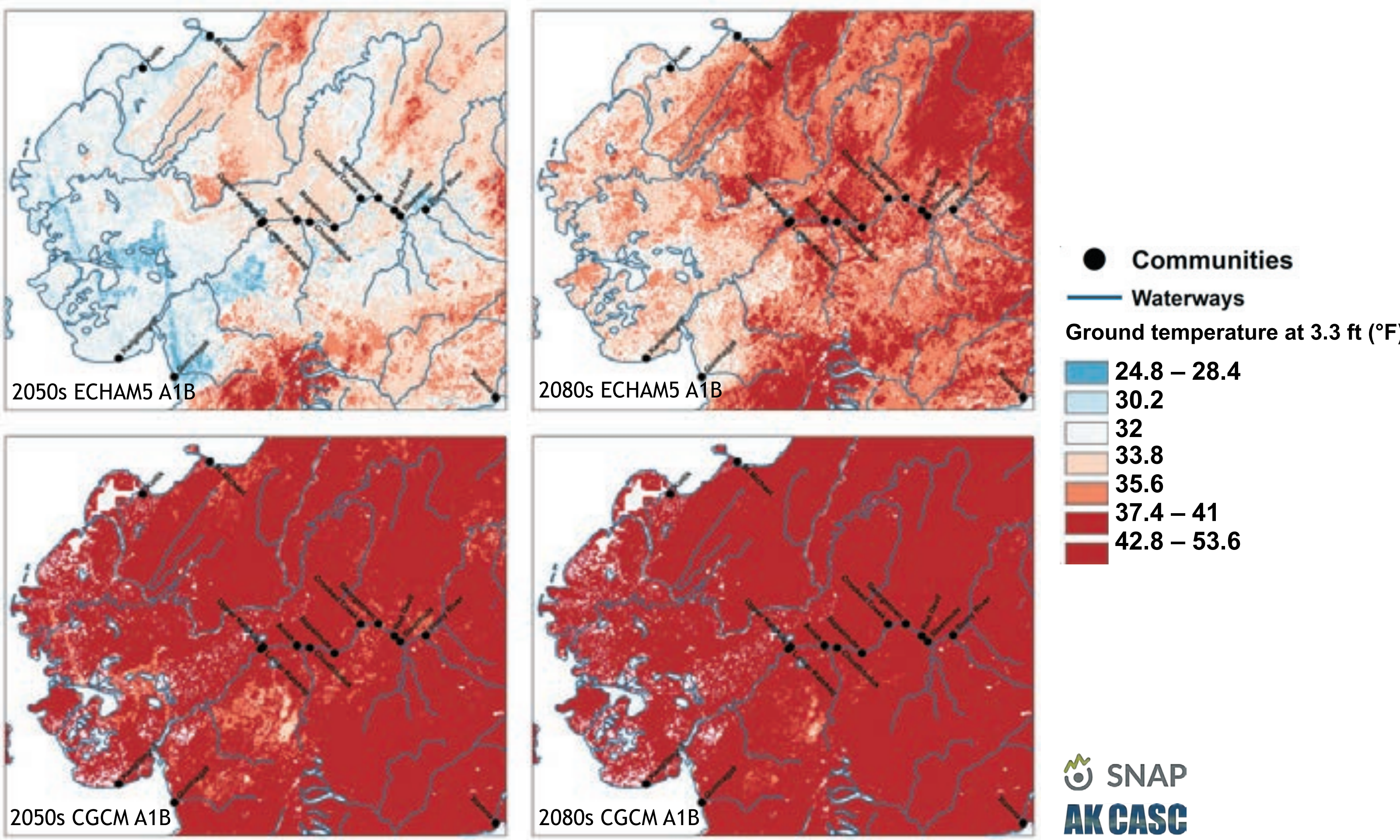
SNAP
AK CASC

Permafrost Thaw

Many factors influence the distribution of permafrost in Alaska, including the climate, hydrology, vegetation, and geology. In Western Alaska, permafrost is more likely to be present closer to the coast, with discontinuous permafrost occurring farther inland. As temperatures warm, the distribution of permafrost is changing as thawing occurs. Thawing permafrost can lead to change in many different parts of the ecosystem, influencing the behavior and distribution of fish and wildlife. Landscape changes include soil subsidence and water movement that contribute to thermokarst terrain in the lowlands, and landslides and erosion in the uplands. Changes in soil temperature and moisture content may allow different plants to thrive, altering the distribution of dominant vegetation in that area. As permafrost thaws, nutrients stored in the frozen soil are released and flow in to the groundwater, eventually flowing in to rivers and lakes (Schuur and Mack, 2018).

Two models are used to project possible permafrost scenarios. MRI-CGCM3 and NCAR-CCSM4 are both climate models from the Coupled Model Intercomparison Project (CMIP5) generation of climate models used in the fifth Intergovernmental Panel on Climate Change assessment and have been found to perform well over the Arctic and Alaska (Walsh et al. 2017). The futures simulated by these models are considered equally likely, but CCSM4 projects warmer temperatures over much of Alaska than CGCM3. The two scenarios can be used to understand a range of conditions when paired with different scenarios of future greenhouse gas concentrations such as those consistent with RCP 4.5 for moderate warming and RCP 8.5 for higher warming.

Figure 9: Change Annual Average Soil Temperature at 1 Meter Depth



Jafarov et al. 2013, Romanovsky and Marchenko 2013

In the Middle Kuskokwim region, communities along the river have documented the increase of arsenic, antimony and mercury in the river water as the permafrost thaws and the river banks erode (Matz etal., 2017). In some communities, such as Stony River, the eroding coast is coming closer to homes and other community infrastructure. Stony River residents are adapting to the erosion by using brush, shrub, and other vegetation to reduce soil exposure, educating community members about how cutting trees affects erosion, and continually monitoring river bank reduction and water levels.

Away from the river, permafrost is changing the landscape in other ways. Permafrost freeze and thaw causes the ground to heave. In some areas, this can shift houses, and damage roads. Road repair is expensive, but can also lead to vehicle damage or interruptions in road access if not addressed. Traveling across the land, residents have noticed that there are more landslides, especially between Bethel and Red Devil. In a LEO Network post from Chuathbaluk, submitted in June of 2014, Robert Hairell wrote that an ATV trail leading in to the Russian Mountains was eroding as the permafrost thawed. The trail was used by community members traveling to pick berries and go hunting (Hairell, 2014). Underground cellars are less common than in previous years, but are still used to store perishables, especially at camps. As permafrost thaws, and cellars are no longer an option, people have to make more frequent trips between camps and their community for perishable foods.

Changes in permafrost may also affect groundwater in the Middle Kuskokwim region. Frozen permafrost restricts groundwater movement, but as it thaws, standing water may soak in to the thawing soil. Middle Kuskokwim residents note that ponds and lakes, once used for hunting, have dried up, signaling possible thaw in those areas. Each community in the Middle Kuskokwim is served by either an individual household well or a community well. Changes in air temperature, the amount of water entrained in the April 1st snowpack, and permafrost thaw may also affect the movement of groundwater serving these wells.

Erosion, Stony River
Photo by Elizabeth Willis

Dust

In communities without paved roads, road dust is becoming a constant issue. Middle Kuskokwim residents remember when the air used to smell fresh in the spring, but now, there are more days when dust is a problem. During winters with less snow, the road becomes exposed and dries out, causing dust during a season when it isn't usually a problem. In the summers, road dust is a frequent concern as vehicles drive up and down the road. More people are experiencing allergies to road dust, and are sometimes more inclined to spend time inside where the air quality is better. Trees and other types of vegetation are important in dust control, but are often cleared as a method of wildfire control.

"When I was little, it used to be fresh. We could smell the leaves, and smell the air. There was not so much dust when I was small. We used to play all over. It so dusty now, we can't smell the freshness."

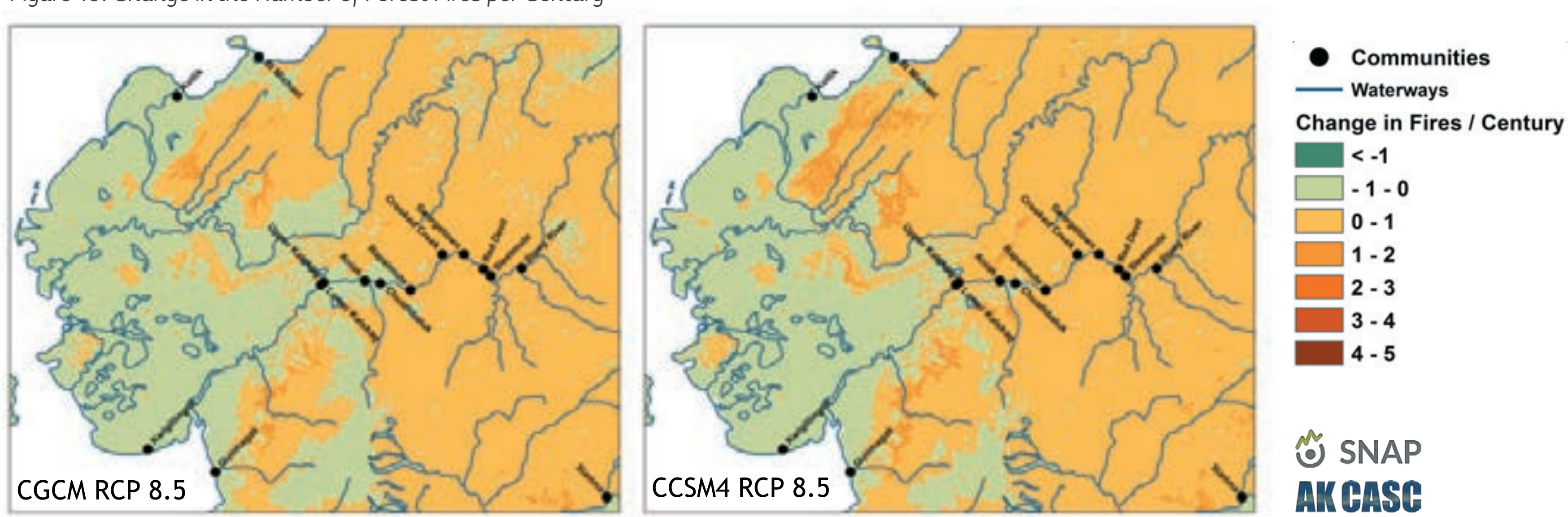
—Phyllis Evan, Lower Kalskag

Bank protection, Stony River
Photo by Elizabeth Willis

Wildfire

Middle Kuskokwim residents have experienced an increase in the number of wildfires, especially during dry years, and more that are caused by lightning strikes. Nearby wildfires may threaten some structures if the area is not cleared of vegetation that can fuel the fire. Wildfire smoke causes significant decreases in outdoor air quality. Elders, and others with respiratory problems, have difficulty breathing when the air is filled with smoke. Poor air quality due to wildfire smoke has occasionally prevented travel in and out of the area.

