CLIMATE CHANGE

ANTICIPATED EFFECTS ON ECOSYSTEM SERVICES AND POTENTIAL ACTIONS BY THE ALASKA REGION, U.S. FOREST SERVICE

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1.0 INTRODUCTION

Climate change has been influencing the planet at an increasing rate for the past 30 years, and is projected to continue to accelerate in its effects. A conclusion of the report of the U.S. Global Change Research Program (2009) is that "global warming is unequivocal and primarily human-induced." The potential effects of climate change, to use a poor play on words, are chilling. While solutions to global warming are far beyond the feasibility or responsibility of the Alaska Region of the Forest Service, it will only be through cooperative efforts by all parties that effective measures can be developed and implemented. Collaboration and partnerships will be essential for effective actions. Anticipating, planning, and mitigating impacts of climate change are necessary to minimize their potential consequences. For these reasons, the Alaska Region should take serious and concerted actions to address this complex but imperative challenge.

In describing his vision for the Forest Service, USDA Secretary Vilsack said, "…the Forest Service must not be viewed as an agency concerned only with the fate of our National Forests, but must instead be acknowledged for its work in protecting all American forests…" He went on to charge the agency with developing an "all-lands approach" that "restore(s) all our forests in order to protect our water and make forests more resilient to climate change." Chief Tidwell responded to this charge by directing the agency to craft "well-coordinated landscape conservation action plans for specific geographic areas and major landscapes." As Secretary Vilsack said, "The threats facing our forests don't recognize property boundaries. So in developing a shared vision around forests we must also be willing to look across property boundaries." By reaching across Forest Service boundaries, we can begin to craft approaches and solutions needed to accommodate climate change and its effects on natural processes, conservation strategies for our public lands, and delivery of the desired ecosystem services that they provide.

This report summarizes potential impacts that are likely from predicted climate change in southern Alaska, identifies on-going collaborative efforts directed at climate change, and suggests some possible responses that the Alaska Region could take to address this challenge. This report has not completed an exhaustive summary of literature pertaining to each potential impact. Reviews by Parsons et al. (2001), the U.S. Global Change Research Program (2009), Kelly et al. (2007) and others provide more detailed synthesis of such documents. This report does identify the breadth of potential impacts and does provide primary sources of information for follow-up, if desired. In addressing partnerships and opportunities, the two broad landscapes encompassing the Chugach and Tongass National Forests identified in the report to the Chief entitled Responding to Climate Change: Integrated Plan for Landscape Conservation for the Pacific Northwest (Oregon, Washington, and Alaska) (2010) are emphasized. While specific climate change impacts to these two target landscapes are the specific focus in this report, a section that discusses State and Private Forestry and its role in assisting with climate change impacts on forests at the state level is included, but potential impacts of climate change on forests in other areas of Alaska and an associated list of climate change initiatives and partnership opportunities has not been included.

2.0 REGIONAL OVERVIEW- ALASKA REGION

The Alaska Region of the Forest Service is comprised of the Chugach and Tongass National Forests as well as the State and Private Forestry program. The Tongass NF includes approximately 17 million acres and 11,000 miles of coastline that stretch along the coast of Southeast Alaska for over 500 miles. The Chugach NF is the most northerly NF in the U.S. and contains approximately 5 million acres with the Kenai Peninsula in the western portion, Prince William Sound in the Center, and the Copper River Delta in the eastern portion. These two forests provided the focus for two delineated landscapes identified for a landscape conservation plan for climate change in the above mentioned report to the Chief. The Southcentral Landscape (Figure 1) included the Chugach Forest, adjacent Kenai Peninsula with its National Wildlife Refuge and National Park, lands managed by the Bureau of Land Management and Department of Defense, and intermixed state, tribal, and private lands. The Southeast Landscape (Figure 2) contained the Tongass NF which comprised 80% of the landscape as well as lands managed by various native corporations, and others. The State and Private Forestry program, working with Alaska DNR Forestry Division, is providing assistance to landowners of the 30 million acres of private forest in the state.

Due to its northerly setting, climate change has been affecting the Alaska Region more than any other region of the U.S., with Alaska recording the most rapid temperature increases over the last century of any of the 11 regions analyzed (Julius and West 2008). Over the past 50 years, Alaska has warmed at more than twice the rate of the rest of the United States. As a result, climate change impacts are much more pronounced than in other regions of the United States (U.S. Global Change Research Program 2009). Various impacts from this temperature increase have already been documented, with many additional impacts projected to occur.

Climate change poses threats to numerous ecosystem services. Key threats include changes to sea levels, increased storm intensities, ocean acidification, warming ocean and stream temperatures, increased retreat of glaciers, changing precipitation amounts and patterns, changes to evapotranspiration rates, changing distributions of species, changing outbreaks of insects, changes to ecosystem productivity, and changing fire regimes. Mitigation of some impacts may be possible with strategic planning, but many impacts cannot be mitigated, and these effects will need to be accounted for and addressed in future forest plans and management actions.

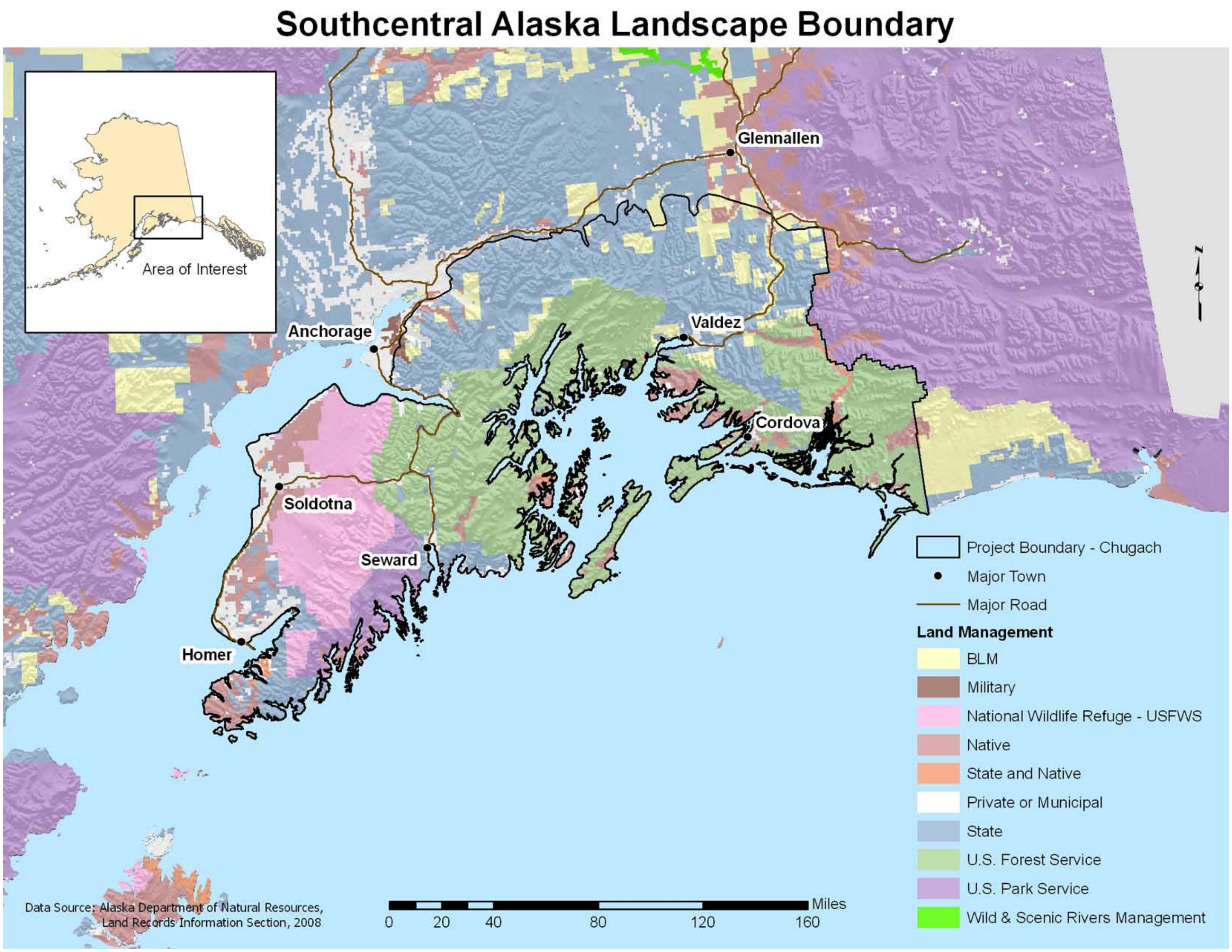

Figure 1. Delineated Southcentral Landscape

Southeast Alaska Landscape Boundary

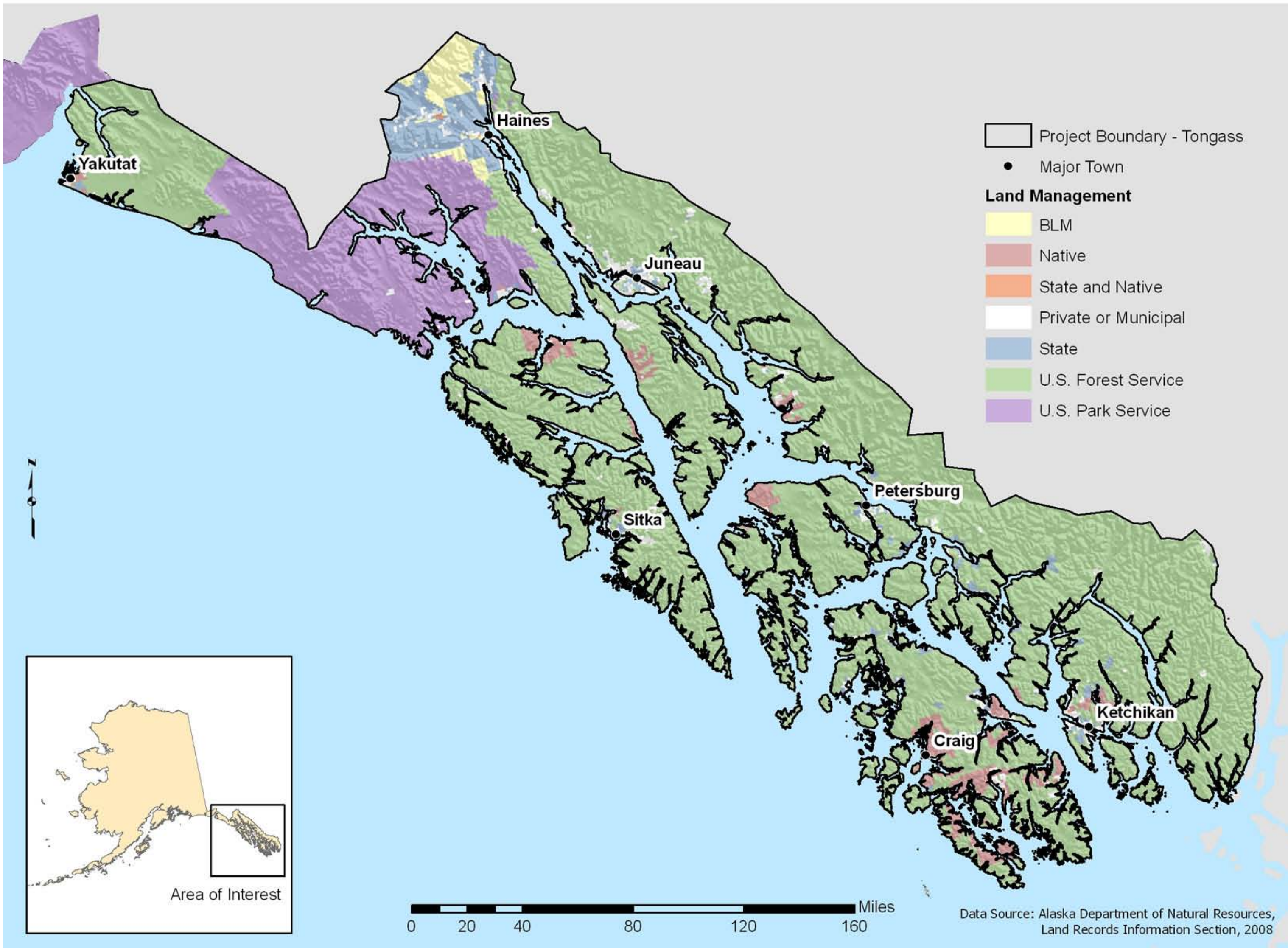

Figure 2. Delineated Southeast Landscape.

3.0 ECOSYSTEM SERVICES OF THE SOUTHCENTRAL AND SOUTHEAST LANDSCAPES

The Southcentral Landscape spans from glacially-dominated mountain ecosystems inland to the coastal area of Prince William Sound and the Copper River Delta and is located near the most developed area of Alaska. The largely "recreational" Chugach NF provides numerous ecosystem services. Recreational activities include hiking, camping, backpacking, fishing, hunting, kayaking, flightseeing and others. Harvesting of forest products is limited in the landscape, but maintaining forests that do not place communities at high risks from wildfire is a desired condition, as exemplified by the fuels thinning project near Hope and Sunrise in the Kenai Peninsula. Much of the landscape serves as an important natural demonstration area with various educational opportunities such as the Portage Valley Learning Center and the Prince William Sound Science Center. The landscape produces important commercial and subsistence resources including fish (especially salmon), shellfish, and wildlife. Because of its largely unmanaged status, the Southcentral landscape can serve as a key monitoring area for the effects of climate change. For example, stream monitoring gauges have been in place in many locations, and considerable monitoring has been on-going in the Copper River. The ability to track the effects of climate change on such unmanaged natural systems may be an important science development opportunity.

The Southeast Landscape is centered on the Alexander Archipelago, the series of islands occurring for hundreds of miles down the southeast coast of Alaska, as well as the adjacent mainland with its snow-capped and glacier-covered mountains. The highly productive coastal rainforests intermixed with the marine and freshwater aquatic environments result in an incredibly diverse and productive natural environment. Recreational activities abound, although access is generally restricted to boat and plane. Cruise ships steam through the inland passages, allowing sightseeing and visits to local cultural programs. Educational opportunities associated with ecological and cultural topics abound. Industries that predominate in addition to tourism include fisheries, forest products, and guiding, supporting numerous communities of varying sizes located throughout the landscape. Subsistence, commercial, and recreational harvests of fish and wildlife are major activities. Human communities tend to be isolated, self reliant due to the transportation constraints, and dependent on the local resources. Wildfire risk has not been a past concern, as the rainforests have been nearly fireproof. Some locations, such as Prince of Wales Island, have seen substantial human development and modification, while other areas, such as Admiralty Island remain nearly pristine. Some areas, such as around Yakutat on the mainland, are still undergoing primary succession from the retreat of the glaciers over the past 10,000 years, providing unique environments for monitoring and research. Numerous critical natural resource areas such as the Yakutat Forelands and Stikine River Flats provide essential stopover sites for migratory birds as well as estuaries that are productive shellfish and fish spawning areas. Recognizing the research, monitoring, and demonstration values that occur in this landscape, the USFS established the Heen Latinee Experimental Forest largely to monitor, evaluate, and demonstrate effects of climate change.

4.0 CLIMATE CHANGE THREATS TO ECOSYSTEM SERVICES IN SOUTHERN COASTAL ALASKA

Climate change has also been termed global warming for the obvious reason that increased temperatures are the primary response to increasing greenhouse gases (although some locations of the world may experience cooling trends due to changes to ocean currents or weather patterns). Increasing trends in temperatures have been well documented, with more northerly locations experiencing the greatest effects. Climate change has been linked to increases in greenhouse gases, with the primary factor being the rise in CO_2 levels. Jouzel et al. (2007) reported that atmospheric levels of CO_2 are higher now than they have been in the past 800,000 years, based on samples obtained from Antarctica ice, and are increasing at a rate never before recorded. A large body of scientific evidence points to human factors as a primary cause of climate change, and ignoring such information in the face of likely effects of climate change would not be responsible management.

The Scenarios Network for Alaska Planning (SNAP) is a cooperative effort to coordinate the development of downscaled climate predictions for regions of Alaska with involvement of various partners including the USFS. Information provided by SNAP includes analyses of climate changes that have occurred to date, and projected changes anticipated for the next 100 years.

OBSERVED CHANGES IN ALASKA'S CLIMATE

SNAP (2008) reported that Alaska has seen a statewide increase in temperatures of 2.69^{0}F since 1971. This has not been equal across the state. Juneau was reported to have an increase of 3.54^{0}F, while Valdez was reported to have an increase in temperature of 3.76^{0}F and Yakutat an increase of 2.75^{0}F. Statewide, Barrow displayed the greatest increase (4.16^{0}F) and Kodiak showed the least (0.87^{0}F), displaying local variation at a state level. These increases in temperature have not been occurring uniformly throughout the year. The U.S. Global Change Research Program (2009) reported that Alaska has experienced a 3.4^{0}F rise in average annual temperatures over the past 50 years, with an increase in winter temperatures of 6.4^{0}F. These increases in temperatures have led to other related changes to climate. The average snow free days have increased across Alaska by an average of 10 days (U.S. Global Change Research Program 2009). Precipitation rates are shifting, with general increased precipitation levels. For example, Figure 3 depicts precipitation levels at Juneau's airport for the past 70 years. Responses to the increased precipitation levels are offset in some locations by the increased temperatures and longer growing seasons which have increased evapotranspiration rates, causing reductions in available moisture through changes to the precipitation- potential evapotranspiration (P-PET) ratio. Increased intensities of storms have been noted. The observed changes in temperatures have already caused notable effects on various resources and ecosystem services, as discussed below. Projections of future changes anticipate even more dramatic effects.

