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Rising Temperatures Trigger Ecological Changes in the Boreal Forest of Alaska

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Fire Science Brief
RESEARCH SUPPORTING SOUND DECISIONS

A natural wonder to behold, the aurora borealis grace the night sky above the boreal forest in Fairbanks, Alaska. Credit: © Patrick J. Endres / www.alaskaphotographics.com.

Rising Temperatures Trigger Ecological Changes in the Boreal Forest of Alaska

Summary

Fundamentally different from the rest of the forest types in the United States, Alaska's boreal forest covers a significant amount of acreage in an increasingly variable climate. With its high latitude location, predictions reveal that this region will be the first to experience the effects of global climate change. In fact, natives of this region are already dealing with warmer temperatures and a changing landscape. As a result, researchers conducted a study to help gather more information about this area and to better understand the effects of climate change and how those effects influence fire and fuels management. An extension of a previous project, researchers joined forces with managers and administrators to establish the study's primary goals, which included gathering empirical data on the effects of stand age, vegetation type, and weather/climate on burn severity and generating predictions of climate changes and their impact on the natural fire regime. Additional research goals included using computer modeling tools, such as ALFRESCO, to create visual simulations of fire-vegetation interactions and to explore a diverse range of scenarios and time scales.

Key Findings

- Understory or overstory Composite Burn Index (CBI) ratings for 10 fires were not substantially affected by slope, aspect, and elevation, but for two of the fires, results related to timing, or burn season, were significant.
- Within the next 50 years, simulation results indicate that boreal forest vegetation will likely shift from primarily spruce-dominated to deciduous-dominated.
- Despite the shift to less flammable deciduous species, simulation results predict an increase in fire frequency and number of acres burned annually.
- ALFRESCO model simulations and changes in the projected cumulative area burned suggest a general rise in fire activity through the end of this century, with the most rapid change in fire activity occurring in the next 20–30 years.

Deep forest

Alaska's boreal forest is a place where the breathtaking aurora borealis, or northern lights, dance in the night sky. Wolves, bears, moose, caribou, and hundreds of other wildlife species abound, along with almost half of the 700 North American bird species. And the land is vast and virtually untouched, comprising up to 25 percent of the Earth's remaining forest.

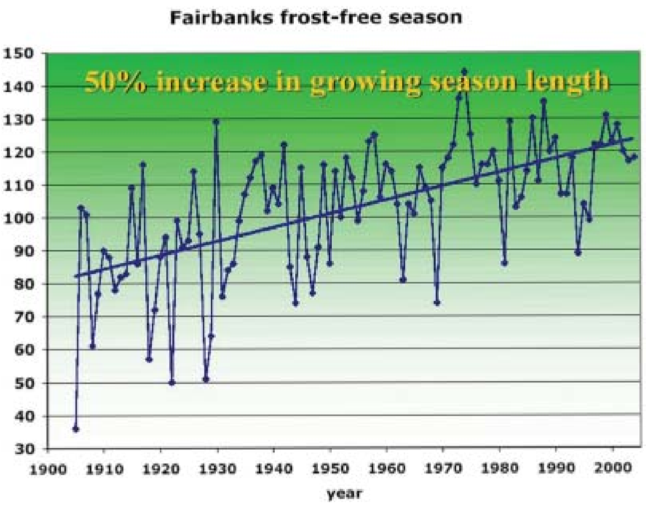
Despite its abundance of life and vegetation, the soil in the boreal forest is surprisingly acidic, nutrient-poor, and thin. Vegetation consists mostly of cold-tolerant evergreens such as spruce with a historical growing season that typically lasted 85 days. Low temperatures dominate in this region, with winters that are dry, cold, and long, followed by short summers that are moderately warm and moist.

The boreal forest serves many key functions as well. Millions of animals, plants, and indigenous peoples benefit from the shade and shelter it provides. The forest also acts as a carbon "sink," helping to regulate the local and global climate by absorbing millions and potentially billions of metric tons of carbon each year.

