Toward Improving Our Application and Understanding of Crown Fire Behavior

Martin E. Alexander, Miguel G. Cruz, and Nicole M. Vaillant

The suggestion has been made that most wildland fire operations personnel base their expectations of how a fire will behave largely on experience and, to a lesser extent, on guides to predicting fire behavior (Burrows 1984). Experienced judgment is certainly needed in any assessment of wildland fire potential but it does have its limitations. The same can be said for mathematical models and computerized decision-support systems. Case history knowledge will prove a useful complement to fire behavior modeling and experienced judgment when it comes to appraising potential fire behavior (Alexander and others 2013b). Weighing each type of input in predicting wildland fire behavior is vital and yet is as much an art s a science.

The Continued Role of Wildland Fire Research

Wildland fire research has done much to contribute to our current understanding of the behavior of crowning forest fires through laboratory experiments, outdoor experimental burning, numerical modeling, and wildfire case histories. Presumably, the future holds similar promise, provided we are readily willing to admit what we still do not know about crown fires with respect to their environment, characteristics, and prediction. Several major research needs were in fact identified during a recent synthesis of knowledge on crown fire behavior (Alexander and others 2013a).

While basic research into fire fundamentals is essential to understanding the physical processes involved in crown fire dynamics, traditional scientific study and evaluating model performance are necessary to develop a complete picture of crown fire dynamics (Alexander and Cruz 2013). As new models are developed, model components (such as built-in functional forms, heat transfer processes, and sensitivity to environmental variables) must undergo the same robust evaluation as model outputs (such as rate of fire spread, flame depth, and flame height).

Wildfire Behavior Monitoring and Documentation Needs

There have been recent attempts to monitor and document the behavior of high-intensity crown fires (Alexander and Thomas 2003a, 2003b). Earlier efforts by fire researchers and fire meteorologists in various regions of the United States in the 1950s and 1960s were, for the most part, not sustained beyond the early 1970s (figure 1). Some efforts are now being made to monitor and document wildfire

The mobile fire laboratory used by the fire behavior documentation team of the Forest Service, Southern Forest Fire Laboratory, Macon, GA, on wildfires and prescribed fires during the 1960s and 1970s. Photo courtesy of Dale D. Wade, Forest Service (retired).

Dr. Marty Alexander is an adjunct professor of wildland fire science and management in the Department of Renewable Resources and Alberta School of Forest Science and Management at the University of Alberta in Edmonton, Alberta, Canada. Dr. Miguel Cruz is a senior research scientist with the CSIRO Ecosystem Sciences and Climate Adaptation Flagship in Canberra, Australian Capital Territory. Dr. Nicole Vaillant is a fire ecologist with the Forest Service, Pacific Northwest Research Station, Western Wildland Environmental Threat Assessment Center.

behavior—for example, by the Fire Behavior Assessment Team described in another article in this issue and by the Texas Forest Service, which has recently completed a number of wildland-urban interface case studies (Ridenour and others 2012).

Regretably, valuable information and insights into free-burning wildland fire behavior are not being captured in a systematic way. Consider for the moment that there is no quantitative data on rate of spread obtained from wildfires or prescribed fires by which to assess the accuracy of physics-based models used to simulate fire behavior in mountain pine beetle-attacked forests (Hoffman and others 2013, Linn and others 2013).

Less than a tenth of 1 percent of all wildfires is documented in a case study or history report. What is required is a permanently staffed, ongoing effort to do so. Alexander (2002) suggested that there is a need to create operational fire behavior research units specifically for this purpose. Recent advances in all aspects of the technology—communications, photography, weather observations, remote sensing, and infrared mapping, including the use of unmanned drones—associated with monitoring and documenting high-intensity wildfires have gradually made that task easier (Cruz and others 2012).

Such observation and documentation of crown fire behavior is crucial to evaluating new and existing predictive models of crown fire behavior (Holcomb and Rogers 2009, WDNR 2005). The completion of case histories on wildfires and prescribed fires is not strictly the domain of fire research; such a task should be regarded as a shared responsibility between wildland fire researchers and fire management personnel as part and parcel of adaptive management. Efforts to foster a culture within the wildland fire community that embraces the value of case histories is sorely needed.

