



FINAL REPORT

- Project Title:** OK-FIRE: A Weather-Based Decision Support System for Wildland Fire Managers in Oklahoma
- JFSP Project Number:** 05-2-1-81
- OK-FIRE Web Site:** <http://okfire.mesonet.org>
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For further information, go to <http://www.firescience.gov>



ABSTRACT

Wildland fire managers deal with both wildfire and prescribed fire, the latter becoming increasingly important as a tool to control fuel buildup and to restore/manage ecosystems. To aid wildland fire managers in their activities, operational weather-based decision support systems are essential, whether the concern be fire danger and wildfire suppression or planning for and conducting a prescribed burn. As a result of Joint Fire Science Program funding in 2005 (05-2-1-81), such a weather-based decision support system known as "OK-FIRE" has been developed over the past four years for the state of Oklahoma. The system has a three-fold emphasis: (1) a comprehensive suite of recent, current, and forecast products for fire weather, fire danger, and smoke dispersion; (2) a dedicated web site (<http://okfire.mesonet.org>) to act as the delivery mechanism; and (3) regional training and customer support for our users.

OK-FIRE utilizes the Oklahoma Mesonet (the state's automated network of 120 weather stations) for recent and current weather data, and integrates weather forecast output from the North American Mesoscale (NAM) model, a numerical model of the National Weather Service, to forecast conditions up to 84 hours in the future. In addition to fire weather conditions, three in-house customized computer models are used to calculate dead fuel moisture (Nelson model), fire danger conditions (Oklahoma Fire Danger Model) and smoke dispersion conditions (Oklahoma Dispersion Model). With the aid of a locally developed browser plug-in, OK-FIRE products come in a variety of formats: dynamic maps with the capacity for animation, zooming, and overlays; charts; and tables.

Largely through intensive training and marketing efforts over the past number of years, OK-FIRE usage has grown tremendously. Web site "hits" for 2009 increased 423% over 2008, and the number of "unique visitors" (IP addresses) increased 310% over 2008. In 2009 the web site had almost 20 million hits and an average number of monthly visitors of almost 1800. Users include a large number of federal agencies with land management responsibilities, state agencies, fire departments, emergency managers, and private landowners and organizations. OK-FIRE is used not only for wildfire anticipation and suppression but also for prescribed fire activities. In summary, OK-FIRE has been a real success story. It is having a tremendous impact on the state of Oklahoma and can serve as a prototype for similar state or national weather-based wildland fire management systems.

I. BACKGROUND AND PURPOSE

With more than half of its land consisting of wildlands (about 22 million acres of rangeland and forest), the importance of wildland fire to Oklahoma becomes obvious. About 2.5 million acres are typically burned in Oklahoma each year, roughly 10% by wildfire and 90% by prescribed fire. During severe fire seasons, however, wildfires can consume many more acres, as was the case during November 2005 through September 2006, when more than 16,000 wildfires burned almost 1.5 million acres.

To aid wildland fire managers in their activities, operational fire and smoke management systems based on recent, current, and forecast weather conditions are critical. With respect to prescribed fire, benefits include better pre-burn planning and management during the burn. With respect to wildfire, benefits include better anticipation of severe wildfire conditions, the ability to better determine future staffing levels, and better suppression strategies during the wildfire itself. Use of such management systems can also help save lives and structures.

In 2004, when the Announcement for Proposals that funded OK-FIRE was issued, many of the pieces to construct such a weather-based operational wildland fire management system in Oklahoma were in place, but nothing was integrated into a unified, user-friendly system. Weather, fire danger, and smoke management products using the Oklahoma Mesonet (McPherson *et al.*, 2007), the state's automated weather station network, were scattered about on various Mesonet web sites, such as Oklahoma AgWeather, a site designed for agricultural interests. In addition, aside from old-technology NGM MOS forecasts, no forecast component was integrated into the weather and fire danger products. Wildland fire managers stressed the need for a multi-day forecast component to better plan for prescribed burns and also to anticipate periods of high fire danger. Finally, another shortcoming was the lack of training opportunities for fire managers on how to use the existing products.

These and other opportunities were identified in the Problem Statement which accompanied our 2004 proposal, which was a response to Task Statement #1 of AFP 2005-2 (Local Research Needs). This Problem Statement, written by Alan Newman of the USDA Forest Service (Ouachita National Forest), described a critical need to incorporate a forecast component into the Mesonet-based fire management tools, to develop a stand-alone dedicated fire management web site, and to provide necessary training to users of the system.

In the original proposal we concentrated on federal agencies with land management responsibilities in Oklahoma (USDA Forest Service, Bureau of Indian Affairs, US Army Corps of Engineers, National Park Service, and US Fish & Wildlife Service), one state agency (Oklahoma Forestry Services), and one private organization (The Nature Conservancy). However, in 2006 we added the National Weather Service to our group of users, and in 2007, the Natural Resources Conservation Service. These groups utilized a password-protected OK-FIRE web site. In the summer of 2008 that restriction was removed and OK-FIRE was opened up to additional groups such as fire departments, emergency managers, and private landowners.

II. PROJECT DESCRIPTION

The overall purpose of OK-FIRE was to provide wildland fire managers in Oklahoma with a weather-based decision support system to aid them in their prescribed burning and/or wildfire anticipation/suppression activities. To accomplish this purpose, three specific objectives were set out in the proposal:

- 1) the development of a **comprehensive suite of operational products incorporating a forecast component** for fire weather, fire danger, and smoke dispersion;
- 2) the development of a **dedicated OK-FIRE wildland fire management web site** to act as the delivery mechanism for the above products; and
- 3) **regional training and customer support** activities for OK-FIRE users

A. Situation at the Start of the OK-FIRE Project

When the OK-FIRE project was funded in 2005, many of the building blocks for Objective 1 (products) were already in place. The Oklahoma Mesonet (McPherson *et al.*, 2007), the state's automated weather station network, had been operational since 1994 and would provide the observed weather data for the fire weather products up to the current time as well as input data for the fire danger and smoke dispersion models. In 2005 there were 116 Mesonet stations reporting weather data every 15 minutes; at present, there are 120 stations reporting weather data every 5 minutes. The map below shows the locations of our 120 10-m tall automated weather stations. There is at least one station in every county with an average station spacing of 19 miles.

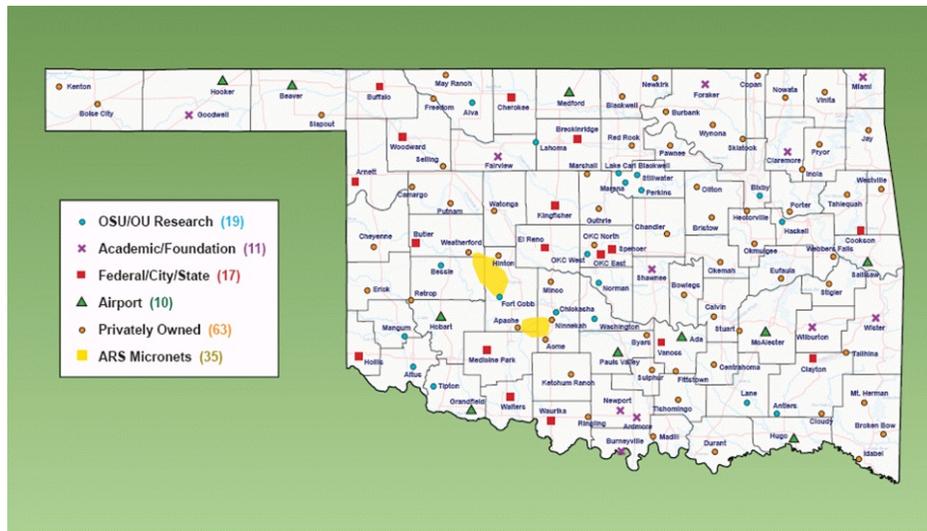


Fig. 1. Location of Oklahoma Mesonet stations.

Operational since 1996, the Oklahoma Fire Danger Model (OKFD) would be the vehicle for calculating fire danger conditions. This model is an implementation of the National Fire Danger Rating System developed by the USDA Forest Service (Bradshaw *et al.*, 1983; Burgan, 1988) and calculates four indices of fire danger: burning index (BI), spread component (SC), energy release component (ERC), and ignition component (IC). The 1988 revision incorporated a drought index, KBDI, into the system. The OKFD model (Carlson *et al.*, 2002; Carlson and Burgan, 2003), as of 2005, used hourly Mesonet weather data as well as weekly satellite imagery (Burgan and Hartford, 1993) to produce colored maps to 1-km resolution of the four NFDRS indices. In addition, interpolated maps of 1-hour dead fuel moisture (using NFDRS algorithms) and KBDI were available. These fire danger maps were only produced through the current time, using Mesonet weather data. Tables of these variables were also available at all Mesonet sites.

The model that would be used for smoke dispersion products was the Oklahoma Dispersion Model, which was developed in the late 1990s (Carlson and Arndt, 2008). It breaks the atmosphere into six categories of surface dispersion (very poor to excellent) and, as of 2005, was producing maps of current dispersion conditions from 15-minute Mesonet data as well as incorporating 48-hour NGM MOS forecasts.