The bad news

Many scientific experts agree that global climate change is becoming a reality—it's just a matter of knowing what the effects will be and what steps must be taken to minimize its impact. For high latitude regions like Alaska, climate models suggest that the effects of global change are imminent, if not already present. Precipitation is expected to increase but so is the temperature, which will encourage general drying and evaporation and likely lead to greater fire frequency and perhaps higher fire severity and number of acres burned. Warmer temperatures will also affect the moisture of some soils, consequently affecting the growth and regeneration of many boreal tree species. In the end, climate change has the potential to shrink the boreal forest and related carbon "sink" by 65 percent.

Additional research also suggests that changes in fire frequency, whether driven by climate, humans, vegetation succession, or species composition, will have a significant impact on the overall landscape-level vegetation patterns and related responses to the future fire regime in the boreal forest.



As temperatures rise, so do the number of days in the boreal forest's growing season. Within the past 100 years, the growing season has increased dramatically, from 85 to 123 days. Credit: Glenn Juday, University of Alaska Fairbanks.

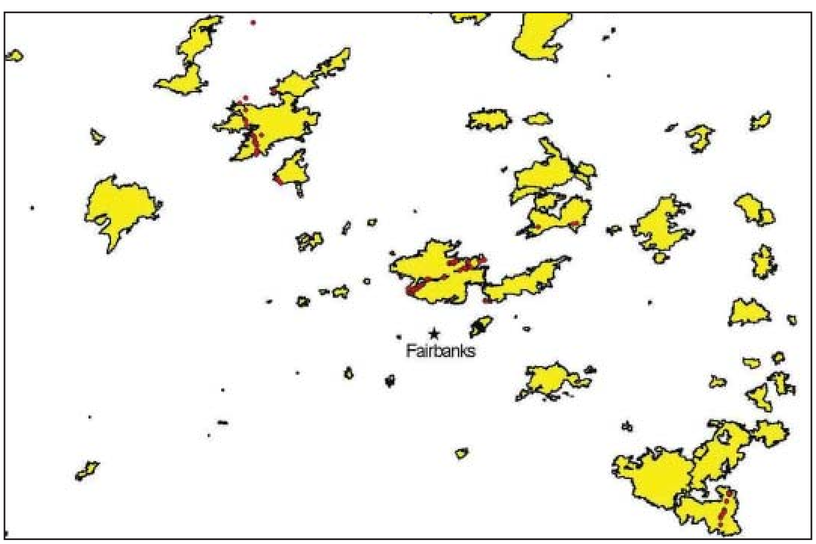
With fire frequency and severity predicted to increase across high latitude regions, wildfires similar to this prescribed burn near Fairbanks, Alaska are likely to become even more common. Credit: Scott Rupp.

In general, it can be tough to respond to a situation when you have little understanding of it. Only five studies have been conducted on Alaska's fire history, compared to the several hundred studies performed in the intermountain West. And since the boreal forest ecosystem is so unique and understudied, it can be difficult for fire and fuel managers to prepare for the coming changes.

To help managers understand these challenges, researchers worked closely with Alaskan land managers and administrators to determine project objectives, which included collecting empirical data on the effects of stand age, vegetation type, and weather/climate on burn severity in the Alaskan boreal forest and generating predictions of climate change effects on the natural fire regime.

Researchers also sought to create a scale-integrative planning and monitoring tool for wildland fuels and fire management that is specifically tailored to Alaska's ecological conditions and that addresses specific threats (particularly climate change) to its natural fire regimes. This tool, known as ALFRESCO, was originally created in the late 1990's and was further enhanced throughout this project. Designed to visually simulate the effects of various fire management practices, disturbances, and climate change on subarctic vegetation, ALFRESCO models the relationship between climate, growing season, and total annual area burned, which can then help fire and fuel managers make more informed management decisions. Users can also employ ALFRESCO to model changes in vegetation flammability due to succession.

Principal investigator, Scott Rupp, stated, "The previous project was a real catalyst for taking the earlier work and applying it to the boreal forest and then thinking about it in terms of the interactions between fire and climate. This follow on project was really trying to take the next step of having developed a model that worked and trying to provide decision support information for the fire management, wildland management, and natural resource management communities."



Located near Fairbanks, Alaska, study plots are indicated in red and 2004 fire perimeters are indicated in yellow.