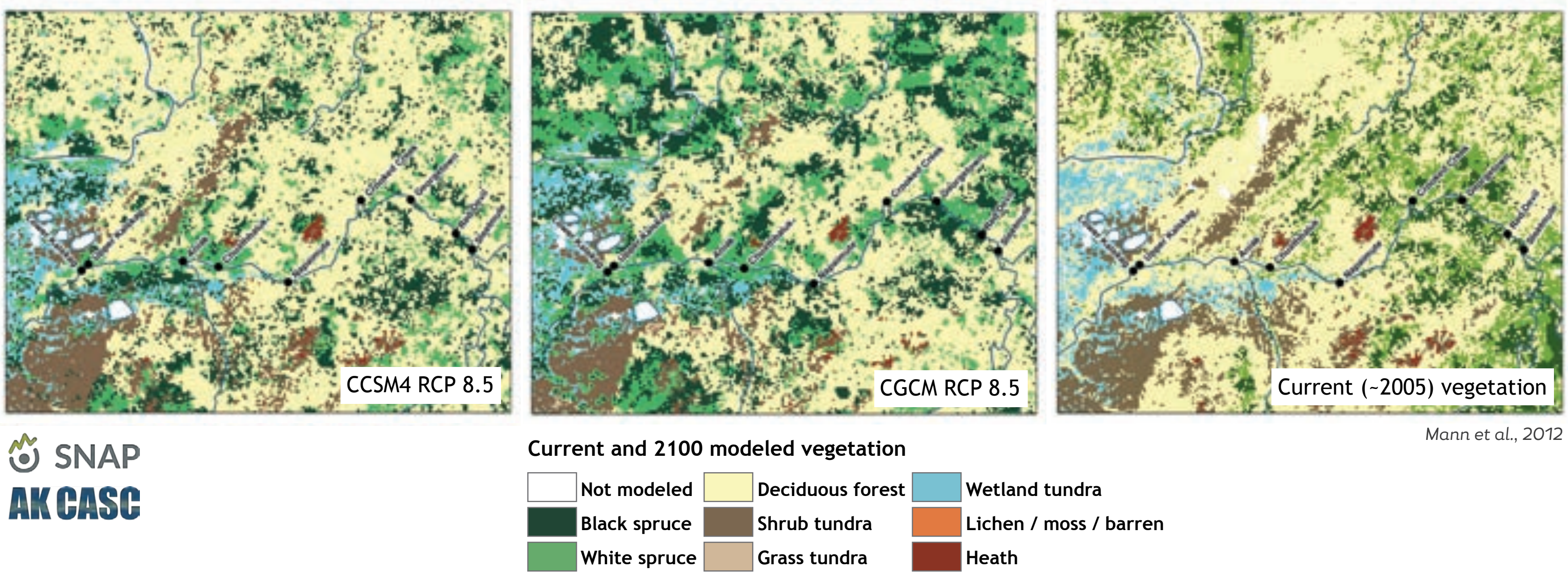
Figure 10: Change in the Number of Forest Fires per Century



Mann et al., 2012

Fire is an important part of forest and tundra ecosystems and helps rejuvenate habitats, provides nutrients to the soil, and promotes vegetation diversity. However, warmer air temperatures are one factor in thunderstorm development and can increase the number of fires from lightning strike (Alaska Division of Forestry, 2019). Under both a lower (RCP 4.5) and higher (RCP 8.5) emissions scenario, the Middle Kuskokwim area will see a slight increase in the number of fires per century by 2099. The increase in fire activity may cause vegetation to change at a slightly higher rate, and lead to a gradual transition from spruce to deciduous forest in some areas.

Figure 11: Change in Dominant Vegetation per Century



Mann et al., 2012

Sisters cutting fish
Photo by Megan Leary

Fishwheel
Photo by Megan Leary

Plants and Animals

The harvest of large and small land mammals, salmon and non-salmon fish, migratory waterfowl and game birds, as well as edible plants and berries is central to the livelihood and tradition of Middle Kuskokwim residents. Changes in temperature, precipitation, permafrost distribution, and the frequency of forest fires, among other species pressures, all impact the distribution and abundance of plants, animals, and fish that people depend on. Residents have observed changes in resource abundance and seasonal timing that affect when and how people harvest. Some hunting and gathering activities require people to travel farther from home, which means more time away from work and more money spent on fuel. Rather than spend more money on travel, some are opting to purchase more food from the local stores, which is less nutritious than traditional foods.

In 2009, the Alaska Department of Fish and Game (ADF&G) Division of Subsistence surveyed the communities of Aniak, Chuathbaluk, Crooked Creek, Lower Kalskag, Red Devil, Sleetmute, Stony River and Upper Kalskag, to understand contemporary harvest and use of subsistence resources. King (Chinook), dog (chum), and coho (silver) salmon made up 65% percent (by weight) of the regional subsistence harvest, followed by moose (11%) and other resources (24%) including non-salmon fish and beaver.

Salmon fishing is central to the history, culture, and lifestyle of the people who live along the Kuskokwim River. The health and abundance of salmon have the potential to be impacted by variables in both freshwater and ocean ecosystems, but residents of the Middle Kuskokwim have seen changes in the abundance of salmon that run up the river. People recalled times in years past, when one net catch full of king salmon would fill the boat. Now, people can no longer rely on adequate numbers of king salmon, and rely more

Drying slabs
Photo by Mary Peltola

heavily on the harvest of other salmon species. When fishing primarily for king, the season used to be over before the Fourth of July, and people had time to attend community festivities and pick berries. However, dog, red (sockeye), and silver salmon run later in the season than king salmon, and are fished after the Fourth of July holiday. More rain falls after the holiday, and makes traditional practices of drying and smoking fish more challenging by increasing the risk of spoilage.

Concerns about the health of fish are related to concerns about water quality. Warmer waters stress the fish and allow more parasites and diseases to thrive, and residents say that more salmon are caught with internal worms, and physical abnormalities such as small bumps and growths. Warmer water also leads to low levels of dissolved oxygen, a phenomenon that was responsible for the deaths of pre-spawned dog and pink salmon across Alaska during the summer of 2019.

Salmon are also observed to be smaller. A common method of cutting fish to dry is called the "butterfly cut," or the "blanket cut," where the back bone is removed and two similar sized salmon are tied together, dried and smoked. Some women are noticing that these cuts are not being used or taught with the smaller sized salmon.

Moose provide a significant amount of healthy meat to the Middle Kuskokwim communities, but changes in moose populations and health are concerning residents. At the time of the ADF&G Division of Subsistence survey, moose populations were below the Board of Game regulatory objectives due to low calf-to-cow ratios and low bull-to-cow ratios (Brown et al., 2009). Although moose populations have begun to recover in this area (Wells, 2014) some successful hunters find that harvested moose are skinnier than usual, or have worms in the meat. Hunts are also becoming more

Smelt fishing
Photo by Megan Leary

Megan Shelley at the fish table
Photo by Megan Leary

difficult as warm temperatures in September keep animals from moving around. Overall, more moose are observed moving downriver than has been usual in the past. This benefits some communities, but others struggle to travel so far.

Berries are an important cultural food source for people who live in the Middle Kuskokwim, but their distribution and abundance are fluctuating. The Middle Kuskokwim area is home to a variety of berries including kavlak or bear berries *(Arctostaphylos alpine)*, cingqullektaq or air berries *(Cornus suecica)*, tan'gerpiit or crowberries/blackberries *(Empetrum nigrum)*, uingiaraat or bog cranberry *(Oxycoccus microcarpus)*, mercuullugpiit or red currant *(Ribes triste)*, puyuraarat or wild raspberry/dward nagoonberry *(Rubus arcticus)*, atsalugpiaq or salmonberry/cloudberry *(Rubus chamaemorus)*, curat or blueberry *(Vaccinium uliginosum)*, kavirlit or low bush cranberry *(Vaccinium vitis-idaea)*, and agautaat or high bush cranberry *(Viburnum edule)*. When there is little rain and snow during the year, berries are observed to be less abundant. However, two years after a fire has burned through the area, berries will often be found in abundance, ripening earlier than usual when summer temperatures are warm. In other areas, places where berries used to grow are covered by trees and grasses. Warm temperatures lead to longer growing season for plants, and more people experience spring and summer allergies. In a LEO Network post submitted in April of 2016, Patricia Yaska describes seeing buds on the birch trees in Chuathbaluk, two months earlier than normal after a mild winter with little snow (Yaska, 2016).

Moose hunt
Photo by Verdene Morgan

Blueberry picking
Photo by Mary Peltola

Many plants have been traditionally used as medicines, to treat ailments such as boils, cuts and infections, as well as ease teething pain for babies. Although use of traditional plants have decreased over time, they are still important both culturally and for medical use. A new threat to traditional plants use is the emergence of invasive plants that are benefiting from warming temperatures. One example of this can be seen in the changing distribution of Caiggluk or wormwood *(Artemisia tilesii)* around Stony River. Traditionally, this plant is used for treating rashes, congestion, chest pain, and other ailments. Dandelions (genus *Taraxacum*) are now growing on the sides of roads, lawns, and in grass fields where Caiggluk used to grow in abundance. In the Middle Kuskokwim, other invasive plants such as splitlip hempnettle *(Galeopsis bifida)*, narrowleaf hawksbeard *(Crepis tectorum)* and yellow toadflax *(Linaria vulgaris)* have already become established in the region. Canada thistle *(Cirsium arvense)*, oxeye daisy *(Leucanthemum vulgare)*, spotted knapweed *(Centaurea biebersteinii)* and meadow hawkweed *(Hieracium caespitosum)* are all present in other Alaskan landscapes, and have the potential to establish themselves in the Middle Kuskokwim as well. Invasive aquatic plants such as elodea *(Elodea Canadensis)* and reed canary grass *(Phalaris arundinacea)* may also become a concern in lakes and streams ((b) Koopman, 2017).

As conditions continue to change and become unpredictable, residents have noticed a change in diets. The majority of food used to be provided by hunting, fishing and gathering. These foods used to be available all the time but are now reserved for special events. People are purchasing meat and shelf stable foods to augment subsistence diets. Shelf stable foods allow budgets to stretch farther, as fresh foods available in stores are often cost prohibitive. As diets have changed, residents have noticed an increase in symptoms of food allergies and intolerances. Residents raised concerns about dietary change and the potential implications for chronic diseases such cancer and diabetes, which may be related to changes in diet and exercise.

The price of butter
Photo by Mary Peltola

Fish soup
Photo by Mary Peltola


EBRATE!
DONLIN
GOLD

"Activities feed our soul and with regulations that say you can't fish, it crushes our soul."

—Marce Simeon, Napaimute

Difficult and dangerous conditions, compounded by the high price of fuel, are preventing people from traveling for gatherings and subsistence activities. Traditional activities such as hunting, fishing, and steaming provided important opportunities for people to connect with each other and maintain healthy relationships. Even taking a steam or packing water, provided outlets for excess energy. Middle Kuskokwim residents notice fewer people engaging in outdoor activities, and instead people spend more time inside with their attention to phones and television.

Physical activity, and time spent on the land, is crucial for maintaining mental health and wellbeing. When conditions prevent people from traveling outside the village, it is more difficult to find healthy emotional outlets. Stress in individuals leads to stress in the broader community. Elders used to take children out camping and berry picking, and use that time to pass on traditional knowledge and values, and teach children to be respectful. Today, elders are frustrated because their knowledge is difficult to apply in a changing climate.

Time spent outside improves physical health as well as mental health. When people spend more time inside, seasonal colds and flus linger longer. There are more instances of walking pneumonia and other respiratory issues, which cause people to miss school and work.

"As indigenous people we are designed very complex. Health and wellbeing depend on different things - physical, mental, spiritual health - everything is connected. What is ecological knowledge? Everything is inter-twined. When I think about health, what we need to be healthy, it is what everyone has said. It is unsafe to travel, we have to go farther or work harder and that is expensive. By design, we are meant to take care of each other. As young men, we are supposed to be providers. When we are not able to do that, it affects physical, mental and spiritual health. Loss of a diet is a loss of a role and that leads to unhealthy choices. We focus on physical health but we have a lot of connections and those are seen more as things change."

—Jonathan Samuelson, Georgetown and Red Devil

Fish cutting contest
Photo by Harvey Hoffman

Adapting to Change

Adaptation Process

> ***"Change has empowered our youth. I used to look around the room and be the youngest person there. But not anymore. Things are more unpredictable and a lot is new so young people are learning at the same time as our elders. It evens the playing field a little – it empowers them to contribute in new ways and inspires more self-confidence. Youth can use the new technology. In some ways, it can bring us back together."***
>
> *—Jonathan Samuelson, Georgetown*

The adaptation planning process had three stages. Residents of the Middle Kuskokwim communities met in February of 2019 to share observations about the types of environmental changes occurring in the region, and the impact those changes have on community health, travel, infrastructure, and the economy. Residents met again during August of 2019 to identify priority adaptation areas and develop adaptation goals and project ideas. Middle Kuskokwim residents gathered together for a third time in February 2020 to further discuss future projects and meet with potential agency partners.

Conversations about environmental change during the first adaptation planning meeting resulted in 66 statements of change categorized by topic area and impact. Topic areas included weather and temperature, river water quality and ice, landscape, plants and animals, and community life. Impact categories included physical health, mental wellbeing, activities and relationships, food security, travel, economy and infrastructure.

