USER GUIDE

Research Summary:
Projecting Vegetation and Wildfire Response to Changing Climate and Fire Management in Interior Alaska

SERDP Project RC-2109

AUGUST 2016

Amy L. Breen
Alec Bennett
Tom Kurkowski
Michael Lindgren
Julien Schroder
A. David McGuire
T. Scott Rupp
University of Alaska Fairbanks

SERDP
DOD • EPA • DOE

Page Intentionally Left Blank

Page Intentionally Left Blank

Research Summary: Projecting vegetation and wildfire response to changing climate and fire management in interior Alaska

Amy L. Breen, Alec Bennett, Tom Kurkowski, Michael Lindgren, Julien Schroder, A. David McGuire, and T. Scott Rupp, University of Alaska Fairbanks

Project Summary

The extent and frequency of wildfires in Alaska's boreal forest are predicted to increase in the coming century. In addition to natural sources of ignition, military lands in Interior Alaska are vulnerable to human ignitions due to their proximity to the road system and training activities. Recent wildfires such as the 2013 Stuart Creek fire, sparked by an explosive ordinance on an army weapons range, demonstrate the need to test alternative fire management scenarios. One method that might reduce future large fires is to increase the level of fire suppression by changing the fire management planning options (FMPOs) for these areas from mostly Limited to Full protection. But will that method work well long-term?

We used the Alaska Frame-based Ecosystem Code (ALFRESCO) vegetation-fire computer model to investigate how increasing fire suppression on military training lands could influence the extent and frequency of wildfire activity within the Upper Tanana Hydrologic Basin through the 21st century. ALFRESCO simulates wildfire, vegetation establishment, and succession—the dominant landscape-scale processes in boreal ecosystems in Alaska. We used a pair of climate models to bracket the uncertainty associated with projecting landscape changes. To simplify outputs, we focused on a single Representative Concentration Pathway (RCP) for greenhouse gases to drive the ALFRESCO model.

Changing all military lands within the study area to Full protection led to an increased number of fires, but a decrease in the total area burned, through 2100 compared to the status quo (mostly Limited protection). These projected changes in fire regime also increased the amount of late successional coniferous forest present on the landscape. In contrast, keeping the areas in mostly Limited protection leads to more early successional deciduous forest on the landscape through the end of the century.

The two climate models, however, drive the greater difference in results. Both models project future conditions warmer than today, but NCAR-CCSM4 projects a much warmer and drier future than MRI-CGCM3. Thus, ALFRESCO outputs using NCAR-CCSM4 predict greater fire activity and a declining conifer:deciduous ratio through the end of the 21st century. In contrast, ALFRESCO outputs using the MRI-CGCM3 model show an increase in the conifer:deciduous ratio over time. The effects of the alternative fire management planning options are subtle, so we recommend an economic study to determine if the cost of implementing such changes is warranted. Furthermore, we caution the results of this study are specific to a limited area within Interior Alaska. Future work will investigate whether modeling more large-scale fire suppression yields similar results.

Acknowledgements: This work evolved from discussions between researchers and land managers at Fort Wainwright during multiple meetings at University of Alaska Fairbanks from 2013-2015. Our research was supported by the Department of Defense Strategic Environmental Research and Development Program through the funded project "Identifying indicators of state change and forecasting future vulnerability in Alaska boreal forest" (Grant No. RC-2109). We thank Nancy Fresco, Hélène Genet, Randi Jandt, and Alison York for comments that greatly improved this research summary.

Where can I learn more about wildfire and wildfire management in Alaska?

Alaska Wildland Fire Information:
https://akfireinfo.com/

Alaska Interagency Coordination Center:
fire.ak.blm.gov

Alaska Division of Forestry, Wildland Fire & Aviation:
http://forestry.alaska.gov/wildland

Alaska Fire Science Consortium:
www.akfireconsortium.uaf.edu

Where are U.S. Department of Defense lands located in Alaska?

The U.S. Department of Defense (DoD) manages approximately 7,000 km^2 (~1,730,000 acres) of land in Alaska. Over 95% of military land is located in the boreal forest of Interior Alaska, associated with Fort Wainwright and Eielson Air Force Base near Fairbanks, and with Fort Greely near Delta Junction. These lands cross two ecologically, economically, and culturally important regions within the Intermontane Boreal Ecoregion—the Tanana-Kuskokwim Lowlands, which covers about 52,000 km^2 (~12,850,000 acres), and the Yukon-Tanana Uplands, which covers about 102,000 km^2 (~25,205,000 acres)(Nowacki et al. 2001, Fig. 1).

Wildfire is the most widespread natural disturbance in these ecoregions. The Yukon-Tanana Uplands have the third highest incidence of lightning strikes in Interior Alaska (Dissing & Verbyla 2003). In addition to high natural sources of ignition, these military lands also experience high human ignition pressures due to their proximity to the road system and urban areas, and the frequency of military testing and training activities. Thus, the Alaska Fire Service designates these military lands in a distinct fire management zone so local fire management officers can address the unique needs of military land management.

