ANALYSIS OF THE PERFORMANCE OF THE BEHAVE MODEL USE IN THE NORTH AND CENTRAL FLORIDA FIRES, SUMMER 1998

By Jacoby Carter

USGS National Wetlands Research Center, Lafayette, LA, 70506

Phone: 318-266-8620   Fax: 318-266-8592

E-mail:jacoby_carter@usgs.gov

ABSTRACT

I attempted to assess the effectiveness of the BEHAVE model for predicting observed fire behavior during the 1998 fire season in North and Central Florida. Archives stored at the Florida Division of Forestry office in Tallahassee Florida were examined on two separate occasions. All records in the archives were examined and selected records were copied for future analysis. Records copied include both electronic records stored on diskettes and paper records. In general it was found that fire behavior analysts (FBAs) did not include copies of the BEHAVE model runs in either their written reports, nor sufficient documentation to reproduce their BEHAVE runs. In those instances where BEHAVE output was included in the archive, it was not possible to compare that output to the recorded fire behavior. In an effort to gather some data on BEHAVE model performance, a FBA was hired to observe some fires during the spring 1999 fire season. Due to logistical difficulties, however, we did not gather enough data to make a comparison. However, the experience did highlight some of the problems in data collection procedures.

INTRODUCTION

During 1998, wildfires in northern and central Florida presented many difficulties for fire fighters. One of the problems reported was that the fire behavior model used, BEHAVE, did not accurately predict fire behavior (Anonymous 1998). BEHAVE is a program used to predict important fire behavior parameters, such as rate-of-spread, flame length, fire line intensity, and spotting distance. BEHAVE uses 13 standard fuel models that roughly correspond to broad fuel characteristics of several vegetation physiognomies (Anderson 1982). In the 1998 fire season, four different fuel models were used, Models 2 (grass dominated with timber overstory), 4 (chaparral), 7 (southern rough), and 9 (hardwood litter). The natural forest vegetation in northern and central Florida is adapted to fire and is classified as temperate broad-leaved evergreen and southern mixed hardwood (Bellis 1995). Local vegetation types were pine plantations, bays and domes dominated by cypress (*Taxodium* sp.), scrub, and shrub bog. Important in carrying the fire in the understory, were palmetto (*Serenoa* sp. and *Sabal* sp.) and gallberry (*Ilex* sp.). In addition to natural forest, pine plantations are a prominent feature of the landscape.

There were several factors that may have contributed to any problems the BEHAVE model may have had in predicting fire behavior. First, extreme fire conditions were in effect due to high fuel loads and extremely high drought indexes (Anonymous 1998). Second, those crews who came in from other regions of the country were surprised by the flammability of live fuels which burned at higher moisture contents and relative humidities than they were used to seeing (Anonymous 1998), or that are predicted in the standard BEHAVE models (Albini 1984). Though some believe that the higher flammability of the live fuels is due to the presence of volatile chemicals, this hypothesis has yet to be substantiated.

OBJECTIVES

First, quantify BEHAVE model performance by comparing its predictions to observed behavior when possible. Second, document how the BEHAVE model was used operationally by the fire behavior analysts (FBAs).

METHODS

Two sources of information on the performance of the BEHAVE model were available; records stored in the fire archives of the State of Florida, Division of Forestry headquarters in Tallahassee, Florida, and communication directly with FBAs who were involved.

FBAs were contacted and questioned as to: (1) additional records in their possession not available in Tallahassee, (2) personal accounts pertaining to their use of the BEHAVE model and, (3) information on how to contact other FBAs. FBAs in Florida were contacted though the FL Division of Forestry and the Florida Nature Conservancy. FBAs from outside of Florida were more difficult to contact since contact information was in most cases incomplete. In one or two cases contact information was included in the reports on file, usually in the form of a note. In most cases however a combination of Internet search techniques and contact tracing was needed to establish contact with the various FBAs.

Fire behavior reports and supplemental materials deposited on file at the State of Florida Division of Forestry headquarters in Tallahassee Florida were examined. Photocopies of paper records and duplication of files on floppy disks were made. The author contacted several FBAs over the course of two months (October-November 1998) to determine if they had any records that might prove useful in this study. Many FBAs indicated that they included floppy disks as an archive for their files. When found, the entire contents of these floppy disks were downloaded onto a laptop hard drive for analysis.

In an effort to get a set of direct observations and predictions for comparison we sent an experienced observer into the field during the spring of 1999 to make some direct comparisons. His BEHAVE runs were analyzed by comparing them with predictions using all current fuel models (1 through 13) and sensitivity analysis focusing on fuel models 2, 4, and 7.