Tribal gathering
Photo by Harvey Hoffman

Summary of Observed Environmental Change

TEMPERATURE & PRECIPITATION	*Overall, annual temperatures and annual precipitation are increasing.* *Weather is becoming unpredictable, and disrupting traditional activities that are based on predicable patterns.*
RIVER ICE	*The Kuskokwim River is freezing later and thawing earlier. Where the river is frozen, there are more areas of unstable ice. Parts of the river do not freeze at all. Changing ice conditions make travel on the river ice more dangerous.*
RIVER WATER	*Water temperatures are warming. Warm water holds less oxygen for fish, and allows parasites and other diseases to thrive.*
PERMAFROST	*Permafrost thaw is causing the river banks to erode more rapidly. Eroding river banks have increased the amount of arsenic, antimony, and mercury in the river water.* *Permafrost thaw is heaving the ground. As the ground heaves, building foundations and roads are damaged.*
AIR QUALITY	*Reduced air quality from dust is becoming an issue year-round. In years with low snow cover, the exposed ground dries and more dust is created.* *There are more wildfires in years with less precipitation. Elders, and others with respiratory problems, have difficulty breathing when the air is filled with smoke.*
VEGETATION	*Invasive vegetation pushes out plants that are traditionally used for traditional medicines. Overall, the use of traditional medicine has decreased as plants become more difficult to find.*
FOOD SECURITY	*Health and abundance of salmon are changing. Changes in the abundance of king (Chinook) salmon cause more people to rely on sockeye salmon, which migrate later. Processing time overlaps with the rainy season, which increases the risk of spoilage. Salmon are smaller, and are more frequently caught with signs of disease and parasites.* *The abundance of berries fluctuates based on precipitation and wildfire. When there is little rain and snow during the year, the berries are less abundant. If there is a wildfire, the berries will become more abundant two years afterwards.* *Moose are changing their migration patterns, which may be affected by changes in temperature and vegetation distribution. More moose are moving downriver, which benefits some communities, but others have to travel longer.*
COMMUNITY LIFE	*Changing weather conditions impact the ability of people to engage in traditional activities.* *Traditional activities such as hunting, fishing, and steaming provided important opportunities for people to connect to each other, and are based on predictable weather and temperature patterns. When these activities are not possible, physical and mental health suffers.* *Diets have changed. The majority of food used to be provided by hunting, fishing and gathering. These foods used to be available all the time but are now reserved for special events, and there is a shift to more shelf stable foods and commercial meat.*

During the second adaptation planning meeting, Middle Kuskokwim residents discussed what the ecosystem may look like in the future, and the intrinsic connections between individuals, communities and the landscape. With these discussions in mind, meeting attendees reviewed and revised the statements of change, topic areas, and impacts, then prioritized each statement of change as "high," "medium," or "low" priority for adaptation.

Impact Prioritization

HIGH	*A critical activity that should be the focus of energy and resources*
MEDIUM	*Makes a substantial contribution to adaptation goals; lower priority for resources*
LOW	*Makes a contribution to adaptation goals, and should be developed as resources or opportunities become available*

Kwethluk fish meeting
Photo by Mary Peltola

Fish camp
Photo by Mary Peltola

From the sixty-six statements, eleven statements were identified as high priority by nine or more (70%) of the people who attended the second meeting, and were reviewed again by the group. These statements described changes to:

Weather and Temperature

- "Berries also depend on snowpack, and there are fewer berries in dryer years."
- "Warmer temperatures make travel on the river and ice road dangerous."

River Water Quality and Ice

- "Water temperatures are fluctuating, which impacts salmon health. Warm water holds less oxygen for fish, and can also allow parasites and fish diseases to thrive."

Landscape

- "There are more wildfires in dry years. Wildfire smoke led to the evacuation of elders and children in Aniak."
- "Elders, and others with respiratory problems, have difficulty breathing when the air is filled with smoke. "

Plants and Animals

- "Diets have changed. The majority of food used to be provided by hunting, fishing and gathering. These foods used to be available all the time but are now reserved for special events."
- "The salmon are smaller and less abundant."
- "Salmon are more frequently caught with physical abnormalities."

Community Life

- "People spend more time inside with their attention to phones and television. Emotional and mental health suffers from lack of physical activity."
- "Seasonal colds and flus linger longer, which may be related to people spending more time inside. Many people suffer from chronic diseases such as cancer and diabetes, which may be related to changes in diet and exercise."
- "The price of gas is expensive, making it expensive to travel for recreation and subsistence."

An additional statement, "*When the river levels are low, the barge carrying fuel cannot reach some communities. This drives up the price of an already expensive commodity*," was added to the discussion by ANTHC staff. Adaptation strategies focused on alternative energy may also address aspects of the statements prioritized by the group.

As a group, workshop participants further explored each of the prioritized statements of change, identifying common themes and topic areas. Through discussion, the twelve statements were combined in to five adaptation focus areas. Each focus area was broken down in to specific goals, with project ideas, potential challenges and potential resources.

Gassing up generator
Photo by Mary Peltola

Adaptation Priorities

Reconnecting Our People with the Natural World
Residents of the Middle Kuskokwim are observing changes to the land and water that affect traditional hunting, fishing and gathering activities. When people are not able to go out on the land, it is harder to learn traditions, values, and ways of understanding the landscape. Participating in community activities helps support physical activity by getting people out of the house and away from televisions and cell phones. These activities also build relationships between people, improving mental and emotional wellbeing.

Goal: Bring community members, including youth and elders, together in a series of activities to share skills, traditional knowledge, and values.

Fish
Photo by Verdene Morgan

Ensure Sustainable Populations of Fish, Game, and Vegetation to Increase the Availability of Traditional Foods

Changing environmental conditions are affecting the health of plants, animals, and fish, which people in the Middle Kuskokwim depend on. Traditional foods are an important part of community gatherings, and daily meals at home. Additionally, traditional foods provide more nutrition than store-bought foods.

To ensure that these resources are available for future generations, it is important to monitor the health of subsistence resources and understand what changes have been seen before and what changes are new. Residents of the Middle Kuskokwim are stewards to the land and the resources, and to continue this tradition, their knowledge and values need to be heard during regulatory decision making.

Goals:
- Amplify the voice of Middle Kuskokwim residents in fisheries related decisions.
- Build the confidence and skill in individuals to effectively communicate with regulatory agencies, journalists, and communities.
- Increase the number of Middle Kuskokwim residents trained as fish biologists and resource managers.
- Monitor the health of subsistence resources.

Ensure Safe Ground Transportation

The Kuskokwim Ice Road is central to winter travel in the Middle Kuskokwim. As temperatures warm, the Kuskokwim River is freezing later than usual, experiencing mid-winter thaw and re-freeze, and breaking up earlier. Unpredictable ice conditions make winter travel over the frozen river dangerous and unreliable. Exploring other transportation methods will help provide safe, cost effective, alternatives when necessary.

Goals:
- Revitalize overland trails.
- Expand capacity for regular trail assessment and documentation.

Reduce the Impact of High Fuel Cost

As the rivers and landscape change, the timing of seasonal animal and fish migrations are changing as well. Middle Kuskokwim residents are spending more on fuel to access subsistence areas. Fuel is delivered to many of the Middle Kuskokwim by barge, but when the river is low or sand bars appear, the barge cannot make its delivery. In those instances, the cost of fuel increases. Partial reliance on renewable energy, and bulk fuel purchase, may allow residents to better accommodate fluctuations in fuel delivery and cost.

Goals:
- Reduce the cost of diesel and unleaded fuel through creation of a fuel consortia.
- Increase use of renewable energy.

Monitor Air Quality

The two primary causes of poor outdoor air quality in the Middle Kuskokwim region are wildfire smoke and road dust. While wildfire smoke is a seasonal issue, road dust is becoming a year-round problem as exposed areas of the ground dry without snow cover. Monitoring outdoor air conditions will allow Middle Kuskokwim residents to document air quality trends, and support adaptation activities like establishing clean rooms.

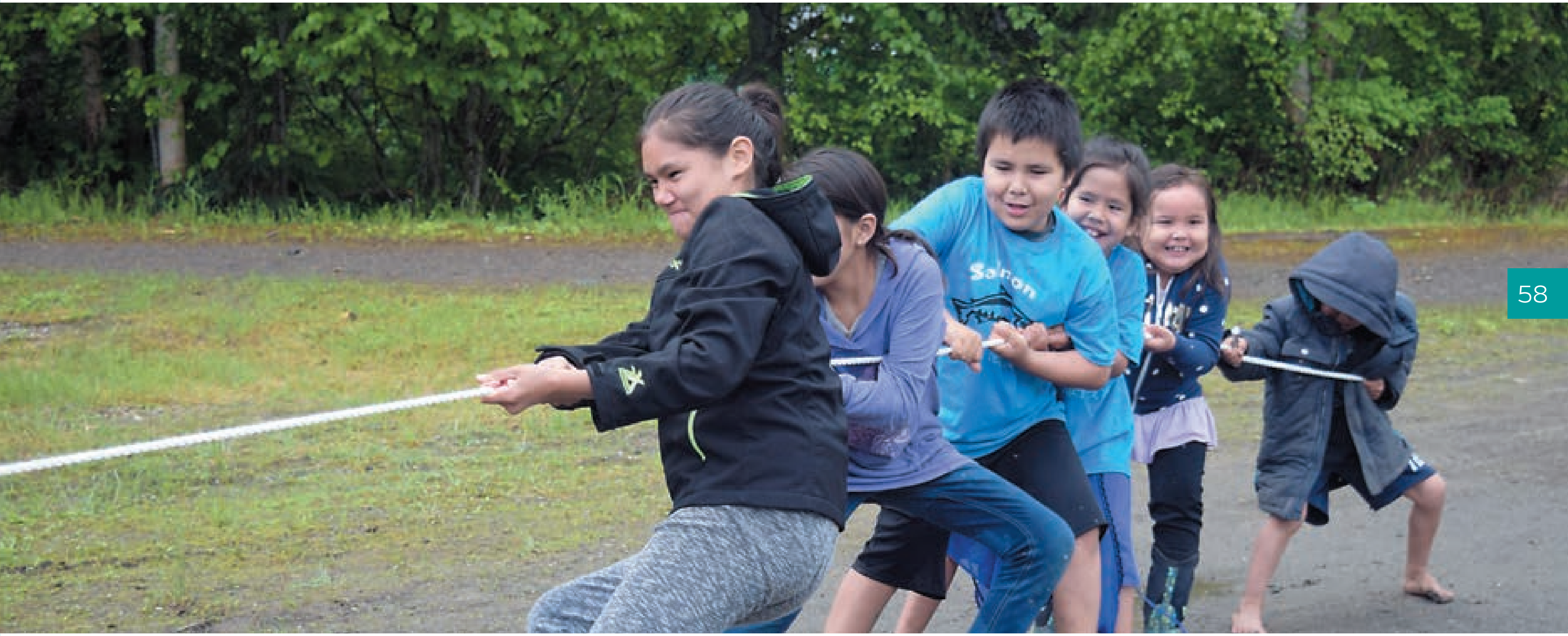
Maintaining indoor air quality is also important for a healthy living environment. As the landscape changes, disrupting some traditional activities, Middle Kuskokwim residents find themselves spending more time inside. Contagious colds and flus tend to linger when people spend more time inside, but a combination of indoor air quality improvements and increased participation in outdoor community events will help maintain community health.

Goals:
- Improve indoor air quality and reduce instances of respiratory illness.
- Improve localized monitoring of outdoor air to improve the health of those with sensitive respiratory systems.

Conclusion

2019 Clean Up Green Up
Photo by Harvey Hoffman

Reliance on customary ways and continuous adaptation have traditionally made Kuskokwim communities resilient. By sharing stories of change, and developing adaptation priority areas, the Middle Kuskokwim communities have shown their commitment to creating a safe, sustainable future for generations to come.



Tug-of-war, Stony River
Photo by Elizabeth Willis

"Elders long ago were not rich with money, they were rich with knowledge about gathering resources and making it through winter."

