

Fire, Fuel, and Smoke Science Program

2012 RESEARCH ACCOMPLISHMENTS

Rocky Mountain Research Station

Missoula Fire Sciences Laboratory

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Cover photos (top, left to right) USDA by U.S. Air Force Master Sgt. Jeremy Lock, and FFS Dan Jimenez and Mick Harrington; (bottom) FFS Program Manager Colin Hardy.

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2012: Year in Review
A Year of Wildland Fires

In 2012, the nation experienced one of the largest wildland fire seasons in US history. More than 9 million acres burned, overwhelming fire-suppression budgets, burning homes and other structures, and taking the lives of both firefighters and civilians around the country. In Montana alone, 1.1 million acres burned, resulting in the largest wildfire year since 1910. As changing climate, insect infestations, exurban development, and other external stresses impact the nation's forests and other wildlands, many anticipate we could experience even longer and more severe fire seasons, and that wildland fires could behave in new and unpredictable ways.

Facing an uncertain future, decision makers need new knowledge and tools to help them save both civilian and firefighter's lives, as well as find more effective (cont...)

Waldo Canyon Fire near Colorado Springs, CO, June 2012

2012 in Review

and cost-effective methods for ensuring the long-term health and viability of the nation's wildlands. As documented in this year's report, scientists and engineers working in the Fire, Fuel and Smoke (FFS) Science Program at the Missoula Fire Sciences Laboratory collaborate with teams of researchers and organizations to better understand the role, behavior, and effects of wildland fire. While some document fire effects at an international scale, others continue to investigate the basic physics of fire, developing new technologies and techniques to adequately measure energy transport and fire spread in both the laboratory and the field.

This kind of fundamental knowledge helps researchers develop more accurate models to anticipate fire behavior in diverse conditions and contributes to the tools managers need to better assess risk. Such improved predictive abilities can also help ensure the safety of firefighters and those living in or near the wildland/urban interface. Ultimately, this knowledge will improve how wildland fire is managed and used.

FFS researchers also continue to investigate the challenges posed by climate change to forests and other wildlands, questioning how a changing climate might affect the severity of fires in the future, and researching how changing fire regimes might impact habitat for everything from western white pine to species such as bull trout and lynx. As significantly, researchers are providing managers with a better understanding of how insect infestations might influence the behavior of wildland fires and affect firefighter safety.

Almost from its founding in 1960, investigators at the Missoula Fire Sciences Laboratory have maintained close communication with managers in the field to identify pressing research needs and ensure that decision makers have the knowledge and tools they need to protect the long-term health of the nation's forests and other wildlands. This on-going communication enhances a two-way exchange of information, and helps researchers transfer results in useable forms, including models, interactive computer programs, publications, and training.

As changing conditions and uncertainty add to the complexity of wildlands management, decision makers look to the Fire Fuel and Smoke Science Program for the critical research needed to help them respond to conditions in real time as well as plan for the future. As documented in this year's report, our research continues to address these pressing needs, helping managers more successfully preserve the nation's forests and wildlands for generations to come.

Colin Hardy, Program Manager
Fire, Fuel, and Smoke Science Program

FFS Program Manager Colin Hardy participated as faculty, observer, and operational crew-person at the National Center for Landscape Fire Analysis' Prescribed Fire Practicum in Georgia.

Partnerships and Collaborations

Wildland fire research requires collaboration and partnerships between scientists, mathematicians, and engineers, bringing together diverse perspectives from a variety of agencies and institutions. Cross-disciplinary teams of Fire, Fuel, and Smoke (FFS) researchers at the Missoula Fire Sciences Laboratory work with national and international colleagues to tackle the increasingly complex wildland fire challenges facing the region, the nation, and the world. At the global scale, teams of FFS researchers have looked at the effects of burning in Northern Eurasia as well as the behavior and effects of peat fires in Southeast Asia. Nationally, FFS researchers have collaborated with scientists from Florida to Alaska to better understand the fundamental basics of wildland fire to its long-term effects. FFS investigators have also established collaborative relationships with diverse teams of researchers at universities around the country and with agencies including the NOAA/National Weather Service, the Department of the Interior, the Department of Defense, the Department of Homeland Security, NASA, and the US Agency for International Development.

Researchers from around the country and around the world regularly visit the Fire Lab to learn about state-of-the-art technology and wildland fire research.

Sharing Expertise and Resources with Universities to Advance Wildland Fire Science

Since 2008, the Fire, Fuel, and Smoke Science Program has worked with the University of Montana, the University of Idaho, and the Rocky Mountain Research Station's Wildland Fire Management R,D&A Program in a novel University-Forest Service partnership with a mission to "improve the management of wildland fire by integrating science, technology, education, and practical experience." Through the Wildland Fire Science Partnership, the Fire Lab and others work to increase their core fire, fuel science, and measurement capabilities; produce timely, reliable, and consistent fire and fuel information; increase access to critical data and applications; and develop the skills and capabilities of future fire managers.

For example, the partners recently developed a mapping system for the western United States, which managers can use to help evaluate potential risks and fire effects, and they completed a new web-enabled spatially referenced version of the Fire Effects Information System (FEIS) national database for disseminating fire science to managers and students. As significantly, the Fire Lab regularly hosts students so that they can experience lab-based state-of-the-art fire research, as well as accompany fire-research experts into the field.

Of particular significance has been the participation of students in prescribed burning in Washington, Oregon, Idaho, Georgia and Nebraska. These travels into the field with Fire Lab researchers and other partners provide students with hands-on opportunities to learn about ecologically based fire management, effective collaboration, and prescribed fire operations while they gain fire experience and training.

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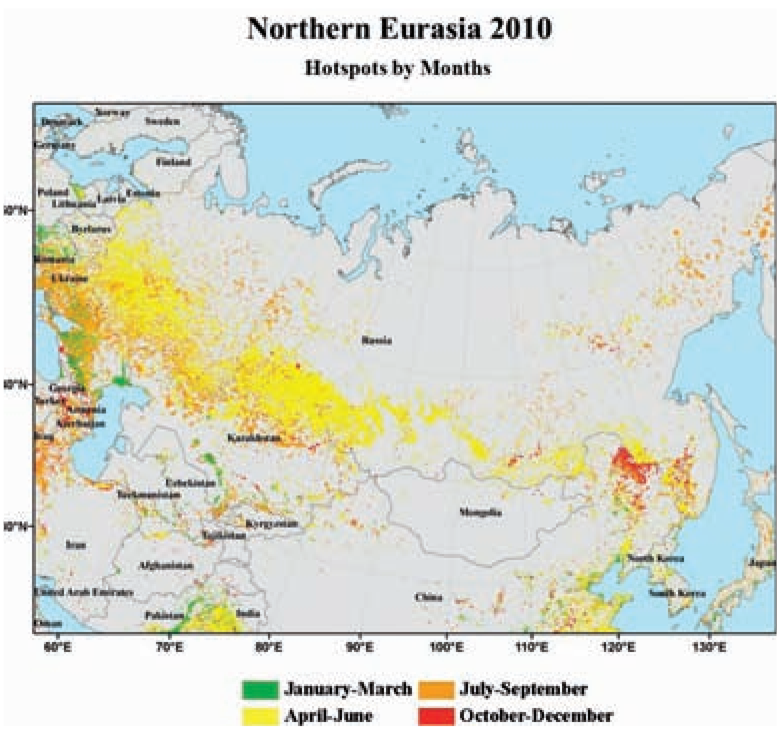
Left: University of Idaho's Fire Behavior class visits the Fire Lab each year for a full day of seminars, demonstrations, and tours. Top right: University of Montana forestry students regularly visit the Fire Lab to learn about wildland fire research.

Documenting Fire Activity in Northern Eurasia, 2002-2010

Northern Eurasia covers 20 percent of the global landmass and contains 70 percent of the boreal forest, representing the largest terrestrial biome on the planet occurring between 50 and 70 degrees north latitudes. Some scientists believe biomass burning in this region may be a significant source of atmospheric black carbon that could accumulate on Arctic ice and accelerate melting.

Using data from NASA's MODIS satellites from 2002 to 2010, research chemist Wei Min Hao and a cross-disciplinary team of scientists examined daily fire occurrences at a 1 km by 1 km resolution in different land-cover categories such as agricultural, grassland, shrubland, and forests. During this 9-year period, researchers did not detect any significant trend of fire occurrences in Northern Eurasia, or within any geographic region or land type.



Agricultural residues are often burned after harvest in the fall or before plowing in the spring, therefore, agricultural fires dominated biomass burning in Northern Eurasia, accounting for approximately 52 percent of satellite fire detections. This was followed by grassland, forest, and shrubland fires. In Russia, agricultural fires accounted for approximately 50 percent of all active fire detections; approximately 25 percent were forest fires. In Eastern Europe, almost all fires were agricultural fires. In Central and Western Asia, more than 50 percent of fire detections were grassland fires, and more than 30 percent were agricultural fires. This critical research contributes to a better understanding of the effects of climate change on fire regimes, dynamics, and emissions in Northern Eurasia that, in-turn, can impact Arctic ice melting and affect global ecosystems.