In the field, on the screen

Using a combined field and modeling approach, researchers gathered field data during Alaska's 2004 severe fire season and applied that data to ALFRESCO, a computer-based, fire management and planning model that can generate visual simulations of fire-vegetation interactions over time, spatial scales, and various climate-change scenarios. The field component consisted of sampling 392 plots from 10 fires across interior Alaska and using Composite Burn Index (CBI) methodology to determine burn severity and ecological effects.

The modeling component of this project consisted of using ALFRESCO to simulate historical fire activity from 1860 to 2002, based on data from the Climatic Research Unit (CRU) and the Potsdam Institute for Climate Impact Research (PICAR.) Both organizations are leaders in climate research and are dedicated to providing the scientific data, methodologies, and tools needed to understand and plan for global climate change. Results from the historic model simulations were then used to create one emissions scenario and six future climate scenarios.

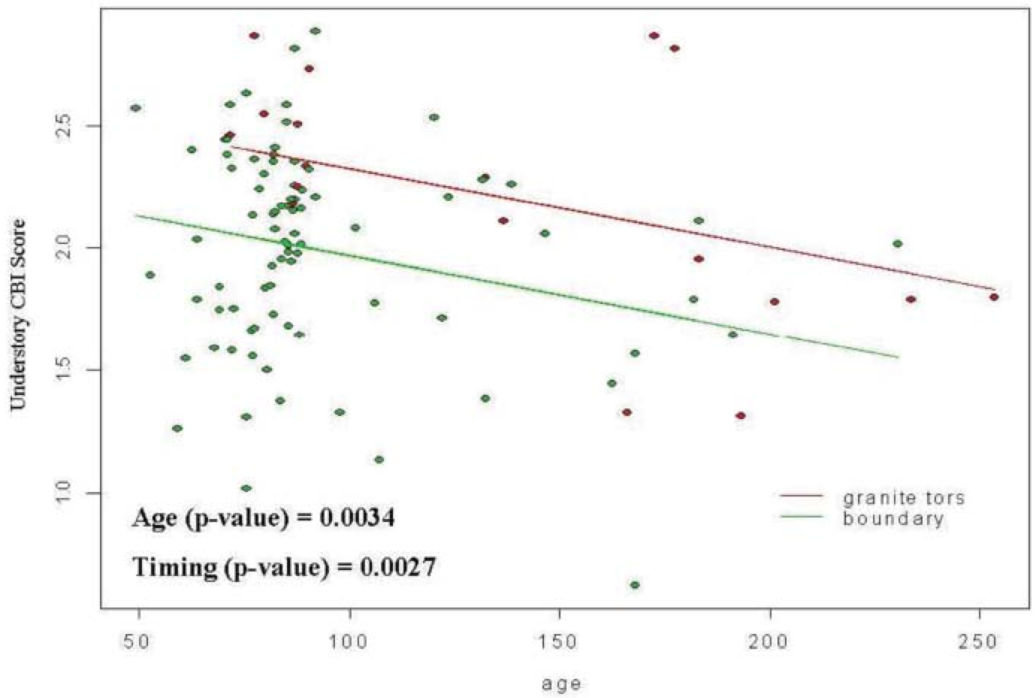
Objectives fulfilled

Data collection

To gather empirical data on the effects of stand age, vegetation type, and weather/climate on burn severity, researchers used the stand age data collected in the field to assess three components of forest flammability: stand-age-dependent flammability, abiotic (non-living) and biotic (living) stand characteristics, and climatic controls. Researchers hoped to identify if a relationship exists between stand age and fire severity and to gain a greater understanding of other potential biotic and abiotic controls over fire severity, such as slope, aspect, and forest structure and type.

According to research results for all 10 burns, a statistically significant, negative relationship exists between stand age and the understory CBI fire severity rating. Yet, the relationship between stand age and the overstory CBI fire severity rating was negligible. The environmental covariates such as slope, aspect, and elevation also had little effect on either the understory or overstory CBI rating. However, for two of the fires, timing, or season of the burn, had a significant influence and helped to slightly improve the model fit.

"Prior to calculating stand age flammability, we felt that there would be a pretty strong relationship between the stand age and how severely these stands were burning. But the fact that it was a much more complicated story than that was surprising. It made us rethink and refocus how we were going to model these relationships," said Rupp.