RESULTS

Analysis of Fire Records

There were three sources used to determine how BEHAVE was used operationally: direct questioning of the FBAs; examination of daily fire forecasts and supporting material; and fire narratives. In response to problems they experienced with BEHAVE model performance, FBAs used a variety of strategies to improve the fire behavior predictions from BEHAVE. One strategy that was often reported was to use one fuel model to predict rate-of-spread another to predict flame height. A second strategy used appears to have been to adjust model parameters such as fuel-moisture content or windspeed until model predictions matched observed behavior. A third strategy appears to have been to abandon the use of BEHAVE entirely once the FBA developed a ‘feel’ for the fire behavior based on observations of local fire behavior and meteorological conditions.

I examined over 120 fire behavior reports by 18 different fire behavior officers on 8 named complexes or incidents. In those reports we found 18 BEHAVE runs included in the reports and associated files and only 2 incidents where actual fire observations were included.   However, it was not possible to tie observed fire behavior to a specific fire behavior prediction for any report.   This is surprising because conversations with the FBAs indicated that all their records and notes had been turned in to be archived, including notes on fire behavior and copies of BEHAVE runs.   However unless the BEHAVE run was attached to the day's fire forecast, it was not included in the archives.   Only 4 FBAs consistently attached their BEHAVE outputs.

Floppy disks were included in several of the packages; the entire contents of the floppy disks included in the archives exceeded 10 megabytes.   We were only able to open 15-20% of the files using two different platforms (Macintosh and PC) and three different word processing programs, 3 different spreadsheet or data base programs, and a variety of graphics programs.   Some of the file formats included were MS Word, WordPerfect, Works, FoxPro, JPEG, GIF, BMP, Excel, and Lotus 123.   The format for many files could not be determined.   We were only able to open 5% of the non-graphic files.

Direct Fire Observation

Due to logistical problems the observer did not get an opportunity to directly observe fire behavior during the spring 1999 fire behavior season in Florida.   However, he tried to coordinate with the FBA on site and data provided by the FBA was used as the bases of our sensitivity analysis.   The FBAs reported parameter estimates were used as the default values for BEHAVE sensitivity analyses.

BEHAVE Sensitivity Analysis

Using the parameters reported by the FBA from the Spring 1999 fire season, all 13 fuel models and various combination of models 2 & 4 and 2 & 7 (Table 1) were run.   A total of 2,940 behave predictions of flame length and rate-of-spread were generated. None of my BEHAVE results matched the BEHAVE results of the FBA, even when running blended models.

Graphical analyses were performed by varying herbaceous fuel moisture in model 2, live woody fuel moisture in models 4 and 7, and mid-flame windspeeds in either 2,4,7 or some combination of models. The range of values used for these analyses were 30-198 for live woody and herbaceous fuel moisture, and 3-9 miles per hour for mid-flame windspeed. The other parameters were held at their default values (Table 1). Both rate-of-spread and flame length increased with windspeed, and decreased with fuel-moisture content (example, Figure 1). While there was interaction between fuel moisture and windspeed, fuel-moisture content was not nearly as important for the parameter ranges examined. In models 2, 4 and 7 mid- flame windspeed had a dramatic effect on both rate-of-spread (increase) and flame length (increase). In model 2 the rate-of-spread and flame length were not significantly affected by herbaceous fuel- moisture content, but were affected by 1-hour fuel-moisture content. In model 7 the rate-of-spread and flame length were not significantly affected by live woody fuel- moisture content. In model 4 live fuel-moisture content did have some effect on rate-of-spread and flame length but mid-flame windspeed was much more significant. As in model 2, 1-hour fuels were more important in determining fire behavior. In model 2, 1-hour fuel-moisture contents above 16% would not sustain a fire. In fuel model 1, a 1-hour fuel- moisture content above 12% would not sustain a fire.

DISCUSSION AND CONCLUSIONS

Analysis of Archives and Recommendations

While fire behavior forecasts may be a useful tool for those fighting fire in the field, they do not contain enough information to evaluate either BEHAVE model performance or even reproduce model output. Several FBAs indicated that all of their files were turned in, including BEHAVE runs. However, little outside of official reports were found in the archives in Tallahassee. While the fire narratives by the FBAs describe in some detail when the BEHAVE model did and didn’t work well and the various strategies used to fix it, there is insufficient information included in the records to verify or quantify the claims.

It is recommended that BEHAVE output be attached to the daily forecast as a way of keeping a record of the model prediction. This would preserve both the input parameters used by the FBA and the model output. It is further recommended that any observations of actual fire behavior be noted on the BEHAVE output, so that fire behavior can be associated with fire predictions. Those cases in which the parameters used to make the model fit the observations are different from the parameters actually measured should be noted on the attached BEHAVE output.