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Investigating Smoldering Combustion in Organic Soils

Tools for evaluating the potential for smoldering combustion in organic soils are limited, with guidelines used in fire planning and suppression based largely on local experience. In response, FFS forester Jim Reardon, working with a research team from IPA Fire Environment Consultants, the North Carolina Division of Forest Resources, the North Carolina Chapter of the Nature Conservancy, and the Department of Defense, has focused on improving a laboratory-based model of smoldering moisture limits. The research team has field tested this model using prescribed burns conducted in North Carolina.

The model to estimate smoldering potential (ESP) was developed to evaluate the risk of smoldering combustion in organic soils associated with pocosin fuels common in North Carolina and along the southeastern US coastal plain. The ESP is representative of common situations where lightning, the passage of wildland fire, or burning embers ignite small, short-term fires but initiate long-term, sustained smoldering. The field research demonstrated that potential smoldering combustion was consistent with estimates based on laboratory burning. Since these burns were conducted on a range of sites and under a range of conditions, they have demonstrated the wide applicability of this model.

The research also revealed that commonly used fire-danger indices are inconsistent indicators of the ground-fire risk in organic soils. These indices are based only on meteorological data and do not incorporate any other soil moisture drivers or soil properties. In response, Reardon and his colleagues developed a prototype ESP sensor array located at 5 stations to collect soil moisture and temperature, fuel moisture and temperature, lightning activity, water table depth, and rainfall. These sensors will help monitor conditions that could contribute to sustained smoldering.

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Smoldering root mat sample (top right) and a view of smoldering in the field (below).

Collecting Integrated Fire Science Data in the Field

The Core Fire Science Caucus, a group of 30 fire scientists and engineers, meets periodically to discuss fire behavior research, identify knowledge gaps, and outline strategic directions for continued research. One area of concern has been the lack of integrated data for development and evaluation of fuels, fire behavior, smoke, and fire effects models. This significant knowledge gap hinders researchers' ability to tackle fundamental fire science questions. The Caucus, therefore, organized a series of collaboratively instrumented data-collection studies on prescribed fires in the southeastern United States in 2008, 2011, and again in 2012.

Called the Prescribed Fire Combustion and Atmospheric Dynamics Research Experiment (RxCADRE), this research project, funded by the Joint Fire Sciences Program, has enabled scientists to develop processes and collect research data across fire-related disciplines before, during, and after the active burning periods of prescribed fires in Georgia and Florida. With these data in hand, the research group plans to identify specific interactions between fuels, fuel consumption, fire behavior, smoke management, and fire effects measurements to help develop and evaluate fire models.

Taking a truly cross-disciplinary and multi-organizational approach, researchers involved in the RxCADRE project include Roger Ottmar, Pacific Northwest (PNW) Research Station Research Forester; Brian Potter, PNW Research Station Research Meteorologist; William (Ruddy) Mell, Pacific Northwest Lab; Bret Butler, FFS Research Engineer; Dan Jimenez, FFS Mechanical Engineer; Shawn Urbanski, FFS Research Chemist; Bryce Nordgren, FFS Data Management; Andy Hudak, RMRS Research Forester; Brian Gullett, EPA; Joe O'Brien, Southern Research Station Research Ecologist; Mathew Dickinson, Northern Research Station Research Ecologist; Craig Clements, San Jose State University; Greg Walker, University of Alaska; Carl Seielstad, University of Montana; Tom Zajkowski, Remote Sensing; and Kevin Heirs, RxCADRE Incident commander, Eglin Air Force Base.

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Rx-CADRE researchers in Florida deliver anemometers to measure wind conditions during test burns in the field (left).
The FFS Rx-CADRE research team (right).

Studying Peatland Fire Dynamics

Peatlands occupy vast areas of the globe. Northern peatlands cover roughly 7 million square miles or approximately 16 percent of the world's land surface. Most are found in Russia (60 percent) and Canada (30 percent), but they also cover roughly 120 million acres in Alaska's interior. The US southeastern Coastal Plain contains roughly 6 million acres of peatlands, but they are also found in wet meadows and prairies in the Midwest. Tropical peatlands are widely distributed but are found principally in Southeast Asia.

Fire is a natural, critical process in the development of many of these peatlands, which commonly contain fuels that support high fire intensity, rapid spread rates, and long-range spotting during high winds after brief drying.

If fires occur during periods of extended drought or where peatlands have been drained, extended ground fires occur, resulting in greenhouse gases, smoke, and high fire-suppression costs. Multi-million dollar, months-long fires are becoming increasingly common in the southeastern United States, as are multiple-fatality accidents on smoke-shrouded highways.

FFS research forester Kevin Ryan, working with an international team representing the Indonesian Climate Change Center, the Australian Agency for International Development, the US Agency for International Development, the Forest Service's International Program, South Dakota State University, and the University of Montana, is studying peatland fire behavior and its effects. In addition to research on the US Coastal Plain, the team is researching peatlands in Indonesia and working on improved models for the ignition and burnout of tropical peat soils, improved atmospheric emissions estimates from peatland fires, and long-range forecasting of critical fire weather. Although focused on the island of Borneo, this research will have broad applicability to global peatlands.

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Research forester Kevin Ryan measuring smoldering peat in Indonesia.

Even though fire managers have a wealth of models to help anticipate fire behavior under a variety of conditions, the fundamental processes responsible for fire spread are not yet well understood. Understanding wildland fire behavior in real-world conditions requires a basic understanding of the physics of fire and what contributes to the series of ignitions that lead to fire spread through different kinds of fuels. Advancements have also been hindered by a lack of understanding of crown fire spread and spread thresholds, the implications of mountain pine beetle attack on crown fires, and fire and fuel dynamics of crown fire ecosystems. FFS researchers and collaborators are working on these and other fundamental questions.

In 2012, the UK Discovery Channel filmed the fundamental wildland fire research conducted at the Fire Lab.

Understanding the Physics of Fire Spread

To better understand how wildland fire spreads under various conditions, the National Fire Decision Support Center, a collaborative effort between Fire and Aviation Management and Research and Development, has supported ongoing research at the Missoula Fire Sciences Laboratory. The research team, including FFS researchers Mark Finney, Sara McAllister, Jack Cohen, Jason Forthofer, Bret Butler, and Matt Jolly, as well as Bob Yokelson (University of Montana), David Lignell (Brigham Young University), and Kozo Saito and Nelson Akafuah (University of Kentucky), have found that the radiant intensities in wildland fires are not sufficient to ignite fine fuel particles such as needles and grasses. Rather, intermittent flame convection provides the critical heating needed to ignite these particles.

Experiments to date have demonstrated that the intermittency of flame contact is due to flow instability in the hot gases resulting in a predictable pulsation frequency related to the dimension of the fire. Because the physical processes of ignition by convective heating may be different than by radiative heating, ignition experiments are also being performed using a unique hot air torch capable of heating air to flame temperatures. The research team also has discovered that the ignition of wood depends on a critical rate of converting solid mass to combustible gas similar to other substances, such as plastic, and that ignition depends on heat flux and wind flow, providing an improved definition of ignition and flammability limits. Recent experiments also demonstrate that this critical rate is also a function of the moisture content of the fuel.

This research suggests a completely new approach to understanding and modeling fire spread that is based on an experimentally supported theory, creating new opportunities for developing models that can be used for wildland fire management applications.

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Crib burns, such as the one shown here, are helping researchers understand what governs the burning rate and residence time of fuel beds.

Measuring Energy Transport in Wildland Fires

To accurately anticipate the behavior of wildland fires, model fire emissions and energy release, and improve public and wildland firefighter safety, it is necessary to understand how energy is released from wildland fires. With support from the Joint Fire Sciences Program, FFS research mechanical engineer Bret Butler and a team of collaborators from Brigham Young University, Eglin Air Force Base, Joseph W. Jones Ecological Research Center, Alaska Fire Service, BLM, and the USDA Forest Service's Pacific Northwest Research Station have conducted an ongoing field-based research effort to better understand how energy is produced and transported in wildland fires.

Radiative heat transfer from one surface to another and convective heat transfer by movement of gases play complementary roles in wildland fire spread. While previous studies reported measurements of energy transport from biomass-fueled flames, their scope was limited and primarily focused on radiative energy transport. Therefore, an improved understanding of how energy is transported through both radiative and convective modes in wildland fires remains a critical yet poorly documented element of wildland fire science, and extreme conditions of wildland fires greatly limit measurement methods.

Results to date indicate that integrated energy release correlated well with fire type for fire radiative energy, but not as clearly for fire convective energy. Scientists are working on formulating a more comprehensive understanding into the complex and dynamic relationship between these synergistic variables.

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FFS researchers setting up sensors to measure fire intensity in the field.