—Nick Levi, Lower Kalskag

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Aniak session 2017
Photo by Byron Nikolai

Appendix A

Climate Change and Health Matrix

TOPIC	DESCRIPTION	OBSERVED CHANGE	COMMUNITY IMPACTS
Weather	Temperature	Increase in year-round air temperature, especially during winter	Variability in river ice quality impacts travel on the ice road
	Precipitation	Variable snowfall amounts	Fewer opportunities to travel by snowmachine and participate in regional activities
		More rain during winter	Roads and walkways become covered in ice
Air	Air Quality	Exposed ground during winter leads to unseasonable road dust	Increased number of days during the year when outdoor air quality is poor Decrease in indoor air quality as people spend more time indoors
		Increase in frequency of wildfire	
		Increase in the duration of seasonal pollen events, and potential for new types of pollen events as vegetation changes	
Water	River Water Quality	Permafrost thaw is increasing the levels of arsenic, antimony, and mercury in river water	Concern about the bio-accumulation of mercury, and other metals, in pike and burbot (lush)
		River water temperatures are rising	Salmon are more frequently caught with signs of disease and parasites
	Groundwater	Permafrost thaw may change ground water movement	Combined with changing temperatures, precipitation, and amount of water entrained in the April 1st snowpack, wells may recharge at different rates
Land	Infrastructure	Permafrost freeze and thaw is heaving the ground	These frost heaves shift buildings and roads
		Permafrost thaw is contributing to river bank erosion	In some communities, erosion threatens community infrastructure
			Erosion increases the amount of sediment in the water, which may prevent barges and boats from traveling safely
Wildlife	Food Security	Moose are changing their movement patterns, which may be related to changes in temperature and vegetation distribution	Disruption of subsistence practice and nutritious food consumption
Vegetation	Traditional Medicine	Increasing abundance of invasive plants	Decrease in the abundance of native plants used for traditional medicine

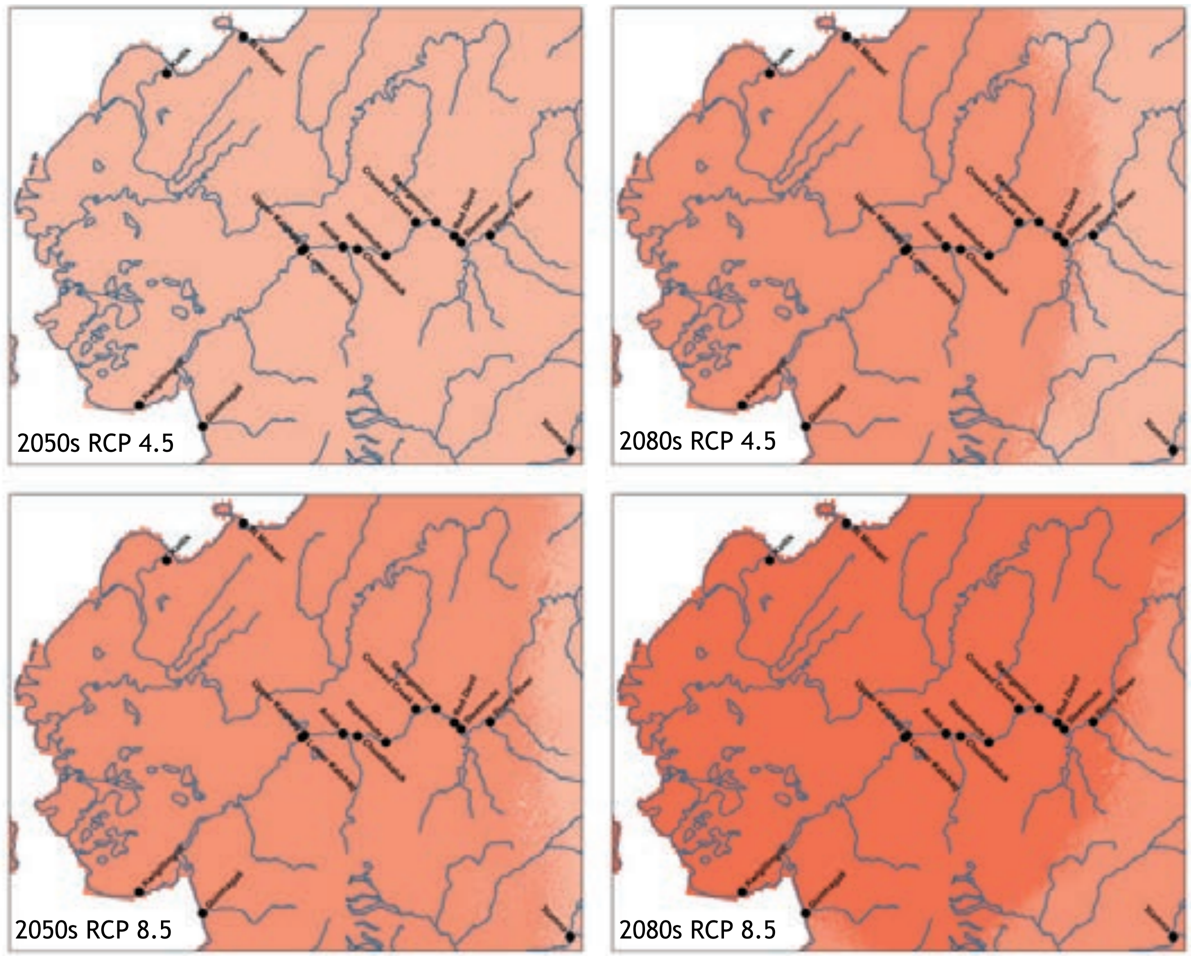
HEALTH CONCERNS	RECOMMENDATIONS
Poor ice conditions increase the risk for accidents during travel.	**Included in 2019 Plan:** Explore phone app to share ice road conditions **Included in 2019 plan:** Revitalize overland trails
Reduced physical activity and increased emotional stress	**Included in 2019 plan:** Bring community members together in a series of activities to share skills, traditional knowledge, and values
Increased risk for physical injury	**ANTHC Recommendation:** Start program to distribute ice cleats to community members, begin a community shuttle program
Respiratory health (sneezing, coughing, wheezing), headache, fatigue, and other associated symptoms	**Included in 2019 plan:** Monitor outdoor air quality **ANTHC Recommendation:** Create clean-rooms in each community, or create evacuation plan, for those with sensitive respiratory systems Implement speed limits to reduce road dust
According to the Alaska Department of Health and Social Services, too much mercury can harm the developing brain and nervous system of unborn babies and young children	**Included in 2019 plan:** Continue water quality monitoring and public notice of monitoring results **ANTHC Recommendation:**Follow the Alaska Department of Health and Social Services fish consumption guidelines for women who are, or who may become, pregnant
Salmon who show signs of illness or abnormality are not consumed, and present a threat to food security	**Included in 2019 plan:** Combine traditional knowledge and science to develop salmon health monitoring program
Middle Kuskokwim communities are served by well water. Changes in water availability may impact the ability of drinking water wells to provide enough water	**ANTHC Recommendation:** If water shortages occur or become a concern, use instruments, such as an electrical sounder, to monitor seasonal changes in water level Develop a plan to provide water to residents if shortages do occur
Damage or disruption of water and sanitary services may increase instance of illness and infection	**ANTHC Recommendation:** Document changes to infrastructure and roads using the LEO Network Identify areas impacted by thaw, and areas that are more resistant to thawing. Construct new infrastructure in resilient areas. Perform development, construction and maintenance in ways to preserve permafrost
Loss of homes and other community infrastructure	**ANTHC Recommendation:** Identify and relocate infrastructure that may be affected by riverbank erosion
Barges carrying fuel and other supplies may not be able to reach every community, which drives up the cost of fuel	**Included in 2019 plan:** Create a fuel consortia to reduce cost burden during fuel shortages, and increase use of renewable energy
Economic burden from the purchase of food from stores Market foods provide less nutrition	Included in 2019 plan: Combine traditional knowledge and science to monitor the health and distribution of subsistence resources
Decrease in the use of traditional medicines	**ANTHC Recommendation:** Develop eradication and re-vegetation program Included in 2019 plan: Combine traditional knowledge and science to monitor abundance of medicinal plants

Temperature – Annual (12 months) as well as four seasons (Spring – March to May; Summer – June to August; Autumn – September to November; Winter – December to February). These represent the change in degrees in surface air temperature, averaged over the year or three-month periods. The changes mapped are compared to the same months in the future projections from climate models.

Figure 1: Change in Annual Average Temperature over the Yukon-Kuskokwim Delta

Change in Annual temperature, F

- 3.2 - 4
- 4.1 - 6
- 6.1 - 8
- 8.1 - 10
- 10.1 - 12
- 12.1 - 14.3



These maps represent the change in annual average temperature (in F, relative to 1970-1999) for 5 climate models averaged together.

<u>5 model means for the region</u>

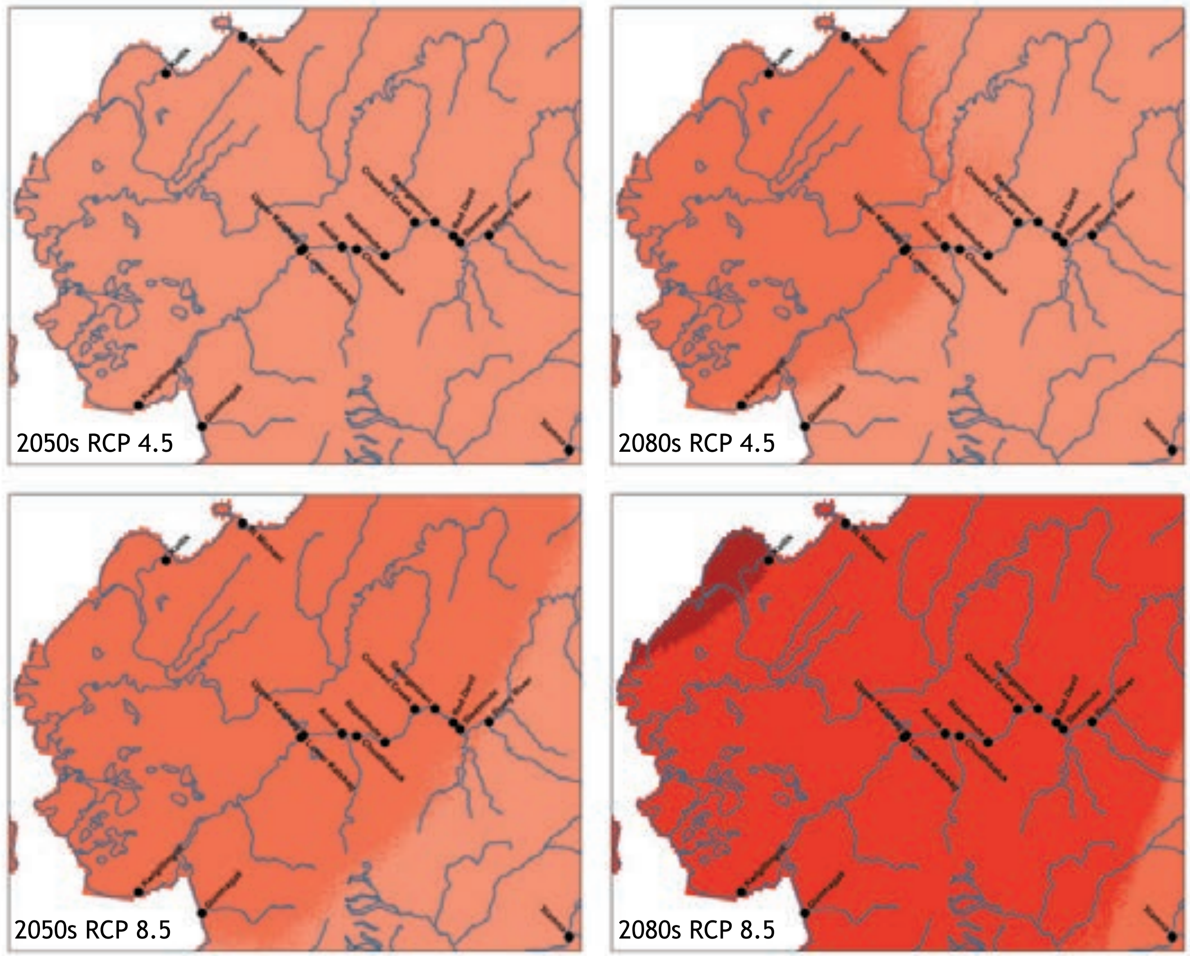
2040 - 2069, RCP 4.5: + 3.2
2040 - 2069, RCP 8.5: + 4.2
2070 - 2099, RCP 4.5: + 4.1
2070 - 2099, RCP 8.5: + 6.2

SNAP
AK CASC

Figure 2: Change in Winter Average Temperature over the Yukon-Kuskokwim Delta

Change in Winter temperature, F

- 3.2 - 4
- 4.1 - 6
- 6.1 - 8
- 8.1 - 10
- 10.1 - 12
- 12.1 - 14.3



These maps represent the change in winter (December to February) average temperature (in F, relative to 1970-1999) for 5 climate models averaged together.

