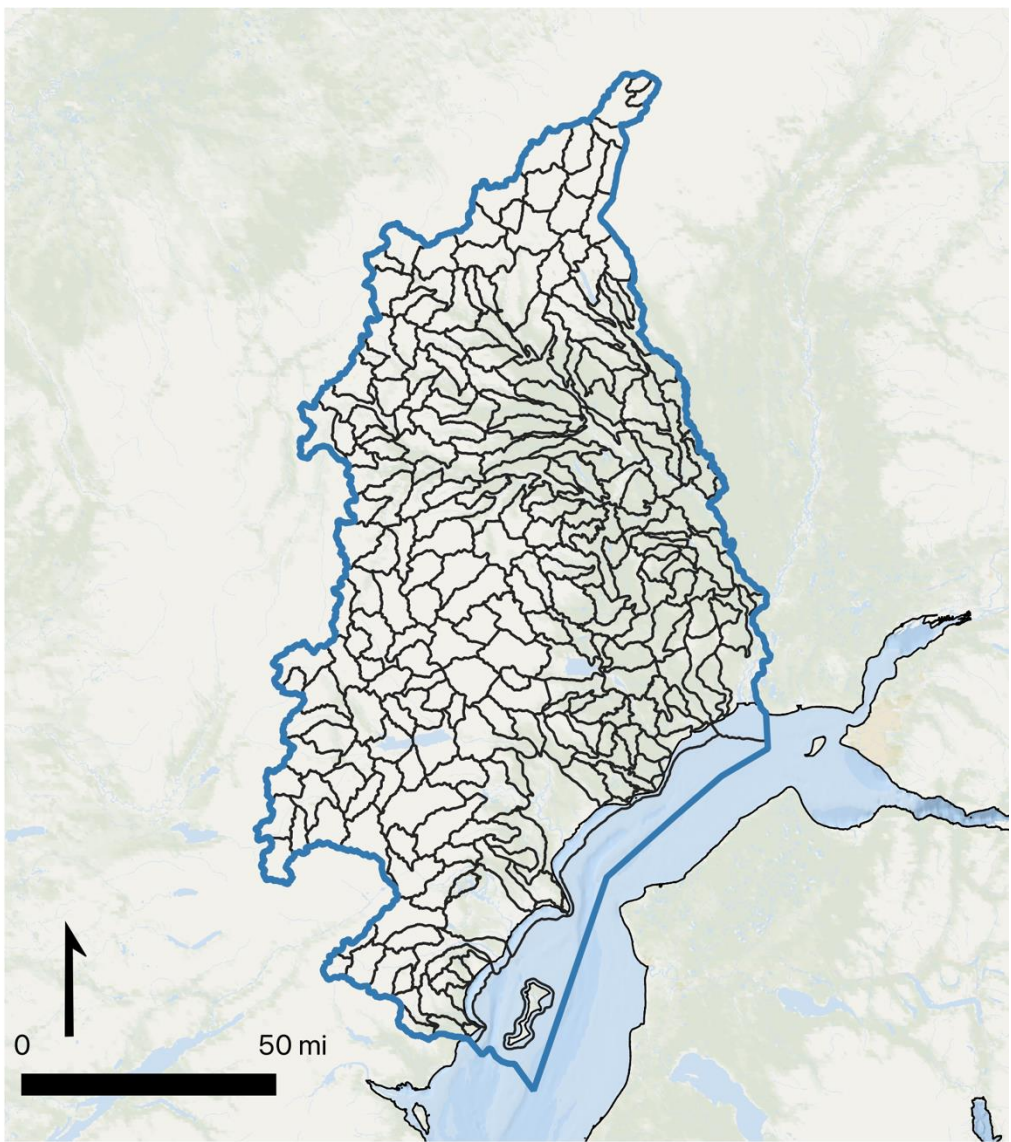




Tyonek Tribal Conservation District

Many of the following maps show average conditions for projected climate change and its projected effects for an area of interest for Tyonek Tribal Conservation District and for watersheds within it. Subregional variation in projected climate changes (such as changes in temperature and precipitation) can be visualized for the whole region. For other projections where detail is more important (such as vegetation and wildfire responses), maps focus on units or subsets of units for clarity.



Tyonek region HUC12 watersheds

Using the unit boundaries in the previous image, watersheds overlapped by the Refuge boundaries were selected. These areas are called hydrologic units, or HUC12s, and are useful for summarizing sub-regional averages in climate or impacts.

Many of the following maps show average conditions for climate change and its effects within each watershed rather than gridded pixels. These averages are available in a spreadsheet with watershed level summaries for every watershed. If these are required, contact Jeremy Littell at jlittell@usgs.gov

Climate change and impacts projections



The climate and impacts projections mapped in this document have been iteratively refined, from publicly available climate downscaling products, by Jeremy Littell at the Alaska Climate Adaptation Science Center. Work for Alaska Native Tribal Health Consortium, the BIA-funded Building Resilience Today project, and USFWS was leveraged to produce these summaries.

Most pages in this document present four future scenarios for each climate variable – a medium warming and higher warming scenario for each of two time frames, called “climatologies”, for the middle of the 21st century and late 21st century). Other variables use a “pseudoensemble” approach, the average of many climate models assuming a global +2°C and +4°C future warming (about twice that in Alaska latitudes). Further information on scenarios is in the written report that describes climate projections for the project.

For temperature, precipitation, permafrost, and snowpack, the historical and projected climate used to develop the mapped changes came from the University of Alaska Fairbanks Scenarios Network for Alaska and Arctic Planning (SNAP) archive. These use statistically downscaled bias-corrected climate model output for five climate models shown to have skill in the Arctic (CGCM3, GFDL CM3, GISS E2R, IPSL CM5A LR, and CCSM4). Mapped averages are the *average* of these five climate models and are presented for Representative Concentration Pathways (RCP) 4.5 and 8.5 to describe a range of likely warming given atmospheric greenhouse gas concentrations. RCP 4.5 is consistent with a medium range of future warming, RCP 8.5 is consistent with a higher (but not necessarily the highest) range of future warming. The mapping for these variables also focuses on two different thirty-year time windows: the 2050s (2040-2069) and the 2080s (2070-2099). Changes are compared to 1970-1999 downscaled historical climate. The changes in the lower left of the page are the model averages for each of the four panels over the region. For runoff (“Q”), potential evapotranspiration, and water balance deficit, output from TerraClimate was summarized for +2°C and +4°C future global warming, roughly consistent with ensemble means for RCP4.5 and RCP 8.5 by 2100.

These choices were made to address the three main sources of climate projection uncertainty. Using multiple models addresses uncertainty due to different climate model construction. Using two RCPs addresses the uncertainty in the rate of future greenhouse gas emissions. Using thirty-year averages decreases the role of natural climate variability in the timing and size of projected changes.

Ecosystem (vegetation and fire) projections were available for two climate models (CGCM3 and CCSM4) used to drive the ALFRESCO landscape fire model under the RCP 8.5 scenario.

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>

Climate and other conditions – descriptions of variables (1)

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 surface air temperature from historical to future, in degrees, averaged over the year or three-month periods.

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 from historical to future, averaged over the year or three-month periods.

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.

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 cool season 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 it is, the more likely permafrost is to persist. Below freezing (0C or 32F), the permafrost is less likely to thaw. Near or 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., 1 would mean a doubling of fire frequency in a place that burned once per century historically); 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).



Climate and other conditions – descriptions of variables (2)

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.

TerraClimate water balance model projections

Projections of changes in seasonal and annual water balance were summarized from TerraClimate, a global source of climate projections and related water balance variables. Instead of using several climate model projections to drive hydrologic models, TerraClimate future projections use a 2°C (about 3.6°F) and a +4 °C (about 7.2°F) global average warming scenario (relative to 1981-2010). In Alaska, these result in similar (within 0.5°C) projected changes in warming to the five models SNAP downscaled for Alaska (see above). See more: <http://www.climatologylab.org/terraclimate.html>

Change in April - September and summer (June– August) potential evapotranspiration– For these maps, the change in growing season (AMJJAS) and summer (JJA) potential evapotranspiration for +2°C and +4°C futures are shown. Potential evapotranspiration describes how much water the atmosphere can evaporate from plants and the land surface. It is affected by temperature, relative humidity, solar radiation, wind, vegetation, and other factors.

Change in April - September and summer (June– August) deficit (PET-AET)–

For these maps, the change in growing season (AMJJAS) and summer (JJA) water balance deficit for +2°C and +4°C futures are shown. Water deficit here is the difference between potential evapotranspiration (above) and how much water plants can use, called actual evapotranspiration. Water deficit is like a metric of drought, and the larger the number, the larger the deficit of water plants could experience. Negative change in deficit means a surplus of water relative to historical conditions.

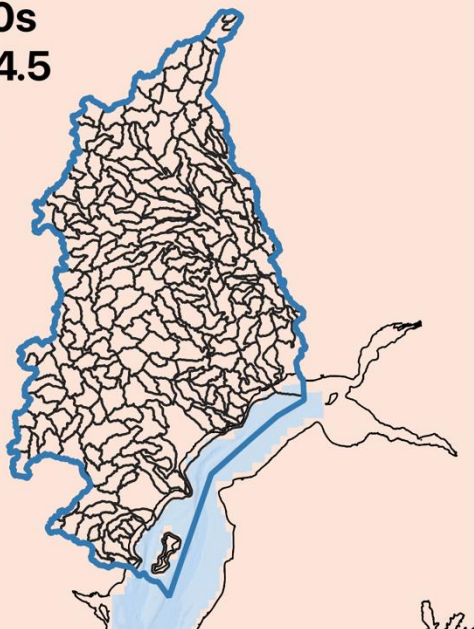


Annual temperature (“Temp”) and precipitation (“Precip”) changes for Arctic NWR, averaged over the refuge domain. Means are for five climate models downscaled for Alaska by SNAP. Ranges are for low model and high model from the five downscaled models.

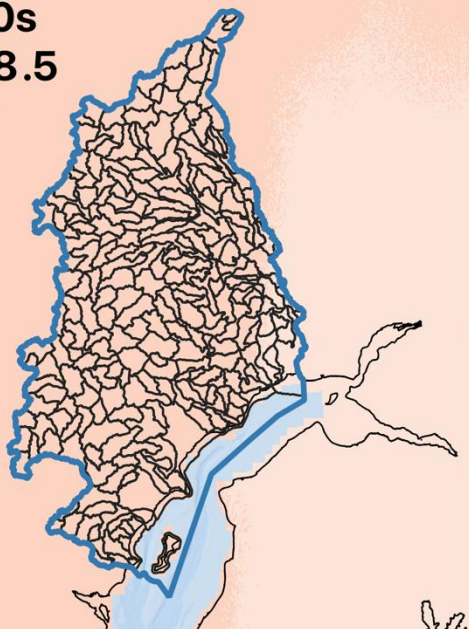
		2050s		2080s	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
Temp	Mean	3.4	4.3	4.3	7.1
(Δ °C, +)	Range	1.7 - 6.7	2.4 - 7.6	2.2 - 8.1	4.4 - 11.3
Temp	Mean	6.1	7.7	7.7	12.7
(Δ °F, +)	Range	3.1 - 12.1	4.3 - 13.7	4.0 - 14.5	7.9 - 20.4
Precip	Mean	45.2	49.1	50.5	72.1
(%, +)	Range	33.8 - 68.8	35.6 - 75.4	39.8 - 75.7	48.3 - 104.6

*Note – these averages vary on the order of 0.2°C from values presented in tables for maps below due to different resolutions of gridded products. This table is for 2km resolution instead of 771m.

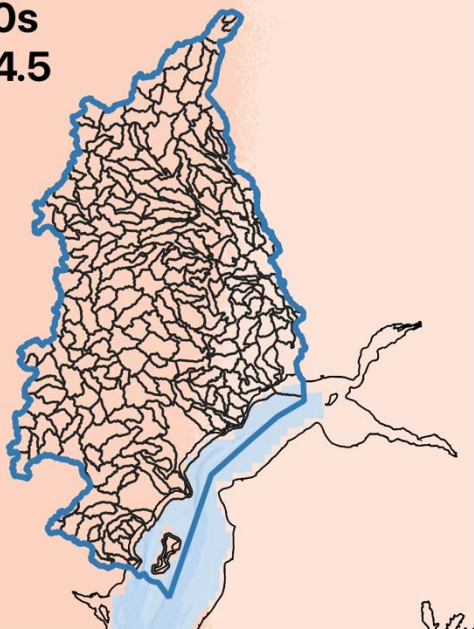
**2050s
RCP4.5
ANN**



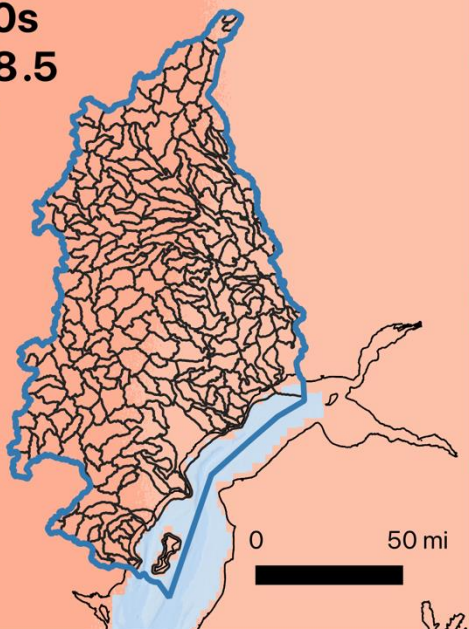
**2050s
RCP8.5
ANN**



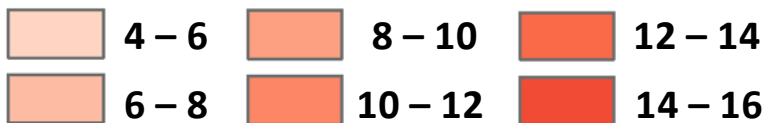
**2080s
RCP4.5
ANN**



**2080s
RCP8.5
ANN**



Change in temperature (°F)



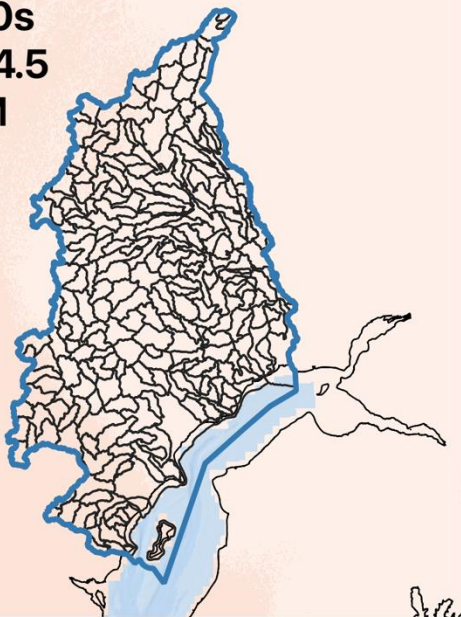
Annual Temperature change, relative to 1970-1999