All lands in Alaska, including military lands, are designated by Fire Management Planning Options (FMPO) that provide for a full range of initial suppression responses from aggressive control and extinguishment to surveillance (sidebar). We chose to focus our modeling effort on the Upper Tanana Hydrologic Basin study area, as it encompasses Fort Wainwright, Eielson Air Force Base, and Fort Greeley, along with the larger urban communities on the road system in Interior Alaska (Fig. 1). The military lands within the study area comprise about 16% of the total land area.

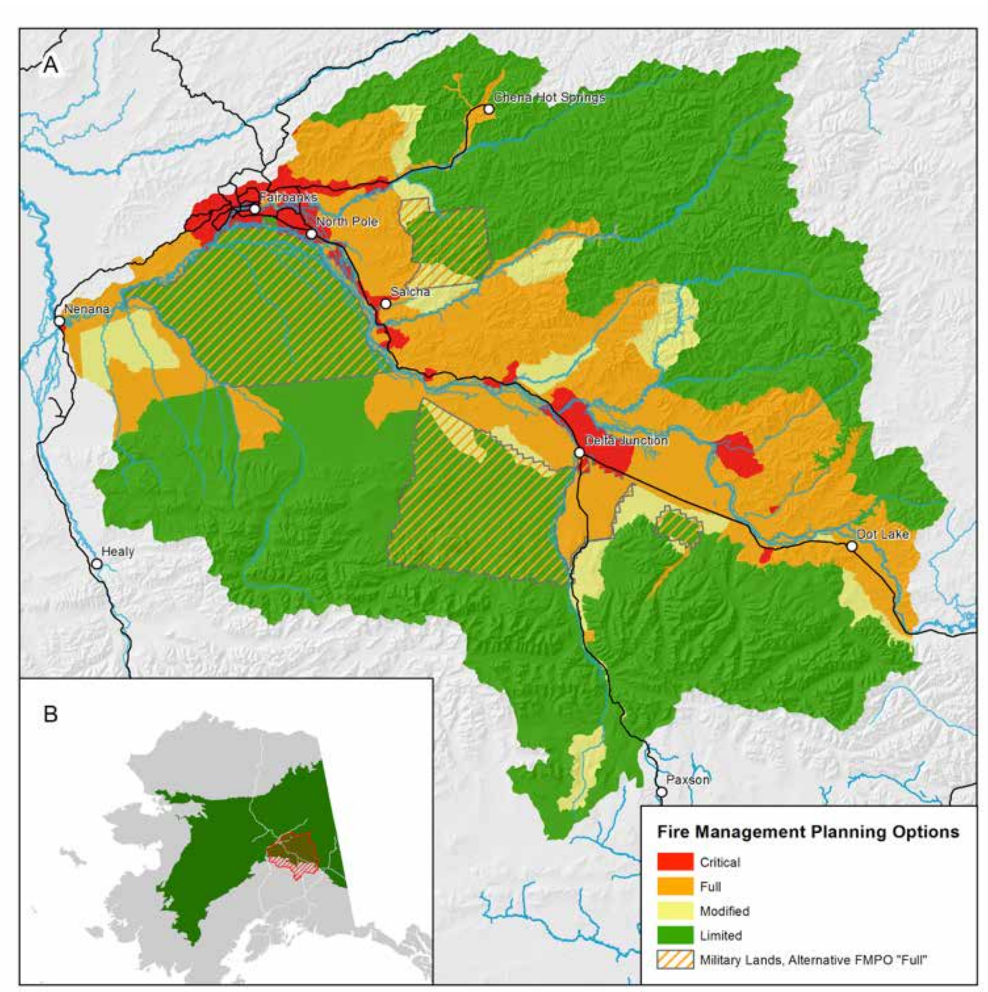


Figure 1. Map showing the A) Upper Tanana Hydrologic Basin study area in Interior Alaska and B) the location of the study area within Alaska. Fire management planning options are shown within the study area, and military lands are outlined in gray. In the inset map, the Intermontane Boreal Ecoregion (Nowaki et al. 2001) over which the ALFRESCO model is calibrated is shown in green and the specific study area is outlined in red. The military lands within the study area comprise about 16% of the total land area.

What are the four Fire Management Planning Options designated in Alaska?

Fire management planning options (FMPOs) in Alaska designate different levels of protection (AWFCG 2010). Values-at-risk, ecological considerations, and suppression costs were all considered to develop the management option criteria. These options include:

1) **Critical Protection** - suppression action provided on a wildland fire that threatens human life, inhabited property, designated physical developments and structural resources such as those designated as National Historic Landmarks. The suppression objective is to provide complete protection to identified sites and control the fire at the smallest acreage reasonably possible. The allocation of suppression resources to fires threatening critical sites is given the highest priority.
2) **Full Protection**- suppression action provided on a wildland fire that threatens uninhabited private property, high-valued natural resource areas, and other high-valued areas such as identified cultural and historical sites. The suppression objective is to control the fire at the smallest acreage reasonably possible. The allocation of suppression resources to fires receiving the full protection option is second in priority only to fires threatening a critical protection area.
3) **Modified Protection** - suppression action provided on a wildland fire in areas where values to be protected do not justify the expense of full protection. The suppression objective is to reduce overall suppression costs without compromising protection of higher-valued adjacent resources. The allocation of suppression resources to fires receiving the modified protection option is of a lower priority than those in critical and full protection areas. A higher level of protection may be given during the peak burning periods of the fire season than early or late in the fire season.
4) **Limited Protection** - lowest level of suppression action provided on a wildland fire in areas where values to be protected do not justify the expense of a higher level of protection, and where opportunities can be provided for fire to help achieve land and resource protection objectives. The suppression objective is to minimize suppression costs without compromising protection of higher-valued adjacent resources. The allocation of suppression resources to fires receiving the limited protection option is of the lowest priority. Surveillance is an acceptable suppression response as long as higher valued adjacent resources are not threatened.