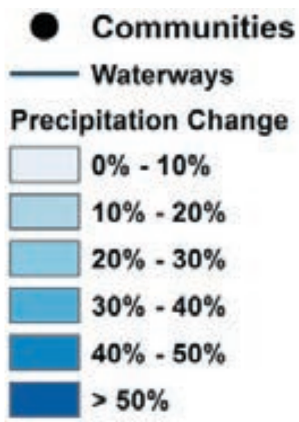
<u>5 model means for the region</u>

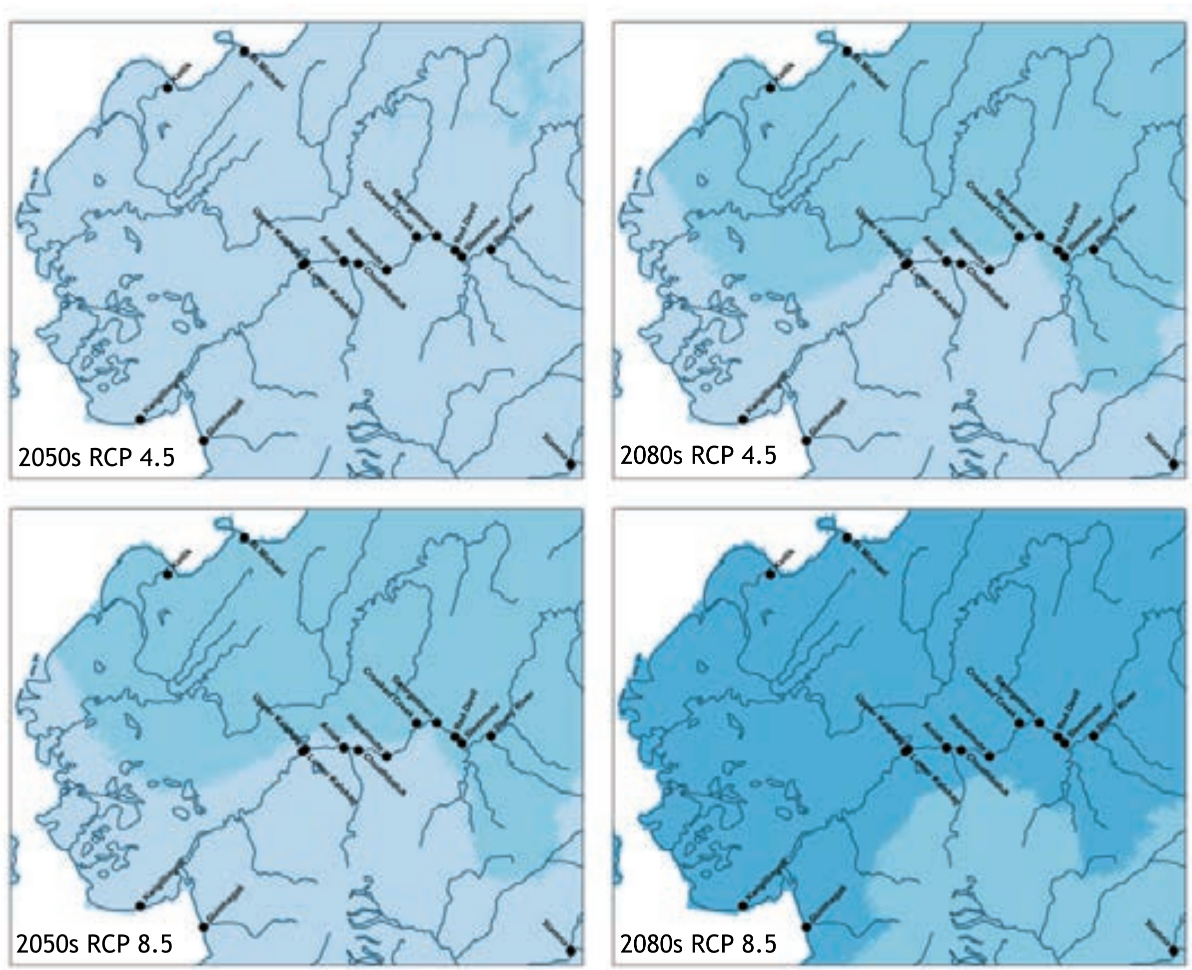
2040 – 2069, RCP 4.5: + 4.5
2040 – 2069, RCP 8.5: + 6.2
2070 – 2099, RCP 4.5: + 5.9
2070 – 2099, RCP 8.5: + 8.8

SNAP
AK CASC

Precipitation – Annual (12 months) as well as four seasons (Spring – March to May; Summer – June to August; Autumn – September to November; Winter – December to February). These represent the percent change in total precipitation, averaged over the year or three-month periods. The changes mapped are compared to the same months in the future projections from climate models.

Figure 3: Change in Average Precipitation over the Yukon-Kuskokwim Delta





These maps represent the change (in percent) in annual precipitation relative to 1970-1999

5 model means for the region

2040 - 2069, RCP 4.5: + 18%
2040 - 2069, RCP 8.5: + 21%
2070 - 2099, RCP 4.5: + 20%
2070 - 2099, RCP 8.5: + 32%

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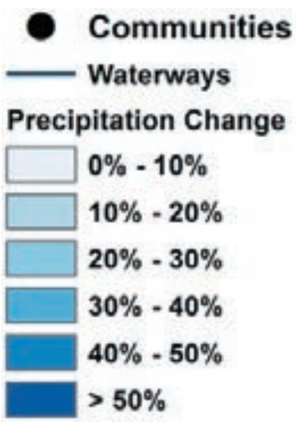
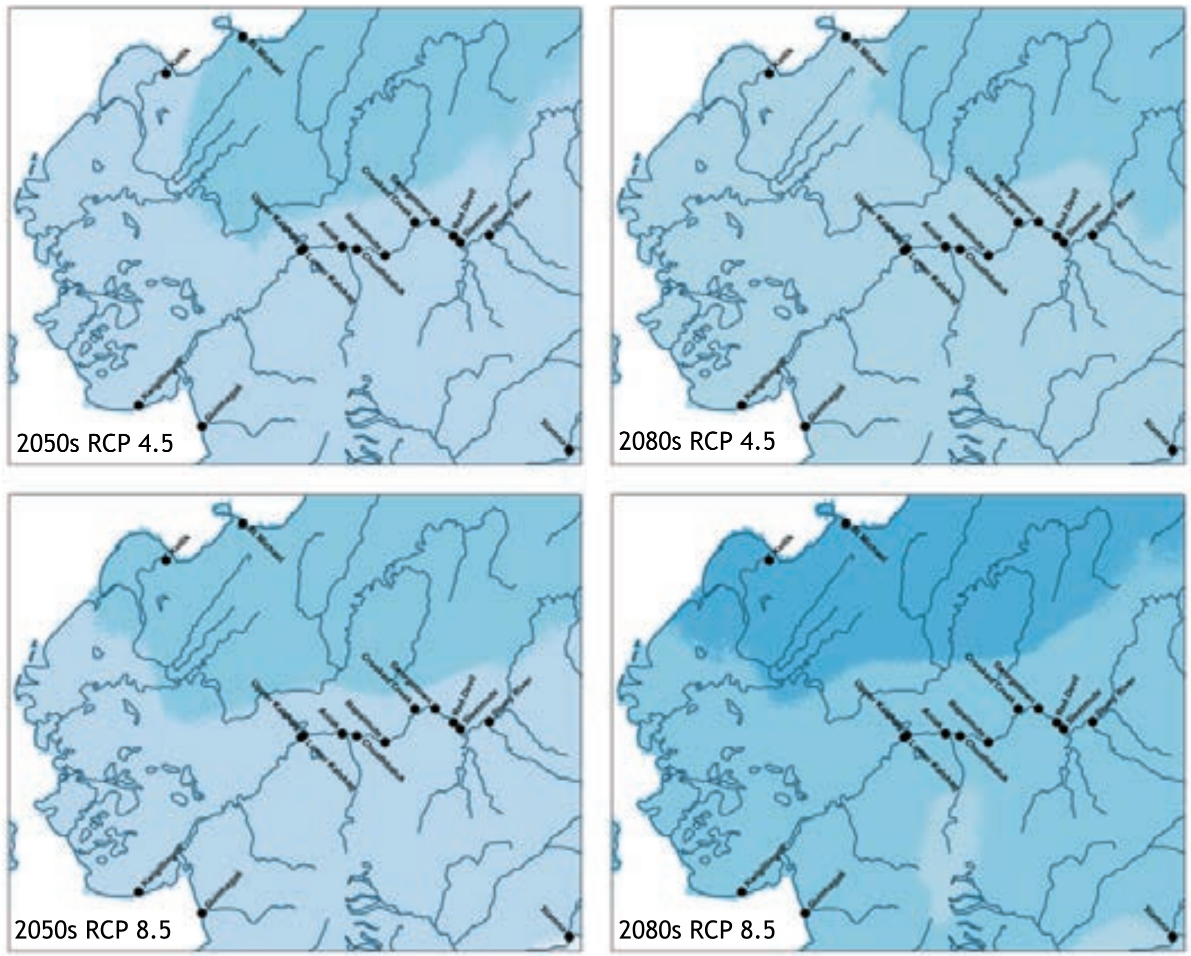
Figure 4: Change in Summer Average Precipitation over the Yukon-Kuskokwim Delta





These maps show changes in summer (JJA average) precipitation.

<u>5 model means for the region</u>

2040 – 2069, RCP 4.5: + 19%
2040 – 2069, RCP 8.5: + 17%
2070 – 2099, RCP 4.5: + 17%
2070 – 2099, RCP 8.5: + 24%

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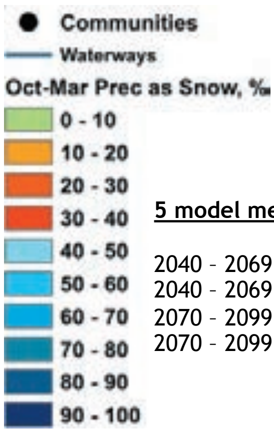
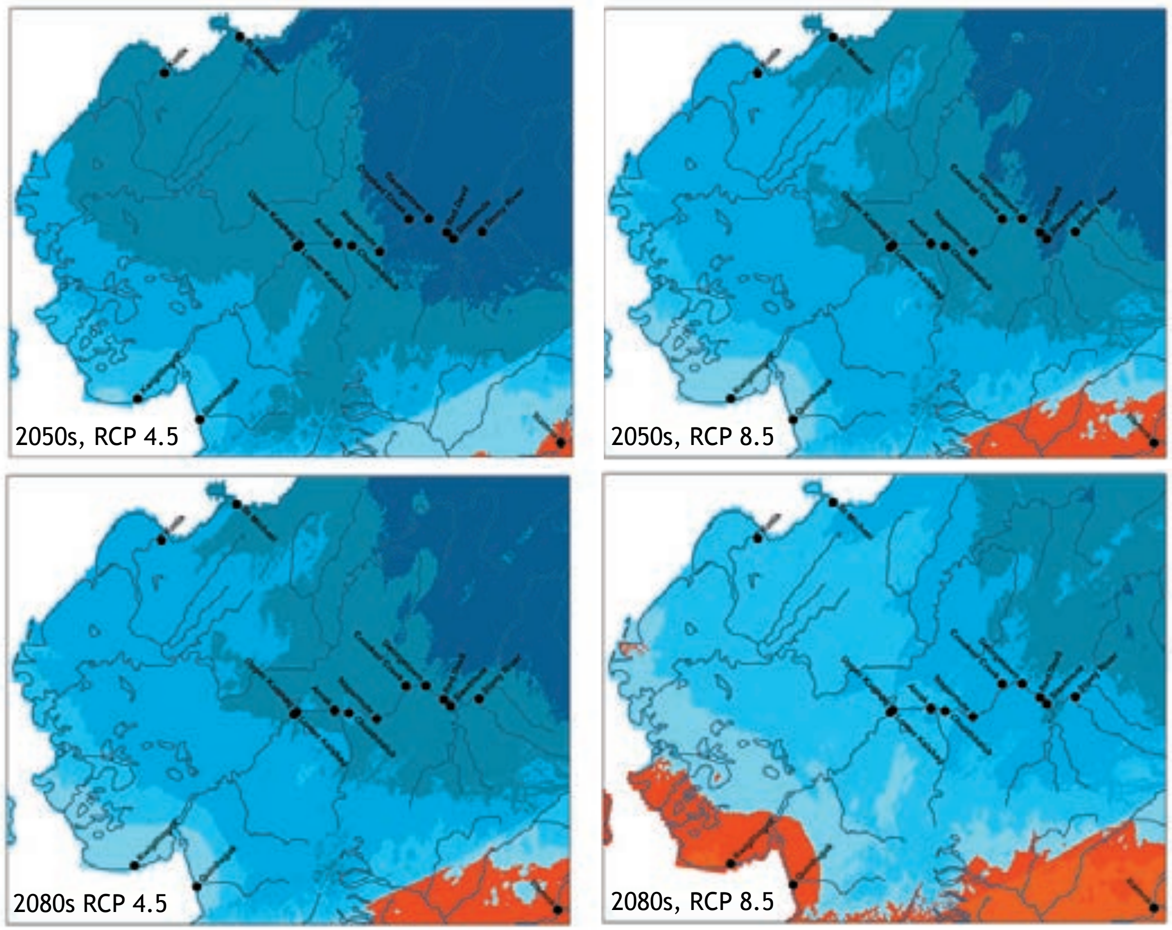
Snow index – October to March amount of total precipitation that is snowfall, measured By the amount of water it contains. These are displayed as a percent (a value of 55% would mean that 55% of the total precipitation falls as snow between October and March. 55% means that 55% of the precipitation was snow, while 45% was rain. Values greater than 40% are snow dominated; values between 10% and 39% are transitional; values between 0% and 9% are rain dominated.