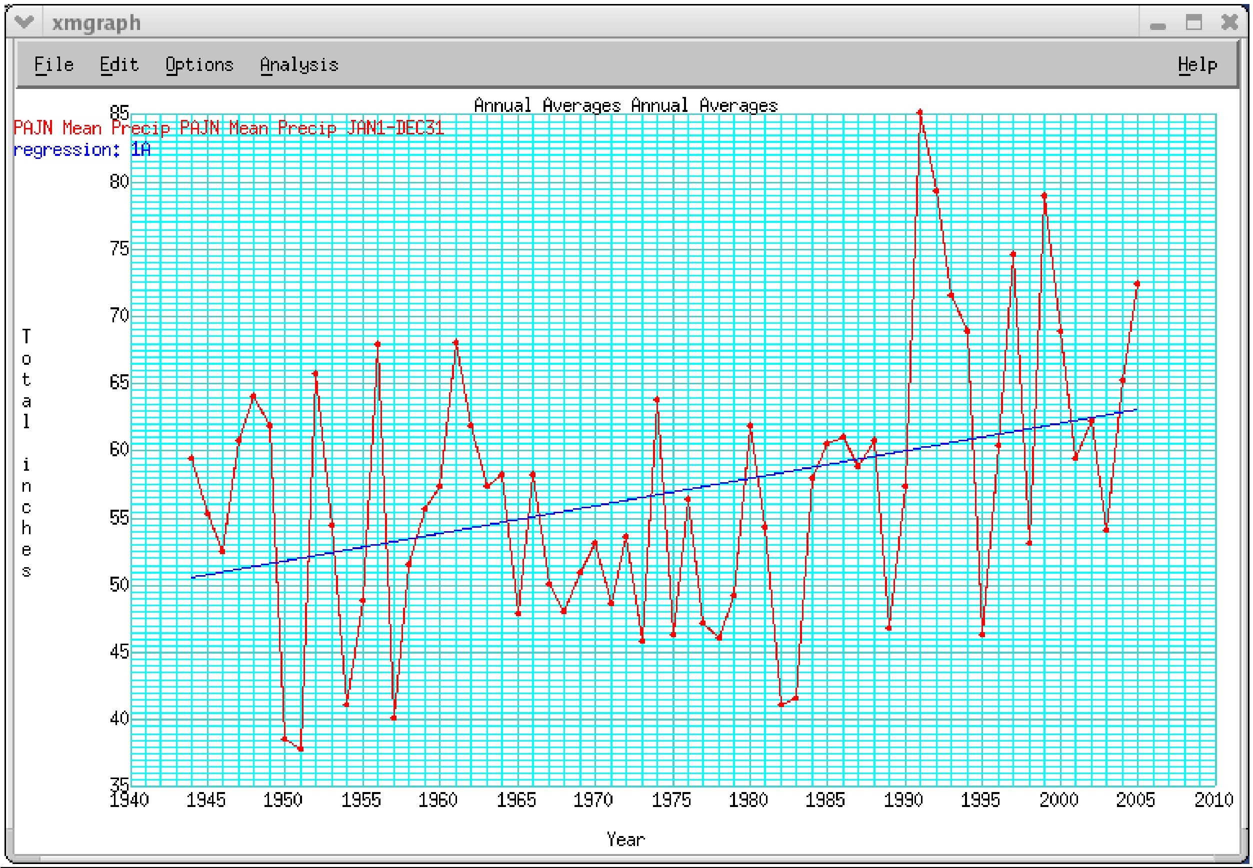

Figure 3. Annual precipitation at Juneau International Airport 1943-2005 (red) and its regression line (blue) showing the best-fit relationship with precipitation over time. The regression line indicates a wetter trend overall (National Weather Service, Juneau). From Kelly et al. (2007)

PREDICTED CHANGES IN ALASKA CLIMATE

The observed changes in climate are based on collected data and statistical analyses. Projections of future effects of climate change are based on global circulation models (GCM's) that anticipate what will occur due to continued increases in greenhouse gases. An unknown is how successful future efforts to curb greenhouse gases will be, and so most models present a range of future predictions. Further, many different models have been developed throughout the world, each emphasizing different locations. Some models are likely to have greater accuracy and thus applicability for some regions than others. SNAP has reviewed these models and has used the best models for application in Alaska. The projections reveal a number of predicted changes that will have significant influences on resources and their management. Growing season length is predicted to increase substantially over the next 100 years in both the Southcentral (Figure A-1) and Southeast (Figure A-6) Landscapes. Summer precipitation and summer temperatures are expected to rise in both landscapes (Figures A-2, A-3, A-7, and A-8). Likewise, winter temperatures and precipitation levels are also expected to increase in both landscapes (Figures A-4, A-5, A-9, and A-10).

Temperatures are expected to continue to rise, with rises in winter temperatures expected to continue to exceed summer. Some of the greatest changes may be caused by increases in length of growing seasons and the effects of this on the P-PER ratio, with further effects on timing of snowmelt, timing of peak runoff, amounts and even occurrence of snow cover, and other effects. For example, the projected temperatures for the Kenai show that temperatures in March and November are expected to shift from being below freezing to above freezing (Figure 4).

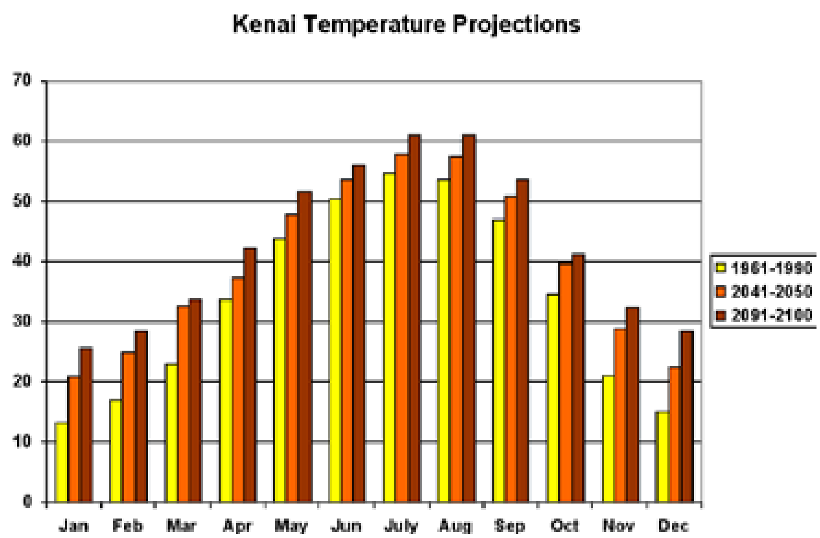

Figure 4. Kenai's projected temperature changes (SNAP 2008).

Related measures, such as the precipitation minus potential evapotranspiration ratio (P-PER ratio) combine information to reveal likely drivers of biological changes. For example, projected changes to P-PER ratios that will influence water availability during the growing season in the Kenai Peninsula reveal a strong influence on possible fire regimes.

A general summary of predicted climate changes for the two delineated landscapes include the following:

- Temperatures will increase, with winter temperatures increasing at a higher rate than summer temperatures,
- Length of growing seasons and frost free days will increase,
- Temperatures in seasonal transition months in many locations will shift from below freezing to above freezing,
- Precipitation will increase,
- More precipitation will fall as rain rather than snow,
- Evaopotranspiration rates will increase,
- P-PET ratios will decrease in summer, causing dryer conditions in summer for many locations, and
- Storm intensities will increase.

5.0 IMPACTS OF CLIMATE CHANGE ON ECOSYSTEM SERVICES

Numerous impacts to ecosystem services are expected to occur as a result of predicted climate changes. Ecosystem services associated with the coastal rainforests and mountains that include the two National Forests in Alaska will be emphasized in this plan. Additional impacts to inland forests, particularly in response to changes to permafrost, fire regimes, and insect outbreaks are anticipated and will be important issues for State and Private Forestry to address. However, the impacts addressed here are those associated with NFS lands and the intermixed lands of other ownerships.

CHANGING SEA LEVELS

Sea levels have been predicted to rise as a global consequence of climate change, due both to the melting of glaciers and ice sheets over land as well as the thermal expansion of ocean water as it warms (http://www.climate.org/topics/sea-level/index.html). The warming of oceans has been estimated to have raised sea levels by 2.5 cm over the past 50 years. The future changes in sea levels remain uncertain, as the melting of ice covering Greenland and Antarctica will largely determine the extent of sea rise. Ice melt in some locations of both Greenland and Antarctica have recently been observed to be exceeding predicted rates in models, so changes could come more rapidly than originally predicted. However, changes to precipitation rates in Antarctica could lead to increased snowfall and increases in ice pack in some areas, partially off-setting melting in other areas, so the net effect on future sea level changes has more uncertainties than some other projections.

Sea level changes could cause a number of impacts in the two landscapes. Obviously, if these changes are great enough, low-lying human developments could be inundated. This has not been identified as a major concern in the coastal areas of southern Alaska, but could become one if sea level rises exceed current projections. Sea level rises could have significant impacts on estuarine ecosystems. Three of these of high ecological and economic significance are the Copper River Delta, Yakutat Forelands and Stikine River Flats. These areas are all extremely important as stopover locations for migratory birds, especially shorebirds, are major spawning areas for many species of fish, and are important shellfish production areas. Sea rise could substantially change the ecology of these areas. However, these areas are also being influenced by glacial isostatic adjustment, so that sea rise may help offset the rise of the bedrock due to this glacial rebound. In addition, the Copper River Delta experienced significant shifts from the 1964 earthquake, and has been adjusting to these changes over the past 36 years. Other smaller estuaries and low lying coastal ecosystems may also be at risk from changes in sea levels. Rising sea levels may also create new estuarine areas depending on the topography of an area, so decreases in ecosystems in some areas may be offset by increases in others. Obviously, the net impacts of sea level changes remain uncertain, but are something that should be considered, evaluated, and monitored over time.

INCREASED OCEAN TEMPERATURES AND CHANGING CIRCULATION PATTERNS

Ocean temperatures have been increasing and are predicted to continue to increase. One minor effect of this is the changes in thermal expansion of seawater that will contribute to rising sea levels. More significantly are potential changes to ocean currents and up-wellings, as well as the ecological impacts of increased ocean temperatures.

Impacts to oceans may be caused by changing levels of freshwater input from melting glaciers. Increased inputs of freshwater in northern locations could cause changes to the thermohaline circulation, where water densities influenced by the combination of temperatures and salinity determine where water sinks, displacing deeper, warmer waters and causing up-wellings of nutrient-rich waters that drive the productivity of oceans in many locations. Changes to these and ocean currents could have dramatic effects on the ecology and productivity of key fisheries.

As an example, one of the reasons that the Copper River supports such a rich fishery is because of the volume of glacially-derived freshwater it delivers into the Gulf of Alaska. This water contains high glacial sediment loads which make it rich in iron but low in nitrates, so the iron and other micronutrients are delivered to the ocean rather than being assimilated in riverine ecosystems which would occur if higher levels of nitrates were also present. Ocean phytoplankton are often limited by iron (Boyd et al. 2004), while also being limited by nitrates. Where the influx of Copper River water and its supply of iron hits Gulf of Alaska waters and especially where it mixes with nitrate-rich upwelling areas in the ocean that provide needed nitrates, highly productive zones are created. The plume of sediments from the river produce more turbid waters providing better concealment from predators for larval and juvenile fish, increasing their overall use and productivity. Changes to the Copper River watershed caused by climate change could change the dynamics of these complex interactions due to initial increases in stream flows due to more rapidly melting glaciers, changes to nitrate loads in the river as more riparian areas are available for growth of nitrogen-fixing plants, or changes mentioned previously to the locations of upwellings. Research being conducted by the PNW station, Prince William Sound Science Center, and others will help to further understand such relationships and monitor climate change effects.

These types of potential changes have such complexity and include variables that are poorly understood that they cannot be presently predicted with any accuracy. Further, there is little that can be done to mitigate their effects other than through actions to address the causes of climate change. Consequently, they are not issues for specific mitigation actions by the Forest Service. However, as they may have significant impacts on ecosystems and human communities in the area, the Forest Service should be engaged in partnerships that are researching and monitoring key variables, and should be ready to assist when and if impacts become more apparent.

Increased ocean temperatures may change habitat quality for aquatic species, decreasing quality for some species and increasing it for others. This is likely to cause shifts in species distributions, as has already been observed in some locations. As these shifts occur, they will influence human uses of resources, causing changes, for example, to commercial and recreational fishing. The specific changes that are likely to occur have not been determined, so specific actions to address potential changes cannot be accurately anticipated. However, monitoring of appropriate populations in a manner that provides the ability to identify distributional shifts and population changes is merited. Chittenden et al. (2009) reported on the effects of ocean warming on salmon populations. They noted the lack of good information on salmon behavior, population dynamics, and mortality rates while in the ocean. They suggested that multidisciplinary teams armed with current technologies are needed to determine more about oceanic activities of salmon and the potential effects of climate change on salmonids. Similar to the previously mentioned threats of climate change, while determining salmonid and other fish responses to changes in ocean temperatures would not be a direct Forest Service responsibility, the Forest Service should be tracking such information so that it can be ready to assist communities which may be impacted by such changes.

Increased Ocean Acidification

Oceans absorb CO_2 from the atmosphere, storing it as carbonic acid. As atmospheric levels of CO_2 increase, more CO_2 is absorbed, decreasing the pH of the ocean. As the oceans become more acidic, the amount of calcium carbonate available to organisms decreases. Shellfish, mollusks, crustaceans, and coral all depend on calcification for their shells or structures. Ocean pH has decreased from 8.17 to 8.09 over the past 200 years (http://www.climate.org/topics/sea-level/index.html). It could drop another 0.5 during this century, if CO_2 levels continue to rise. At this level of change, it is predicted that a 60% decrease in availability of calcium carbonate could occur, dramatically reducing the potential productivity of the oceans for calcium dependent organisms. Significant declines and even extinctions of some species could result, altering human food sources as well as marine communities and food chains. Pteropods, planktonic mollusks that are critically important as key food sources for salmon and other species have been reported to be particularly vulnerable to increasing acidity in Alaska's marine waters (PMEL 2008, Adaptation Advisory Group to the Alaska Climate Change Sub-Cabinet 2009).

As with warming of oceans, the Forest Service has little ability to affect this potential change other than by doing its part in reducing its carbon footprint. However, the Forest Service should be aware of the potential consequences of ocean acidification, could partner on monitoring programs looking at potentially vulnerable populations, and should be ready to assist communities that could be directly impacted from the loss of shellfish for commercial, recreational, or subsistence uses, or indirectly through changes to the food base for salmon or other species.

Increased Storm Intensities

As oceans warm, weather patterns are altered, and storms increase in intensity. A more northern shift in storm tracks and greater storm intensities are a predicted effect of climate change (U.S. Global Change Program 2009). Increasing storm intensities have been observed in Alaska. The consequences of these storms are expected to be greater in more northern coastal regions of the state. However, increased storm intensities are expected for the southern coastal region as well.

Increased storm intensities may cause several potential impacts to the area. First, windthrow has historically been one of the primary disturbance processes in coastal rainforests. Increased storm intensities may increase the role of this disturbance, changing forest ecosystem dynamics in some areas, and altering wildlife habitat. While the likelihood of increasing windthrow to the point of causing dramatic changes to forest ecosystems seems remote, its potential is certainly something that should be monitored. A second effect of greater storm intensities may be storm surges and increased coastline battery from waves and wind. This has already been documented to be causing problems in coastal areas in the northwestern shorelines of Alaska. The coastal areas of southern Alaska have not been identified as having the same potential for negative effects. However, some areas, particularly estuaries or other low-lying ecosystems could be impacted by this new level of storm effects. Again, monitoring is recommended to determine if increased impacts are occurring. A final impact of increased storm intensities is the effects of this on transportation, tourism, and commercial and recreational boating and fishing. More severe storms may restrict boats from moving out of harbors for more days each year. This may cause a reduction in income for those whose businesses depend on access to the ocean, and reduce recreational opportunities. Tourism, while potentially benefiting from warmer temperatures in this region, could be negatively affected by the increases in storm intensities.

Changes to Stream Temperatures and Flows

Streams and rivers in southern Alaska support a diversity of aquatic species. The species of greatest interest are the salmonids. These are a keystone species for the aquatic ecosystems in many streams and rivers as well as a food base for many terrestrial species. They also provide commercial, subsistence, and recreational harvests upon which many individuals and communities heavily rely. Climate change will undoubtedly cause changes to stream temperatures and flows. This will happen in a couple of ways. First, general warming of the environment will cause warming of stream temperatures as the background temperatures increase. For some streams, this may reduce the quality of the stream for salmon, while for others it may increase the quality, as least for some species of salmon. In some drainages there will be changes in the timing of run-off as snow packs move higher, and snowmelt occurs sooner in the spring. For glacial-fed streams, other changes are possible. As glaciers experience more rapid melting, stream flows may initially increase. In other areas, as glaciers decrease in size or disappear, stream flows may go down considerably, especially in summer months. Glaciers feeding some drainages may disappear completely, changing both water flows, temperatures, and sediment loads.