Fire is a natural part of the boreal forest—an ecosystem dominated by black and white spruce. (T. S. Rupp)

How do vegetation and wildfire interact to create the landscape mosaic found in Interior Alaska?

The boreal region of Interior Alaska is comprised of a mosaic of coniferous, deciduous, and mixed forest ecosystems interspersed with herbaceous or shrubby wetlands. Coniferous stands dominated by black spruce, or *Picea mariana*, are the most abundant forest type in Interior Alaska, and are frequently underlain by permanently frozen, or permafrost, soils.

Black spruce forests are highly flammable and typically burn during stand-replacing fires every 70-130 years. Stable cycles of fire disturbance and spruce self-replacement have persisted for over 8,000 years since black spruce came to dominate the evergreen forests of Interior Alaska.

White spruce, or *Picea glauca*, is less flammable than black spruce, as illustrated by a long history during the Holocene of white spruce dominance (8-10,000 years before present) with concurrent low fire frequency. However, the juxtaposition of black and white spruce forest stands on the landscape means that white spruce often burns in tandem within the fire regime of black spruce, as do shrubby or herbaceous wetlands where surface organic soils can serve as a ground fuel to carry fire during dry months.

In contrast, deciduous early successional stands have less ground fuel, and while they can burn—especially in warm spring seasons before green-up—they often reduce the spread of fire relative to other ecosystem types during the height of the growing season. Projected changes in future climate, however, could affect the stability of boreal ecosystems through an increase in fire size, frequency and severity.

Why simulate an altered fire management scenario using the ALFRESCO computer model? How did we alter the current fire management planning designations?

To provide meaningful information to fire managers about the potential future impacts of climate change on fire regimes at a landscape scale, a University of Alaska Fairbanks research team met multiple times with fire and resource management groups that work on military lands in Interior Alaska. Fire management can influence the natural fire regime by affecting the spatial patterning and timing of fire occurrence, and thus the successional state of an ecosystem within a managed area.

The groups discussed relevant fire management scenarios that could be used to alter current wildfire trends on DoD training lands and to explore their influence on future fire and vegetation dynamics. Recent wildfires demonstrate the need to test alternate FMPOs as one potential method to reduce future large fires and/or manage associated smoke impacts to communities. We investigated how changing these FMPOs within military training lands would influence the future fire regime and concurrent boreal forest vegetation dynamics.

To simulate fire management scenarios, we used the Alaska Frame-based Ecosystem Code (ALFRESCO, Fig. 2) vegetation-fire model. Since one important aspect of fire spread is suppression effort, we modified ALFRESCO's fire routine to include the general effects of fire suppression by influencing the likelihood of fire to spread after it has started. We informed the fire routine with information on acreage burned ratios across the different FMPOs reported by Calef et al. (2015). We then simulated two different FMPO scenarios:

1) the current FMPO designation, and
2) a hypothetical alternative FMPO designation in which we changed the protection status of all military lands that are currently designated as either Modified or Limited protection to Full protection (Fig. 1).

Based on these two model scenarios we then analyzed the difference, and ultimately the potential effects on fire regime and vegetation dynamics, of an altered FMPO scenario.