Measuring, Mapping, and Modeling Fire Behavior and Risk

To understand wildland fire behavior and effects, FFS researchers gather critical data in both the laboratory and the field and then analyze and synthesize this information to create tools to describe wildland fire behavior under varying conditions. They also apply 3-dimensional (3D) fire models and other sophisticated tools to help managers better understand fire regimes in the past and plan for changes in the future. Other investigations have created large-scale mapping and other tools to help managers visualize wildfire risk, assessed the impacts of parasitic plants, and developed new inventory techniques for improving the performance of predictive models.

Rx-CADRE researchers install an array of fire behavior sensors at the Eglin Air Force Base in Northwest Florida.

Extending Plot-Level Data to a Landscape Scale

New 3D models such as HIGRAD-FIRETEC have opened up a whole new arena of fire behavior to better understand the complex and dynamic interactions between fire, wildland fuels, weather, and topography with greater detail than has been possible in the past. They also improve the ability to evaluate and plan fuel treatments, anticipate risks to firefighter safety, and understand interactions between fire and other disturbances such as insect attacks or blowdowns.

That said, these new models require more detailed canopy fuel information than is currently available from other programs. Research ecologist Russ Parsons and a team of FFS researchers have, therefore, applied field-measured plot-level fuels data to develop a thematic raster map in which each 30-meter pixel is linked to a list of trees. This approach provides the best of both worlds: wall-to-wall comprehensive spatial coverage of LANDFIRE fuels maps with higher detail from plot data.

Researchers are now working on sensitivity analyses to determine how much detail is needed, and the effects of differences in fuels representation on factors important to fire behavior. This work greatly extends and facilitates researchers' ability to simulate fire across larger landscapes and will contribute to a better understanding of potentially catastrophic fires with complex wind, fuels, and plume dynamics to inform future fire management decisions.

For more information, contact:

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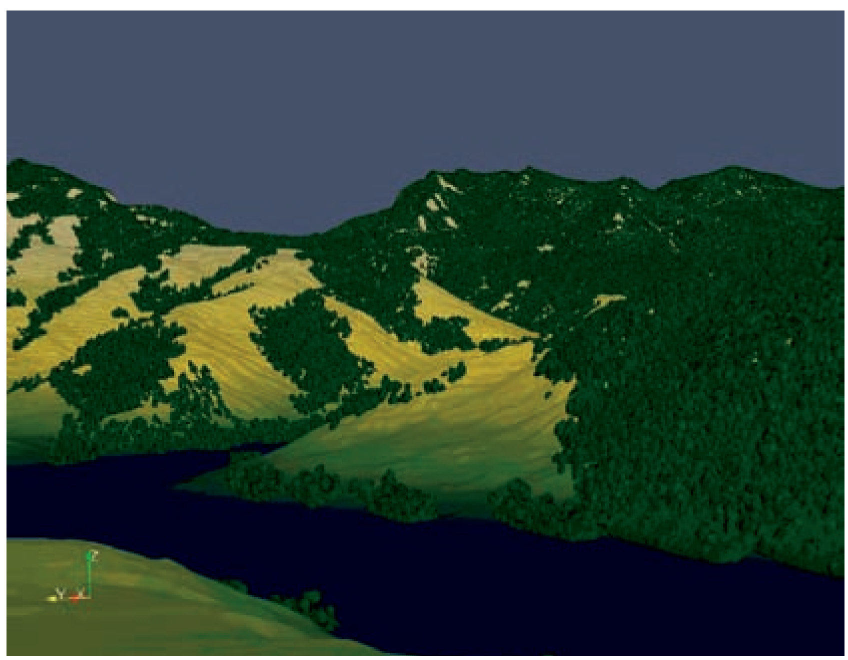
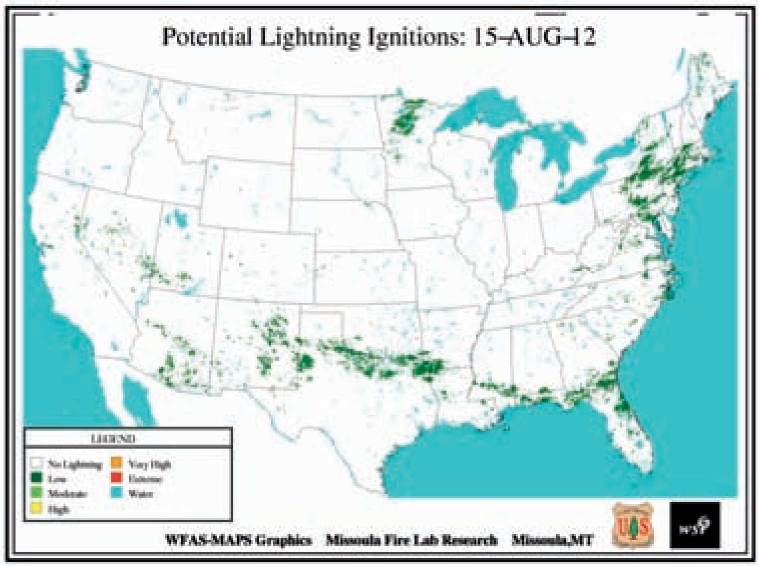


Simulated 3D fuels at landscape scale for an area near Helena, MT, populated with trees from plot-level data.

Mapping Potential Dry Lightning Strikes

Dry lightning refers to strikes that produce .10 inch or less of rainfall nearby (or .25 inch east of the Mississippi). This kind of lightning storm occurs frequently in the western US during the summer months and is the most common source of natural wildland fire ignitions. Thus, being able to anticipate dry lightning storms is of particular interest to land managers. Recent dry lightning research has concentrated on using upper air measurements -- atmospheric stability and moisture content -- to predict dry lightning episodes in advance.



Paul Sopko, a FFS physical scientist, has integrated this and other research to produce detailed maps that provide land managers with visual tools to identify potential lightning ignitions and where dry lightning has occurred immediately after the storms have passed. Both maps are created daily to help managers identify areas that have a high likelihood of new lightning-caused wildland fire ignitions.

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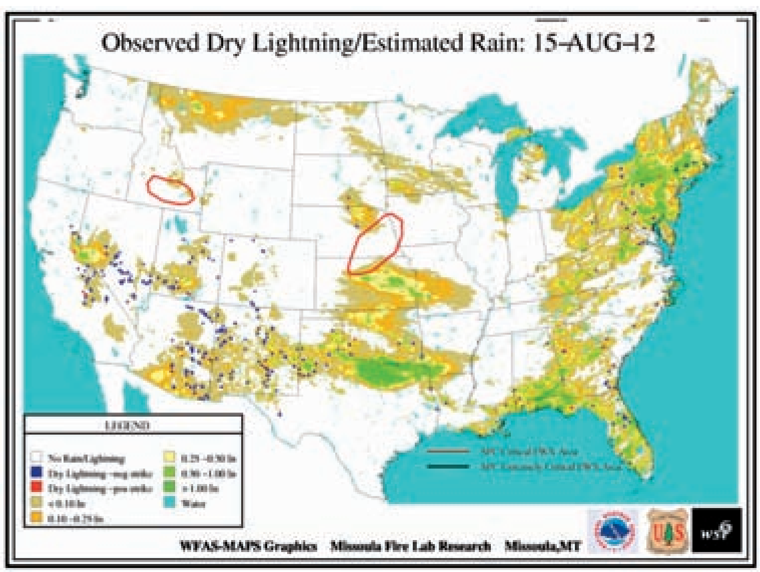
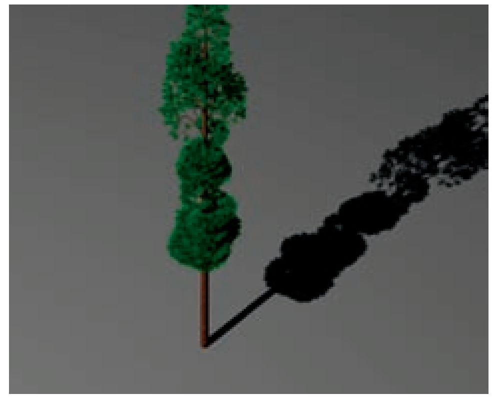


Potential for Lightning Ignitions and Observed Dry Lightning, August 2012.

Assessing Mistletoe as a Potential Fuel

Mistletoe is an endemic parasitic plant that lives on many tree species, sometimes significantly impacting forest stands. Mistletoe can greatly alter the geometry and biomass distributions in affected trees, possibly increasing fire hazard. While the biology of mistletoe is well studied, the effects of mistletoe on canopy fuel structure are poorly understood. The plant is found in many areas of the country, but existing fuel models fail to characterize mistletoe because they are unable to adequately represent its location and size, particularly at scales within individual tree crowns. The widespread nature of mistletoe and uncertainty about its effects on fire behavior make it difficult to decide if and when management action is needed.

FFS researchers Russ Parsons and Greg Cohn, with collaborator Chad Hoffman from Colorado State University, measured the fuel geometry, structure, and biomass of both healthy and mistletoe-affected branches from three tree species. They then carried out statistical analyses to assess the differences between them and used a 3D fuel distribution model (FUEL3D) to simulate these different fuel architectures. Documenting that healthy and mistletoe-affected branches are very different in several key aspects, researchers are now exploring the degree to which these differences affect potential fire behavior.