References

Alexander, M.E. 2002. The staff ride approach to wildland fire behavior and firefighter safety. Fire Management Today. 62(4): 25–30.

Alexander, M.E.; Cruz, M.G. 2013. Are the applications of wildland fire behaviour models getting ahead of their evaluation again? Environmental Modelling and Software. 41: 65–71.

Alexander, M.E.; Cruz, M.G.; Vaillant, N.M.; Peterson, D.L. 2013a. Crown fire behavior characteristics and prediction in conifer forests: a state-of-knowledge synthesis. JFSP 09-S-03-1 Final Report. Boise, ID: Joint Fire Science Program. 39 p.

Alexander, M.E.; Heathcott, M.J.; Schwanke, R.L. 2013b. Fire behaviour case study of two early winter grass fires in southern Alberta, 27 November 2011. Edmonton, AB: Partners in Protection Association. 76 p.

Alexander, M.E.; Thomas, D.A. 2003a. Wildland fire behavior case studies and analyses: Value, approaches, and practical uses. Fire Management Today. 63(3): 4–8.

Alexander, M.E.; Thomas, D.A. 2003b. Wildland fire behavior case studies and analyses: Other examples, methods, reporting standards, and some practical advice. Fire Management Today 63(4): 4–12.

Burrows, N.D. 1984. Predicting blow-up fires in the jarrah forest. Tech. Pap. No. 12. Perth, Western Australia: Forests Department of Western Australia. 27 p.

Cruz, M.G.; Sullivan, A.L.; Gould, J.S.; Sims, N.C.; Bannister, A.J.; Hollis, J.J.; Hurley, R. 2012. Anatomy of a catastrophic wildfire: The Black Saturday Kilmore East Fire. Forest Ecology and Management. 284: 269–285.

Hoffman, C.M.; Morgan, P.; Mell, W.; Parsons, R.; Strand, E.; Cook, S. 2013. Surface fire intensity influences simulated crown fire behavior in lodgepole pine forests with recent mountain pine beetle-caused tree mortality. Forest Science. 59: 390–399.

Holcomb, J.; Rogers, G. 2009. North Fork complex wildfire—August 1–October 16, 2009—case study. Pendleton, OR: U.S. Department of Agriculture, Forest Service, Umatilla National Forest. 31 p.

Linn, R.R.; Sieg, C.H.; Hoffman, C.M.; Winterkamp, J.; McMillin, J.D. 2013. Modeling wind fields and fire propagation following bark beetle outbreaks in spatially-heterogeneous pinyon-juniper woodland fuel complexes. Agricultural and Forest Meteorology. 173: 139–153.

Ridenour, K.; Rissel, S.; Powell, W.; Gray, S.; Fisher, M.; Sommerfeld, J. 2012. Bastrop complex wildfire case study. College Station and Bastrop, TX: Texas Forest Service and Bastrop County Office of Emergency Management. 166 p.

U.S. Department of Agriculture, Forest Service. 1958. The Pond Pine Fire. In: Annual Report – 1957. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 53-54.

U.S. Department of Agriculture, Forest Service. 1959. Fire behavior studies on going fires. In: Highlights in Research, Annual Report – 1958. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 36.

U.S. Department of Agriculture, Forest Service. 1970. Alaska wildfire rate of spread rapid. In: 1969 Annual Report. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 15 p.

WDNR. 2005. The Cottonville Fire, May 5, 2005: Final report. Madison, WI: Wisconsin Department of Natural Resources. 131 p.

