LOOKING FORWARD, LOOKING BACK

Building Resilience Today

Community Report

St. Michael, AK

October 2-4, 2019

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City of St. Michael - Harold Hawkins and Frank Myomic

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COMMUNITY DESCRIPTION*

St. Michael is located on the western coast of Alaska, in the Norton Sound of the Bering Strait region. It is 125 miles southeast of Nome and 48 miles southwest of Unalakleet. Taciq is the Central Yupik name for the community area, which translates as Sandspit. The village of Tachik is northeast of the current site. In 1833 the Russian-American Company established a trading post called Redoubt Saint Michael due to the natural harbor and proximity to the mouth of the Yukon River. Later during the goldrush of 1897, St. Michael's population grew to 10,000 as it was a major hub for those in route to Interior Alaska.

The current population is 474. The beach is a beautiful black volcanic rock and the land is elevated. Clear Lake provides St. Michael with water filtered from the volcanic rock. The community is governed by the St. Michael Tribe, which owns a herd of reindeer that is available to the community as a food source. The City of St. Michael was created in 1969, and St. Michael Native corporation established under the Alaska Native Claims Settlement Act in 1971.

With a warming climate, the community is facing permafrost degradation, erosion, loss of sea ice and an increase in extreme heat events, which impacts subsistence food sources, travel and safety, human health and local infrastructure.

* Compiled from D. Chiskok's draft community description during the LFLB BRT Intensive Work Session, March 5, 2020. Anchorage, AK and the State of Alaska Division of Community and Regional Affairs Community Database Informational Portal

PROJECT DESCRIPTION

The Alaska Climate Adaptation Science Center (AK CASC), in partnership with the Aleutian Pribilof Islands Association (APIA), designed the Looking Forward, Looking Back: Building Resilience Today (hereafter 'BRT') project as a series of trainings and workshops with tribal community leadership and members. The overarching goal of the project was to collaboratively develop the Indigenous knowledge and western science knowledge for adaptation planning. We worked with five community teams consisting of up to four leaders from communities that chose to participate in the project: Iliamna, Kotlik, Kwigillingok, Quinhagak, and St. Michael. Community teams were developed through the application process and the project duration. Community teams were encouraged to have involvement from multiple governing bodies within the community that could include the Tribal Council, city government, and village corporation. The project title, with its references to the future (Looking Forward), past (Looking Back), and present (Building Resilience Today), refers to the idea that adaptation planning relies on all three perspectives. Equally important, however, is the dialogue to exchange past and present information, context, and what we expect in the future. Accordingly, two training sessions held at the International Arctic Research Center in Fairbanks, Alaska at the beginning and near the end of the project were developed to provide community team interaction with each other and with university and federal science partners. The project team also traveled to the partner communities and held a series of onsite events with community members to document locally-relevant information and share climate science tailored to the needs and conditions of each community. This report represents the community information shared during those onsite events. The Meeting Announcement (page 5) shows the date and description of the outreach events.

The purpose of these events was to: 1) facilitate mapping of a Traditional Use Area to refine an area for climate projections; 2) construct current and past seasonal Subsistence Calendars to identify important species and times of the year; 3) document Indigenous and local knowledge from current community members about environmental changes they have observed over their lifetimes; and 4) assist with documenting what the community perceived to be climate-related issues through photos and interviews. The agenda of the visits was co-produced with the community team. In each community, the community team and the project team co-hosted an open-to-the-public meeting and met with various groups. The community team advertised the meetings by posting community fliers, making announcements on the community radio, and reaching out to individuals that would contribute to the engagement discussions. Each community meeting focused on activities to develop seasonal Subsistence Calendars, map Traditional Use Areas, and document observed environmental changes. Community members spent time at stations dedicated to each of these activities working with project team members. The project team also met with various groups of individuals that included village corporation, tribal council, and city representatives where additional information about observed environmental changes was gathered. This community report presents some of the information developed in these activities.

MEETING ANNOUNCEMENT

CLIMATE CHANGE IN ST. MICHAEL

Share your experiences.

A team of St. Michael community leaders, along with the Aleutian Pribilof Islands Association and the Alaska Climate Adaptation Science Center, invites you to attend a series of community events on **October 2nd-4th** to discuss climate change impacts and gather information on changes to local lands, waters, and fish and wildlife.

Schedule

Event	Time & Location	Description
Work session with local community team	Wednesday, Oct. 2nd, 1:30pm Location: IRA Office	Review schedule of events and activities.
Meetings with City, Tribe, and Corporation leadership	Wednesday, Oct. 2nd, 4pm Location: City Bingo	Visiting partners and community team meet with local leadership.
School outreach 7-8th grade	Thursday, Oct. 3rd, morning hours Location: Anthony A. Andrews School	Explore the Arctic food web through Eco-Chains card game.
Community work session	Thursday, Oct. 3rd, 7pm Location: City Bingo	Hear about future climate change impacts projected for the St. Michael area and share information on community change.

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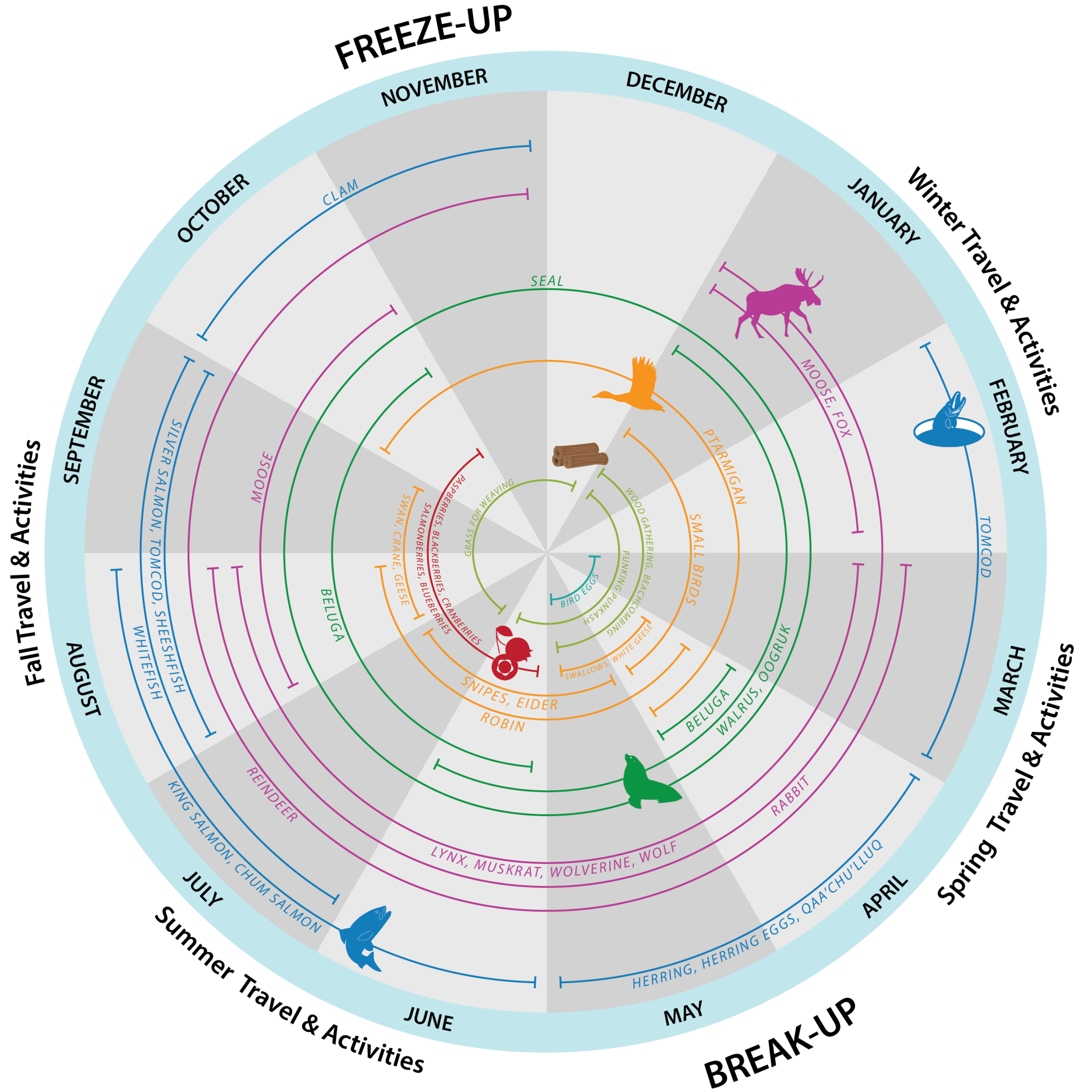


SUBSISTENCE CALENDAR

At the Subsistence Calendar station participants worked on two separate sheets of paper to list the many plant, marine mammal, fish, bird and animal species they rely on and harvest. One list focused on the current subsistence species while the other list focused on subsistence species in the past. After the list of species had been completed, participants then placed the species on a circular calendar during the time of year the species were harvested. In order to document observed changes, participants were asked to list past and current subsistence hunting or gathering practices, identifying any observed changes in the arrival, harvesting or hunting time of key species. This exercise provided an opportunity to recognize the variety of species that each community depends on and has concerns about. Participants also had further opportunities to share brief stories and observations of change.

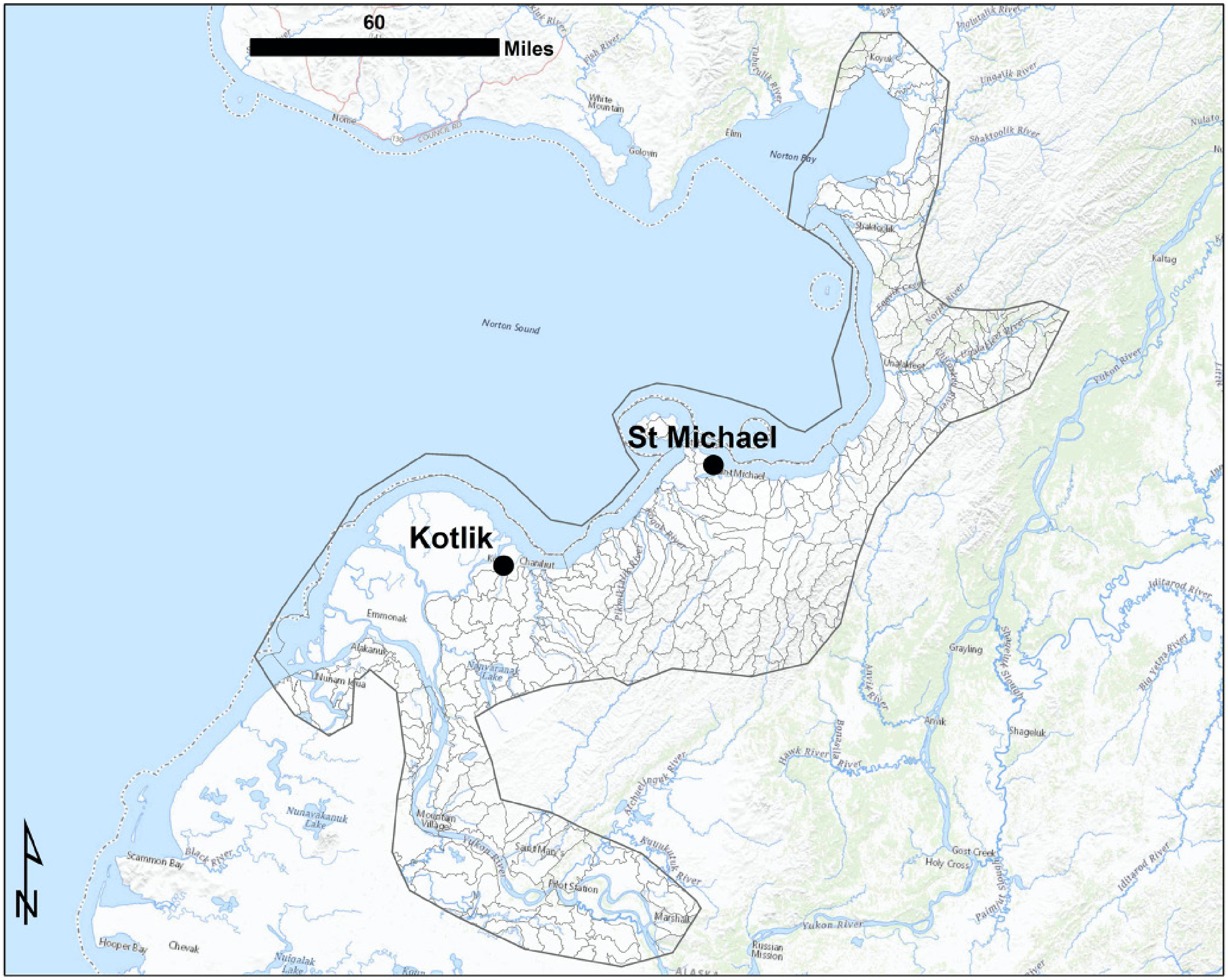
Participatory Mapping of Traditional Use Area by some community members of St. Michael.

ST. MICHAEL COMMUNITY MAP

St. Michael community members meeting with project team to discuss activities in the community.

Each Alaska Native community in Alaska historically had a Traditional Use Area, or traditional territory, prior to the 1971 passage of the Alaska Native Claims Settlement Act (ANCSA). Alaska Native communities still have common use areas that may be based on current land use and ownership, or historical land use. For this exercise, we asked communities to identify these areas. In addition, we asked communities to identify anywhere they traveled by foot, boat, ATV, or snow machine for purposes beyond subsistence that included potlatches, basketball tournaments, and other travel.

At the Traditional Use Area activity station, the project team provided the community teams and participants with large scale maps of the land and area around their villages (United States Geological Survey topomaps) and various colored markers. Working in their teams, they identified a use area by drawing directly on the large paper maps. Each community constructed their own legend that described the map they drew. The project team then used these maps to develop detailed regional climate projections for each community. Many communities identified general subsistence areas and routes taken to access these areas and other communities.



Footprint of the Traditional Use Area identified by participating St. Michael community members.

DIGITIZED COMMUNITY MAP

The community members outlined a Traditional Use Area during community meetings. Areas and trails were drawn on a printed USGS map. These were transferred to a digital representation using computer Geographical Information System (GIS) software (ESRI ArcMap within the GIS). A 'footprint' of the area was also created that encompassed the entire Traditional Use Area. Participants have a digital version of their Traditional Use Area for future purposes. These digitized 'footprints' were then used to refine the spatial extent of the climate projections averaged for the region of interest.

School in St. Michael.

ENVIRONMENTAL OBSERVATIONS

During the public community meetings and the smaller group meetings during the community visits, participants were asked if they had observed any environmental changes throughout their lifetime. These observations were documented and attributed by the project team during the community visit. After the community visit, project team member R. Toohey organized observations into themes by one or more topics (traditional methods, subsistence, weather and climate, etc. – see below, pages 10-13) using a process called 'coding'. The same observation could belong to several different themes as long as it pertained to the theme in some way. These themes were developed from the observations so that community members could quickly find Indigenous and local knowledge that pertained to a certain subject. The community teams reviewed and agreed on these themes when they reviewed the draft documented observations during the second team training (see Project Description above, page 3).

Notes on observations were taken rapidly by hand in a necessarily informal form and were reviewed and appoved by the community. In the interest of preserving the words of the community as closely as possible to this original form, editing in the following section was kept to a minimum and only utilized to preserve space and increase readability.

Community team member Michelle Snowball shows St. Michael shore armoring to project team members Malinda Chase and Jeremy Littell. St. Michael's coastline is eroding due to permafrost thaw and changes in sea ice timing.

QUESTIONS

Community members raised the following questions during the community meeting activities:

Do we need to relocate? - Michelle

How is permafrost thaw going to affect our infrastructure? - Michelle

OBSERVATIONS

In the distance, the eroding coastline of St. Michael.

Weather & Climate

- Big change in system. Water warmed up really fast. - Charlie
- Hotter. - Unattributed

Snow

- Older son is 25 years old, when she was pregnant with him, tons of snow on Halloween. Now, no snow on Halloween or turkey tournament too (around Thanksgiving). Now nobody can come by snowmachine. - Bobbi

Ice

- Lots of open water from here to Nome last winter. - Michelle & Darlene
- We used to have ice, now we don't have ice. It affects seals and temperature of the ocean. - Charlie

Wind

- Hurricane force winds going straight, not in circles. - Unattributed

Seasons

- Spring time comes earlier. - Charlie

Vegetation

- Lots more willows. Vegetation is taller, tougher to walk. through. - Bobbi
- Willows are moving down from the mountains and lining the roads too. - Michelle
- Grass is growing all over (everywhere) more than tundra, very tall. Willows coming down from the mountains. It follows roads, really tall. Alders coming in and spruce in the mountains. - Harold and Michelle.

Water

- Sinking holes, drying lakes. - Michelle & Darlene
- Water warmed up really fast. - Charlie
- Near Nome, we have warm water, new fish coming. - Charlie
- Lakes drying out around the drinking water source lake. - Michelle & Robin

Flooding

- More flooding, higher storm surges. We relocated five homes from the coast to higher ground. Twenty-nine homes threatened by coastal erosion. - Michelle
- Increased storm surges running into the lake. - Unattributed
- Kotzebue flooding. - Unattributed
- Coastal impacts - facing flooding. - Unattributed

Many buildings within the community of St. Michael are low-elevation or on eroding bluffs.

