US FOREST SERVICE NORTHERN RESEARCH STATION

Research *Review*

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Forest Service Scientists Are Developing Fire-Weather and Smoke Prediction Tools—Where There's Fire, There's Smoke

Today's headlines highlight the problem that wildland fires have become in the United States, especially in the West. A century of aggressive fire suppression resulted in the growth of fire-susceptible forests in many places where fire-dependent and fire-resistant ecosystems had previously flourished. Complicating today's fire problems is the building of more communities and second homes in the wildland-urban interface (WUI), putting more people and their possessions directly in the path of fires.

Weather and climate affect wildland fires in many ways. Drought can kill vegetation, creating fuels that are conducive to extreme and erratic fire behavior. Episodic high temperatures and low relative humidity exacerbate longer-term drought effects and make fires harder to extinguish. Ambient and fire-induced winds can intensify the flames, often carrying fire into tree crowns and across roads and firebreaks and spreading embers miles away. Lightning starts many fires in dry regions. Knowing the specific weather conditions and dangers in fire-prone areas and specifically at fire lines is vital to good management and to the safety of fire crews.

continued on page two

Prescribed fire in a Florida pine forest.
Photo by Roger Ottmar, U.S. Forest Service.

continued from page one

WILDFIRES AND SMOKE CAN BE HEALTH AND SAFETY HAZARDS

Smoke generated by wildland fires creates multiple risks. Smoke is a health problem for residents living near fires and especially for firefighters who inhale smoke chronically. Wildfires and notably prescribed fires used to control fuels and maintain fire-dependent ecosystems can produce smoke that lingers for relatively long periods of time. People with conditions such as asthma, emphysema, chronic obstructive pulmonary disease (COPD), heart disease, and migraines are vulnerable. Smoke from wildland fires can also reduce visibility over nearby and downwind roads and highways.

SMOKE MANAGEMENT OF CONCERN THROUGHOUT THE NATION

Big, dramatic, and dangerous western wildfires certainly make the news. But even though large wildfires in the Northeast and Midwest are infrequent, they still happen; consider the 93,000-acre Pagami Creek Fire in the Boundary Waters Canoe Area Wilderness in 2011 or the 25,000-acre Mack Lake Fire in Michigan in 1980. Historically, several fires in the Midwest were terrible tragedies—Time magazine's list of Top 10 wildfires worldwide puts the October 1871 Peshtigo Fire in Wisconsin as #1 (2,500 dead, 1.2 million acres burned, and 12 towns destroyed) and the October 1918 Cloquet Fire in Minnesota as #7 (453 people dead, 250,000 acres and 52,000 homes burned, and 30 towns destroyed).

Prescribed fires (that is, those set by land managers for a defined goal), are used extensively in the Northeast and Midwest for fuels management, assisting oak regeneration, and enhancing wildlife habitat. In addition, there are indigenous fire-dependent ecosystems in these regions that burn frequently or need prescribed burning. (A fire-dependent ecosystem is an ecosystem that depends on periodic wildland fires to maintain habitats, promote plant and wildlife diversity, and remove accumulations of live and dead plant material.) These are the pitch pine barrens near the coastal Northeast, the oak-hickory forests in Pennsylvania and West Virginia, the Midwest tallgrass prairies, and the jack pine communities in the Great Lakes region.

Managing wildland fires in the densely populated Northeast and Midwest is challenging. To aid fire managers in these regions, fire and atmospheric scientists in the Forest Service's Northern Research Station (NRS) are developing new science-based tools to anticipate when and where extreme fire behavior will occur during wildfires and when and where smoke will adversely affect air quality.

Smoke from a low-intensity prescribed fire in the New Jersey Pine Barrens.
Photo by Warren Heilman, U.S. Forest Service.

NRS SCIENTISTS STUDY FIRE-ATMOSPHERE INTERACTIONS

NRS scientists are carrying out research and product development studies that will increase our understanding of how the atmosphere interacts with wildland fires and are using this knowledge to develop new predictive tools for fire and air-quality managers.

