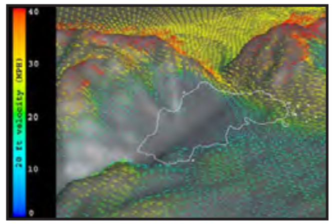
The Fire Lab's first smoke measurements were obtained from instruments located at Miller Creek in 1967 (left). But local information is not sufficient: Fires on all continents contribute to pollutants and greenhouse gases in the atmosphere. In 1987, the Fire Lab began studying the chemistry of smoke from burning biomass, whether wildfires or cooking fires. Chemists conducted field experiments in Brazil, South Africa, Russia, Mexico (right), and many other nations to describe the compounds in smoke, how they change over time, and where they go. Chemist Wei Min Hao contributed results to the United Nation's Intergovernmental Panel for Climate Change, which earned the Nobel Peace Prize in 2007 for increasing understanding of climate change.



Research at the Missoula Fire Sciences Lab continues to build on what has been learned in the past, and new technology is opening entire new fields of inquiry. A few examples:

- LIDAR (LIght Detection And Ranging) imagery describes smoke plumes in ever greater detail.
- Mathematical models are being used to map wind flow. This information improves the accuracy of fire spread predictions.
- Field work increases managers' ability to predict tree mortality caused by fire and bark beetles.
- Experimental work contributes to improved guidelines for safety of firefighters and homes.

Captions for selected illustrations:
p. 2, lower right: Fire Danger Class map for conterminus United States, September 9, 2010.
p. 3, 2nd from top: FARSITE (1994) simulates the growth of fires over complex terrain and under varying weather conditions.
p. 3, bottom: A 1x1 m area containing 4.5 kg of woody fuel, 2010.
p. 4, bottom center: Fires have created a complex pattern on this wilderness landscape as of 2010.
p. 5, bottom center: An old-growth ponderosa pine/western larch stand restored with thinning and fire,1990s.
p. 5,bottom right: A 2010 publication describes innovative methods for restoring whitebark pine.
p. 6, bottom: Measuring heat transfer into a section of tree stem.
p. 7, top left: State-and-transition diagram shows potential paths of succession. PP=ponderosa pine; DF=Douglas-fir.
p. 7, right: In a watershed currently dominated by forest, FIREBGCv2 predicts shrubs will dominate after 200 years of influence from changed climate and wildfire (2009).
p. 8, 2nd from bottom: WindWizard predicts wind patterns across a landscape, 2010.

The Missoula Fire Sciences Laboratory continues to produce new knowledge for safer, more effective, and ecologically appropriate management of wildland fire.
For more information, visit firelab.org.

By Jane Kapler Smith and Diane Smith. Review draft. If you have corrections or suggestions, please contact Jane (jsmith09@fs.fed.us, 406-329-4805).

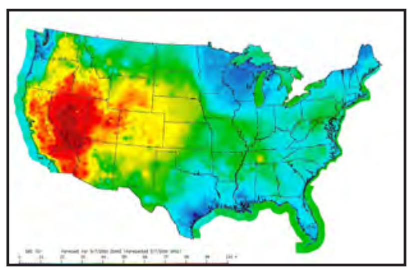
Missoula Fire Sciences Laboratory
1960 50 Years 2010

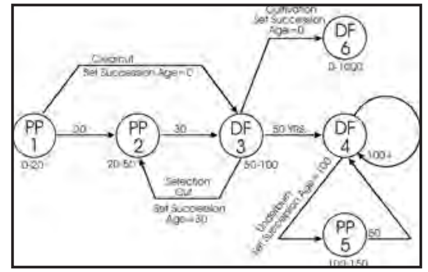
A 50-Year Trajectory of Research for Fire Management

On September 12, 1960, the brand-new Northern Forest Fire Laboratory was dedicated in Missoula, Montana. The Fire Lab's mission was to improve scientific understanding of wildland fire so it can be managed more safely and effectively in the field. The first scientists to work at the Lab initiated research that continues to be used, refined, and extended to this day. The questions studied and the technology used at the Fire Lab have evolved continually since 1960, and the Lab's name has changed more than once—today it is the Missoula Fire Sciences Laboratory. But the original focus—on developing greater understanding of fire and using the best technology available to get that knowledge into the hands of managers—has been a way of life for Fire Lab scientists for a half-century.