Land

- We could never see the lights at the airport, now we can because the land is sinking. Lots of power poles slanting/leaning. Houses getting big gaps under them from leaning. - Michelle & Darlene

Erosion

- Access to the coast is harder because of calving coastlines. Now we have steep access, when before it was more gentle and easier to descend. - Darlene
- Twenty-nine homes threatened by coastal erosion. - Michelle
- More erosion - Unattributed
- From coastal erosion, old graves (from the tuberculosis era) were exposed in the coastal bluffs. - Bobbi

Subsistence

- Fish, animals, birds dying off. - Charlie

Salmon

- Salmon had some with red lesions, slimy, smelled bad. - Harold

Other Fish

- Near Nome, they have warm water. New fish are coming. - Charlie
- Herrings were earlier. - Unattributed

Small Mammals

- Porcupines too, coming down from the mountains, some dogs have had run ins. - Bill
- Marmot and porcupine now in village (new). - Kathleen

Seals

- No seals (all fall so far) in ocean right now, usually a good hunting time; not seen one seal. - Michelle
- We used to have ice, now we don't have ice. That affects seals and temperature of the ocean. - Charlie

Moose

- You used to see Yukon Delta full of Delta moose. - Charlie

Caribou

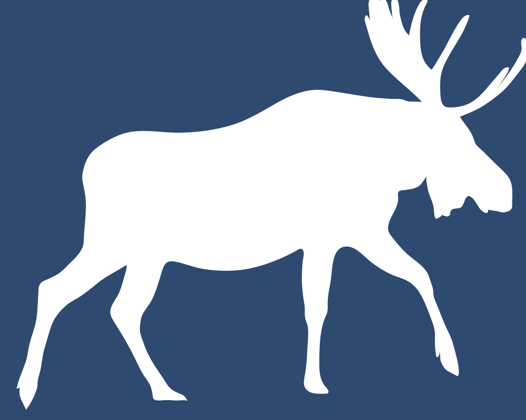
- Difference in animal migration. There are no more caribou. - Charlie

Birds

- No more puffins (egg gathering). - Michelle

Otters

- We have seen more otter. More otters moving into the area. There are otter out on the point. - Michelle & Darlene



Public Health

- Frozen water and sewer line. Construction around our water source. - Unattributed

Frogs

- More frogs, spiders. - Bill

Infrastructure

- Lots of power poles slanting/leaning. Houses getting big gaps under them from leaning. - Michelle & Darlene
- Relocated 5 homes from the coast to higher ground. Twenty-nine homes threatened by coastal erosion. - Michelle
- Lakes drying out around the drinking water source lake. - Michelle & Robin
- Old graves were exposed (from TB era) in the coastal bluffs. - Bobbi
- Planning inland move. - Unattributed
- Consider changing water source due to drying of lake. - Unattributed

Fire

- New tundra fires on nearby point. Really hard to put out. It kept reigniting after they thought it was out. - Bobbi
- There was more smoke this summer. One fire even burned through the winter time. - Michelle
- Could see embers from house. - Harold

Insects

- More frogs, spiders. - Bill

Miscellaneous

- More jellyfish. - Unattributed

Jeremy Littell goes over climate scenarios and projections with some of the St. Michael community members.

SNAP ONLINE TOOLS

Overview

The second Fairbanks training (see project description, page 4) introduced community teams to online climate information tools developed by The Scenarios Network for Alaska and Arctic Planning (SNAP) at University of Alaska Fairbanks, where the training was held. The goal of these sessions was to introduce community team members to how they might use these tools to develop information for their planning efforts and to learn more about potential impacts in their regions. For this report, the region around each community was considered and a specific narrative for that region was developed to illustrate the potential changes and impacts indicated by each tool. The following pages illustrate the results from each tool for Quinhagak.

To explore how climate change might affect youuse the SNAP web tools at https://www.snap.uaf.edu/tools to get a hands-on, user-friendly overview of how climate change may affect regions or resources of concern to you. Many of these tools were introduced during the BRT Training 2 in Fairbanks. All of them can be freely shared. The summaries below help explain the results from each tool for St. Michael.

Questions & Feedback

SNAP is always seeking feedback about the usefulness of our online tools, and about the way we share climate change information. As you read through this document and explore these online tools, it may help to keep following questions in mind – and to think about how your feedback might help us improve:

1. How do changes in average temperatures affect your experience on the land in both the short-term and the long-term? Are short-term effects such as extremely hot days more important, or are long-term trends such as loss of permafrost and river ice more important?
2. What effects that you are experiencing can be linked to changes in vegetation? Which aspects of climate (e.g. hotter summers, fewer cold winter days, drying soils) do you think are most important in causing these changes in vegetation?
3. Is loss of sea ice important to your community? Directly, or only indirectly? What do you think would happen if sea ice almost entirely disappeared in the Bering Sea?
4. What would you like to measure and track in your community (e.g. water temperature, berry crops, dates of seasonal events, numbers of animals sighted) in order to get better data on climate change?

About SNAP

The Scenarios Network for Alaska and Arctic Planning (SNAP) is a climate change research group in UAF's International Arctic Research Center (IARC). Since 2007, SNAP has used climate data to create and share ideas of what a future Northern climate could look like. SNAP works with people, communities, and organizations to plan for a changing climate. To learn more about climate models, methods and projects in Alaska, visit SNAP's website at www.snap.uaf.edu. Some of these data were used to create climate projections for the BRT project.

SNAP

Community Climate Charts

https://snap.uaf.edu/tools/community-charts

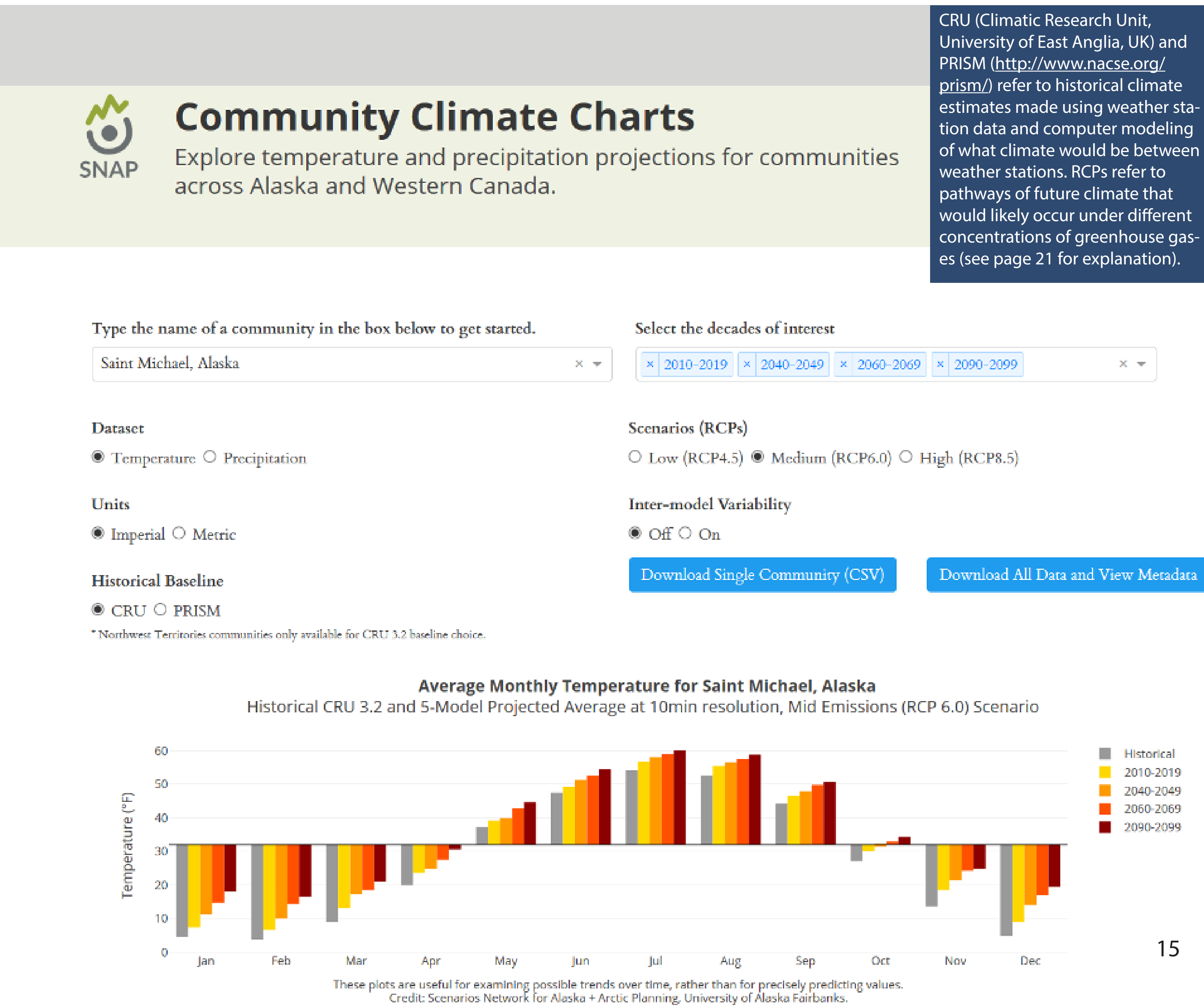
The Community Climate Charts tool allows users to select their own community, and view a graph of temperature or precipitation projections by decade, as compared to historical baseline values. In this case, Saint Michael has been selected, and the graph shows temperature for the past, for the approximate present, and for future decades.

Note that overall changes in temperature tend to be greatest in winter, but shifts in fall and spring freeze and thaw may prove to have the greatest impacts. For example, although historically the month of October had average temperatures well below freezing, by the end of this century October is projected to average well above freezing.

Connections to changes described in St. Michael BRT community meetings and activities:

- No snow in fall, affects travel/snowmachines

CRU (Climatic Research Unit, University of East Anglia, UK) and PRISM (http://www.nacse.org/prism/) refer to historical climate estimates made using weather station data and computer modeling of what climate would be between weather stations. RCPs refer to pathways of future climate that would likely occur under different concentrations of greenhouse gases (see page 21 for explanation).



Community Permafrost Data

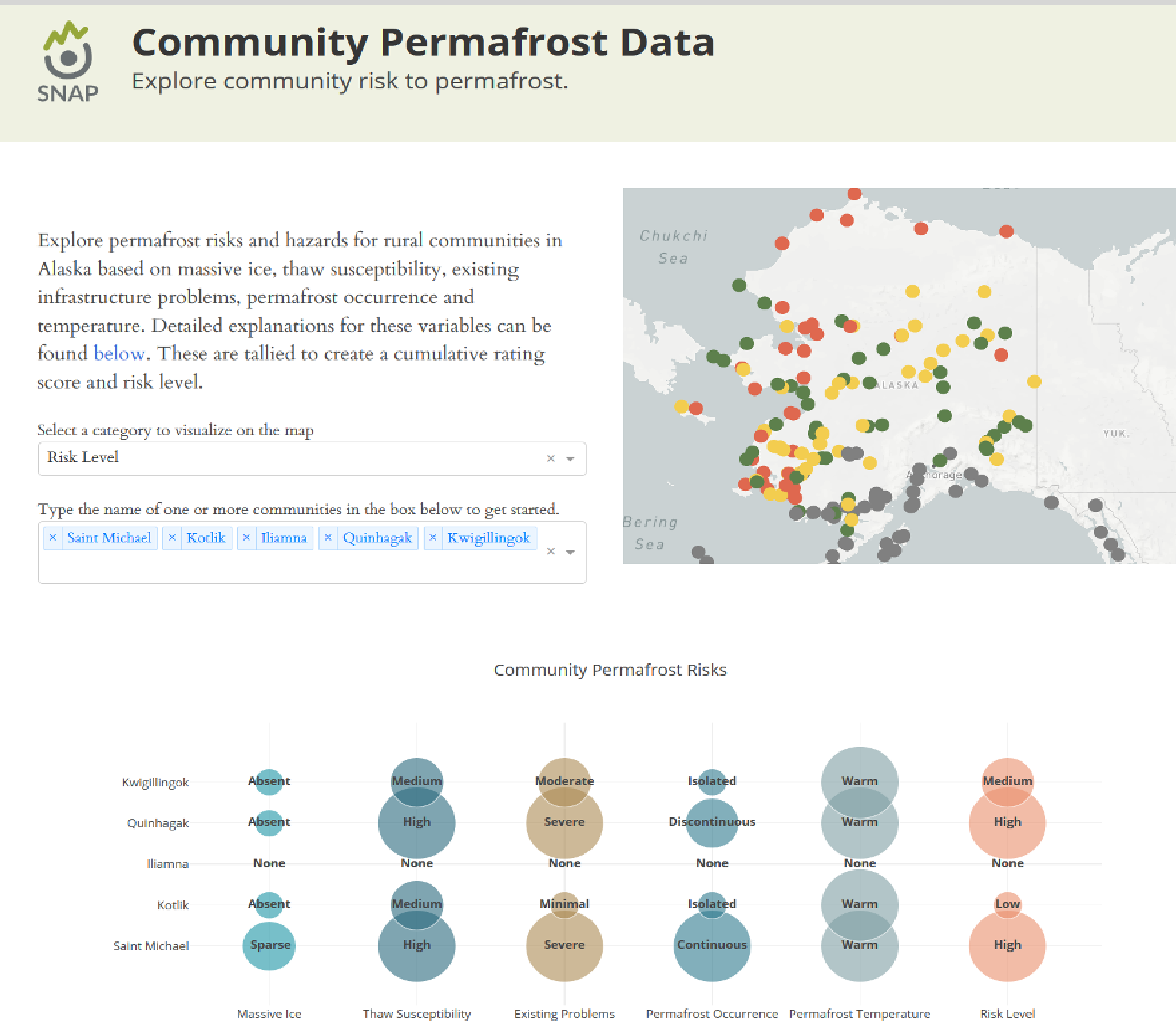
https://snap.uaf.edu/tools/permafrost

The Community Permafrost Data tool allows users to select one community or multiple communities, and to see relative conditions for several permafrost characteristics including: massive ice, thaw susceptibility, existing problems, permafrost occurrence, permafrost temperature, rating score, and risk level. Here, the project team selected all the communities that participated in the BRT project so that community team members can see the differences.

Note that variables are linked. For example, where permafrost has already been lost, risks are generally considered low. In Saint Michael, overall risk level is ranked as "high". Continuous permafrost is present, and is warm and at great risk of thaw in the near future. Existing problems are already severe.

Connections to changes described in St. Michael BRT community meetings and activities:

- Sinking lands poles tilting, houses with gaps underneath, leaning, 5 moved and 29 at risk
- Permafrost thaw, thermokarst, coastal erosion, slumping, preferential flow
- Drying lakes, may affect drinking water
- Graves eroding



Historical Sea Ice Atlas

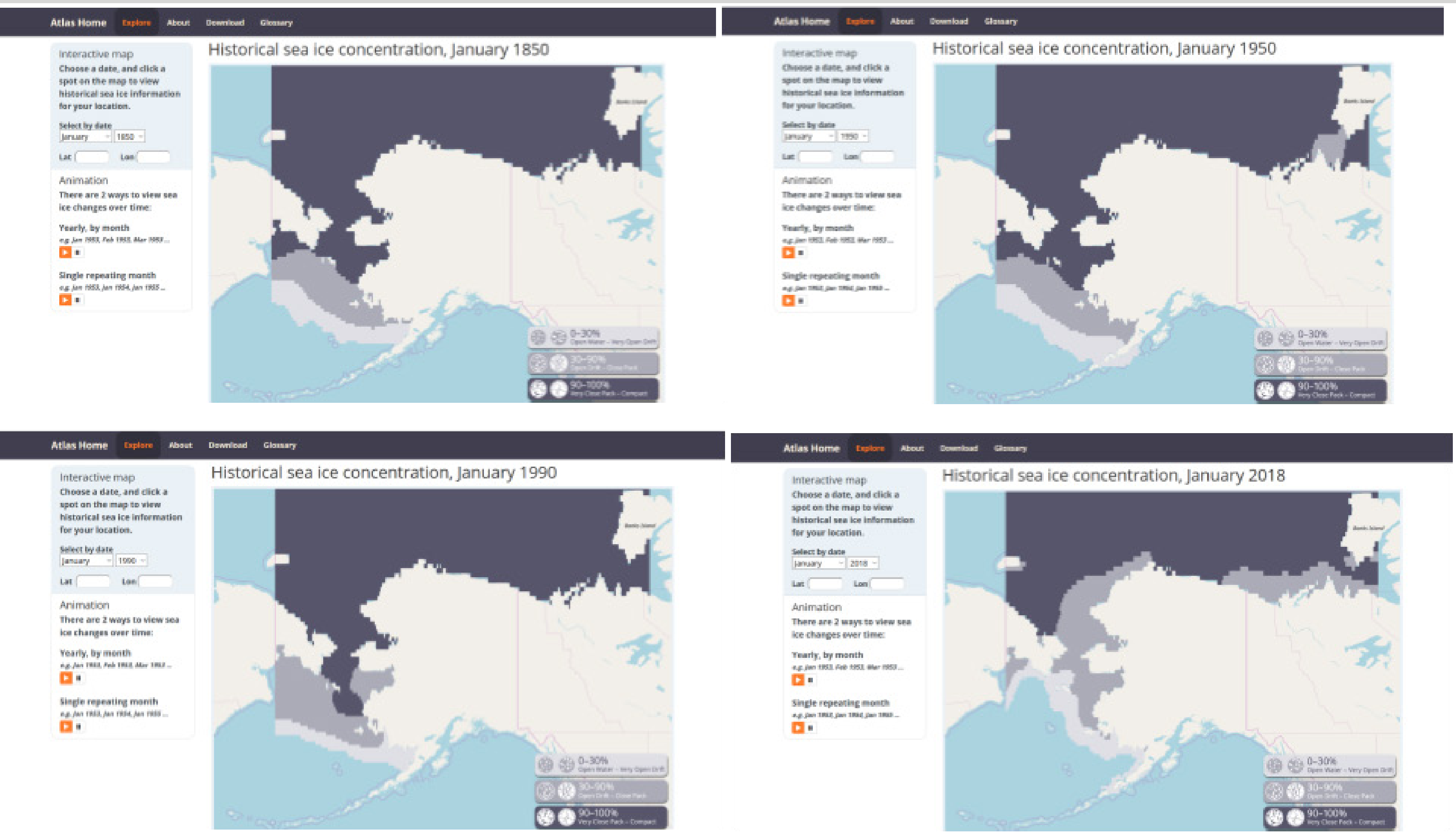
http://seaiceatlas.snap.uaf.edu/explore

The Historical Sea Ice Atlas shows historical sea ice for any month of any year from 1850 to the present. It can be animated to show change over time by month or by year. This tool does not provide future projections, but can be a useful visualization for showing trends that are expected to continue.

As shown in the figure and supported by local observations and memories, ice coverage used to be consistent, decade after decade. Declines started in the 1970s, and have continued thereafter. Around Saint Michael, areas that reliably had substantial or total ice coverage are now seeing poor ice coverage or open water. Seasons are becoming shorter in both spring and fall. Shorter ice seasons disrupt many species and many traditional activities.