B. OK-FIRE Project Implementation

Starting with these “building blocks” in 2005, we concentrated in the first project year upon developing an expanded suite of products, integrating a forecast component into these products, and developing the first prototype OK-FIRE web site. The second project year saw the first round of training workshops (Fall 2006), followed by beta-testing of the web site and development of new products and further refinement of the web site. The third project year saw a second round of workshops (Fall 2007), followed by beta-testing and the further development of new products and refinement of the web site. A one-year no-cost extension was granted in 2008, allowing for a fourth project year. The password protection on the web site was removed in summer 2008 and a third round of workshops took place in Fall 2008 followed by further product and web site development in 2009. Although the project “officially ended” in September 2009, a fourth round of training workshops took place last fall.

The following lengthy section will detail the development and accomplishments of OK-FIRE in all three areas: products, web site, and training activities. Working together with our technology colleagues at Mesonet headquarters in Norman, we succeeded in developing what is a most effective, state-of-the-art operational system for wildland fire management.

III. PROJECT DEVELOPMENT AND OUTCOMES

As an introduction to this section, OK-FIRE products cover time periods from 5 days in the past through 84 hours into the future. Data sources include the Oklahoma Mesonet for current/recent conditions and 84-hour weather forecast output from the North American Mesoscale (NAM) model for future conditions. Weekly NDVI satellite imagery is used for the fire danger model.

The products also come in three major formats: (1) maps, (2) graphs, and (3) tables. Through use of a Mesonet-developed browser plugin (WeatherScope), many OK-FIRE maps are dynamic (rather than static gif images), capable of animation, zooming, and overlays. At individual Mesonet sites, graph and table formats over past or future periods are available; the plugin is used in creating the graphs. For current conditions, site-specific "data boxes" are available.

Through a subcontract with the Oklahoma Climatological Survey in Norman, we worked closely with the technology group of the Oklahoma Mesonet, which, under the PI's direction, modified the models, developed the products, and implemented the web site. The operational computers which run the models, products, and web site are stationed at Mesonet headquarters in Norman as well.

A. Products

In this section we will highlight some of the major developments that occurred in this aspect of the project (products).

NAM Forecast

One of the major tasks during the first project year was to obtain, ingest, and integrate digital forecast output from a numerical weather model into our products. We decided on the 12-km resolution North American Mesoscale (NAM) model of the National Weather Service run at the National Centers for Environmental Prediction (NCEP), since this version of the NAM was one of the most recent models, calculated all the variables needed in our OK-FIRE models, and produced forecast output out to 3+ days. The NAM model uses the non-hydrostatic mesoscale model (WRF-NMM) of the WRF (Weather Research and Forecasting Model) and produces 84-hour forecasts four times a day (00Z, 06Z, 12Z, and 18Z).

In 2006 we developed methodology to download and ingest two cycles of the NAM forecasts (00Z and 12Z), which involved getting the files in GRIB1 (at the time) format, obtaining the variables of interest, using linear interpolation to interpolate between the 3-hour interval NAM output to produce hourly output, and then interpolating these hourly data points to our Mesonet locations (the common input structure to our Mesonet-based products, so that Mesonet and forecast input files would have the same structure). The 00Z and 12Z cycles were integrated into the Nelson dead fuel moisture model (to be next discussed), the fire danger model, and the fire weather products.

In 2007 the switch at NCEP was made to GRIB2 format, and appropriate conversion in our ingest software was made. In addition, we integrated two more cycles of the NAM model (06Z and 18Z) into our products, so that now NAM updates were available on OK-FIRE every six hours. Furthermore, we discontinued use of the 48-hour NGM MOS forecasts in the Oklahoma Dispersion Model and started using the 84-hour NAM forecasts in that model instead.

Nelson Dead Fuel Moisture Model

In the late 1990s and early 2000s, the PI was independently working with Ralph Nelson of the USDA Forest Service in providing field data for the development of a next-generation model for dead fuel moisture, an important variable for fire danger. Working with the USDA Forest Service Missoula Fire Sciences Lab, we developed a numerical version of this model, called the “Nelson” model, for use with the four sizes of dead fuels: 1-hour, 10-hour, 100-hour, and 1000-hour. Additionally, the PI had a research agreement during the mid 2000s with Missoula concentrating on evaluation of this model in a near-real-time and forecast environment (Carlson *et al.*, 2007). Because of these studies, software developed by the Mesonet technology group in Norman was already in place in 2005 (when the OK-FIRE grant began) to start operational calculation of dead fuel moisture using both Mesonet data and forecast data.

In 2006 the Nelson model was made operational and its output (dead fuel moisture for all four fuel sizes) was integrated into the Oklahoma Fire Danger Model. The new model replaced the much older NFDRS algorithms for dead fuel moisture. In addition to its input into the fire danger model, individual products for dead fuel moisture were also made available (e.g., maps, graphs, and tables). The Nelson model uses 15-minute data from the Oklahoma Mesonet and hourly forecast data from the NAM.

In 2008 calibration factors (based on comparison of the Nelson model with a 21-month database of dead fuel moisture from Slapout, OK) were developed. These, in turn, were applied operationally to the output of the Nelson model.

Use of Browser Plugin

For the first time in our fire weather, fire danger, and smoke dispersion products, we started to incorporate a browser plugin that was developed by the Mesonet technology group in Norman. Initially, in 2006, we used a plugin called “WxScope” to create maps and charts for our fire weather and fire danger products. Prior to this, all of our maps had been static gif images, but the new technology allowed for animations, zooming, and overlays on the maps as well as increased flexibility in the charts. In 2007 we converted our existing plugin products over to a new plugin, “WeatherScope”, and for the first time made our dispersion model products compatible with the plugin technology as well as our satellite greenness products (used in the fire danger model).

Examples of OK-FIRE Map and Chart Products

On April 9, 2009, there was a “perfect storm” for wildfire outbreaks across the south central Plains. In Oklahoma alone there were at least 14 large wildfires consuming over 115,000 acres, with over 60 people injured and at least 160 homes destroyed, and with estimated losses of over \$30 million. Below is an infrared satellite view around 1800 Central Daylight Time showing the areas of the large wildfires.

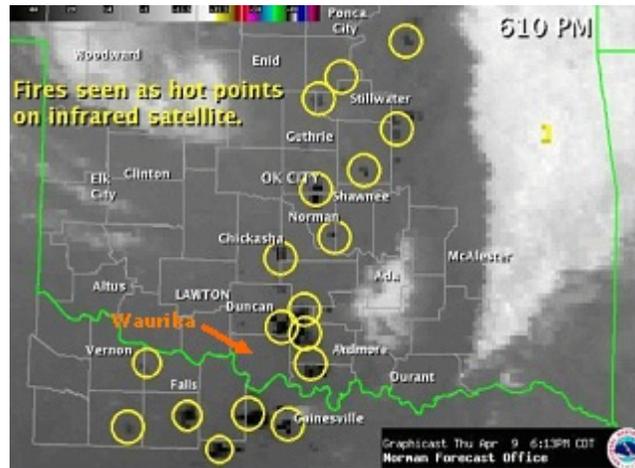


Fig. 2. Infrared satellite detection of large wildfires occurring on April 9, 2009.

Our OK-FIRE products captured this episode very well and provided fire managers with advance warning. In fact, I was in Oklahoma City the day before giving a talk about OK-FIRE and demonstrating the web site. I saw the fire danger forecast for the next day and warned the county commissioners (at their spring annual meeting) that something bad could potentially happen the following day. The chart/table below shows the number of hits on the OK-FIRE web site during each day of April, showing that OK-FIRE was indeed used during this severe wildfire episode.

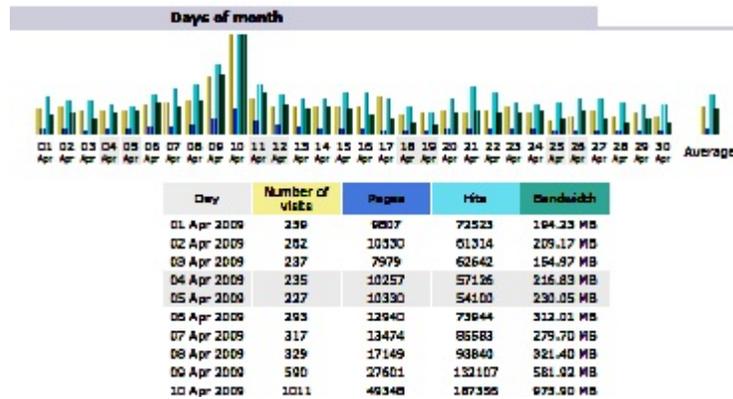


Fig. 3. Daily web site statistics for OK-FIRE during April 2009.

Below is the relative humidity map (using the plugin) for 1600 CDT, April 9 showing a strong dryline oriented north-south across central Oklahoma. Extremely dry air (relative humidity values less than 15%) behind the dryline (to the west of it) is present in the area of the wildfires.