Figure 5: Change in Snow Dominance over the Yukon-Kuskokwim Delta



<u>5 model means for the region</u>

2040 – 2069, RCP 4.5: 79
2040 – 2069, RCP 8.5: 77
2070 – 2099, RCP 4.5: 75
2070 – 2099, RCP 8.5: 64



These maps represent the amount of October – March precipitation that ends up in April 1 snowpack. Blues represent "snow dominated", where the annual runoff from precipitation is dominated by snow melt. Reds and oranges represent "transitional" watersheds, where the annual runoff is driven by both rain and snow. If there were greens on the map, they would be rain dominated. The middle Kuskokwim remains snow dominated, but moves toward transitional in these scenarios.

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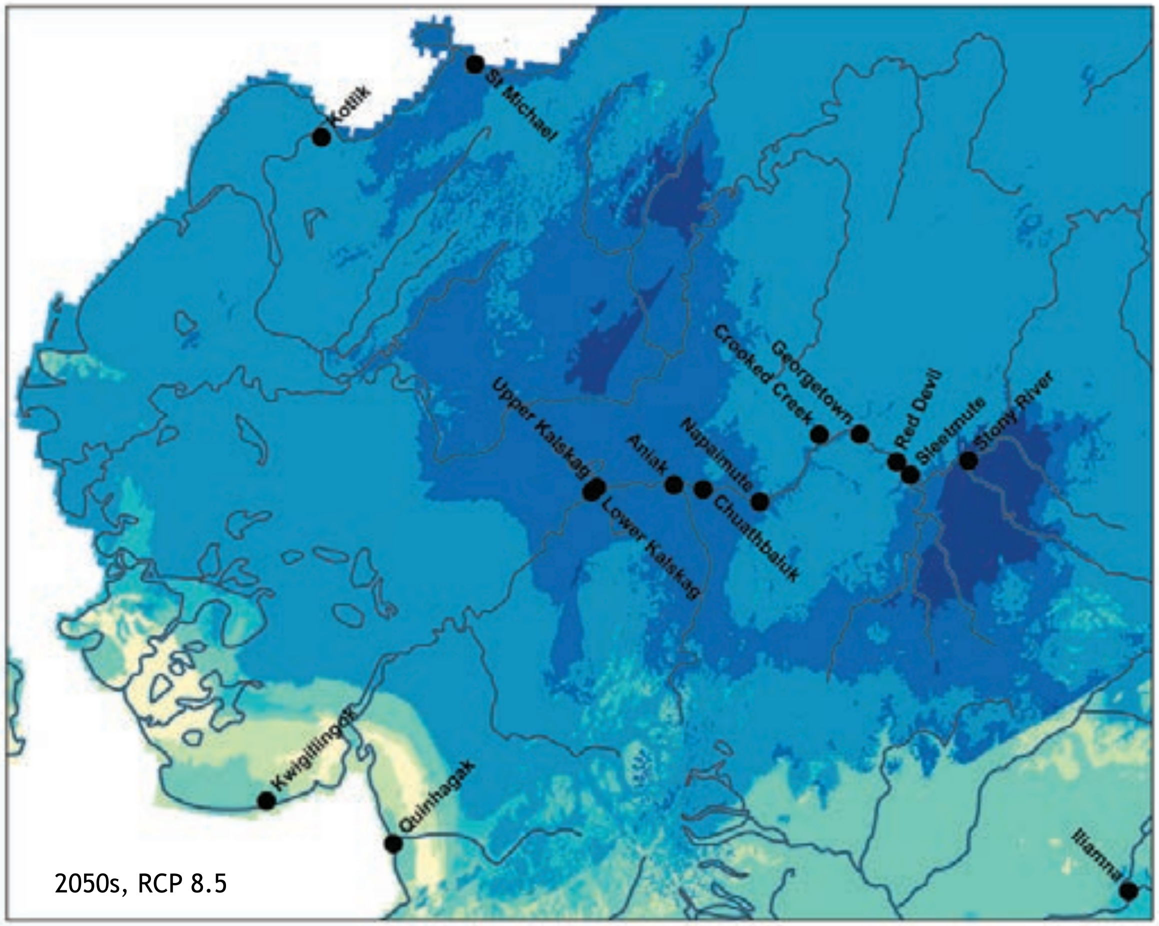
Change in months of reliable snow – For this map, a month with "reliable snow" was defined as a month where, on average, more than 70% of the precipitation arrived as snow. The historical (1970-1999) months of reliable snow were compared to the future (2040-2069) months of reliable snow for RCP 8.5 (higher emissions), and the change calculated as future minus historical.

Figure 6: Change in Number of Months with Reliable Snow Cover Between 2040-2069



This map shows the change in months of reliable snow, defined as 70% or more of the monthly precipitation arriving as snow. Some parts of the YK Delta loose as many as 5 or 6 months of reliable snow, suggesting a shift to mixed rain and snow in most or even all parts of the winter. The middle Kuskowkim loses 0 to two months depending on location.

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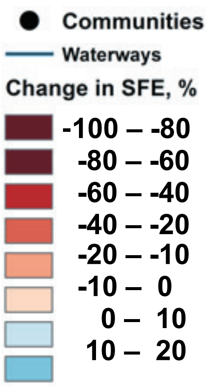
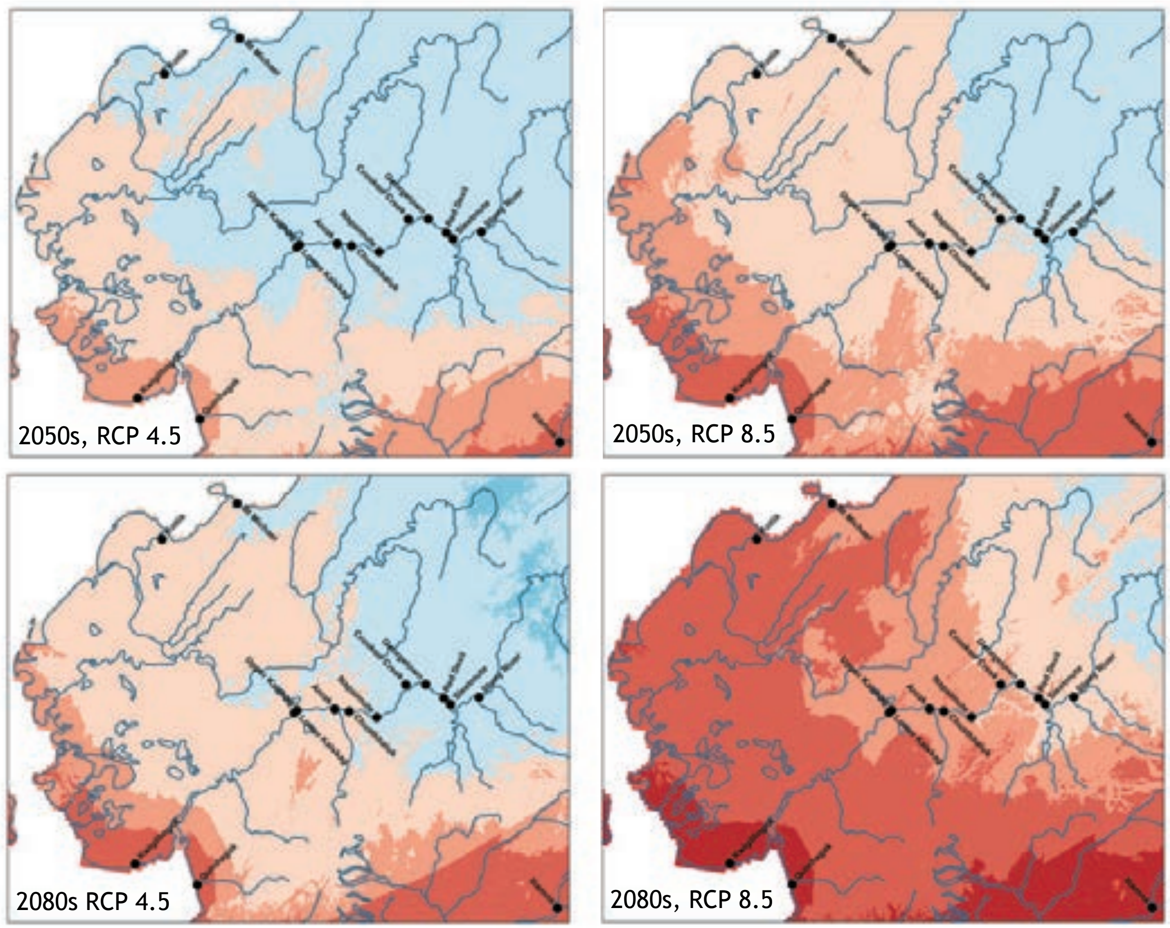
Snowfall, or snowfall water equivalent – October to March amount of snowfall, measured By the amount of water it contains. These represent the percent change in total snowfall. The changes mapped are compared to the same months in the historical projections from climate models.

Figure 7: Change in the Amount of Water Entrained in April 1st Snowpack over the Yukon-Kuskokwim Delta





These maps represent the change in the amount of October - March snowfall precipitation (snowfall water equivalent, or SFE) as an estimate of April 1 snowpack. Blues are increases, where it is still cold enough in the future for the increase in precipitation to arrive as snow. Reds indicate decreases in snowfall water.

<u>**5 model means for the region**</u>

2040 - 2069, RCP 4.5: + 4%
2040 - 2069, RCP 8.5: - 1%
2070 - 2099, RCP 4.5: + 2%
2070 - 2099, RCP 8.5: -13%

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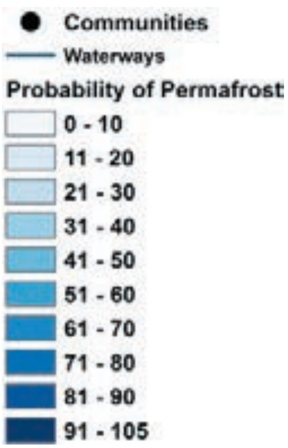
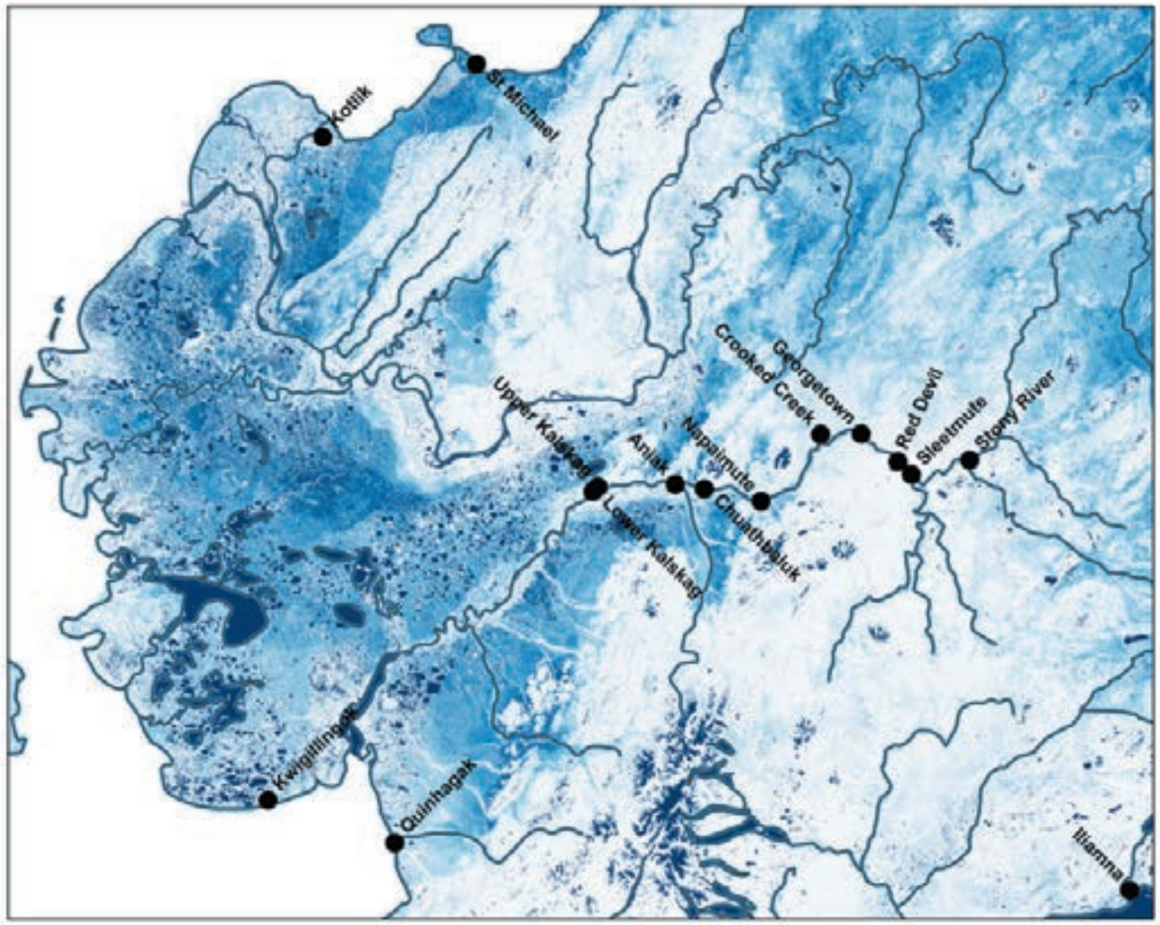
Ground temperature at 1m (3.3ft) depth – Annual average ground temperature at 1 meter (3.3 feet) deep in the ground. This is an index of permafrost stability or thaw. The colder it is, the more likely permafrost is to persist. Near freezing (0C or 32F), the permafrost is more likely to thaw. Above freezing, it is unlikely to persist into the future.

