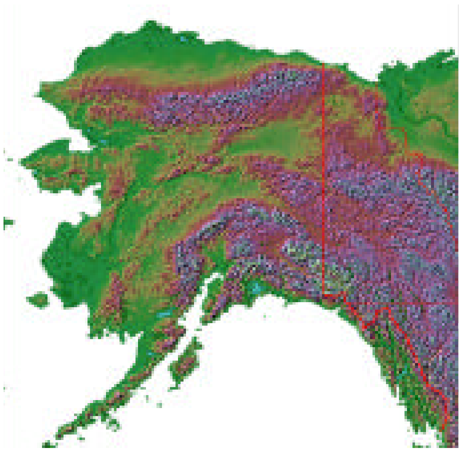


ALASKA

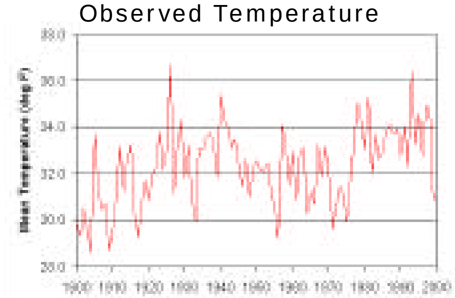
Alaska spans an area nearly a fifth the size of the entire lower 48 states,and includes a wide range of physical, climatic,and ecological diversity in its rainforests,mountain glaciers,boreal spruce forest,and vast tundra,peatlands, and meadows. It contains 75% by area of US national parks and 90% of wildlife refuges,63% of wetlands,and more glaciers and active volcanoes than all other states combined. Direct human pressures on the state's land environment are light,but pressures on its marine environment from large commercial fisheries are substantial. Lightly populated (614,000 people) and growing about 1.5% per year,Alaska has the nations' highest median household income,with an economy dominated by government (44% of incomes) and natural resources (oil 35%, fisheries 7%). Diverse subsistence livelihoods,practiced primarily by native communities,depend on fish,marine mammals,and other wildlife,and play a social and cultural role vastly greater than their contribution to monetary incomes.

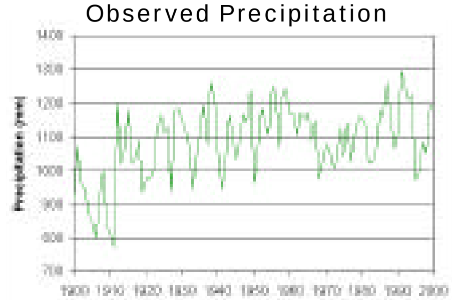
KEY ISSUES

- **Permafrost Thawing and Sea Ice Melting**
- **Increased Risk of Fire and Insect Damage to Forests**
- **Sensitivity of Fisheries and Marine Ecosystems**
- **Increased Stresses on Subsistence Livelihoods**

Observed Climate Trends

Alaska has warmed substantially over the 20th century, particularly over the past few decades. Average warming since the 1950s has been 4°F (2°C). The largest warming, about 7°F (4°C),has occurred in the interior in winter. The growing season has lengthened by more than 14 days since the 1950s. Some records suggest that much of the recent warming occurred suddenly around 1977. Alaska has also grown wetter recently, with precipitation over most of the state increasing 30% between 1968 and 1990. The observed warming is part of a larger trend through most of the Arctic corroborated by many





Over the 20th century, average temperature and precipitation in Alaska have both increased.

"Everything is Tied to Everything Else" A Lesson from Alaska

Caleb Pungowiyi is a Yupik Eskimo who lives in the Arctic, moving back and forth from Alaska to Siberia in pursuit of walrus and other sea mammals. Gathering food directly from the land and the sea makes the Yupiks very careful observers of what is going on around them. In recent years they have noticed, for example, that winters are warmer, that the walrus are looking thinner and their blubber is less nutritious, and that they have had to go further and further from shore to reach the ice pack where young seals are being fed fish caught by their parents. The Yupiks have even noticed that some killer whales have begun eating sea otters, an unusual shift in their diet apparently brought on by the reduced number of fish and seals. But are all of these changes connected, and, if so, what do they portend for the future?