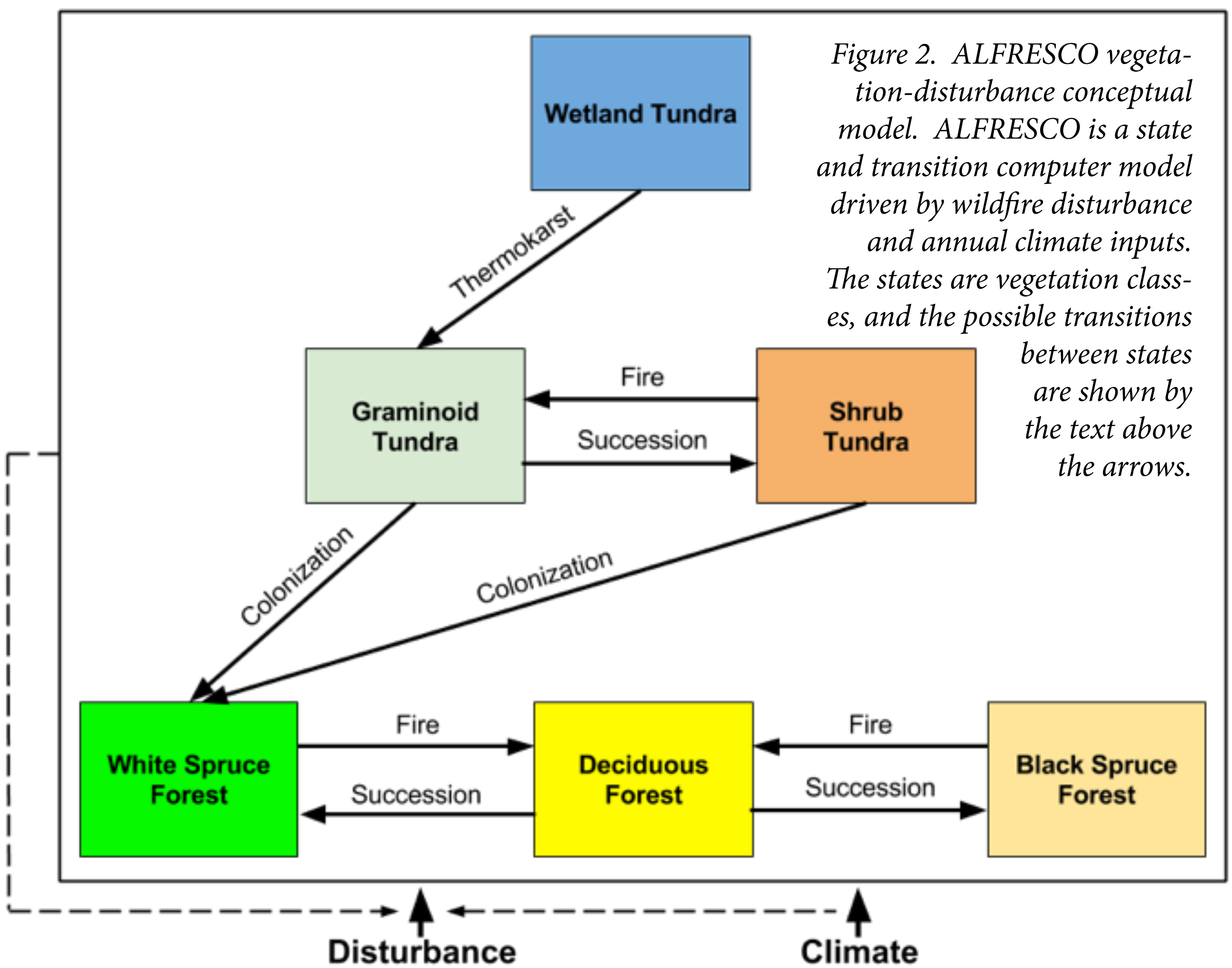


Figure 2. ALFRESCO vegetation-disturbance conceptual model. ALFRESCO is a state and transition computer model driven by wildfire disturbance and annual climate inputs. The states are vegetation classes, and the possible transitions between states are shown by the text above the arrows.

