PROJECTED

CLIMATE CHANGE SCENARIOS for the

BUREAU OF LAND MANAGEMENT

EASTERN INTERIOR MANAGEMENT AREA,

ALASKA, 2001 – 2099

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EXECUTIVE SUMMARY

This report was commissioned by the Bureau of Land Management (BLM) to identify vegetation and fire regime response to projected future climate changes in Interior Alaska. The BLM requires climate change projections to develop more informed long-term management guidelines and decisions for resource management plans and permitting activities. Information presented in this report was widely used in the development of a Resource Management Plan and associated Environmental Impact Statement for the BLM Eastern Interior Management Area (Fig. 1).

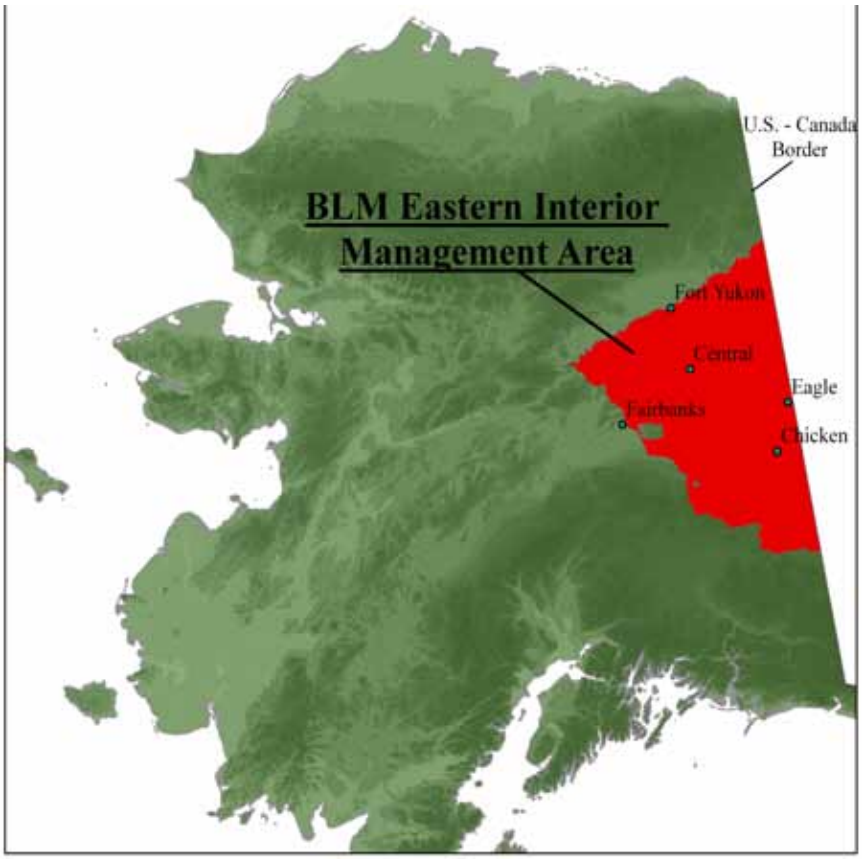

Figure 1 – Location of the BLM Eastern Interior Management Area within the state of Alaska.

Eastern Interior Alaska is projected to become warmer and drier over the next century. Warmer temperatures and a longer growing season are expected to increase evapotranspiration enough to outweigh a regional increase in precipitation. Seasonal changes in climate will have profound impacts on the condition and health of wildlife habitat, lead to increased fire risk[1], and contribute to the likelihood of wetlands, streams, and lakes drying[2].

[1] Statewide data available in the SNAP publication *Preliminary Statewide Report.* (www.snap.uaf.edu/downloads/reports-boreal-alfresco)
[2] Statewide data available for projections of water availability in the SNAP publication *Climate Change Impacts on Water Availability in Alaska*. (www.snap.uaf.edu/downloads/reports-boreal-alfresco)

In order to understand what these changes may be like, data from a composite of five down-scaled global circulation models[3] was used to estimate decadal averages of future temperature and precipitation values and associated effects on water availability, changes in vegetation, and wildfire frequency within Interior Alaska. These models are based on the A1B emissions scenario[4], and assume a steady increase in carbon dioxide (CO2) emissions from fossil fuel combustion over the first several decades of the 21st century, followed by a gradual decline in emissions as several kinds of low-emission energy alternatives become more prevalent. The A1B emissions regime is considered a "moderate" estimate. Several other scenarios have predicted higher emission rates, and scientists have since determined current levels[5] are significantly greater than even the most extreme concentrations analyzed by the Intergovernmental Panel on Climate Change[6], rising by 3.5% per year[7]. Higher emissions rates will likely accelerate changes in climate and lead to more severe ecosystem impacts. The down-scaled global circulation models used in this study do not explicitly account for future climate effects of teleconnections, such as the Pacific Decadal Oscillation (PDO) and the El Niño-Southern Oscillation (ENSO), which may have considerable impact on future Interior Alaska climate.