It is recommended for both hardware and software reasons that if the intent is to archive BEHAVE output for long periods of time, files should not be stored in electronic format. There are two general hardware problems with archiving electronic media. First, magnetic media may slowly degrade over time so that individual files, or the entire contents of disks may be lost. Second, with the rapid changes in hardware technology over the years older formats, like the 5.25 inch disks, can no longer be read by currently produced commercial computers. There is good reason to suspect that this will also become the case for 3.5-inch diskettes as other, higher density media such as zip drives, become popular. Software presents similar problems. There are no standard formats for text-based data besides ASCII. Reports or databases written in one program are not likely to be readable by another program. Also, new versions of programs often have difficulty handling older file formats of the same program. Therefore it is recommended that paper be the only approved format for archiving purposes. Graphic files should be printed out and stored along with text and database files. Graphic images should have at a minimum, attached information about location, date, subject, photographer, and contact information.

If it is determined that files should be stored electronically, then all files should be stored on a data server that will be in long-term operation, regularly backed up, accessible via ftp, and have attached metadata. Data and reports should be in ASCII format; graphic files should be in non-proprietary formats such as JPEG, PICT, TIFF, and GIF. Harvard Graphics, PowerPoint, Adobe Illustrator, and other proprietary formats should be avoided. The last requirement should not be too much of a burden since most graphic packages do have functions that permit saving files in one or more of the “universal” formats.

Analysis of the Use of BEHAVE and Model Performance and Recommendations

Though many FBAs noted that the BEHAVE model did not perform well, until the circumstances in which the model does not perform well are documented and quantified, it will be impossible to use the many different ways available to adjust the BEHAVE model. Based on conversations with FBAs, one could argue that better parameter estimation might be part of the solution. The sensitivity analysis focused on herbaceous and live woody fuel-moisture content because conversations with FBAs indicated these were operationally the hardest parameters to estimate. Several instances were reported where estimates of fuel-moisture content used in model runs were based on data collected weeks or months before. However, with respect to rate-of-spread and flame length, for the fuel models 2, 4, and 7, improved parameter estimation of live woody or herbaceous fuel moisture would not have significantly improve model performance. Accurate estimation of windspeed however is important and that number is easily obtained. 1-hour fuel-moisture content is important for both models 2 and 4, and some effort should be made to more accurately estimate those values.

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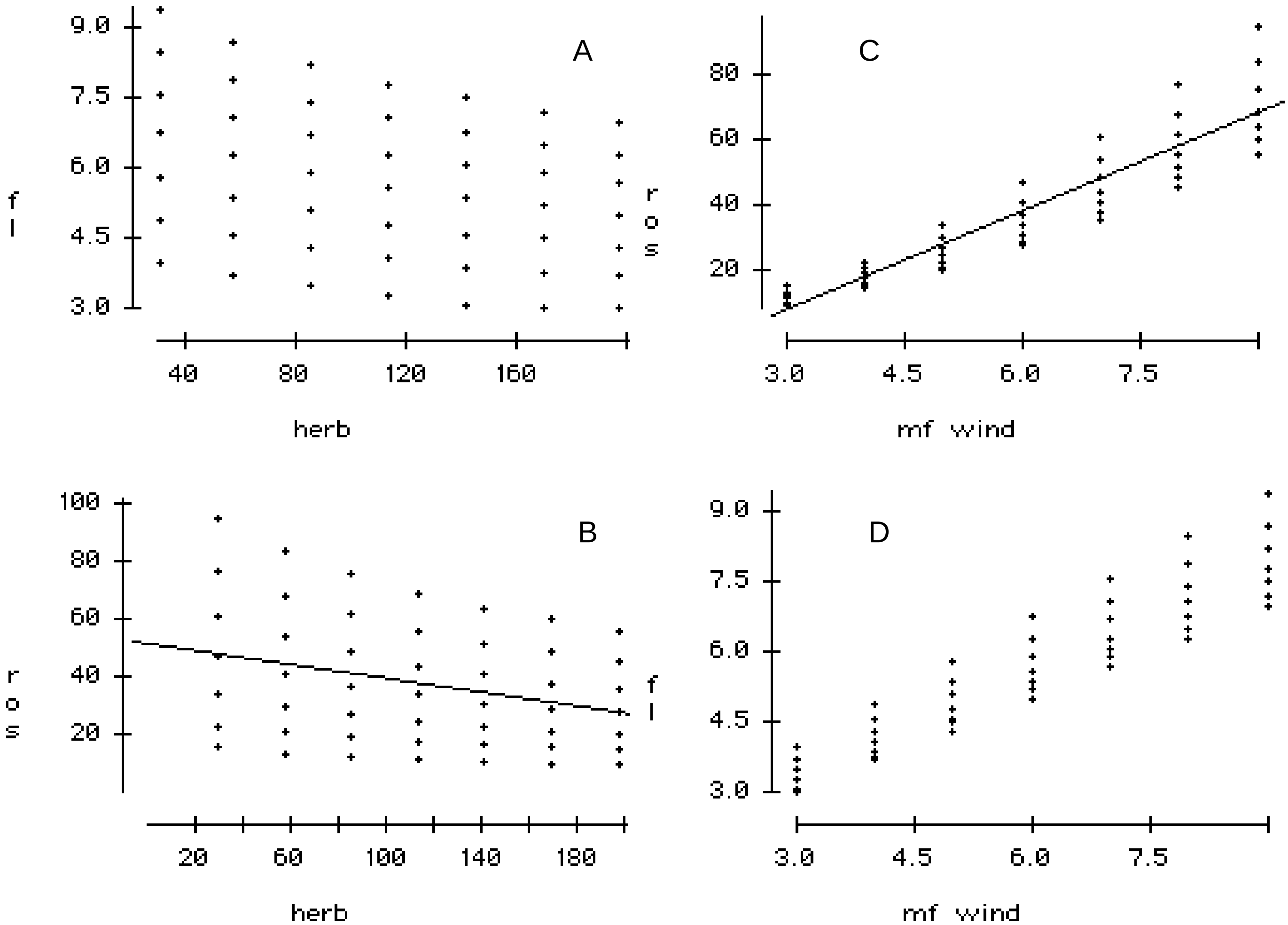