Annual temperature is projected to increase under all scenarios:

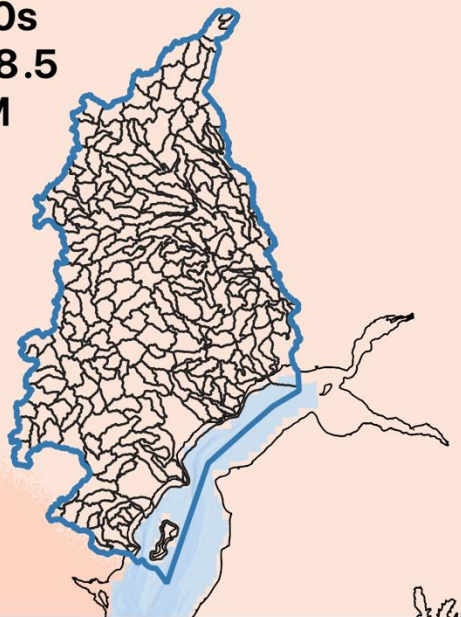
	2050s, RCP 4.5		2050s, RCP 8.5		2080s, RCP 4.5		2080s, RCP 8.5	
	°F	°C	°F	°C	°F	°C	°F	°C
Tyonek	4.7	2.9	6.5	3.6	6.3	3.5	10.0	5.6



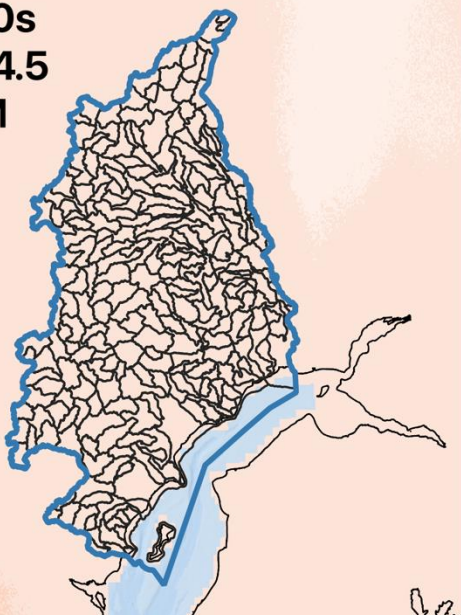
**2050s
RCP4.5
MAM**



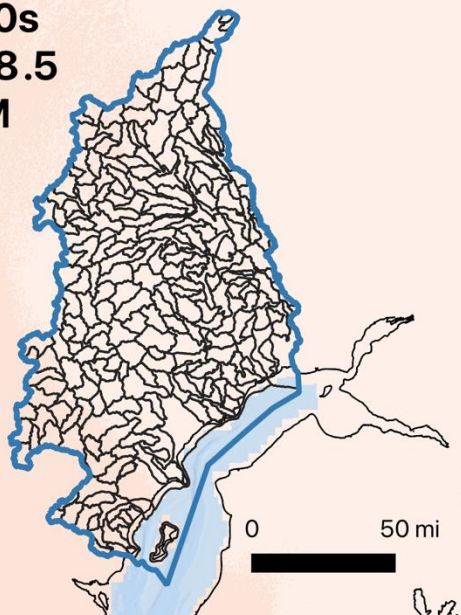
**2050s
RCP8.5
MAM**



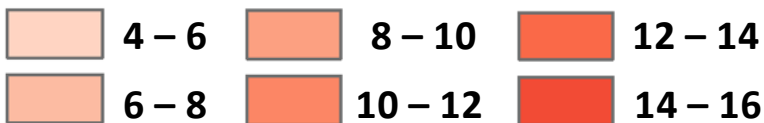
**2080s
RCP4.5
MAM**



**2080s
RCP8.5
MAM**



Change in temperature (°F)

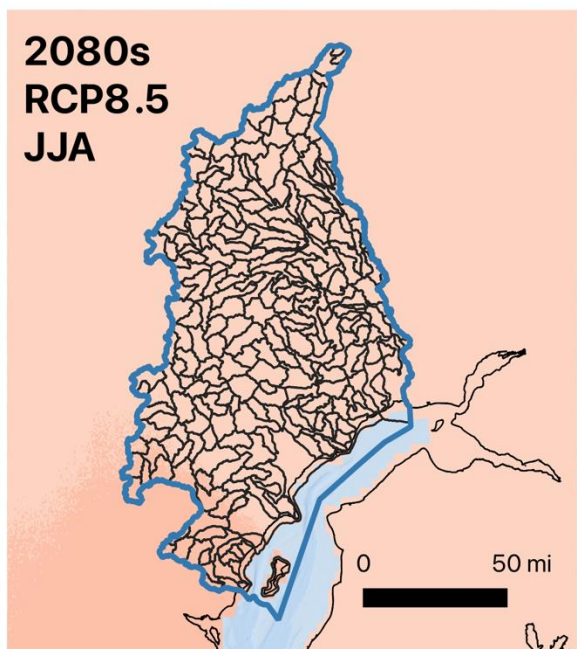
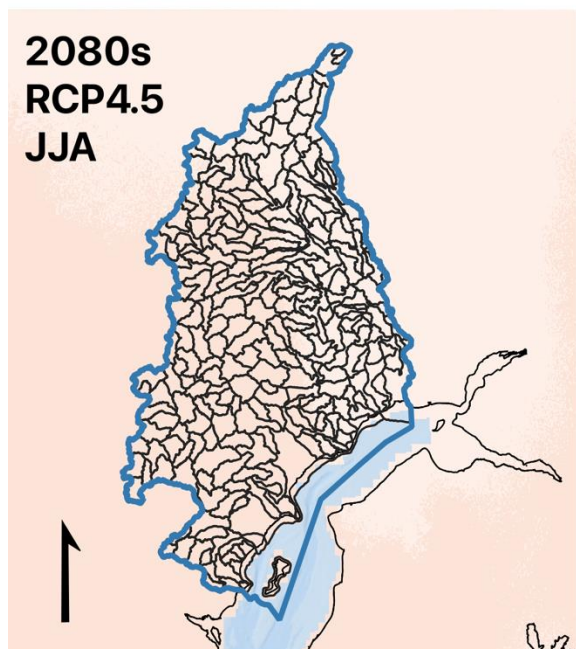
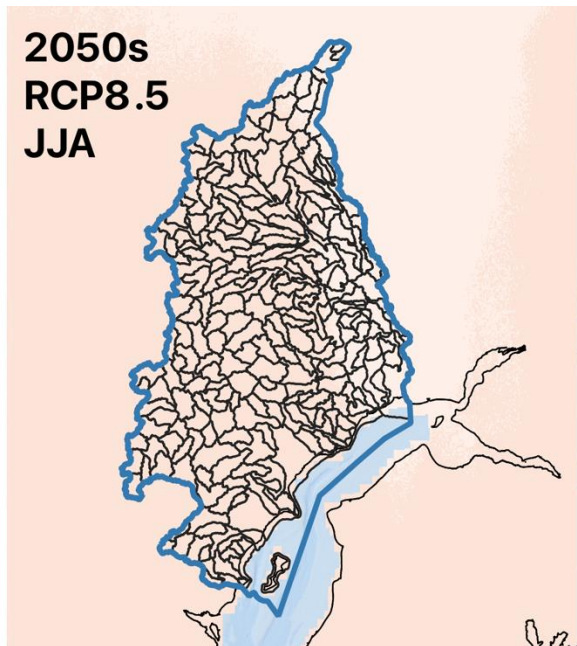
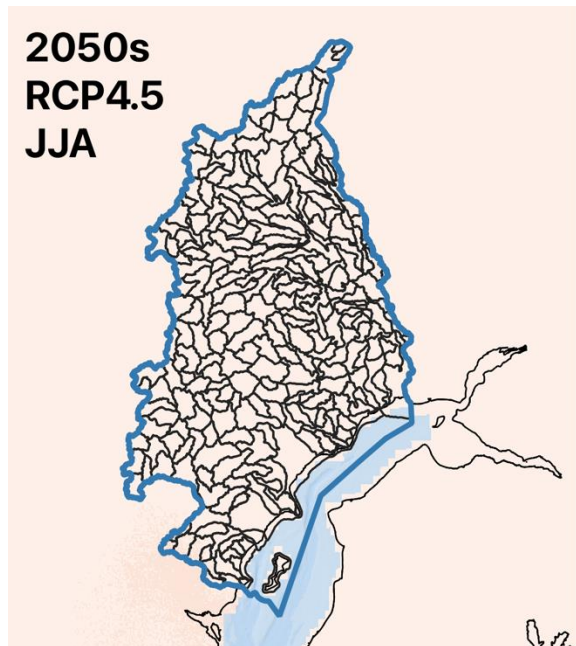


Spring (March – May) Temperature change, relative to 1970-1999

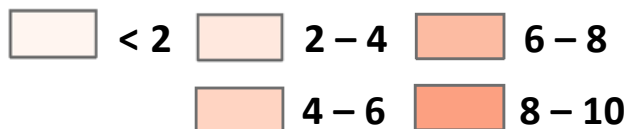
Spring temperature is projected to increase under all scenarios:

	2050s, RCP 4.5		2050s, RCP 8.5		2080s, RCP 4.5		2080s, RCP 8.5	
	°F	°C	°F	°C	°F	°C	°F	°C
Tyonek	3.8	2.1	5.3	2.9	4.8	2.7	8.4	4.7





Change in temperature (°F)

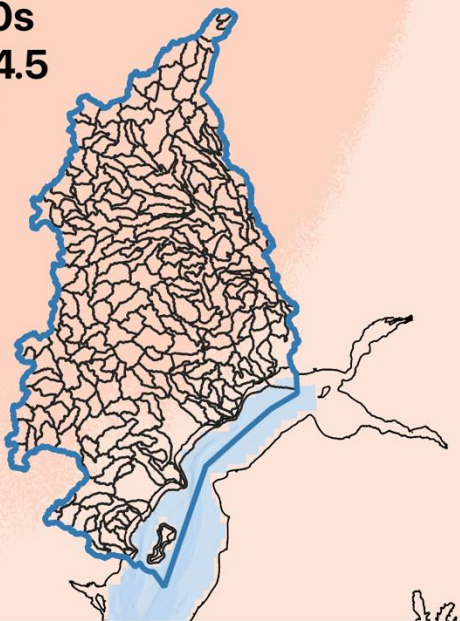


Summer (June– August) Temperature change, relative to 1970-1999

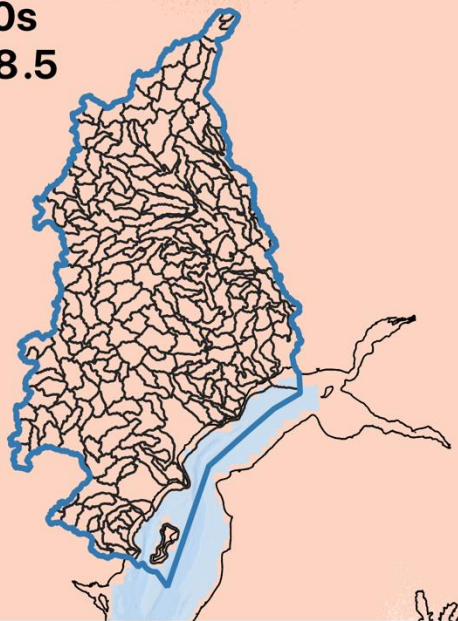
Summer temperature is projected to increase under all scenarios:

	2050s, RCP 4.5		2050s, RCP 8.5		2080s, RCP 4.5		2080s, RCP 8.5	
	°F	°C	°F	°C	°F	°C	°F	°C
Tyonek	3.1	1.7	4.3	2.4	4.1	2.3	7.4	4.1

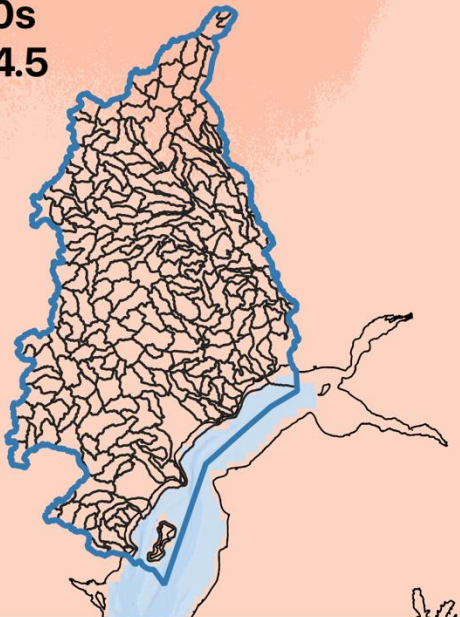
**2050s
RCP4.5
SON**



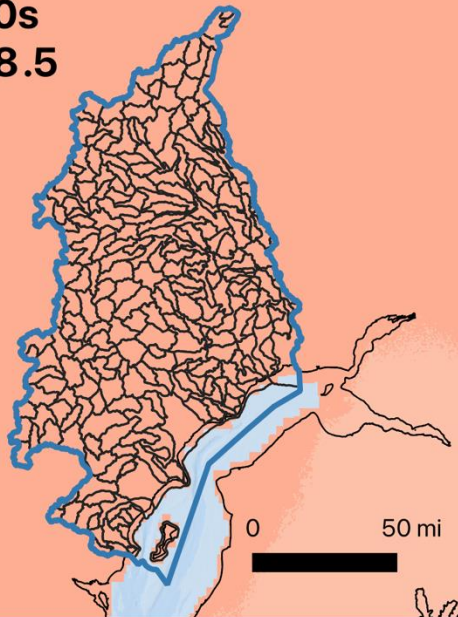
**2050s
RCP8.5
SON**



**2080s
RCP4.5
SON**



**2080s
RCP8.5
SON**



Change in temperature (°F)