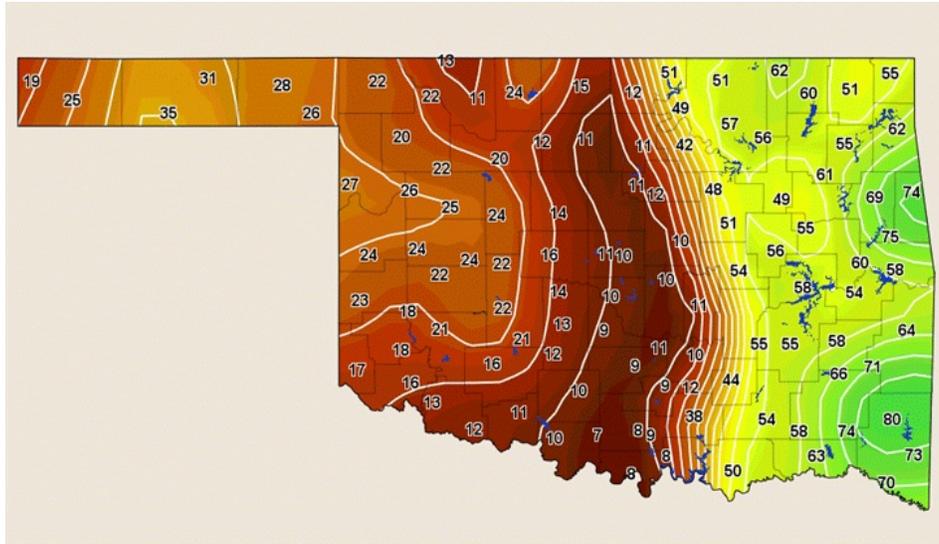


Fig. 4. *Relative humidity map from OK-FIRE for 1600 CDT, April 9, 2009.*

The next map shows the wind directions and wind speeds (our wind vector map) for the same time. Note that 10-m winds are sustained anywhere from 25 to 40 mph; gusts (not shown on this map) were from 40 to 60 mph in the fire areas.

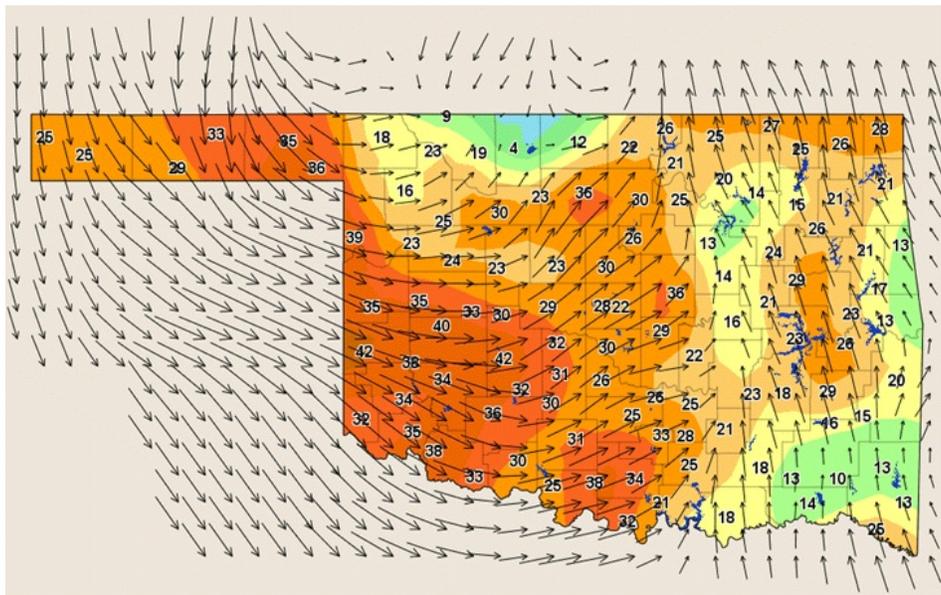


Fig. 5. *Wind map from OK-FIRE for 1600 CDT, April 9, 2009.*

The next map shows the 1-hour dead fuel moisture, the moisture content of the fine (grassy) fuels. Note that most areas in the wildfire region are well below 5%; some areas in south central Oklahoma are only at 2%, which is extremely low (the Nelson model has a built-in minimum of 1%).

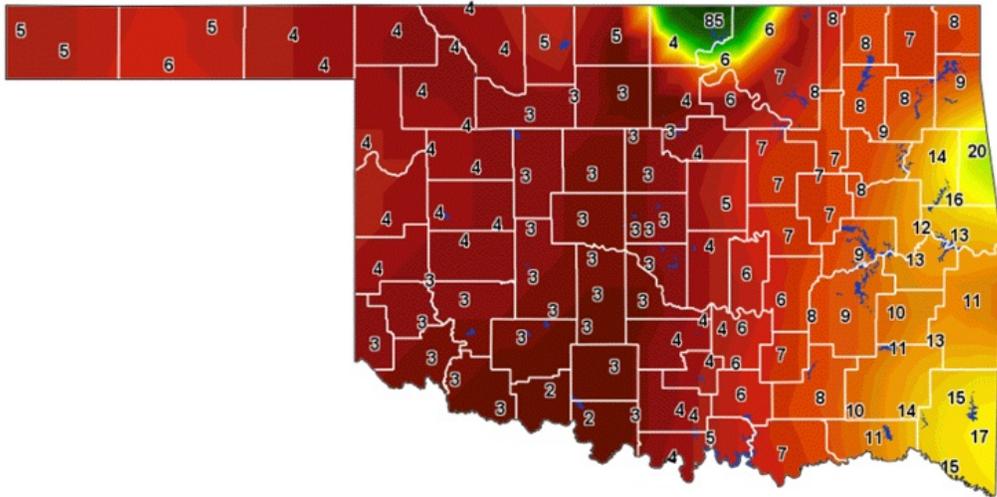


Fig. 6. Map of 1-hour dead fuel moisture from OK-FIRE for 1600 CDT, April 9, 2009.

The last map to be shown is the burning index (BI), which is directly related to the intensity of a fire and its difficulty of control. Values over 40 are considered high fire danger, over 80 severe, and over 110 extreme. Note how most wildfire areas are well over 40 with values well into the 100s in south central and southwest Oklahoma.

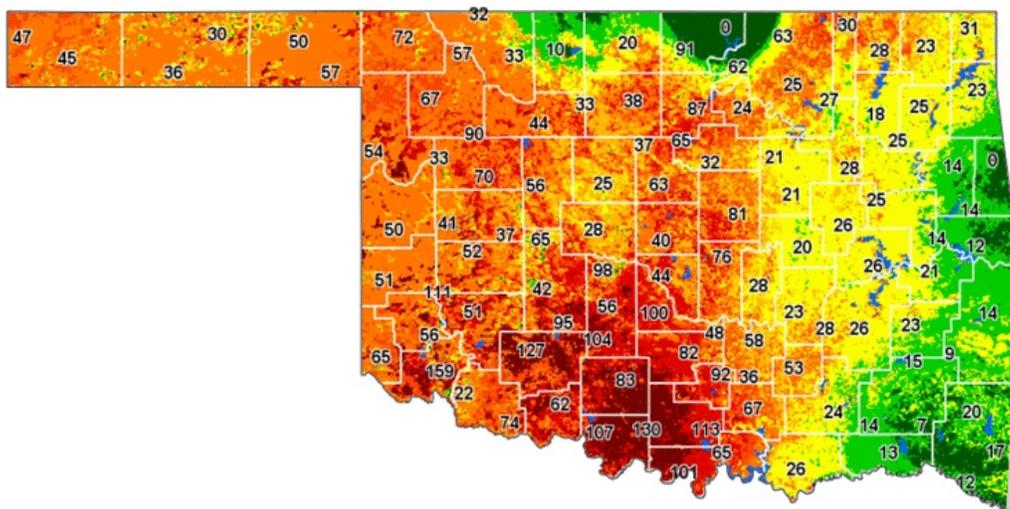


Fig. 7. Burning index (BI) map from OK-FIRE for 1600 CDT, April 9, 2009.

Below are two graphs (centered about April 9) for the Mesonet tower at Waurika (whose location is depicted by the orange arrow in Fig. 2). The first graph shows the wind directions and wind speeds (10-m sustained winds in blue; 10-m gusts in purple). Sustained winds near 30 mph and gusts near 50 mph occurred on the afternoon of April 9.

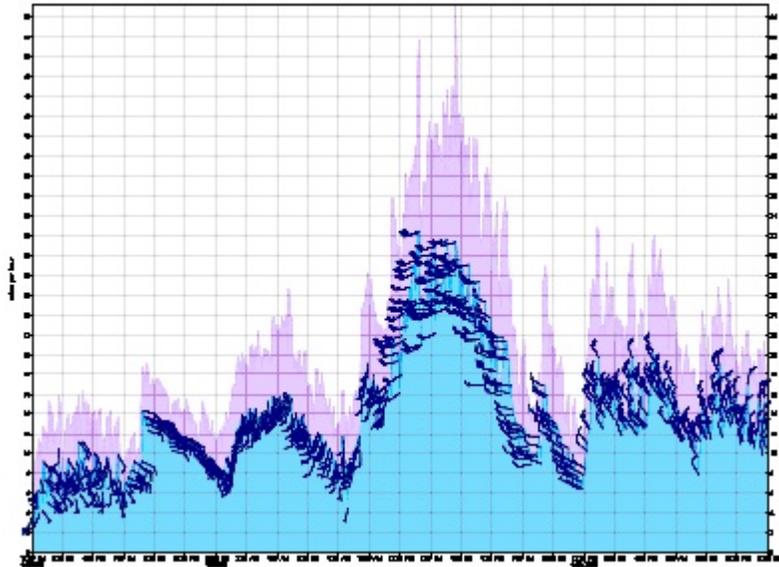


Fig. 8. Time-series wind graph at Waurika from OK-FIRE centered about April 9, 2009.

The next graph is the time-series plot of burning index at Waurika centered around April 9, 2009. Note that BI values as high as 120 are reached on April 9.