Connections to changes described in St. Michael BRT community meetings and activities:

- Open water, ocean not freezing, no ice, affects seals
- More otters



Alaska Garden Helper

https://snap.uaf.edu/tools/gardenhelper

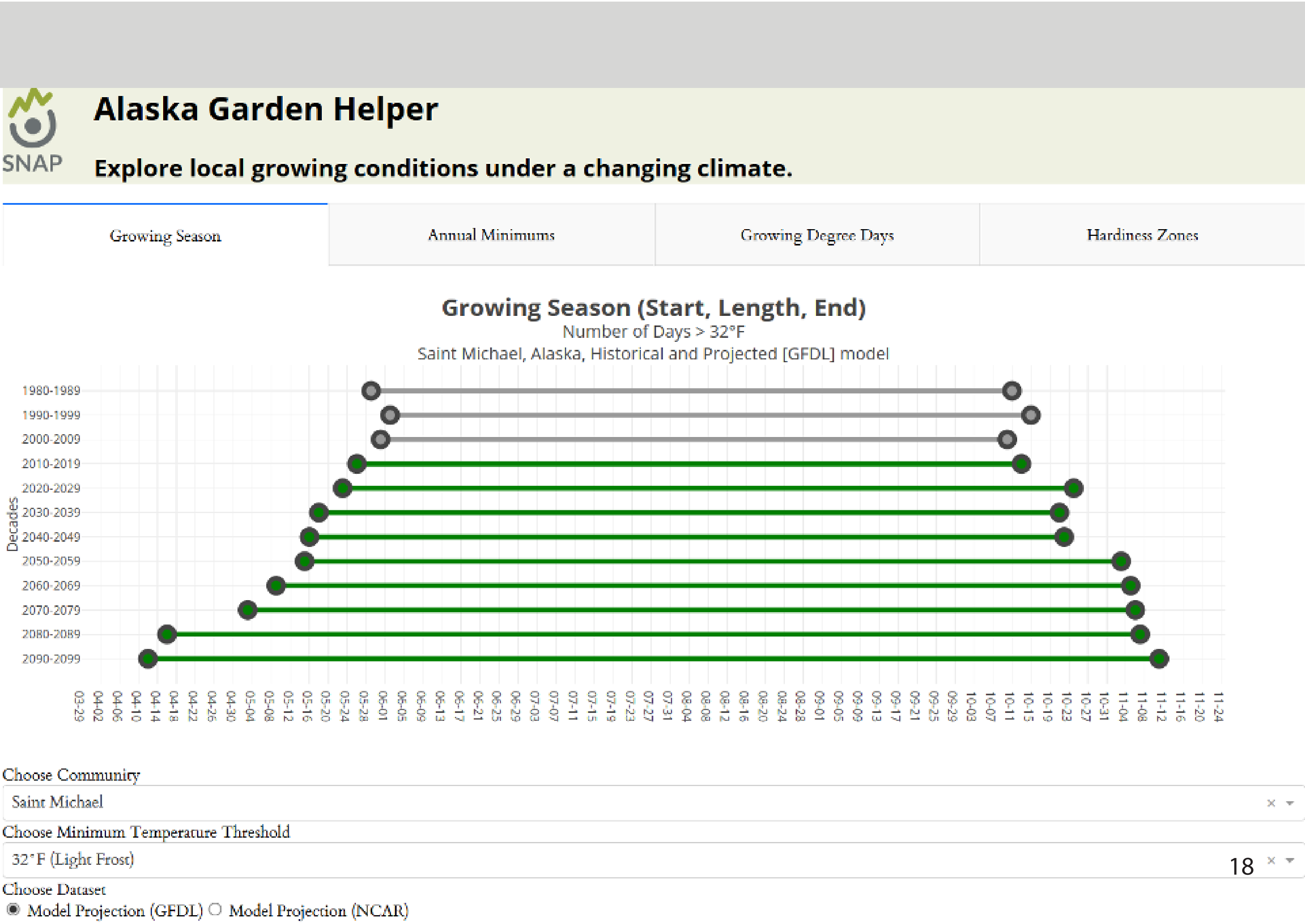
Though designed for gardeners and farmers, this Alaska Garden Helper tool provides useful projections of warm season length and extreme winter cold – variables that also affect natural ecosystems. Longer summers, hotter summers, and loss of limiting cold in winter can greatly change the plants and animals on the land and in the water – changes that community members are already reporting in St. Michael.

Users can select their community and can choose from several tools and temperature thresholds, including 28°F, 32°F, 40°F, and 50°F. Each selection will generate a new graph.

Summer season length in Saint Michael, as measured by the precise dates of last frost and first frost, will continue to be highly variable, since a difference of one degree can register as a large shift. However, on average the summer season will expand greatly into the spring and fall. Coldest winter temperatures will become much warmer, as shown by the "Annual Minimums" and "Hardiness Zones" tabs within this tool.

Connections to changes described in St. Michael BRT community meetings and activities:

- Grass, shrubs and taller vegetation, affects ability to walk, willow, alder, spruce

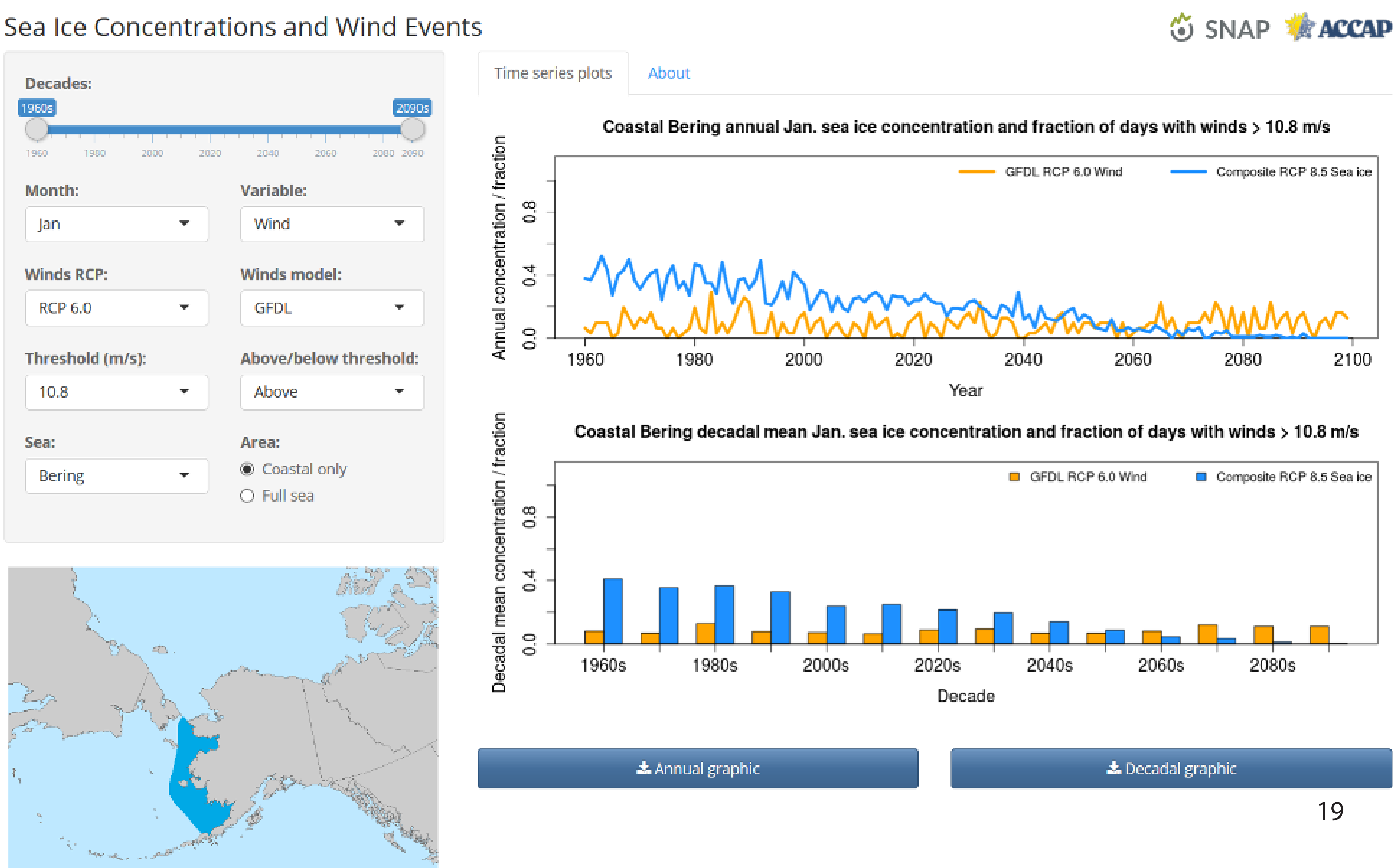


Sea Ice and Wind

https://://uasnap.shinyapps.io/sea_ice_winds/

This Sea Ice and Wind tool explores the interactions of wind and ice. Users can select a sea – in this case, the Bering Sea – and generate graphs for selected months and time periods.

Outputs for wind are highly variable, and may not indicate clear patterns of change, but outputs for ice show obvious severe declines, ongoing and into the future. These results are averaged across the area of the Bering Sea shown in the map, and thus are not specific to any one community. However, with normal variability in winds and wind events, loss of ice can lead to severe erosion throughout coastal regions.



Wildfire in Alaska

http://mapventure.org/#/map/fires

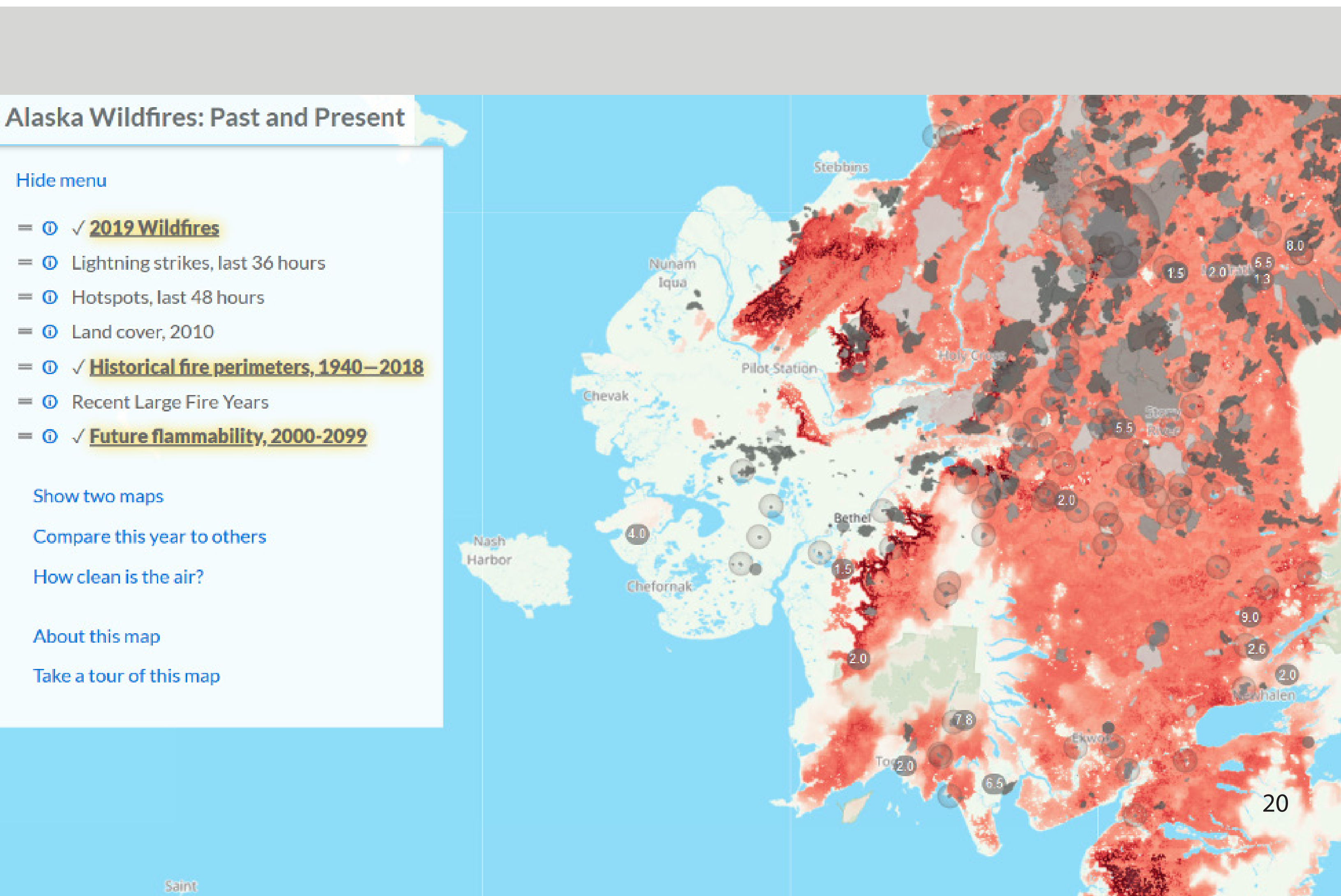
This Wildfire in Alaska map tool explores past and future fires statewide. The map is zoomable, and offers multiple features that can be turned on or off.

The map below shows eighty years of past fire scars, shown as gray patches. The summer fires of 2019 are shown as small gray circles. Note that many 2019 fires occurred in areas much farther southwest and much closer to the coast than typical historical fires. This map also shows modeled future flammability, with darker reds indicating larger changes in future flammability. See page 45 for traditional use area scenarios for changes in flammability. Due to hotter temperatures and expansion of shrubs and trees, flammability is spreading closer to areas such as Saint Michael that have little or no history of fires.

Smoke from fires can affect areas that are not themselves on fire or fire-prone. Thus, an increase in fires – particularly fires that are relatively close -- can affect the health, activities, and quality of life of community members in Saint Michael.

Connections to changes described in St. Michael BRT community meetings and activities:

- Tundra fires – smoke and danger.



CLIMATE CHANGE AND IMPACTS PROJECTIONS

Overview

In each community workshop, we reviewed potential future climate conditions and some changes in the environment that we would expect from those conditions. These future conditions are called "scenarios" because we don't know exactly what the weather and climate will be like, so we look at a range of possibilities from some warming to more warming. We also use two time ranges for these futures, 2040-2069 and 2070-2100, because different climate effects might take different lengths of time to happen. We learned in the Fairbanks trainings how scientists use complicated computer climate models to work out what the climate might be and how it affects fire, plants, and permafrost. We also learned that there are a lot of these models, and while all of them are scientifically reasonable, the future climates they project vary. So we also use the average of five different climate models for future climate scenarios. For the fire, land, and permafrost changes, two different climate models (a warmer one and one with less change) were used. At the community visits, we brought maps of these changes for the region and talked about them with community members.

For temperature, precipitation, and snow, the historical and future climate used to map changes came from University of Alaska Fairbanks Scenarios Network for Alaska and Arctic Planning (SNAP). Climate models simplify the real world, and this computer version of the world can be too simple for community planning because the model can only see detail for larger areas (like a square with 50 or more miles on a side). The climate for this project has been mapped to smaller areas (like squares less than a mile on a side). The climate for this project has been mapped to smaller areas of less than a mile on a side. This information is available for five climate models that work well in the Arctic – they describe sea ice and the atmosphere in ways that look like historical weather we know occurred.

The average changes from these five models are shown for two futures: one where there is moderate warming, but eventually it slows down because of less coal, oil and gas use (which cause an increase of climate warming gasses in the atmosphere) and one where there is higher warming that continues to increase. These are called "representative concentration pathways" or RCPs for short - RCP4.5 is medium warming and RCP8.5 is higher warming. Lower rates of warming are possible with large changes in global policy and changes in coal, oil, and gas use, but we are currently heading for the moderate or high warming future so we did not choose a low warming scenario (RCP 2.6). The climate changes in the maps are compared to the 1970-1999 historical climate. The numbers in the upper left of each map page are the scenario averages for the four panels over the community-defined Traditional Use Area.

During the Fairbanks training we talked about when climate models do a pretty good job and when and why they are more uncertain. The scenarios that result in the maps in the next section address three main kinds of uncertainty. Using several climate models accounts for differences in climate models. Using a medium warming future and a high warming future addresses the uncertainty in how much change from climate warming gasses we think may happen. Using thirty-year averages decreases the effect of warmer or cooler, wetter or drier decades that happen for natural reasons. Together, these three things (using 5 climate models, using a medium and high warming scenario, using multiple decades) give us a more reliable range of future climates we can expect.

Permafrost futures (average yearly ground temperature at 3 feet deep) were available for two climate models under an older scenario (called A1B), which is in between the medium and high warming futures for the climate, fire, and land changes. The fire and land changes were available for two climate models used to provide temperature and precipitation to a land model that simulates vegetation and fire under the higher warming future.

Specific questions about any of the projections mapped here? Contact Jeremy Littell, Alaska Climate Adaptation Science Center, jlittell@usgs.gov. Further details on variables can be found in the SNAP data archives:

http://ckan. snap.uaf.edu/dataset

SNAP AK CASC

St. Michael projected climate changes and impacts

For the near future, about 2040-2069, St. Michael Traditional Use Area average annual temperatures are expected to increase +5.8 °F under medium warming and +7.8 °F under higher warming compared to 1970-1999. For the later future, about 2070-2099, St. Michael average annual temperatures are expected to increase +7.6 °F under medium warming and +11.7 °F under higher warming compared to the period 1970-1999. Warming will probably be greater in autumn and winter than spring and summer. Annual average precipitation (rain and snowfall) is expected to increase about +19% under medium warming and about +25% under higher warming for the near future 2040-2069 relative to 1970- 1999. Annual average precipitation is expected to increase about +22% under medium warming and about +37% under higher warming for the later future 2070-2099 relative to 1970-1999.

Precipitation increases will probably be greater in autumn and winter than spring and summer. However, in northern forests like those in Alaska, it has been found that about 15% more precipitation is needed to keep up with the increase in water demand of about 2 degrees F. So it is possible that even with more rainfall, water in plants during the warm season could decrease because precipitation increases would not be enough to keep up with the amount of water the heat can evaporate from the land and plants.

For 2040-2069, the amount of water available in April 1 snowpack (October to March snowfall water) is expected to remain similar (+1%) under medium warming and decrease -6% under higher warming, compared to 1970-1999. For 2070-2099, the amount of water available in April 1 snowpack is expected to decrease -2% under medium warming and -21% under higher warming, compared to 1970-1999. Averaged across the St. Michael region, average winters are still expected to be snow dominant for at least the 2050s and possibly the 2080s, which means that snowmelt will still usually be the main driver of streamflow responses. However, by the 2080s, rain and snow mixed may become more common and more winters than in recent times could have a shorter snow season or more mixed rain and snow. Some areas of permafrost might stay until the 2050s under a lower warming climate model (called ECHAM5), but decrease under all other scenarios.