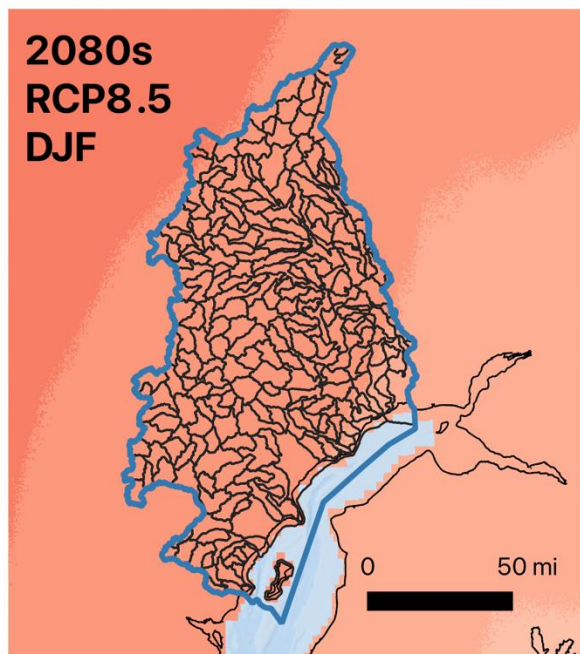
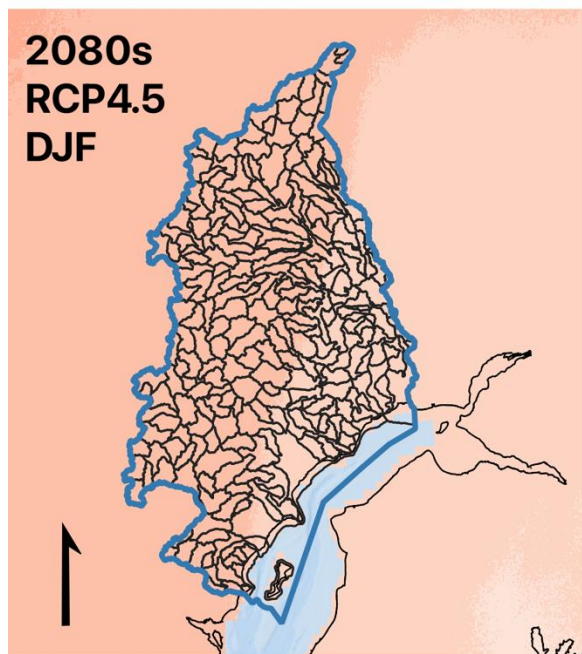
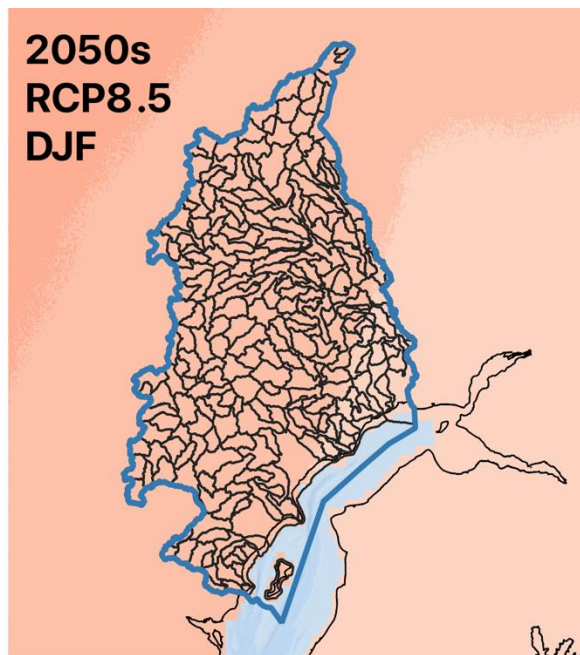
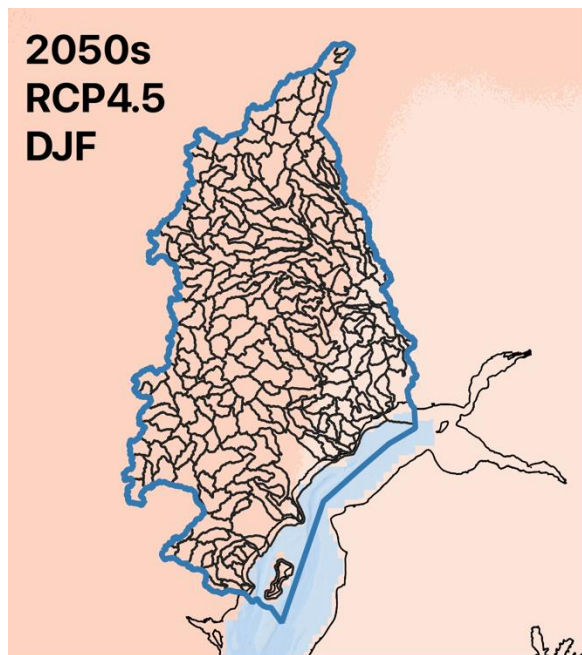


Autumn (Sep. – Nov.) Temperature change, relative to 1970-1999

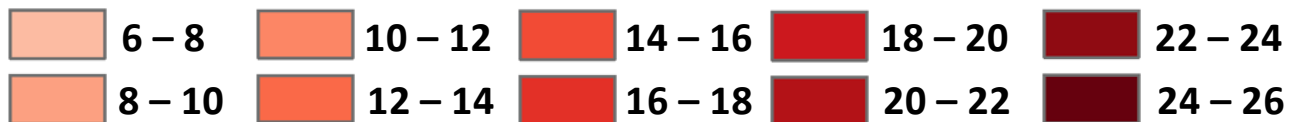
Autumn temperature is projected to increase under all scenarios:

	2050s, RCP 4.5		2050s, RCP 8.5		2080s, RCP 4.5		2080s, RCP 8.5	
	°F	°C	°F	°C	°F	°C	°F	°C
Tyonek	6.1	3.4	7.5	4.2	7.8	4.3	11.1	6.2





Change in temperature (°F)

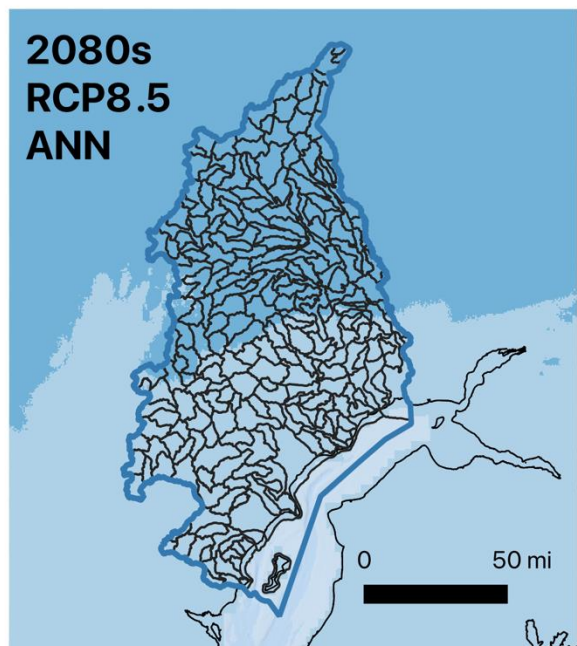
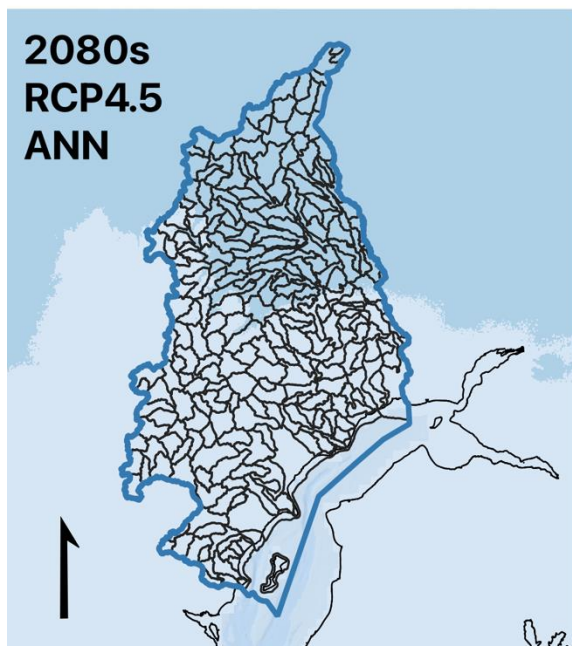
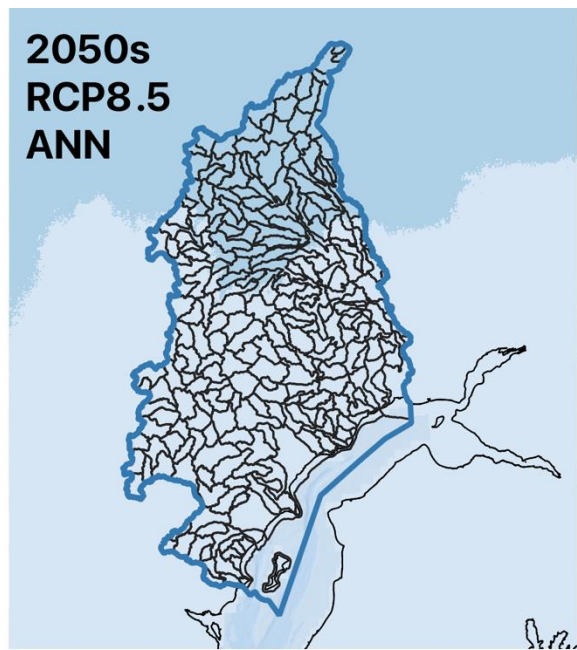
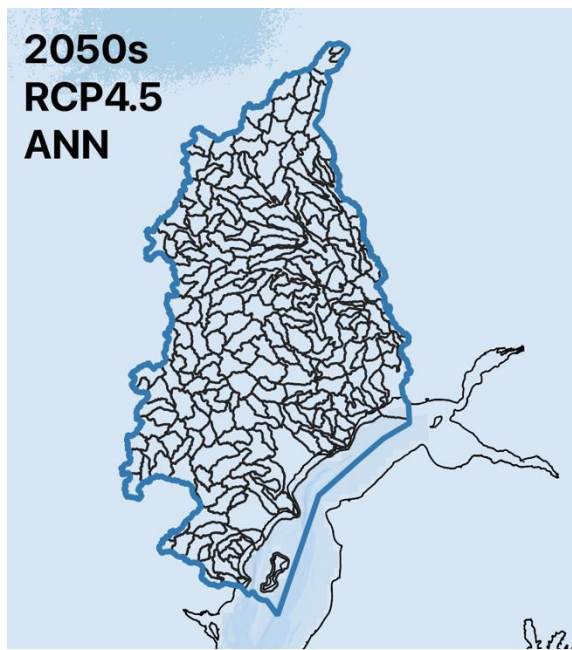


Winter (Dec. – Feb.) Temperature change, relative to 1970-1999

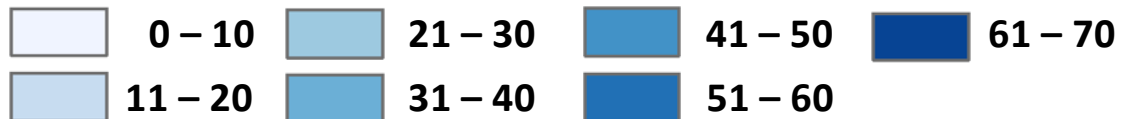
Winter temperature is projected to increase under all scenarios:

	2050s, RCP 4.5		2050s, RCP 8.5		2080s, RCP 4.5		2080s, RCP 8.5	
	°F	°C	°F	°C	°F	°C	°F	°C
Tyonek	6.5	3.6	8.7	4.8	8.2	4.6	12.9	7.2





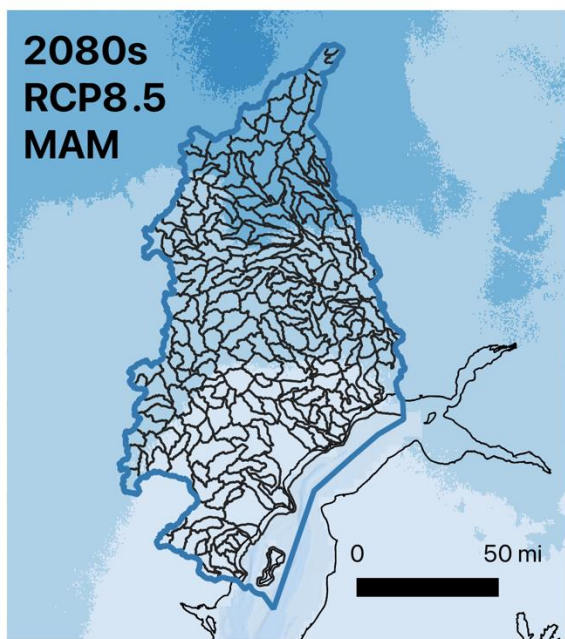
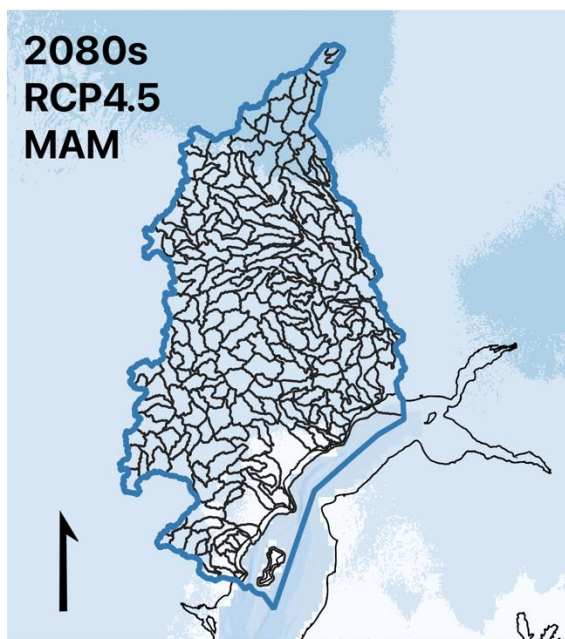
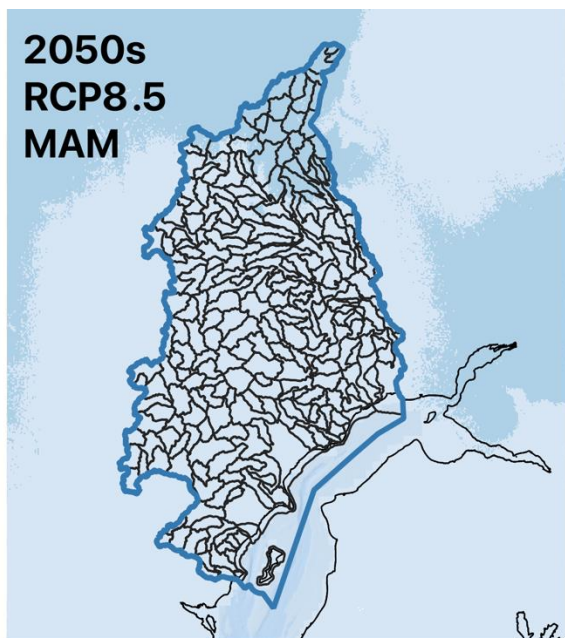
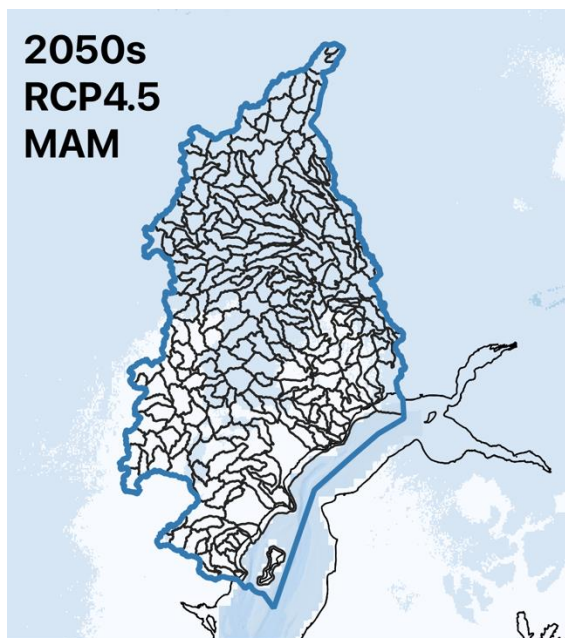
Change in precipitation (%)