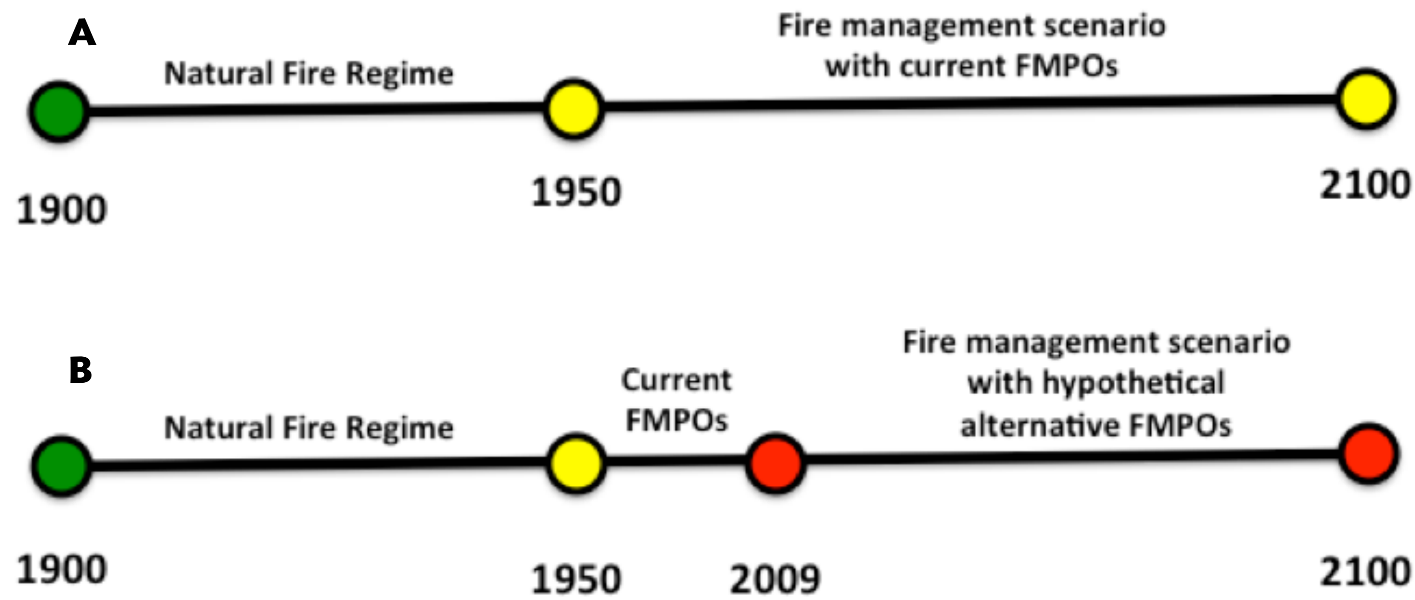


Figure 3. Timeline showing fire management scenarios implemented in the ALFRESCO computer model for A) current FMPOs and B) hypothetical alternative FMPOs for the Upper Tanana Hydrologic Basin in Interior Alaska. The hypothetical alternative fire management scenario changes all military lands within the study area to the full protection fire management planning option.

The timeline for implementation of the FMPOs differs (Fig. 3). After model spin-up, transition from a natural fire regime, equivalent to the limited fire protection class, to the current FMPOs occurs in 1950. While we are aware FMPOs were not implemented until the mid-1980s, fire suppression was commonplace in urban areas before this time, so this early date to switch to the current FMPOs is justified and is a better match to the historical record. The hypothetical future FMPO scenario is implemented in 2009 because this is the year the climate data switches from observed to projected.

Model calibration was performed over the Intermontane Boreal Ecoregion in Interior Alaska. The FMPO simulations were analyzed for the Upper Tanana Hydrologic Basin study area only. For each model run, 200 replicates were generated. All model data inputs and outputs are at a 1 x 1 km spatial resolution.

What were the specific questions addressed in this research?

We used ALFRESCO to investigate how altering FMPOs within military training lands influences the extent and frequency of wildfire activity within the Upper Tanana Hydrologic Basin through the 21st century.

We performed separate model simulations using two alternative fire management scenarios. The first scenario uses the current FMPO designation for the Upper Tanana Hydrologic Basin, and the second scenario represents a hypothetical scenario in which military lands within the study area are changed from primarily Limited and Modified to 100% Full protection (Figs. 2 & 4).

We addressed the following questions:

1) How might increasing fire suppression within military training land boundaries influence the frequency and extent of wildfire activity and vegetation dynamics on, and adjacent to, military lands in the Upper Tanana Hydrologic Basin during the 21st century?

2) How does the frequency and extent of future wildfire activity and vegetation dynamics vary depending on the driving climate scenario?

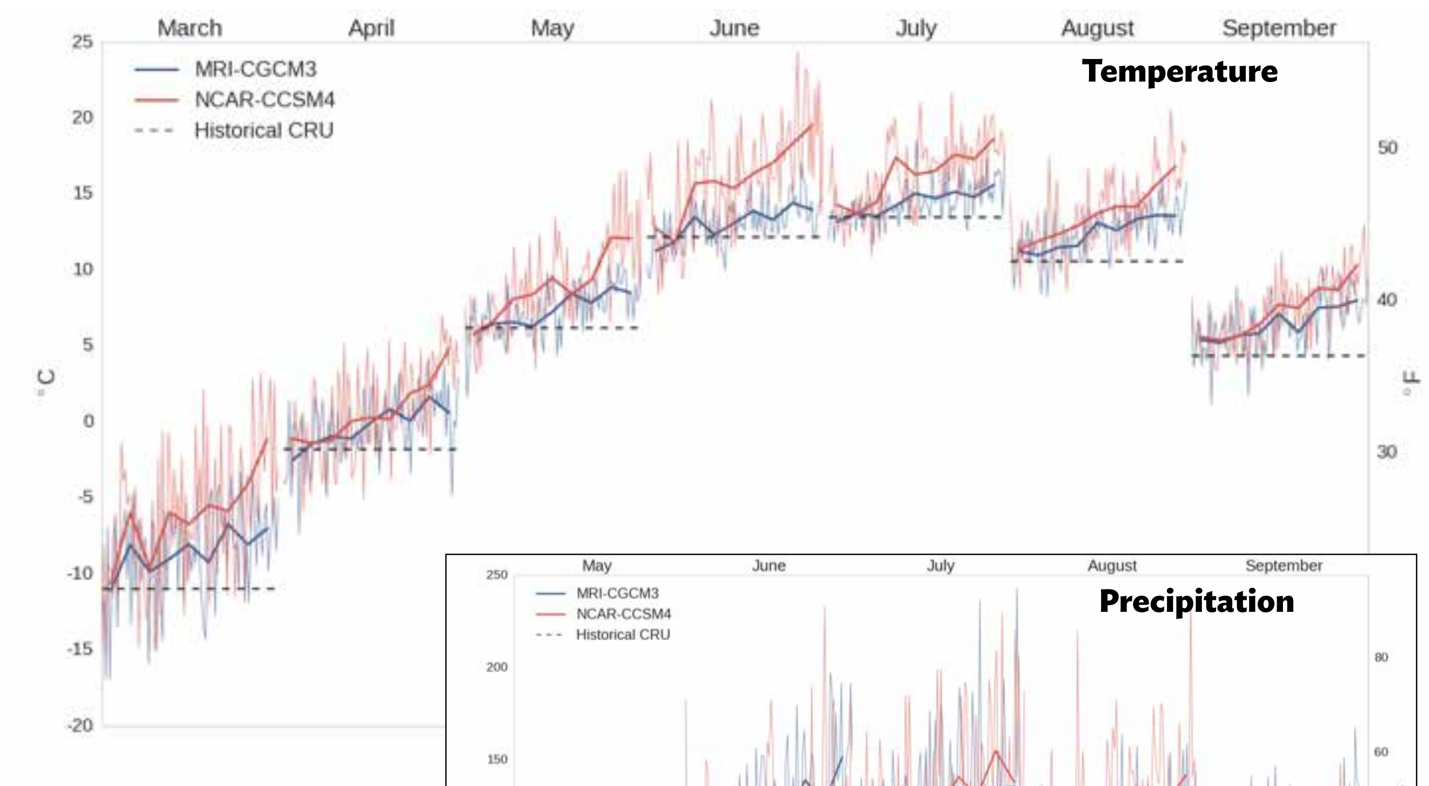
What climate models and greenhouse gas scenarios are used to drive the ALFRESCO computer model?