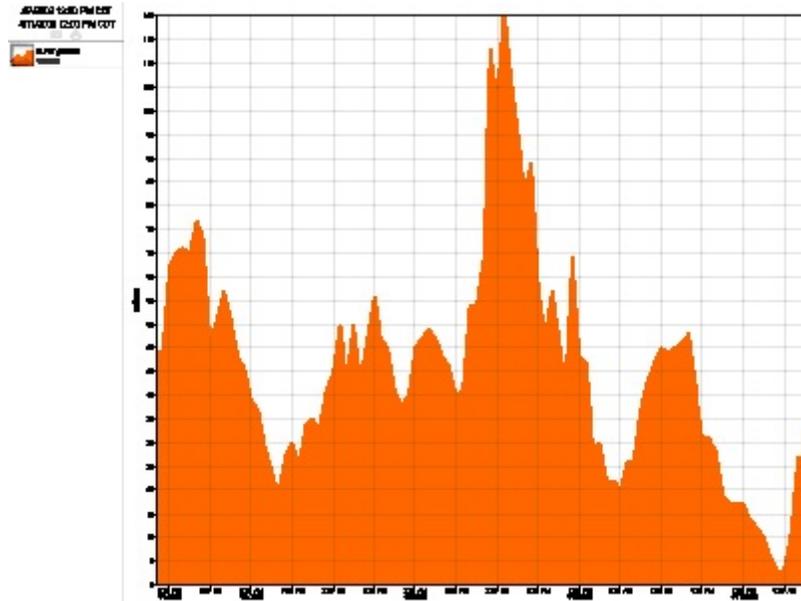


Fig. 9. Time-series plot of burning index (BI) at Waurika from OK-FIRE centered about April 9, 2009.

Example of OK-FIRE Table Products (Fire Prescription Planner)

Our most popular product, which is in tabular format, is the “Fire Prescription Planner”, which was originally developed in 2007. In 2008 wind direction was added as a prescription variable; based on extensive surveying of our users, 8 wind direction sectors were chosen instead of 16.

Based solely on the NAM model, the Fire Prescription Planner allows users to set “prescriptions” for a number of weather, fire, and dispersion variables. Except for wind direction where sectors are chosen, users set lower and/or upper limits on the variables of interest. The example below illustrates a possible prescribed burn application. Here the prescription is for relative humidity between 30 and 60%, wind speeds between 5 and 15 mph, dispersion conditions “Moderately Good” or better, 1-h dead fuel moisture between 7 and 20%, 10-h dead fuel moisture between 7 and 15%, and winds out of the NW, W, or SW sectors.

The screenshot shows the 'FIRE PRESCRIPTION PLANNER' interface. It features a table for setting limits on various forecast elements, a wind direction compass, and navigation buttons.

Prescription Forecast Element	Lower Limit	Upper Limit
Air Temperature (F)	<input type="text"/>	<input type="text"/>
Relative Humidity (%)	<input type="text" value="30"/>	<input type="text" value="60"/>
Wind Speed (mph)	<input type="text" value="5"/>	<input type="text" value="15"/>
1-hour Precipitation (inches)	<input type="text"/>	<input type="text"/>
Dispersion Conditions	Moderately Good <input type="text"/>	
1-hour Dead Fuel Moisture (%)	<input type="text" value="7"/>	<input type="text" value="20"/>
10-hour Dead Fuel Moisture (%)	<input type="text" value="7"/>	<input type="text" value="15"/>
Burning Index (10*ft)	<input type="text"/>	<input type="text"/>
Ignition Component (%)	<input type="text"/>	<input type="text"/>
Spread Component (ft/min)	<input type="text"/>	<input type="text"/>
Energy Release Component (BTU/ft2)	<input type="text"/>	<input type="text"/>
KBDI (0-800)	<input type="text"/>	<input type="text"/>

Wind Direction

A circular compass rose shows 8 wind sectors with arrows pointing towards the center. The sectors are labeled with cardinal and ordinal directions and their corresponding angles: N (0°), NE (45°), E (90°), SE (135°), S (180°), SW (225°), W (270°), and NW (315°). The sectors for NW, W, and SW are highlighted in orange, indicating they are selected for the prescription. Below the compass, the text reads 'click on the sectors you wish to prescribe'.

At the bottom of the interface are three buttons: 'Help', 'Reset', and 'Next'.

Fig. 10. Entry of prescription elements in Fire Prescription Planner.

After the user selects a Mesonet location (next step, not shown), the NAM hourly forecast is searched as well as the forecast output of the fire danger and dispersion models. The resulting forecast table contains hourly output of the variables of interest through the end of the latest 84-hour forecast period. Each prescription variable has its cells highlighted in green for those hours when the criteria for that variable are met and highlighted in red for those hours when the criteria are not met. The first column after the "DATE TIME" column reads "Criteria Met?" and those cells will contain "Yes" and be highlighted in bright green for those hours for which ALL of the prescription criteria are met. Hours when all of the criteria are not met will contain "No" and be highlighted in bright red. In the table below one clearly sees a "window of opportunity" for a prescribed burn (based on the entered prescription criteria) for the period between 8 a.m. and 4 p.m. CST the next day.

Fire Prescription Table for Skiatook

Disclaimer: This forecast table, as with other OK-FIRE products, is based solely on output from the latest 84-h NAM forecast. As no weather forecast model is perfect, users are encouraged to check the official forecasts of the National Weather Service for consistency or discrepancies in the weather variable portion of this forecast. In particular, consult the "National Weather Service" or "NWS Prescription Planner" links in the Weather/Forecasts section of the OK-FIRE web site.

[Change Prescription](#)

[Change Station](#)

DATE TIME	Criteria Met?	RELH	WDIR	WSPD	DISPERSION	1h DFM	10h DFM	TAIR	RAIN_1H	BI	IC	SC	ERC	KBDI
Nov 07, 2008 5:00 pm CST	No	35%	WNW	11 mph	4 (MG)	6%	9%	57°F	0.00 in.	16	12%	8	5	3
Nov 07, 2008 6:00 pm CST	No	37%	WNW	8 mph	2 (P)	6%	9%	55°F	0.00 in.	13	9%	5	5	3
Nov 07, 2008 7:00 pm CST	No	38%	WNW	7 mph	1 (VP)	7%	9%	54°F	0.00 in.	12	7%	4	5	3
Nov 07, 2008 8:00 pm CST	No	40%	WNW	6 mph	1 (VP)	7%	9%	52°F	0.00 in.	10	6%	3	5	3
Nov 07, 2008 9:00 pm CST	No	41%	W	5 mph	1 (VP)	7%	9%	51°F	0.00 in.	9	5%	2	5	3
Nov 07, 2008 10:00 pm CST	No	43%	W	5 mph	1 (VP)	7%	9%	50°F	0.00 in.	9	5%	2	5	3
Nov 07, 2008 11:00 pm CST	No	44%	W	5 mph	1 (VP)	8%	9%	49°F	0.00 in.	9	5%	2	4	3
Nov 08, 2008 12:00 am CST	No	46%	W	6 mph	1 (VP)	8%	9%	48°F	0.00 in.	10	5%	3	4	3
Nov 08, 2008 1:00 am CST	No	48%	W	6 mph	1 (VP)	8%	10%	46°F	0.00 in.	10	4%	3	4	3
Nov 08, 2008 2:00 am CST	No	50%	WNW	6 mph	1 (VP)	9%	10%	45°F	0.00 in.	10	4%	3	4	3
Nov 08, 2008 3:00 am CST	No	51%	WNW	6 mph	1 (VP)	9%	10%	44°F	0.00 in.	10	4%	3	4	3
Nov 08, 2008 4:00 am CST	No	53%	WNW	6 mph	1 (VP)	10%	10%	42°F	0.00 in.	10	4%	3	4	3
Nov 08, 2008 5:00 am CST	No	55%	WNW	7 mph	1 (VP)	10%	10%	41°F	0.00 in.	10	4%	4	3	3
Nov 08, 2008 6:00 am CST	No	57%	WNW	7 mph	1 (VP)	10%	10%	40°F	0.00 in.	10	3%	4	3	3
Nov 08, 2008 7:00 am CST	No	55%	WNW	8 mph	3 (MP)	10%	10%	41°F	0.00 in.	11	4%	5	3	3
Nov 08, 2008 8:00 am CST	Yes	54%	WNW	10 mph	5 (G)	10%	10%	43°F	0.00 in.	13	5%	6	4	3
Nov 08, 2008 9:00 am CST	Yes	53%	WNW	12 mph	4 (MG)	9%	9%	44°F	0.00 in.	14	6%	7	4	3
Nov 08, 2008 10:00 am CST	Yes	50%	WNW	13 mph	4 (MG)	9%	9%	46°F	0.00 in.	15	7%	8	4	3
Nov 08, 2008 11:00 am CST	Yes	47%	WNW	14 mph	4 (MG)	9%	9%	49°F	0.00 in.	17	8%	9	4	3
Nov 08, 2008 12:00 pm CST	Yes	43%	WNW	15 mph	4 (MG)	8%	8%	51°F	0.00 in.	18	10%	10	5	3
Nov 08, 2008 1:00 pm CST	Yes	42%	WNW	14 mph	4 (MG)	7%	8%	52°F	0.00 in.	18	11%	10	5	3
Nov 08, 2008 2:00 pm CST	Yes	42%	WNW	14 mph	4 (MG)	7%	8%	54°F	0.00 in.	18	11%	10	5	3
Nov 08, 2008 3:00 pm CST	Yes	41%	WNW	13 mph	4 (MG)	7%	8%	55°F	0.00 in.	18	11%	9	5	3
Nov 08, 2008 4:00 pm CST	Yes	43%	WNW	11 mph	5 (G)	7%	8%	53°F	0.00 in.	16	10%	7	5	4
Nov 08, 2008 5:00 pm CST	No	45%	WNW	8 mph	3 (MP)	7%	8%	52°F	0.00 in.	13	7%	5	5	4
Nov 08, 2008 6:00 pm CST	No	48%	WNW	6 mph	1 (VP)	8%	8%	51°F	0.00 in.	10	5%	3	5	4
Nov 08, 2008 7:00 pm CST	No	50%	NW	5 mph	1 (VP)	8%	8%	49°F	0.00 in.	9	4%	2	4	4
Nov 08, 2008 8:00 pm CST	No	52%	NW	5 mph	1 (VP)	9%	9%	48°F	0.00 in.	8	4%	2	4	4

Fig. 11. Resulting hourly forecast table from the Fire Prescription Planner.