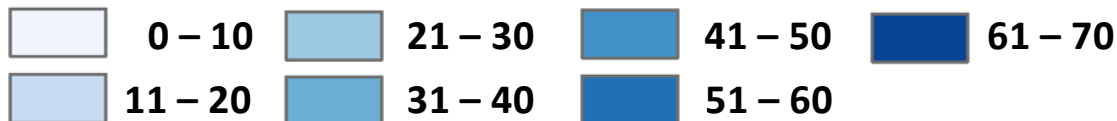
Change in Annual precipitation, relative to 1970-1999

Annual precipitation is projected to increase under all scenarios:

	2050s, RCP 4.5	2050s, RCP 8.5	2080s, RCP 4.5	2080s, RCP 8.5
Tyonek	15.8	18.3	19.5	30.0



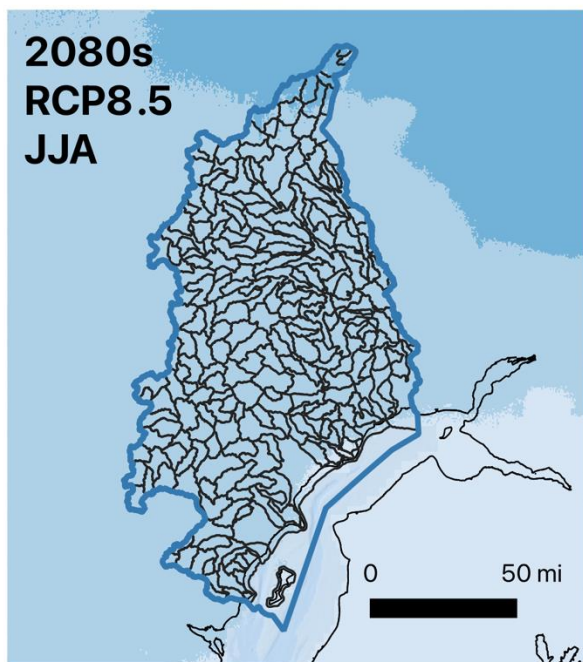
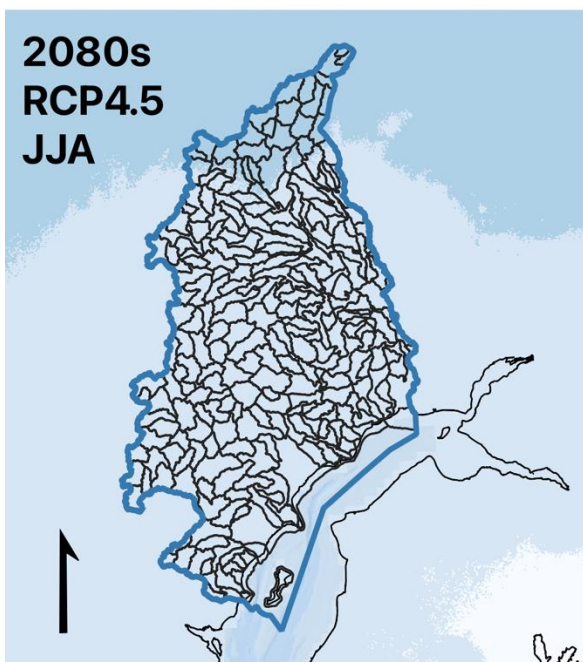
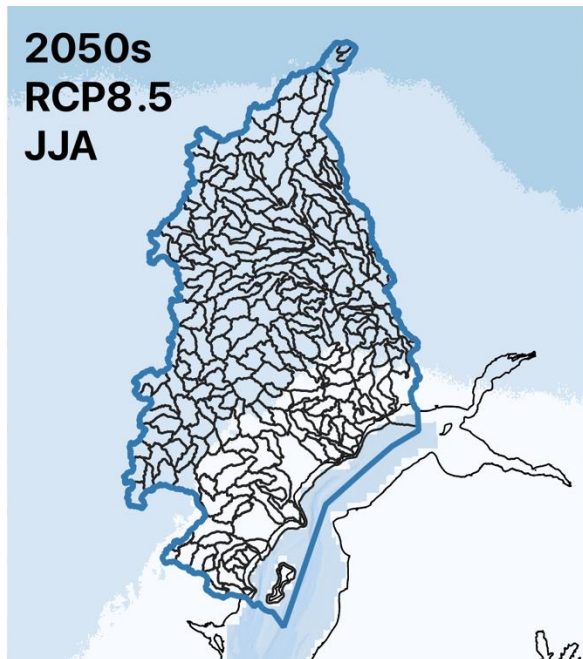
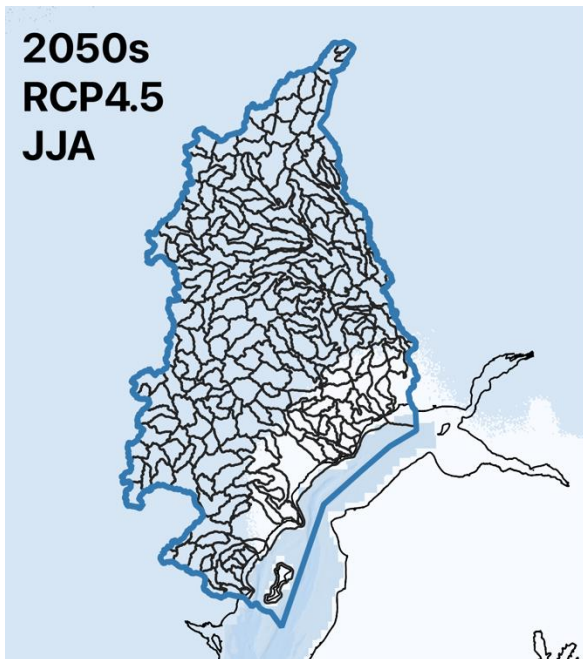
Change in precipitation (%)



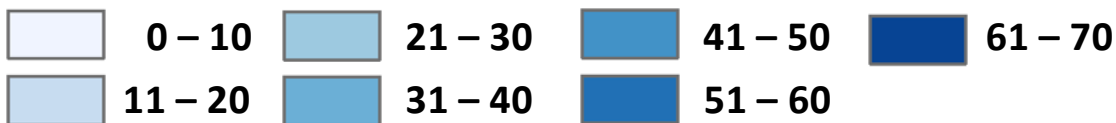
Change in Spring (March – May) precipitation, relative to 1970-1999

Spring precipitation is projected to increase under all scenarios:

	2050s, RCP 4.5	2050s, RCP 8.5	2080s, RCP 4.5	2080s, RCP 8.5
Tyonek	10.7	16.4	14.5	23.8



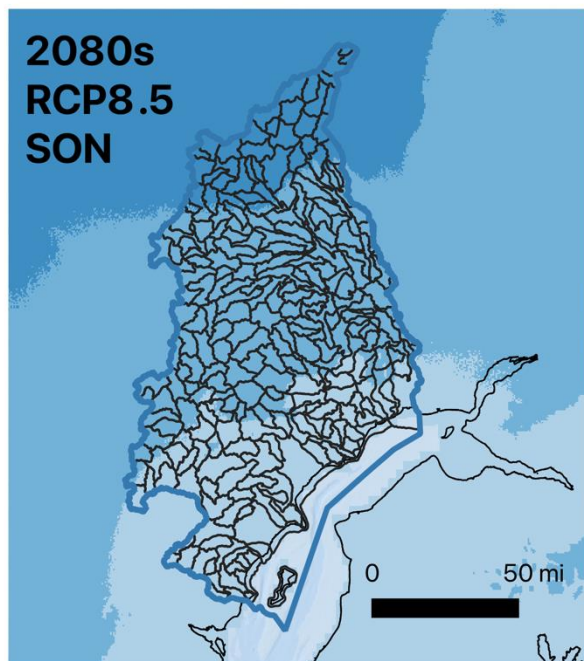
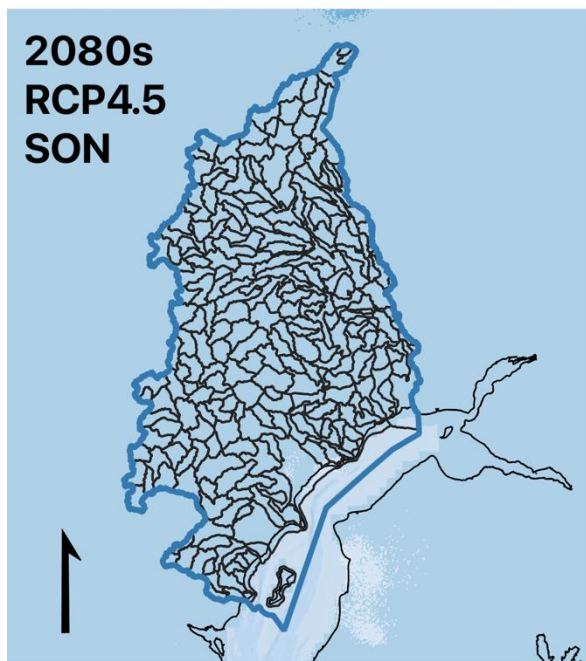
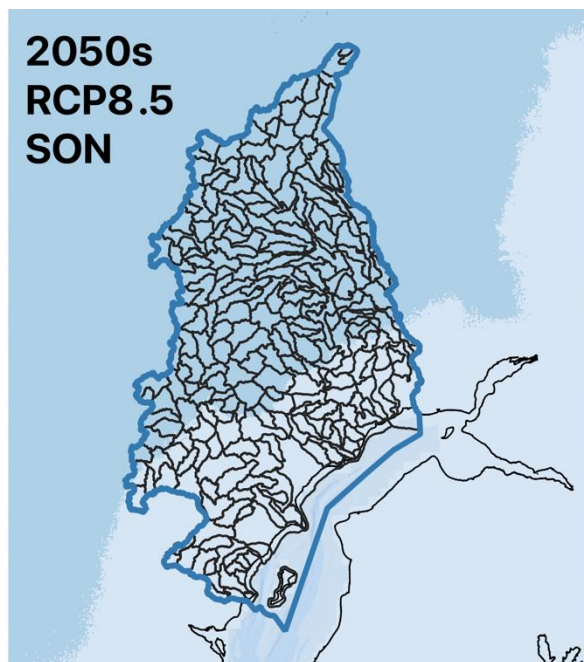
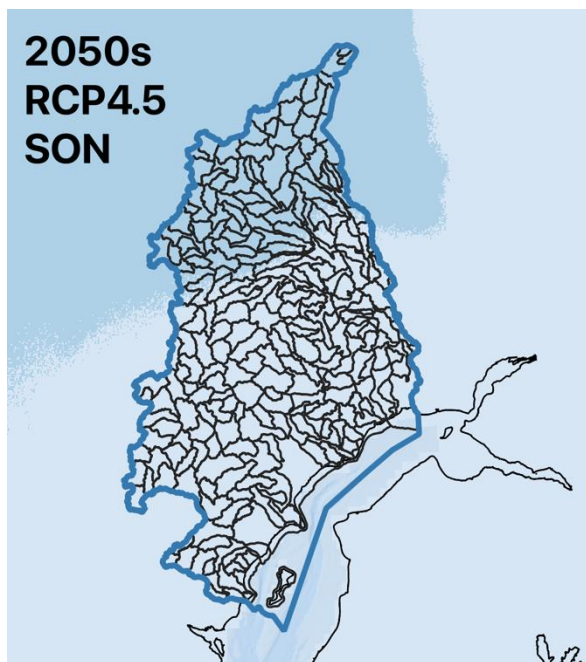
Change in precipitation (%)



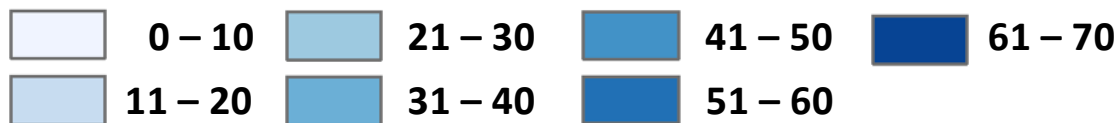
Change in Summer (Jun.– Aug.) precipitation, relative to 1970-1999

Summer precipitation is projected to increase under all scenarios:

	2050s, RCP 4.5	2050s, RCP 8.5	2080s, RCP 4.5	2080s, RCP 8.5
Tyonek	12.5	12.5	16.4	24.6