Figure 8: Current Probability of Permafrost





Pastick et al. current probability of near-surface permafrost, modeled from landform, vegetation, and climate data. Dark blues indicate higher prevalence of likely permafrost; lighter colors suggest permafrost is unlikely or sporadic

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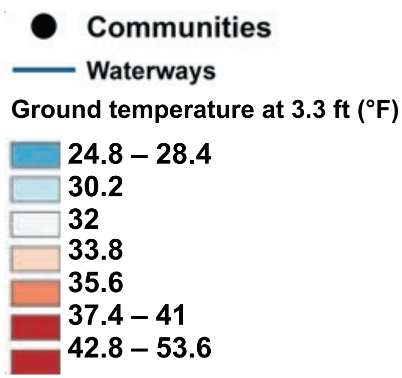
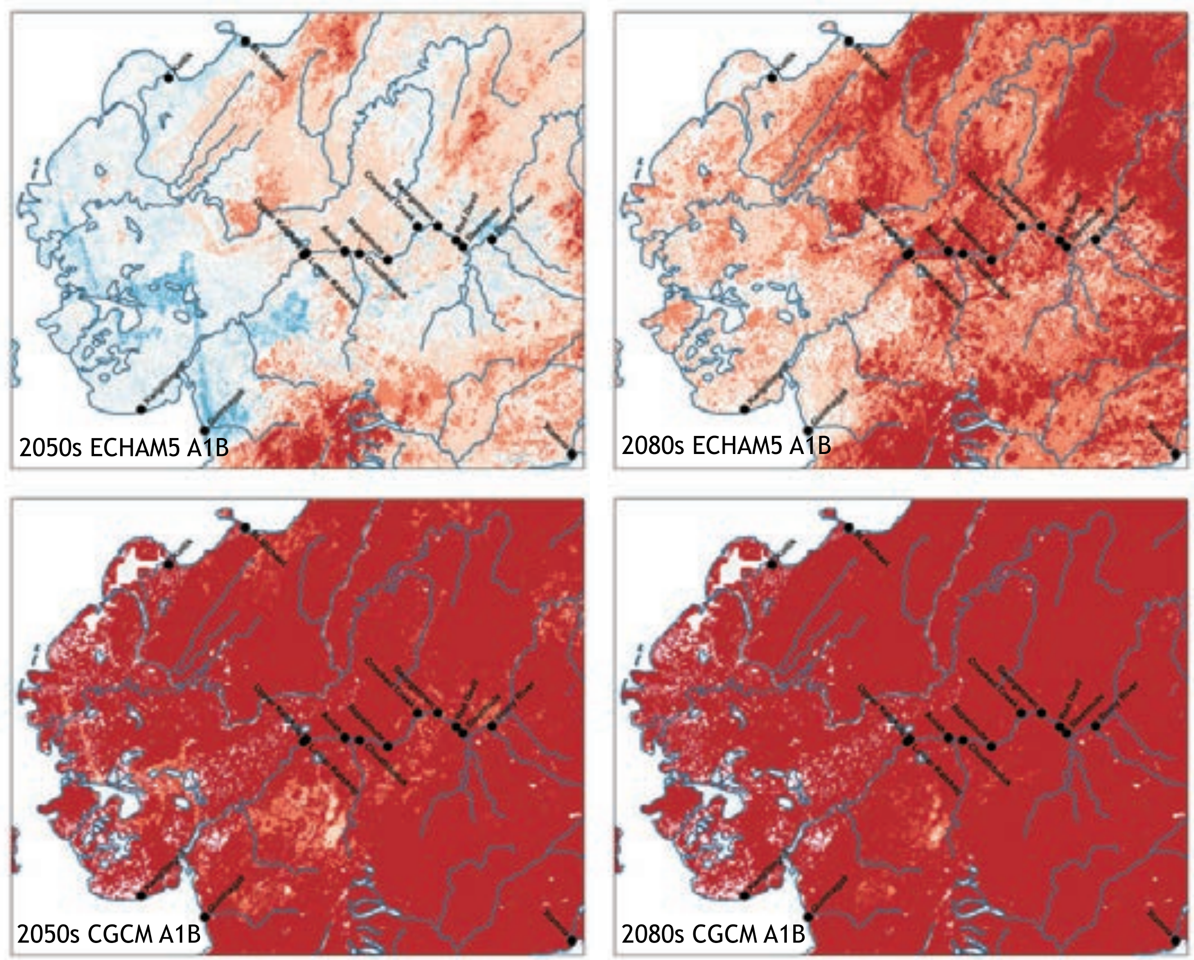
Current probability of permafrost – This map shows the current probability that the area has permafrost under it. Darker blue indicates a higher probability of permafrost.

Figure 9: Change Annual Average Soil Temperature at 1 Meter Depth





These maps represent the annual average temperature at 1m (~3.3ft) deep in the ground from the GIPL permafrost model. Places where this temperature is over -30.2 or 32 can't support near-surface permafrost, while places colder than that may. Only the coolest scenario indicates the potential for some permafrost persistence in the region.

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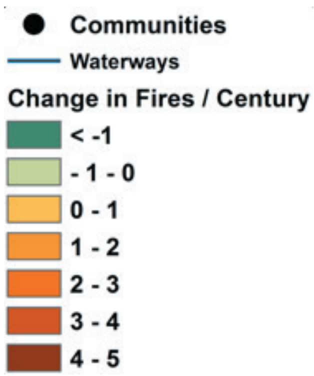
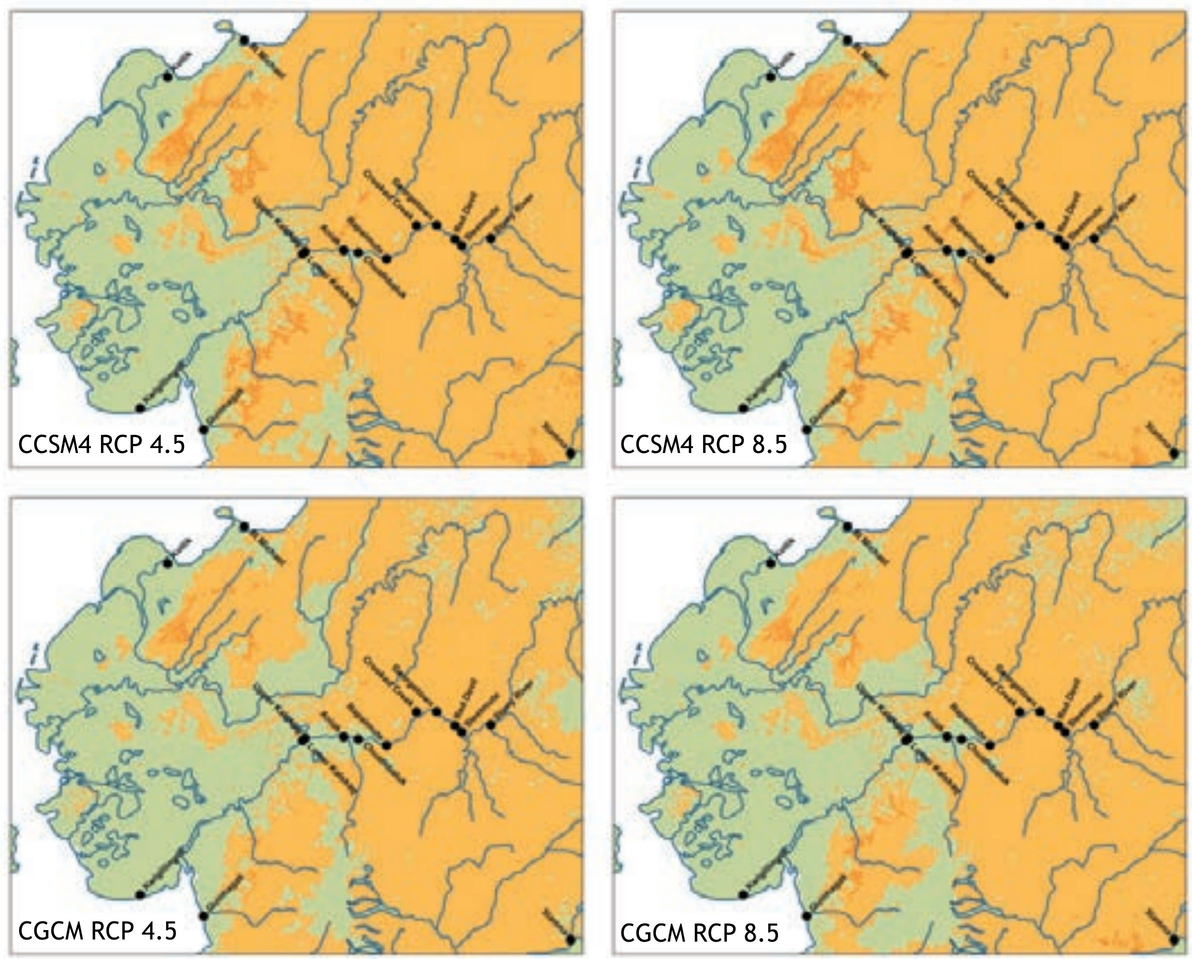
Changes in fires per century – The times an area burned under simulated historical (1901 – 2000) conditions is compared to the number of times an area burned under simulated future (2001-2100) conditions. Numbers over 0 mean an increase in fire (e.g., 2 would mean a doubling of fire frequency); numbers less than 0 mean a decrease in fire.

Figure 10: Change in the Number of Forest Fires per Century





These maps represent the change in the number of fires per century between 2000 and 2099 compared to 1900 and 1999 simulated by the ALFRESCO fire model. Negative numbers (greens) indicate decreases in fire activity from the 20th to 21st century, while positive numbers (yellows and oranges) indicate increases in fire activity. In this region, the light greens represent little change, but the smaller areas of darker orange indicate the potential for reburns faster than will support spruce forest, or rates of tundra burning that exceed historical.