Smoke Transport: For example, in the area of smoke transport, NRS scientists Warren Heilman, Jay Charney, and Xindi Bian, in collaboration with researchers Sharon Zhong and Michael Kiefer at Michigan State University, are developing and evaluating a coupled meteorological and smoke dispersion modeling system for predicting the local atmospheric and air-quality impacts of low-intensity prescribed surface fires carried out beneath forest canopies. This modeling system (ARPS-CANOPY/PILT) is based on the Advanced Regional Prediction System (ARPS) atmospheric model (developed by the Center for Analysis and Prediction of Storms at the University of Oklahoma) coupled with the Pacific Northwest National Laboratory (PNNL) Integrated Lagrangian Transport (PILT) model. The system has been successfully applied to actual prescribed fire events in the New Jersey Pine Barrens and used as an analysis tool for assessing the air-quality impacts of a prescribed fire carried out at an EPA Superfund site in Pennsylvania. Further evaluations of the modeling system are underway in preparation for integrating the system into an appropriate operational smoke modeling framework. When integrated into such a framework, ARPS-CANOPY/PILT would offer fire managers an alternative tool for predicting how wildland fires in forested environments will affect local air quality, which is a limitation of current operational air-quality predictive tools because they don't account for the effects on forest overstory on local smoke transport.

Fire Weather: In the area of fire-weather processes, Charney is collaborating with Dan Keyser at the State University of New York at Albany; Brian Colle at the State University of New York at Stony Brook; Lifeng Luo at Michigan State University; and Alan Srock at St. Cloud State University to investigate the representation of meteorological processes within weather prediction models and to develop new tools to help use model outputs to improve fire weather forecasting and inform fire management decisions. These tools include assessments of (1) fire danger, which provide information about when weather conditions over the course of the next 1 to 5 days could promote the initiation and spread of wildland fires; and (2) fire behavior, which indicate the potential for weather to impact an existing fire such that increasingly severe or unexpected activity could occur that has the potential to endanger fire crews or complicate management decisions.

Fire-Atmosphere Interaction: NRS researchers are also investigating how meteorological phenomena and structures affect the evolution of wildland fires. They use high-resolution imagery, coupled fire-atmosphere models, and experimental data to simulate conditions and predict fire dangers. Heilman, Charney, and Bian are collaborating with William (Ruddy) Mell in the Pacific Northwest Research Station; Zhong and Kiefer at Michigan State University; Matt Dickinson at the NRS laboratory in Delaware, OH; and Kathleen Kavanagh at the University of Idaho in the use of the Wildland-urban Interface Fire Dynamics Simulator (WFDS) to explicitly simulate elements of the combustion processes that determine the spread characteristics and intensity of a fire, and then compare the simulations against high-resolution meteorological models such as ARPS-CANOPY to verify that the weather components of the WFDS are realistic. The results from both of the models are then used to assess the extent to which prescribed fires and wildfires affect live trees and the ecology of the affected forest. Finally, Heilman and Bian, in collaboration with Craig Clements and Daisuke Seto at San Jose State University and fellow NRS scientists John Hom at Newtown Square, PA; Kenneth Clark at the Silas Little Experimental Forest, New Lisbon, NJ; and Nicholas Skowronski at Morgantown, WV, are involved in a number of wildland fire experiments at the Silas Little EF to collect and analyze fire-atmosphere interaction data for assessing the role of atmospheric turbulence and forest vegetation in affecting fire behavior and smoke transport. Results from this research point to the need for including forest canopy effects in forecast tools used to predict how smoke from wildland fires is dispersed.

Photo supplied by the Joint Fire Science Program.

Prescribed fire in southern pine plantation. Photo by Scott Buell, Southern Fire Exchange, used with permission.

The Eastern Area Modeling Consortium

Heilman, Charney, and Bian represent the NRS in the Eastern Area Modeling Consortium (EAMC), one of five groups in the National Fire Consortia for Advanced Modeling of Meteorology and Smoke (FCAMMS) established in 2001 by the U.S. National Fire Plan. The EAMC is a multi-agency, informal coalition of researchers, fire managers, air-quality mangers, and natural resource managers at the federal, state, and local levels. This coalition works together to identify fire research needs, conduct fire-related scientific studies, develop products, and transfer new scientific knowledge and technology related to fire-weather dynamics, air-quality impacts, and fire-atmosphere interactions to serve the needs of the fire management community, air resource managers, scientists, and policymakers. Check out the EAMC web site at www.nrs.fs.fed.us/eamc for further details about the EAMC's current research studies and for obtaining real-time fire-weather predictions for the Midwest and Northeast.