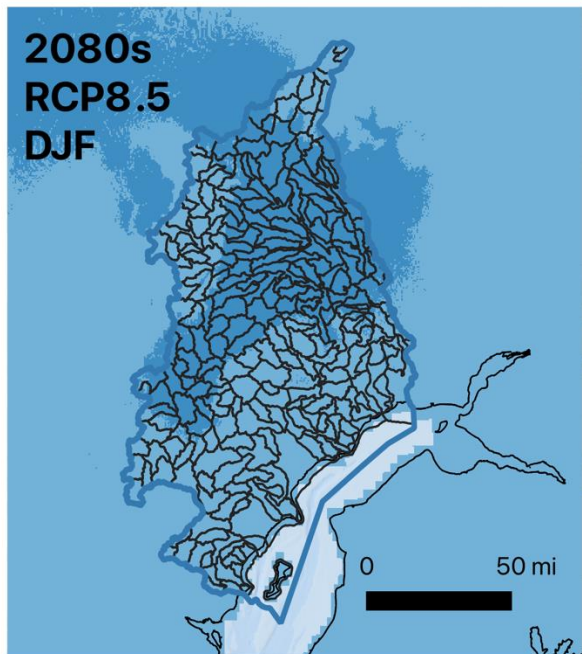
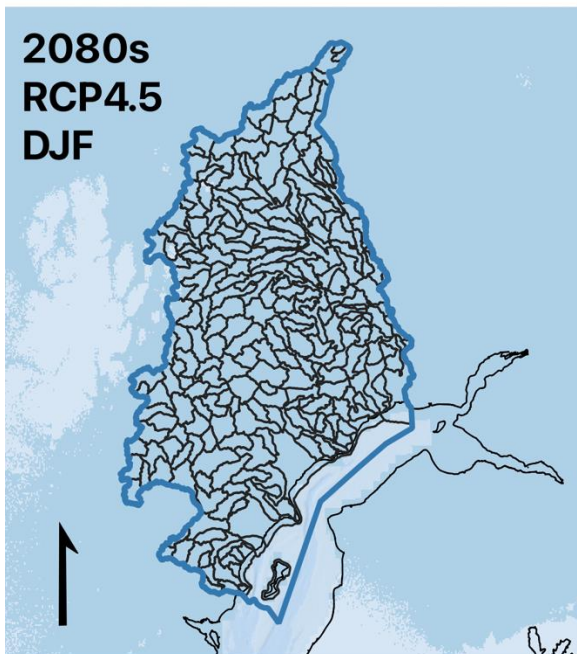
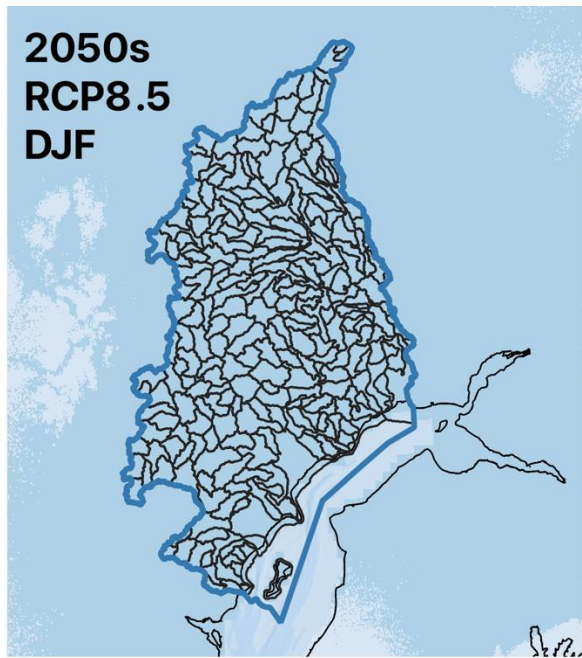
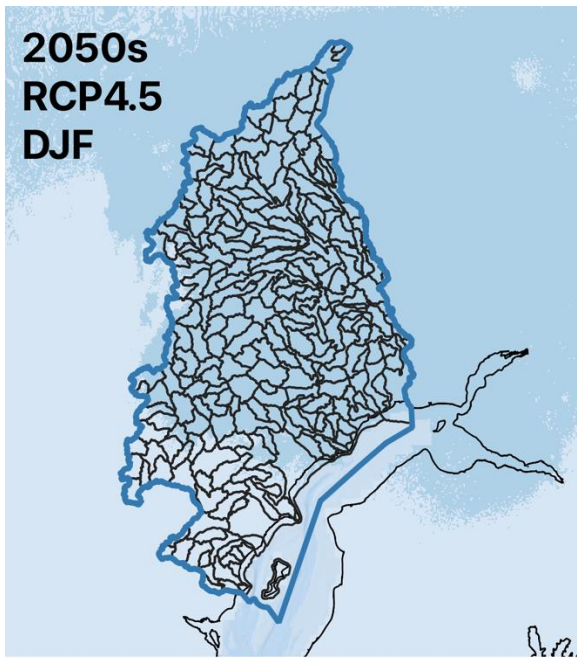
Change in precipitation (%)



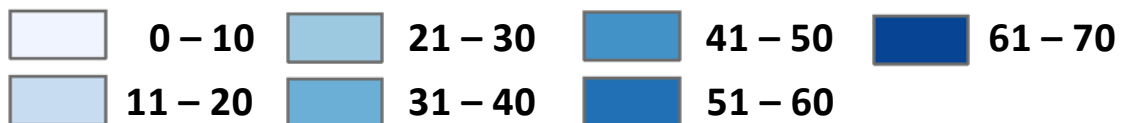
Change in Autumn (Sep.– Nov.) precipitation, relative to 1970-1999

Autumn precipitation is projected to increase under all scenarios:

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18.5	21.9	23.7	33.3



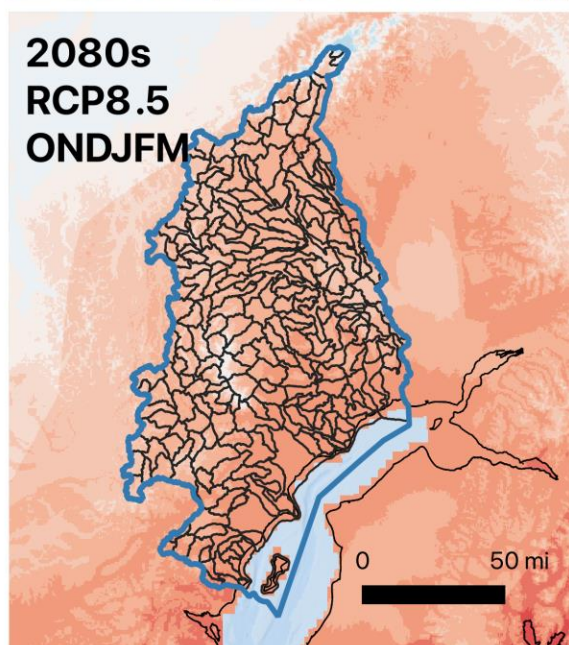
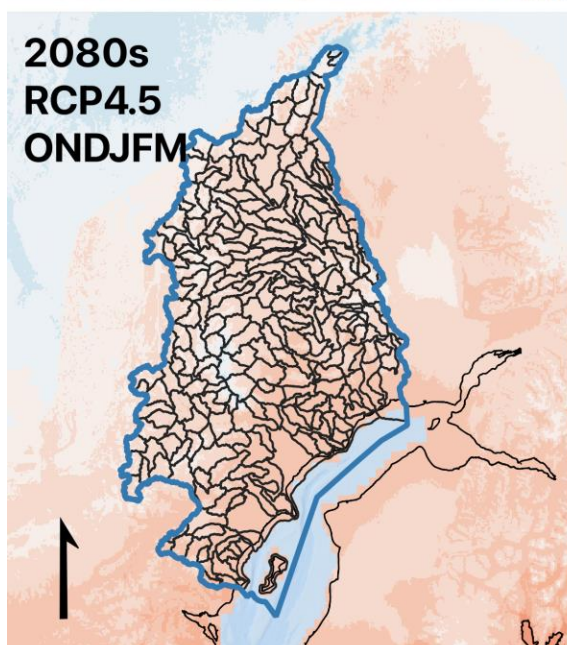
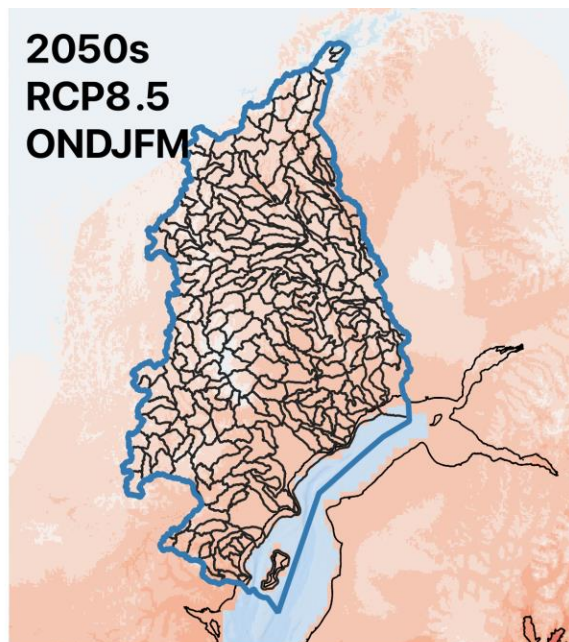
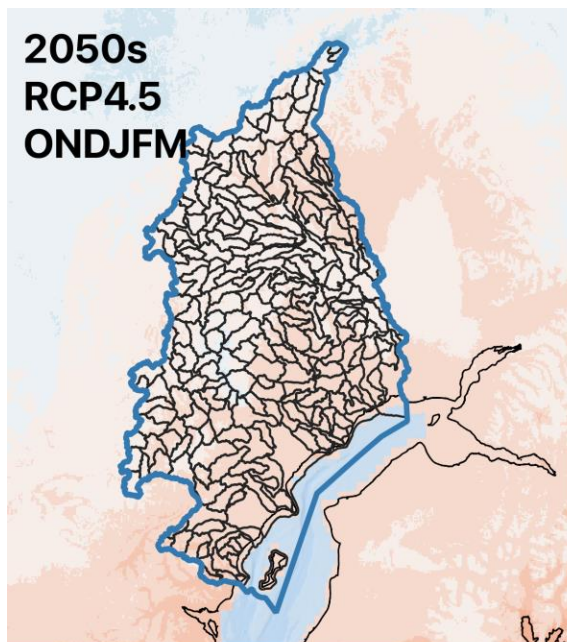
Change in precipitation (%)



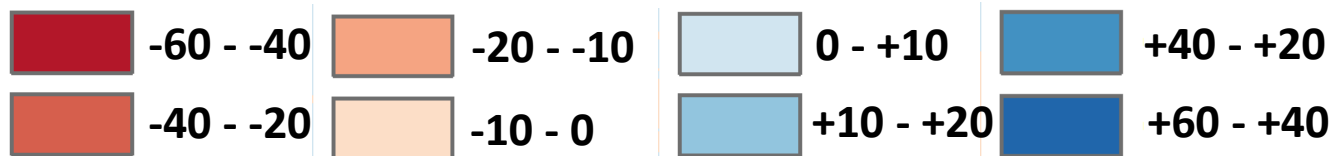
Change in Winter (Dec.– Feb.) precipitation, relative to 1970-1999

Winter precipitation is projected to increase under all scenarios:

	2050s, RCP 4.5	2050s, RCP 8.5	2080s, RCP 4.5	2080s, RCP 8.5
Tyonek	15.8	18.3	19.5	30.0

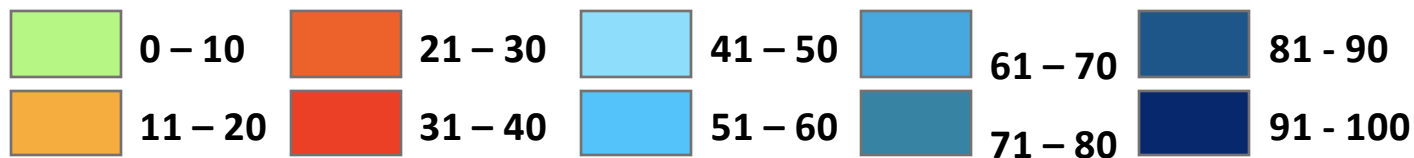
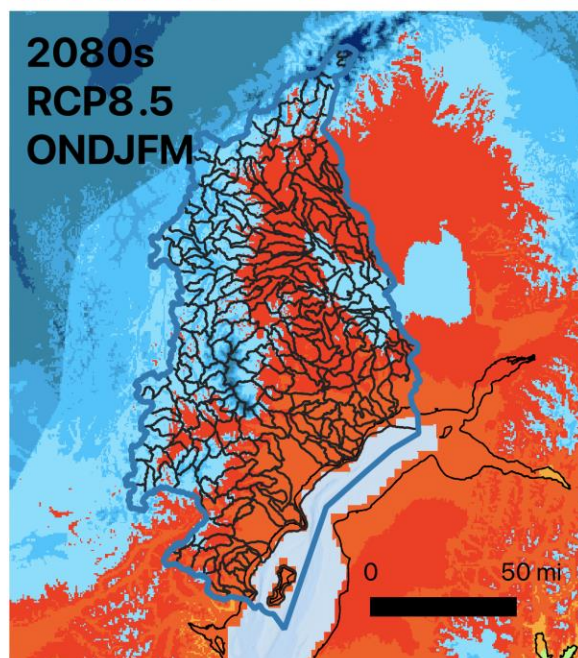
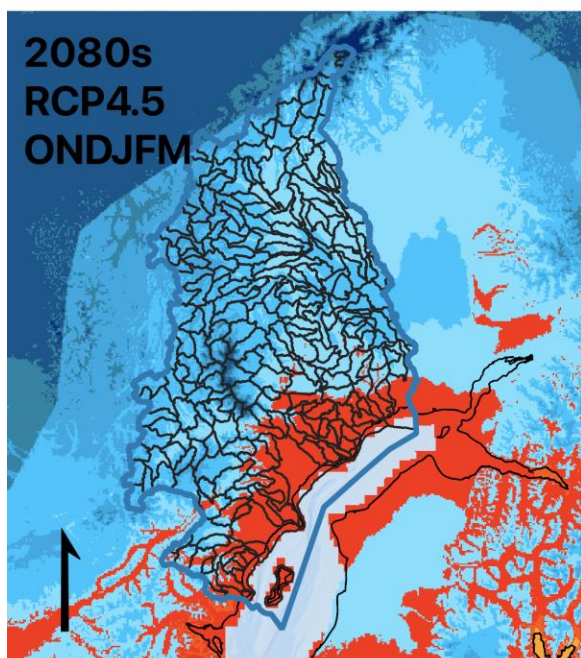
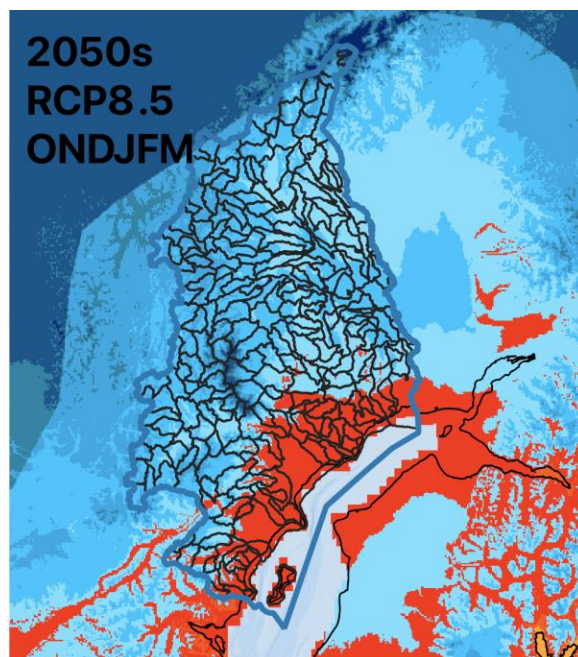
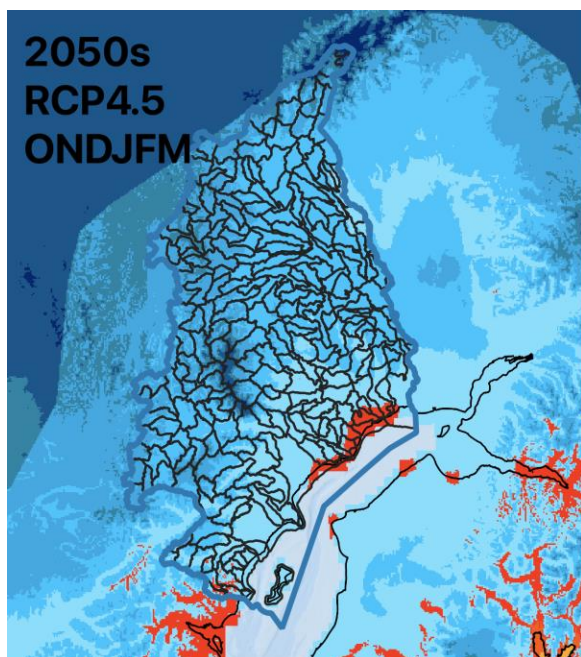