Potential impacts of stream and river alterations have received some investigation, and are a substantial concern. Figure 5 displays the primary anadromous salmonid streams in the Southcentral Landscape and Figure 6 displays the primary anadromous salmonid streams in the Southeast Landscape. A more

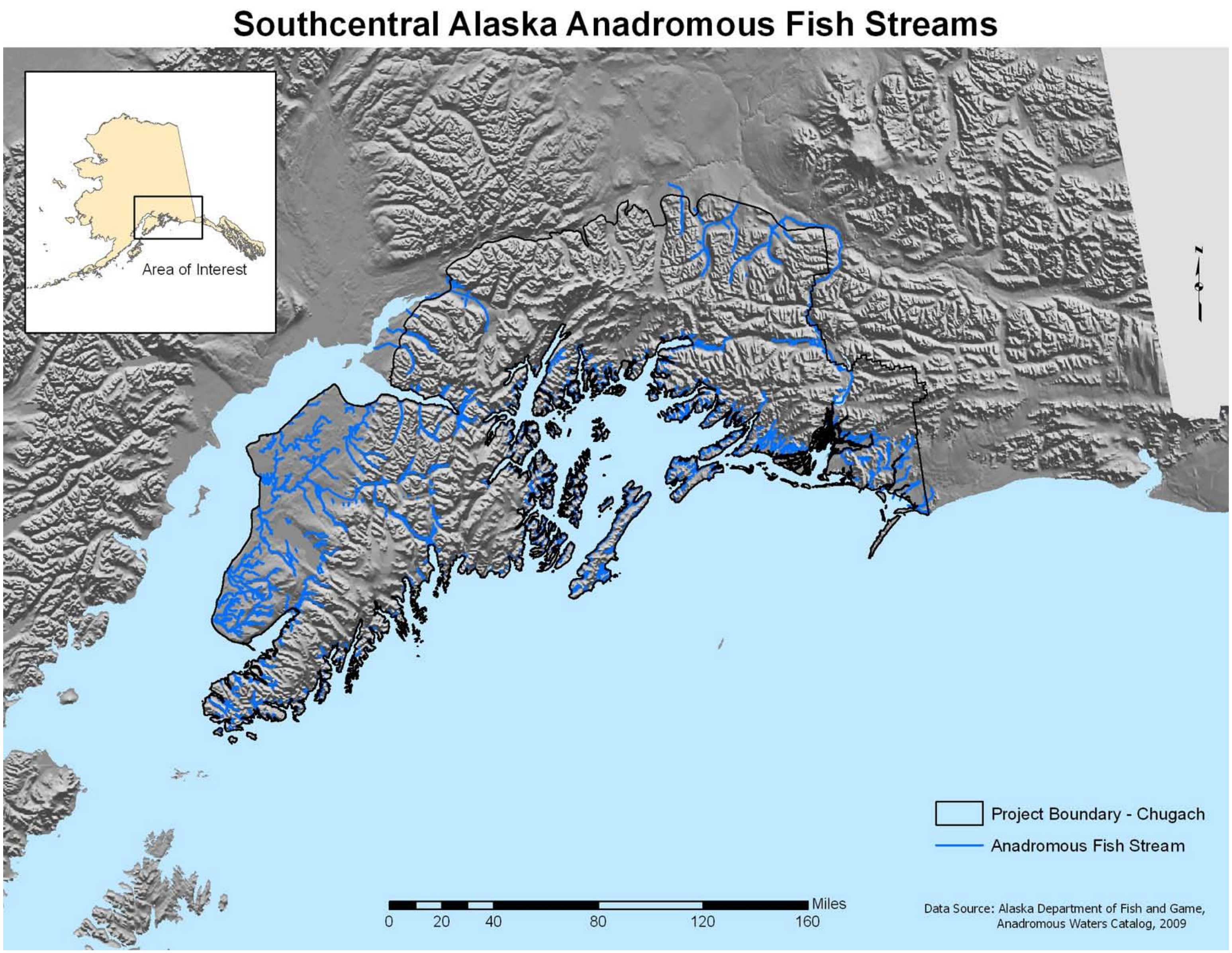

Figure 5. Streams supporting anadromous fish in the Southcentral Landscape.

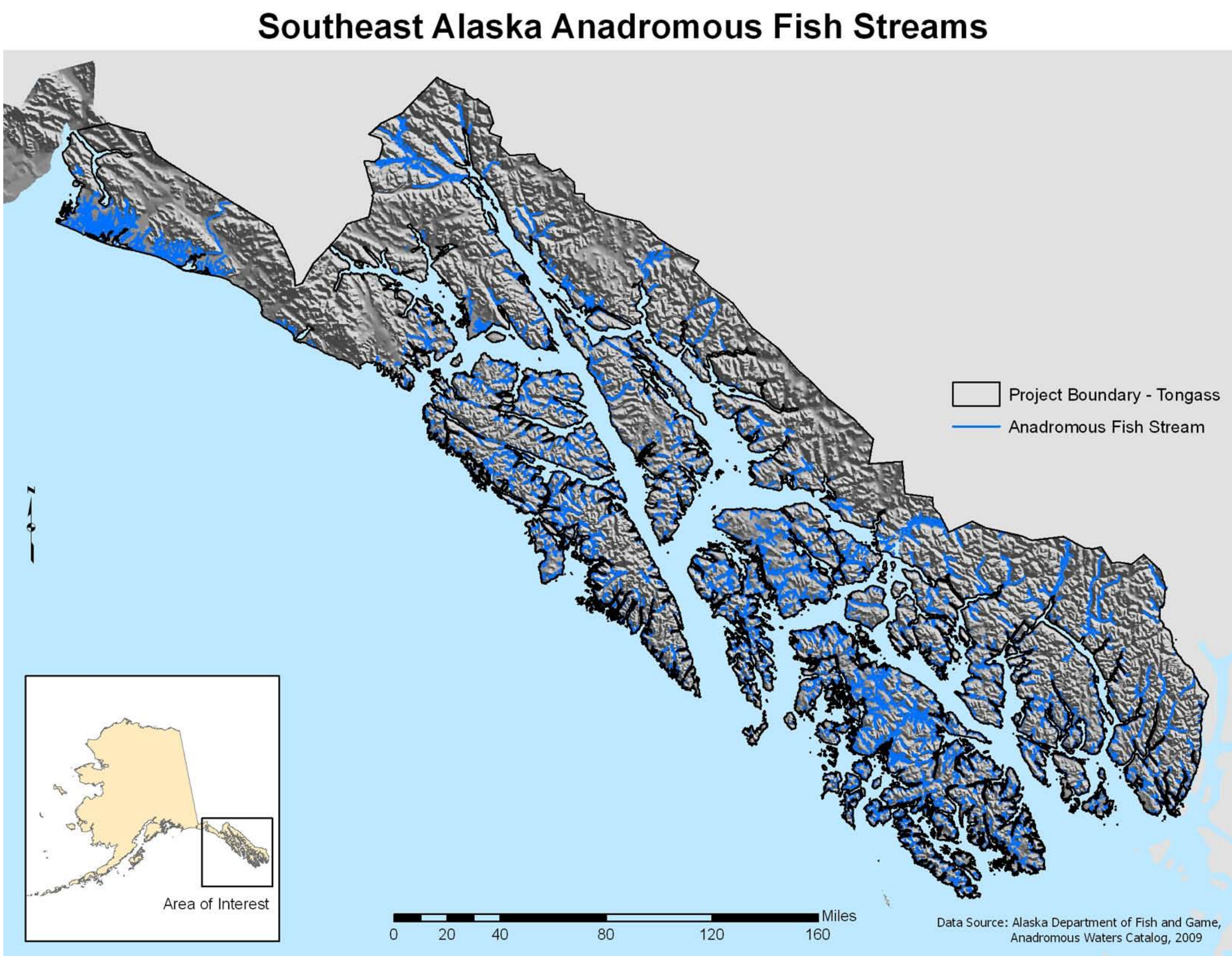

Figure 6. Streams supporting anadromous fish in the Southeast Landscape.

detailed review of the potential for each of these streams to be either positively or negatively impacted by climate change in terms of salmonid populations is warranted.

Bryant (2009) presented a good overview of climate change effects on salmonids, and reported the following: "Although anadromous salmonids exist over a wide range of climatic conditions along the Pacific coast, individual stocks have adapted life history strategies—time of emergence, run timing, and residence time in freshwater—that are often unique to region and watersheds. The response of anadromous salmonids will differ among species depending on their life cycle in freshwater. For pink (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*) that migrate to the ocean shortly after they emerge from the gravel, higher temperatures during spawning and incubation may result in earlier entry into the ocean when food resources are low. Shifts in thermal regimes in lakes will change trophic conditions that will affect juvenile sockeye salmon growth and survival. Decreased summer stream flows and higher water temperatures will affect growth and survival of juvenile coho salmon (*Oncorhynchus kisutch*). Rising sea-levels will inundate low elevation spawning areas for pink salmon and floodplain rearing habitats for juvenile coho salmon. Rapid changes in climatic conditions may not extirpate anadromous salmonids in the region, but they will impose greater stress on many stocks that are adapted to present climatic conditions. Survival of sustainable populations will depend on the existing genetic diversity within and among stocks, conservative harvest management, and habitat conservation." Bryant (2009) provides the following summary of possible climate change effects on salmon:

Pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*Oncorhynchus keta*)

- Increased frequency and extent of pre-spawner mortality resulting from increasing temperatures and decreasing summer flows
- Earlier emergence time and entry into the marine environment with less favorable conditions for early feeding and growth
- Deterioration of spawning habitats
- Greater upslope landslide activity increasing scour and sediment infiltration
- Incursion of saltwater from rising sea levels into spawning areas
- Alterations in sediment dynamics with changes in sea level
- Alterations in run timing as a result of shifts in temperature and discharge

Sockeye salmon (*Oncorhynchus nerka*)

- Shifts in spawning time with subsequent changes in time of emergence of fry
- Spawning habitat deterioration from upslope landslides induced by increased rainfall intensity
- Changes in growth and survival resulting from alteration of trophic status of lakes
- Shifts in zooplankton availability
- Changes in lake physical and chemical dynamics resulting from either increases or decreases in water recharge
- Decreasing rearing capacity and secondary production from saltwater intrusion
- Increased predation as thermal characteristics become more favorable for natural or introduced predators

Chinook salmon (*Oncorhynchus tshawytscha*)

- Changes in run timing forced by temperature and/or discharge regimes
- Increased stress and mortality during spawning migration resulting from loss of thermal refuges in large pools
- Deterioration of spawning habitat caused by increased frequency of upslope landslides
- Loss of rearing habitat as thermal refuges are lost

Coho salmon(*Oncorhynchus kisutch*)

- Deterioration of spawning habitat from landslides that scour spawning beds and deposit sediment on downstream spawning areas
- Changes in fry emergence timing and emigration
- Effects of climate change induced temperatures on growth and survival of juvenile coho salmon
- Increased growth as temperatures in streams increase above 10◦C but remain below 18◦C
- Decreased survival as metabolic demands increase but food supplies become limited
- Loss of rearing habitats
- Decrease in summer rearing habitats as flow decreases and pool abundance and quality decrease
- Deterioration of off-channel habitats as temperatures exceed optimum ranges
- Loss of off-channel habitats through more frequent high intensity rainfall events that remove instream structure and beaver dams during fall and winter
- Intrusion of salt water into low elevation rearing areas

Taylor (2008) conducted a study of sockeye salmon (*Oncorhynchus nerka*) in Auke Creek north of Juneau, AK and analyzed a data set collected over a 34 year time span from 1972-2005. This study noted the general increase in temperatures over this time span and found that dates of migration of pink salmon were occurring early over time in association with the earlier rise in stream temperatures. The study stated: "Given the trend for salmon fry to migrate earlier, a larger portion of the population may become mismatched with optimum environmental conditions during their early marine life history."

Overall salmon numbers in southern coastal areas of Alaska may not experience major population declines due to climate change, although many unknowns exist. However, various predictions indicate that impacts to local stocks are likely, some of which could have significant local effects. Ocean changes could dramatically alter salmon distributions or populations, but these impacts are more speculative at the present. Impacts to salmon populations in specific streams and rivers are likely. Current recommendations call for considering thermal refugia for salmonids where possible, and closely monitoring harvests to ensure that overharvesting does not become a factor in declines of salmon stocks. Continued research and monitoring will be essential to identify and address these possible threats.

Loss of Glaciers

Glaciers serve various functions and offer some unique environmental conditions, such as periglacial environments that are dominated by the close proximity of a glacier. Marine or tidewater glaciers, those running into the ocean, are at substantial risk due to climate change. The unique environments created by these glaciers are used by a small but specialized group of species. For example, the Kittlitz's murrelet (*Brachyramphus brevirostris*) feeds in waters around tidewater glaciers. It is considered a critically endangered species as glaciers recede. The Southcentral Landscape is one of its primary areas, as exemplified by the estimated loss of 7-15% of its population from the Exxon Valdez oil spill. This species has been reported to be experiencing an annual estimated decline of around 18%, attributed primarily to climate change, although the specific causes of its decline have not been determined. Specific actions by the Forest Service to address declines in glaciers are not proposed, other than minimizing the agency's carbon footprint. Minimizing impacts to other habitat needs of species such as Kittlitz's murrelet is prudent, but in this example, this species nests in remote, high elevation settings where human impacts are minimal.

Changes to Wetlands

Climate change predictions for southern coastal areas of Alaska indicate that the area should receive increased precipitation. However, this increase may be offset in some areas by the increase in P-PET ratios. This increase in P-PET ratios is expected to impact some wetlands, an effect that has already been observed (Klein et al. 2005, Berg et al. 2009). In the Kenai Peninsula, over 2/3rds of the water bodies were observed to have decreased in area between 1950 and 1996 (Klein et al. 2005). Berg et al. (2009) reported an 11% decadal decrease in the herbaceous area of 11 wetlands from 1968-1996 as forests invaded these sites as they became drier. These trends are likely to increase in the future under predicted climate change, potentially threatening the integrity of many wetlands which support a substantial proportion of the biodiversity of the region.

Forest Temperature and Precipitation Changes

Forest ecosystems are expected to undergo various changes as a result of climate change. These changes include shifts in distributions as a result of changes to temperatures or precipitation levels, changes caused by modifications to other disturbance processes such as fire and avalanches, and changes to insect or pathogen outbreaks.

Temperature and precipitation increases expected for southern Alaska coastal forests will cause changes to forest ecosystems. As Kelly et al. (2007) noted temperatures are expected to rise up to 6- 9^0 F over the next 100 years. A 3^0 F decrease in temperature is typically associated with a 1000 ft gain in elevation. Thus, forest ecosystems could see a 2-3000 ft upward shift in distributions as a result of climate change. This would obviously produce a substantial change in landscape configurations in southern coastal forests, with a proportionate decrease in alpine or tundra vegetation types. A related but somewhat different effect of climate change was noted by Veblen and Alaback (1996). They reported that changes in elevations and amounts of snowfall were likely to change avalanche patterns, a potential change also reported by Kelly et al. (2007). Avalanches currently keep some vegetation, specifically trees, from occurring in areas with frequent avalanches. As frequency decreases with changes in snowfall, former avalanche chutes or tundra areas may be invaded by tree cover.

A significant impact to forests in southern coastal areas of Alaska is the potential for changes to fire regimes. Fire as a major disturbance to forest ecosystems has already been observed to be increasing in the Kenai Peninsula. While fire has been an historical disturbance factor in the Kenai Peninsula, especially in black spruce (*Picea mariana*) forests (Berg and Anderson 2006), the occurrence and sizes of fire have been increasing, especially for white (*P. glauca)* and Lutz spruce (*P. lutzii*) forests. Large acreages of spruce forests have been killed by massive beetle *(Dendroctonus rufipennis*) outbreaks (Figure 8) (Berg et al. 2006), opening up the canopy and allowing growth of dense grasses, often 5-6' tall. These "flashy" fuels, when dry, can cause rapidly spreading fires in areas around the Kenai and Russian Rivers which attract thousands of anglers each summer, and also support many homes and cabins. In the past, fires in the Kenai Peninsula were generally small, requiring only a relatively small fire suppression contingency. In 2009, the Mile 17 East End Road Fire and the Shanta Creek Fire revealed the potential for larger and more dangerous fires. With increasing temperatures, dryer forest conditions are expected in the summer, expanded areas of beetle-killed forest are likely, and fire conditions are predicted to get more severe with much larger fires. Community Wildfire Protection Plans are needed (Oja et al. 2004) and need to address anticipated increases in fire severity and sizes predicted from climate change. The All Lands/All Hands program recognized the need for collaborative action following the beetle outbreak (Oja et al. 2004). This initiative was not fully aware of the likely extent of climate changes at its inception, a factor that has only added to its important role in this landscape.