ALFRESCO requires mean monthly temperature and precipitation inputs. The source of this information can either be historical data or future climate scenarios generated by General Circulation Models (GCMs). We used a new generation of GCMs and projections (AR5; IPCC 2013) that use representative concentration pathways, or RCPs. RCPs are defined by varying degrees of "radiative forcing," or the balance between incoming and outgoing radiation. A positive forcing (more incoming radiation) tends to warm the system, while a negative forcing (more outgoing energy) tends to cool the system. Increasing concentrations of greenhouse gases, such as carbon dioxide, cause a positive forcing.

Two GCMs, operating under the anticipated RCP 8.5 emissions scenario, were chosen to represent the range of warming and precipitation expected to occur across Alaska:

- the Community Climate System Model, v. 4.0 (NCAR-CCSM4), and
- the Meteorological Research Institute-Coupled General Circulation Model v. 3.0 (MRI-CGCM3)

These were chosen among a suite of AR5 GCMs ranked among the top five best performing models across Alaska and the Arctic using the methods described in Walsh et al. (2008). These two climate models were selected because they produce the largest differences in simulated future area burned, where NCAR-CCSM4 burns the most and MRI-CGCM3 burns the least (Fig. 4).



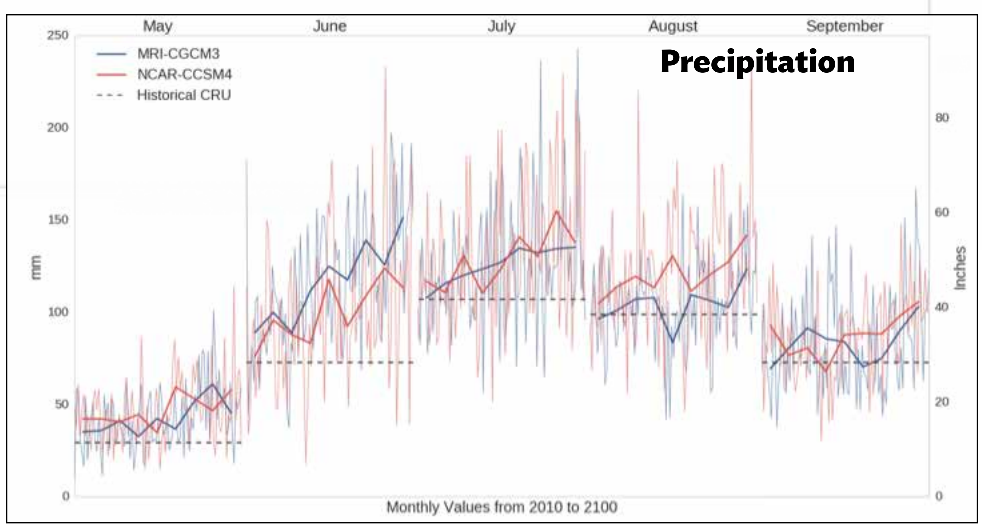


Figure 4. Projected mean monthly temperature (above) and precipitation (lower) for growing season months across the Intermontane Boreal Ecoregion of Interior Alaska for 2010-2100. The two general circulation models (NCAR-CCSM4 and MRI-CGCM3) and single scenario (RCP 8.5) used to drive the ALFRESCO computer model are presented. Narrow lines are yearly monthly averages showing the annual variability, bold lines are decadal monthly averages, and the dashed line shows the historical average from 1980-2010.