Ultimately, this research will improve understanding of fuel and fire behavior changes associated with mistletoe. This in turn will help managers identify situations in which intervention may be needed as well as to anticipate the potential effectiveness of such interventions.

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Sampling mistletoe in lodgepole pine near Bend, Oregon (bottom), and simulating a mistletoe-infected tree for modeling its effects (top).

Quantifying Spatial Variability of Wildland Fuel

Wildland fuel is the one factor that can be directly manipulated to achieve fire management goals such as lowering fire intensity, minimizing plant mortality, reducing erosion, and restoring fire-adapted ecosystems. Fire behavior fuel models frequently assign the average of fuel values across large areas, ignoring the extraordinary influence that fuel variability can have on wildland fire processes. Therefore, the great variability of fuel loading in one area could have more of an effect than the loading average on fire behavior, and also on post-fire plant mortality, growth, and colonization dynamics. A comprehensive description of fuels is needed for nearly all phases of fire management, including fighting wildfires, implementing prescribed burns, describing fire danger, and predicting fire effects.

FFS research ecologist Robert Keane has quantified the spatial variability of surface and canopy fuel characteristics for dry forest and shrub ecosystems of the northern Rocky Mountains. Results show that most surface fuel components have very high variability in both amounts present (fuel loading and bulk density) and characteristics (fuel density and mineral content). Canopy fuel properties have much less variability than surface fuels and vary over larger spatial scales, ranging from 100 to 400 meters. Results from this study will be used to redesign wildland fuel inventory, monitoring, and mapping programs to account for spatial variability in sampling methods.

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Researchers created an artificial fuel bed in the parking lot behind the Missoula Fire Sciences Laboratory to test sampling of woody fuels.

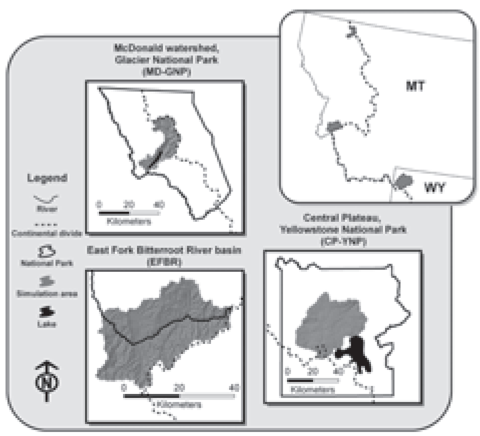
Changing Climate in a Changing World

Climate change is projected to have a profound influence on vegetation patterns and community compositions in the future, either directly through increased species mortality and shifts in species distributions or indirectly through disturbance dynamics such as increased wildfire activity and extent, shifting fire regimes, and the development of potentially deadly diseases. Mountainous landscapes have been shown to be particularly sensitive to climate changes and are likely to experience significant impacts under predicted future climate regimes. These changes could have a significant impact on both wildlands and threatened wildlife.

Waldo Canyon Fire, Colorado, 2012, USDA photo by U.S. Air Force Master Sgt. Jeremy Lock

Simulating the Effects of Climate Change

Climate projections for the next 20-50 years forecast higher temperatures and variable precipitation for many landscapes in the western United States. Climate changes may cause or contribute to threshold shifts, or tipping points, where relatively small changes in climate result in large, abrupt, and persistent changes in landscape patterns and fire regimes. Post-doctoral scientist Rachel Loehman developed sets of progressively warmer and drier or wetter climate scenarios that span and exceed the range of Global Climate Model (GCM) projections for the western U.S. These climate scenarios were used to simulate potential future fire and vegetation dynamics in three study areas in the western United States: McDonald watershed, Glacier National Park (MT), the central plateau of Yellowstone National Park (WY), and the East Fork Bitterroot River basin (MT). These landscapes encompass a diverse range of biophysical settings, vegetation species, forest structure, and fire regime, and were expected, therefore, to differ in their sensitivity to climate changes and exhibit unique threshold behavior following climatic and wildfire perturbations.



Each of the study areas proved sensitive to simulated changes in temperature and precipitation, as reflected in shifts in mean annual burned area, crown fire area, and fire-caused tree mortality. Sensitivity to climate changes also differed across landscapes. For example, a significant decline in basal area occurred at temperature shifts of 3 °C and above for the Yellowstone National Park study area, 4 °C and above for the Glacier National Park study area, and above 5°C for the East Fork Bitterroot River basin. Moreover, shifts in basal area were strongly related to changes in area burned and fire regime characteristics, suggesting that synergistic interactions of climate and fire will be important in determining future landscape patterns. The report based on Loehman's research won the 2012 Rocky Mountain Research Station's Outstanding Early Career Scientist Publication.

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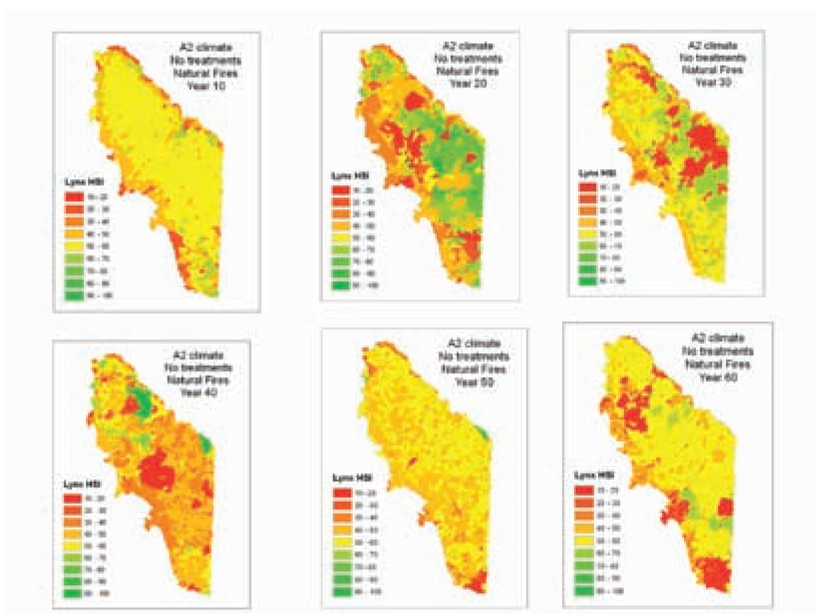
Study areas: McDonald watershed, Glacier National Park (MT), the central plateau of Yellowstone National Park (WY), and the East Fork Bitterroot River basin (MT).

Predicting Future Canada Lynx Habitat

Managers can use simulation modeling to understand future conditions and test how different management treatments might affect wildlife habitat. Simulations are useful when attempting to assess future impacts of climate change, since there is no precedent managers can use for reference. Modeling also allows for landscape-level analysis, which is particularly important for wide-ranging species.

FFS research ecologists Robin Silverstein and Robert Keane, coordinating with the Rocky Mountain Research Station wildlife unit, are testing the use of simulation modeling to predict future habitat suitability for Canada lynx (Lynx canadensis). The Canada lynx is a specialist predator feeding primarily on showshoe hare. Snowshoe hare have specific habitat requirements that are, therefore, shared by Canada lynx: areas of high-altitude forest with dense cover of shrubs and saplings. Studying a portion of the Flathead National Forest northeast of Big Fork, Montana, the researchers have modeled future scenarios that vary by climate change, fuel treatments, and fire suppression. Results suggest that climate change and fuel treatments at expected future levels do not affect lynx habitat very much. However, fire suppression has a much more noticeable impact on lynx habitat.

These findings illustrate the important role fire plays in first providing and then removing quality lynx habitat. Lynx and snowshoe hare require a density of understory vegetation that primarily occurs about 10 to 20 years after fire. Without fire, the succession of plants moves beyond the structural stage snowshoe hare prefer for hiding cover. When fire is too frequent, the succession cycle is continually restarted and fails to reach the intermediary stages considered quality lynx habitat. The current level of fire suppression, set to 90 percent in the model, maintained more quality lynx habitat then allowing natural fires to burn. This result may be an artifact of nearly a century of fire suppression yielding a forest that simply can't be returned to natural conditions in the current climate without consequences to wildlife. This work provides important insights into the long-term preservation of wildlife habitat as well as adapts vegetation and disturbance simulation model to the field of wildlife habitat modeling.



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Example of Lynx habitat suitability maps at future 10-year intervals under climate change without fire suppression or fuel treatments.

Analyzing the Impact of Climate Change on Western White Pine

Western white pine (*Pinus monticola*), a five-needle pine species that forms the most diverse of the white pine forest cover types in the western United States, is vulnerable to interacting threats such as climate change, fire suppression, white pine blister rust (*Cronartium ribicola*), and mountain pine beetles (*Dendroctonus ponderosae*) that already have caused major changes in species distribution and abundance. FFS post-doctoral scientist Rachel Loehman used the mechanistic model FireBGCv2 to simulate effects of climate change and fire management on western white pines in a mountainous watershed in Glacier National Park, Montana.