Past Efforts of Monitoring Wildfire Behavior in Conifer Forests

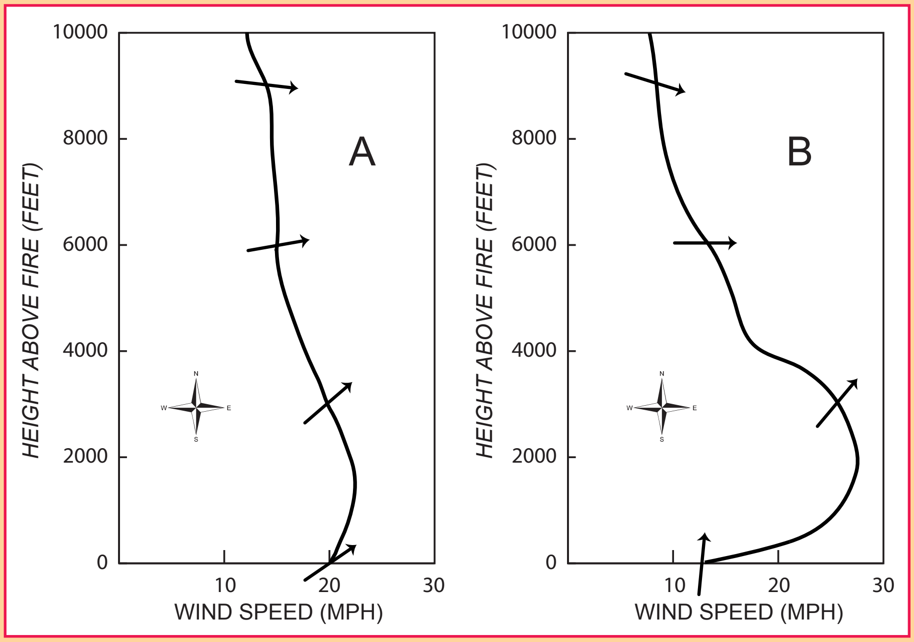
1957 Pond Pine Fire, North Carolina (adapted from U.S. Department of Agriculture 1958)

The so-called Pond Pine Fire started in Tyrrell County, North Carolina, in a flat, swampy, organic soil area and burned an estimated 5,000 acres [2,205 ha] during an 8-hour period following 2:00 p.m. on May 9, 1957. Although surface fuels were fairly dry, neither the buildup nor burning indexes were considered critical; the same was true of relative humidity and surface winds. In short, there was little on the surface to indicate that such an explosive, high-intensity fire would develop.

The fire started at 10:45 a.m. and early on had a tendency to generate spot fires for short distances ahead of the flame front. About 2 hours later, backfires were started from highways, but before they could burn an effective distance, the main head spotted for several hundred feet beyond one of the highways. A strong convection column then developed. At about 4:15 p.m., the fiercely burning fire spotted across a second highway and continued as a firestorm at a rate of 5 miles [8 km] in 3 hours. According to a plane observer, the head reached maximum intensity at about 5 o'clock. At that time, spot fires were being set as much as 3/4 mile [1.2 km] ahead of the main front. The convection column was of the towering type, with a white condensation cap. The height to the base of the cap was estimated at 4,600 feet [1,400 m] and to the top, 7,300 feet [2,225 m]. At about 10:00 p.m., a backfire and high relative humidity stopped the head.

The unusual characteristics of the fire can most reasonably be explained on the basis of winds aloft. Three U.S. Weather Bureau Stations (Raleigh and Cape Hatteras, NC, and Norfolk, VA) form a triangle, with the fire area roughly at its center. As soundings on May 9 at all three stations agreed closely as to high-altitude wind velocity and direction profiles, it seemed safe to assume that the same conditions prevailed over the fire. A composite of upper air soundings from the three stations indicated a dangerous wind profile, with a low-level jet stream and decreasing winds aloft highly conducive to the formation of a strong convection column—conducive to long-distance spotting of firebrands.

The Pond Pine Fire is another in a growing list of case histories that strengthen the concepts that were originally advanced several years ago regarding the significance of the wind profile in blowup fires.



Estimated wind profile curves in the vicinity of the Pond Pine Fire on May 9, 1957. The curves are composites of the upper air soundings from Raleigh and Cape Hatteras, NC, and Norfolk, VA. Composite wind directions aloft are indicated by the arrows; (A) represents conditions at 3:30 p.m. and (B) at 9:30 p.m.