B. Web Site (<http://okfire.mesonet.org>)

The original OK-FIRE web site was developed in 2006 in time for the first round of OK-FIRE training workshops in the fall of 2006. With each successive year, in conjunction with the development of products and revisions of the web site, a new version of the web site was released just prior to the annual fall training workshops. The web site was password protected for beta testing by our initial user groups, but in August 2008 we removed that restriction and opened up the site to the public. Accordingly, we began to focus on new user groups in our training sessions, such as fire departments and emergency managers.

The home page of OK-FIRE is shown below (Fig. 12). The major sections of the web site are listed across the top - WEATHER, FIRE, SMOKE, SATELLITE, RADAR, AIR QUALITY, BURN SITE, and LINKS. The OK-FIRE products (based on the Mesonet and NAM model), among other products, are contained in the WEATHER, FIRE, and SMOKE sections. We added the other major sections for completeness. Both the SATELLITE and RADAR sections feature regional and national imagery which can be animated if desired. The AIR QUALITY section has links to web sites that forecast national ozone and particulate matter concentrations. The BURN SITE section, which was added in 2007, features links to road, satellite/aerial, and topographical maps. The LINKS section has linkages to national/regional weather, fire, and climate/drought web sites as well as links to other Oklahoma weather/climate web sites.

Forecast based on 2009-09-18 12Z NAM; NEXT forecast update expected 5 pm CDT

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WEATHER FIRE SMOKE SATELLITE RADAR AIR QUALITY BURN SITE LINKS

Stillwater 9/18/09
Weather 1:35 pm CDT
Temperature: 75°F
Relative Humidity: 64%
10-m Wind: NNE 10 mph
Rainfall since 7 pm: 0.0"
Dispersion Conditions: Moderately Good

Fire Danger 1:00 pm CDT
Burning Index: 9
Spread Component: 4
Ignition Component: 4%
1-hr Fuel Moisture: 10%
10-hr Fuel Moisture: 15%
KBDI: 33
Relative Greenness: 61%

Sunrise: 7:12 AM
Sunset: 7:33 PM

CHOOSE A STATION

Weather-based Decision Support Products for Wildland Fire Management in Oklahoma

Fall 2009 Training Sessions Announced

WeatherScope 1.7 required

The interactive features of this web site require the free WeatherScope software.

Click Here to download WeatherScope.

DOWNLOAD NOW

Fire Prescription Planner

OK-FIRE is a joint project between OSU, the Oklahoma Climatological Survey, and the USDA Forest Service. It is funded by a grant from the Joint Fire Science Program (Project # 05-2-1-51). Copyright © 2008-2009 Board of Regents of the University of Oklahoma. All Rights Reserved. webmaster@mesonet.org

OSU Mesonet U.S. Forest Service

Fig. 12. Home page of the OK-FIRE site.

On the left side of the home page are several data boxes for weather, fire danger, and sunrise/sunset information for a single Mesonet station location. Users can customize OK-FIRE to whatever Mesonet site they wish by clicking on "Choose a Station" and selecting the site of interest. Once that is done, the newly selected station remains the default station upon entering OK-FIRE in the future, as well as the default station for chart and table products throughout the web site.

C. Training

The third focus of OK-FIRE is on training our users on the interpretation of the products and navigation of the web site. To this end the PI has continued to conduct an annual series of fall training workshops since 2006. The workshops are held in computer labs at regional technology centers and universities throughout the state. The format is a series of presentations and web site demonstrations given by the PI on the various sections of the web site (and products contained therein) interspersed with lab exercises on the computer whereby the attendee can become familiar with the products and the web site (Figs. 13 and 14). In the 2007 workshops the co-PI taught a segment on prescribed fire. The attendees are also provided with an OK-FIRE notebook containing a variety of information on the program, the products, and the web site. At the end of the workshops, a survey is given out to assess the training just completed and to address possible directions for the future.

In the falls of 2006 and 2007, full-day computer workshops were given for our users. At this point in time, the web site was password-protected and we were concentrating largely on federal agencies having land management responsibilities within Oklahoma as well as on Oklahoma Forestry Services. In 2006 we held 8 regional workshops which were attended by 101 people, mainly fire professionals. In 2007 we held 9 regional workshops attended by 136 people.

In August of 2008, the OK-FIRE web site was made public. Based on earlier discussions that summer with regional rural fire coordinators, plans were made to target fire departments in the fall. We decided to change to a half-day workshop format to encourage more people to attend. Accordingly, 18 half-day computer workshops were held at 10 locations throughout the state in fall of 2008. We also held one full-day workshop for the rural fire coordinators. A total of 151 people attended the 19 workshops.

For 2009, in addition to fire departments, we decided to target emergency managers and agricultural extension agents throughout Oklahoma. We also decided to offer an abbreviated 2.5 hour evening session (no computer lab exercises) in addition to the half-day computer workshops. A total of 208 people attended 7 evening sessions and 21 half-day workshops at 16 different locations throughout the state.

Thus, a total of almost 600 people, mainly fire professionals, have been trained in fall OK-FIRE training workshops since 2006. In addition to the fall workshops, the PI has given numerous shorter presentations on OK-FIRE throughout Oklahoma during these years, so

a good deal more people have become familiar with OK-FIRE. Also, a tri-fold brochure on OK-FIRE has been published, as well as two extension publications on smoke management and prescribed fire co-authored by the PI which have sections describing OK-FIRE and some of its products. These serve to further educate the wildland fire management community on OK-FIRE and use of its products. Refer to Section VIII for a list of these presentations and publications.

The PI has also given presentations on OK-FIRE at a number of professional conferences throughout the nation since 2007, so OK-FIRE is gaining national and international attention. Plans are in the works to submit a journal article on OK-FIRE in 2010.



Fig. 13. *PI giving presentation at an OK-FIRE workshop.*



Fig. 14. *Attendees working on computer lab exercises at an OK-FIRE workshop.*

IV. MANAGEMENT IMPLICATIONS

As mentioned in the beginning of this report, the purpose behind the OK-FIRE project was to create a weather-based operational system for wildland fire management. Thus, “management” has always been in view, and OK-FIRE is used for prescribed fire, for wildfire applications, and for smoke management. The two major ways of determining whether wildland fire managers are using OK-FIRE are by looking at the web site statistics and by soliciting feedback from our users on the workshop surveys as well as through e-mails and personal conversations. This section will look first at the web site statistics, then on prescribed fire and wildfire applications, and finally on implications outside of Oklahoma.

A. Web Site Usage

The OK-FIRE web site was designed to be the primary vehicle for dissemination of the weather-based fire weather, fire danger, and smoke management products. Learning to use the OK-FIRE web site has always been one of the major objectives of the fall OK-FIRE computer workshops. To see if we are meeting our goal in getting such information out via the web site, it is instructive to look at the statistics for OK-FIRE web site usage for the three full calendar years (2007-2009) during which it’s been in existence (see Fig. 15 below).

	<u>UNIQUE VISITORS</u>			<u>NUMBER OF VISITS</u>			<u>HITS</u>		
	2009	2008	2007	2009	2008	2007	2009	2008	2007
JANUARY	1,788	360	88	7,171	1,228	202	2,164,663	225,088	20,543
FEBRUARY	2,666	258	113	9,184	1,077	331	2,390,737	271,827	63,931
MARCH	3,346	432	154	9,893	1,882	520	2,705,028	401,896	158,363
APRIL	3,207	222	129	8,637	960	302	2,214,487	232,638	45,638
MAY	1,318	114	59	3,641	408	190	1,249,574	155,027	23,170
JUNE	1,182	155	62	3,212	484	194	1,014,616	118,332	25,383
JULY	1,120	145	36	3,020	524	86	988,759	160,298	15,395
AUGUST	1,179	323	77	3,455	813	222	1,020,174	195,645	33,180
SEPTEMBER	1,046	575	66	3,023	1,355	156	892,864	194,451	69,359
OCTOBER	1,102	818	176	3,510	1,827	543	1,229,560	445,688	144,122
NOVEMBER	1,487	1796	194	4,594	5,791	573	1,578,159	1,177,026	148,808
DECEMBER	1,637	1599	169	5,008	5,717	532	2,205,919	1,064,450	95,870
ANNUAL									
Avg. per month	1,757	566	110	5,362	1,839	321	1,637,878	386,864	70,314
Total for Year				64,348	22,066	3,851	19,654,540	4,642,366	843,762

Fig. 15. OK-FIRE web site statistics during 2007 through 2009.