Fire has generally not been a factor in Southeast Alaska coastal forests (Murphy and Witten 2006). However, climate predictions indicate that P-PET ratios could cause drying of forests in the summer, even with higher projected precipitation rates. Weather extremes are generally expected to be more common with climate change, so that occasional droughts are more likely to occur. If areas of coastal forests become dry and a fire gets started, it is likely to be of very high intensity (Murphy and Witten 2006). The likelihood of fire occurring in Southeast forests should be considered as a result of climate change.

A species that is predicted to see substantial changes in southern Alaskan coastal forests due to climate change is yellow-cedar (*Callitropsis nootkatensis*) (see Figure 7 for its current distribution). This species

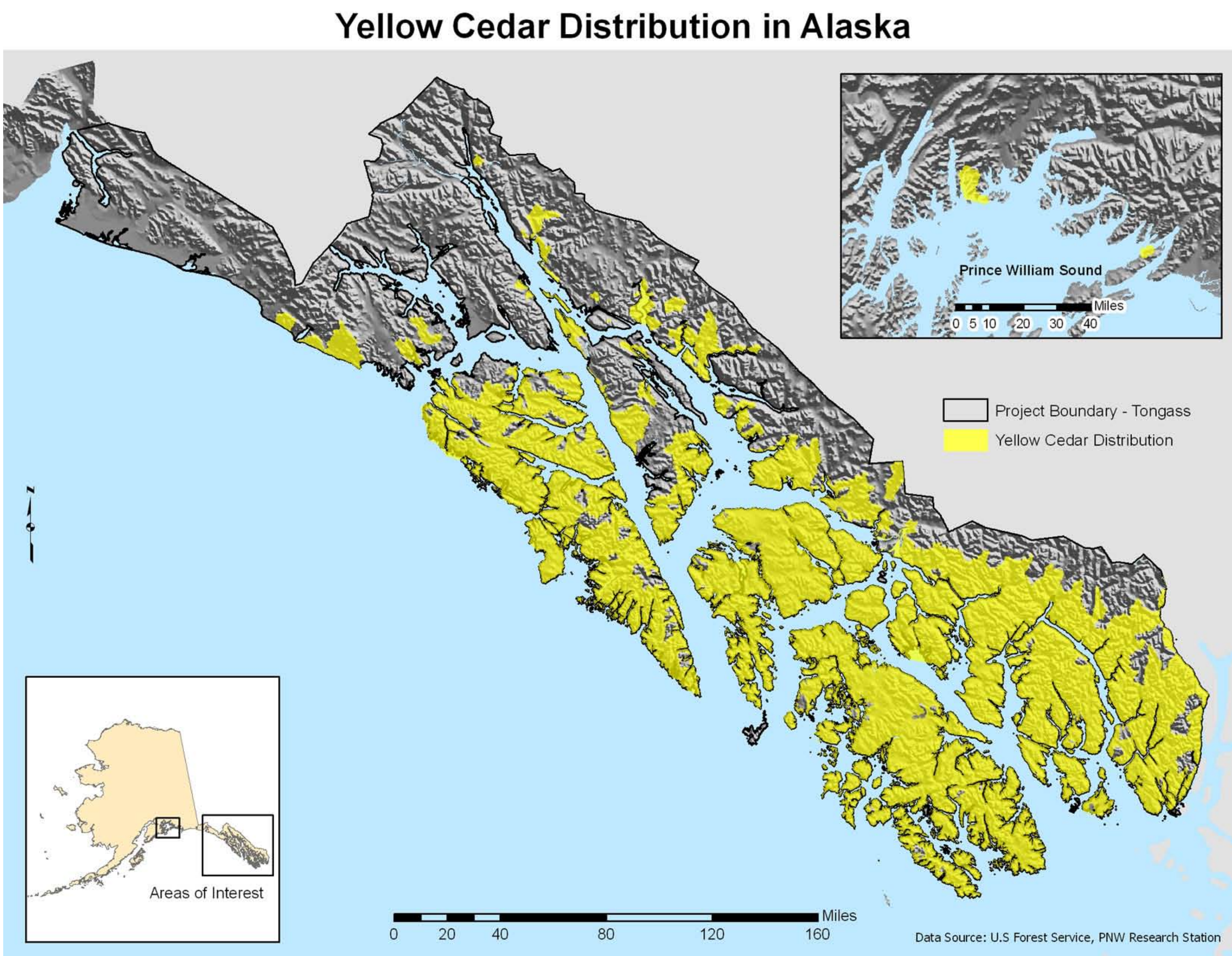

Figure 7. Yellow-cedar distribution in southeast and southcentral Alaska.

has been undergoing changes in distributions for the last 100 years, but these changes are increasing due to climate change, and will be further exacerbated by future predicted change (Hennon and Shaw 1997, Beier et al. 2008 Hennon et al. 2008). Researchers, primarily with the PNW station, have discovered that the primary cause of the decline appears to be loss of snow cover at lower elevations. This allows soils to be exposed to freezing and thawing cycles in late winter that kills the roots of the yellow-cedar on all but deep soils. Yellow-cedar at higher elevations in areas where snow cover occurs through the late winter remains healthy. However, as snow levels rise and earlier snow melt occurs, more areas of yellow-cedar will be exposed to the unfavorable conditions and will be expected to die off. Hennon et al. (2008) have proposed management strategies to address the threats to this species.

Insects outbreaks are expected to occur as a result of climate change. One well documented outbreak that has already been associated with increasing temperatures is that of the spruce beetle in the Kenai Peninsula (Figure 8). Inkley et al. (2004) reported that 80% of the spruce trees in this location have been killed by the beetle outbreak, the largest recorded past die-off of trees reported in North America (Werner 1996). Western balsam bark beetles (*Dryocoetes confuses*) have also impacted substantial areas of subalpine fir in southern coastal forests of Alaska in recent years, especially around Skagway (Wittwer 2002, Kelly et al. 2007). As temperatures warm, this species is expected to exert increasing impacts at higher elevations. Mountain pine beetles (*Dendroctonus* ponderosae) are showing increased activity at higher elevations (Williams and Liebhold 2002), and may soon impact lodgepole pine forests in new areas of southern Alaska coastal forests.

Figure 8. Spruce trees killed by beetle outbreaks in forests of the Kenai Peninsula. Photo from the All Lands/All Hands report (Oja et al. 2004).

Coastal forests are likely to see increases in productivity with climate change. The increased length of growing seasons has been found to increase productivity in some locations (Myneni et al.1997). While some of the potential increase in growth may be ameliorated in some areas by reduced water availability caused by increases in the P-PET ratios, in many sites the increased length of seasons with temperatures above freezing should increase growth of many plant species. This increased growth may benefit production of many forest products, and may require new planning for future forest management. However, these changes may also alter competitive relationships of species, causing shifts in species compositions or changes to species distributions.

An additional anticipated effect of climate change on coastal forests concerns the potential release of carbon stored in forest ecosystems to aquatic ecosystems and the ocean. As reported by D'Amore and Edwards (no date) "The Tongass is carbon rich, containing 8 percent of all the carbon currently stored in United States forests….Cumulative annual discharge from Tongass watersheds equals or exceeds that of the Yukon River in an area 1/13th the size. Dissolved organic carbon (DOC) concentrations are high and the total DOC flux from the Tongass is the highest per unit area of any ecosystem in the world. The volume of carbon moving in this single export vector indicates that changes in temperature and precipitation could mobilize carbon stored in forest soils and flush large amounts of carbon, nitrogen, and phosphorus from the forest to the adjacent marine ecosystem with potentially large impacts on marine productivity and the regional carbon balance." The PNW Research Station has initiated research efforts to better understand carbon cycles in the temperate rainforests of the coast of Alaska.

INCREASES IN INVASIVE SPECIES

Invasive plants are another aspect of climate change that can have detrimental impacts on a region's economy and natural resources. The landscapes in southern Alaska and their human communities are more isolated than most other parts of the U.S., so introduction and spread of invasive species has not been as significant as in many other areas of the U.S. However, spread of invasive species is occurring such as the establishment of spotted knapweed (*Centaurea* maculosa) and purple loosestrife (*Lythrum salicaria*) in various locations. Climate change will create additional favorable conditions for the establishment and spread of many invasive species. Increased temperatures may make Alaskan landscapes more conducive to invasion by many invasive species associated with warmer climates. In addition, climate change may stress some native species, providing opportunities for exotic species to be more competitive. Finally, higher atmospheric CO_2 levels are likely to make chemical control of invasive species more difficult. The Alaska Region Invasive Species Strategy 2006-2010 emphasizes the prevention and early detection of introductions of invasive species and the eradication of pockets that may be located through on-going surveys and monitoring. This strategy should be extended and updated as new information and threats are identified.

6.0 INITIATIVES FOR CLIMATE CHANGE IN SOUTHERN ALASKA COASTAL LANDSCAPES

Descriptions of various initiatives, agencies, and entities that have on-going or developing programs contributing to climate change needs in southern Alaska Landscapes are provided below.

Alaska Center for Climate Action and Policy (ACCAP)

ACCAP is one of nine Regional Integrated Sciences and Assessments (RISA) programs nation-wide, funded by the Climate Program Office of NOAA (http://www.uaf.edu/accap/). This center was started in 2006 and designed as a collaborative among University of Alaska campuses and institutes to assist Alaskan businesses, agencies and citizens in adapting to a changing environment. The center provides a state-wide resource for climate change information exchange and research design and development. The mission of the ACCAP is to assess the socio-economic and biophysical impacts of climate variability in Alaska, make this information available to local and regional decision-makers, and improve the ability of Alaskans to adapt to a changing climate. It cooperates with the Scenarios Network for Alaska Planning (SNAP) to disseminate scientifically credible information about climate change in formats that are useful for decision-makers. The center hosts monthly Climate Teleconferences/Webinars.

Scenarios Network for Alaska (SNAP)

SNAP is a network linking university researchers with communities and resource managers. Through collaborative partnerships involving data sharing, research, modeling, and interpretation of model results, SNAP addresses some of the complex challenges of adapting to future conditions. The Forest Service is a partner of SNAP, along with the USFWS, USDA Cooperative Extension Service, The Nature Conservancy, The Wilderness Society, and many others.

Alaska Climate Services Partnership

NOAA intends to build on its cooperative efforts with multiple partners (all levels of government, Native communities & organizations, private and public business sectors, research entities, and international bodies) by fulfilling a vision of long-term planning for Alaska by establishing an Alaska Climate Service Partnership by 2015. Plans call for NOAA to identify and share applicable products and to harness existing services to support Alaskan customers in immediate action, adaptation, and mitigation efforts.

National Climate Change and Wildlife Center

"The U.S. Geological Survey (USGS), science agency of the U.S. Department of the Interior, is in early planning stages of establishing a national Climate Change and Wildlife Center to inform adaptation or management of fish and wildlife in the face of climate change. The Center is being designed with input from Federal, State, and Tribal science and management agencies; NGOs; academia; and others. Mobilization of existing assessment and monitoring capabilities, and coordination of interagency and inter-organizational efforts will be tapped for timely forecasting of responses at multiple spatial and temporal scales." (Adaptation Advisory Group to the Alaska Climate Change Sub-group 2009).

Alaska Climate Change Knowledge Network (ACCKN)

The purpose of the ACCKN is to foster coordination among the various entities with responsibilities for collecting, interpreting, and using climate change data in Alaska. "The ACCKN will leverage current efforts to facilitate the following functions:

- Organize, archive when needed, and inventory data and other resources pertinent to understanding climate change and its effects in Alaska.
- Promote enhanced online access to the above data, information, and knowledge in ways that facilitate use.
- Identify and communicate (to data and information providers) the needs of communities for information to understand and plan for climate change.
- Share information on specific geographic areas of concern such as the Arctic and on specific thematic issues or trends of concern such as ocean acidification.
- Incorporate community and other entities' (e.g., the private sector, non-profit, and citizen science efforts) data, information, and knowledge about the effects of climate change and feedback on adaptation efforts.
- Integrate and analyze data and information for better understanding of climate change impacts and effects, including identifying gaps where additional data may be needed.
- Provide a point of coordination with federal efforts in Alaska such as National Oceanic and Atmospheric Administration's (NOAA) activities to develop a Regional Climate Service partnership and U.S. Geological Survey (USGS) activities related to their Alaska Science Center." (Adaptation Advisory Group to the Alaska Climate Change Sub-group 2009).

Alaska Climate Research Center (ACRC)

The ACRC is a research and service organization at the Geophysical Institute, University of Alaska Fairbanks. ACRC conducts research focusing on the climatology of Alaska and polar-regions and archives climatological data for Alaska.

The Alaska Executive Climate Roundtable

This initiative was established jointly by the U.S. Fish and Wildlife Service and the U.S. Geological Survey in 2007, and is a forum of some twenty State, Federal, University, and NGO senior executives who, in a region of the nation already experiencing some of the most significant impacts from climate change, share strategies and challenges as a means for improved coordination and collaborative action. The Forest Service has been a participant in this Roundtable.

Alaska Governor's Climate Change Sub-cabinet

The Sub-Cabinet has been working on a collaborative strategy that is addressing:

- Building the state's knowledge of the actual and foreseeable effects of climate warming in Alaska,
- Developing appropriate measures and policies to prepare communities in Alaska for the anticipated impacts from climate change, and
- Providing guidance regarding Alaska's participation in regional and national efforts addressing causes and effects of climate change. (http://www.climatechange.alaska.gov/).

North Pacific Landscape Conservation Cooperative

"Landscape Conservation Cooperatives (LCCs) are shared management-science partnerships between the U.S. Fish and Wildlife Service (USFWS), the United States Geological Survey (USGS), states, federal resource management agencies, tribes, NGOs, universities and other entities within a geographic area which inform resource management decisions to address climate change and other stressors in an integrated fashion across landscapes. LCCs provide scientific and technical support for landscape conservation in an adaptive management framework, with an emphasis on biological planning, conservation design, prioritizing research and designing inventory and monitoring programs. Products developed by the LCC help inform conservation delivery efforts on the ground" (USFWS brochure).

All Lands/All Hands initiative

The Kenai Forest, Wildland Fire and Fuels Management Coordinating Committee was established in 2003 to address the long term effects of the spruce bark beetle outbreak in the Kenai Peninsula. The committee chartered the development of a collaborative, interagency, action plan to identify and prioritize fire prevention and protection, hazardous fuels, forest health and ecosystem restoration, and community assistance projects on the Kenai Peninsula. The plan encouraged communities to identify Wildland Urban Interfaces and emphasized the need for the 20 communities on the Kenai Peninsula to complete Community Wildfire Protection Plans. This interagency committee includes representatives from the USDA Forest Service, Alaska Region; the Kenai Peninsula Borough; the Alaska State Division of Forestry; Chugachmiut Inc.; the USFWS Kenai National Wildlife Refuge; the Bureau of Land Management; the Bureau of Indian Affairs; the Kenai Fjords National Park; and other cooperators.

Strategic Environmental Research & Development Program (SERDP), Department of Defense (DOD)

In 2010, SERDP released a Statement of Need requesting research proposals for projects to improve DOD's understanding of the potential impacts of climate change to ecological systems that occur on DOD testing and training lands in Alaska. Of particular concern are climate change impacts that could lead to state changes or regime shifts in ecological systems.

Prince William Sound Science Center

The Prince William Sound Science Center, located in Cordova, was created in 1989. This center has facilitated and conducted research and education programs to increase understanding of the Prince William Sound and Copper River Delta ecosystems. These programs emphasize the long-term diversity, and health and sustainability of resources upon which local people depend, while also serving a multitude of stakeholders in the broader region. The center has taken a leading role in understanding ecological change caused by shifts in atmospheric and ocean climate that threaten livelihoods and create other problems for those in the area. The Chugach NF and PNW Station are partners with this center.

The Copper River International Migratory Bird Initiative (CRIMBI)

The 700,000-acre Copper River Delta comprises the largest continuous wetland on the Pacific Coast of North America. The Delta has been designated a Western Hemisphere Shorebird Reserve—Hemispheric Site, which is the most important designation awarded to a world shorebird site. CRIMBI is a newly formed partnership effort of the Wings Across America program of the USFS. The USDA Forest Service International Programs, the Pacific Northwest Research Station, the Chugach National Forest, and Ducks Unlimited are partners. The initiative will work with established conservation plans including the North American Waterfowl Management Plan, United States Shorebird Conservation Plan, North American Waterbird Conservation Plan, Western Boreal Forest Initiative, and the North American Bird Conservation Initiative to enhance existing conservation strategies. While this initiative has not specifically noted climate change as its focus, this will undoubtedly be one of its primary issues.

Pacific Coast Joint Venture (PCJV)

The mission of the Alaska PCJV is to protect wetlands and migratory bird habitat and to maintain the ecological diversity of Alaska's coastal ecosystems. Alaska joint venture partners include government agencies, conservation organizations, land trusts, and private entities. The main goals of the Alaska PCJV are to:

- Work with partners to coordinate and implement the goals of national, flyway and state bird conservation plans,
- Link local conservation partners and agency resources, and
- Provide forums where partners can collaboratively plan and prioritize habitat protection projects.
- This program has not specifically targeted climate change, however as with CRIMBI, this will undoubtedly be an important component of its work.

Copper River Watershed Project

The Copper River Watershed Project provides residents with a forum to consider and implement innovative approaches for achieving balance between a diverse economy and healthy ecosystems while maintaining their quality of life and cultural heritage. It is a membership organization open to all residents within its boundaries, but partners with resource management agencies, tribal entities, and others in the area.