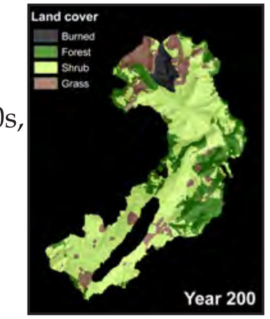
Severe, life-destroying fires plagued US forests in the late 19th and early 20th centuries. To help field rangers predict and suppress such fires, the agency initiated a fire research program. In the 1920s, scientist Harry Gisborne (top) began developing a way to predict fire danger. Believing that the moisture content of fuels (grass, leaves, twigs, and other material on the forest floor) was key, Gisborne weighed known amounts of fuel regularly, calculated their moisture content, and related the changes to weather conditions. These results were immediately put to use in the field. But to improve fire danger predictions, a laboratory was needed. This need was met with the opening of three research laboratories, including the Missoula Lab in 1960. Jack Barrows (bottom) was named Chief.

Barrows brought in foresters, physicists, and engineers to develop quantitative indicators of fire danger. Within 5 years, these scientists had conducted more than 200 experimental burns and identified thresholds of fuel moisture that could be used to identify "red-flag" conditions, when fire danger was increasing rapidly. Continued experiments contributed to release of the National Fire Danger Rating System (NFDRS) in 1972, which provided managers with a nationally standardized system for assessing fire danger from local weather observations. With revisions in 1978 and 1988, the NFDRS still forms the basis for local fire danger rating, shared with the public on hundreds of Smokey Bear signs throughout the nation (left). In 1994, Fire Lab scientists developed the Wildland Fire Assessment System (WFAS), which consolidates data from thousands of local weather stations to map fire danger across the country (right), alerting field managers to regional changes and emerging needs for fire suppression.

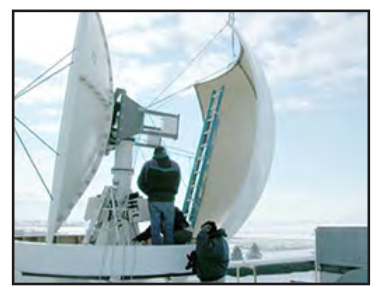




Ecosystems are constantly changing, with or without fire. How can these changes be predicted? Starting in the 1970s, scientists used state-and-transition diagrams (left) to illustrate patterns of vegetation change ("succession") after fire. When probabilities are assigned to these pathways, they can serve as predictive models. However, these models assume that the environment remains unchanging through time. In contrast, the FIRE-BioGeoChemical Succession Model (FIRE-BGC), initially developed in the 1990s, bases predictions on the flow of material and energy through ecosystems as influenced by weather, climate, fire, and many other factors. An updated version of the model is currently being used to explore potential changes in ecosystems due to changes in climate (right).



The sooner a manager knows where a fire is, the better—but it is not easy to locate fires in millions of acres of wildlands. In 1962, Fire Lab scientists began using aerial infrared photography to detect and map fires (top). Within a few years, managers adopted this technology to identify problem areas within fires, plan safety zones for firefighters, and locate spot fires. Infrared flights could map 3,000 square miles in an hour. Today's MODIS satellite imagery maps "hot spots" across the country several times a day. The Fire Lab receives this information via a globe-shaped satellite dish on the roof (bottom). Scientists use the data to map the burned area of on-going fires, which helps predict smoke production, the height of smoke plumes, and smoke dispersion rates, all matters of concern for safety and human health. These data also help scientists estimate the interactions between fire and climate change.



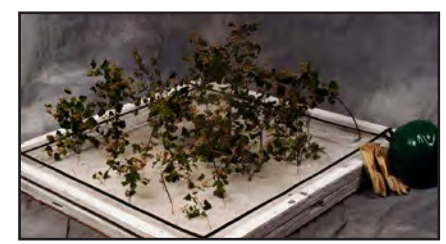
The Fire Lab not only produces new knowledge but also packages knowledge from around the world so it can be readily used by fire managers. From 1978-1981, Fire Lab scientists authored two of the six "Rainbow series" publications that detail how fire affects various ecosystem components. A comprehensive revision of this series began in 2000, with Fire Lab scientists editing 4 of the 6 new volumes (3 shown). The First Order Fire Effects Model (bottom) contains equations from research nation-wide predicting tree mortality, fuel consumption, soil heating, and smoke emissions from fire. Ecologists at the Lab also synthesize knowledge from thousands of studies, packaging the results in the Internet-based Fire Effects Information System, which currently hosts literature reviews covering more than 1,100 species (www.fs.fed.us/database/feis).

What kind of fire behavior would kill organisms in the soil? How much heat does it take to kill a tree? In the early 1980s, Fire Lab scientists conducted experiments measuring the transfer of heat from fire into soil and living organisms. Using the knowledge gained in these experiments, they developed a model to predict soil heating. This model helps managers predict the effects of fires on soil fertility and living things. Later experiments looked at heat transfer through the bark of trees into living cells. The FireStem model being developed jointly between the Missoula Fire Sciences Laboratory and the Forest Service's Northeastern Research Station describes heat transfer through tree bark (right). FireStem will help managers predict tree mortality based on fire behavior.