The BLM Eastern Interior Resource Management Planning Area is within a region of Alaska expected to see some of the greatest changes over the next 30-40 years and out to 2099. These changes include rising temperatures, decreased water availability, and increased fire activity resulting in greater deciduous dominance on the landscape. We present the data in three time steps. A 1961-1990 historical 30-year average is used as a baseline, and two future projected decadal averages are presented (2040-2049 and 2090-2099). Average annual temperatures are expected to rise above the freezing point by 2099 (an increase of ~9°F from 1961-1990 historical averages), which could have implications for soil stability if any existing permafrost begins to thaw. It may also amplify and/or alter the effects of increasing dryness as water loss to the atmosphere increases over the century. Average annual precipitation is expected to increase by 30% by 2099, but it will not be enough to offset increases in potential evapotranspiration in the Eastern Interior, especially in the last half of this century.

In spite of the shift in vegetation towards less flammable age classes and towards deciduous species, the simulation results indicate that there will be more frequent fires burning; resulting in an overall increase in area burned annually. The central portion of the Eastern Interior has the highest probability of burning, especially in the next 20-30 years, leading to potentially better moose habitat in that area based on stand age.

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[3] The models used to form the composite are Echam5, Gfdl2.1, Miroc3.2MR, HadCM3, and CGCM3.1 from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment, published in 2007.
[4] Nakicenovic, N., et al., *Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change*, Cambridge Univ. Press, New York, 2000.
[5] Recent rates of global CO2 emissions can be found on the Carbon Dioxide Information Analysis Center website (cdiac.esd.ornl.gov).
[6] Solomon, S., et al., *Climate Change 2007: The Physical Science Basis*, Cambridge Univ. Press, New York, 2007
[7] *Climate Change Science Compendium 2009*, United Nations Environment Programme, 2009.

PROJECTED TEMPERATURE

Temperatures changes in Eastern Interior Alaska are projected to increase over the coming decades at an average rate of about 1°F per decade from the 1961-1990 historic 30-year average (Table 1). Average annual temperature is expected to rise by about 6.4°F by 2049 and as much as 9.4°F by 2099. Considering the natural variation in temperatures across the study area, this is likely to result in a transition from average annual temperatures well below the freezing point (~24°F), to temperatures near or above the freezing point (~33°F, Fig. 2). A likely outcome of these changes is a lengthening of the growing season (May – Sep.), a change that could have profound effects on wildlife mating cycles, plant growth and flowering, water availability in soil and rivers, and hunting and fishing. Winter (Nov. – Mar.) temperatures are projected to change the most dramatically. Mean winter temperatures could reach a high of more than 13°F by 2099, a figure that represents an impressive 15°F rise from the 1961-1990 historical 6°F average. Average growing season temperatures are projected to rise by about 5.8°F by 2099 (from ~50°F to ~56°F). Some species may benefit from these changes, while others may not be able to adapt or find suitable habitat conditions to sustain their populations.