Change in snow (%)



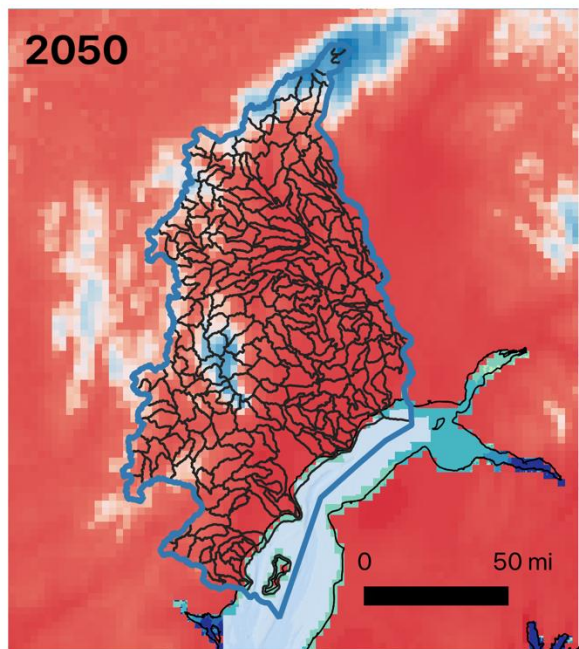
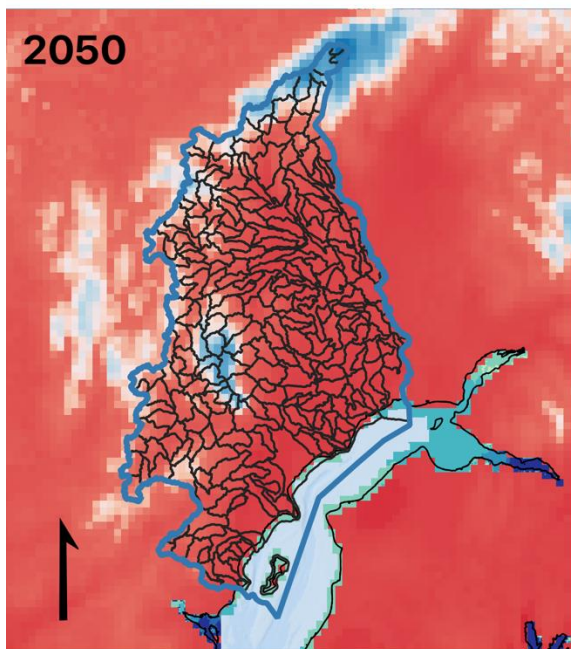
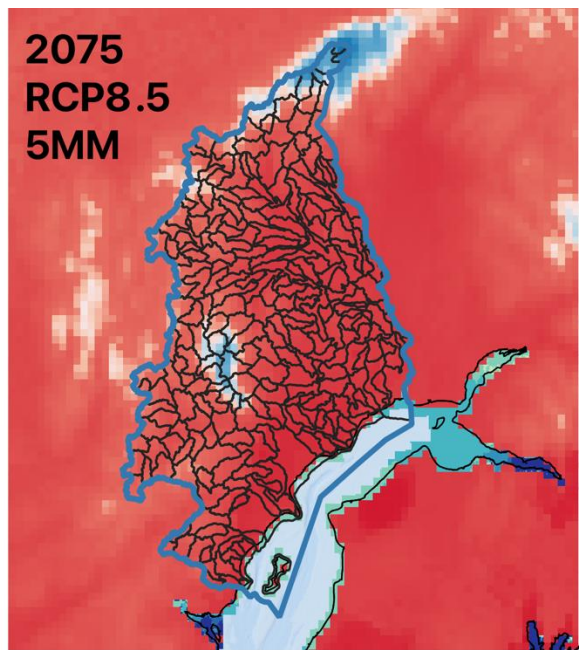
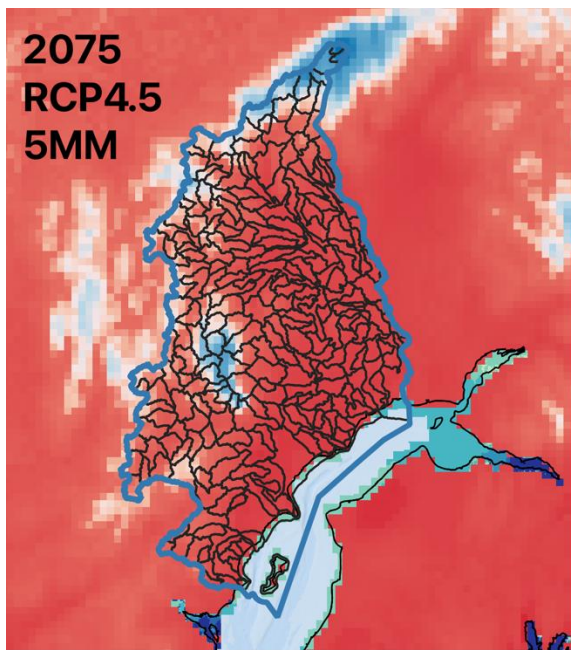
Change in October to March snowfall water equivalent (snowfall), relative to 1970-1999. This is the change in the amount of snow that falls

	2050s, RCP 4.5	2050s, RCP 8.5	2080s, RCP 4.5	2080s, RCP 8.5
Tyonek	-9.9	-18.1	-15.7	-35.0

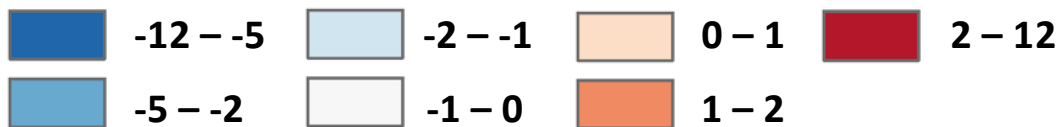


Snow index, Oct. to Mar. % of precipitation total snow. This is a measure of how snow-dominated runoff is likely to be. Blues indicate snow dominated, reds and oranges are in between snow dominated and rain dominated. Greens represent rain dominated.

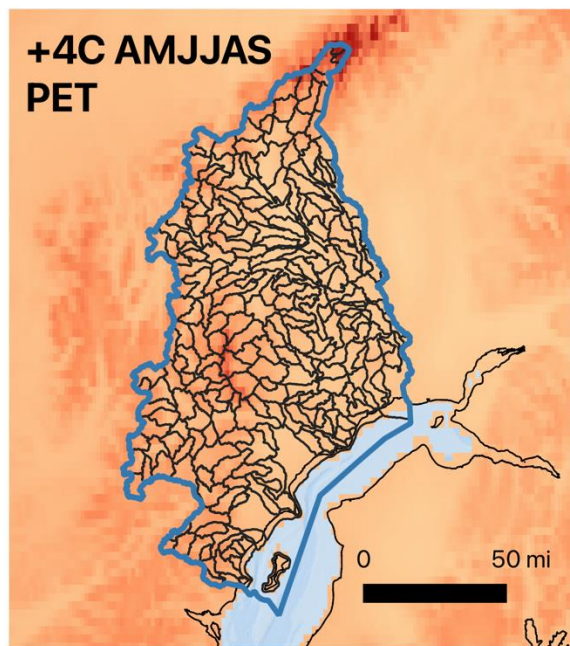
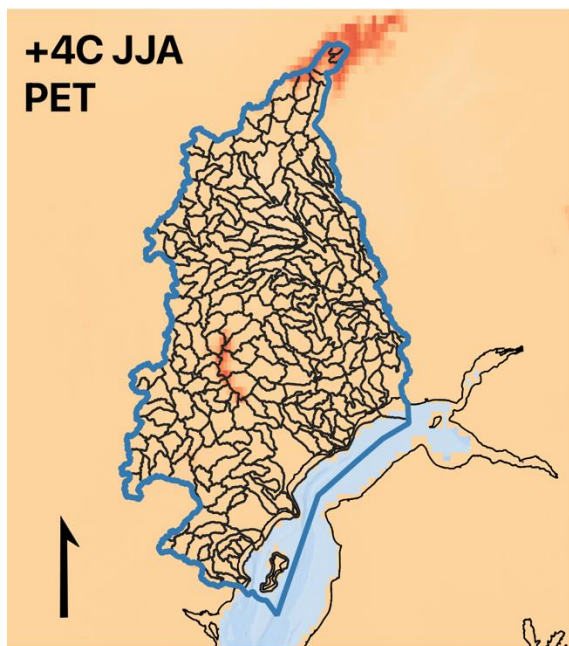
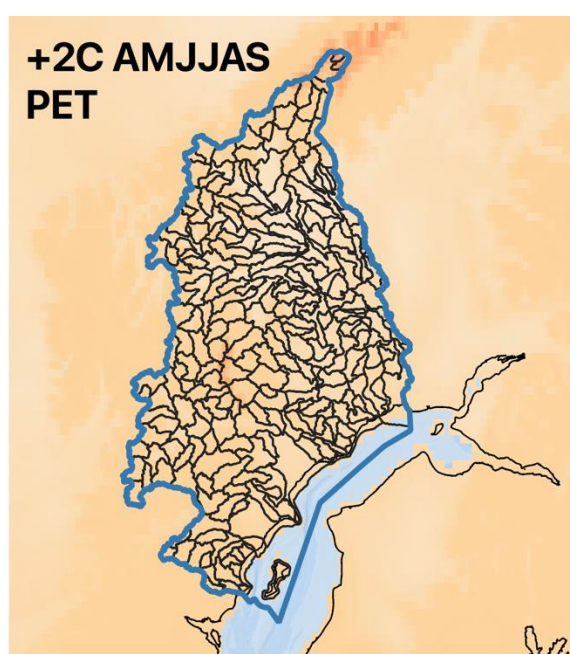
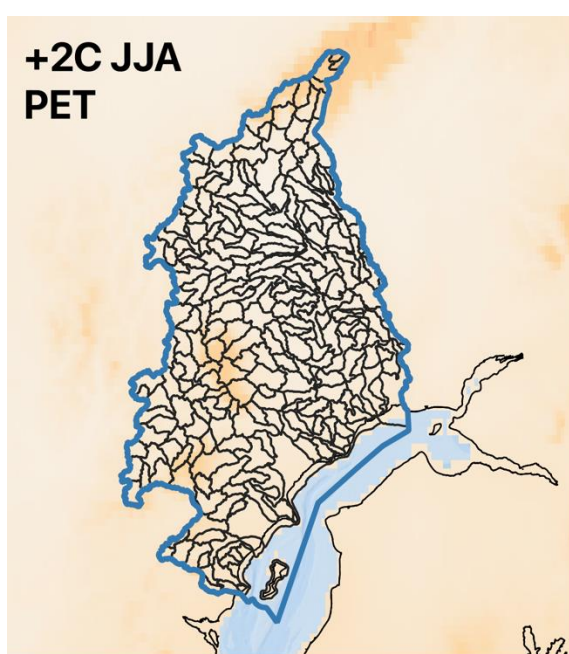
	2050s, RCP 4.5	2050s, RCP 8.5	2080s, RCP 4.5	2080s, RCP 8.5
Tyonek	56.2	51.2	50.8	39.4



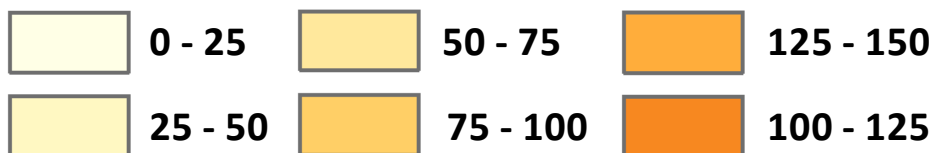
Ground temperature at 1 m depth (°C)



Annual average ground temperature 1m (3.3 ft) deep This is an index of how likely permafrost is to remain under climate change. Once annual average ground temperatures rise close to freezing (0°C, or 32°F red) permafrost thaw is faster and deeper and permafrost is unlikely to persist near the surface. This is for the average of 5 climate models (Melvin et al. 2017)