Alaska Invasive Species Working Group (AISWG)

The mission of the AISWG is to minimize invasive species impacts in Alaska by facilitating collaboration, cooperation and communication among AISWG members and the people of Alaska. Comprised of a very inclusive list of partners, the AISWG has set up subcommittees to address research, education, communication, and management relating to invasive species.

Kenai Borough Spruce Bark Beetle Mitigation Program

The mission of the Kenai Borough Spruce Bark Beetle Mitigation Program is to help protect the lives and property of the residents of the Kenai Peninsula Borough by identifying and mitigating wildfire and other hazards related to spruce bark beetle-killed spruce, and to replant forests impacted by the spruce bark beetle outbreak. With links to the All Lands/All Hands initiative, this program helps mitigate hazards created by the beetle outbreak. Community Wildfire Protection Plans (CWPP's) are being developed throughout the Kenai, with initial plans completed for all of the extreme risk areas. The Forest Service is a partner to this group and to the development of the CWPP's.

Alaska Coastal Rainforest Center (ACRC)

ACRC will stimulate and develop temperate rainforest education and research, including a focus on climate change. ACRC is a collaborative venture of the University of Alaska Southeast, University of Alaska Fairbanks, the Forest Service's Pacific Northwest Research Station, the Forest Service's Alaska Region, the U.S. Fish and Wildlife Service's Alaska Region, and the City and Borough of Juneau, Alaska. ACRC will foster a collaborative environment that expands and enhances education and research opportunities by coordinating activities among the six cooperating agencies. In particular, the center will:

- Provide formal and informal education at the university and community school levels as well as professional training relating to coastal rain forest ecosystems;
- Apply knowledge gained through the collaboration to meet education and management needs for sustainable resource use within coastal rain forest ecosystems;
- Facilitate public policy discussions and foster public understanding of rain forest ecosystems.
- It also will support work at the newly established Héen Latinee Experimental Forest.

Chugach Children's Forest

In 2008, the Chugach National Forest designated itself a Children's Forest, a symbolic designation that creates exciting, new, and innovative opportunities for connecting Alaska's youth and communities with the outdoors. The Chugach Children's Forest is dedicated to producing a healthier tomorrow for Alaska's youth, communities, and forests. It uses innovative education in science and technology to increase public awareness and youth leadership in finding solutions to climate change issues. This partnership effort includes Alaska Geographic and the Chugach National Forest along with Alaskan communities, educators, non-profits, and public lands. "The Chugach Children's Forest is actively working to address the challenges of climate change by integrating climate change awareness, education, and research across the entire range of youth programs, community partnerships, and outreach efforts. The goal is to directly engage the general public and make climate change--and its solutions--relevant to their personal lives." (http://www.alaskageographic.org/static/1091/childrens-forest-climate-change)

The Wolverine Glacier Research Natural Area

Wolverine Glacier is one of three long-term glacial monitoring sites established in North America by the U.S. Geological Survey. The data collected are instrumental to understanding glacier-related hydrologic processes, hazards, and climate change. The monitoring site has been in continual operation since1966, and provides an invaluable data source on glacial movement, mass balance, and stream runoff. A weather station is also on-site, providing the only high-altitude, long-term, year-round climate data for the mountains of southcentral Alaska. http://fs.usda.gov/Internet/FSE_DOCUMENTS/fsm8_028808.pdf)

Potential Partnerships for Climate Change in Southcentral and Southeast Landscapes

The list of potential partners that might be included in USFS climate change initiatives in the Southcentral or Southeast Landscapes of the Alaska Region.

Partner	Role
USFWS	Strategic Species Plans Landscape Conservation Cooperative Pacific Coast Joint Venture Executive Climate Roundtable
BLM	Resource management within landscape, cooperative education/demonstration projects
DOD	Climate change research and related management on DOD lands
NOAA	Fish habitat protection, climate projections and data collection
Alaska Department of Environmental Conservation	State climate change lead for Governor's Climate Change Sub-cabinet
Alaska Dept. of Fish and Wildlife	Wildlife Action Plan, wildlife and fish monitoring and studies, harvest regulations
Alaska Division of Forestry	Programs for private forest landowners, state-wide assessments and forest management on state lands
U.S. Geological Survey	Research and monitoring on physical and biological environments and resources, educational programs
U.S. Coast Guard	Monitoring and data collection
National Park Service	Management of adjacent lands Cooperative climate programs and educational programs
Copper River Watershed Project	Collaborative watershed project
Ducks Unlimited	Cooperative management programs such as CRIMBI
Alaska Geographic	Cooperative educational projects
The Nature Conservancy	Climate change analyses and land conservation initiatives,
Alaska Invasive Species Working Group	Programs to address invasive species with expected challenges from climate change
Sealaska Corp., Chugach Alaska Corp, Cook Inlet Inc., Ahtna Corp.	Alaska Native corporations involved in resource management
Kenai Peninsula Borough Spruce Bark Beetle Task Force	Cooperative forest monitoring and management
The Wilderness Society	Research on climate change
University of Alaska	SNAP cooperative climate change modeling, research on resources and climate change, educational programs
Tribal entities	Collaboration on climate related issues and mitigation
Prince William Sound Science Center	Research, monitoring, and educational programs on climate change
Alaska Coastal Rainforest Center	Research and education including responses to environmental change
City and Borough of Juneau	Cooperative education and planning efforts

7.0 STRATEGIC PLAN FOR CLIMATE CHANGE

Various strategies were identified in the Integrated Plan submitted to the Chief that could be adopted for the Southcentral and Southeast Landscapes to help mitigate the effects of climate change. Landscape conservation strategies are essential given the scope and scale of the likely impacts. While these strategies specifically focus on the Forest Service, all should also be viewed in the landscape context with partnerships in mind. Each of these strategies relate to the 7 goals of the USFS Strategic Framework for Responding to Climate Change. These 7 goals are indicated in this strategic plan by their corresponding numbers:

1. **SCIENCE** - Advance our understanding of the implications of climate change,
2. **ADAPTATION** - Adapt to the environmental stresses of climate change and maintain ecosystem services,
3. **MITIGATION** – Promote management to reduce greenhouse gases and sustain ecosystem services,
4. **POLICY** - Integrate climate change policies, program guidance, and communications,
5. **SUSTAINABLE OPERATIONS** - Reduce environmental footprints and exemplify a green organization,
6. **EDUCATION** - Advance awareness and understanding of resource management in a changing climate, and
7. **ALLIANCES** - Establish, enhance, and retain alliances and partners at all levels.

Landscape conservation strategies include the following: provide education on climate change and its impacts; demonstrate responsible energy use and carbon balances; establish policy statements, guidelines, and action plans for addressing climate change; model ecosystem dynamics to understand relationships and predicted climate change effects; monitor key indicators of climate change; research key questions concerning climate change; establish model watersheds to support monitoring and adaptive management; assess risks to identify changes that can be mitigated; mitigate and adapt to anticipated and observed effects; and build possible and necessary alliances and partnerships for addressing climate change impacts.

EDUCATION INITIATIVES

Educational initiatives address the education goal of the USFS Strategic Framework for Responding to Climate Change. Three avenues for education may be appropriate for the Alaska Region to consider including in a strategy for climate change, with considerable efforts already on-going for all three. First, providing factual and focused information to the public about climate change is important to develop a knowledgeable citizenry. Some of the public may be reached through the internet, with websites that specifically address the issues and challenges of climate change. Various websites on climate change in

Alaska currently exist, and do not need to be duplicated. However, information on climate change and how it has and will impact both NFs and the Region could be very information to the public. Such information is not currently available on any of the USFS websites for the Region or its NFs. The Alaska Region and the two NFs have an excellent opportunities to be leaders in dissemination of information to the public about real changes expected form climate change, and actions that can help to properly anticipate potential impacts, with websites providing a good forum for this dissemination.

A second educational opportunity is one that the NFs and Region have already initiated. Educational opportunities about climate change offered through learning centers, educational programs, and educational materials are already on-going. The Chugach Children's Forest, Portage Valley Learning Center, Heen Latinee Experimental Forest, Prince William Sound Science Center, displays at several glacier visitor areas, and other such programs are excellent opportunities to engage and educate the public concerning climate change. Few other places have as good a setting for educating about climate change as the Tongass and Chugach NFs, with glaciers providing a strong visual message about the effects of rising temperatures. Numerous opportunities for partnerships, many of which are already in place, can be developed around education opportunities concerning climate change. A review of on-going programs and analysis of the potential for additional educational opportunities would seem warranted as part of a Regional strategy for climate change.

The third educational opportunity could be directed at USFS employees. FS employees should be well-informed about climate change, and what their agency is doing to prepare for its potential impacts. While certainly those in the agency that are directly involved in climate change-related programs will be knowledgeable, will all employees understand and be able to explain why the FS is concerned and what it is doing about climate change? In-house seminars, workshops, or other programs could be conducted to ensure that all employees have a basic understanding of the threats of climate change, how the FS is planning to address current and potential impacts, and that the FS takes this issue very seriously.

Demonstration Programs

Demonstration addresses both the mitigation and the sustainable operations goals of the USFS Strategic Framework for Responding to Climate Change. One of the most effective ways of showing commitment and in convincing others of the importance of an issue is through demonstration. In other words, don't just talk the talk, walk the talk. The FS is in an excellent position to do this relative to climate change, and has already started this in many ways. First, the FS should minimize its carbon footprint by maximizing its energy efficiency and by reducing its use of fossil fuels and water. Some of this is on-going. For example, the Tongass NF has or is planning to:

- Reduce energy intensity by 3% annually by 2015 using 2003 as a baseline,
- Conduct energy and water audits at 10% of facilities each year,
- Apply sustainable design principles to new construction,
- Design buildings to be 30% more efficient than current standards so long as they are life-cycle cost effective,

- Decrease fuel consumption (a 19.6% reduction was achieved in 2008 compared to 2007 and a 14.9% reduction was noted in the 2nd quarter of 2009 compared to the same time period in 2008), and
- Conduct greenhouse gas inventories.

This is an excellent example of demonstrating the commitment the agency has for climate change, and can be something that is included, as appropriate, in the educational opportunities discussed above.

The FS can also demonstrate its commitment to addressing climate change in its field operations. On-going work is investigating and quantifying carbon sequestration in coastal rainforests. The coastal rainforests of Alaska sequester a huge amount of carbon. How this may change with climate change is an important question that is the subject of various research efforts, including projects of the PNW Station. In addition, the types of actions that can increase future sequestration should be considered as part of vegetation treatments planned in the Region. Where opportunities exist to sequester more carbon while meeting other management objectives, these could be incorporated into the project, and described to the public.

Policy Modifications

The USFS Framework calls for the agency to integrate climate change policies, program guidance, and communications. Forest plans serve as the primary documents for program guidance. These plans could be checked to ensure that they incorporate climate change considerations in future management activities. If appropriate and needed, new policies could be identified to address climate change opportunities. For example, considering carbon sequestration, as discussed above, in project designs could be a policy designed to address climate change.

Additional policies at the forest or regional level could also be considered. For example, setting policies such as making energy conservation a priority in operations could then help highlight the importance of this, and can lead to new ideas and initiatives to creatively reduce carbon footprints.

Related to policies, it may be important to ensure that the Conservation Strategy of the Tongass NF Plan will be effective in maintaining the viability of species under climate change. New information on endemic populations of species in the Alexander Archipelago has raised questions concerning the viability of these populations. If climate change is projected to add additional stressors to these populations due to their isolated distributions and inabilities of some species to shift their distributions, then the viability of these species may decline. Anticipatory planning to address possible future concerns may be a prudent action to ensure continuity in management programs.

A final policy-related action could be to formally establish and adopt a landscape scale conservation strategy for climate change. Fully articulating such a strategy and adopting it as a policy by the Region would help formalize climate change anticipatory actions. The strategy for climate change developed by the Forest Health Program of State and Private Forestry (see Appendix B) is a good example. A more encompassing strategy that is hierarchical, identifying policies and region-wide programs at the regional level, tiered to forest-specific or program-specific strategies would clearly establish a comprehensive and anticipatory program for climate change.

MODEL PREDICTED CHANGES

Climate change impacts, as discussed previously, can be divided into current, observed changes, and future, predicted changes. Future changes are based on predictive models of climate change that address temperature, precipitation, frost-free seasons, and related information (see Appendix A). These then are further evaluated to determine what their effects are likely to be on ecological or human systems. Models of expected impacts to ecological or human systems would help to establish a logic framework for each anticipated impact. Such models identify potential cause and effect relationships; helping to reveal the most important variables or parameters to monitor that will determine what changes are occurring and the primary causes of these changes. This helps ensure that key variables are monitored, and that monitoring is being conducted as efficiently as possible. Models help establish and quantify expected relationships that can either be verified or refuted through monitoring. Thresholds can be identified in models that would help guide when certain response actions are needed. Trigger points can be set that are predetermined levels that indicate when monitored values exceed predicted parameters that would cause model relationships to need adjustment. Use of models in this manner can be a major help in establishing the most effective and efficient monitoring programs, helping achieve monitoring objectives while helping reduce costs.

The use and types of models that will assist in addressing climate change should be incorporated in policies, partnerships, and budgets. They can be a key part of a landscape strategy for climate change.

MONITORING

Much about climate change is uncertain. That climate change is occurring and will continue to occur should not be considered uncertain. However, how it will specifically influence local areas, the level and rate of changes, and ecological responses and impacts to that change are all, to varying degrees, uncertain. Monitoring will be essential to understand and quantify change, to determine specific causes and interactions of change, and to effectively anticipate additional future change. Monitoring is a key component of the science and adaptation goals of the Framework for Climate Change.

Monitoring can be of several types, all of which are important for climate change. One type of monitoring is the recording of changes and rates of changes to various physical or ecological parameters as a result of climate change. For example, on-going efforts to monitor receding of glaciers, temperatures of streams, expansion of insect outbreaks, occurrence and rates of spread of invasive species, shifts in species distributions, community compositions or productivity are all important information for documenting and predicting impacts of climate change, and in devising adaptations to these changes. Such monitoring is critical but will require careful planning and evaluation with involvement and assistance from numerous partners to ensure that the most effective and efficient variables are included.

A second type of monitoring addresses the effectiveness of treatments or management actions. Given the uncertainty surrounding climate change and how it will potentially change ecological responses to treatments, monitoring is increasingly important. Adaptive management is a buzzword included in nearly all management plans, but that is typically only given lip-service. Active-adaptive management that models expected outcomes of treatments and then monitors if the outcomes are produced, and hopefully replicates the treatments, will provide essential information on what works and what doesn't work under new environmental conditions. This is not to say that management should be set up under strict experimental designs based on sophisticated quantitative models, but that pre-planned monitoring of variables relating to important desired outcomes is established and maintained for sufficient time post-treatment to guide future management.

A final type of monitoring is that which allows an overall documentation of accomplishments relating to climate change. A landscape conservation strategy for climate change should have milestones and expected outputs that should have a "monitoring" component that allows for an evaluation of success or that highlights needed adjustments to the strategy.

Funding for monitoring has traditionally struggled to be included and maintained in budget reviews during lean times. Climate change and its uncertainties increase the importance of maintaining appropriate monitoring as a high priority in future budgets.

Numerous monitoring programs are already in place and on-going. These should be evaluated relative to their contributions to documenting impacts of climate change or responses to management actions directed at climate change effects. Additional monitoring will be needed, and a systematic process for developing a comprehensive and integrated monitoring system should be established. As discussed above, modeling of various key relationships can help inform this system and the parameters to measure. Established programs such as FIA plots provide important continuous monitoring information, but may need substantial increases in numbers if information that will be useful for local planning is to be generated rather than information needed for national planning that this system was designed to address.

Research

Because of the uncertainties associated with climate change, research will be an important part of a landscape conservation strategy for climate change. This is a component of the science goal of the USFS Framework. The mission of the PNW Station is to assist with this type of need. Coordinated initiatives with the Region and other partners are needed to produce the most effective research programs. Establishing key research locations including model watersheds can help such coordination occur. The

Heen Latinee Experimental Forest, Alaskan Coastal Rainforest Center, Cooper River Model Watershed, and the Maybeso Watershed are all excellent areas for coordinated research and/or adaptive management programs.

Many questions about climate change, such as potential changes to carbon outputs from coastal forest ecosystems to river and ocean ecosystems involve basic research on these relationships. Other more applied topics address specific questions important to managers, such as where should yellow-cedar management areas be located in the future under predicted climate changes, or what are the best restoration practices for Kenai spruce forests that have been decimated by spruce beetle outbreaks. Potential climate change impacts to fish populations could be significant problems. Coordinating research and management for these resources will be important to meet future needs and demands.

The more applied questions and information needs may be addressed not only by formal "research" projects, but also by adaptive management incorporated into management programs. Monitoring provides information critical to both management and research. Good communication between researchers and managers can help ensure that monitoring is set up in ways that provide for the needs of both types of use.