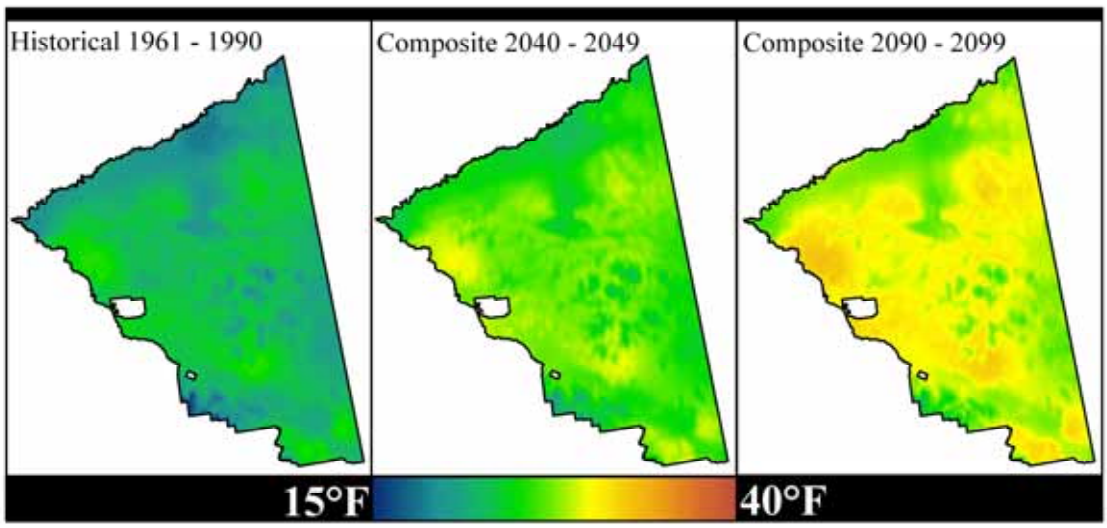

Figure 2 – Mean annual temperature (°F) for a historic 30-year average and two future projected decades.

SEASON	TIME	Avg. TEMP (°F)	Δ TEMP (°F)
Annual	Historical	24.4	*NA*
	2040-2049	30.8	6.4
	2090-2099	33.8	9.4
Growing Season	Historical	50.1	*NA*
	2040-2049	52.6	2.5
	2090-2099	55.9	5.8
Winter	Historical	-1.1	*NA*
	2040-2049	8.5	9.6
	2090-2099	13.6	14.7

Table 1 – Mean annual, growing season, and winter temperatures (°F) for three time periods and the change over time from the 30-year average Historical value.

PROJECTED PRECIPITATION

Annual precipitation is predicted to increase across the Eastern Interior study area by 0.5" per decade over this century (Fig. 3). Despite this area-wide increase, conditions are expected to become substantially drier in the growing season and fall and potentially icier in winter (Nov. – Mar.) due to temperature increases. Although growing season (May – Sep.) rainfall is expected to rise by 25% by 2099 (Table 2), this increase is unlikely to be enough to offset an increase in evapotranspiration caused by warmer temperatures and a longer growing season. Winter precipitation may also increase by as much as 50% and could fall in the form of snow, ice, or rain, depending on the temperature. Ultimately, the timing and intensity of precipitation will determine how these changes affect the landscape and hydrology of Interior Alaska.

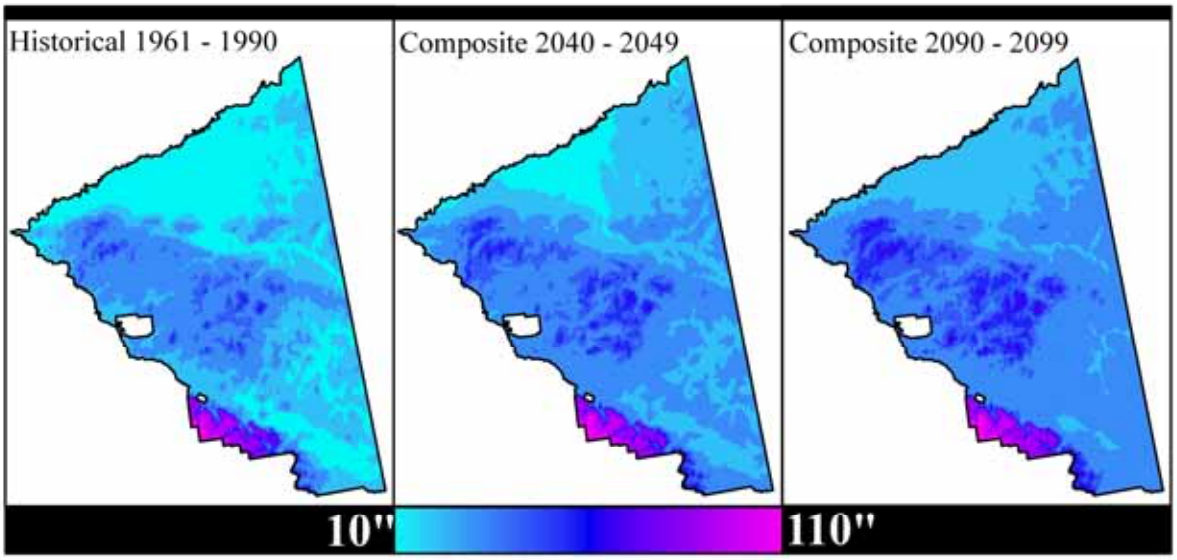

Figure 3 – Total annual precipitation (inches) for a historic 30-year average and two future projected decades.