This graph represents the relationship between understory CBI burn severity, stand age, and timing of burn. The early season burn, or boundary fire, is indicated in green and the late season burn, or Granite Tors fire, is indicated in red.

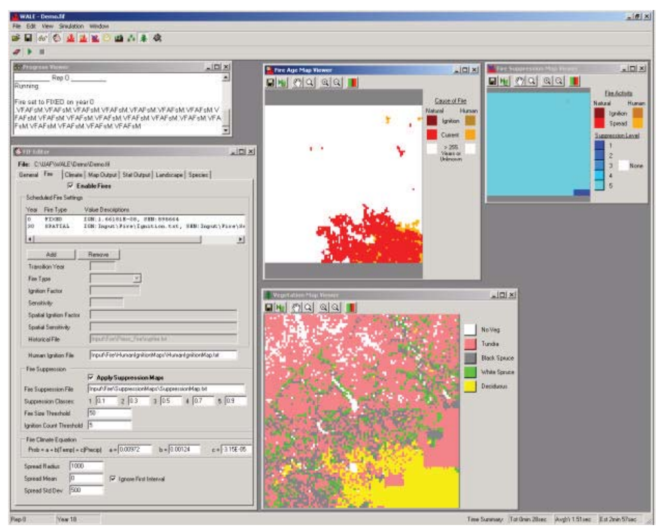
Climate change predictions

For fire activity and vegetation response predictions, statewide simulation results showed consistent trends. Individual simulations revealed a variety of potential responses to diverse climate scenarios; however, all model results implied that boreal forest vegetation will undergo a dramatic change within the next 50 years, shifting from the spruce-dominated landscapes of the last century to more deciduous vegetation.

As deciduous vegetation begins to dominate the landscape, shifts in fire frequency and patch dynamics may also occur. Despite the fact that the deciduous vegetation is less flammable, simulation results suggest an increase in fire frequency and number of acres burned annually. Patch dynamics between vegetation types and age are also expected to change. Large, contiguous areas of mature, unburned spruce will likely be replaced by a more patchy distribution of deciduous forests and younger stages of spruce. In response to simulated increases in fire activity, this change is projected to occur over the next few decades, eventually reaching a plateau where the patch dynamics may self-perpetuate for many decades and potentially centuries.

In response to projected warming temperatures, fire activity is also likely to increase, according to ALFRESCO model simulations. The most rapid change in fire activity and vegetation dynamics is expected to occur in the next 20–30 years, as indicated by changes in the projected cumulative area burned. In addition, future fire activity suggests a decrease in the magnitude of small fire seasons and an increase in the frequency of large fires that have the capacity to burn a significant amount of acreage (more than one million acres).

These two results appear to drive the simulated change in landscape dynamics where increased landscape flammability, driven by climate change, modifies landscape-level vegetation (i.e., fuels) distribution and pattern, which in turn feeds back to future fire activity by reducing vegetation patch size (i.e., fuel continuity).



Managers can initiate, simulate, and analyze a wide range of current and future scenarios of interest using ALFRESCO.

Modeling tools

Through previous and current project efforts, the ALFRESCO model has been enhanced to provide users with the ability to:

- Predict changes in stand age, vegetation, and fire regimes under various climate scenarios.

- Capture seasonal variation more often by running on monthly time steps.
- Access a helpful new reference condition that visually depicts an untouched boreal forest landscape.
- Assess downscaled climate observations and future projection data provided by the University of Alaska Scenarios Network for Alaska Planning (SNAP).
- Utilize a finer, more accurate resolution of data from the National Land Cover Database (NLCD), which helps identify pixels with erratic pockets of vegetation types and assigns them to their specific vegetation category.

In addition, a utility tool was developed within ALFRESCO to help model population growth. As more of the unpopulated areas become populated by private landowners and small communities, fire managers must begin monitoring and excluding fire in areas that were previously allowed to burn. ALFRESCO can help managers think about and plan for these changes and their potential effects and thus determine how to best modify their organizational structure and management tactics.