Risk Assessment

Climate change has the potential for producing widespread and far-reaching impacts on ecological and human systems. It will not be possible to apply adaptations and respond to all of the expected changes. Funding and resources will need to be focused on those impacts that affect the resources of greatest concern. A risk assessment would identify all ecosystem services provided from forest ecosystems, identify the expected impacts to these services, and prioritize the most important services in relation to their anticipated impacts. For example, salmon are a resource of extremely high value in southern Alaska, both ecologically and for human communities. Impacts to salmon populations are expected but uncertain at this time, but even small changes could have significant consequences. It is likely that salmon would be a resource of high-priority for specific climate change adaptive actions. However, until a full risk assessment is conducted, the relative importance of all ecosystem services with likely impacts remains hazy. Risk assessment is a component of adaptation identified in the USFS Framework.

Adaptation

Impacts from climate change will be varied and diverse. Other than minimizing the agency's carbon footprint and encouraging others to do the same, the ability to curb the effects of climate change on most resources is limited. Direct effects of rising temperatures, changing precipitation patterns and the like will produce numerous changes to the resources and ecosystem services associated with FS management. The question then is what can be done to minimize the impacts of these changes, and to adapt to the changes as they occur. This is the adaptation goal of the Framework.

The FS should plan adaptations for those projected impacts that have a high certainty of happening, and that the FS can specifically address. On-going research and planning to address shifting distributions of yellow-cedar is a good example. Potential shifts in distributions of forests and additional changes to species compositions should be anticipated and incorporated into forest management. Potential changes to forest productivity should be evaluated, and adjustments to forest plans anticipated. Addressing increasing risks of fire in the Kenai Peninsula is another good example of on-going actions in response to climate change impacts. Anticipatory planning for possible fires in the Southeast Landscape would seem prudent. Actions such as increasing efforts to keep new invasive species from being introduced into southern Alaska landscapes can help deter some detrimental changes that climate change could acerbate. Establishing weed strategies to aggressively respond to invasive species that are introduced is an important related action.

Anticipatory actions should be developed in response to the risk assessment. Possible impacts of climate change should be anticipated, and their effects on ecosystem services and human needs identified. These impacts should be prioritized for their potential harm as well as for the ability of the FS and other agencies to take responsive actions. Monitoring should be designed to assess the status of these potential changes. For high priority impacts, trigger points should be identified so that adaptive actions are implemented as soon as possible once the likelihood of the impact is indicated from the monitoring, so that responses are initiated prior to the impacts reaching a crisis stage.

Partnerships

The Framework for Climate Change identifies alliances as a key goal. Landscape conservation strategies for climate change rely on this as a key component, recognizing that climate change influences entire landscapes and addressing impacts will require cross-boundary collaboration. Numerous cooperative efforts are on-going in the Alaska Region and its two NFs. Climate change will require even more cooperation and collaborative efforts in the future. Participation on such initiatives as the Executive Roundtable is essential for inter-agency collaboration. But equally important will be alliances at the local level, such as with partners like the Copper River Watershed Partnership and the Kenai Borough Spruce Beetle Task Force. A key partner in many areas will be tribal entities. A climate change strategy needs to recognize, endorse, and encourage such relationships, and identify actions to expand such opportunities. Table 1 identifies strategic plan action steps and potential partners, where appropriate, as well as the applicable landscape and USFS framework goal addressed by the action.

Table 1. Strategic plan action steps and potential partners included in the report on climate change submitted to the Chief.

Strategy	*Action*	*Landscape*	*Potential Partnership*[a]	*USFS Framework Goal (1-7)*[b]
Educate	Maintain and expand website information on climate change	Both	1	6
Educate	Expand climate change education (e.g., Portage Valley Learning Center, Chugach Children's Forest, Prince William Sound Science Center, Forest Ranger Academy, Alaska Coastal Rainforest Center)	Both	1,2,3,9,13,14, 15,16,17,18,19 20,21,22,25	6
Educate	Develop in-house training programs for staff	Both	1	6
Demonstrate	Continue to evaluate energy use in buildings and vehicles for shift to alternative fuels where feasible	Both		5, 6
Demonstrate	Evaluate current carbon sequestration and identify and publicize ways to increase sequestration	Both	1	1,2,3,5,6
Set Policies	Ensure forest plans address climate change	Both	1	2,3,4,7
Set Policies	Evaluate Tongass Conservation Strategy including species viability and effectiveness considering climate change and archipelago effects.	Southeast	1,2,6,13	2,3,4,7
Set Policies	Develop and implement this integrated landscape conservation strategy for climate change	Both	All	4
Set Policies	Develop policies and guidelines integrated into programs and operations that address climate change	Both		4
Model	Model predicted changes and ecological effects of climate change	Both	1,2,3,9,12,13, 19	1,2
Monitor	Incorporate climate change into on-going programs, i.e., Wolverine Glacier Research Natural Area, photographic monitoring project	Southcentral		1,2,7
Monitor	Monitor key coastal wetlands (Yakutat Forelands, Stikine River Flats, Copper River Delta) including bird, fish, and shellfish status	Both	1,2,13,18, 19,22	1,2,7
Monitor	Select key metrics and areas for monitoring that are indicators of climate change	Both	1,2,4,13,14,19, 20,21,22	1,2
Monitor	Monitor insect outbreaks and invasive species	Both	1,2,10,13,14, 19	1,2,7
Monitor	Continue and expand FIA analyses to address climate change effects	Both		1,2,7

Strategy	Action	Landscape	Potential Partnership[a]	USFS Framework Goal (1-7)[b]
Research	Monitor Copper River model watershed and establish research priorities for investigating climate change impacts (PNW)	Southcentral	1,2,9,13,20,22	1,2,7
Research	Establish model watershed for Maybeso River	Southeast	1	1,2,7
Research	Establish research and monitoring programs for Héen Latinee Experimental Forest focusing on effects of climate change (PNW)	Southeast	1	1,2,7
Research	Establish research and education projects for the Alaska Coastal Rainforest Center focusing on climate change concerns (PNW)	Southeast	9,19,25	1,2,7
Risk assessment	Identify at risk ecosystem services that can be mitigated with management actions	Both	1,2,13,14	1,2,3
Mitigate	Adjust Kenai forest management for insects/fire risks	Southcentral	14	2,3
Mitigate	Adjust timber harvest plans and schedules considering potential changes to productivity	Southeast		2,3
Mitigate	Develop management plans for yellow cedar forests	Southeast	1	2,3
Mitigate	Restore past disturbed streams to improve their functions	Both	2,13,20,21	2,3,
Mitigate	Work with appropriate partners to adjust fish/shellfish and wildlife harvests	Both	13,24	2,3
Partner	Identify key research questions related to climate change through on-going and new research projects (PNW)	Both	All	1,7
Partner	Actively participate in regional climate change initiatives	Both	All	7
Partner	Collaborate with tribal entities about mutual responses to climate change	Both	6,7,8,22,23,24	7

[a] Partnership opportunities: 1 PNW Research Station, 2 USGS, 3 NOAA, 4 U.S. Coast Guard, 5 Sealaska Corp., 6 Cook Inlet Inc., 7 Chugach Alaska Corp., 8 Ahtna Corp., 9 USFWS, 10 USNPS, 11 BLM, 12 DOD, 13 Alaska Fish and Game, 14 Alaska Dept. of Natural Resources Forestry Div., 15 Alaska Geographic, 16 The Nature Conservancy, 17 The Wilderness Society, 18 Alaska Pacific Coast Joint Venture, 19 University of Alaska, 20 Copper River Watershed Project, 21 Prince William Sound Regional Citizens' Advisory Group, 22 Other Tribal Entities, 23 Bureau of Indian Affairs, 24 Federal Subsistence Board, 25 City and Borough of Juneau.

[b] USFS Framework goal: 1- Science, 2- adaptation, 3- mitigation, 4- setting policy, 5-sustainable operations, 6-education, 7- alliances.

State and Private Forestry Climate Change Strategic Plan

The State and Private Forestry Program (SPF) has responsibilities to provide information and technical assistance to private forestlands throughout the state. The three primary focus areas of State and Private Forestry include Cooperative Forestry, Fire Management, and Forest Health Protection. Climate change will impact all three of these programs, but has particular significance for changes to fire regimes, pest outbreaks, and invasive species. The SPF has recognized the importance of climate change, and has incorporated it into its 2008-2012 strategic plan for Forest Health. Included as one of its three identified goals, management for climate change should "proactively apply interpretations of observed and predicted forest ecosystem changes in Alaska toward effective and adaptive strategies" (http://www.fs.fed.us/r10/spf/fhp/pubs/R10%20FHP%20Strategic%20Plan%20v2.1.pdf). Appendix B presents a simplified version of this proactive strategy.

Changes to fire regimes in southern landscapes discussed above have certainly been a focus of State and Private Forestry. In addition, even more potentially significant changes to fire regimes are expected in many of the central forests of Alaska. SFP is providing technical assistance to address these new challenges. A good example is the All Lands/All Hands program in the Kenai Peninsula that involves numerous partners including the Chugach NF and SPF. In this landscape, Community Wildfire Protection Plans have been developed for most communities, and are at least on-going for all communities at moderate, high, or extreme risks. These plans identify fuel mitigation strategies that need to be implemented to reduce risks to lives and properties, risks that are projected to increase with effects of climate change.

Climate change, as discussed above, has substantial potential for aiding expansions of invasive species. SPF is engaged in numerous efforts to control invasive species, and has established partnerships with a wide array of local, state, and federal partners to address this threat. Various strategies for weed control have been developed at different levels, some targeted at keeping invasive species from entering the state (a focus of the Alaska Pest Advisory Group) and others directed at specific landscapes (i.e., Lamb and Shephard 2007). Resources and partnerships to effectively implement effective strategies for control of invasive species will be needed to address this potential threat to the integrity of forest ecosystems throughout Alaska, especially as climate change increases this challenge.

SPF has also initiated a repeat photograph project (http://www.fs.fed.us/r10/spf/fhp/repeat_photo_se/index.php) designed to show changes that have occurred in response to various changes or disturbances, including climate change. This photo record is a valuable archive that dramatically displays change. If a picture is worth a thousand words, then this project represents thousands of words about changes to many sites.

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9.0 APPENDIX A

Climate Predictions for southcentral and southeast Alaska – Figures A1 to A10

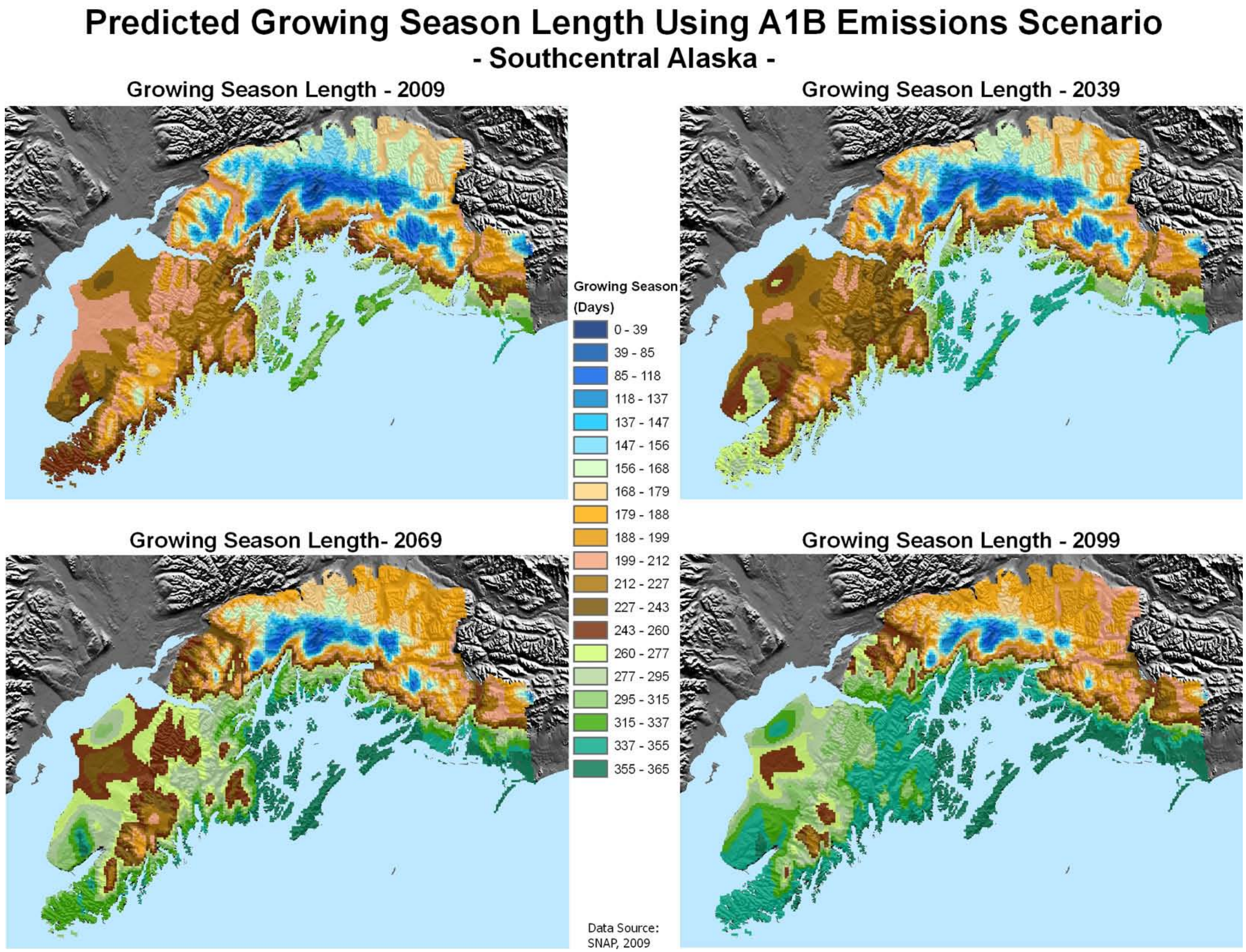

Figure A-1. Predicted growing season length in the Southcentral Landscape.

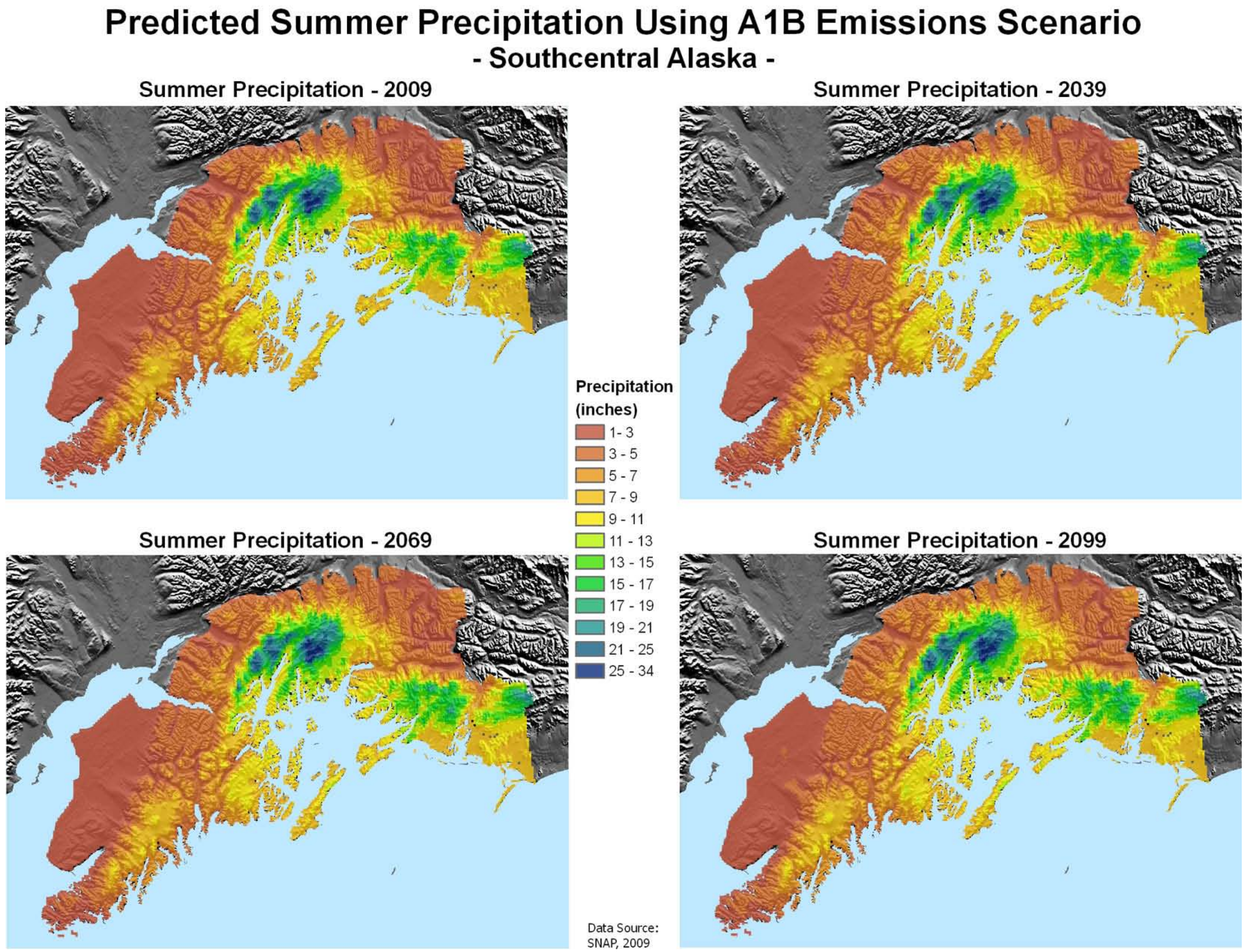

Figure A-2. Predicted summer precipitation in the Southcentral Landscape.