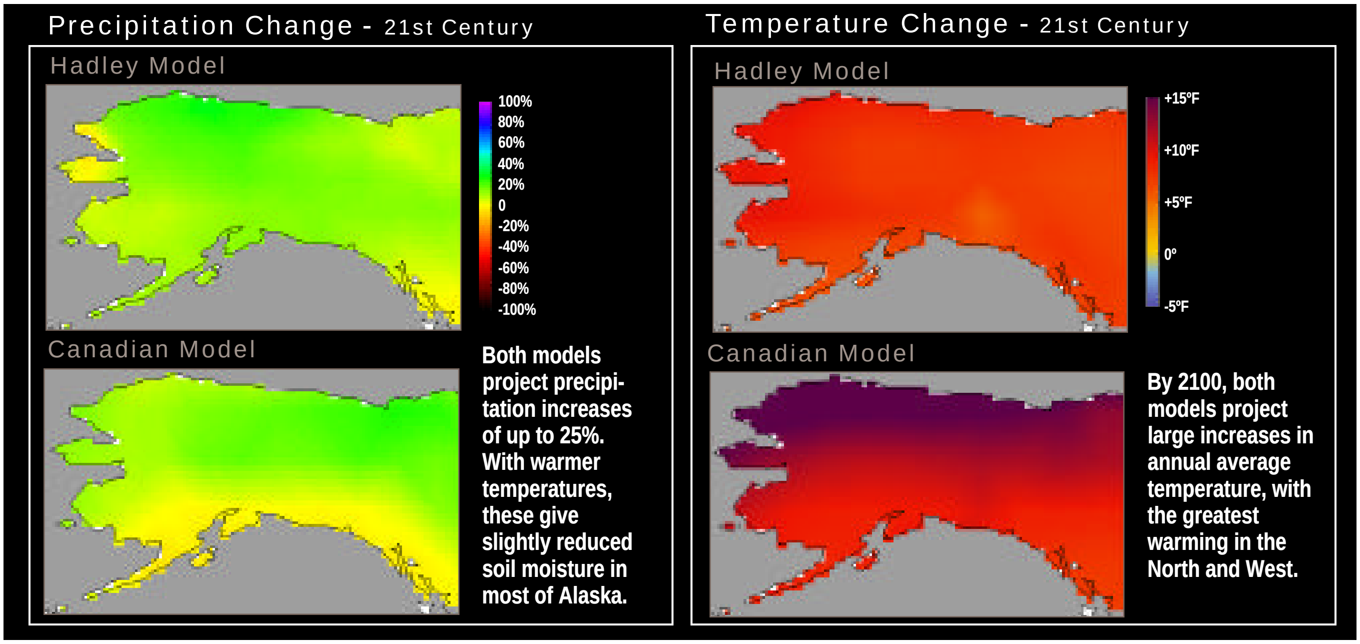
Satellite observations confirm that the sea ice retreat noticed by the Yupiks is happening much more widely, as temperatures warm over most of the Arctic region.

independent measurements of sea ice, glaciers, permafrost, vegetation, and snow cover. In contrast to other regions, the most severe environmental stresses in Alaska at present are climate-related.

For Alaska, the Hadley and Canadian models project 1.5-5°F (1-3°C) more warming by 2030, and 5-12°F (3-6.5°C) (Hadley) or 7-18°F (4-10°C) (Canadian) by 2100.

Scenarios of Future Climate

Models project that rapid Arctic warming will continue. For Alaska, the Hadley and Canadian models project 1.5-5°F (1-3°C) more warming by 2030, and 5-12°F (3-6.5°C) (Hadley) or 7-18°F (4-10°C) (Canadian) by 2100. The warming is projected to be strongest in the north and in winter. Both models also project continued precipitation increases in most of the state reaching 20-25% in the north and northwest, with areas of up to 10% decrease along the south coast. Projections indicate that increased evaporation from warming will more than offset increased precipitation, however, making soils drier throughout most of the state.