This table lists the number of unique visitors, number of visits, and number of hits during each month during those three years. A “visit” refers to an event when the OK-FIRE web site was opened and then closed; obviously, there can be multiple hits on various products within a single visit. “Unique visitors” refers to unique IP addresses (i.e., unique computers) that are accessing the system.

The peak fire season in Oklahoma, both for wildfires and prescribed burning, is November through April, and this is generally reflected in the monthly distribution of web hits and visits during each year. Also, the web site was password-protected from the time of its debut (September 2006) through August 2008, at which time it was opened to the public. That may help explain the huge jump in usage between 2008 and 2009, but also the continuing series of intensive OK-FIRE fall workshops no doubt serves to increase the usage. Monthly weather between year to year also plays a role as well, for if the weather is unsuitable for wildfires or prescribed burning, usage typically will go down.

As can be seen in Fig. 15, OK-FIRE usage skyrocketed in 2009, with 19,654,540 total hits in 2009 compared to 4,642,366 in 2008 (an increase of 423%). Total visits rose from 22,066 in 2008 to 64,348 in 2009 (an increase of 292%). The average monthly number of unique visitors, which is the indicator of number of users, rose from 566 in 2008 to 1757 in 2009 (an increase of 310%). In summary, these figures indicate the number of OK-FIRE users is increasing and along with that, the number of hits to various products. It would therefore appear that more and more wildland fire managers are using OK-FIRE as a management tool in their work, which is certainly one of the major goals of OK-FIRE.

B. Application to Prescribed Fire

One of the major focal areas of the Joint Fire Science Program is on prescribed fire as a way of managing fuels and on systems that help wildland fire managers plan and conduct such burns. OK-FIRE certainly is such a system and the fact that it is being used for such purposes can be seen in a variety of feedback we have received over the years, largely from written comments on our fall workshop surveys. OK-FIRE allows for better pre-burn planning and management during prescribed burns. Following are a number of comments related to the prescribed fire application from a variety of our user groups:

“I have a great deal of experience with prescribed fires, but even with all my experience I won’t consider burning before using the information that is now available to us. It removes much of what used to be at best an educated guess. Thanks very much for providing us with such an effective tool. The OK-FIRE system is just as important as a drip torch and backpack fire pumps.”

- Steve Sanders, US Army Corps of Engineers

“I’ve attended several NWCG fire training courses lately with folks from around the U.S., and the OK-FIRE web site is by far the most informative and user friendly fire danger forecast site I’ve seen. Great instruction, very thorough. OK-FIRE is the premiere web-based fire information system in the U.S.”

- Chris Hise, The Nature Conservancy

"I was very impressed with your presentation OK-FIRE. I have attended numerous fire training sessions over the last 25 years and you by far did the best. You were able to bring fire behavior, current weather, and forecasted fire weather together in a very understandable format .. This program provides today's fire managers with all the information in one spot"

- Dennis Weiland, Chief Ranger, National Park Service

"Thank you for teaching such a useful workshop. I think the web site is a tremendous asset to those of us who use prescribed fire in Oklahoma."

- Jona Tucker, The Nature Conservancy

"Great program! OK-FIRE is a great tool for fire management in the eastern Oklahoma region."

- Jansen Fine, Bureau of Indian Affairs

"OK-FIRE is a great 'packaging' of fire-related information. Very valuable to the prescribed fire practitioner and those in wildfire control."

- Bob Hamilton, The Nature Conservancy

"Useful information on smoke dispersion is getting to be more and more important due to population sprawl."

- Jim Montgomery, US Army Corps of Engineers

"Very useful in determining where and when to do our prescribed burns."

- Shannon Hudgens, USDA Forest Service

"This program is a very useful tool to help me plan my burns safely."

- Jamie Hyslop, US Army Corps of Engineers

"I think every fire department should be required to attend this class so they can keep firefighters safe and inform the public on prescribed burn times."

- Rick Mitchell, Fire Chief, Okmulgee Fire Department

"The OK-FIRE web site is a very useful tool for prescribed burning. I do not conduct a burn without first consulting this web site"

- Will Moseley, Noble Foundation, Ardmore

"OK-FIRE is a great tool for both planning a prescribed burn and planning suppression on a wildfire."

- Paul Clark, Natural Resources Conservation Service

"We will use OK-FIRE for prescribed burns, when considering burn bans, and for wildfire control."

- Cheryl Jackson, Carmen Fire and Rescue

C. Application to Wildfire

The other major application of OK-FIRE is wildfire. During the last two years of fall workshops, we have largely targeted those who are interested in this application - fire departments (rural, combined, and city) and emergency managers. OK-FIRE offers those who work in wildfire suppression not only detailed guidance during a wildfire, including future conditions critical for managing the fire, but also the ability to anticipate future periods of high fire danger and thus optimize staffing levels. Another use of OK-FIRE is as a tool to decide when to issue burn bans and when to rescind them. Recently in 2008, state legislation was passed in Oklahoma that gave county commissioners the ability to declare/rescind burn bans for their individual counties, based on input from fire departments and emergency managers. On a state level the Governor can also declare/rescind burn bans. Following are a number of comments from our users which address the importance of OK-FIRE to wildfire management:

"As a fire chief, I see OK-FIRE as a great tool in planning for the potential of fire and the possible resources needed in containing the incident."

- Keith Bryan, Fire Chief, Nichols Hills Fire Department

"I think every fire department should be required to attend this class so they can keep firefighters safe and inform the public on prescribed burn times."

- Rick Mitchell, Fire Chief, Okmulgee Fire Department

"The OK-FIRE system is a great tool for our community to use to: (1) determine when (actual time frames) to call additional personnel in to staff wildland firefighting trucks; (2) give fire incident commanders an idea of fire control tactics which may, or may not, be effective; (3) to alert community decision makers on the threat to Stillwater; and (4) to warn the public of impending danger .. We continue to use this technology to help us determine appropriate staffing levels, response procedures, and pre-fire planning and community risk assessment."

- Larry Mullikin, former Fire Chief, Stillwater Fire Department

"OK-FIRE is a great web site and those agencies it serves in Oklahoma are fortunate to have an all-in-one-place to go for information. I wish similar web sites existed for fire/forestry agencies in the other three states for which our office provides weather forecasts. Texas Forest Service has a fair web site providing fire danger indices and such, but is a distant second to OK-FIRE."

- Bill Adams, National Weather Service, Shreveport, LA

"I think OK-FIRE is a great tool in the use of forest fire suppression activities and planning the next days' needs for manpower and equipment."

- Rick Chambless, Oklahoma Forestry Services

"OK-FIRE helps me as a manager plan what staffing level I need during moderate to high fire danger days."

- Sam McFarland, USDA Forest Service

“The OK-FIRE site is very important in predicting high fire danger staffing levels. The site-specific data are used to pre-position suppression resources.”

- Sheldon Sankey, Bureau of Indian Affairs

“The OK-FIRE web site has been invaluable to personnel at all levels of our organization, in terms of firefighter and public safety. The fire intelligence modeling products found on this web site cannot be found anywhere else. Thanks for making this useful web site available to us and for the service provided to the citizens of Oklahoma.”

- Mark Masters, Oklahoma-Arkansas Interagency Fire Coordination Center,
Bureau of Indian Affairs, Hot Springs, AR

“Extremely valuable program - planning and forecasting. This program is a must.”

- Rob Hill, Stillwater Emergency Management

“Good program and training - more need it !”

- David Barnes, Oklahoma County Emergency Management

“I will use the program for fire suppression and tactics, also for fire predictions to help plan the day's activities so men can be ready and rested.”

- Sam Smith, Ada Fire Department

“The OK-FIRE site will be very useful to determine days with the highest fire danger and what hours firefighters should be on high alert.”

- Steve Grayson, Altus Emergency Management

“This was an excellent class. I will use OK-FIRE more this coming season since I know more of its capabilities.”

- Bobby Tallchief, Emergency Management, Osage Nation

D. Implications Outside of Oklahoma

It should be obvious by now that OK-FIRE is growing program in Oklahoma and having a positive impact on the wildland fire management community as well as on public safety within the state. In other geographical areas having substantial acreage of wildlands, it's not difficult to extend the lessons learned here and postulate that such systems would benefit and be used by wildland fire managers in other areas of the country and indeed the world. In the next section we will comment on some of the other systems currently used in various parts of the United States, but what would it take to create an OK-FIRE like system in other geographical areas outside of Oklahoma ?

As has been seen, OK-FIRE utilizes both a statewide automated weather station network (the Oklahoma Mesonet) for recent/current conditions and an 84-hour numerical forecast (NAM model) for future conditions. Such numerical forecasts are available for other sections of the U.S. and indeed the world, but not every state or region has an automated weather station network due to their cost and maintenance, although they are becoming more prevalent.

At a very minimum (given computational resources and computer programmers), a forecast component could be developed for fire weather variables and for surface smoke dispersion (using the methodologies in the Oklahoma Dispersion Model). These forecasts are not dependent on antecedent conditions that would require an automated weather station network. Such a forecast component could also be included for 1-hour dead fuel moisture, since fuel moisture in these fine fuels is not that dependent on antecedent conditions. For 10-hour, 100-hour, and 1000-hour fuels, however, the Nelson dead fuel moisture model relies heavily on initial fuel moisture conditions at the start of the forecast period, and these initial states are based on former weather conditions that would need to be monitored by an automated weather station network.