Loehman's research results suggest that warming temperatures favor increased abundance of western white pine over existing climax and shade-tolerant species in the study area, mainly because warmer conditions affected fire dynamics, such as increased wildfire frequency and extent that facilitate regeneration.

Suppression of wildfires reduced the area dominated by western white pine, but fire suppression was less effective at limiting burned area extent and fire frequency in a warmer and drier climate. Wildfires created canopy gaps that allowed for western white pine regeneration at a high enough rate to escape local extirpation from white pine blister rust. Western white pine appears to be a resilient species even under fairly extreme warming trajectories and shifting fire regimes, and may provide a hedge against the shift of vegetation communities away from forest types and toward grass and shrub lands.

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Dense 160-year old western white pine stand on a lower north slope, Idaho, 1937.
U.S. Forest Service photo by K.D. Swan courtesy of the Forest History Society, Durham, N.C.

Synthesis, Outreach, and Lessons Learned

While FFS scientists and engineers investigate the current and future research needs of managers, they also synthesize and transfer their research results to ensure their work reaches decision makers in the field. Information transfer can take the form of publications, presentations, interactive computer programs, and training for diverse audiences. Researchers have also revisited study sites and evaluated previous research to ensure that the lessons learned in the past continue to be applied if still relevant. Scientists have even developed curricula and other materials to educate the next generation.

The Fire Lab hosts regular seminars featuring FFS researchers and experts from around the country to discuss ongoing research and transfer lessons learned to the wildland fire research and education communities.

Providing Expert Testimony

In late June 2012, the Waldo Canyon Fire swept through Colorado Springs destroying hundreds of homes. Later that summer, Senator Mark Udall hosted a Senate Energy and Natural Resources Committee hearing to address the issues of wildland fire at the Colorado Springs campus of the University of Colorado. FFS research scientist Jack Cohen testified at the August 15 hearing as a subject matter expert on preventing home ignitions during wildland fires.

After the Senate hearing, Cohen spent the afternoon interviewed at the site of the Waldo Canyon Fire for a documentary on what homeowners can do to protect their homes during extreme wildfire conditions such as those that occurred in Colorado Springs. That evening, in a public meeting, Cohen presented what his research has documented about how fire disasters occur and how homes ignite during such disasters. He introduced the concept of the home ignition zone and demonstrated how homeowners could make their homes ignition resistant during extreme wildfires. He also emphasized that firefighters depend on homeowners to make their homes ignition resistant to help them protect homes during extreme wildfire conditions.

For more information, contact:
Jack Cohen at jcohen@fs.fed.us

For a documentary on protecting homes from wildland fires produced by Awareness Media, Cohen emphasized how the home ignition zone -- the characteristics of a home and its immediate surroundings within 30 m. (100 ft.) – primarily determines home ignition potential during extreme wildfire conditions and how homeowners can effectively mitigate the zone to make their homes ignition resistant.

After the wildfires in Colorado Springs in 2012, FFS research scientist Jack Cohen gave a public presentation to homeowners on how to protect their property from wildland fire.

Managing Two-Aged Lodgepole Pine Forests in Central Montana

Lodgepole pine is one of the most widely distributed conifers in North America. Throughout much of its range, the fire regime is mixed-severity rather than stand replacement, resulting in patchy and often multi-aged lodgepole pine forests. With fire exclusion, lodgepole pine forests gradually become more homogeneous and one-age.

To determine the most appropriate treatment to create multi-aged lodgepole pine stands, FFS ecologist Sharon Hood, working with Helen Smith, David Wright, and Lance Glasgow, implemented a combination of thinning and prescribed burning treatments on the Tenderfoot Creek Experimental Forest in Montana. Thinning treatments included an even-distribution thin and a group-distribution thin. The researchers measured changes in fuel loading, tree density, and tree mortality due to fire, finding that even-distribution thinning alone, or combined with prescribed fire, resulted in extremely low overstory density, while group thins retained higher overstory density. Research indicated that prescribed fire in lodgepole pine stands should be very patchy to limit mortality.

The investigators have produced a guide to help managers determine potential effects of harvesting and prescribed burning in lodgepole pine to create multi-aged stands. They report changes in tree density and fuel loading following thinning and prescribed burning, as well as make recommendations for areas where wind throw is a concern. Results are organized by unit so that users can match a study unit stand condition and treatment to their own stand and proposed treatment to estimate potential effects.

For more information, contact:

Sharon Hood at shood@fs.fed.us

Crews measured vegetation and fuels before and after prescribed burns in each unit. They then returned six years later to measure vegetation and fuels.

Learning from Incomplete Fuel Treatments

Researchers have worked to assess the impacts of biomass reduction in high-risk areas such as the wildland/urban interface where treatments are intended to minimize the risk of wildfire behavior, allow for more effective suppression, and reduce severe fire effects when a wildland fire does occur. As a result, the scientific literature dealing with fuel treatment effectiveness is growing. However, general results in the literature are quite variable, showing reduced, increased, or no effect on fire behavior and fire effects.

To better understand this variability, researchers conducted a retrospective assessment of the influence of a fuel treatment on fire behavior and effects in the Tin Cup Fire of 2007 in the Bitterroot National Forest. FFS research forester Mick Harrington and collaborator Erin Noonan-Wright collected detailed data from the 2007 fire including field sampling of stand attributes, surface/ground fuels, and fire impacts; interviews with fire fighters, including incident commander's notes; photographs and GIS data; nearest weather station data; and internet fire data. The study, while small in scale, revealed variable results within the treated vs. untreated study area but, as significantly, led to an assessment of the types of data and other information needed to best evaluate fuel treatment influences in the future.

As a result of this review, the researchers developed the following recommendations to help reduce uncertainty concerning fuel treatment effectiveness: 1) understand weather and fire behavior in each comparative treatment; 2) discern the quality and quantity of fire suppression activity in each comparative treatment; 3) determine species composition and stand structure to understand tree mortality; and 4) distinguish surface and canopy fuels in each comparative treatment. By collecting data in all four recommendations as part of their analysis, managers can increase what is known about effective treatments. Taking such an approach can also help others make more informed decisions about when, how, or if to treat biomass accumulation in high-risk and other areas.

For more information contact:

Mick Harrington at mharrington01@fs.fed.us

Fire severity was 34% tree mortality in the left photo compared to the right photo with 77% mortality.
Contrasting fire weather was the main influence of fire behavior and severity in these adjacent sites and not the fuel treatment.

Characterizing Information on Fire and Invasive Plants

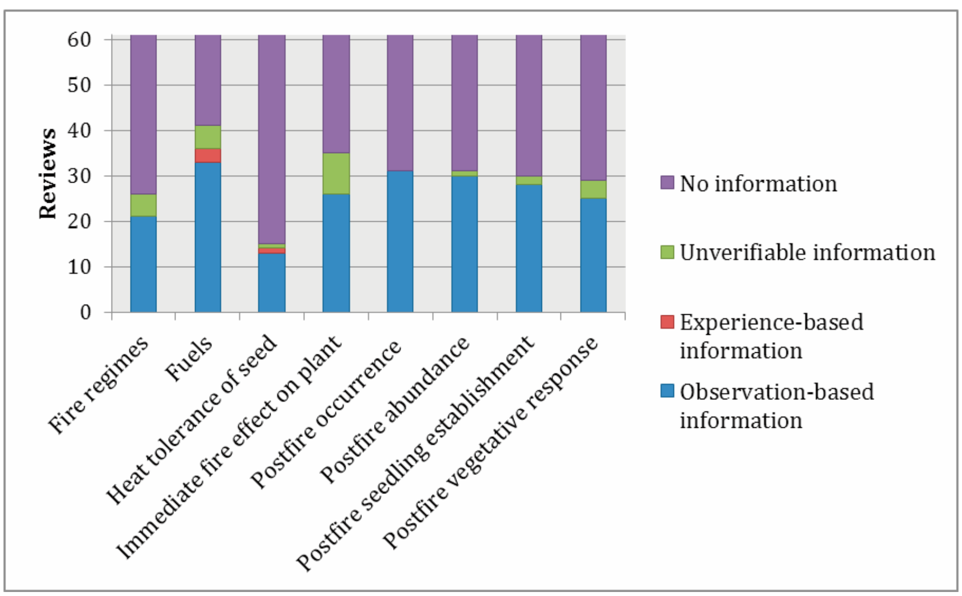
Wildland managers need detailed information about the responses of invasive species to fire and the conditions that increase site invasibility in order to effectively manage fire without introducing or increasing populations of invasive plants. Literature reviews and syntheses of original research are important sources of this information, but the usefulness of a review is limited by the quantity, quality, and geographic coverage of information available when it is written. A study recently published in *Fire Ecology* (Volume 8, Issue 2) analyzed the information available for 61 syntheses published in the Fire Effects Information System be¬tween 2008 and 2011, covering 74 species of invasive plants in the eastern United States.