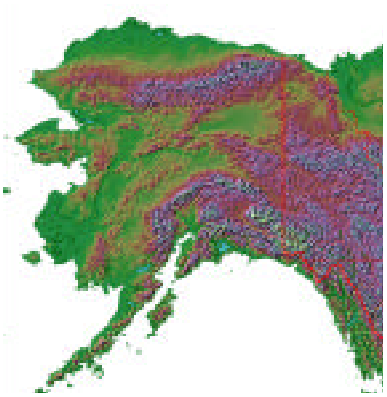


Both models project precipitation increases of up to 25%. With warmer temperatures, these give slightly reduced soil moisture in most of Alaska.

By 2100, both models project large increases in annual average temperature, with the greatest warming in the North and West.

Because the edge of the sea ice is further out to sea in deeper water, walrus – which rest on the ice and feed on the bottom – must dive deeper to feed and find less food, causing their weakened condition. Because sea ice is melting back earlier in the year, the seal pups being raised on the edge are smaller when they must leave the ice, worsening their chance of survival. With fewer seal pups, sea otters become an alternative food source for whales. Because a favorite food of sea otters is sea urchins, fewer sea otters will mean more sea urchins. Sea urchins' favorite food is the kelp that provide the breeding grounds for the fish, so more sea urchins will mean less kelp and thus fewer fish. And with walrus and seal populations declining, it is these very fish that the Yupik need more than ever to feed themselves.

It may seem like only a little warming in a very cold place, but for the Yupiks, the warming is significantly disrupting their traditional food sources because as Caleb Pungowiyi says, in their environment, like all environments, "everything is tied to everything else."



ALASKA KEY ISSUES

Permafrost Thawing and Sea Ice Melting

The rapid warming Alaska is already experiencing is bringing substantial ecological and socioeconomic impacts,many of which result from thawing permafrost or melting sea ice. Permafrost underlies most of Alaska,and the recent several decades of warming have been accompanied by extensive thawing, causing increased erosion,landslides, sinking of the ground surface,and disruption and damage to forests,buildings,and infrastructure. Thawing is projected to accelerate under future warming,with as much as the top 30 to 35 feet (10 meters) of discontinuous permafrost thawing by 2100. Warming is also likely to impair transport by shortening the seasonal use of ice roads.

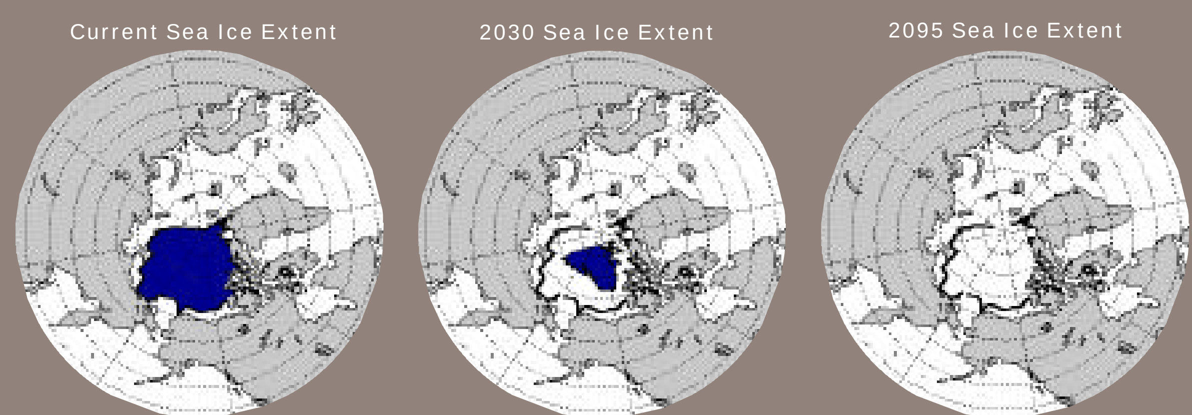
Sea ice off the Alaskan coast is retreating and thinning,with widespread effects on marine ecosystems,coastal climate,human settlements,and subsistence activities. The area of multi-year Arctic sea ice has decreased 14% since 1978,with an apparent sharp increase in the annual rate of loss in the 1990s. Since the 1960s,sea ice over large areas of the Arctic basin has thinned by 3 to 6 feet (1 to 2 meters),losing about 40% of its total thickness. All climate models project large continued loss of sea ice,with year-round ice disappearing completely in the Canadian model by 2100.