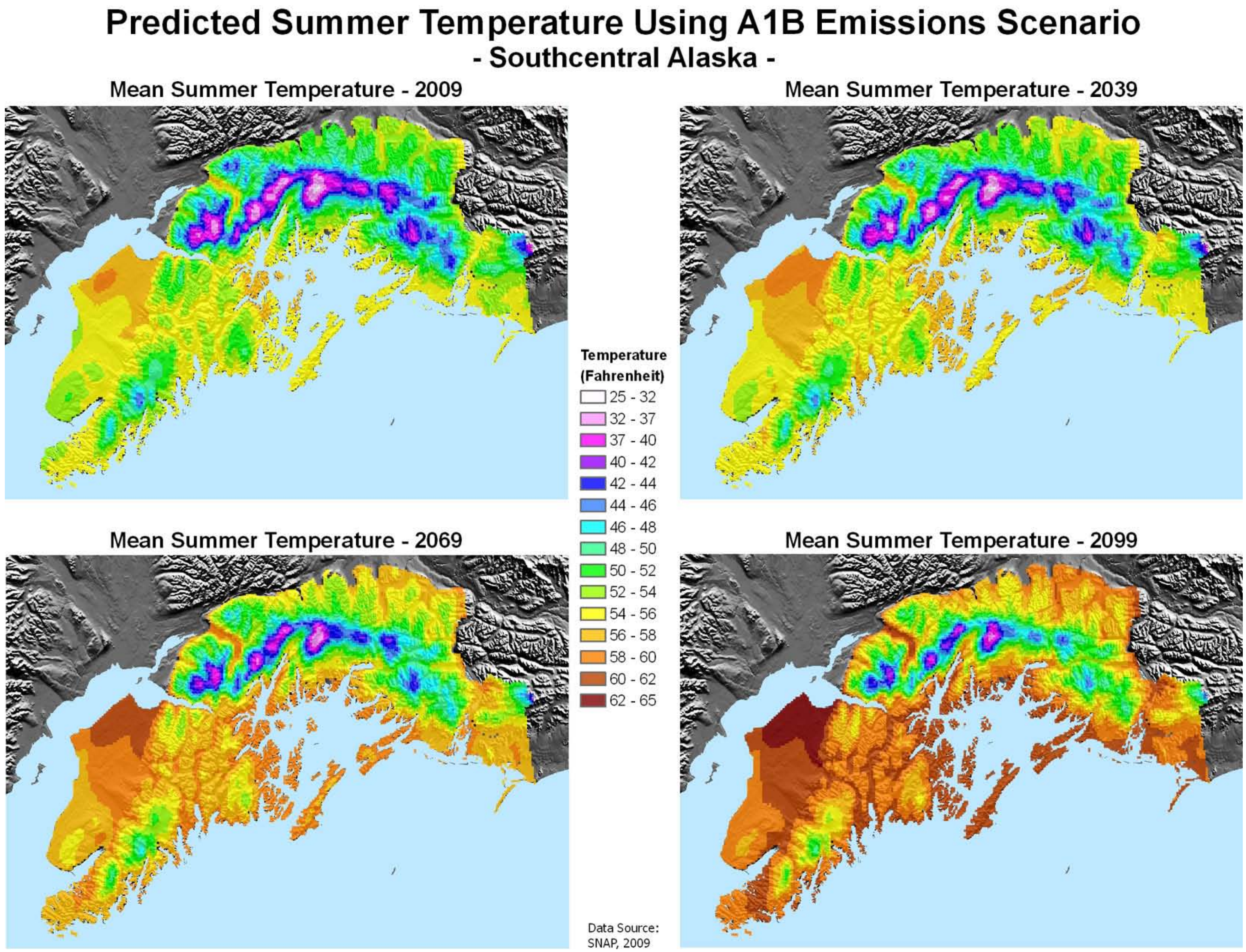

Figure A-3. Predicted summer temperature in the Southcentral Landscape.

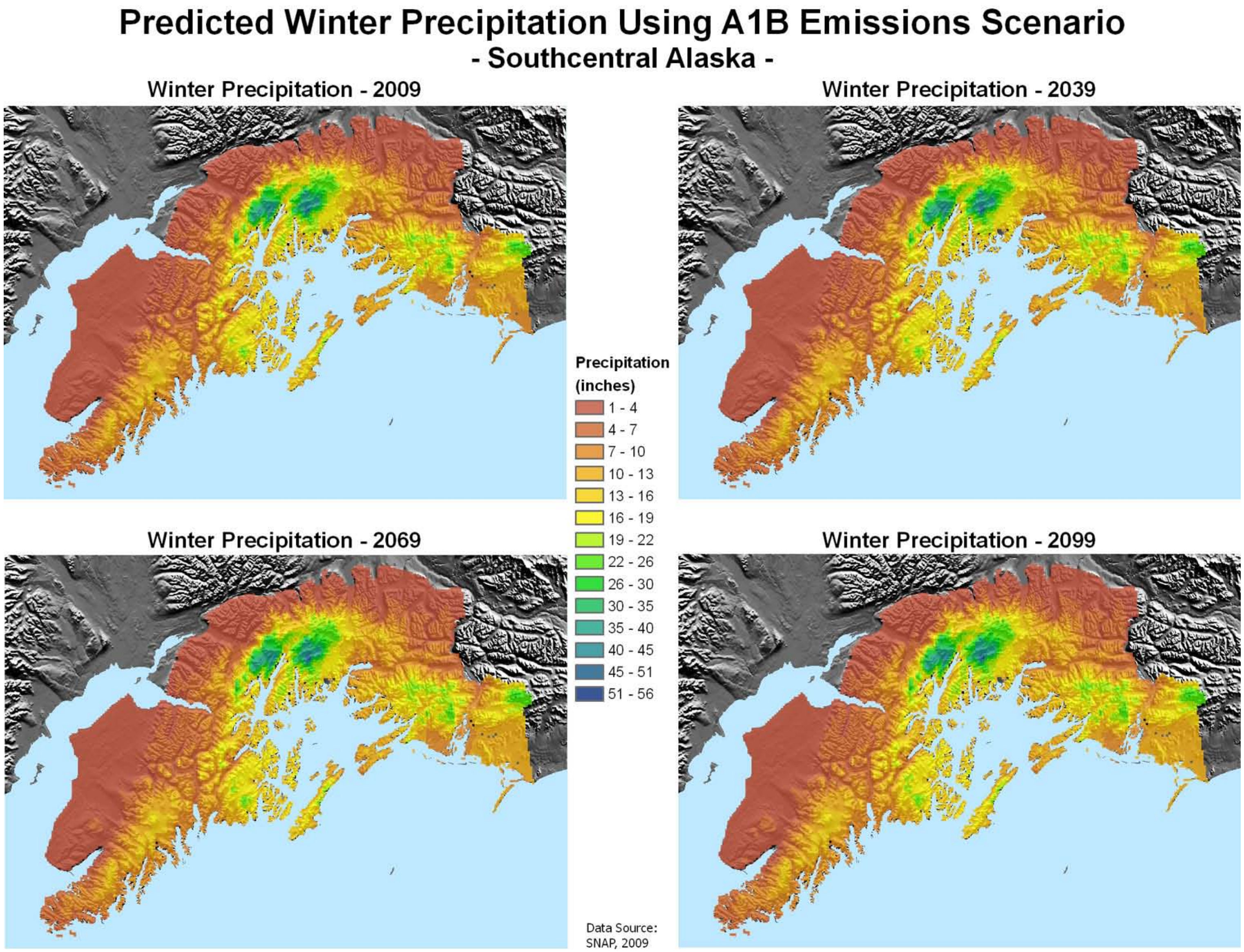

Figure A-4. Predicted winter precipitation in the Southcentral Landscape.

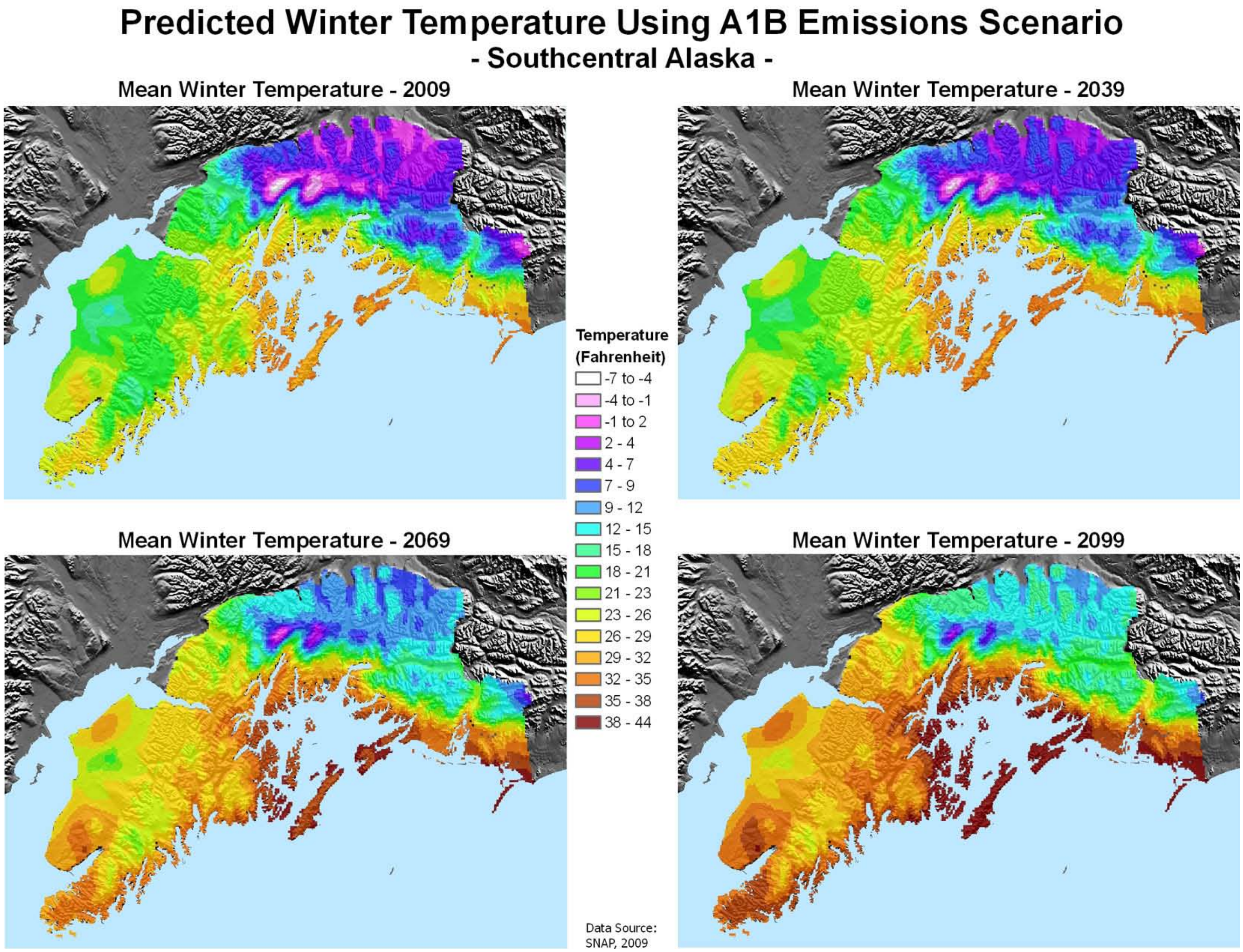

Figure A-5. Predicted winter temperature in the Southcentral Landscape.

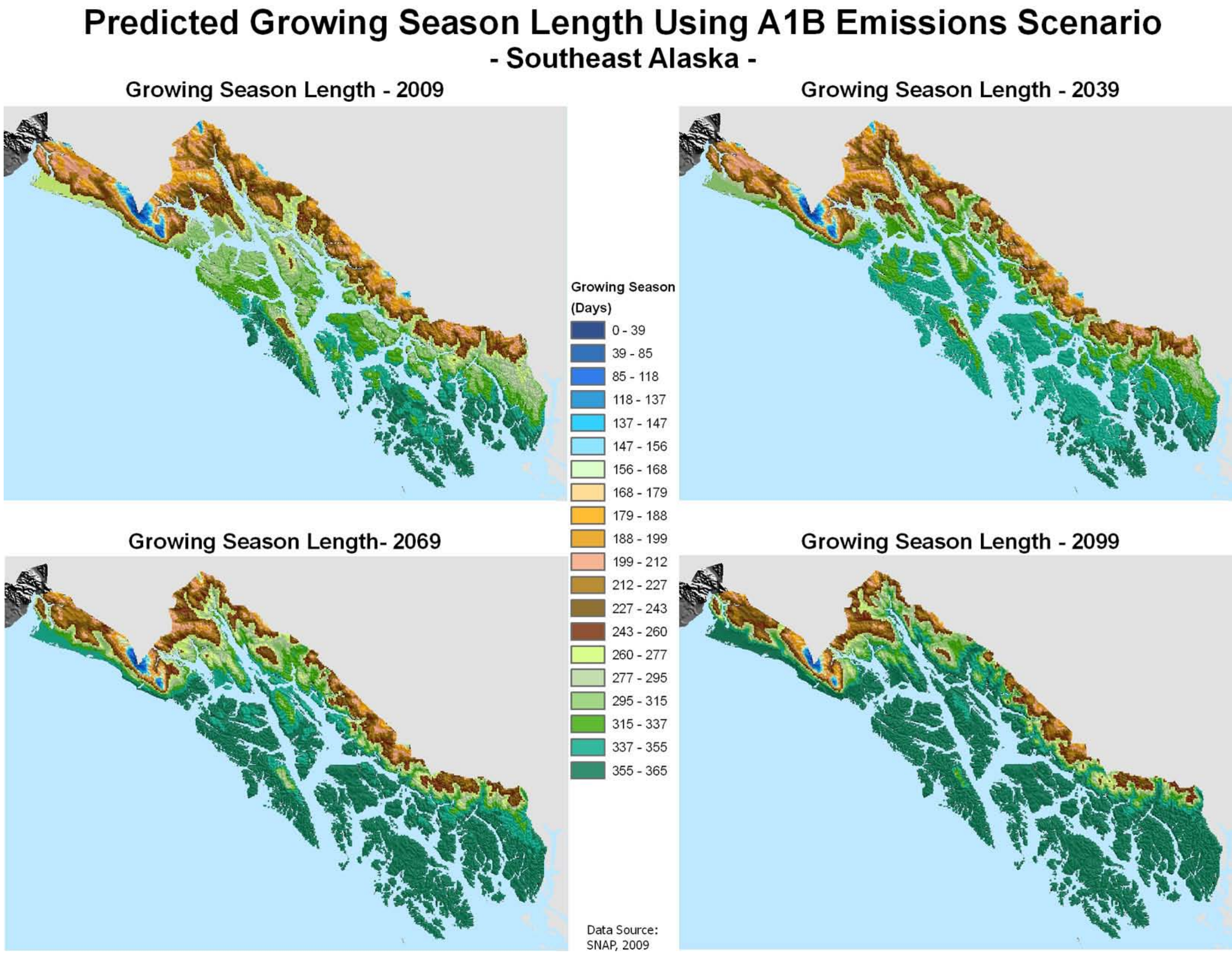

Figure A-6. Predicted growing season in the Southeast Landscape.