Figure 1. Rate-of-spread (ros) and flame length (fl) in BEHAVE using fuel model 2. Herbaceous fuel-moisture content (herb) was run from 30 to 198 and the mid-flame windspeed (mf wind) was run from 3 to 9 miles per hour. Other model parameters were held constant. A, B, C, and D used the same values for herbaceous fuel-moisture content and mid-flame windspeed. Figures A and D show flame length (feet) predictions and Figures B and C show the same rate-of-spread (chains per hour) predictions.

		Fuel-Moisture Content				
Fuel Model	1-hr	10-hr	100-hr	live woody	live herbaceous	Wind-speed (m/h)
1	(6) [12] 1-55	*	*	*	*	0-96 {4-10}
2	(6) [16] 1-55	(10) 1-55	(12) 1-55	*	(30) 58-198	1-97 {32-64}
3	(6) 1-55	*	*	*	*	1-97 {30}
4	(6) [20] 1-55	(10) 1-60	(12) 1-55	(107) 30-150	*	3-98 {16-80}
5	(6)	(10)	*	(107) 103-109	*	1-97 {22-25}
6	(6)	(10)	(12)	*	*	1-97 {19} [1]
7	(6) 1-31	(10) 1-31	(12) 1-31	(107) 30-270	*	(3-9) {18-22} 3-26
8	(6)	(10)	(12)	*	*	1-97 {9} [1]
9	(6)	(10)	(12)	*	*	1-97 {24}
10	(6)	(10)	(12)	(107) 103-109	*	1-97 {59-60}
11	(6)	(10)	(12)	*	*	1-97 {24}
12	(6)	(10)	(12)	*	*	1-97 {66}
13	(6)	(10)	(12)	*	*	1-97 {97}

Table 1. Summary of BEHAVE sensitivity analysis. The default values used are in parenthesis. An asterisk (*) indicates a parameter not applicable to the particular fuel model. Ranges over which parameters were adjusted are separated by a hyphen (-). Values in square brackets ([ ]) are those for which the rate-of-spread is 0. Mid-flame windspeed was adjusted until the‘wind limit’ was determined. The wind limit is the windspeed above which there is no increase in the rate-of-spread or flame length. The wind limit is in curly brackets ({}) and in models where the wind limit was effected by fuel-moisture content, the number provided is the range. All values are rounded to the nearest mile per hour or % moisture content. No separate values are given for combined models since combined-model output consisted of the respective individual model output results. The model parameter numbers 8-10 (slope, wind vector, direction of spread) were set to 0 for all runs.
Fuel Models Names: 1= short grass; 2= timber (grass & understory); 3= tall grass; 4= chaparral; 5= brush; 6= dormant brush, hardwood slash; 7= southern rough; 8= closed timber, litter; 9= hardwood litter; 10= timber (litter & understory); 11= light logging slash; 12= medium logging slash and; 13= heavy logging slash.