Retreat of sea ice allows larger storm surges to develop,increasing the risk of inundation and increasing erosion on coasts that are also made vulnerable by permafrost thawing. In some regions,shorelines have retreated more than 1500 feet (400 meters) due to erosion, over the past few decades. Several Alaskan coastal villages will soon have to be fortified or relocated. Loss of sea ice also causes large-scale changes in marine ecosystems,threatening populations of marine mammals and polar bears that depend on ice,and the subsistence livelihoods that depend on them. It is possible that further retreat of sea ice will also bring some benefits, principally to ocean shipping and offshore oil exploration and extraction, and will have major implications for trade and national defense.

Adaptations: Adaptations to thawing depend on the site.Minimizing surface disruption and heat transfer from buildings can reduce local contributions to thawing.Selecting sites without ice-rich permafrost,where feasible,can reduce the likelihood of subsidence. Otherwise,structures'vulnerability to thawing can only be reduced through such costly measures as building on very deep or refrigerated piles,or alternatively by stripping surface soil five years or more in advance,in order to let thawing occur before construction. Coastal settlements can be fortified or moved inland,but these options are likely to be expensive. No effective protection is likely to be available for forests or natural coastlines.

Projected Summer Sea Ice Change

Canadian Model: an ice-free Arctic summer

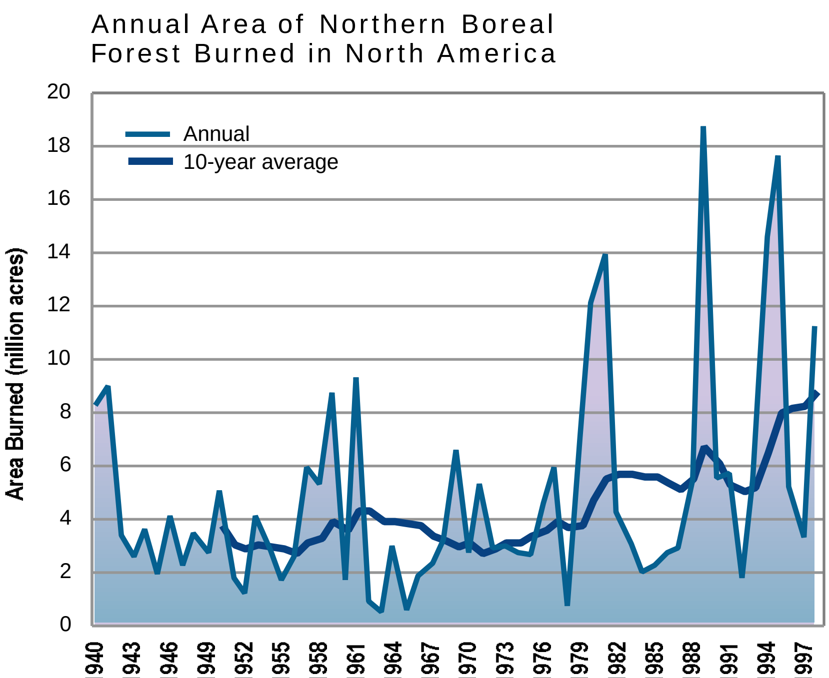


Both models project substantial further retreat of sea ice through the 21st century, with complete loss of summer Arctic sea ice in the Canadian model by 2095. Sea ice outputs were not available for the Hadley scenario, but a reconstruction based on sea-surface temperature shows a 40 to 50% loss of summer sea ice by the 2090s.