Reviewers focused on the origin of information available in source documents, particularly whether or not it was based on actual observations. They found that observation-based information available on fire and eastern invasive species was sparse, typically came from a small portion of the species' North American range, and had many other limitations. Their study led to a series of recommendations for scientists, managers, and the authors of syntheses, including important standards for these kinds of reviews in the future.

For more information, contact:

Kris Zouhar at kzouhar@fs.fed.us or

Jane Kapler Smith at jsmith09@fs.fed.us



Educating the Next Generation

In addition to outreach and training for wildland fire professionals and other land managers, researchers at the Missoula Fire Sciences Laboratory have organized a Conservation Education Committee to transfer knowledge about wildland fire and native species to teachers and their students. As one of their many educational projects, these FFS researchers have created a new curriculum for Montana native prairie.

Inspired by a Forest Service poster of trees of the United States published in the 1970s, students are sent on a "scavenger hunt," seeking plants that match photos in their workbooks. Students mark their finds on a game board as they review pictures and facts about each species, including the plants' response to fire.

In 2012, 15 elementary school children field tested the curriculum in the native prairie garden adjoining the Fire Lab. The curriculum will be refined based on feedback from the students and their teacher.

The Conservation Education Committee plans to include more advanced materials suitable for middle school students. When completed, the educational materials and templates will be available at the Fire Lab's website.

For more information, contact:

Faith Ann Heinsch at faheinsch@fs.fed.us

Missoula-area elementary school students on a native prairie scavenger hunt.

Expanding a Curriculum for Indian Country

This project adapted the Rocky Mountain Research Station's FireWorks program for educational use in the northern Great Plains, especially in the Missouri River watershed. "FireWorks for Missouri River Country" addresses wildland fire from the spine of the Rockies to the edge of the Tallgrass Prairie. Developed by ecologists at the Missoula Fire Sciences Lab, the program uses hands-on activities to bring the science of wildland fire to students in K-12 classrooms. The program consists of a curriculum and a trunk of materials, including laboratory equipment, specimens, CDs, books, and kits of specialized materials for teachers, and focuses on fire ecology, fire behavior, and human influences on fire-dependent ecosystems.

The curriculum is designed to incorporate traditional ecological knowledge and technology from individual tribes, such as fire carriers and use of fire-dependent plant and animal species. Two complete FireWorks for Missouri River Country trunks have been assembled and delivered, one to the Great Plains Region and the other to the Rocky Mountain Region of the Bureau of Indian Affairs.

For more information, contact:

Jane Kapler Smith at jsmith09@fs.fed.us

Participants in a teacher workshop use the FireWorks felt board to demonstrate the role of fire on the prairies of the Missouri River country.

The Research Continues

The quest to understand wildland fire behavior and its effects is an ongoing process, with some research, by design, spanning multiple years. The following provides a brief overview of some of the Fire, Fuel, and Smoke Science projects currently underway at the Missoula Fire Sciences Lab.

Western juniper snag in Eastern Oregon, photo by Richard F. Miller

Improving Smoke Transport Models with Airborne Experiments

Wildland fires are a significant source of airborne pollutants. While much progress has been achieved in understanding the smoke chemistry of prescribed burning, significant knowledge gaps have hindered the development of reliable wildland fire smoke modeling systems. FFS atmospheric chemist Shawn Urbanski has been working on a multi-year smoke chemistry field research project, measuring emissions and smoke dispersion from 25 wildfires in the western U.S. Using a Forest Service Cessna aircraft, he and fellow researchers have found that wildfires in the interior mountain west burned with much lower combustion efficiency than prescribed fires. Thus, for a given mass of vegetation burned, wildfires emit more fine particulate matter, and more non-methane organic compounds, which lead to increased levels of ground-level ozone. This can negatively impact human health, as well as wildlife and terrestrial ecosystems. These results indicate that previous estimates of wildfire emissions underestimated the production of these pollutants and the potential of wildfires to degrade local and regional air quality.

For more information, contact:
Shawn Urbanski at surbanski@fs.fed.us

Crossdating the Trees of Central Oregon

FFS research forester Emily Heyerdahl, working with the Central Oregon Fire Management Service (a consortium of the Deschutes and Ochoco National Forests, the Prineville BLM, and the Crooked River National Grassland), the Nature Conservancy, and a dendroecologist from the University of Arizona, continues her study to crossdate wood more than 6000 trees sampled in a range of forest types including mixed conifer, lodgepole pine, and western juniper. This analysis will be used to identify the range of variation in historical fire regimes across forest types in the region, as well as the climate drivers of past regional fire years. When completed, it also will help managers and others better plan for future climate change and disturbances.

For more information, contact: Emily Heyerdahl at eheyerdahl@fs.fed.us

The Research Continues

Quantifying the Potential Effects of Mountain Pine Beetle on Wildland Fire Behavior

Many areas of the Rocky Mountain West continue to be affected by the mountain pine beetle (Dendroctonus ponderosae) due, in part, to single-age stands and warmer climate. FFS scientists have continued to investigate changes in foliar chemistry and moisture in affected stands and how they impact fire behavior. In laboratory tests, flaming embers were dropped into collected pine needles from beetle-affected trees. Needles with moisture levels in the mid-teens consistently caught fire from a single ember. Additionally, FFS scientists found that the red needles of attacked trees ignite three times faster than the needles of healthy trees and that both foliar chemistry and needle moisture content were the most important factors in determining a needle's flammability. This suggests that forests with large number of beetle-killed trees are at a significantly higher risk of burning as actively spreading crown fires.

Crown fires cannot be directly suppressed by ground resources, and are very dangerous to firefighters and communities. Researchers are continuing to test the rates of needle loss, simulated fire behavior, and detection. While still ongoing, this research provides justification for fuel treatments in beetle-killed forests, helps to increase firefighter awareness of dangerous situations, and assists managers in identifying areas at high risk for ignition and extreme fire behavior. Because of its importance and potential to save lives, preliminary results have been presented to regional fire managers.

For more information, contact:

Matt Jolly at mjolly@fs.fed.us or

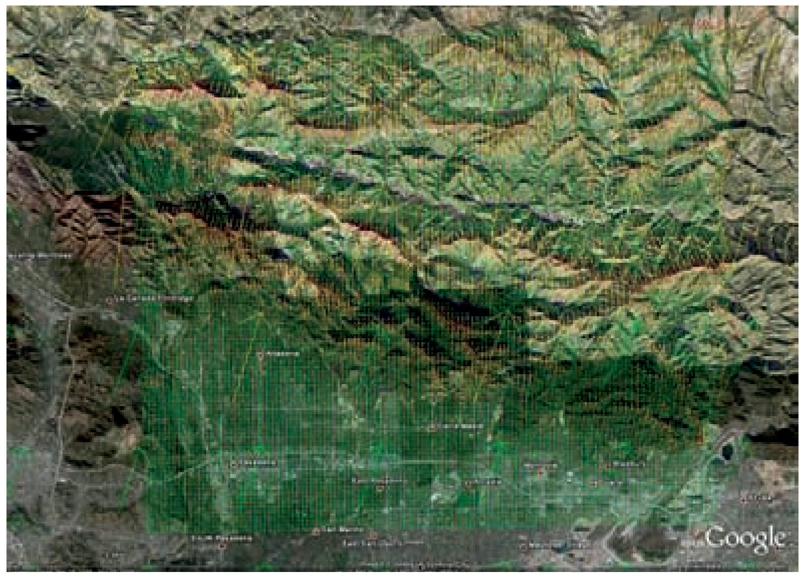
Russ Parsons at rparsons@fs.fed.us

Photo: NEMO Ops Chiefs on Salt Fire

The Research Continues

Using WindNinja to Downscale Weather Model Data

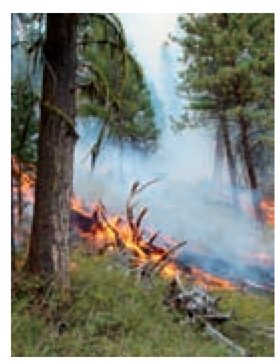
Wind can be the dominant environmental variable affecting wildland fire intensity and spread. When fire is burning in mountainous terrain, winds can vary widely in speed and direction over scales of 3 to 200 feet. The result is rapid changes in fire intensity at small scales that can have significant influences on fire growth at larger scales. Supported by the Joint Fire Science Program, FFS researchers Bret Butler and Jason Forthofer and partner GCS Research continue to develop new tools to simulate surface wind flow at these micro scales and to apply these new applications into a recently developed wind model, WindNinja, available from the U.S. Forest Service.



For more information, contact: Bret Butler at bwbutler@fs.fed.us

Classifying Fire Severity Based on Surface Fuel Combustion

Post-doctoral researcher Pamela Sikkink and research ecologist Robert Keane have continued their work to develop a fire-severity classification that quantifies unique biomass consumption, fire residence time, fire intensities, and depth and temperatures of burns. Their work to summarize the complex interactions of fire, fuels, and the biophysical environment into distinct severity classes promotes a better understanding of how surface fuels and moisture affect burn severity. The nine classes developed in their study are being used to develop fire-severity keys for a mapping system for real-time fire management (FIRESEV). They can also be used for making burn-severity estimates from prescribed fire plans or fuel reduction projects.