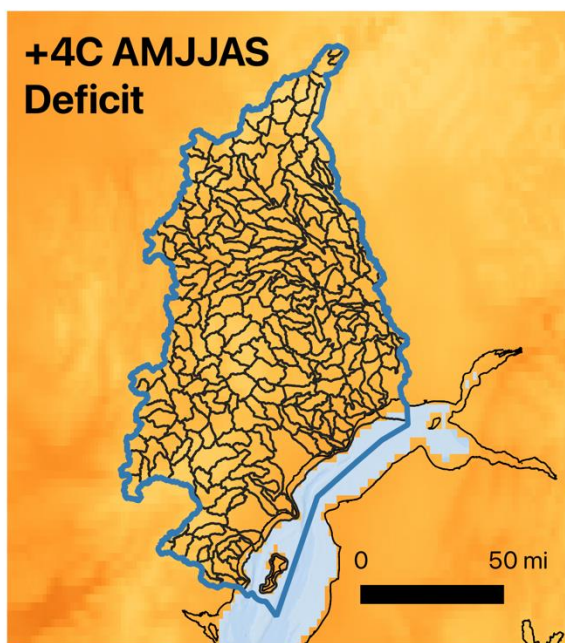
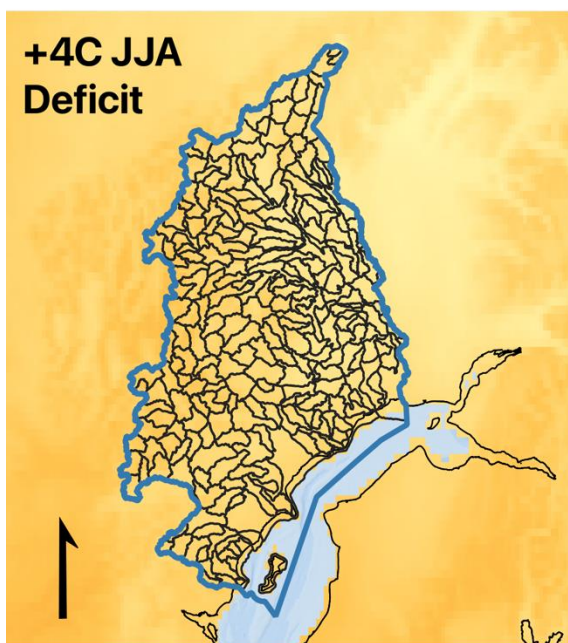
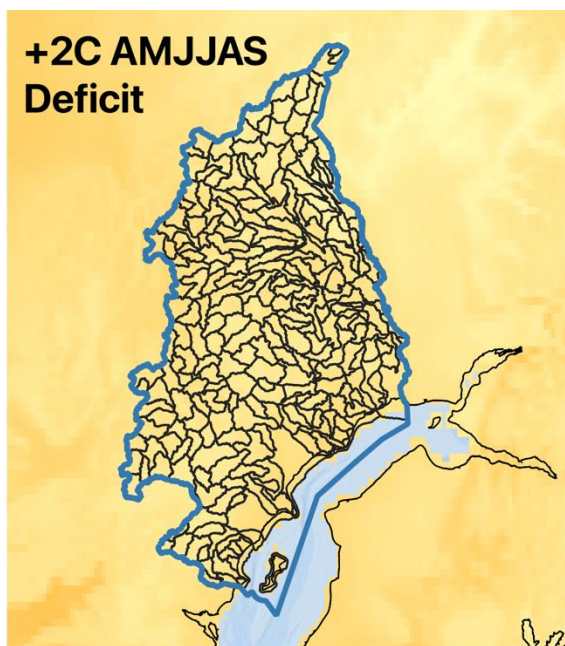
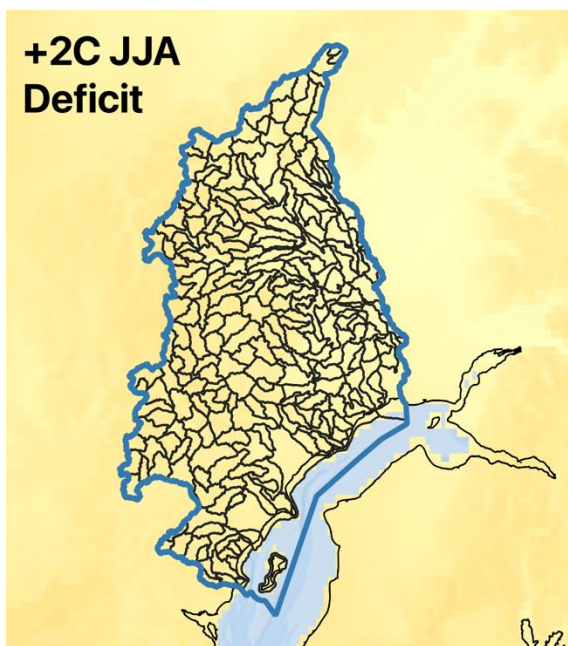


Increase in potential evapotranspiration (mm)

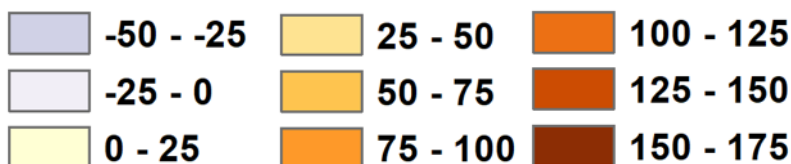


Summer (JJA) and Growing Season (Apr-Sep) PET This shows the change in the amount of water demand the atmosphere places on plants. Each color represents roughly an inch of water.

	+ 2C AMJJAS	+2C JJA	+ 4C AMJJAS	+4C JJA
YFWR	32.9	15.8	88.9	38.7

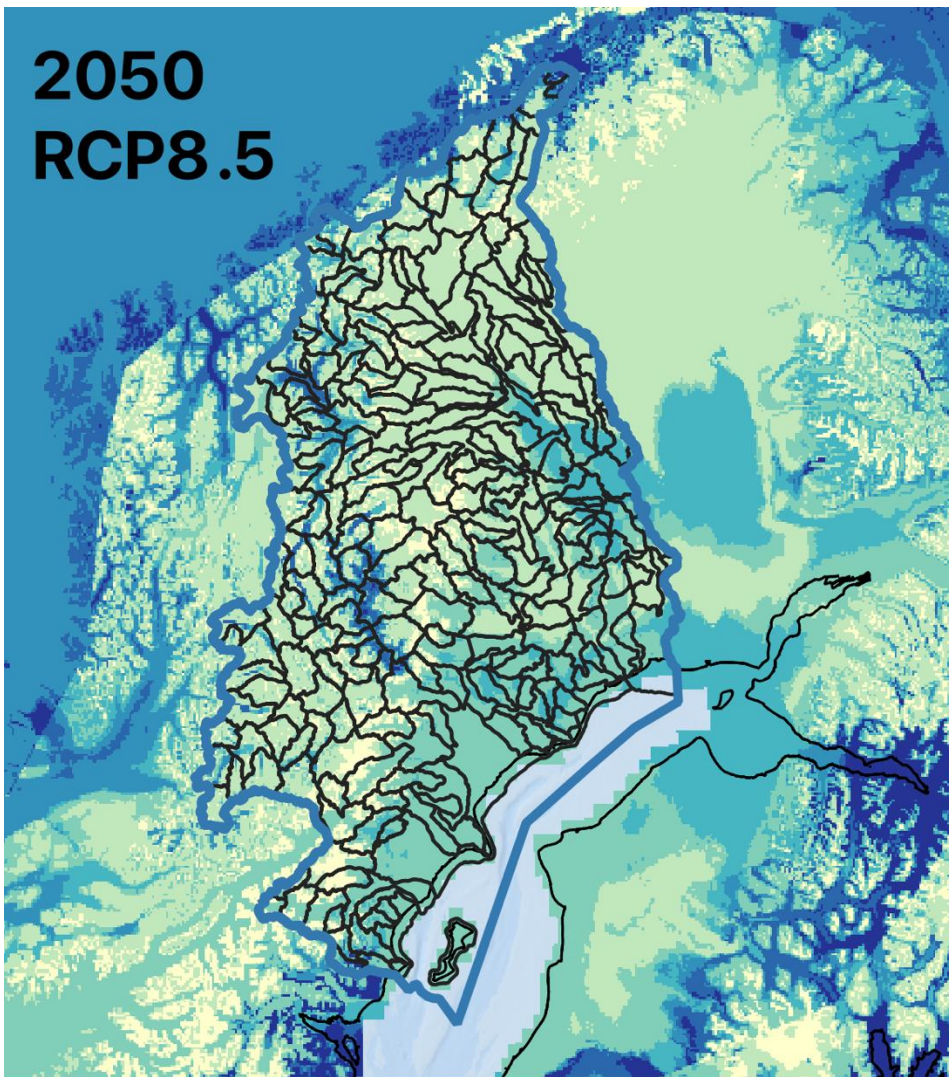


Change in water deficit (mm)



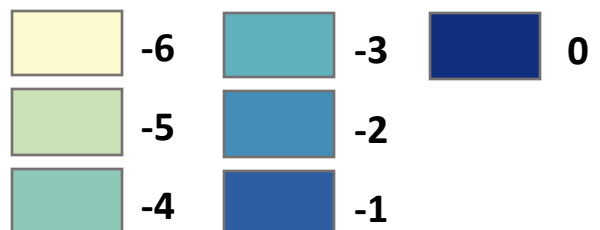
Change in summer (JJA) and growing season (Apr-Sep) deficit This shows the difference between atmospheric demand for water and the amount of water vegetation has access to for meeting that demand. The larger the number, the larger the *decrease* in effective water availability.

	+ 2C AMJJAS	+2C JJA	+ 4C AMJJAS	+4C JJA
YFWR	-14.3	-21.2	+21.8	-6.5



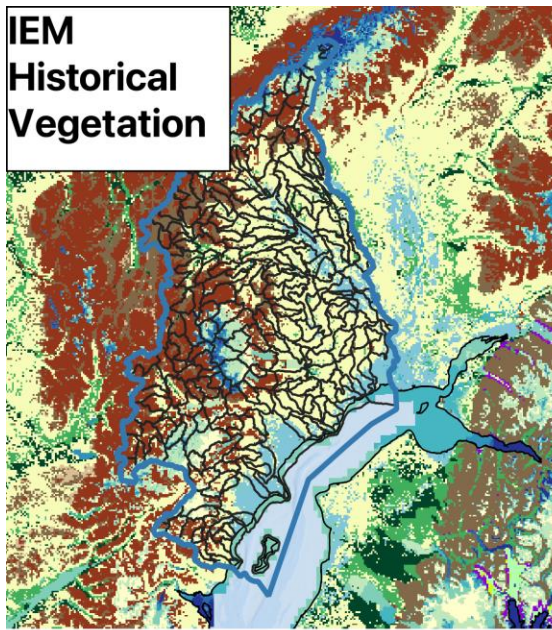
**Change in snow months,
2040-2069 , RCP 8.5**

Change in reliable snow (months)

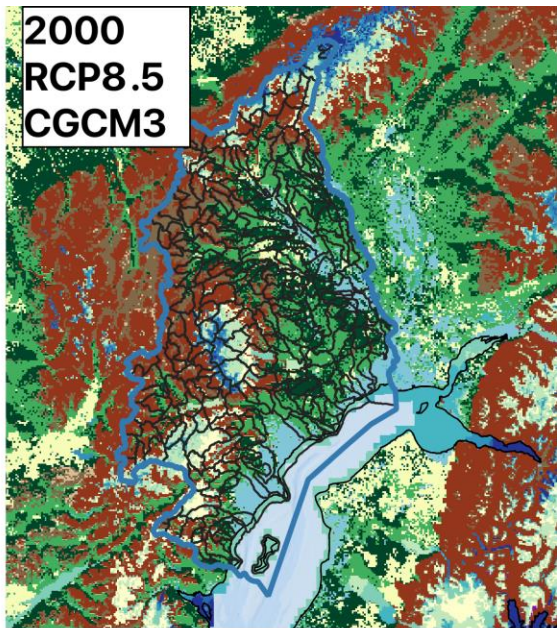


Snow months are similar to historical in the northernmost and higher elevation watersheds, but decrease substantially in other places in the region.