SEASON	TIME	Avg. PRECIP (in)	Δ PRECIP (in)	% Δ PRECIP
Annual	Historical	16.0	*NA*	*NA*
	2040-2049	19.6	3.6	22.5
	2090-2099	21.1	5.1	31.9
Growing Season	Historical	10.3	*NA*	*NA*
	2040-2049	12.5	2.2	21.4
	2090-2099	12.9	2.6	25.2
Winter	Historical	3.7	*NA*	*NA*
	2040-2049	4.8	1.1	29.7
	2090-2099	5.6	1.9	51.3

Table 2 – Total annual, growing season and winter precipitation (inches) for three time periods and the change over time from the 30-year average Historical value.

WATER AVAILABILITY

In Alaska's northern climate, much of the precipitation that falls during winter months, accumulates in the snowpack and contributes to water storage across the landscape. Some of this wintertime storage is lost to cold, dry air through sublimation, but the majority remains until the spring snowmelt converts it to runoff that serves to recharge rivers, lakes, and soils. The greatest losses of water occur during the growing season, when temperatures rise above freezing and evaporation returns water from the landscape back into the atmosphere. Vegetation also depletes water storage as water vapor is lost through transpiration from growing plants.

Peak Growing Season Water Availability

The term potential evapotranspiration (PET) is used to describe the likely amount of water that could be returned to the atmosphere through the combination of evaporation and transpiration. In Alaska, PET during growing season months typically exceeds incoming precipitation, resulting in an overall water deficit (P – PET) during this time. Our analysis reveals that the typical water deficit in June, at the peak of the growing season, will become even greater in the future due to significant increases in PET without comparable increases in precipitation in the Eastern Interior Management Area (Fig. 4). Specifically, we see a June decrease of up to 0.7 inches by the 2040s (Table 3). By the end of the century, June water availability is expected to decrease as much as to 1.6 inches in the most extreme areas, with an average decrease of 0.2 inches in most places.

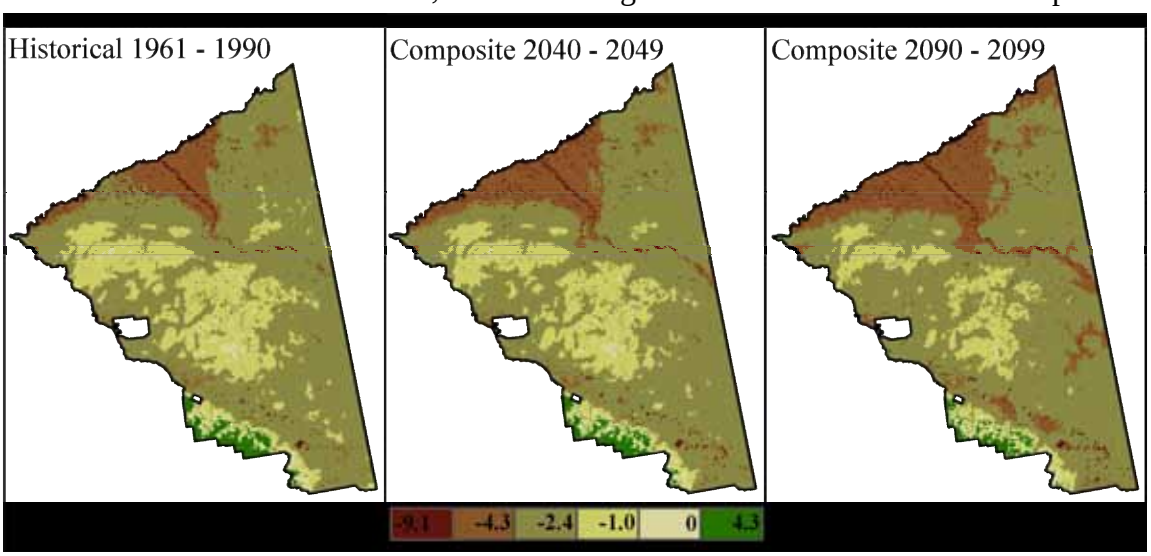

Figure 4 – Water deficits (P-PET, inches) for June, at three time steps.