With the addition of an automated weather station network, such a system could be expanded to look more similar to OK-FIRE. Obviously recent and current fire weather conditions could now be made available, as well as recent and current smoke dispersion conditions. Since the Oklahoma Fire Danger Model requires “memory” for the calculation of 10-, 100-, and 1000-hour fuel moisture, as well as KBDI, the NFDRS could now be implemented to the area of concern. If the fire danger model were to be similar to the Oklahoma Fire Danger Model, weekly satellite NDVI data would also need to be integrated into the model to calculate visual and relative greenness, to calculate live fuel moisture, and to apportion loads between live and dead fuels for the fuel model assigned each 1-km pixel of land. Note that implementing an automated weather station network into the Nelson and fire danger models represents a level of programming much more difficult and time consuming than the system discussed in the paragraph above, which is a forecast-only system.

The display of products on the OK-FIRE web site relies (for its charts and maps) on a locally developed browser plugin, so for other geographical areas either a similar type plugin could be developed or another technology used. After the products and web site had been developed (the first two focal areas of OK-FIRE), training workshops similar to those in OK-FIRE could be implemented.

V. RELATIONSHIP TO OTHER SYSTEMS AND ONGOING WORK

OK-FIRE is an example of an operational wildland fire management system, of which many types exist. With respect to time frame, some systems only deal with recent/current conditions, while others may add a forecast component or concentrate exclusively on forecast conditions. Elements for consideration include fire weather, fire danger, and smoke dispersion; most systems include fire weather, but others may cover two or even all three of these elements. Most systems use the internet (web sites) as the delivery mechanism for such information, although other means of communication may be used as well.

OK-FIRE, as has been seen, covers both current/recent conditions and future conditions (up to 84 hours). It includes all three elements (fire weather, fire danger, and smoke dispersion) and utilizes a dedicated web site for the delivery of its products. It also

has a strong training component. While it is not our intention in this section to offer a comprehensive review of all such operational fire management systems, it would be instructive to view OK-FIRE in the light of some other current systems in the United States.

As an example of a *national* operational system for fire danger estimation, the USDA Forest Service operates the Wildland Fire Assessment System (WFAS), which currently has a number of products for both current and forecast periods. Using remote automated weather stations (RAWS) and input from WIMS (Weather Information Management System), current assessments are available for the nation (48 states plus Alaska) for fire danger adjective class (using BI or ERC), dead fuel moisture, and KBDI. Using the same satellite imagery that OK-FIRE uses, weekly maps of visual and relative greenness are also produced and used to estimate live fuel moisture. A number of forecast products are available. Using the NWS' national digital forecast database, daily ERC forecasts for NFDRS fuel model G are calculated up to 6 days in the future (for mid-afternoon conditions). Using the NAM model, next-day forecasts (mid-afternoon conditions) are also produced using the 1-km national fuel model map for BI, ERC, SC, and IC, as well as for 10-, 100-, and 1000-hour dead fuel moisture; certain weather variables are forecast as well.

The mesoscale MM5 model is operationally run at a number of locations across the country to produce weather, fire danger, and smoke dispersion forecasts up to three days in the future for different geographical regions. Many of the regional modeling centers of the FCAMMS (Fire Consortium for the Advanced Modeling of Meteorology and Smoke) run the MM5 to produce mesoscale hourly weather forecasts as well as indices related to fire danger (such as the Fosberg Fire Weather Index and Haines Index) and smoke dispersion (such as the Lavdas Dispersion Index and Ventilation Index). Some states such as Florida run the MM5 themselves (Florida Division of Forestry). Two of the FCAMMS are also producing national forecasts of NFDRS indices. The California and Nevada Smoke and Air Committee (CANSAC) is producing, through the Desert Research Institute, operational 15-day ERC forecasts for NFDRS fuel model G for the lower 48 states using the Global Forecast System (GFS) model. The Rocky Mountain Center (RMC), as of late, is producing forecasts up to 75 hours of hourly NFDRS indices for the nation using either the MM5 or a new "MFF" mesoscale model. All four categories of dead fuel moisture as well as KBDI are calculated. The user can also select which of 20 NFDRS fuel models to be utilized in the NFDRS calculations.

National Weather Service offices throughout the nation provide "fire weather" forecasts that also include parameters for smoke dispersion (such as mixing height and Ventilation Index). These products typically (at least for offices that cover Oklahoma) are forecast in 12-hour intervals (Tulsa NWS uses 3-hour intervals) over the next 48 hours, followed by daily (mid-afternoon) conditions out through Day 7. Hourly weather variable forecasts through 144 hours (six days) are available via their "Hourly Weather Graph" product. NWS offices also issue Red Flag Watches and Warnings based on the expected weather (fuels information is also taken into account).

A number of states operate automated weather station networks, either throughout their state (e.g., Kentucky Mesonet) or in certain portions of their state (e.g., West Texas

Mesonet). Also, certain regions of the country may combine automated weather stations across a number of states into one system (e.g., Automated Weather Data Network of the High Plains Regional Climate Center). Many of these networks are utilized for agricultural applications. To our knowledge, outside of Oklahoma, few of these statewide or regional networks are currently being used for operational fire management systems (e.g., fire danger and/or smoke dispersion).

In the above context, OK-FIRE would appear to be on the cutting edge among national, regional, and statewide fire management systems. Using an automated weather station network (the Oklahoma Mesonet) in conjunction with a digital forecast (NAM model), OK-FIRE calculates both current (updated every hour) and *hourly* forecast values out to 84 hours of all NFDRS fire danger indices (BI, SC, ERC, and IC) to 1-km resolution, as well as current and hourly forecast values of 1-, 10-, 100-, and 1000-hour dead fuel moisture using the Nelson model. Aside from the Rocky Mountain Center, the systems which do forecast NFDRS indices do so only for one time per day, not every hour, through the forecast period. In addition, those systems (such as WFAS) that rely on RAWS stations for some of their products have large geographical data gaps in certain states such as Oklahoma, which only has three such stations, in contrast to the 120 stations OK-FIRE uses via the Oklahoma Mesonet. Also, OK-FIRE is the only system using the Oklahoma Dispersion Model for surface smoke dispersion predictions. Most other systems predict boundary-layer variables such as mixing height, Ventilation Index, and Dispersion Index; more complex smoke modeling systems do exist, however, which have not been discussed, such as BlueSky which is also being run by RMC.

With respect to local ongoing work, OK-FIRE represents yet another application of the Oklahoma Mesonet, which has been operational since 1994. It incorporates models that have been developed in the past through work of the PI - namely, the Oklahoma Fire Danger Model, the Oklahoma Dispersion Model, and the more recent Nelson model for dead fuel moisture. OK-FIRE relies on the technological and operational support provided at Mesonet headquarters at the Oklahoma Climatological Survey in Norman, OK. We will continue to work together to keep improving OK-FIRE.

VI. FUTURE WORK NEEDED

As has been earlier discussed, OK-FIRE has a three-fold focus consisting of: (1) a suite of products for fire weather, fire danger, and smoke dispersal; (2) a dedicated delivery mechanism (the OK-FIRE web site) for the products; and (3) training for our users. As we look to the future, work will continue in all three areas.

With respect to products, every year of the OK-FIRE project has seen modifications to forecast ingest, models, and/or products as well as development of new products. This activity is expected to continue into the future. A simple example of this for 2010 would be the development of an accumulated precipitation variable over the 84-hour forecast period; currently, we calculate and display only 1-hour precipitation. More complex examples on which we hope to work over the next several years will now be discussed.

We have recently discovered that the NAM model is now producing output at *hourly* intervals through the 84-hour forecast period. Currently we are using 3-hourly output and employing linear interpolation in time to calculate hourly values. This rather basic interpolation scheme, however, often means we miss the extremes of the day, such as highest temperature and lowest relative humidity. Modifying our ingest software to take advantage of the NAM hourly output will put these problems to rest and make for more accurate hourly predictions on the OK-FIRE system.

Another area of importance to the fire danger model has to do with fuel models. Currently, every 1-km pixel of land in Oklahoma (except for lake areas) is assigned one of five NFDRS fuel models (the Mesonet site is assigned the fuel model of the pixel in which it resides). However, if the user wants to use a different fuel model to calculate the NFDRS indices, he or she is currently unable to do so. In 2010 we hope to give the user the ability to choose one of 10 NFDRS fuel models at any Mesonet site and have that NFDRS information displayed.

A further area of importance has to do with the observed greenness values (visual and relative greenness) of each 1-km pixel as calculated by weekly satellite NDVI data. These data are critical to the model as they are used to calculate live fuel moisture and apportion loads between live and dead fuels on a weekly basis. However, there are a number of problems associated with using such satellite information - cloudy or partly cloudy pixels can result in inaccurate greenness readings, and partially or fully snow-covered pixels result in unrealistically low greenness values. Other problems arise in agricultural pixels, where growing crops or harvested crops (and bare fields) result in greenness levels much different than that of native vegetation, to which the fuel models and fire danger model apply. It would be nice to give the user the ability to specify, for example, one of five relative greenness levels (10, 30, 50, 70, and 90%) at any Mesonet site and have the resulting NFDRS information displayed. This would be similar to the 1988 NFDRS where the user had the option of specifying "greenness factors".