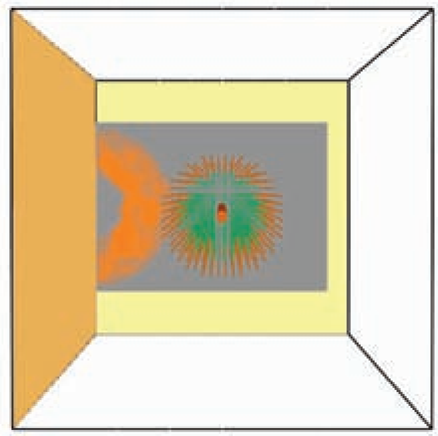
For more information, contact: Pamela Sikkink, psikkink@fs.fed.us or Robert Keane at rkeane@fs.fed.us

The top photo illustrates WindNinja simulation of weather model forecast winds for the Indians Fire Southeast of Monterey, CA.

The Research Continues

Isolating the Effects of Western Spruce Budworm

Insects are often thought to increase fire hazard or behavior, but precise links between historical western spruce budworm outbreaks and fire are difficult to make from dendrochronology alone. FFS researchers Greg Cohn, Russ Parsons, and Emily Heyerdahl, working with Dan Gavin at the University of Oregon, are using 3D fire models, to understand the impact and magnitude of western spruce budworm outbreaks in the Interior West.



To isolate the effect of defoliation on crown fuels, FFS researchers simulated single-tree torching across a range of crown fuel changes that occur during western spruce budworm infestations. By isolating the effects on a single tree and simulating them in a 3D fire model (WFDS), researchers identified precise links between western spruce budworm disturbance and fire behavior changes. Initial findings show that defoliation dampens crown fire behavior by increasing the surface fire intensity necessary to ignite a tree and by inhibiting fire spread between crowns.

For more information, contact: Greg Cohn at gcohn@fs.fed.us

Innovating with LIDAR Technology

LIDAR (Light Detection and Ranging) technology uses a laser beam to determine atmospheric properties and provide a three-dimensional image of the optical characteristics. For investigating wildfires, LIDAR is generally mounted on an airplane, making the process expensive to use and limited in its range of applications. To move this kind of technology into the field, the researchers at the Missoula Fire Sciences Laboratory have developed a truck-mounted LIDAR scanning system designed specifically for smoke plume monitoring. The LIDAR can be programmed to scan in any direction, providing critical real-time (short- or long-term) monitoring while operating from a safety zone outside a burn area, guaranteeing the safety of research personnel.

For more information, contact:
Vladimir Kovalev at akovalev@fs.fed.us

Western spruce budworm-induced foliage reduction (top right), modeled in a three-dimensional fire model.

Tracking Climate, Wildland Fires, and Native Trout

Many native fish, such as bull trout and cutthroat trout, evolved with fire, and their populations are resilient to fire's effects if their habitat is otherwise unaffected, or if fish from nearby, robust populations have freedom of movement. This resiliency has been reduced in many watersheds because of stream habitat fragmentation and degradation, and the invasion of nonnative fishes such as brook trout and brown trout that tolerate warmer water temperatures. Climate change may further weaken this resiliency by directly increasing water temperatures and by changing the influence of fire. Thus, forecasting the persistence of native trout undergoing climate change requires an understanding of fire dynamics – including size, distribution, frequency, severity, and the influence of fuels management – and the responses of nonnative fish species.

FFS ecologist Lisa Holsinger, collaborating with researchers at the University of Montana, continues to investigate how a changing climate might affect wildland fire regimes and stream temperatures. Using a landscape fire succession simulation model Fire-BGCv2, a stream temperature model, and a trout growth model, researchers are forecasting potential changes in trout species distributions and productivity in the East Fork Bitterroot River basin in Montana. This basin has a history of large, stand-replacing fires, yet still supports native fish populations in many tributaries so the researchers hope to develop an understanding about those fire and landscape characteristics that pose higher risks for native trout species.

For more information, contact: Lisa Holsinger at lholsinger@fs.fed.us

Photograph: Joel Sartore/ National Geographic & Wade Fredenberg/ US Fish and Wildlife Service

The Research Continues

Identifying Fire Safety Zones

All wildland firefighters in the United States are required to identify safety zones when working on or near a fire. In 1999 and 2000, researchers conducted a survey of wildland fire managers as part of a training presentation. The results from the surveys indicate wide discrepancies in size and/or distance from fires when evaluating the safety zones. Clearly, better guidelines are needed to protect firefighters on the job.

Ongoing work by FFS researchers Bret Butler and Russ Parsons, collaborating with the Pacific Wildland Fire Sciences Laboratory (PNW Research Station) and Brigham Young University, has shown that when located on a flat terrain in the absence of significant winds, safety zone models based on radiant-only energy transport can be relatively accurate and vary from 2 to 8 times the flame height. However, in the presence of slope and wind, convective energy transport becomes increasingly significant, increasing the minimum acceptable safe distance from flames to prevent injury. Funded by the Joint Fire Sciences Program, this research will result in new safety zone guidelines.

For more information, contact: Bret Butler at bwbutler@fs.fed.us

Fire fighters from California arrive at the Mount Saint Francois area of Colorado Springs, CO, in June, 2012. USDA photo by U.S. Air Force Master Sgt. Jeremy Lock.

The Fire, Fuel, and Smoke (FFS) Science Program of the Rocky Mountain Research Station focuses on fundamental and applied research related to the processes and effects of wildland fire. While the research crosses disciplines and involves investigators from different agencies and organizations, the FFS Science Program focuses on six primary focus areas: physical fire processes, fuel dynamics, smoke emissions and dispersion, fire ecology, fire and fuel management strategies, and science synthesis and delivery. The following list provides an overview of 2012 publications that focus on these six areas, including links to the publication when available.

Physical Fire Processes

Andrews, P.L. 2012. Modeling wind adjustment factor and midflame wind speed for Rothermel's surface fire spread model. Gen. Tech. Rep. RMRS-GTR-266. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 39 p. http://www.treesearch.fs.fed.us/pubs/39729

Finney, Mark A.; Cohen, Jack D.; McAllister, Sara S.; Jolly, W. Matt. 2012. On the need for a theory of wildland fire spread. International Journal of Wildland Fire. http://dx.doi.org/10.1071/WF11117. http://www.treesearch.fs.fed.us/pubs/41395

Frankman, David; Webb, Brent W.; Butler, Bret W.; Jimenez, Daniel; Forthofer, Jason M.; Sopko, Paul; Shannon, Kyle S.; Hiers, Kevin J.; Ottmar, Roger D. 2012. Measurements of convective and radiative heating in wildland fires. International Journal of Wildland Fire. http://dx.doi.org/10.1071/WF11097. http://www.treesearch.fs.fed.us/pubs/42185

Frankman, David; Webb, Brent W.; Butler, Bret W.; Jimenez, Daniel; Harrington, Michael. 2012. The effect of sampling rate on interpretation of the temporal characteristics of radiative and convective heating in wildland flames. International Journal of Wildland Fire. http://dx.doi.org/10.1071/WF12034. http://www.treesearch.fs.fed.us/pubs/42186

Jolly, W. Matt; Parsons, Russell A.; Hadlow, Ann M.; Cohn, Greg M.; McAllister, Sara S.; Popp, John B.; Hubbard, Robert M.; Negron, Jose F. 2012. Relationships between moisture, chemistry, and ignition of Pinus contorta needles during the early stages of mountain pine beetle attack. Forest Ecology and Management. 269: 52-59. http://www.treesearch.fs.fed.us/pubs/40129

McAllister, S.; Grenfell, I.; Hadlow, A.; Jolly, W.M.; Finney, M.; Cohen, J. 2012. Piloted ignition of live forest fuels. Fire Safety Journal. 51: 133-142. http://www.treesearch.fs.fed.us/pubs/41114

Nelson, Ralph M., Jr.; Butler, Bret W.; Weise, David R. 2012. Entrainment regimes and flame characteristics of wildland fires. Int. J. Wildland Fire. 21: 127-140. http://www.treesearch.fs.fed.us/pubs/40492

2012 Publications

Fuel Dynamics

Contreras, M.A.; Parsons, R.A.; Chung, W. 2012. Modeling tree-level fuel connectivity to evaluate the effectiveness of thinning treatments for reducing crown fire potential. Forest Ecology and Management. 264: 134-149. http://www.treesearch.fs.fed.us/pubs/40160

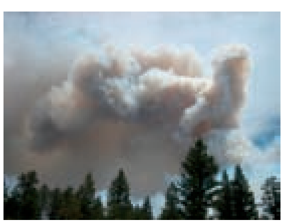
Jolly, W. Matt; Hadlow, Ann M. 2012. A comparison of two methods for estimating conifer live foliar moisture content. International Journal of Wildland Fire. 21: 180-185. http://www.treesearch.fs.fed.us/pubs/41392