A crucial component of the National Fire Danger Rating System was the fire model developed by Richard (Dick) Rothermel (top) and published in 1972. The model predicts the spread and intensity of surface fire based on fuel properties, fuel moisture, wind, and slope. Soon after publication, the model was put to work for predicting fire behavior:

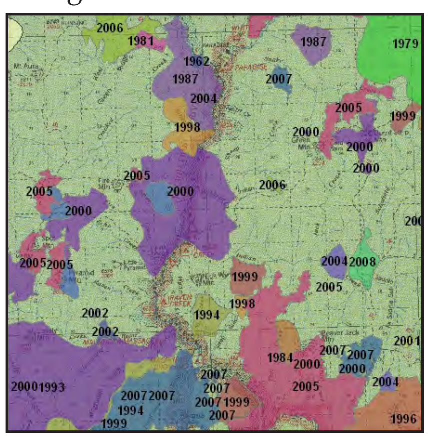
- Initially, a system of graphs and charts captured model results. Soon hand-held calculators were programmed to predict fire spread in the field.
- In the 1970s, the Rothermel model was integrated with dozens of supporting models into the BEHAVE system for predicting fire behavior in multiple weather and fuel conditions.
- In the 1990s, the availability of geospatial data on fuels and topography allowed the Rothermel model to be integrated with other models into programs for predicting fire perimeters and spatial fire behavior (bottom).
- In 2007, new systems were developed for simulating fire growth under thousands of weather scenarios so managers can estimate the likelihood of fire impacts.

How much fuel is available to "feed" a fire? Scientist Jim Brown (left) developed methods for measuring the amount of woody, shrub, and herbaceous fuels on the forest floor. Some of these measurements were consolidated into tables of numbers describing the fuels that "feed" the Rothermel fire model. Dozens of such fuel models are in use throughout the United States today. A recent innovation enables managers to match field observations with photographs of known amounts of fuel (right) to improve the accuracy, precision, and efficiency of fuel biomass estimation.



Fire spread in the forest canopy is more complex than on the forest floor. Careful dissection of hundreds of tree crowns (left) in the late 1990s enabled scientists to describe the vertical distribution of crown fuels. Research currently underway uses fractal mathematics to generate 3-dimensional models of crown fuels (right). These models can be used to describe fuel properties that are difficult to measure directly, such as surface area and distribution of particle sizes in tree crowns. This approach will improve managers' ability to predict crown fire behavior and estimate fire effects in the complex, discontinuous fuels of the canopy.

Through the 1960s, managers became increasingly aware of fire as a natural agent of change and renewal. In the early 1970s, scientist Robert (Bob) Mutch helped managers develop area-specific "prescriptions" for allowing some lightning fires to burn in the Selway-Bitterroot Wilderness. The first such fire occurred in 1972 (left), burned for 4 days, and covered all of 600 square feet. Since that time, lightning fires have burned more than 500,000 acres in the Selway-Bitterroot and Frank Church River of No Return Wilderness areas, producing an intricate mosaic of habitats across the landscape (right). Managers of natural areas across the country now recognize and welcome the ecological benefits of fire.



Most ecosystems have a specific relationship with fire, known as the fire "regime"—how often fires occur, their size, season and severity. Beginning in the 1970s, research forester Steve Arno (top, at right of photo) used fire scars on trees to determine the frequency of surface fires in ponderosa pine-Douglas-fir forests of the northern Rockies. More recently, research forester Emily Heyerdahl used fire scars (bottom) and tree growth rings to determine the climate during years of widespread fires in Idaho and western Montana. She identified 32 years when fires burned at many sites across the region. These years had warm springs followed by warm, dry summers.

In the late 1960s, the Fire Lab, with multiple collaborators, initiated a rigorous field study addressing the role of fire in forests of spruce, fir, and western larch—the Miller Creek-Newman Ridge project (left). In more than 30 publications, scientists reported the effects of prescribed fire in clearcut units on tree regeneration, small mammals, physical and chemical properties of soils, hydrology, re-establishment of shrubs and herbs, and smoke production. Since that time, Fire Lab scientists have studied ecosystem-level fire effects throughout the United States, particularly in forests dominated by ponderosa pine (below, center), Douglas-fir, lodgepole pine, and whitebark pine. Research on whitebark pine has led to international collaboration as scientists and managers seek ways to restore this unique ecosystem (right).