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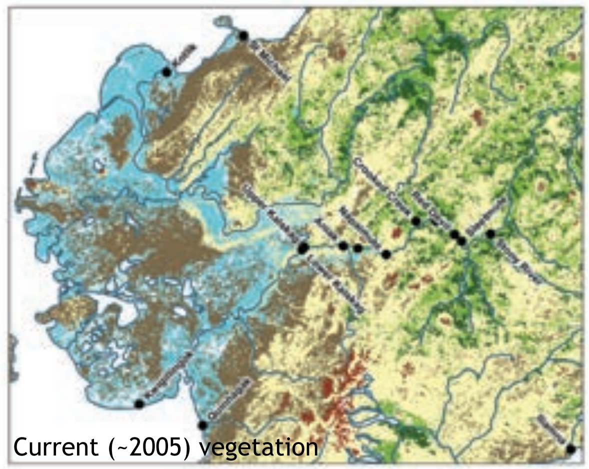
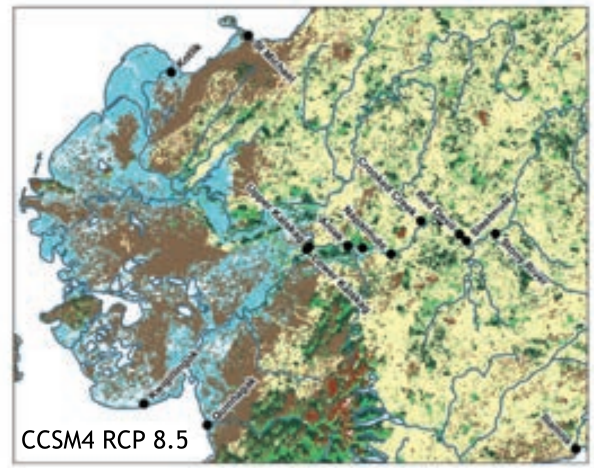
Changes in vegetation per century – The times the dominant vegetation in an area changed under simulated historical (1901 – 2000) conditions is compared to the number of times vegetation changes under simulated future (2001-2100) conditions. Numbers over 0 mean an increase in landscape change (e.g., 2 could mean a change from shrub tundra to spruce followed by a change to deciduous forest).

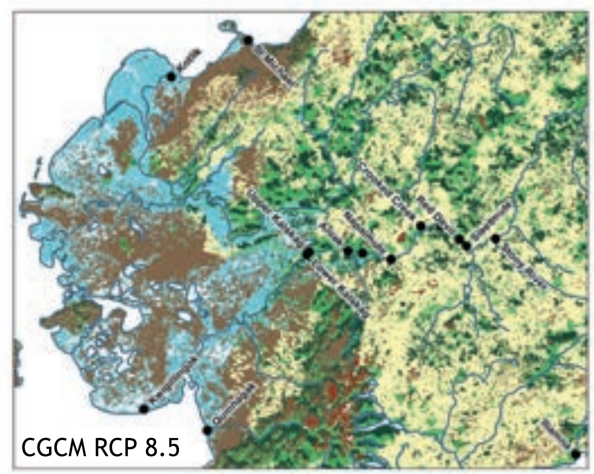
Figure 11a: Change in Dominant Vegetation per Century

Future vegetation changes simulated by the ALFRESCO vegetation model project spruce will establish in the southwest part of the region east of Quinhagak. Similar establishment occurs in both climate models in the middle Kuksokwim valley between Lower Kalskag and Napaimute. In the CGCM model, this establishment is also evident further upriver toward Sleetmute.

In much of the middle Kuskokwim, current spruce forests transition to deciduous forests as a result of the increase in fire activity. This change is more evident under the CCSM4 climate model than the CCSM4 climate model.







Current and 2100 modeled vegetation

Not modeled	Deciduous forest	Wetland tundra
Black spruce	Shrub tundra	Lichen / moss / barren
White spruce	Grass tundra	Heath

SNAP

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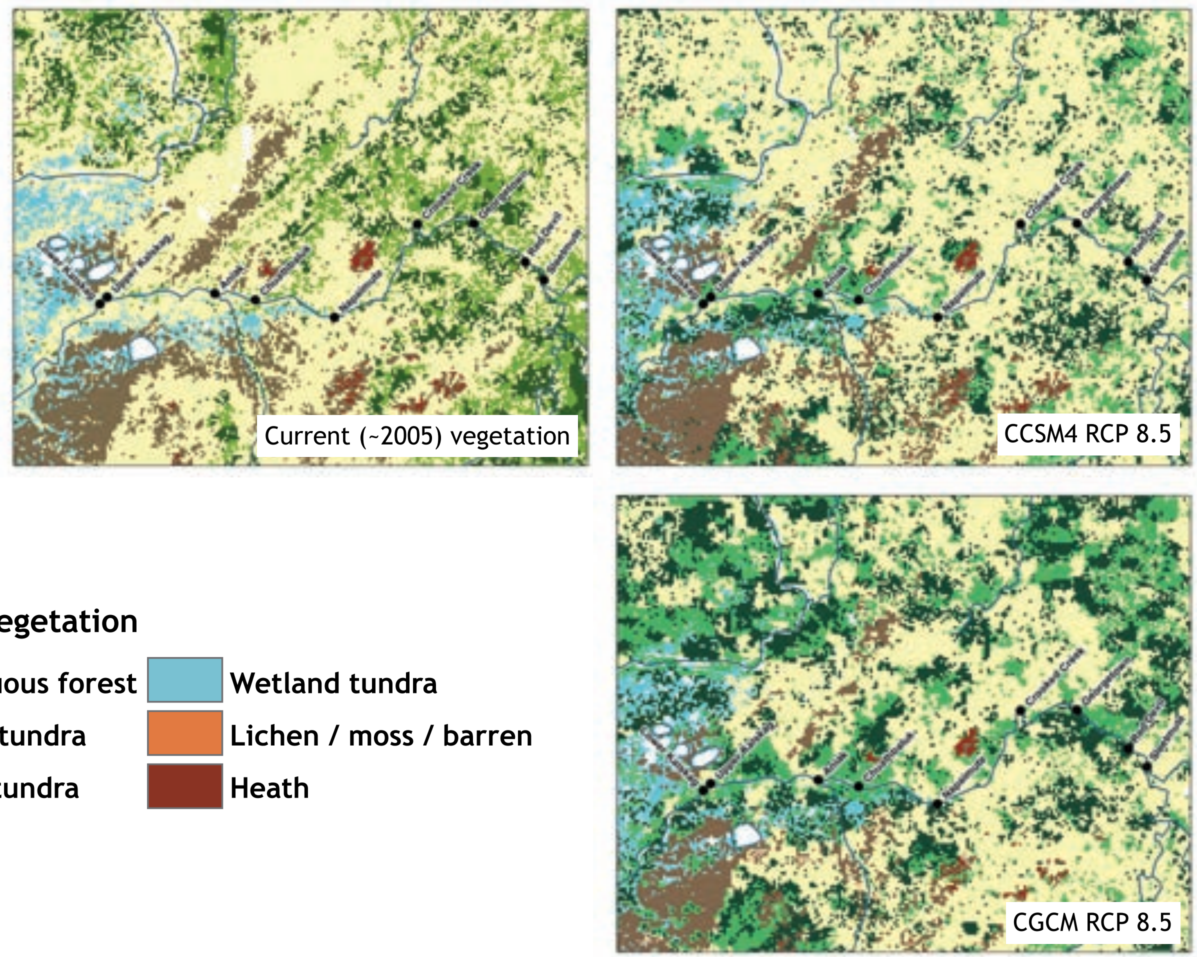
Figure 11b: Current Local Vegetation Compared to 2100 Modeled Vegetation

Future vegetation changes simulated by the ALFRESCO vegetation model project spruce will establish in the southwest part of the region east of Quinhagak. Similar establishment occurs in both climate models in the middle Kuksokwim valley between Lower Kalskag and Napaimute. In the CGCM model, this establishment is also evident further upriver toward and northeast of Sleetmute.

In much of the middle Kuskokwim region, current spruce forests transition to deciduous forests as a result of the increase in fire activity. This change is more evident under the CCSM4 climate model than the CCSM4 climate model.



Current and 2100 modeled vegetation

Not modeled	Deciduous forest	Wetland tundra
Black spruce	Shrub tundra	Lichen / moss / barren
White spruce	Grass tundra	Heath

SNAP
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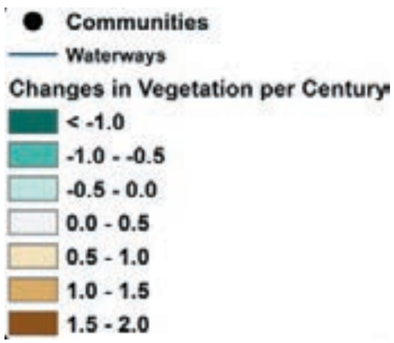
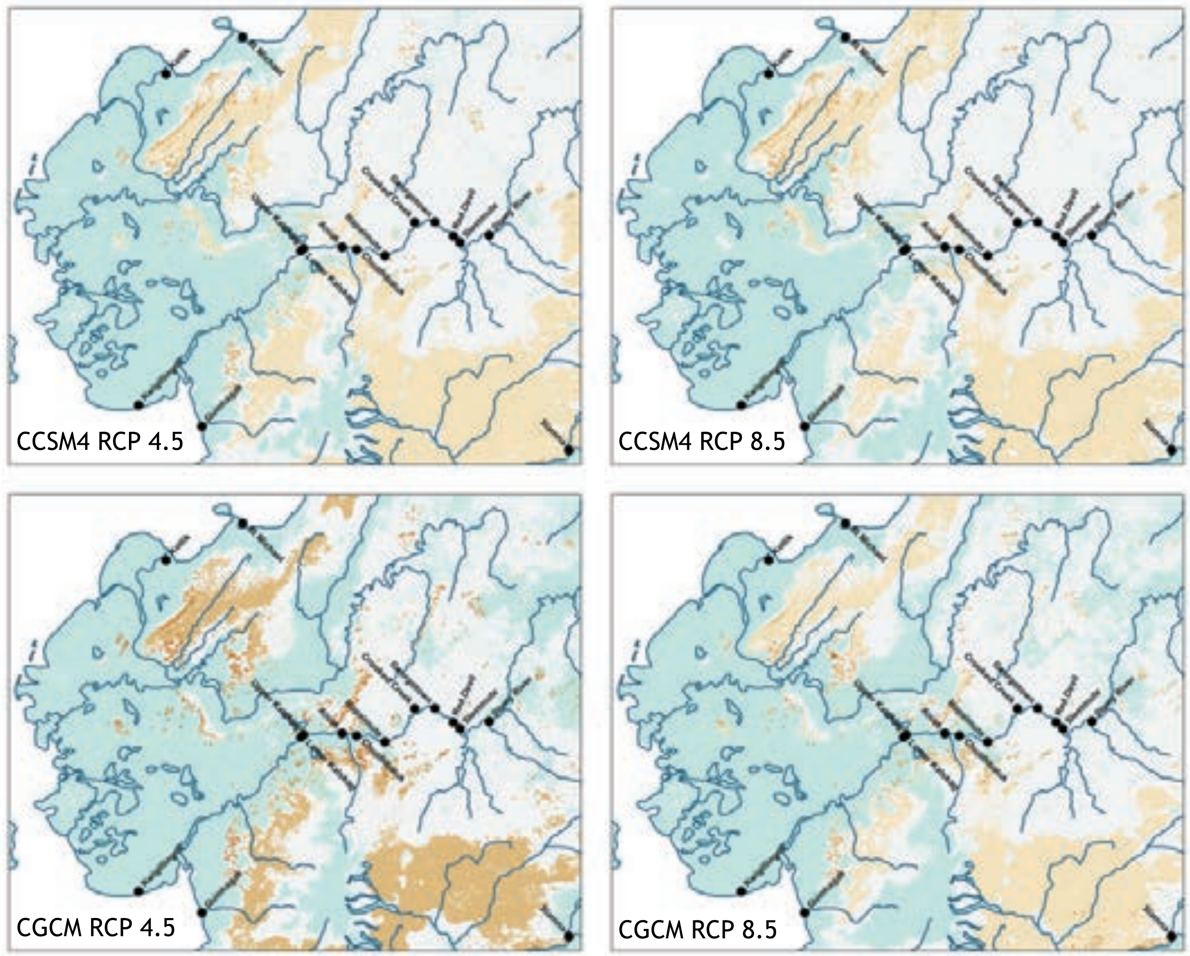
Figure 12: Changes in Vegetation per Century





These maps represent the number of changes in the dominant ecosystem vegetation per century between 2000 and 2099 compared to 1900 and 1999 simulated by the ALFRESCO fire model. Negative numbers (greens) indicate decreases in rate of change from the 20th to 21st century, while positive numbers (browns) indicate increases in ecosystem type changes. In this region, the light greens represent less change, but the smaller areas of darker brown indicate the potential for faster vegetation change than historical.

Weed whacking at fish camp
Photo by Mary Peltola

Hoar frost
Photo by Patty Yaska

We would like to express our appreciation to our partners in the tribal governments and tribal organizations in the Middle Kuskokwim Region for making this project possible.

ALASKA NATIVE TRIBAL HEALTH CONSORTIUM

Native Village of GEORGETOWN

U.S. DEPARTMENT OF THE INTERIOR 1824 BUREAU OF INDIAN AFFAIRS