With respect to delivery mechanisms for the products, the OK-FIRE web site has been the major vehicle developed thus far. Each year of the project has seen a new version of the web site that contains improved features. This work is expected to continue. However, not many fire managers, especially when fighting fires or conducting a prescribed burn, have access to computers in the field with internet connectivity. The increasing use of cell phones, and especially "smart" phones, affords additional opportunities for OK-FIRE access. Over the coming years, resources permitting, we will investigate the possibility of developing a cell-phone optimized version of OK-FIRE and also consider text downloads of information to cell phones.

With respect to training, we plan to continue the fall OK-FIRE workshops at least for a number of years more. They have been very popular, as has been seen. In 2010 I would like to offer both an introductory half-day workshop as well as an advanced half-day workshop for those who have already attended an introductory class in the past. The advanced workshop would concentrate on more complex topics such as fuel models and greenness.

Besides the workshops (to which not everyone who would like to attend can come due to travel distance or work), we also need to develop some on-line training modules (e.g., Flash files) so that more people can learn how to use OK-FIRE on their own. The response to such an idea was overwhelming positive in the post-workshop surveys we conducted.

In addition, and this relates to general awareness of OK-FIRE, we need to do a better job talking about OK-FIRE in the media (e.g., TV, radio, agricultural publications). It would also be nice if we could develop some type of newsletter (e.g., quarterly) to send to our users and other interested outlets.

Professionally, we would like to submit a journal article in 2010 about OK-FIRE to the *International Journal of Wildland Fire*. As future opportunities arise, we will also continue to make presentations about various aspects of OK-FIRE at professional conferences and symposia.

Finally, with the original funding for OK-FIRE having ended, it is important to secure continuing support from the Oklahoma Mesonet to keep OK-FIRE a viable and growing program. Outside of training, which the PI can conduct independently, we rely on the technological and operational resources of the Oklahoma Mesonet for continuing modifications and improvements to the forecast ingest system, the models, the products, and the web site, as well as for the hardware on which to run them operationally. OK-FIRE is just one of many programs of the Oklahoma Mesonet and getting the needed resources (time and people) to make this program a high priority becomes more difficult without dedicated grant funding.

VII. DELIVERABLES CROSSWALK TABLE

In the table to follow, the original deliverables (through “Final Report”) in the 2004 proposal are listed first, followed by some additional deliverables. Note that a one-year no-cost extension was obtained to take the project through 2009.

Deliverable	Status
Annual progress report (first year, 2005-06)	Completed (2006)
First set of products and initial web site (http://okfire.mesonet.org)	Completed (Sep 2006)
First round of regional training workshops	Completed (Sep - Nov 2006)
Annual progress report (second year, 2006-07)	Completed (2007)
Second set of products and enhanced web site	Completed (Sep 2007)
Second round of regional training workshops	Completed (Sep - Dec 2007)
Annual progress report (third year, 2007-08)	Completed (2008)
Third set of products and enhanced web site	Completed (Sep 2008)
Third round of regional training workshops	Completed (Oct - Dec 2008)
Project evaluation survey	Surveys given at each round of workshops; not fully evaluated yet
“Final” set of products and “final” version of web site	Completed (Sep 2009)
Final report	Completed (Feb 2010)
Fourth round of regional training workshops	Completed (Sep - Dec 2009)
Project-related publications	Completed; see Section VIII
Project-related professional presentations	Completed; see Section VIII
Other OK-FIRE presentations	Completed; see Section VIII

VIII. REFERENCES AND OK-FIRE RELATED WORK

Literature Cited

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Project-Related Publications

Carlson, J.D. and T.G. Bidwell, 2008. OK-FIRE: A New Weather-Based Decision Support System for Wildland Fire Managers, OSU Cooperative Extension Service, L-326, tri-fold brochure.

Carlson, J. D., R. Jabrzemski, S. Blackburn, J. M. Wolfinbarger, and R. A. McPherson, 2008. OK-FIRE: A weather-based decision support system for wildland fire management in Oklahoma. Conference CD, *17th Conference on Applied Climatology*, Aug. 11-15, Whistler, BC, Paper P1.4, 6 pp.

Carlson, J.D., T.G. Bidwell, S. Blackburn, R. Jabrzemski, and J.M. Wolfinbarger, 2009. OK-FIRE: A weather-based decision support system for wildland fire management in Oklahoma. Poster P1.20 (PDF), *Eighth Symposium on Fire and Forest Meteorology*, Oct. 13-15, Kalispell, MT.

Weir, J.R. and J. D. Carlson, 2008. Smoke Management for Prescribed Burning, OSU Cooperative Extension Service, E-1008, 13 pp.

Weir, J.R., Elmore, D., Bidwell, T.G., Engle, D.M., Carlson, J.D. and S.D. Fuhlendorf, 2009. Oklahoma Prescribed Burning Handbook, OSU Cooperative Extension Service, E-1010, 58 pp.

Project-Related Professional Presentations

Carlson, J.D. and T. G. Bidwell, 2007. OK-FIRE: A weather-based decision support system for wildland fire managers in Oklahoma. Oral presentation at *Second Fire Behavior and Fuels Conference*, Mar. 26-30, Destin, FL.

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Carlson, J.D., Jabrzemski, R., Blackburn, S., Wolfinbarger, J.M., and R.A. McPherson, 2008. OK-FIRE: A weather-based decision support system for wildland fire management in Oklahoma. Poster presentation (P1.4) at *17th Conference on Applied Climatology*, Aug. 11-15, Whistler, BC.

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Carlson, J.D., Bidwell, T.G., Blackburn, S., Jabrzemski, R., and J.M. Wolfinbarger, 2009. OK-FIRE: A weather-based decision support system for wildland fire management in Oklahoma. Poster presentation (P1.20) at the *Eighth Symposium on Fire and Forest Meteorology*, Oct. 13-15, Kalispell, MT.

Other OK-FIRE Presentations

2006 Federal/state fire managers (Talihina, May 16; Tulsa, Jun. 9; Oklahoma City (OKC), Jun. 19; Sulphur, Jun. 20; Medicine Park and Cheyenne, Jun. 21)

2007 Oklahoma Dept. Environ. Quality and State Fire Marshal (May 25); Gary Sherrer - OSU (Jun. 11); Danny Hilliard - OU (Jun. 12); Ralph Brown - OSU (Jun. 26); R. White, J. Ramsey, J. Trapp, C. Watson - OSU (Aug. 13); Senator Bass and Rep. Armes - Lawton (Sep. 17); Senator Myers - Ponca City (Sep. 19)

Fire Environment Working Team of the National Wildfire Coordinating Group, Norman (Jun. 12)

National Weather Service regional fire weather workshop, Shreveport, LA (Jun. 24)

Annual meeting of Oklahoma City and Tulsa area fire chiefs, Stillwater (Aug. 17)

2008 Noble Foundation Annual Prescribed Burn School (Ardmore, Jan. 24); OSU Fire Protection Publications (Jun. 10); OKC fire chiefs and State Fire Marshal (OKC, Jun. 11); NOAA fire weather committee (Norman, Jun. 19); Rural Fire Coordinators and Fire Service Training coordinators (Goldsby, Jul. 10); Metro Fire Chiefs annual meeting (Stillwater, Aug. 22)

2009 Payne County commissioners (Stillwater, Feb. 6); "Ag Mafia" at the Capitol (OKC, Mar. 16); Spring meeting, Association of County Commissioners of Oklahoma (OKC, Apr. 8); Norman Chamber of Commerce (Norman, Jun. 16)

OK-FIRE Training Workshops

2006 Eight one-day OK-FIRE computer workshops: Bartlesville (Sep. 28), Idabel (Oct. 5), Muskogee (Oct. 12), Talihina (Oct. 19), Woodward (Oct. 26), Sulphur (Nov. 2), Chickasha (Nov. 16, 21)

2007 Nine one-day OK-FIRE computer workshops: Bartlesville (Sep. 27), Idabel (Oct. 4), Muskogee (Oct. 11), Talihina (Oct. 18), Woodward (Nov. 1), Sulphur (Nov. 8), Duncan (Nov. 13), El Reno (Nov. 20), Stillwater (Dec. 13)

2008 Eighteen half-day and one full-day OK-FIRE computer workshops: Jenks (Oct. 1-2), Choctaw (Oct. 7-9), Enid (Oct. 15), McAlester (Oct. 23), Woodward (Oct. 30), Duncan (Nov. 6), Muskogee (Nov. 13), Idabel (Nov. 18), Durant (Nov. 19), Stillwater (Dec. 11)

2009 Nine 2-hour OK-FIRE workshops: Noble Foundation, Ardmore (Jan.7), Pawhuska (Feb. 23), Enid (Sep. 23), El Reno (Oct. 1), Burns Flat (Oct. 27), Woodward (Nov. 3), Muskogee (Nov. 10), Altus (Nov. 23), Shawnee (Dec. 1)

23 half-day OK-FIRE computer workshops: Tulsa (Feb. 10), Enid (Sep. 24), El Reno (Oct. 2), Burns Flat (Oct. 28), Weatherford (Oct. 29), Woodward (Nov. 4), Goodwell (Nov. 6), Muskogee (Nov. 11), Bartlesville (Nov. 12), Talihina (Nov. 18), McAlester (Nov. 20), Altus (Nov. 24), Shawnee (Dec. 2), Ada (Dec. 3), Duncan (Dec. 10), Ardmore (Dec. 11), Stillwater (Dec. 16)

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