Management Implications

- An increased dominance of deciduous vegetation on the landscape will impact Alaska's fire management community because it will alter the fuel types and distribution of those fuel types on the landscape, thus altering both short- and long-term fire management strategies.
- Wildland management will also be affected by climate change in terms of adjusting management plans in a way that can provide a balance between fire management and the protection of wildlife habitats and species populations.
- Fire and land managers can use ALFRESCO to simulate how changes in fire management may transform the future landscape, as well as to assess how particular vegetation age classes may represent habitat conditions for important wildlife resources and how they may be affected by fire, vegetation, and climate interactions.

Managing climate change

According to Rupp, "One of the interesting things about Alaska is that it's not that climate change is *going* to happen, but that it's already happening." Climate change has been documented in Alaska as well as other regions, and natives are already dealing with some of the consequences. In fact, if boreal forests in other parts of the world cross similar ecological thresholds, together they could have globally significant effects on greenhouse gas emissions and radiation budgets.

As stated earlier, the boreal forest vegetation will change from being primarily spruce-dominated to deciduous-dominated. For the first 30–40 years post fire, the landscape will consist of deciduous trees but will eventually shift back to looking like the spruce forest that burned up 40 years prior. From a fire and fuel management perspective, this could be seen as a good thing, as deciduous vegetation is a less flammable fuel type and therefore tends to be easier to manage. Also, the moose population will likely benefit as they thrive in open areas with young growth of birch, willow, and aspen saplings and herbaceous vegetation.

In contrast, caribou will not benefit from this vegetation shift. To survive the harsh Alaskan winters, caribou feed on lichen, which grows in older spruce stands. As more spruce trees burn and are replaced by deciduous vegetation, there will be less food for caribou. Therefore, it has become the focus of federal agencies in these areas to try to manage these habitats in a way that provides for both species. For example, there's one instance of a wildlife refuge where the management strategies were altered in a way to protect some of the older successional spruce stands that are considered prime winter caribou habitat due to the high lichen content.

During this period of relatively rapid ecological change, fire and land management decisions will influence the structure and pattern of vegetation across the boreal forest in Alaska. It is therefore critical for fire managers to consider how land management objectives may be affected by the predicted changes to natural fire on the landscape. To help with this process, managers can use the ALFRESCO model to help simulate changes in fire management and the potential effects of these various changes on the future landscape. ALFRESCO can also be used to assess vegetation age classes that may represent habitat conditions for important wildlife resources and to help determine how those resources may be affected by future fire, vegetation, and climate interactions.

Rupp said, "The development of this model and the ability to provide information to the Alaskan fire management community on how the fire regime is changing and how the vegetation will respond to those changes is really important. We're not modeling fire behavior so that information is not used, such as operationally on a specific fire, however, we are focused on providing a big picture view of how fire might be changing in terms of its frequency, severity, and timing."

The boreal biome is offering a sobering glimpse into the effects of climate change—and yet there is still much we don't know about the greater implications of these effects. More intensive research is needed on boreal ecosystem feedbacks to the climate system as well as on dynamic coupling of disturbance-succession processes and biogeochemistry. Additional decision support tools will also help to provide Alaskan fire and land managers with the specific information and predictive capabilities they need to better understand and plan for climate change.

Further Information: Publications and Web Resources

Climate Research Unit Website: http://www.cru.uea.ac.uk

Effects of climate change on boreal forests, from the Greenpeace Website: http://archive.greenpeace.org/climate/arctic99/html/content/factsheets/oldreports/forests.html

Potsdam Institute for Climate Impact Research: http://www.pik-potsdam.de

Scenarios Network for Alaska Planning (SNAP) Website, ALFRESCO documentation and downloads available at http://www.snap.uaf.edu/downloads/boreal-alfresco

Scenarios Network for Alaska Planning Website (SNAP), ALFRESCO datasets available at http://www.snap.uaf.edu/downloads/datasets-boreal-alfresco

Scientist Profile

Professor of Forestry at the University of Alaska Fairbanks and Director for Scenarios Network for Alaska and Arctic Planning (SNAP), **Scott Rupp** earned a BS in Forest Management from Pennsylvania State University and a PhD in Forest Ecology from University of Alaska Fairbanks. Dr. Rupp's research focus is on landscape and ecosystem ecology in subarctic and boreal forests with a specific emphasis on regeneration, secondary succession, and disturbance dynamics.

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