	P-PET (in)	Δ P-PET (in)	% Δ P-PET
Historical	-2.9	*NA*	*NA*
2040-2049	-3.1	-0.2	-6.8%
2090-2099	-3.5	-0.4	-13.8%

Table 3 – Water deficit (inches) during the growing season for three time periods and the change over time from the 30-year average Historical value.

Evaporation and Seasonal Transitions

The most profound changes in water availability are likely to occur in areas where sub-freezing temperatures have historically limited PET, but where future warming to above freezing temperatures will result in greater water losses as PET becomes active. In most areas, these changes will occur in the spring and fall, as temperatures rise above freezing and the growing season lengthens.

As a result, many areas are projected to undergo a transition from being non-evaporative environments (PET=0) in April and October to areas that are experiencing some amount of evaporation (PET>0) in April and October in the future (Fig. 5). While the Eastern Interior Management Area has not historically experienced much evapotranspiration during April, this is predicted to change by mid-century. By the end of the century much of the Eastern Interior will have gone through this change in October, as well, although these increases in PET are not forecasted to be as large as those in April (Table 4).

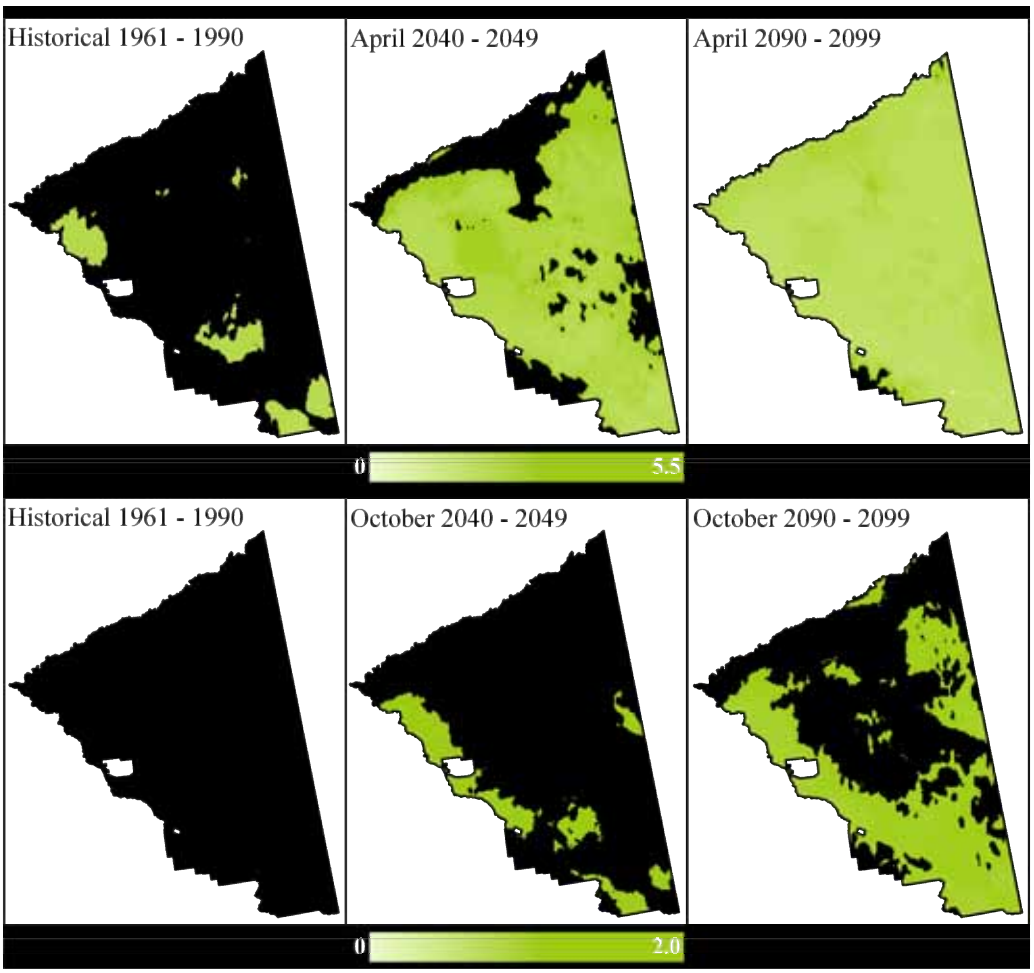

Figure 5– Historical and future estimates of PET (inches) during April and October. Changes from black (PET=0) to color represent the activation of PET in the future as the growing season becomes longer.