Increased Risk of Fire and Insect Damage to Forests

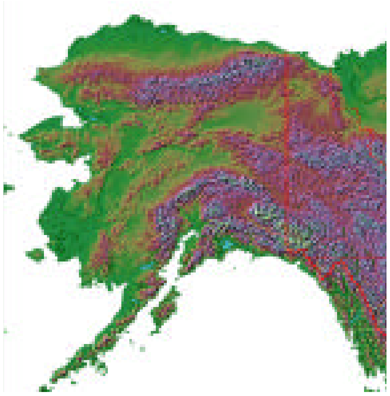
One third of Alaska is covered by forests that support subsistence livelihoods, recreation,and in the southeastern part of the state, a timber industry. Recent warming has increased average growing degree-days by about 20% over the state, apparently increasing productivity where forests are not moisture limited (mainly on the southern coast), but reducing productivity where they are (in much of the interior). The climate increasingly favors expansion of boreal forest into the tundra zone, particularly on the Seward Peninsula. Recent warming has also been accompanied by unprecedented increases in forest disturbances, including insects, blow-downs and fire. A sustained infestation of spruce bark beetles,which in the past have been limited by cold,has caused widespread tree deaths over 2.3 million acres on the Kenai Peninsula since 1992,the largest loss to insects ever recorded in North America. At the same time,increases in blowdowns from intense windstorms,and in canopy breakage from the heavy snows typical of warm winters may have increased vulnerability of forests to insect attack. Significant increases in fire frequency and intensity, both related to summer warming,have also occurred. Simultaneously, the potential damage from forest fires has increased due to a rapid increase in dispersed human settlement in forests. The projected further warming is likely to increase risk of both fire and insect disturbances, even in the near term. In the longer term, large-scale transformation of landscapes is possible,including expansion of boreal forest into the tundra zone,shifts of forest types due to fire and moisture stress,northward expansion of some commercially valuable species, and the appearance of significant fire risk in the coastal forest for the first time since observations began. In present commercial forests,management practices must adapt to heightened fire and pest risk,including potential interactions between them. In the longer term, there is some chance that northward shift of forest productivity and commercially valuable species will hold substantial opportunities for new commercial timber development.

In the longer term, large-scale transformation of landscapes is possible, including expansion of boreal forest into the tundra zone, shifts of forest types due to fire and moisture stress, northward expansion of some commercially valuable species, and the appearance of significant fire risk in the coastal forest for the first time since observations began.



The Alaskan boreal forest is a small part of an enormous forest that extends continuously across the northern part of North America. The average area of this forest burned annually has more than doubled since 1970.

Alaska's fisheries, the largest in the nation, appear to have shown substantial sensitivity to climate fluctuations over the 20th century.



ALASKA KEY ISSUES

Sensitivity of Marine Ecosystems and Fisheries

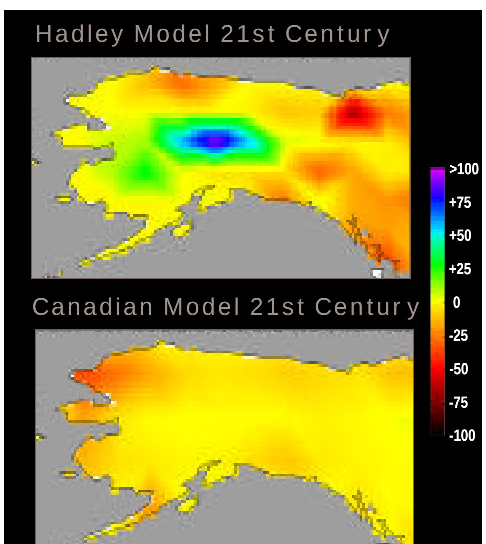
The Gulf of Alaska and Bering Sea support marine ecosystems of great diversity and productivity, and the nation's largest commercial fishery. In 1995,Alaskan fisheries landed 2.1 million tons ($1.45 billion worth), representing 54% of the landings and 37% of the value of all US fisheries. The productivity of these ecosystems fluctuates with year-to-year and especially decade-to-decade climate variability. Some data suggest that climate fluctuations have caused extreme regime shifts in these ecosystems several times since 1900,most recently in the late 1970s and perhaps again in the 1990s. Salmon stocks soared in 1977 and most groundfish stocks a few years later, while forage fish such as capelin and herring declined sharply, bringing subsequent declines in the seabirds and marine mammals that feed on them. These changes likely reflect joint effects of climate fluctuations, ocean circulation,and human harvesting. Consequently, while the effect of projected climate change on these ecosystems is likely to be large,little is known of its specific character.