Areas to the south of St. Michael become good for spruce growth, mostly in places that were shrub tundra. More spruce growth is expected under the moderate climate model (called CGCM3) than the warmer climate model (called CCSM4). Future computer model land changes suggest spruce could become more common to the east, with more spruce for the moderate climate model than the warmer climate model. Fire could become more common to the south and east of St. Michael, up the coast toward Unalakleet, and in areas near Yukon River south of Kotlik. Changes in vegetation are new kinds of plants growing where different plants used to be. These changes happen as new areas become good for plants, either because the climate is better for them or after fire or other disturbance. Both models project large landscape changes.

Descriptions of variables

Temperature

Annual averages (12 months) as well as four seasons (Spring – March to May; Summer – June to August; Autumn – Septem¬ber to November; Winter – December to February). Maps (pages 26-30) show "deltas", or future projected changes, in surface air temperature from climate models compared to the same historical months or three-month seasons. The mapped changes are averages of 5 climate models and are displayed for two time periods as well as for both moderate and high warming scenarios.

Precipitation

Annual totals (12 months) as well as four seasons (Spring – March to May; Summer – June to August; Autumn – September to November; Winter – December to February).Maps (pages 31-35) show future percent change in precipitation (rain and snow) projected by climate models compared to the same historical months or three-month seasons. The mapped changes are averages of 5 climate models and are displayed for two time periods as well as for both moderate and high warming scenarios.

Snowfall, or snowfall water equivalent

Maps (page 36) show future percent change in total snowfall derived from climate model projections compared to the same historical months or three-month seasons. The mapped changes are averages of 5 climate models and are displayed for two time periods as well as for both moderate and high warming scenarios.

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.

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 itis, the more likely permafrost is to persist. Near freezing (0 °C or 32 °F), the permafrost is more likely to thaw. Above freezing, it is unlikely to persist into the future.

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.

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).

Descriptions of variables (Continued)

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.

Thermokarst predisposition

Thermorkarst occurs where permafrost thaws and causes the ground to slump or cave in. Dark blues indicate areas where a model designed to predict thermokarst potential indicates it is likely. **If the graphic is absent, the model indicated no thermokarst predisposition in the region, so the map was not printed.**

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.

Map picture file abbreviations

All maps in this file are also in a folder with each map by itself. There are "small" maps that you can use in Word or PowerPoint (or other software) documents for reading. There are also "big" high resolution maps that could be printed off as posters or zoomed in on the screen and keep higher detail. The file names are abbreviations– here is what they mean:

dPann – change in annual (January to December) precipitation
dPdjf – change in winter (December, January, February) precipitation
dPjja – change in summer (June, July, August) precipitation
dPmam – change in spring (March, April, May) precipitation
dPson – change in autumn (September, October, November) precipitation

dTann – change in annual (January to December) temperature
dTdjf – change in winter (December, January, February) temperature
dTjja – change in summer (June, July, August) temperature
dTmam – change in spring (March, April, May) temperature
dTson – change in autumn (September, October, November) temperature

dswe – change in snowfall water amount, October to March
dFireCen – changes in numbers of fires per century
dVegCen – changes in vegetation per century
sno – snow index, the range between rain dominated and snow dominated
t1 – temperature at 1m ground depth

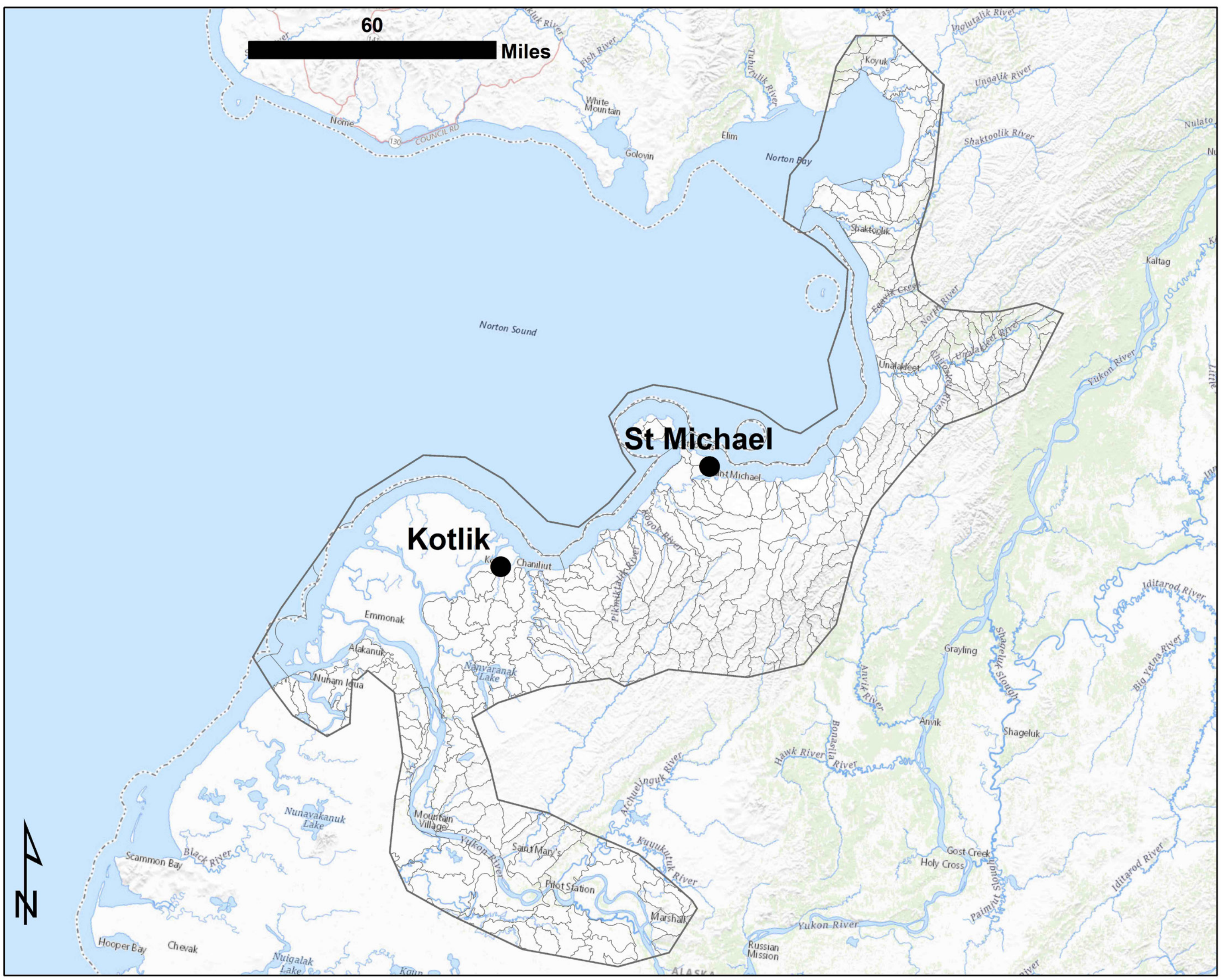
5045 – 2050s (2050-2069), RCP 4.5 (mid century, medium emissions)
5085 – 2050s (2040-2069), RCP 8.5 (mid century, higher emissions)
8045 – 2080s (2050-2069), RCP 4.5 (late century, medium emissions)
8085 – 2080s (2040-2069), RCP 8.5 (late century, higher emissions)

CCMA and ECHAM5 refer to climate models used in permafrost work. CGCM3, GFDL CM3, GISS E2R, IPSL CM5A LR, and CCSM4 refer to climate models used in the projections of temperature, precipitation, and snow. CGCM3 and CCSM4 are used in the vegetation and fire projections.

St. Michael region and watershed boundaries

St Michael region outlined includes the areas defined by community workshop participants as important. The many lines within the region show watershed boundaries (called hydrologic units or HUC12s). Many of the following maps show average conditions for climate change and its effects within each watershed.

Background map: United States Geological Survey National Map

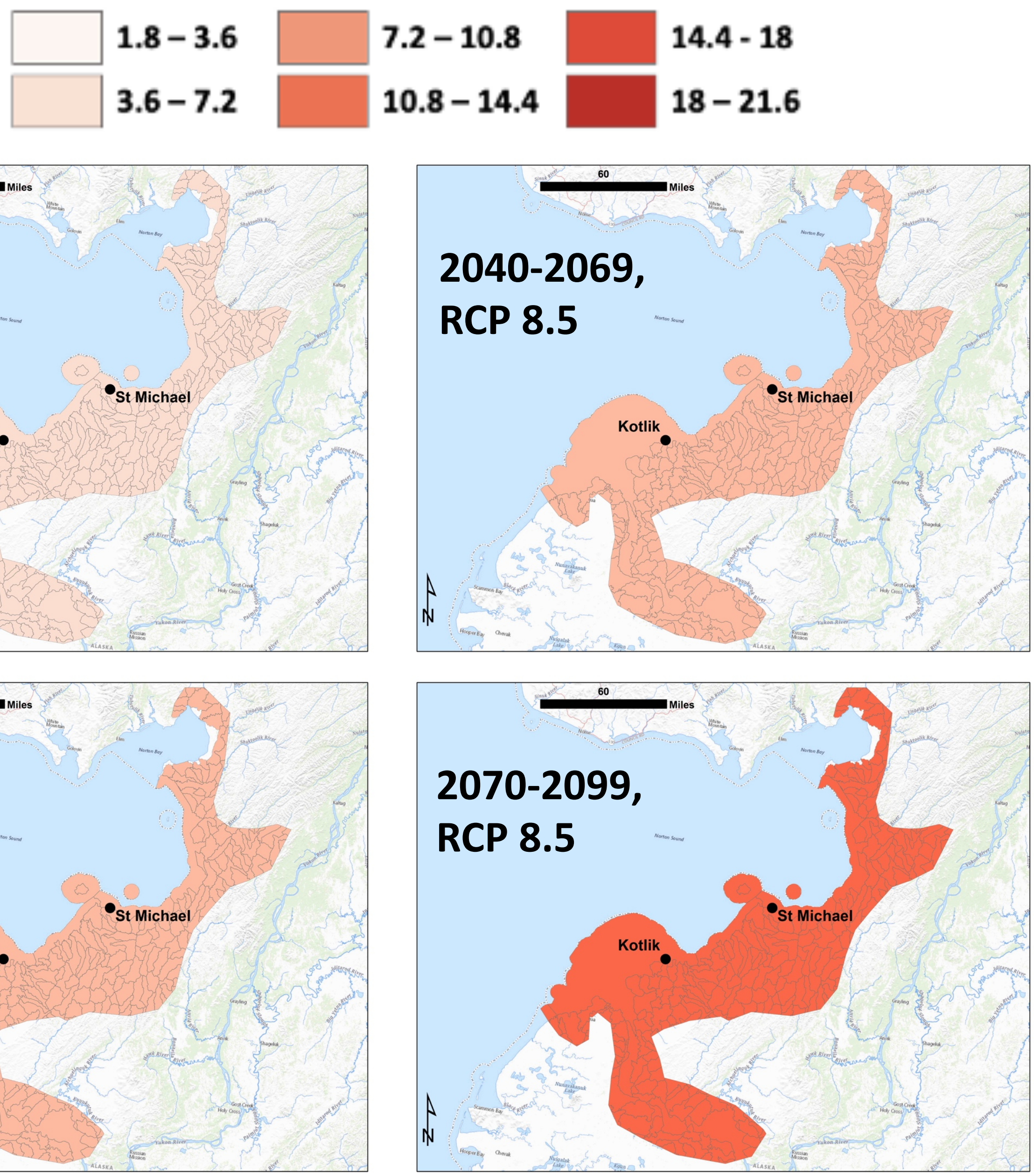


Annual temperature change, relative to 1970 - 1999

Annual temperature is projected to increase under all scenarios:

+ 5.8 °F (2050s, RCP 4.5)
+ 7.8 °F (2050s, RCP 8.5)
+ 7.6 °F (2080s, RCP 4.5)
+ 11.7 °F (2080s, RCP 8.5)

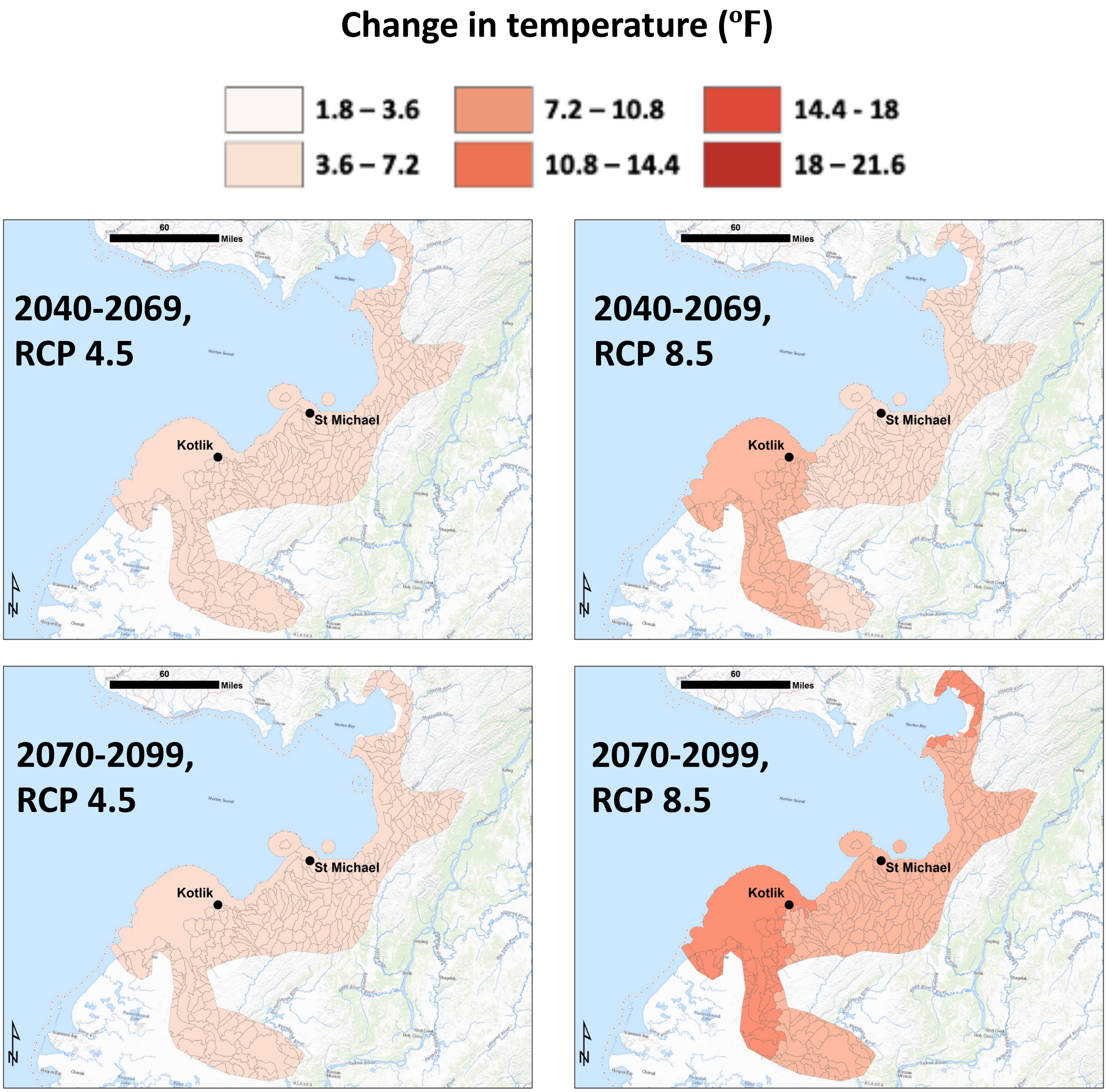
Change in temperature (°F)



Spring (Mar - May) temperature change, relative to 1970 - 1999

Spring temperature is projected to increase under all scenarios:

+ 5.4 °F (2050s, RCP 4.5)
+ 7.1 °F (2050s, RCP 8.5)
+ 6.6 °F (2080s, RCP 4.5)
+ 10.6 °F (2080s, RCP 8.5)

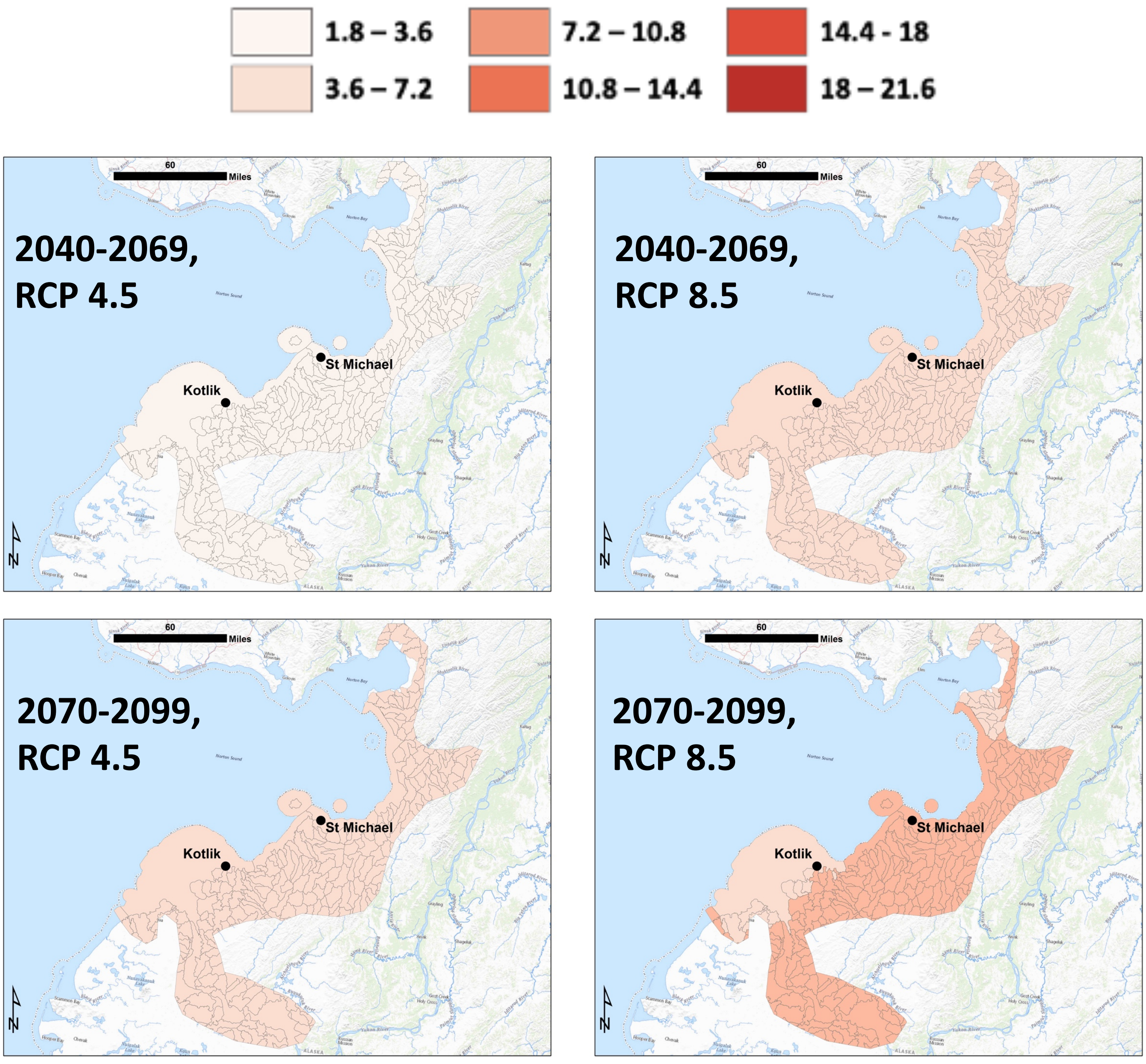


Summer (June - Aug) temperature change, relative to 1970 - 1999

Summer temperature is projected to increase under all scenarios:

+ 3.3 °F (2050s, RCP 4.5)
+ 4.5 °F (2050s, RCP 8.5)
+ 4.4 °F (2080s, RCP 4.5)
+ 7.3 °F (2080s, RCP 8.5)

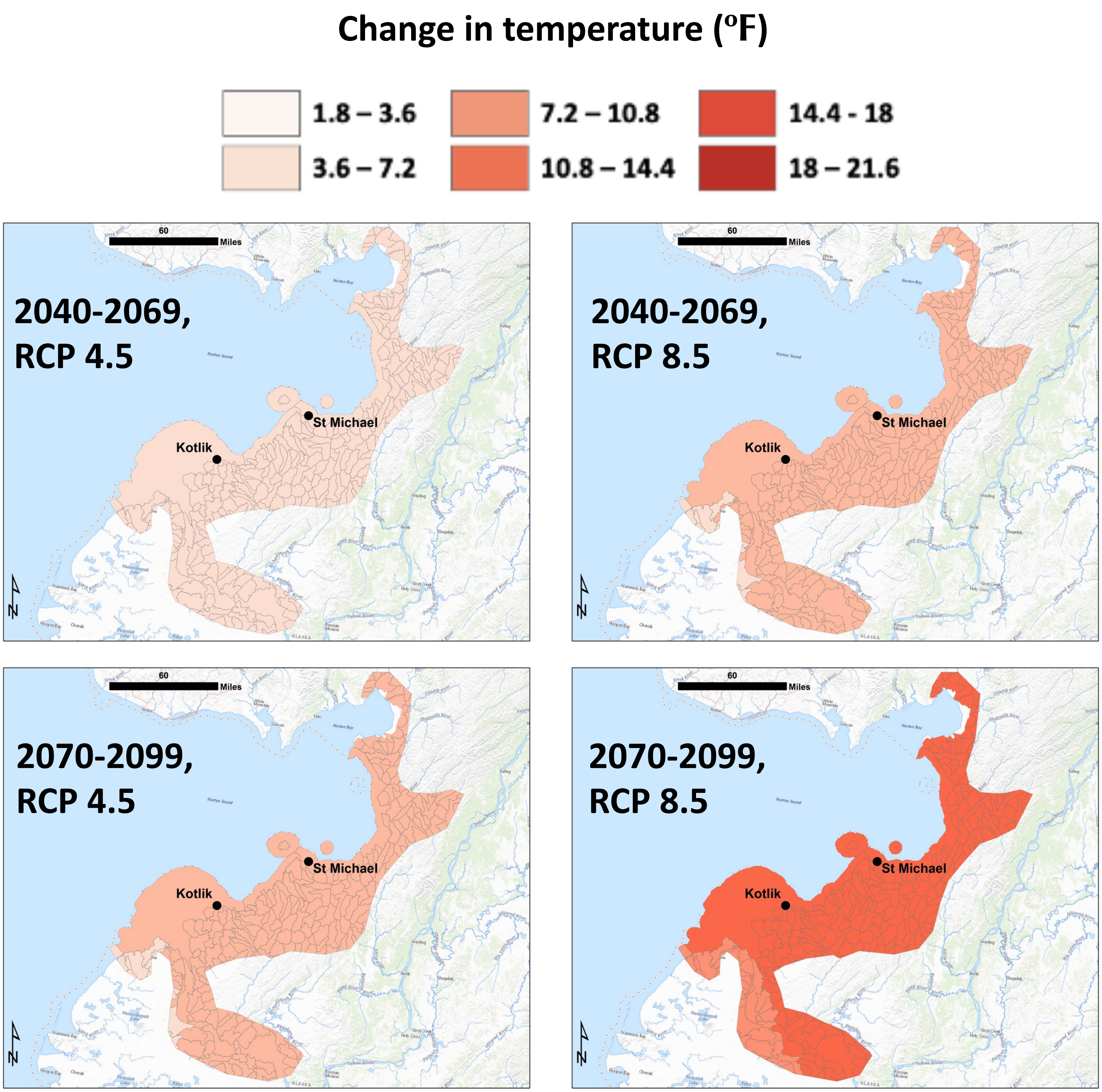
Change in temperature (°F)



Autumn (Sep - Nov) temperature change, relative to 1970 - 1999

Autumn temperature is projected to increase under all scenarios:

+ 6.0 °F (2050s, RCP 4.5)
+ 7.7 °F (2050s, RCP 8.5)
+ 7.7 °F (2080s, RCP 4.5)
+ 11.3 °F (2080s, RCP 8.5)

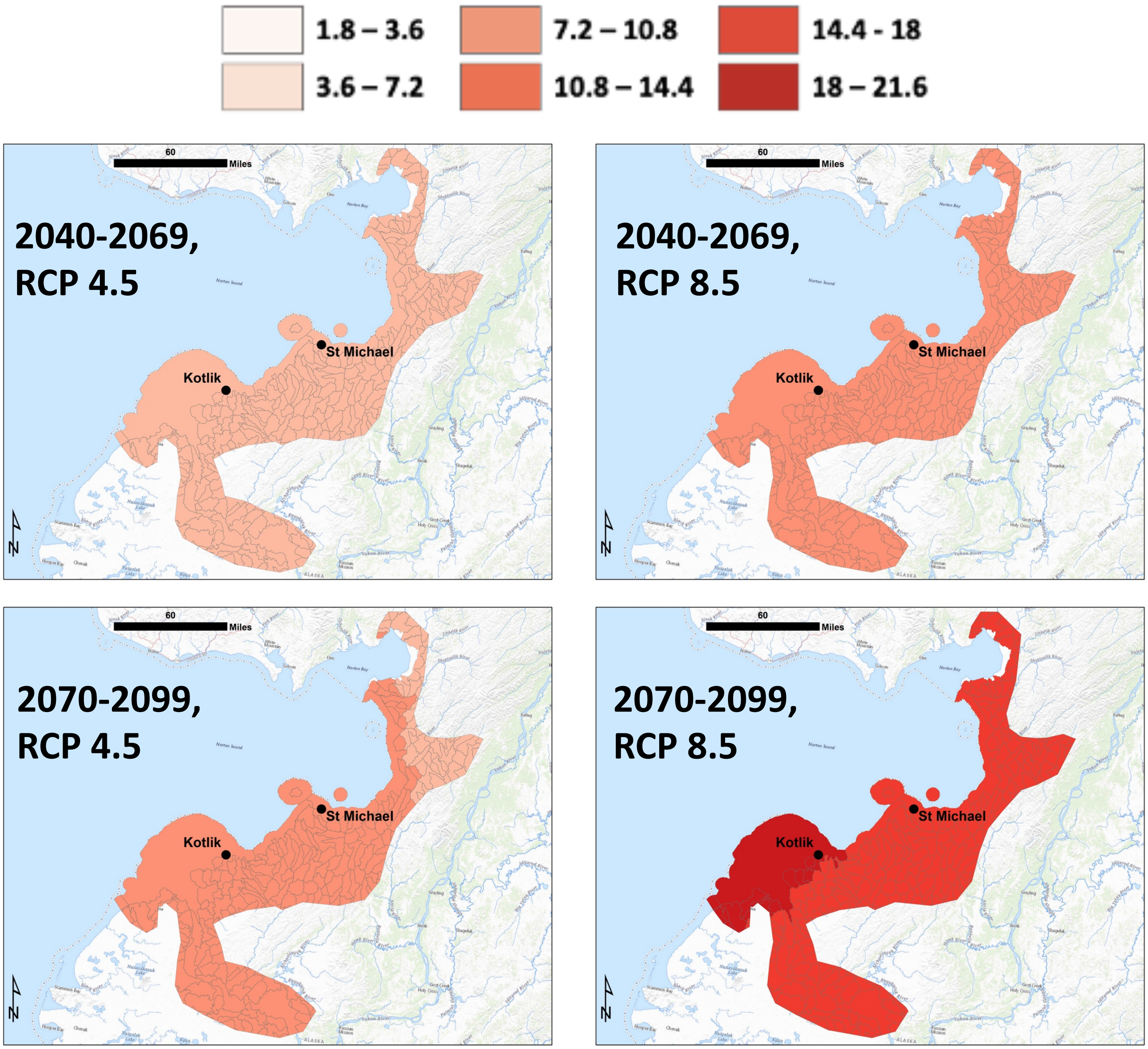


Winter (Dec - Feb) temperature change, relative to 1970 - 1999

Winter temperature is projected to increase under all scenarios:

+ 8.3 °F (2050s, RCP 4.5)
+ 11.7 °F (2050s, RCP 8.5)
+ 11.3 °F (2080s, RCP 4.5)
+ 17.1 °F (2080s, RCP 8.5)

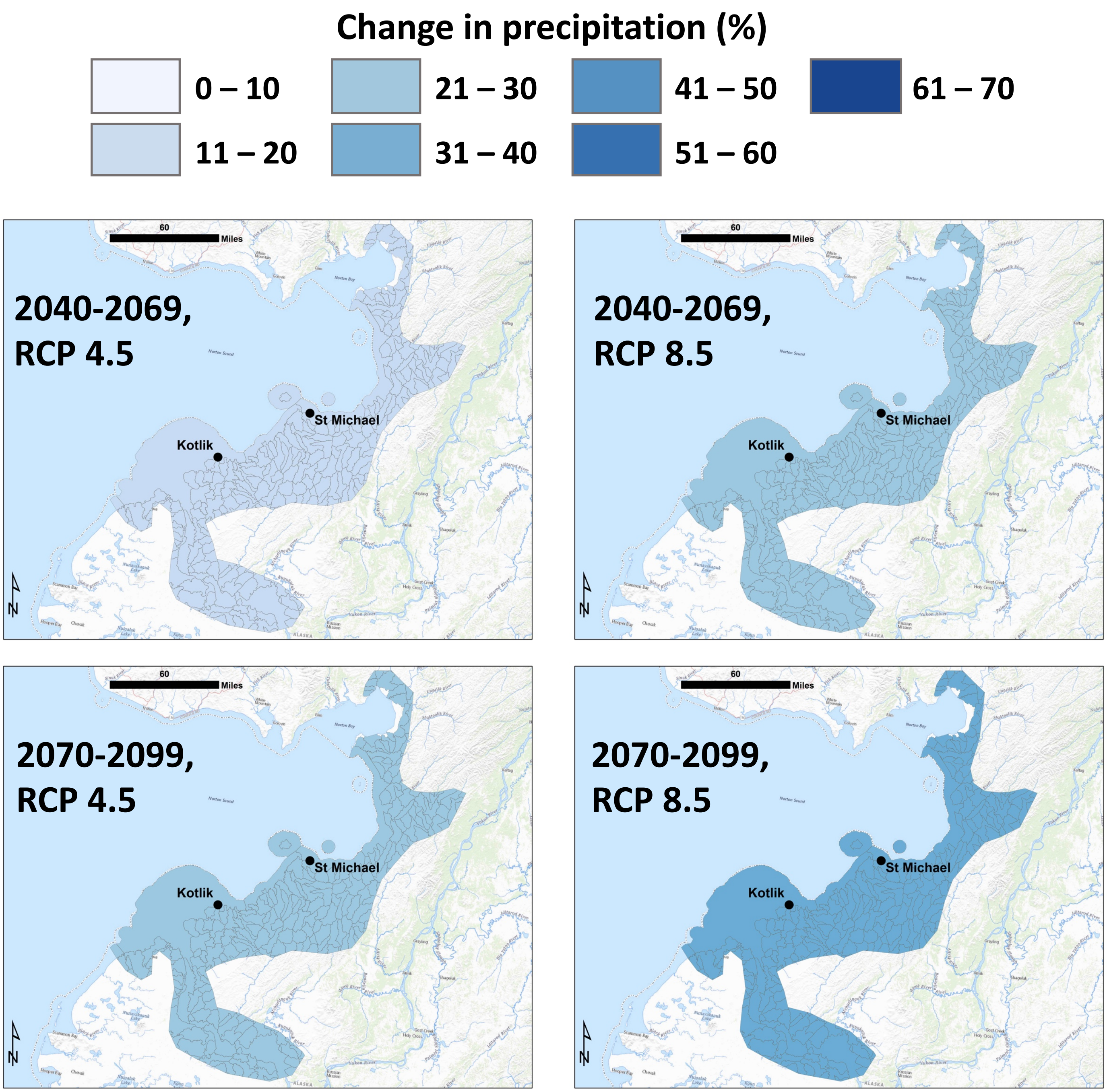
Change in temperature (°F)



Annual precipitation change, relative to 1970 - 1999

Annual precipitation is projected to increase under all scenarios:

+ 16 % (2050s, RCP 4.5)
+ 20 % (2050s, RCP 8.5)
+ 18 % (2080s, RCP 4.5)
+ 31 % (2080s, RCP 8.5)



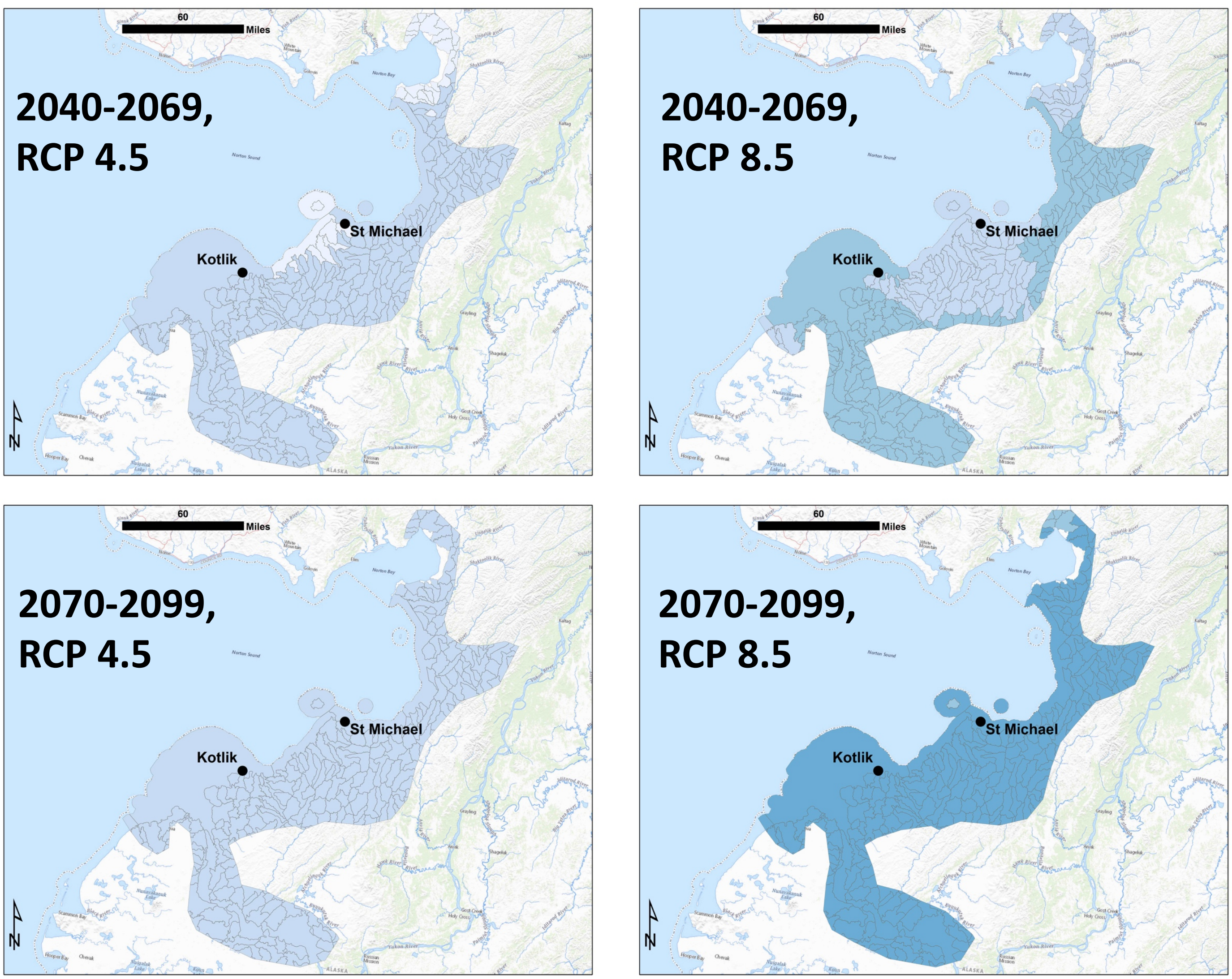
Spring (Mar - May) precipitation change, relative to 1970 - 1999

Spring precipitation is projected to increase under all scenarios.