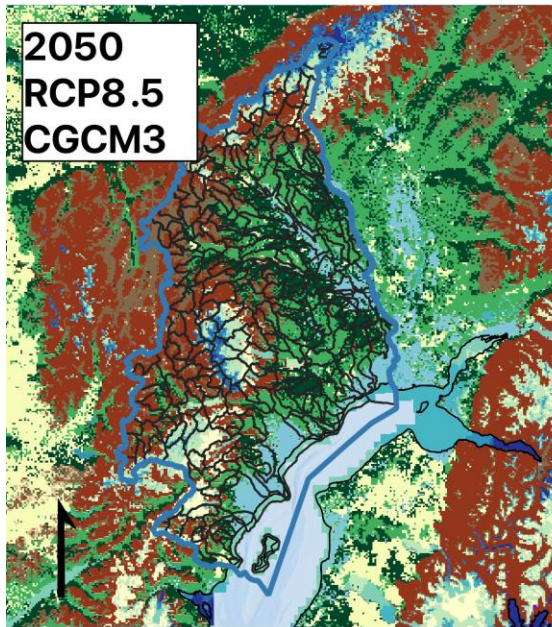
**IEM
Historical
Vegetation**



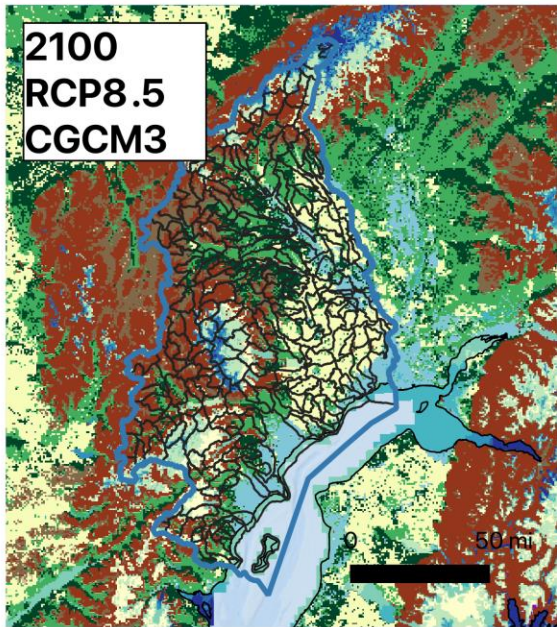
**2000
RCP8.5
CGCM3**



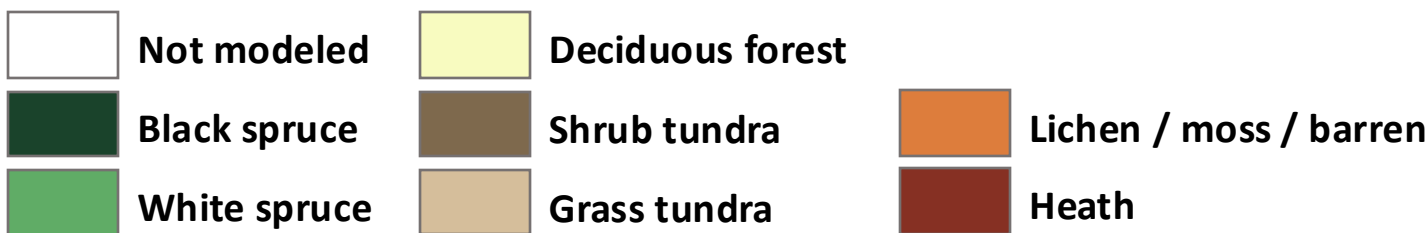
**2050
RCP8.5
CGCM3**



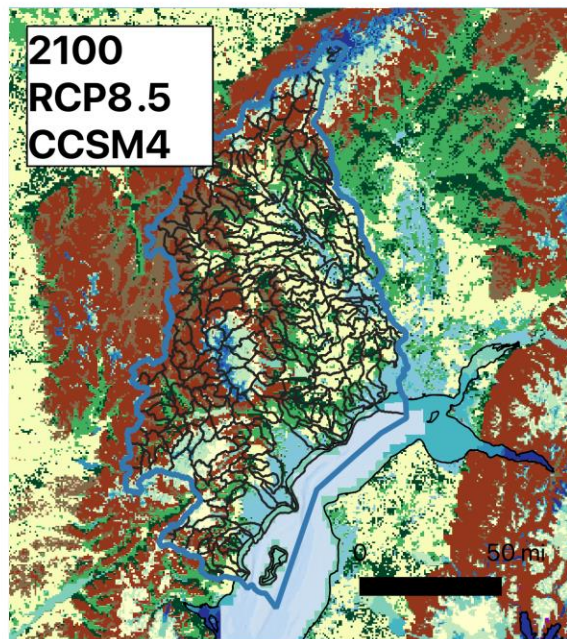
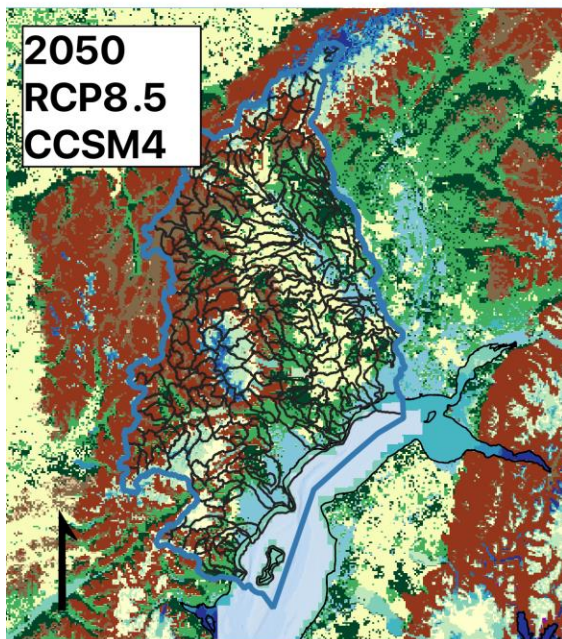
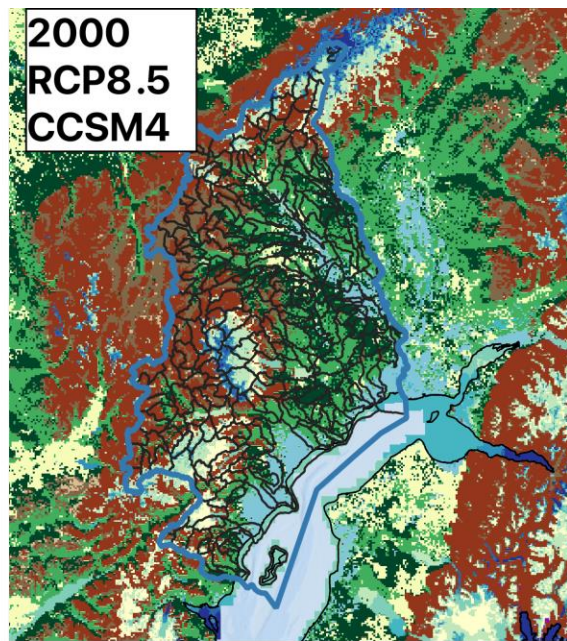
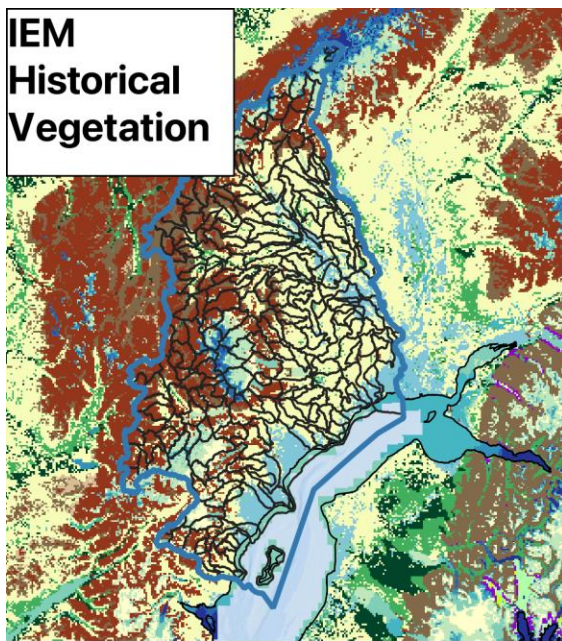
**2100
RCP8.5
CGCM3**



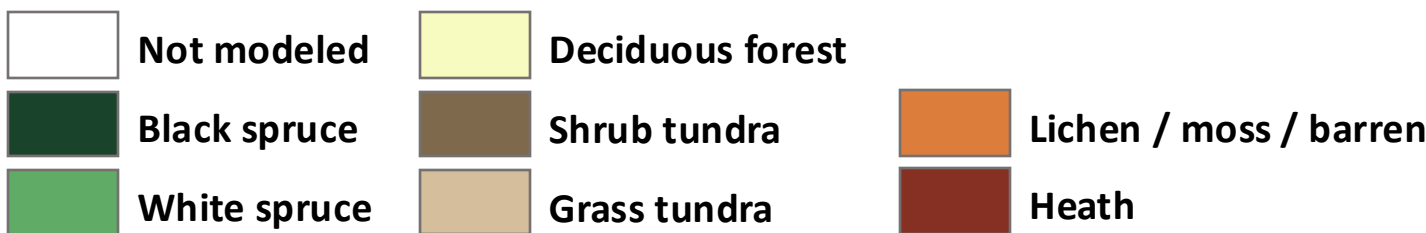
Historical and MRI CGCM3 future vegetation



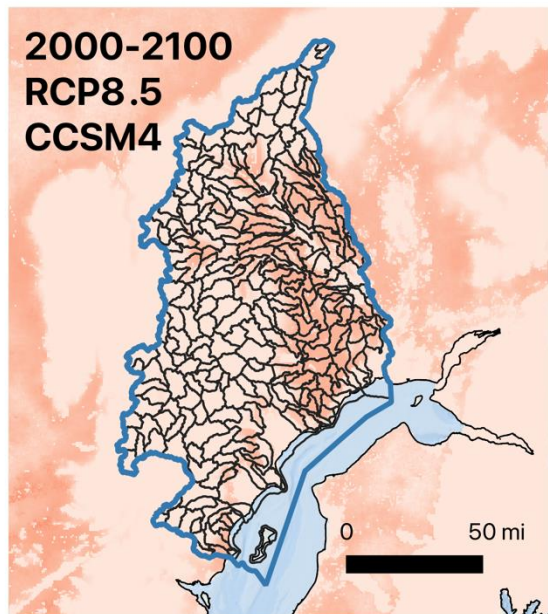
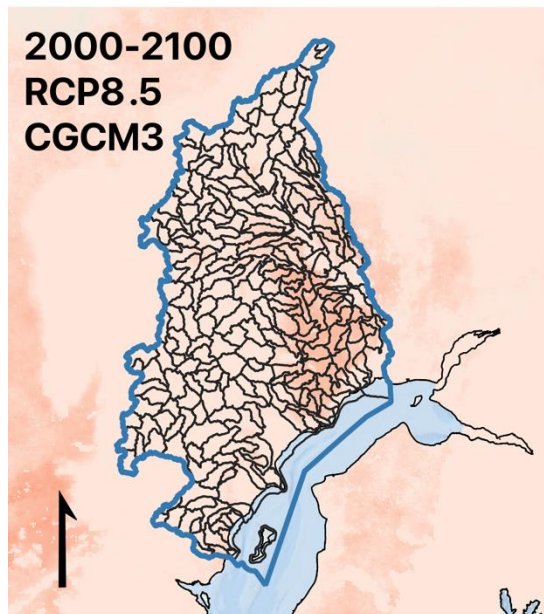
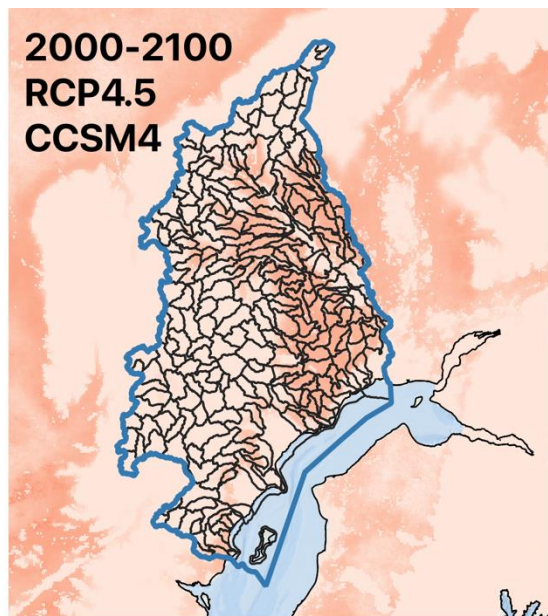
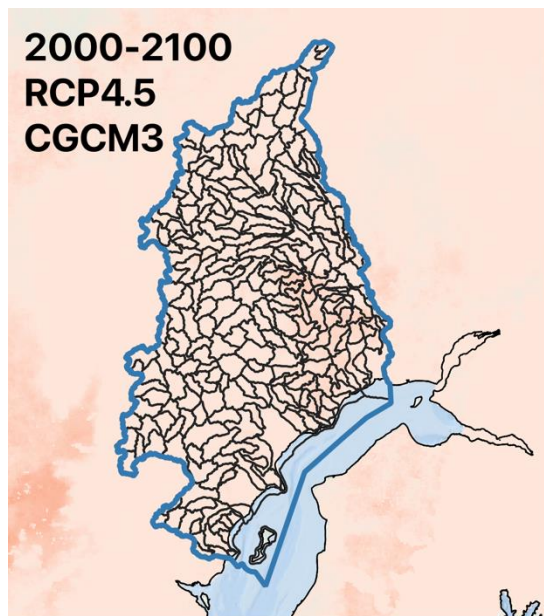
IEM output indicates potential for landscape vegetation change in the boreal forest part of the region, but the changes differ with driving climate. The CGCM3 model indicates later conversion of historical spruce to deciduous forest than CCSM4.



Historical and NCAR CCSM4 future vegetation



IEM output indicates potential for landscape vegetation change in the boreal forest part of the region, but the changes differ with driving climate. The warmer CCSM4 model indicates more widespread conversion of historical spruce to deciduous forest by 2050.

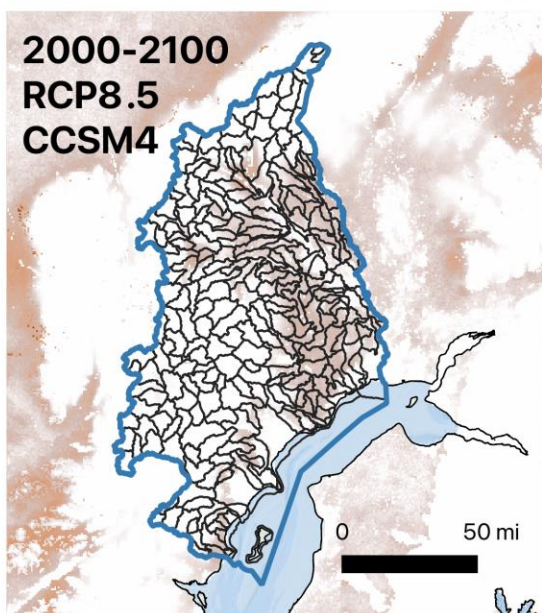
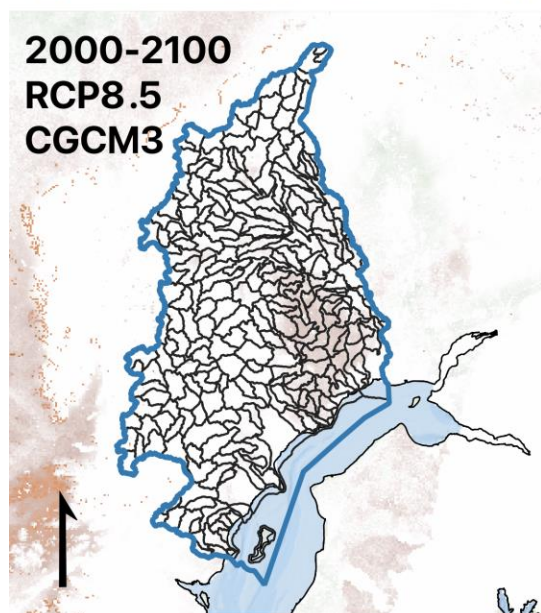
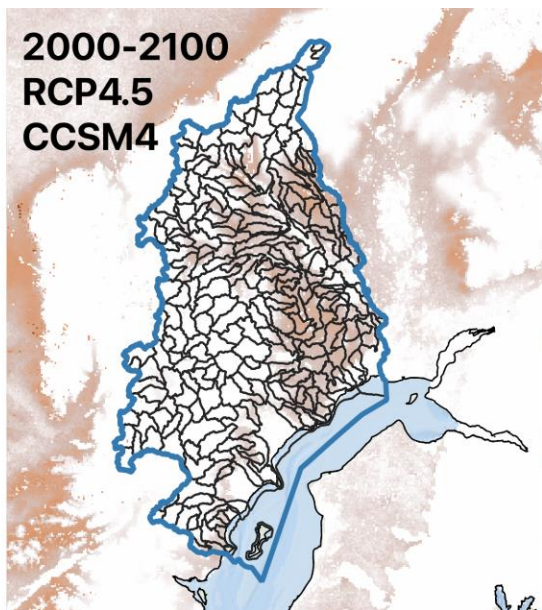
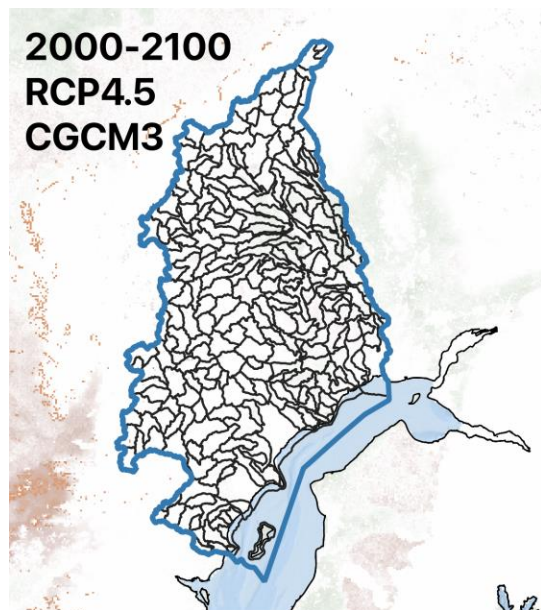


Change in fires per century – MRI CGCM3



Changes in fires per century, relative to 20th century

The number of fires per century is projected to increase over the western part of the region, though more under CCSM4 climate model. No substantial areas of decreased fire activity are projected for the 21st century.



Change in vegetation changes per century



Changes in vegetation changes per century, relative to 20th century

Changes in vegetation are essentially vegetation type changes. These changes happen as new areas become favorable to different vegetation types, due to climate changes or after fire or other disturbance. Both models project faster vegetation changes in parts of the region where fire increases.