Jolly, W. Matt; Parsons, Russell; Varner, J. Morgan; Butler, Bret W.; Ryan, Kevin C.; Gucker, Corey L. 2012. Do mountain pine beetle outbreaks change the probability of active crown fire in lodgepole pine forests? Comment. Ecology. 93(4): 941-946. http://www.treesearch.fs.fed.us/pubs/41115

Keane, Robert E.; Gray, Kathy; Bacciu, Valentina; Leirfallom, Signe. 2012. Spatial scaling of wildland fuels for six forest and rangeland ecosystems of the northern Rocky Mountains, USA. Landscape Ecology. doi: 10.1007/s10980-012-9773-9. http://www.treesearch.fs.fed.us/pubs/41391

Keane, Robert E.; Gray, Kathy; Bacciu, Valentina. 2012. Spatial variability of wildland fuel characteristics in northern Rocky Mountain ecosystems. Res. Pap. RMRS-RP-98. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Smoke Emission and Dispersion



Akagi, S.K.; Craven, J. S.; Taylor, J.W.; McMeeking, G.R.; Yokelson, R.J.; Burling, I.R.; Urbanski, S.P.; Wold, C.E.; Seinfeld, J.H.; Coe, H.; Alvarado, M.J.; Weise, D.R. 2012. Evolution of trace gases and particles emitted by a chaparral fire in California. Atmos. Chem. Phys. 12: 1397-1421. http://www.treesearch.fs.fed.us/pubs/40140

Akagi, S. K.; Yokelson, R. J.; Burling, I. R.; Meinardi, S.; Simpson, I.; Blake, D. R.; McMeeking, G. R.; Sullivan, A.; Lee, T.; Kreidenweis, S.; Urbanski, S.; Reardon, J.; Griffith, D. W. T.; Johnson, T. J.; Weise, D. R. 2012. Measurements of reactive trace gases and variable O3 formation rates in some South Carolina biomass burning plumes. Atmos. Chem. Phys. Discuss. 12: 25255-25328.

Kovalev, Vladimir; Wold, Cyle; Petkov, Alexander; Hao, Wei Min. 2012. Direct multiangle solution for poorly stratified atmospheres. Applied Optics. 51(25): 6139-6146. http://www.treesearch.fs.fed.us/pubs/41488

Kovalev, V.A.; Wold, C.; Petkov, A.; Hao, W.M. 2012. Profiling of poorly stratified atmospheres with scanning lidar (elastic lidar and HSRL in scanning mode: comparison). In: Proceedings: 26th International Lasar Radar Conference; 2012 June 25-29; Porto Heli, Greece. Poster.

Kovalev, Vladimir; Wold, Cyle; Petkov, Alexander; Hao, Wei Min. 2012. Profiling of poorly stratified smoky atmospheres with scanning lidar. In: Papayannis, Alexandros; Balis, Dimitrios; Amiridis, Vassilis, eds. Proceedings: 26th International Laser Radar Conference; 2012 June 25-29; Porto Heli, Greece. 1: 289-292. http://www.treesearch.fs.fed.us/pubs/41390

Samsonov, Y. N.; Ivanov, V. A.; McRae, D. J.; Baker, S. P. 2012. Chemical and dispersal characteristics of particulate emissions from forest fires in Siberia. International Journal of Wildland Fire. http://dx.doi.org/10.1071/WF11038. http://www.treesearch.fs.fed.us/pubs/41389

Wang, Yuesi; Xin, Jinyuan; Li, Zhanqing; Wang, Shigong; Wang, Pucai; Hao, Wei Min; Nordgren, Bryce L.; Chen, Hongbin; Wang, Lili; Sun, Yang. 2012. Seasonal variations in aerosol optical properties over China. Journal of Geophysical Research. 116: D18209. http://www.treesearch.fs.fed.us/pubs/41491

Wold, Cyle E.; Kovalev, Vladimir A.; Petkov, Alexander P.; Hao, Wei Min. 2012. Data processing technique for lidar sounding of poorly stratified polluted atmospheres. Theory and experiment. In: Proceedings of the Aerosol and Atmospheric Optics: Visibility & Air Pollution Specialty Conference; 24-28 September 2012; Whitefish, Montana. Poster.

Wold, Cyle E.; Kovalev, Vladimir A.; Petkov, Alexander P.; Hao, Wei Min. 2012. Data processing technique for multiangle lidar sounding of poorly stratified polluted atmospheres. Theory and experiment. In: Proceedings of the Aerosol and Atmospheric Optics: Visibility & Air Pollution Specialty Conference; 24-28 September 2012; Whitefish, Montana. Extended Abstract #12: 6 p.

Yokelson, R. J.; Burling, I. R.; Gilman, J. B.; Warneke, C.; Stockwell, C. E.; de Gouw, J.; Akagi, S. K.; Urbanski, S. P.; Veres, P.; Roberts, J. M.; Kuster, W. C.; Reardon, J.; Griffith, D. W. T.; Johnson, T. J.; Hosseini, S.; Miller, J. W.; Cocker, D. R. III; Jung, H.; Weise, D. R. 2012. Coupling field and laboratory measurements to estimate the emission factors of identified and unidentified trace gases for prescribed fires. Atmos. Chem. Phys. Discuss. 12: 21517-21578. 56 p. http://www.treesearch.fs.fed.us/pubs/42170

Fire Ecology

Harrington, Michael G. 2012. Duff mound consumption and cambium injury for centuries-old western larch from prescribed burning in western Montana. International Journal of Wildland Fire. doi: http://dx.doi.org/10.1071/WF12038

Hood, Sharon M.; Smith, Helen Y.; Wright, David K.; Glasgow, Lance S. 2012. Management guide to ecosystem restoration treatments: two-aged lodgepole pine forests of central Montana, USA. Gen. Tech. Rep. RMRS-GTR-294. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 126 p. http://www.treesearch.fs.fed.us/pubs/42173

Heyerdahl, E.K.; Lertzman, K.; Wong, C.M. 2012. Mixed-severity fire regimes in dry forests of southern interior British Columbia, Canada. Can J. For. Res. 42: 88-98. http://www.treesearch.fs.fed.us/pubs/40159

Keane, Robert E. 2012. Creating historical range of variation (HRV) time series using landscape modeling: Overview and issues. In: Wiens, John A.; Hayward, Gregory D.; Safford, Hugh D.; Giffen, Catherine M., eds. Historical environmental variation in conservation and natural resource management. West Sussex, UK: John Wiley & Sons, Ltd.: 113-127. http://www.treesearch.fs.fed.us/pubs/41490

Keane, Robert E. 2012. Modeling historic variation and its application for understanding future variability. In: Wiens, John A.; Hayward, Gregory D.; Safford, Hugh D.; Giffen, Catherine M., eds. Historical environmental variation in conservation and natural resource management. West Sussex, UK: John Wiley & Sons, Ltd.: 111-112. http://www.treesearch.fs.fed.us/pubs/41489

Loehman, Rachel A.; Elias, Joran; Douglass, Richard J.; Kuenzi, Amy J.; Mills, James N.; Wagoner, Kent. 2012. Prediction of Peromyscus maniculatus (deer mouse) population dynamics in Montana, USA, using satellite-driven vegetation productivity and weather data. Journal of Wildlife Diseases. 48(2): 348-360. http://www.treesearch.fs.fed.us/pubs/40687

Ryan, Kevin C.; Jones, Ann Trinkle; Koerner, Cassandra L.; Lee, Kristine M. 2012. Wildland fire in ecosystems: effects of fire on cultural resources and archaeology. Gen. Tech. Rep. RMRS-GTR-42-vol. 3. Fort Collins, Co: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 224 p. http://www.treesearch.fs.fed.us/pubs/40417

Ryan, Kevin C.; Koerner, Cassandra L.; Lee, Kristine M.; Siefkin, Nelson. 2012. Effects of fire on cultural resources-Introduction [Chapter 1]. In: Ryan, Kevin C.; Jones, Ann Trinkle; Koerner, Cassandra L.; Lee, Kristine M (tech. eds.). Wildland fire in ecosystems: effects of fire on cultural resources and archaeology. Gen. Tech. Rep. RMRS-GTR-42-vol. 3. Fort Collins, Co: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 224 p. http://www.treesearch.fs.fed.us/pubs/40426

National Park Service photograph by Ann Deutch

2012 Publications

Ryan, Kevin C.; Koerner, Cassandra L. 2012. Fire behavior and effects: Principles for archaeologists [Chapter 2]. In: Ryan, Kevin C.; Jones, Ann Trinkle; Koerner, Cassandra L.; Lee, Kristine M (tech. eds.). Wildland fire in ecosystems: effects of fire on cultural resources and archaeology. Gen. Tech. Rep. RMRS-GTR-42-vol. 3. Fort Collins, Co: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 224 p. http://www.treesearch.fs.fed.us/pubs/40427

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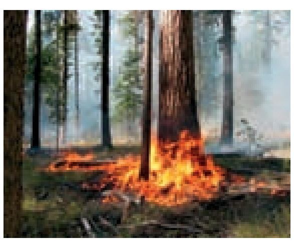

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