Adaptations: Potential adaptation measures include reducing the specialization of the fisheries capital equipment to particular species in particular places,to increase the industry's robustness to potential shifts in species'location and abundance;increasing the flexibility of fishing regulations through such measures as variable quotas or buy-backs;and limiting other ecosystem stresses such as marine pollution or disruption of nursery grounds.

Increased Stress on Subsistence Livelihoods

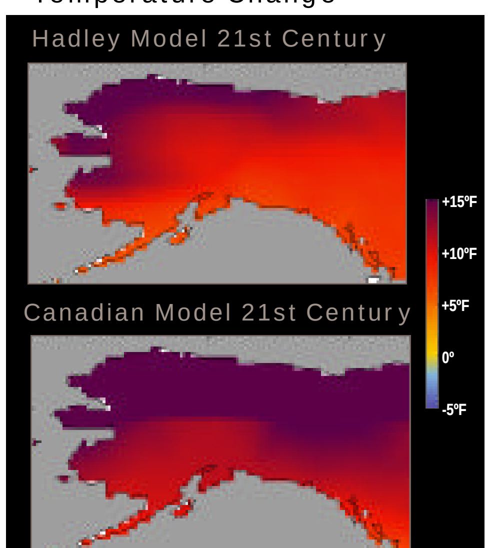
Subsistence makes an important contribution to livelihoods in many isolated rural communities, especially but not exclusively for native peoples. Subsistence is practiced to gather food,but is also important to health,culture,and identity. Alaska's 117,000 rural residents collect about 43 million pounds of wild food annually, equivalent to 375 pounds per person each year. In some remote communities,the subsistence harvest is as high as 800 pounds per person. Fish comprise 60% of the wild harvest,but there is substantial regional variation: west

Summer Soil Moisture Change

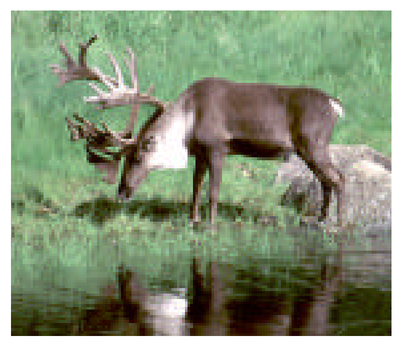


The Hadley model projects increased summer soil moisture in central Alaska and decreases in the north and south, while the Canadian model projects moderate decreases throughout the state.

Winter Maximum Temperature Change



The largest projected warming is in winter, when both models show average daily-high temperatures increasing more than 15ºF over the northern half of the state.



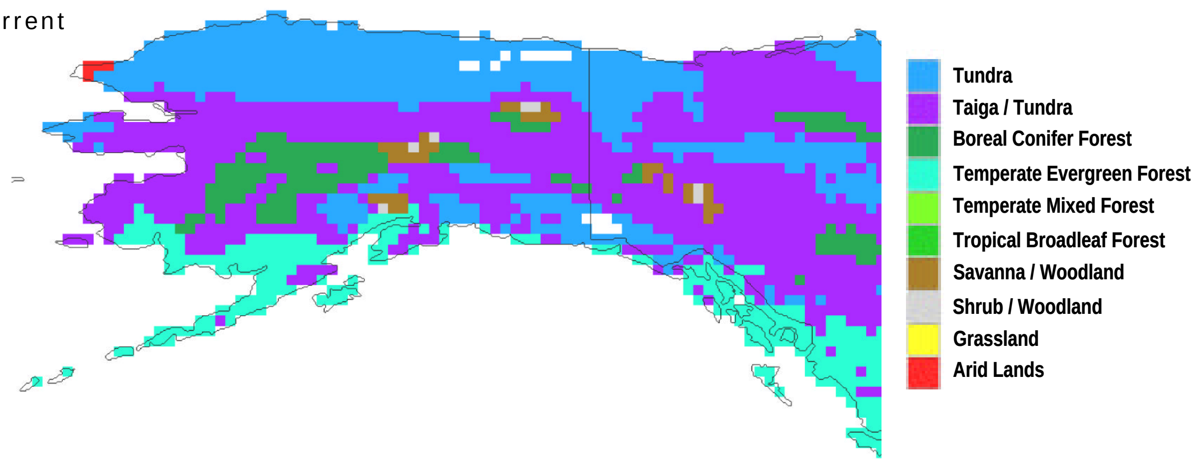
Habitats for wildlife, on land and in the ocean, will come under increasing pressure from vegetation shifts and sea ice retreat.