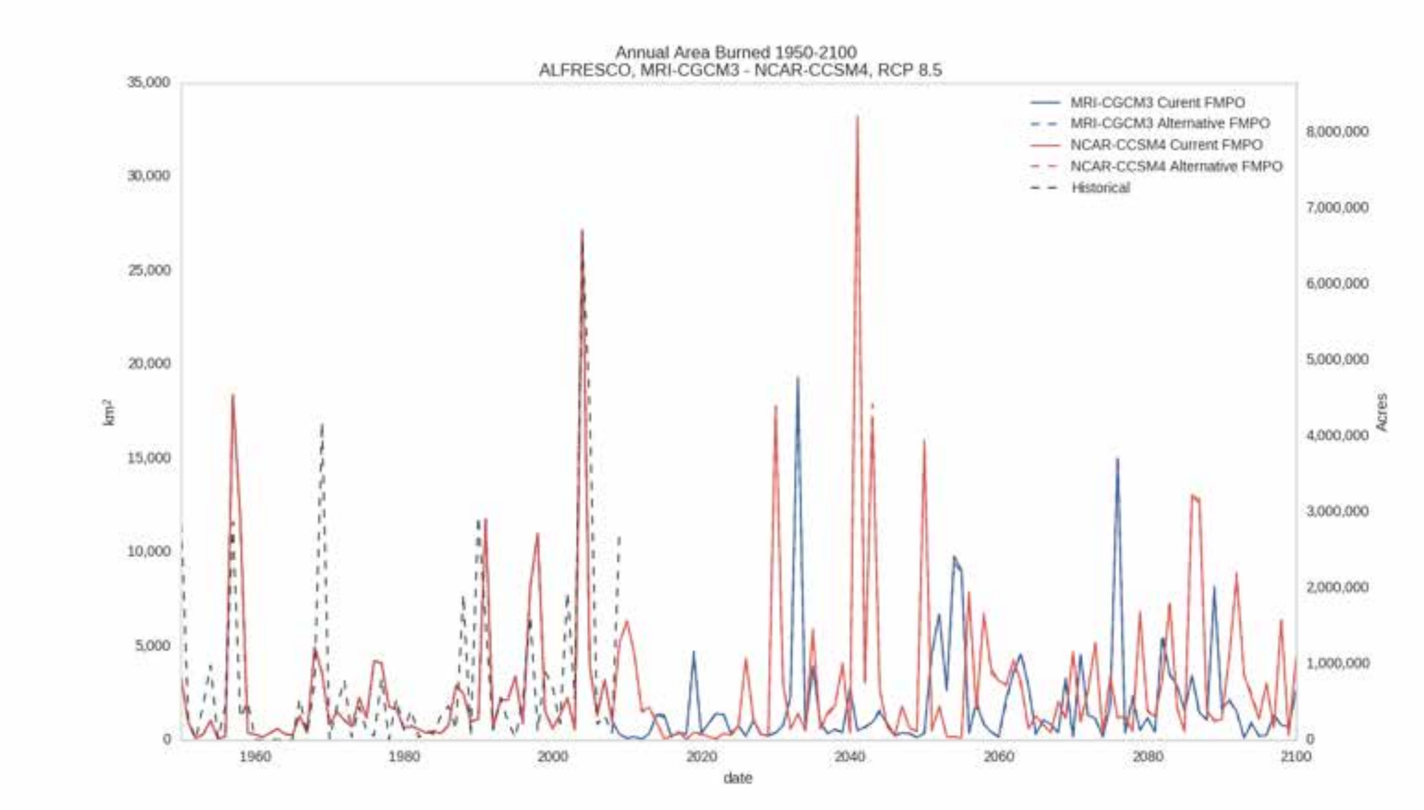


Figure 5. Annual area burned over the historical (1950-2009) and projected (2010-2100) periods for the Intermontane Boreal Ecoregion in Interior Alaska. Model results are presented for fire management scenarios driven by the NCAR-CCSM4 and MRI-CGCM3 global circulation models for the RCP 8.5 scenario. Data presented are the average from 200 model replicates. Dashed lines indicating the alternative FMPO scenarios are essentially indistinguishable from the current FMPO scenarios (solid red and blue).

What do the ALFRESCO model results tell us about potential future fire regimes and landscape dynamics in Interior Alaska?

The ALFRESCO results show that changing all military lands within the study area to full protection led to a modest increase in the number of fires per decade, while decreasing the annual area and cumulative area burned through 2100 compared to the status quo (Figs. 5 & 6).

The greatest difference between the scenarios, however, is observed not in the comparison between FMPOs but between the two driving climate models. While the number of fires per decade is similar (~35) between the very warm and drier NCAR-CCSM4 and the moderately warm and wetter MRI-CGCM3 model, the annual and cumulative area burned is not. Projected fire activity differs significantly between the two models, with the greatest difference observed at the end of the 21st century, when the cumulative area burned is over 10,000 km² (2,470,000 acres) greater for the NCAR-CCSM4 model compared to MRI-CGCM3 model (Fig. 6).