+ 11 % (2050s, RCP 4.5)
+ 18 % (2050s, RCP 8.5)
+ 16 % (2080s, RCP 4.5)
+ 29% (2080s, RCP 8.5)

Change in precipitation (%)

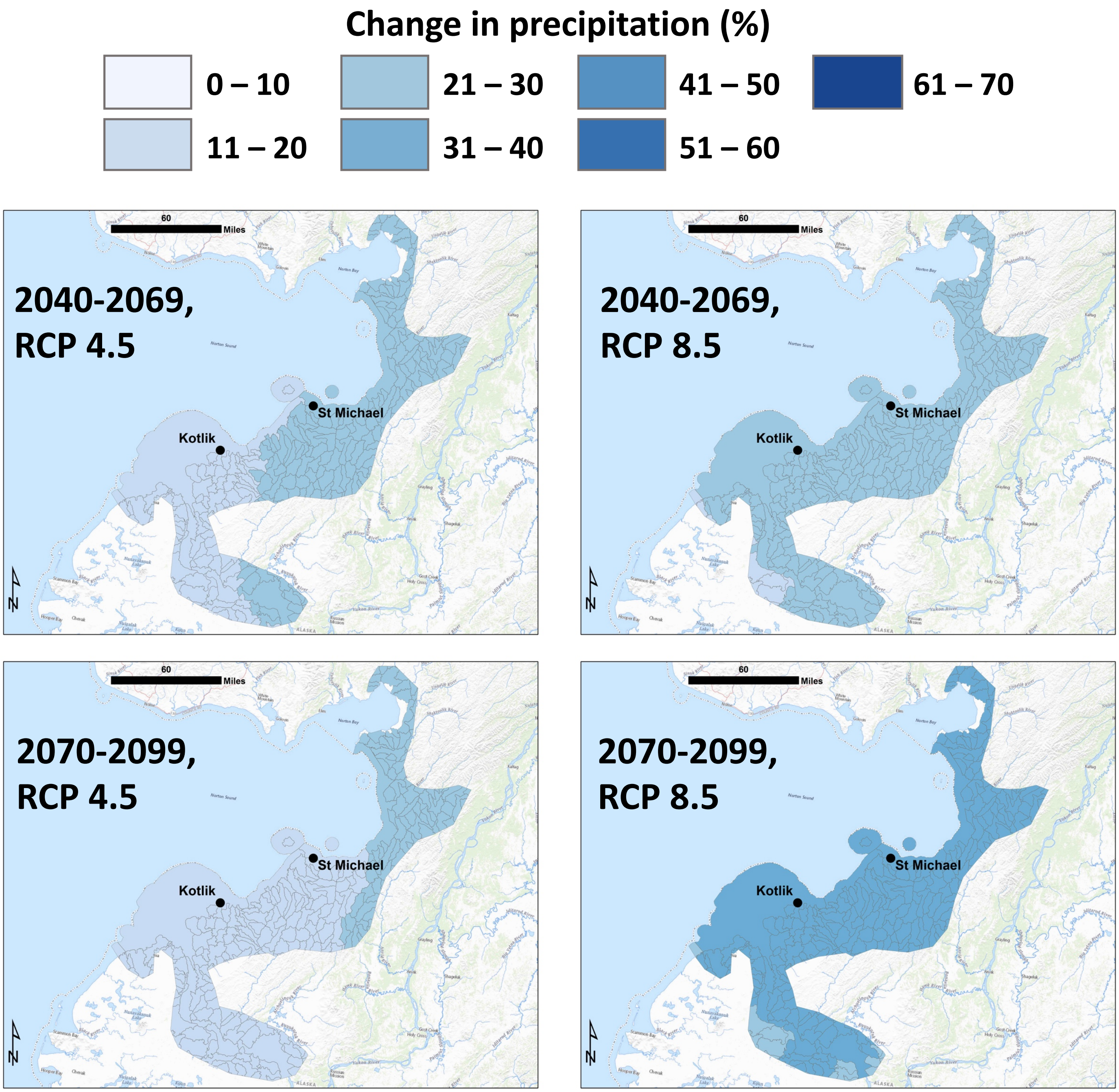
- 0 – 10
- 11 – 20
- 21 – 30
- 31 – 40
- 41 – 50
- 51 – 60
- 61 – 70



Summer (June - Aug) precipitation change, relative to 1970 - 1999

Summer precipitation is projected to increase under all scenarios.

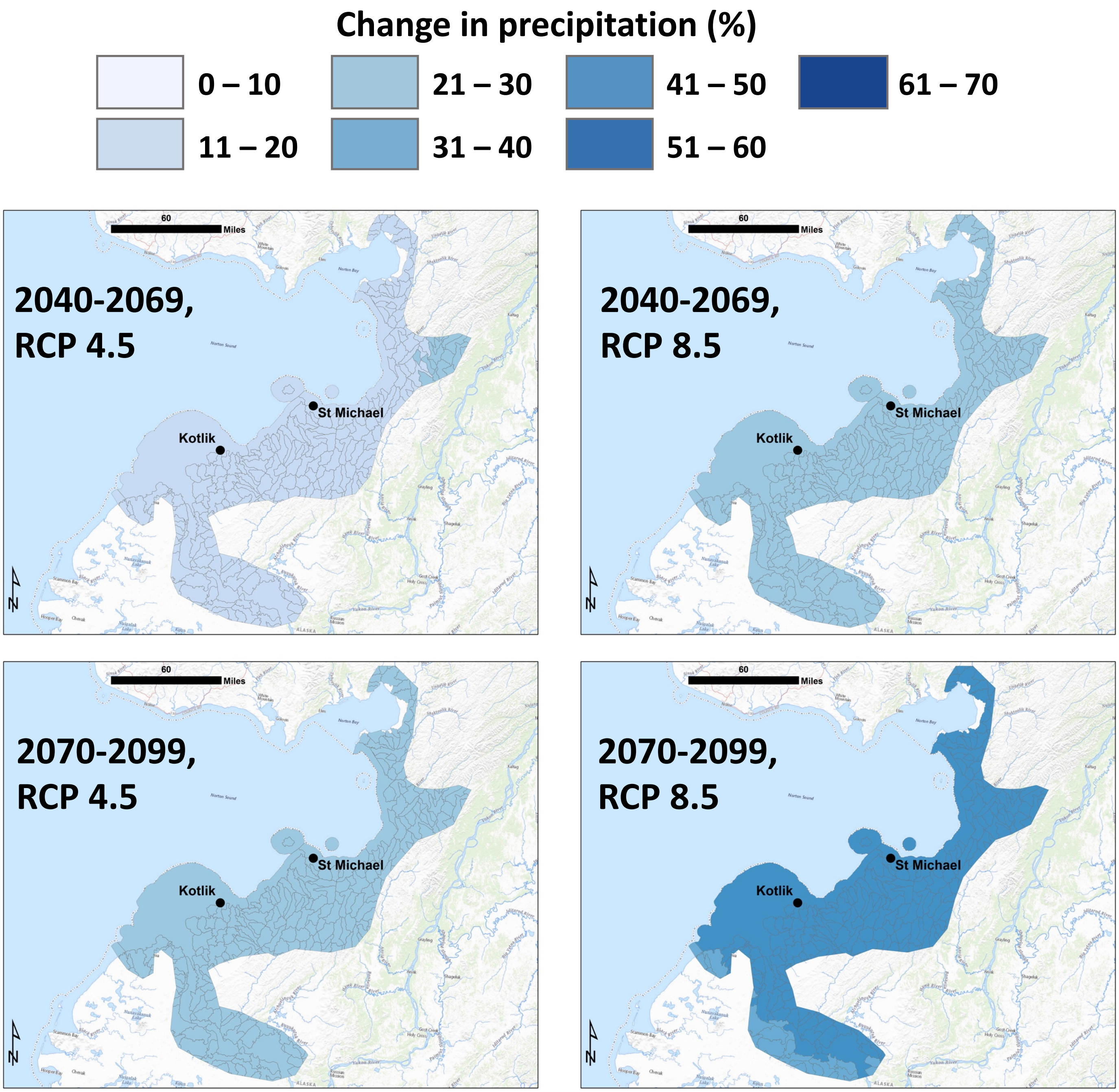
+ 16 % (2050s, RCP 4.5)
+ 16 % (2050s, RCP 8.5)
+ 13 % (2080s, RCP 4.5)
+ 25 % (2080s, RCP 8.5)



Autumn (Sep - Nov) precipitation change, relative to 1970 - 1999

Autumn precipitation is projected to increase under all scenarios.

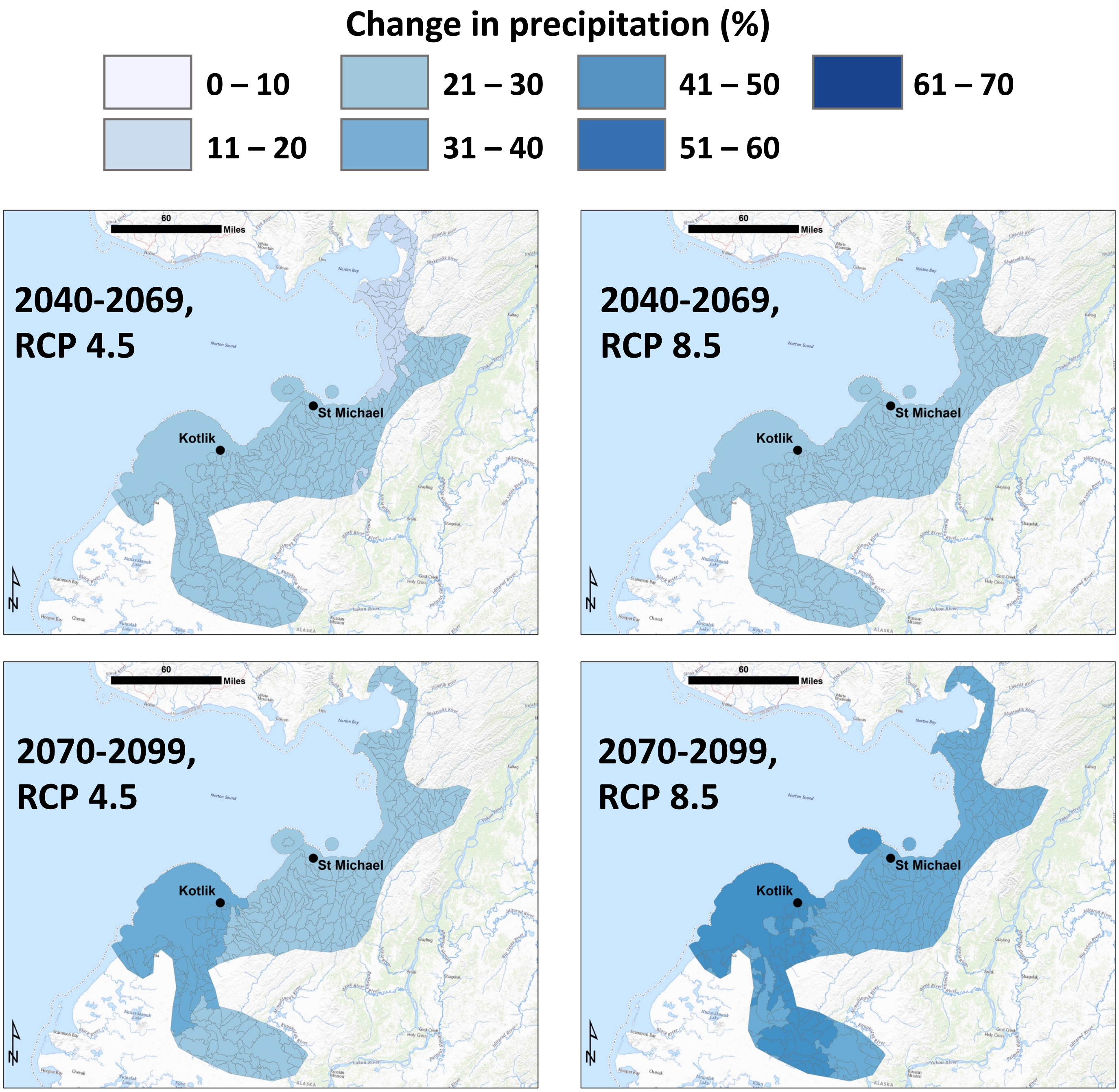
+ 17 % (2050s, RCP 4.5)
+ 23 % (2050s, RCP 8.5)
+ 21 % (2080s, RCP 4.5)
+ 35 % (2080s, RCP 8.5)



Winter (Dec - Feb) precipitation change, relative to 1970 - 1999

Winter precipitation is projected to increase under all scenarios.

+ 21 % (2050s, RCP 4.5)
+ 23 % (2050s, RCP 8.5)
+ 27 % (2080s, RCP 4.5)
+ 39 % (2080s, RCP 8.5)

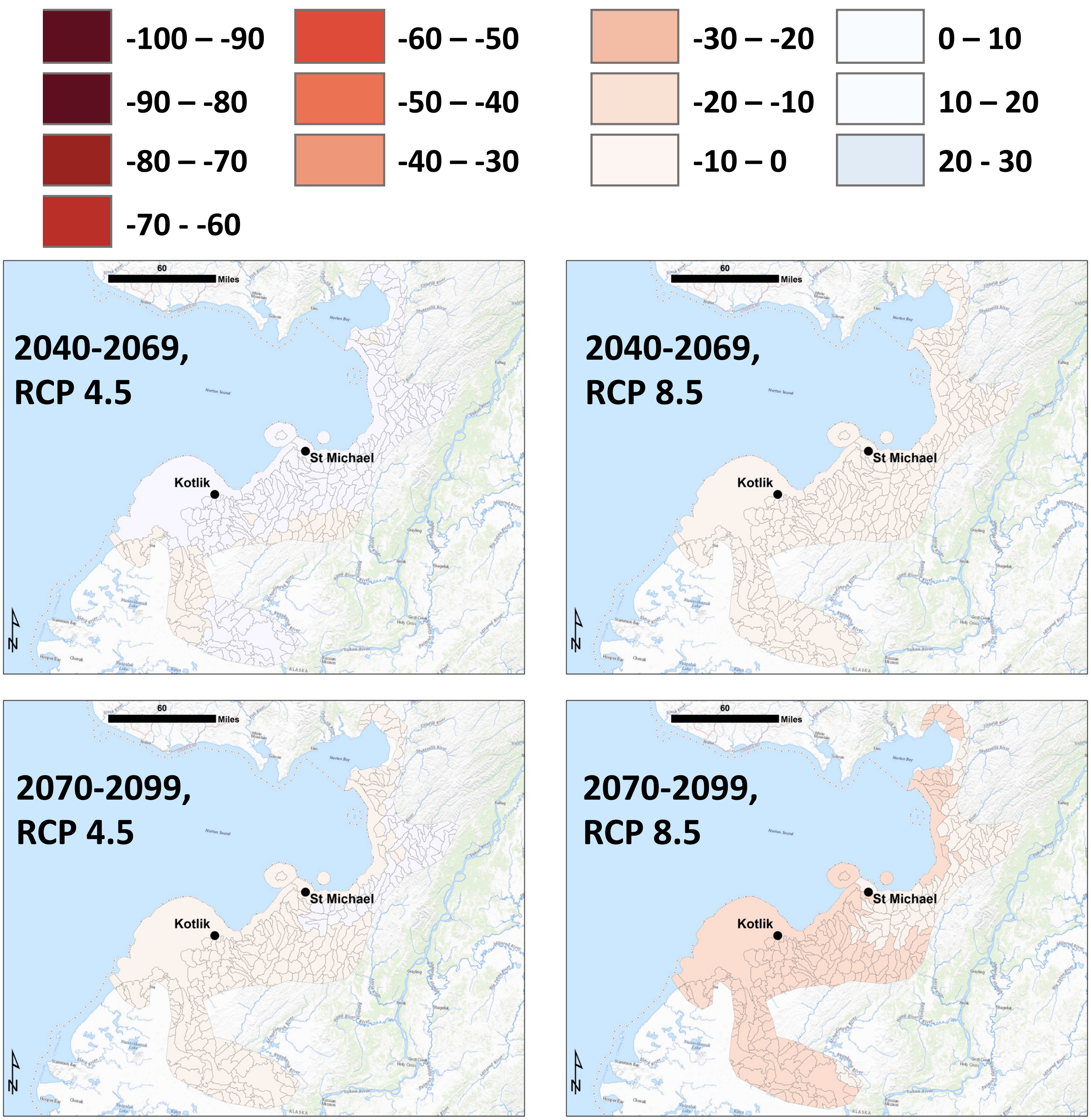


Snowfall water equivalent (snowfall) change in October to March, relative to 1970 - 1999

This is the change in the amount of snow that falls. Snowfall decreases in all four scenarios.

-7 % (2050s, RCP 4.5)
-17 % (2050s, RCP 8.5)
-14 % (2080s, RCP 4.5)
-34 % (2080s, RCP 8.5)

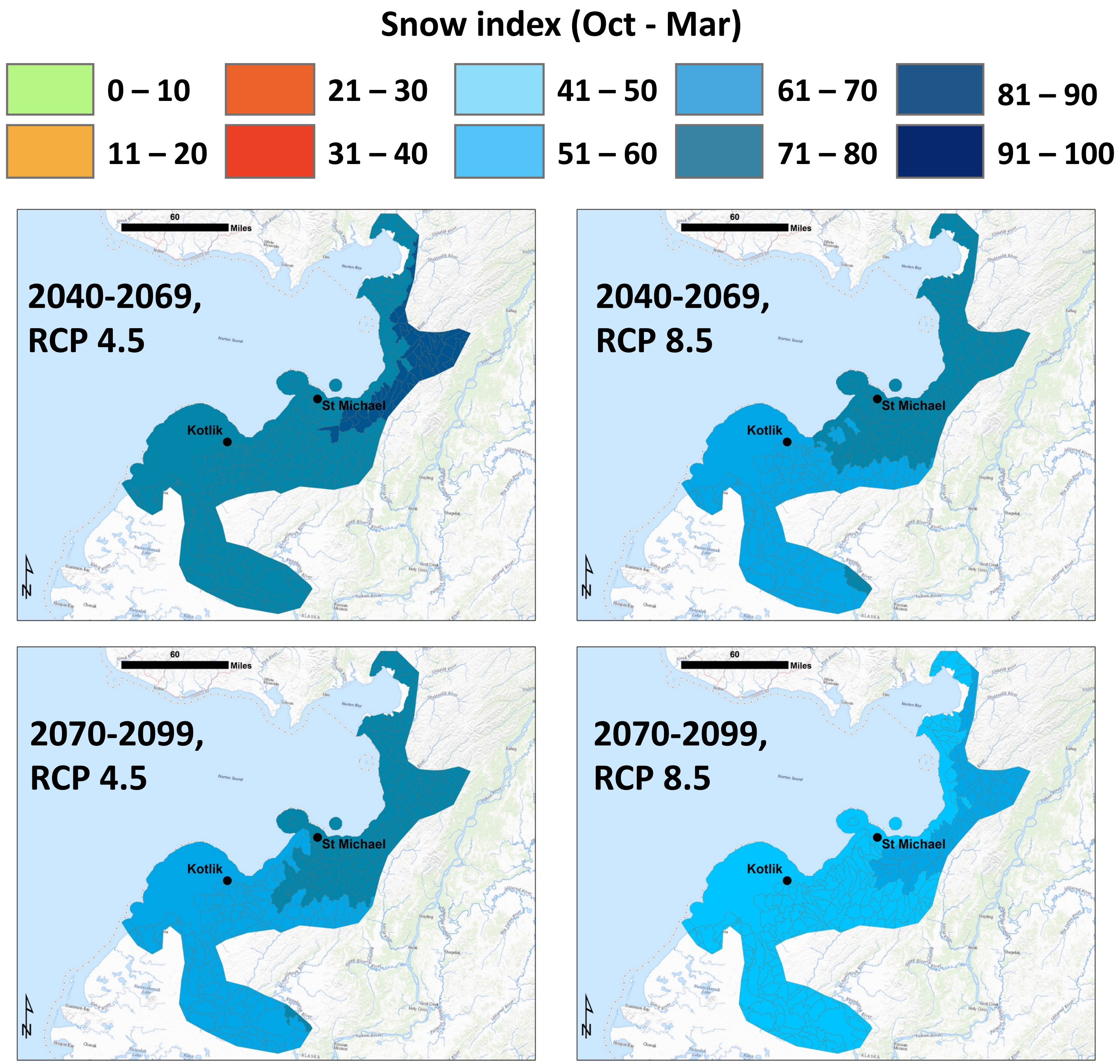
Change in snow (%)



Snow index, October to March % of precipitation in April 1 snow, relative to 1970 - 1999

This is a measure of how snow-dominated the climate is. Blues indicate snow dominated, reds and oranges are in between snow dominated and rain dominated. Greens represent rain dominated. St. Michael was historically snow dominated. Under all scenarios, the region remains snow dominated, but becomes closer to transitional (in between snow and rain dominated) by the end of the 21st century.