coast communities rely principally on fish, while northern ones rely more on marine mammals, and interior ones on both fish and land mammals. Present climate change already poses serious harms to subsistence livelihoods. Many populations of marine mammals, fish, and seabirds have been reduced or displaced. Reduced snow cover, a shorter river ice season, and thawing of permafrost all obstruct travel to harvest wild food. Retreat and thinning of sea ice, with associated stress on marine mammal and polar bear populations and increased open-water roughness, have made hunting more difficult, more dangerous, and less productive. It is possible that projected near-term climate changes will enhance certain subsistence harvests, but in general are likely to intensify present harms, through further loss of sea ice, river ice, and permafrost. In the longer term, projected ecosystem shifts are likely to displace or change the resources available for subsistence, requiring communities to change their practices or move. Shifts in the composition of tundra vegetation may decrease nutrition available for caribou and reindeer, while invasion of the tundra by boreal or mixed forest is likely to curtail the range of caribou and musk-ox.

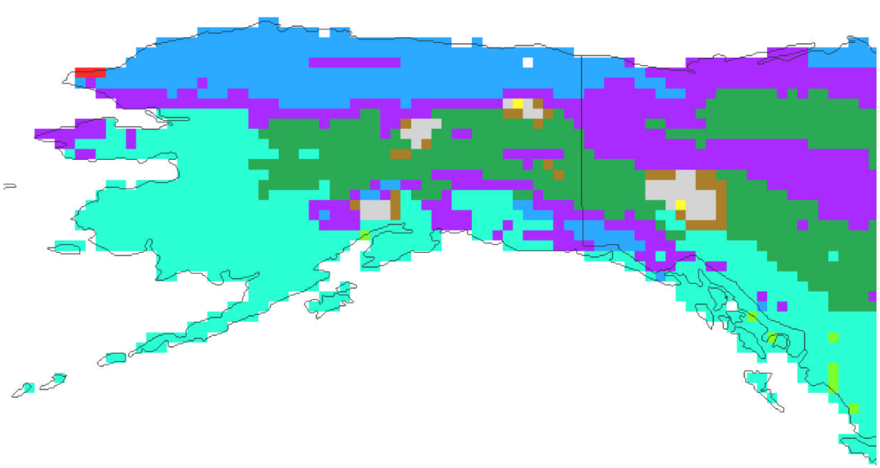
Adaptations: Although subsistence cultures have historically adapted to climate variability by shifting practices and target species, subsistence practices are now both hotly contested and extensively regulated, posing challenges to traditional means of adaptation. It is possible that projected climate change will overwhelm the available responses, particularly for communities that rely on marine mammals. Some communities may be forced to reduce their dependence on the wild harvest, or relocate. General measures to increase incomes may mitigate some impacts, on nutrition for example, but not the cultural effects of lost subsistence resources.

Simulated Vegetation Distribution

Current



Hadley Model 2090s



Under the Hadley scenario, the MAPSS biogeography model projects large-scale loss of tundra and taiga ecosystems as forests expand north and west. Likely consequences include disruption of wildlife migration and associated subsistence livelihoods, as well as the potential for large releases of soil carbon.