1958 Coal Creek Fire, Montana (adapted from USDA Forest Service 1959)

Large forest fires offer opportunity to obtain fundamental information on fire behavior. On an ongoing fire, we can study rate of spread, characteristics of the flame front, and action of the convection column in relation to fuel, topography, and weather. However, the use of large fires as a source of basic data requires development of equipment and techniques for measuring these key variables. During 1958, we started developing plans for organizing a mobile fire research team that could move rapidly with necessary equipment to the scene of a fire.

The Coal Creek Fire in Glacier National Park (August 1958) gave an excellent opportunity to test this method of gathering research information. Prompt relay of information about this fire to the forest fire research staff at Missoula enabled a six-man team to be dispatched to the scene fast enough for measurement and observation of fire behavior during the second—and most important—period of the major fire activity. Observations and measurements were continued through the fourth day of fire activity. This research team included two research foresters, two research meteorologists, a forestry aid, and an airplane pilot. Their equipment included a Cessna 180 aircraft instrumented for temperature, humidity, and pressure measurements; two portable fire-weather stations; four belt weather kits; four time-lapse motion picture cameras; three FM portable radios; and other miscellaneous gear. This operation showed that such a team equipped for both aerial and ground measurement of fire behavior factors can gather important basic data needed in our research program.

Portable fire weather station developed by the Forest Service's Intermountain Forest and Range Experiment Station of Forest Fire Research in use at the scene of the Coal Creek Fire.

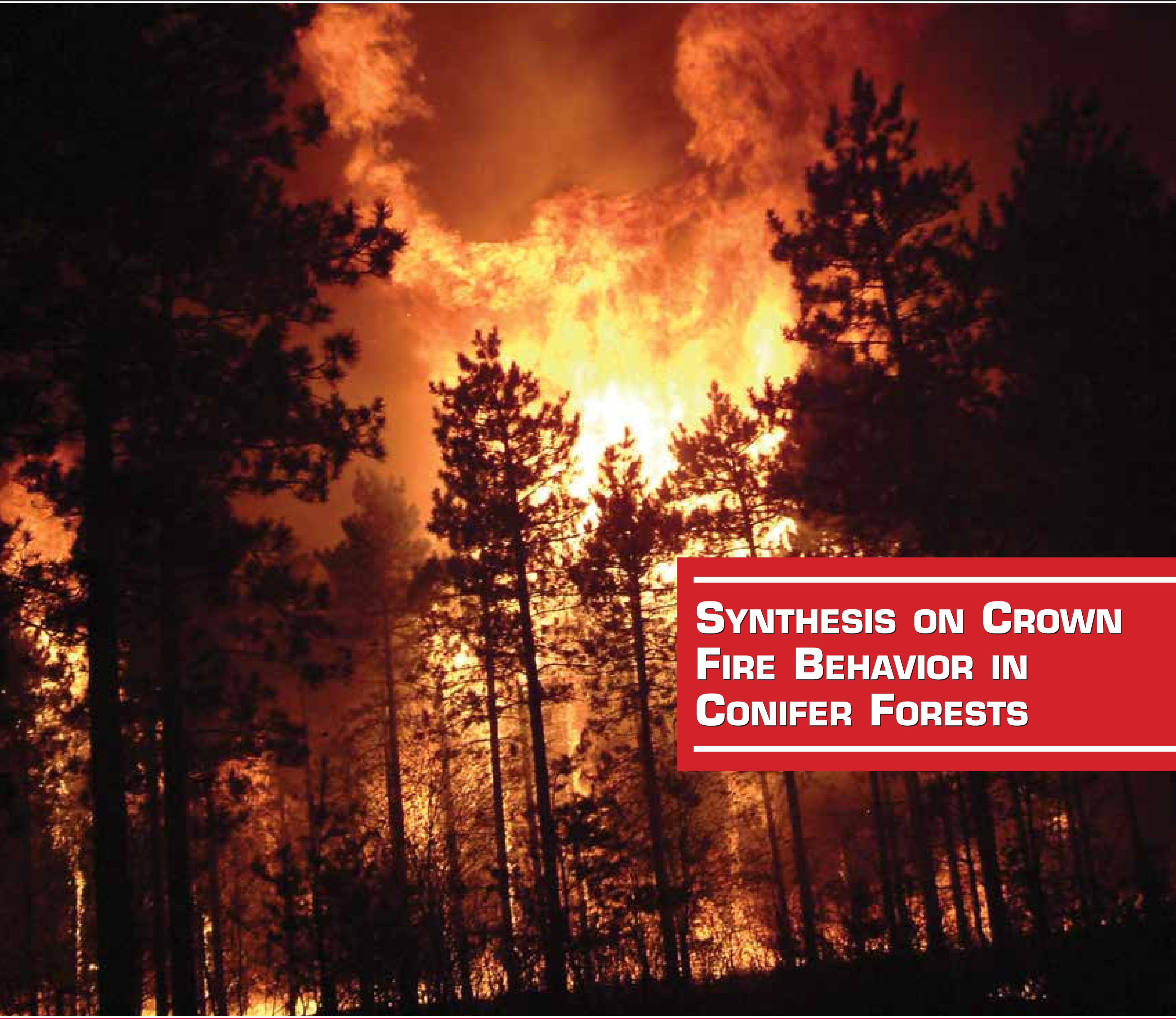
1969 Fire Season, Alaska (from USDA Forest Service 1970)