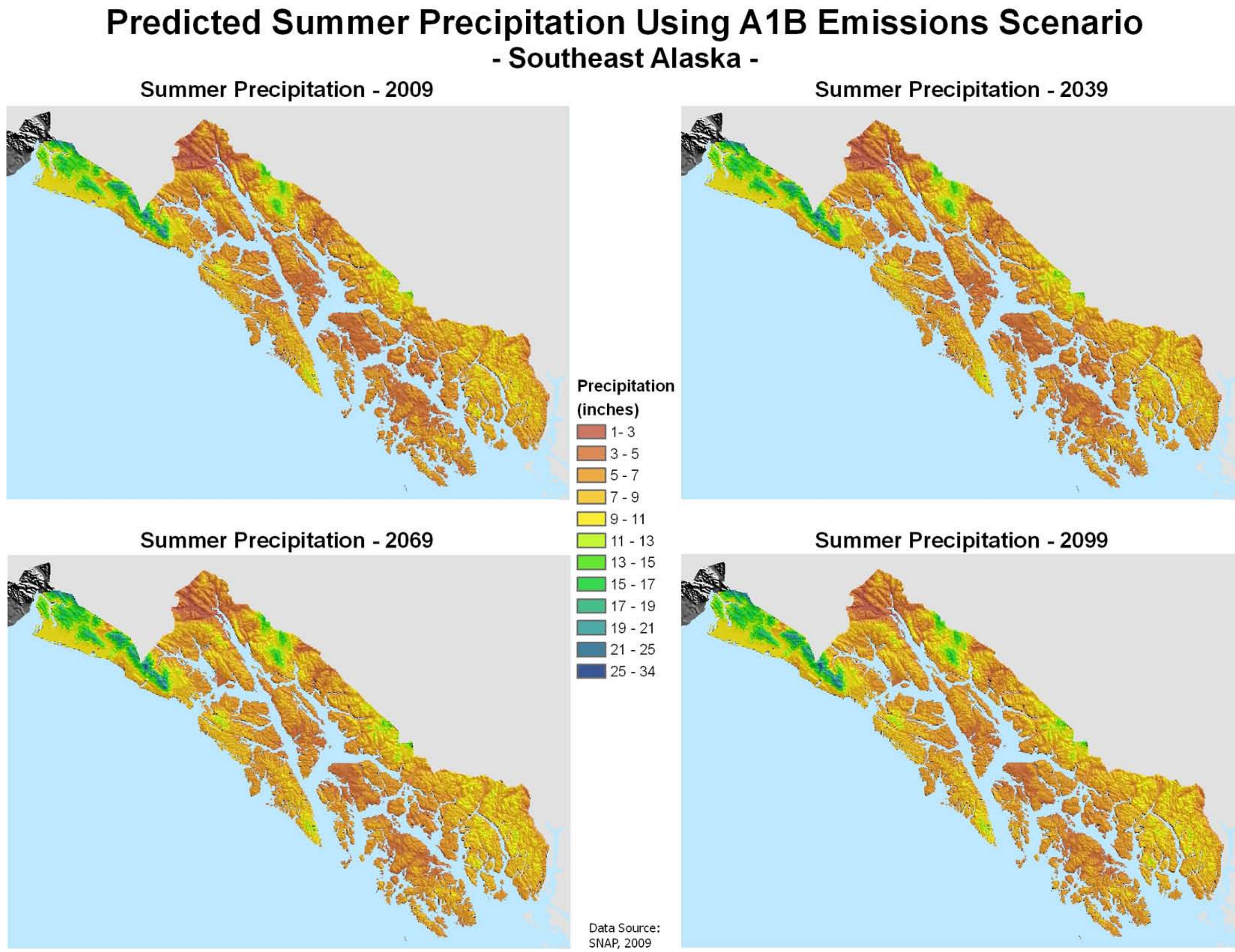

Figure A-7. Predicted summer precipitation in the Southeast Landscape.

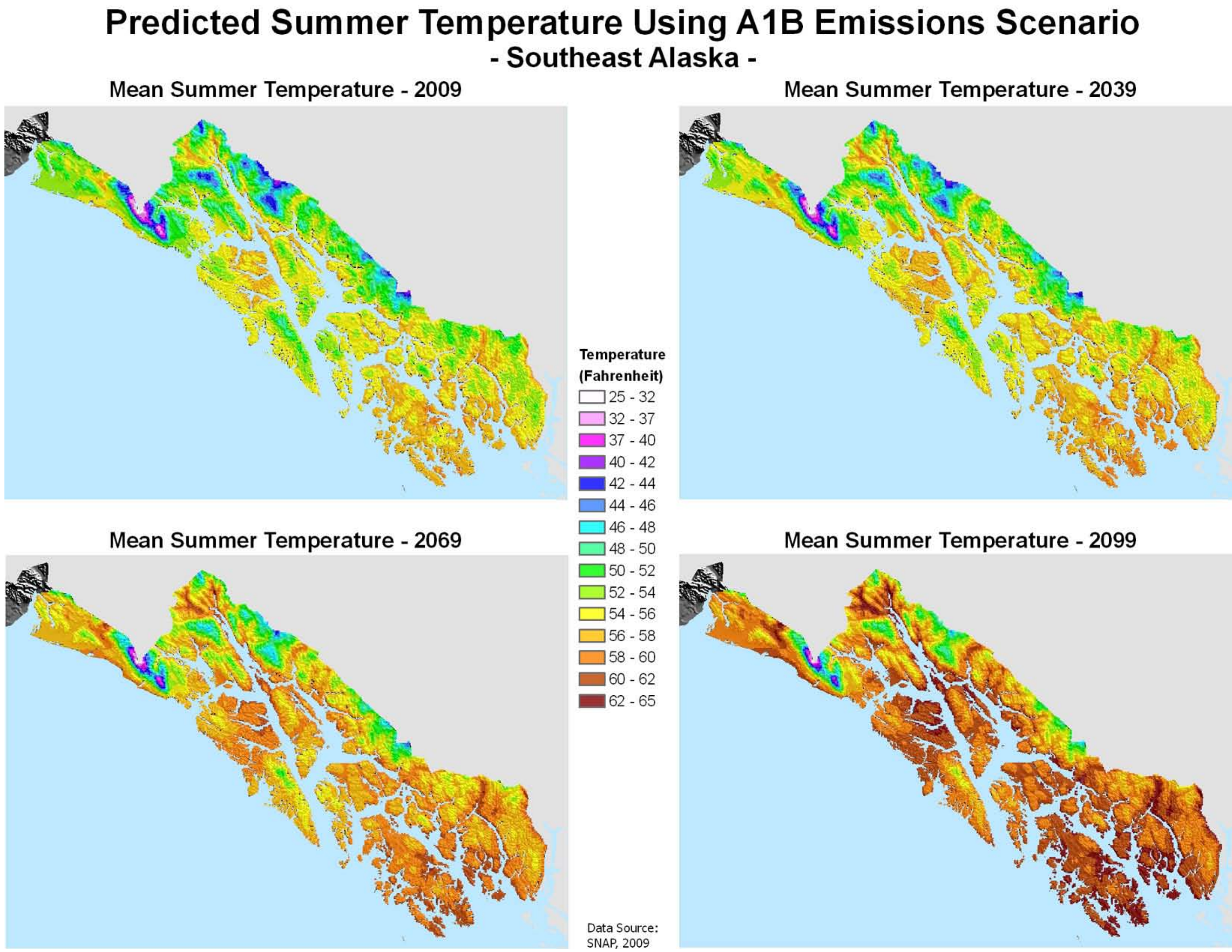

Figure A-8. Predicted summer temperature in the Southeast Landscape.

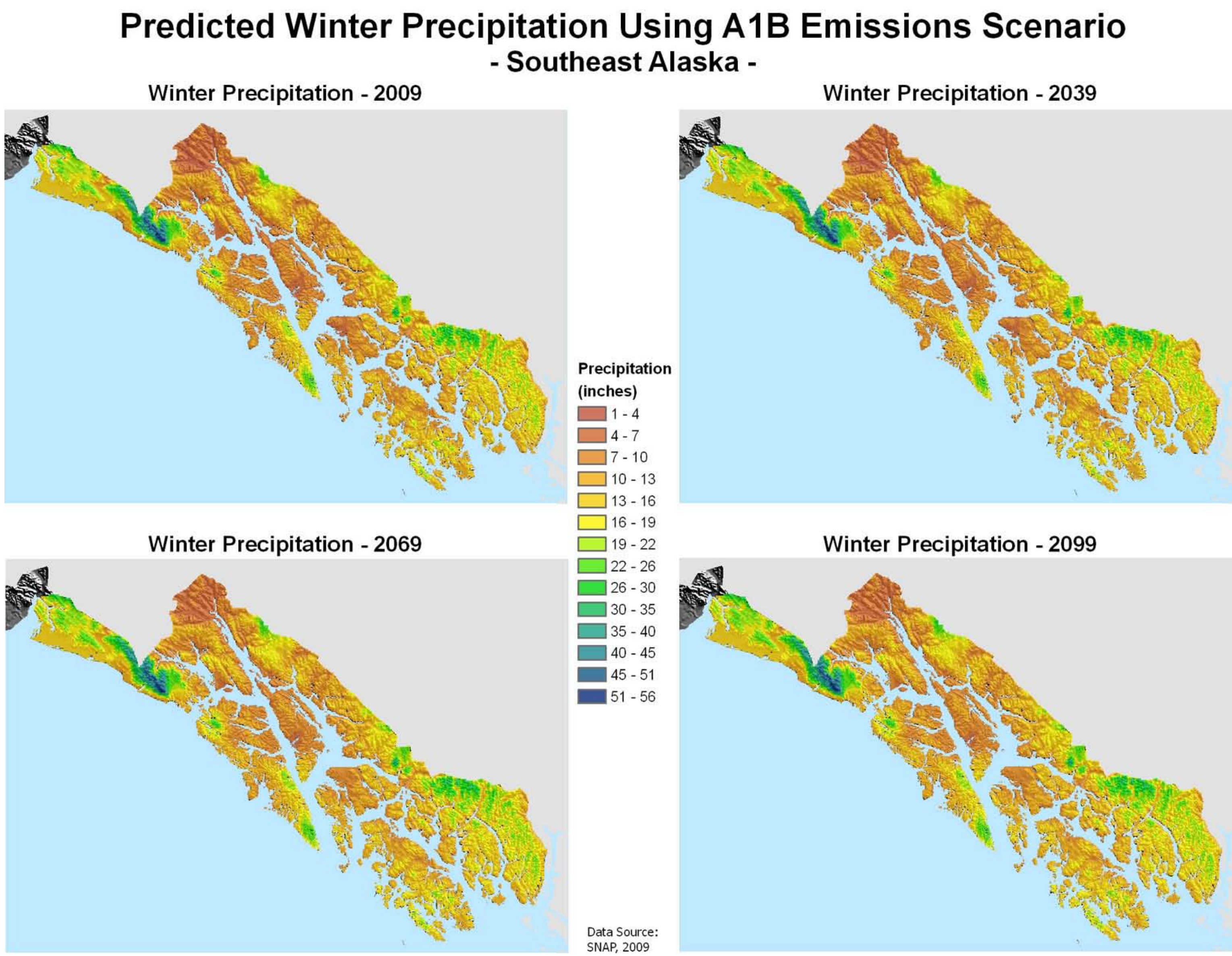

Figure A-9. Predicted winter precipitation in the Southeast Landscape.

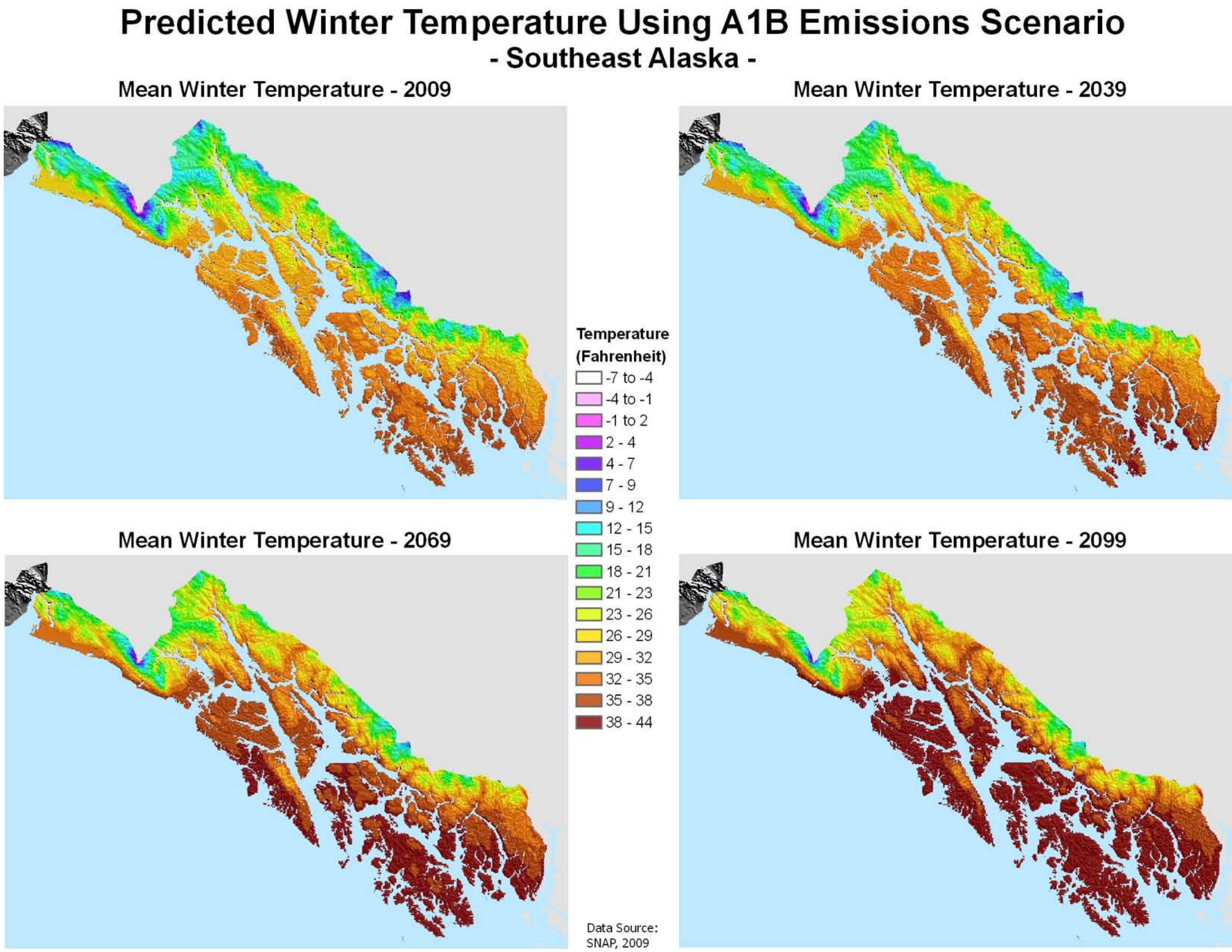

Figure A-10. Predicted winter temperature in the Southeast Landscape.

10.0 APPENDIX B

Condensed State and Private Forestry Program Strategic Plan, Climate Change Section

OBJECTIVE A: Redefine and communicate "forest health" in the context of climate change. Raise awareness about a new paradigm of desired forest condition.

- **A1. ACTION**: Compile an annotated list of experts currently working on climate-forest issues in Alaska, and a list of relevant literature.
- **A2. ACTION**: Prepare R10 briefing paper on our state-of-the-art knowledge of the effects of climate change on forest health in Alaska.
- **A3. ACTION** Conduct RLT briefing to familiarize R10 leadership with new concepts on forest management in a warming climate.

OBJECTIVE B: Monitor and describe current and near-term responses of forest insect, disease, and decline to climate change in Alaska.

- **B1. ACTION**: a) Summarize current forest health issues related to climate change in Alaska; where appropriate, use case studies (spruce beetle, cedar decline, spruce aphid). Prepare a summary document that describes the history of insect outbreaks in Alaska and define historical baseline conditions for forest insect pests in Alaska, and the "normal" fluctuations in insect occurrence that are associated this baseline. Include analysis of weather on outbreaks. Fold this information into the briefing paper above (A2) and ultimate publication in Journal of Forestry and/or comparable publication. b) Develop a separate page on the FHP website
- **B2. ACTION**: Determine influence of weather parameters on defoliator populations. Relate this to historic data from aerial survey ground population sampling (larval counts) and acres detected aerially.
- **B3. ACTION**: Establish and annually monitor latitudinal transect from (Homer to Barrow) to determine influence of climate variation on forest insect populations. Expand to include pathogens and invasive plants as appropriate.
- **B4. ACTION**: Determine impact and plant succession trends (vigor and growth of tree species) in cedar decline-impacted forests. Note: This is a 2-3 yr project with mainly field efforts, including new plots. Might be able to use PTIPS funding for the new plots. A smaller FIA effort would use FIA plots with cedar decline to evaluate the live residual tree species.
- **B5. ACTION:** Develop tools, methods and metrics (e.g., spatial analysis tools using remote sensing and spatial modeling) that can be used to monitor landscape scale patterns and distributional trends of forest insect pests in time.
- **B6. ACTION**: Determine what needs to be shown in order to prove the role of climate change in the etiology of forest health events; e.g., long-term correlations, spatial synchrony, etc.

OBJECTIVE C: Predict longer-term effects of climate change on forests (forest tree range shifts, altered forest cover, forest declines, insect and disease outbreaks, and carbon cycling).

- **C1. ACTION** Advocate and participate in modeling to predict forest type and tree species range shifts due to climate change. Engage insect and disease information into these predicted shifts.
- **C2. ACTION**: Use knowledge of current insect and diseases in Alaska to predict which species or groups of species (guilds, e.g., bark beetles, foliar fungi, etc.) will be favored by projected changes in climate. Add to the website above and annual conditions report "on-focus".

C3. ACTION: Explore availability and support developmental efforts of key GIS data needed for the revision of the 2010 risk map/hazard rating systems allowing integration of climate change and host species variables. Evaluate current and future responses of insects, diseases, declines, and invasive plants.

A) acquire and become versed in available PRISM climate data for Alaska

B) use climate inputs build host models based on climate preferences

C) collaborate and aid existing host mapping efforts by TNC, Landfire, FHTET, and Heritage Group.

C4. ACTION Participate in projects on carbon cycling in forests related to insect, disease, and wood decay fungi

OBJECTIVE D: develop specific management and mitigation strategies to sustain forest health in the context of climate change-induced problems.

D1. ACTION: Use climate models, snow projections, new cedar distribution maps, and predictions of yellow-cedar decline spread to identify parts of the landscape in southeast and southcentral Alaska where yellow-cedar will be adapted and can be favored by passive and active management for the next 100 years.

D2. ACTION Work with forest managers to plant and thin young-growth yellow-cedar to gain experience in yellow-cedar silvics and management to maintain yellow-cedar populations in Alaska.