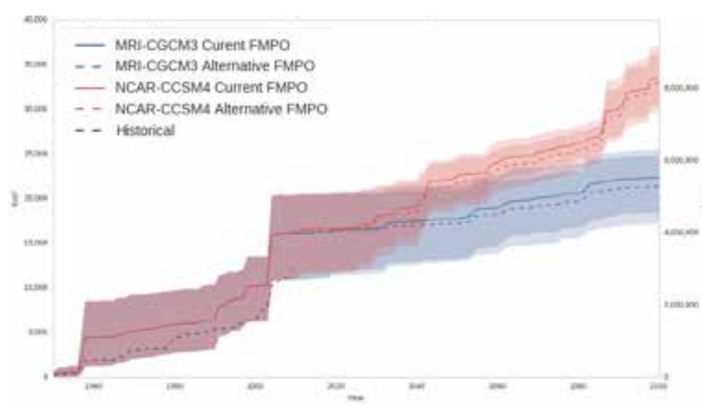


Figure 6. Cumulative area burned during the historical (1950-2009) and projected (2010-2100) periods for the Upper Tanana Hydrological Basin in Interior Alaska. Model results are presented for fire management scenarios driven by the NCAR-CCSM4 and MRI-CGCM3 global circulation models for the RCP 8.5 scenario. Data presented are means and shading indicates results from 200 model replicates.

These projected changes in fire regime also led to concurrent changes in the amount of late successional coniferous forest and early-successional deciduous forest present on the landscape in contrast to the current FMPOs.(Fig. 7). Similar to the fire regime, the greater difference in vegetation distribution and composition is more attributable to the driving climate models than to differences in suppression activity. The greater fire activity in the warmer and drier NCAR-CCSM4 scenario leads to a declining conifer:deciduous ratio through the end of the 21st century, regardless of suppression regime, although suppression slows the shift. The moderately warm and wetter MRI-CGCM3 model projects the opposite trend—an increase in the conifer:deciduous ratio over time, again with suppression favoring a coniferous-dominated landscape. The driving climate models bracket the projected conifer:-deciduous ratio from 0.5-2.0.

Overall, the simulated effects of the increased fire suppression scenario (i.e., the hypothetical alternative FMPOs) were subtle, and warrant additional analysis and research that could assess cost/benefit considerations and whether such changes to the FMPOs are warranted.

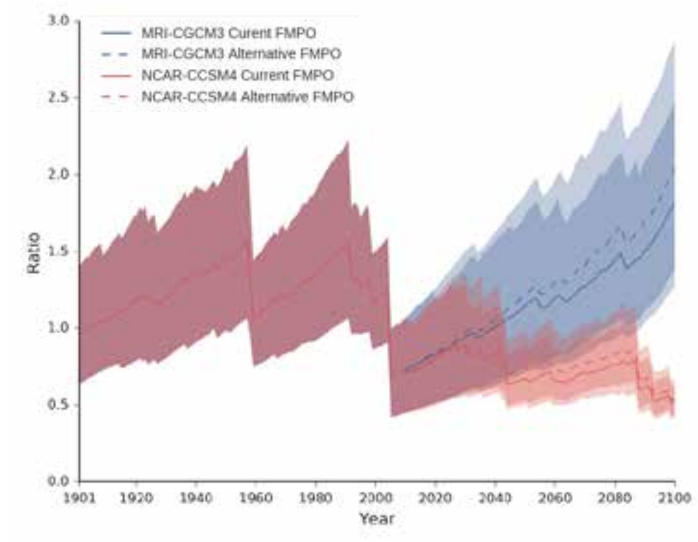


Figure 7. Conifer:Deciduous ratios for the model spin-up (1901-1949), historical (1950-2009) and projected (2010-2100) periods for the Upper Tanana Hydrological Basin in Interior Alaska. Model results are presented for fire management scenarios driven by the NCAR-CCSM4 and MRI-CGCM3 global circulation models for the RCP 8.5 emission scenario. Data presented are means and shading indicates results from 200 model replicates.

References

Alaska Wildland Fire Coordinating Group (AWFCG). 2010. Alaska Interagency Wildland Fire Management Plan. http://fire.ak.blm.gov/content/planning/aiwfmp_2010.pdf

Calef, M.P., A. Varvak, A.D. McGuire, F.S. Chapin III, and K.B. Reinhold. 2015. Recent Changes in Annual Area Burned in Interior Alaska: The Impact of Fire Management. Earth Interactions 19(5): 1-17.

Dissing, D., and Verbyla, D. L. 2003. Spatial patterns of lightning strikes in interior Alaska and their relations to elevation and vegetation. Canadian Journal of Forest Research (33): 770–782.

IPCC. 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324.

Moss, R. H., Edmonds, J. A., Hibbard, K. A., Manning, M. R., Rose, S. K., van Vuuren, D. P., Carter, T.R., Emori, S., Kainuma, M., Kram, T., Meehl, G. A., Mitchell, J. F., Nakicenovic, N., Riahi, K., Smith, S. J., Stouffer, R. J., Thomson, A. M., Weyant, J. P. & Wilbanks, T. J. (2010). The next generation of scenarios for climate change research and assessment. Nature 463 (7282):747-56.

Nowacki, G.; Spencer, P., Fleming, M., Brock, T. & Jorgenson, T. Ecoregions of Alaska: 2001. U.S. Geological Survey Open-File Report 02-297 (map).

Walsh, J. E., Chapman, W. L., Romanovsky V., Christensen, J. H. & Stendel, M. 2008. Global Climate Model Performance over Alaska and Greenland. Journal of Climate 21 (23): 6156–74.

For more information on this project, contact Amy Breen at albreen@alaska.edu