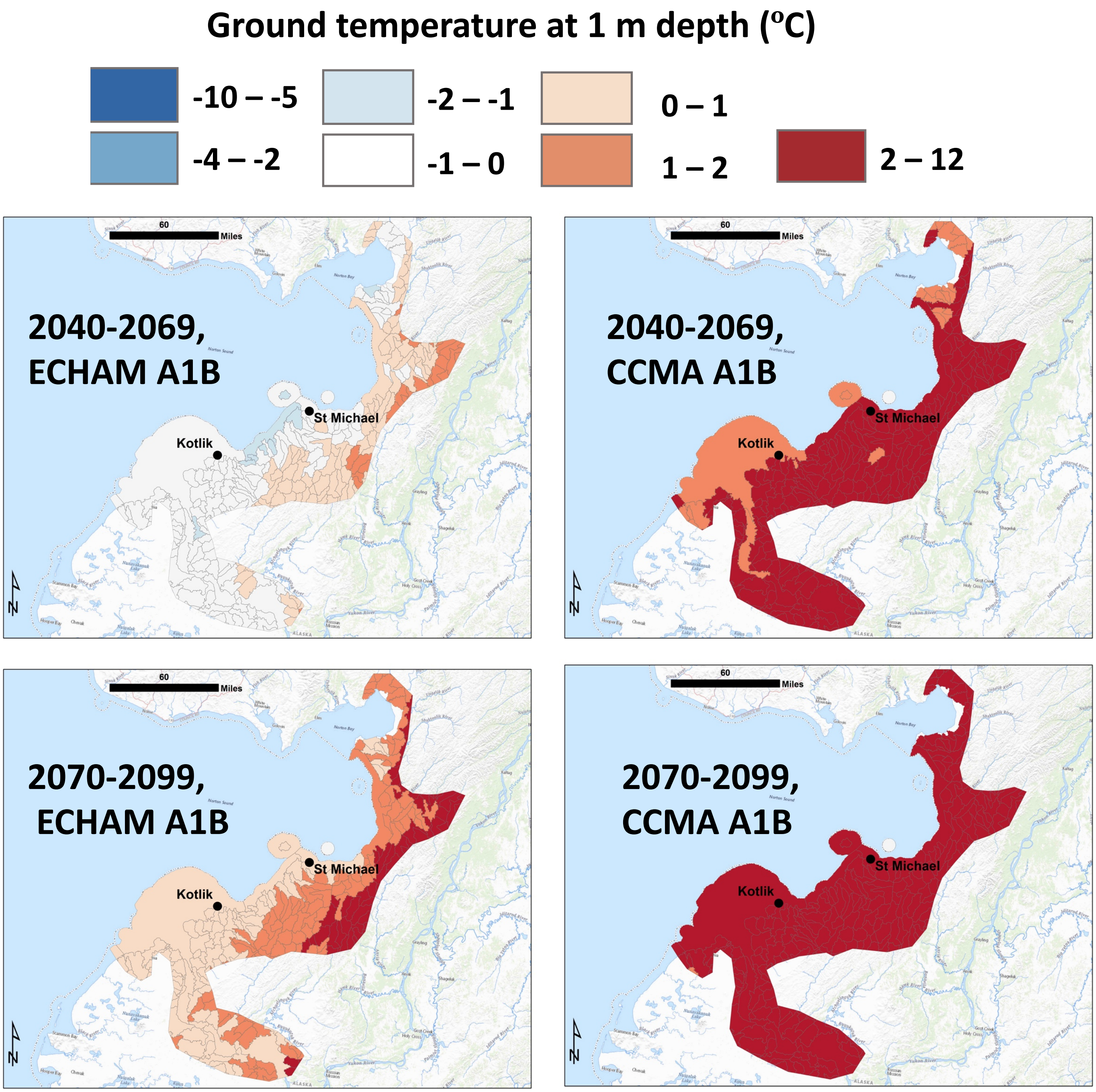
62% (2050s, RCP 4.5)
55% (2050s, RCP 8.5)
55% (2080s, RCP 4.5)
42% (2080s, RCP 8.5)



Annual average ground temperature at 1m (3.3ft) deep

This is an index of how likely permafrost is to remain under climate change. Once annual average temperatures rise above freezing (0°) permafrost thaw likely increases. Some areas of permafrost might persist until the 2050s under the ECHAM model, but decrease under all others.

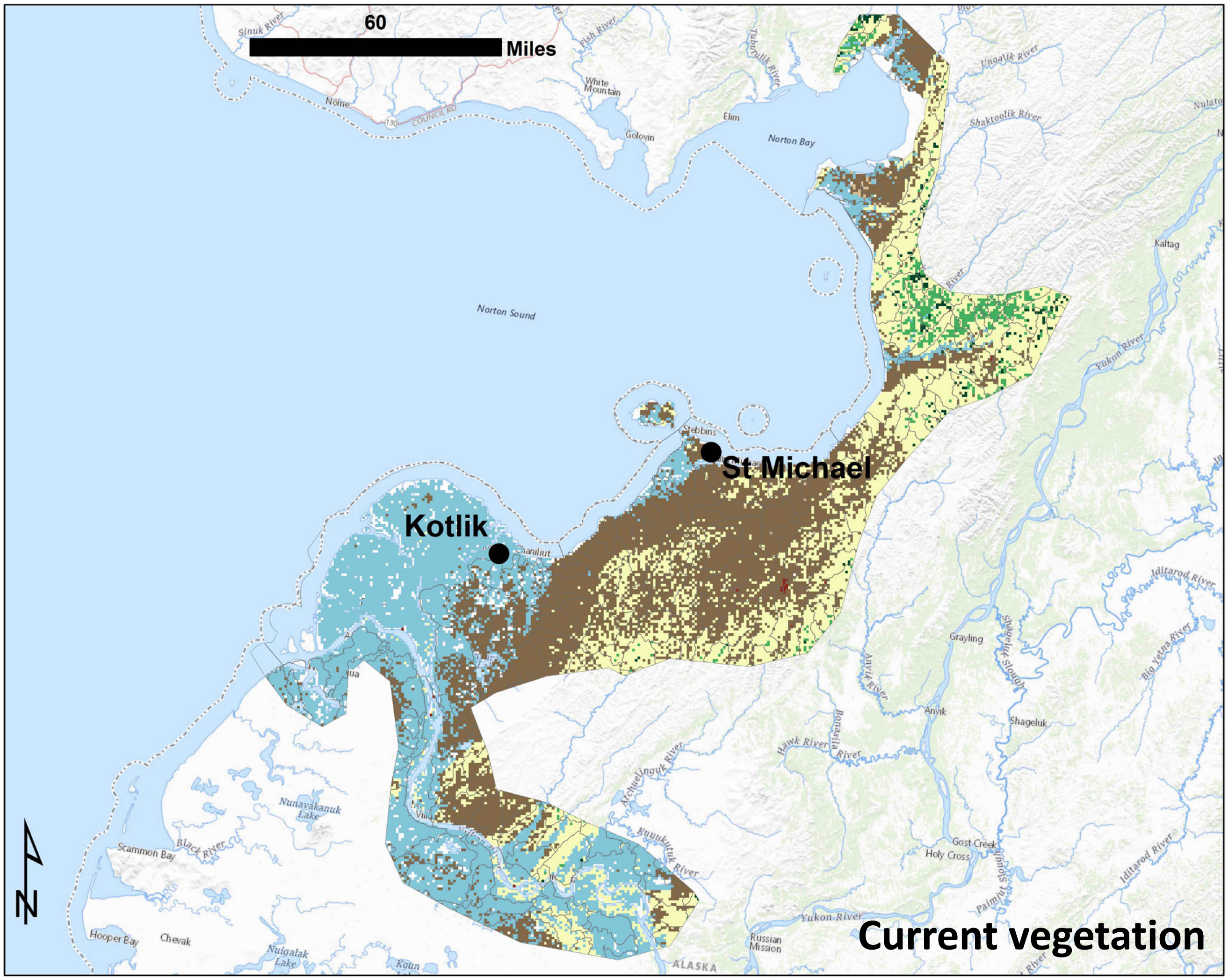
-0.8°C (2050s, ECHAM A1B)
2.1°C (2050s, CCMA A1B)
0.1°C (2080s, ECHAM A1B)
3.0°C (2080s, CCMA A1B)



Current vegetation

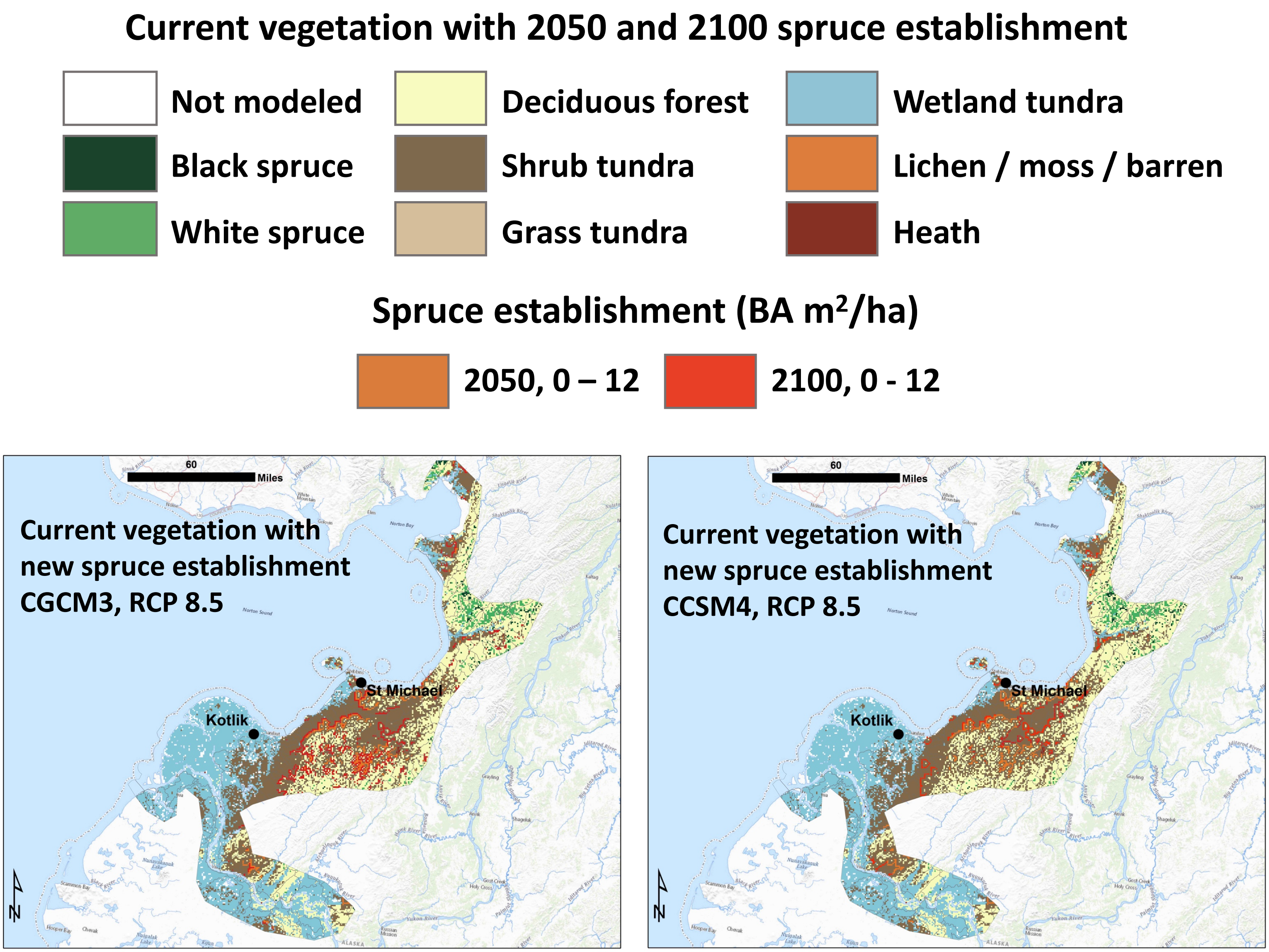
Deciduous forest is birch, aspen, willow, cottonwood and/or alder.

- Not modeled
- Black spruce
- White spruce
- Deciduous forest
- Shrub tundra
- Grass tundra
- Wetland tundra
- Lichen / moss / barren
- Heath
- Maritime upland forest
- Maritime forested wetland
- Maritime fen
- Maritime alder shrubland



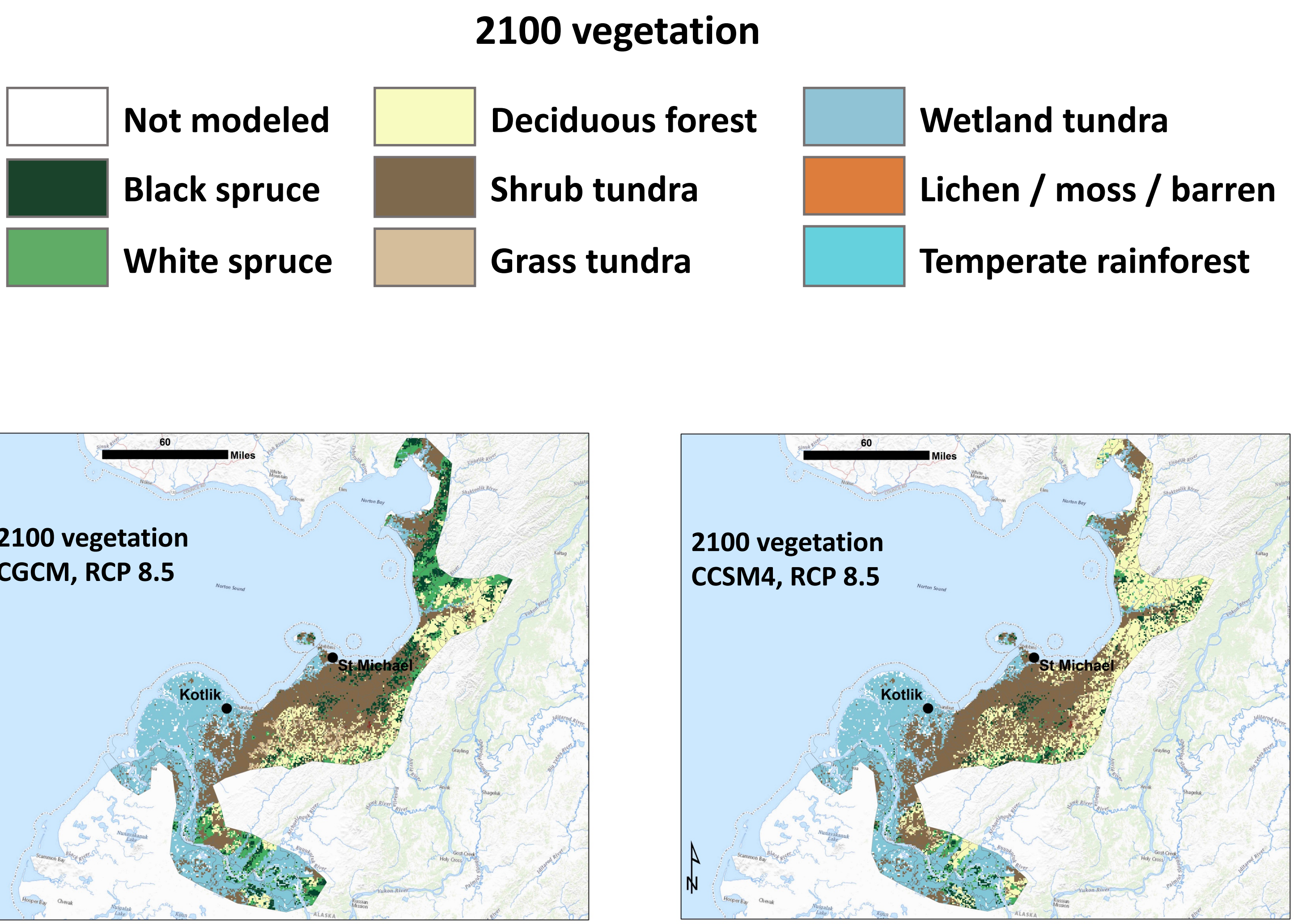
Current vegetation with 2050 and 2100 spruce establishment

Areas (in red) to the south of St. Michael become favorable for spruce establishment, generally in what was historically shrub tundra. More establishment is projected under the CGCM3 climate model than the CCSM4 climate model.