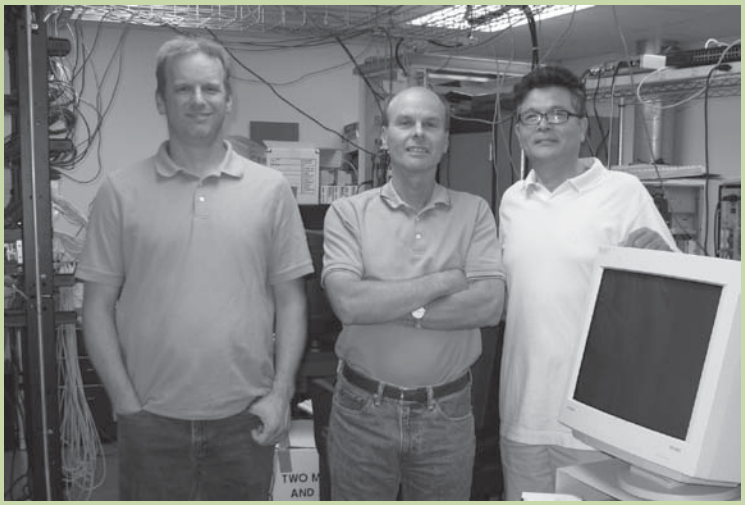
Fire personnel setting off prescribed burn in Midwestern prairie. Photo by Sherry Leis, Fire Science Program leader, Missouri State University, used with permission.

BIOGRAPHIES

Xindi (Randy) Bian is a meteorologist in the "Climate, Fire, and Carbon Cycle Sciences" unit, at Lansing, MI; he received an MS in water resources from Iowa State University (1993), and BS (1982) and MS (1985) in atmospheric sciences from Nanjing University, China. He joined the Forest Service in 2002.

Joseph J. (Jay) Charney, a research meteorologist at Lansing, MI, received his PhD in meteorology (1997) and a BS in physics (1990) from The Pennsylvania State University; he also received an MS in meteorology (1992) from the University of Maryland. He joined the Forest Service in 2001.

Warren E. Heilman is a research meteorologist stationed in Lansing, MI. He joined the Forest Service in 1990 and received his PhD (1988) and MS (1984) in meteorology from Iowa State University and his BS in physics from South Dakota State University (1979).



The research efforts of Heilman (center), Charney (left), and Bian (right) contribute to an improved understanding of fire-atmosphere interactions that will help produce the next generation of fire-weather, fire behavior, and smoke dispersion predictive tools.
Photo by Sharon Hobrla, USFS.

RESOURCES AND REFERENCES

Web Resources:

USFS Northern Research Station, Climate, Fire, and Carbon Cycle Sciences unit: www.nrs.fs.fed.us/units/climate/
Fire Research and Management Exchanges: www.frames.gov/rcs/8000/8187.html
Eastern Area Modeling Consortium: www.nrs.fe.fed.us/eamc
Eastern Area Coordination Center: gacc.nifc.gov/eacc
Eastern area daily fire danger map: wfas.net/images/firedanger/subsets/fdc_f_ea.png
Joint Fire Science Program: www.firescience.gov
National Interagency Fire Center, Boise, ID: www.nifc.gov
National Fire Plan: www.forestandrangelands.gov
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Fire predictions for 2014: www.predictiveservices.nifc.gov/statelinks.htm
Forest History Society: www.foresthistory.org/ASPNET/Policy/Fire/Research/Research.aspx
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EPA brochure on smoke health effects: www.epa.gov/airnow/particle/pm-color.pdf
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NRS Research Review is published quarterly by the Communications and Science Delivery Group of the Northern Research Station (NRS), U.S. Forest Service. As part of the Nation's largest forestry research organization, NRS serves the Northeast and Midwest and beyond, providing the latest research on current problems and issues affecting forests and the people who depend on them. Our research themes are (1) Forest Disturbance Processes, (2) Urban Natural Resources Stewardship, (3) Sustaining Forests, (4) Providing Clean Air and Water, and (5) Natural Resources Inventory and Monitoring.

There are 111 NRS scientists working at 20 field offices, 24 experimental forests, and universities located across 20 states, from Maine to Maryland, Missouri to Minnesota.