	Historical	2040-2049	2090-2099
April	8.8%	76.6%	99.1%
October	0.0%	11.5%	43.5%

Table 4 – Percent of Eastern Interior Management Area with active PET in April or October (out of 48,370 mi^2).

FIRE ACTIVITY

Preliminary results from the statewide simulations identify consistent trends in projected future fire activity and vegetation response. The simulation results show a general increase in fire activity through the end of this century in response to projected warming temperatures and less available moisture and suggest that boreal forest vegetation will change dramatically from the spruce dominated landscapes of the last century, to a more deciduous-dominated landscape.

The Eastern Interior domain lies in an area expected to be one of the greatest areas of change in the state and its simulation results produce the same consistent trends in projected future fire activity and vegetation response as do the state-wide simulations. Here we show different future time steps (2001-2050 and 2051-2099). This is so we can calculate fire return intervals over a greater period of time. Note that the end points of these time steps (2050 and 2099) coincide with the end points of the future time steps in previous sections (2049 and 2099). This is true for the following section on vegetation response, as well. Changes in the projected cumulative area burned suggest the next 30-40 years will experience the most rapid change in fire activity and the associated changes in vegetation dynamics (Table 5). The central portion of the simulation area showed the highest fire risk in the near future (Fig. 6).

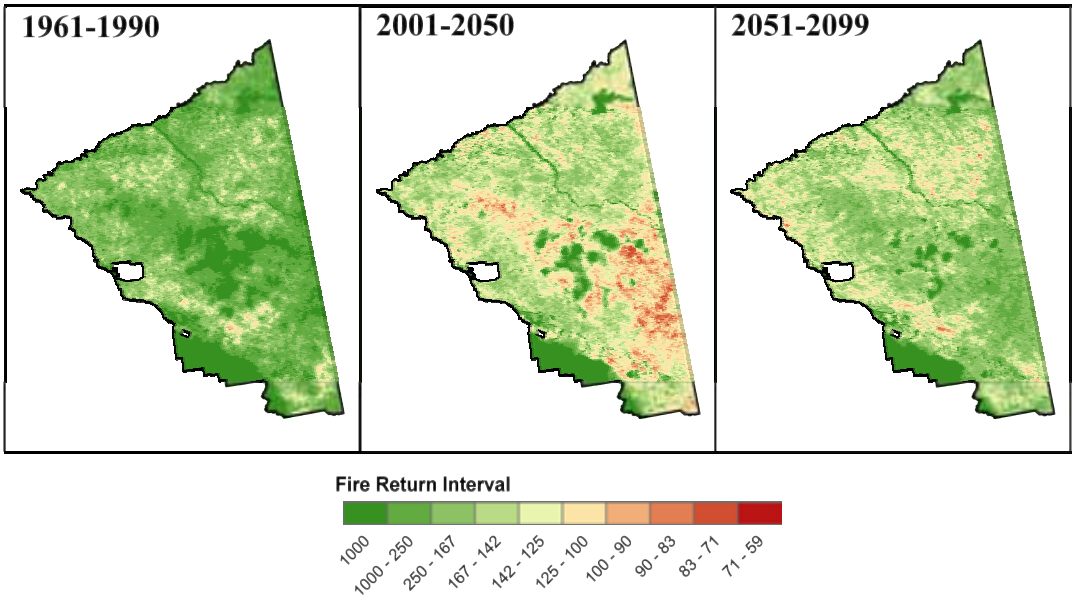

Figure 6 – Maps showing the probability of a cell burning during any one year for 3 different time frames.

	1990	2050	2099
Fire Return Interval (yrs)	250	100	100
50% Deciduous (mi^2)	10.7%	75.6%	76.0%

Table 5 – Simulated fire return interval (years) at three time steps, along with associated shifts towards deciduous vegetation. Deciduous values represent the percent of the total Eastern Interior Management Area (48,370 mi^2) that shows simulated deciduous vegetation more than 50% of the time, at each time step.