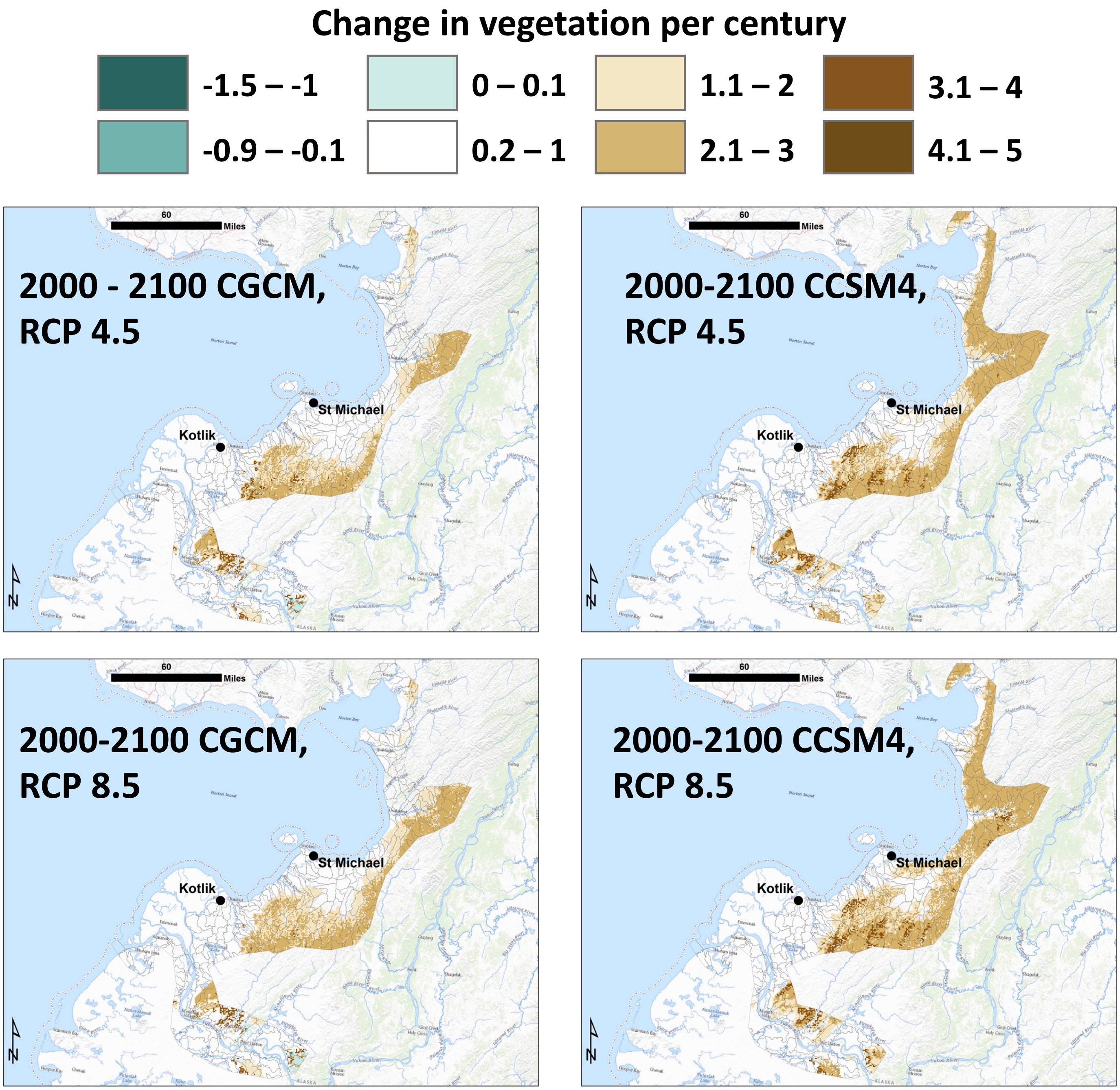
2100 vegetation

Future vegetation changes simulated by a vegetation model project spruce will establish in the eastern region. More establishment is projected under the CGCM3 climate model than the CCSM4 climate model.



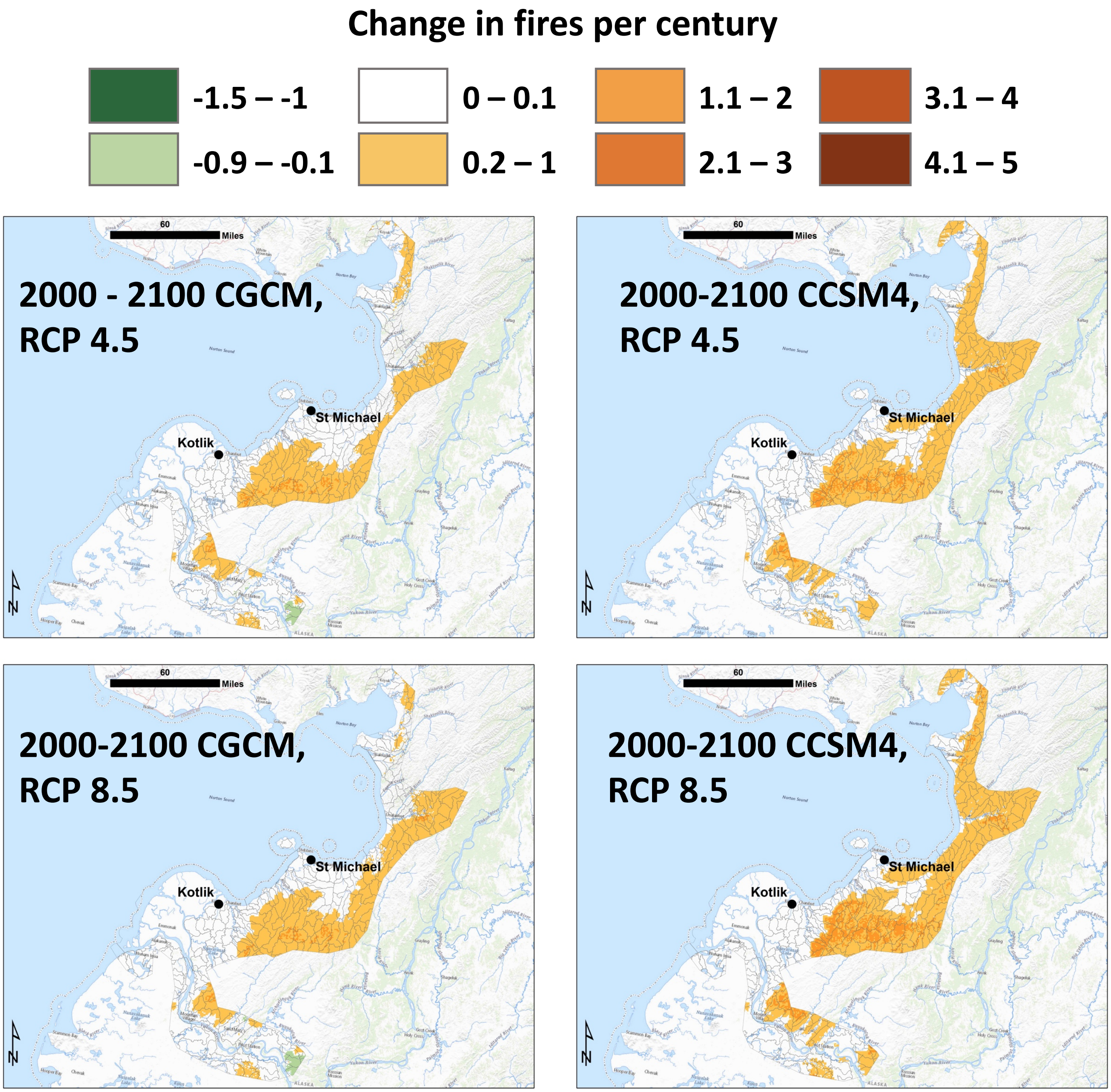
Change in vegetation per century, relative to 20th century

Changes in vegetation are new kinds of plants establishing where different plants used to be. These changes happen as new areas become favorable to plants, either due just to climate changes or after fire or other disturbance. Both models project significant landscape changes , especially for the CCSM4 climate mode.



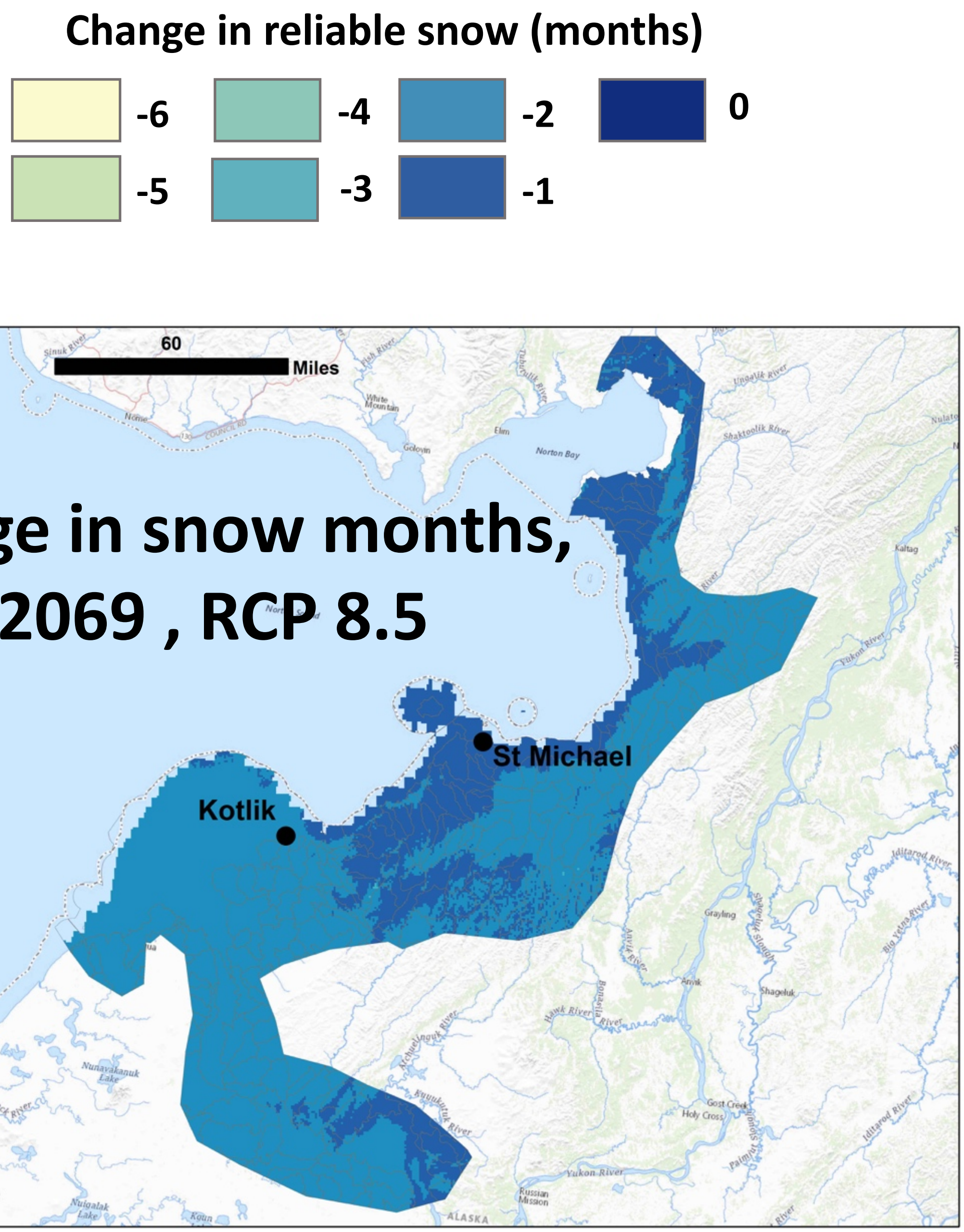
Change in fires per century, relative to 20th century

The number of fires per century is projected to increase by 1 (light orange) to 2 (darker orange) fires per century on average in the areas southeast and southwest of St. Michael, up the coast toward Unalakleet, and in areas of the Yukon River drainage south of Kotlik.



Change in reliable snow (months)

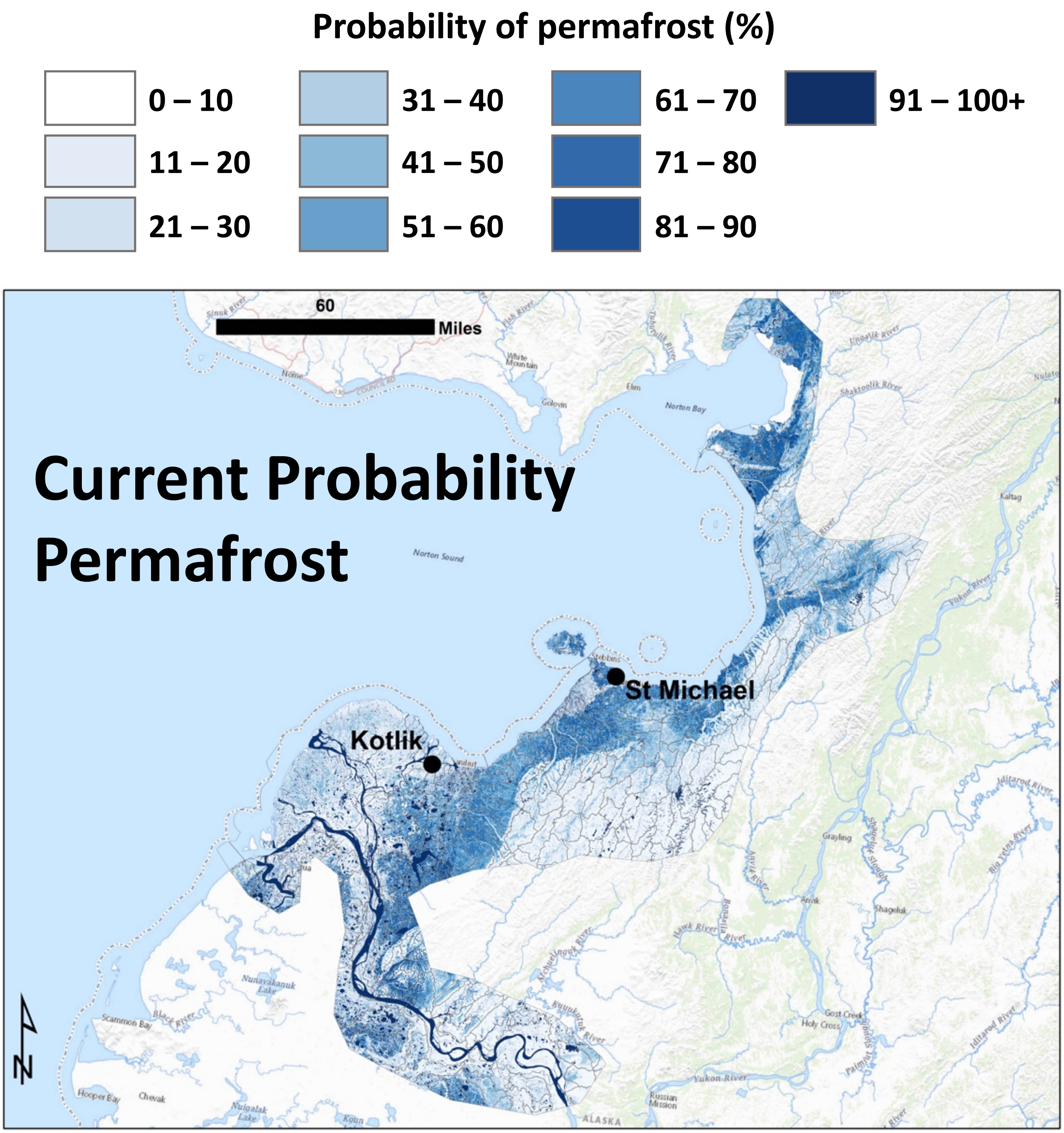
Snow months decrease by 1 to 2 months across much of the region, with largest decreases in the east and north of the region.



Probability of permafrost (%)

Snow months decrease by 3 to 4 months across much of the region, with largest decreases in the northeast of the region.

Currently, permafrost in the region is thought to be patchy but locally important.



Data tables

PRECIPITATION CHANGES – Percent (%) change averaged over the St. Michael region

	2040 - 2069				2070 - 2099			
	RCP 4.5		RCP 8.5		RCP 4.5		RCP 8.5	
	Average	Range	Average	Range	Average	Range	Average	Range
Annual	**19**	**16 - 20**	**25**	**23 - 26**	**22**	**21 - 24**	**37**	**34 - 40**
Spring	11	9 - 14	20	18 - 23	16	14 - 18	32	30 - 36
Summer	20	15 - 23	24	19 - 29	20	14- 18	33	30 - 36
Autumn	19	17 - 21	28	26 - 30	26	23 - 28	43	40 - 46
Winter	21	18 - 23	23	20 - 28	27	21 - 33	39	36 - 41

TEMPERATURE – Change (in °F) averaged over the St. Michael region

	2040 - 2069				2070 - 2099			
	RCP 4.5		RCP8.5		RCP 4.5		RCP 8.5	
	Average	Range	Average	Range	Average	Range	Average	Range
Annual	**5.8**	**5.7 - 6.0**	**7.8**	**7.7 - 8.0**	**7.6**	**7.4 - 7.8**	**11.7**	**11.4 - 12.0**
Spring	5.4	5.1 - 5.8	7.1	6.7 - 7.5	6.6	6.1 - 7.1	10.6	10.3 - 11.1
Summer	3.3	3.1 - 3.5	4.5	4.4 - 4.8	4.4	4.2 - 4.7	7.3	7.1 - 7.7
Autumn	6.0	5.6 - 6.8	7.7	7.1 - 8.7	7.7	7.1 - 8.5	11.3	10.5 - 12.5
Winter	8.3	7.7 - 9.4	11.7	11.0 - 12.9	11.3	10.5 - 12.7	17.1	16.4 - 18.4

SNOWPACK - Percent (%) change (snowfall) and percent (%) (snow index) averaged over the St. Michael region

	2040-2069				2070 - 2099			
	RCP 4.5		RCP 8.5		RCP 4.5		RCP 8.5	
	Average	Range	Average	Range	Average	Range	Average	Range
Snowfall water	1	-2 - +5	-6	-10 - 0	-2	-5- +3	-21	-26 - -12
Snow index	77	71 - 84	71	65 - 79	71	65 - 79	58	51- 67

*Averages are for five climate models. Ranges are across HUC 12 (12 digit Hydrological Unit Code) watersheds. See the PowerPoint with the regional maps file for descriptions of the variables.