Over 4 million acres [1.6 million ha] of forest and rangeland burned in interior Alaska during 1969, contributing to one of the worst fire seasons on record. Smoke from the fires, some of which were larger than 500,000 acres [200,000 ha], reached as far south as Washington and Montana, and the widespread smoke pall over Alaska was so great that it was seen and recorded by weather satellites. During the period, we made rate-of-spread measurements on several fires in cooperation with the Office of Civil Defense and the Bureau of Land Management. Rates of spread on the Swanson River Fire exceeded 1 mile per hour. This study of free-burning, field-size fires provides a basis for testing predictive fire behavior models for use by firefighters in planning fire control strategies.

A Forest Service fire researcher with the Pacific Northwest Forest and Range Experiment Station collecting information on rate of spread and supplementary data on the Swanson River Fire for fire behavior analysis purposes.

Fire Management today

Volume 73 • No. 4 • 2014



Synthesis on Crown Fire Behavior in Conifer Forests

USDA

United States Department of Agriculture
Forest Service

Fire Management Today is published by the Forest Service of the U.S. Department of Agriculture, Washington, DC. The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department.

Fire Management Today is for sale by the Superintendent of Documents, U.S. Government Printing Office, at:
Internet: bookstore.gpo.gov Phone: 202-512-1800 Fax: 202-512-2250
Mail: Stop SSOP, Washington, DC 20402-0001

Fire Management Today is available on the World Wide Web at <http://www.fs.fed.us/fire/fmt/index.html>.

Tom Vilsack, Secretary
U.S. Department of Agriculture

Thomas L. Tidwell, Chief
Forest Service

Tom Harbour, Director
Fire and Aviation Management

Melissa Frey
General Manager

Mark Riffe
Editor

August 2014

Fire Management *today*

Volume 73 • No. 4 • 2014

On the Cover:

Crowning associated with the major run of the Cottonville Fire in central Wisconsin at 5:11 p.m. CDT on May 5, 2005, in a red pine plantation. Photo taken by Mike Lehman, Wisconsin Department of Natural Resources.

The USDA Forest Service's Fire and Aviation Management Staff has adopted a logo reflecting three central principles of wildland fire management:

- *Innovation:* We will respect and value thinking minds, voices, and thoughts of those that challenge the status quo while focusing on the greater good.
- *Execution:* We will do what we say we will do. Achieving program objectives, improving diversity, and accomplishing targets are essential to our credibility.
- *Discipline:* What we do, we will do well. Fiscal, managerial, and operational discipline are at the core of our ability to fulfill our mission.

Firefighter and public safety is our first priority.

Contents

Short Features