VEGETATION RESPONSE

In the wake of this fire activity, we predict that deciduous vegetation will become increasingly dominant on the landscape (Table 5). The large regions of mature unburned spruce existing today will likely be replaced by a more patchy distribution of deciduous forests and younger stages of spruce (Fig. 7). The simulation results suggest that this change may reach an equilibrium stage where the patch dynamics may self-perpetuate for many decades if not centuries (Fig. 8).

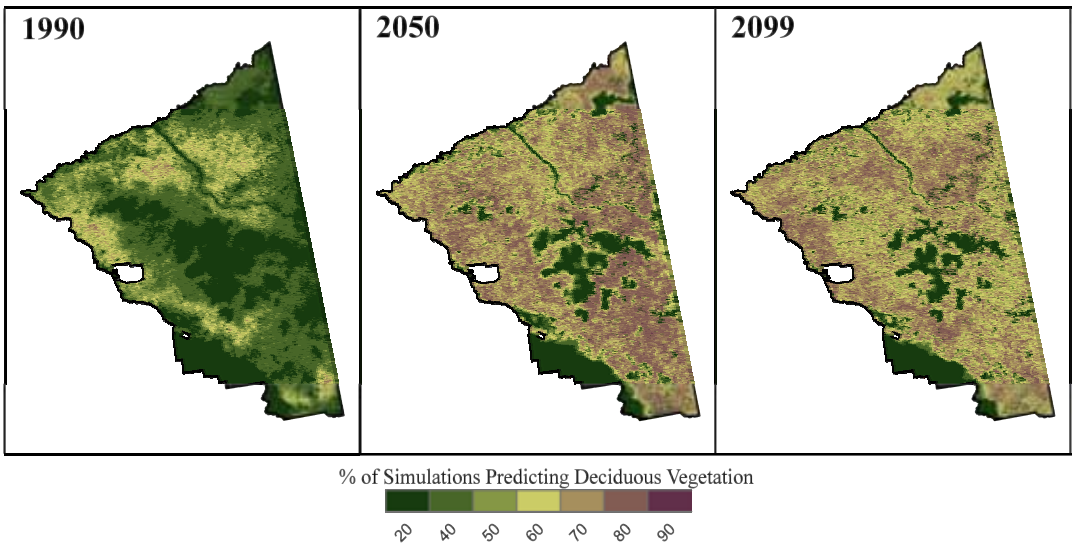

Figure 7– Vegetation map showing the percentage of simulations that predicted deciduous vegetation in any given spot on the Eastern Interior landscape.

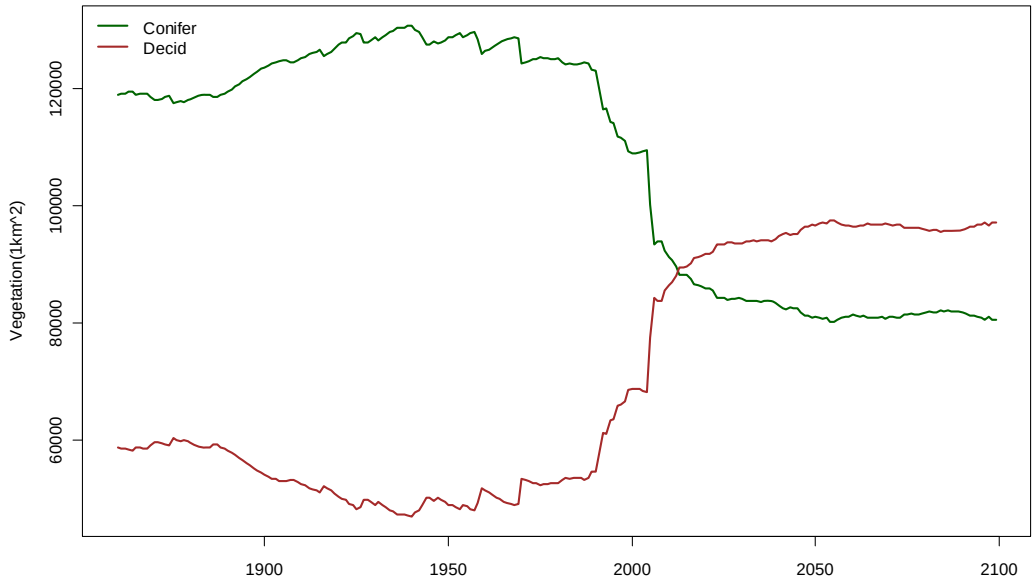

Figure 8– Time series showing the total simulated amount of conifer (green line) versus deciduous (brown line) vegetation, 1860-2099.

CHANGES TO WILDLIFE HABITAT

Along with this potential vegetation shift, we can utilize simulation output of vegetation type and time since last fire (i.e., stand age) to develop potential habitat metrics. For example, Rupp et al. (2006)[8] analyzed the potential change in total amount of winter habitat for the Nelchina caribou herd using an algorithm to track preferred vegetation type (spruce forest and woodland spruce stands) and age class (> 80 yr). Other metrics could be developed and implemented as part of the post-processing of the simulation output. Below are projections for caribou winter habitat (following Rupp et al. 2006) as well as moose habitat (Fig. 9). Moose habitat in this example is defined as deciduous vegetation between 10 and 30 yr (based on Maier et al. 2005)[9].

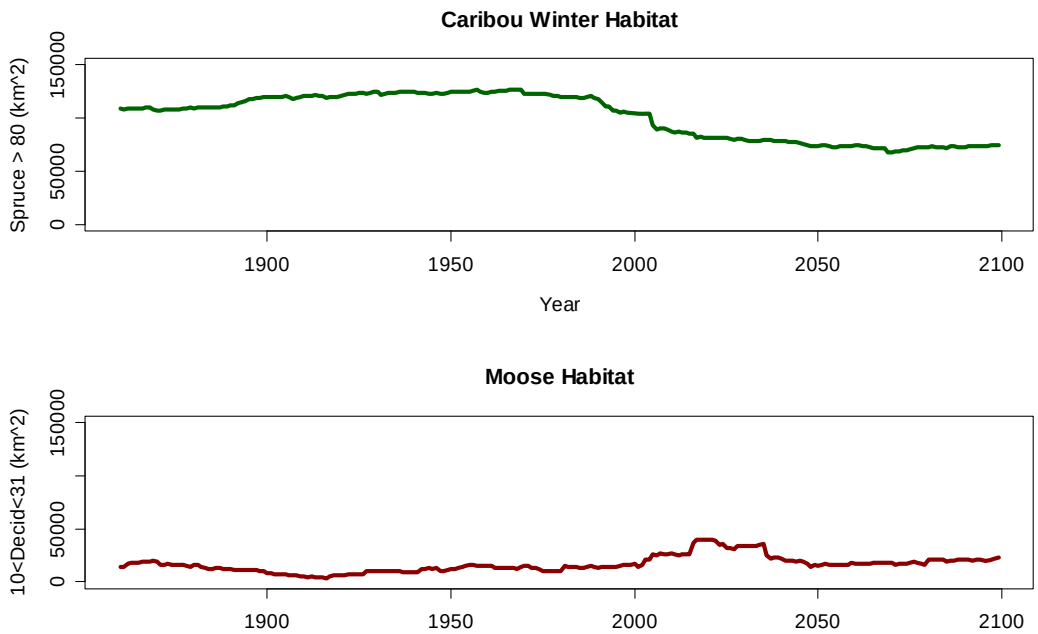

Figure 9 – Habitat graphs showing projected changes in caribou (spruce > 80 yr) and moose (deciduous between 10 and 30 yr) habitat from simulated fire activity.

CONCLUSION

The BLM Eastern Interior Management Area is within a region of Alaska expected to see some of the greatest changes over the next 30 years and out to 2099. These changes include increased temperatures, decreased water availability, and increased fire activity resulting in greater deciduous dominance on the landscape.

[8] Rupp, T.S., Olson, M., Henkelman, J., Adams, L., Dale, B., Joly, K., Collins, W., and A.M. Starfield. 2006. Simulating the influence of a changing fire regime on caribou winter foraging habitat. Ecological Applications. 16(5):1730-1743.

[9] Maier, J.A.K., Ver Hoef, J.M., McGuire, A.D., Bowyer, R.T, Saperstein, L. and H.A. Maier. 2005. Distribution and density of moose in relation to landscape characteristics: effects of scale. Canadian Journal of Forest Research. 35(9): 2233-2243.