P1.2 FIRE GROWTH SIMULATIONS OF THE PRICE CANYON, THIRTYMILE AND STORM KING MOUNTAIN FIRES USING HIGH RESOLUTION WIND SIMULATION TOOLS AND FARSITE

B. W. Butler,* J.M. Forthofer, R.D. Stratton, M.A. Finney, and L.S. Bradshaw
USDA Forest Service, RMRS, Fire Sciences Laboratory, Missoula, MT

1. Introduction

1.1 Wind Modeling

Wind is one of the primary environmental variables influencing wildland fire spread and intensity (Rothermel 1972, Catchpole and others 1998). Nevertheless, methods to model local wind speed and direction are not readily available. In many cases, wind information available to fire incident personnel is limited to that available from weather forecasts and/or weather observations from a few specific locations, none of which may be actually near the fire. Mountainsides, valleys, ridges, and the fire itself, influence both the speed and direction of wind flows. A major source of uncertainty in fire behavior predictions is the lack of detailed wind speed and direction information for use in the fire behavior calculations. Wind and its spatial variability in mountainous terrain was a major factor in the fire behavior associated with recent fire incidents that resulted in firefighter entrapments and/or fatalities: South Canyon Fire 1994 (Butler and others 1998), Thirtymile fire (USDA Forest Service 2001), and Price Canyon Fire (Thomas and Vergari 2002). Fire behavior forecasts, fire growth projections and firefighter safety could greatly benefit from detailed local wind information.

1.2 A Wind Flow Simulation Tool

In 2003 a study was initiated with three objectives: 1) explore the utility of computational fluid dynamics (CFD) software for simulating surface wind flows in mountainous terrain, 2) identify how detailed surface wind information can assist wildland fire operations, and 3) develop a methodology by which the technology may be accessed by wildland fire incident management teams. Efforts to date have demonstrated the utility of this technology for providing detailed wind information in support of fire planning and management.

This application of CFD is not new, some previous studies have focused on the use of CFD technology for simulating wind flow over complex terrain (Raithby, Stubley and Taylor 1987, Alm and Nygaard 1995, Montavon 1998, Kim and others 2000). A few studies explored the interaction between wind and mountainous terrain within the context of wildland fire, but none have directly linked a method for producing wind simulations to support wildland fire management efforts.

This methodology assumes a neutrally stable atmosphere, meaning that they it does not take into account density driven flows (diurnal winds and fire induced winds). Neglecting these flows introduces some error (especially at low wind speeds); however as the upper air wind speed increases the relative magnitude of this error decreases. Nor does this methodology account for momentum transfer due to thermal instability in the atmosphere.

The accuracy of the wind simulations has been evaluated by comparing simulated winds against measured wind averages at discrete points from the Askervein hill project (Taylor and Teunissen 1987). The results indicate general agreement (Figs 1 and 2). While not conclusive the studies completed so far indicated that the simulated wind speeds and directions derived from this method are most accurate for pressure gradients such as cold fronts, Foehn (Santa Ana), onshore/offshore winds and are less accurate for the low speed density driven flows such as those associated with diurnal heating and cooling of the earth's surface.

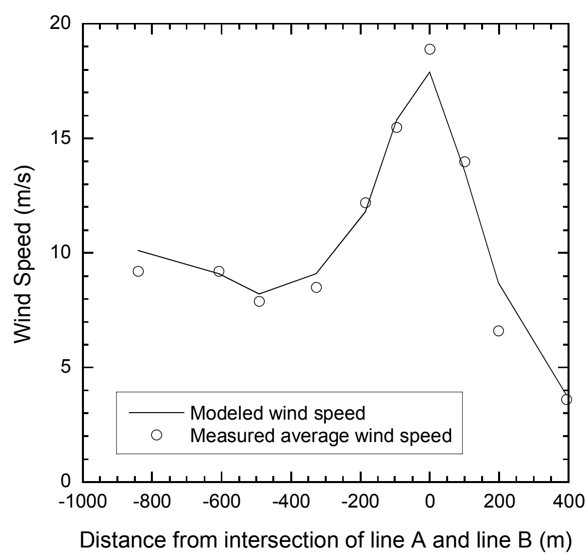

Figure 1 – Comparison of measured and simulated wind speeds for the Askervein Hill data. The distance along the horizontal axis represents the distance either upstream (negative) or downstream (positive) measured from the peak of the hill.

* Corresponding author address: Bret Butler, USDA Forest Service, RMRS, Fire Sciences Laboratory, 5775 Hwy 10 W, Missoula, MT 59808; e-mail: bwbutler@fs.fed.us

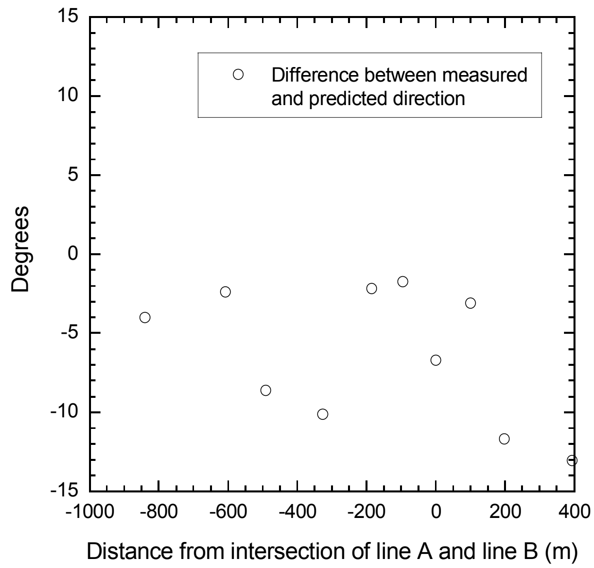

Figure 2 – Comparison of measured and simulated wind direction for the Askervein Hill data. The distance along the horizontal axis represents the distance either upstream (negative) or downstream (positive) measured from the peak of the hill.

2. Fire Growth Simulations

One method for evaluating the accuracy of this methodology is to compare fire growth simulations based on the wind simulations against those from actual fires. Simulations were performed for the Price Canyon fire that burned in Southern Utah on June 30, 2002 (Thomas and Vergari 2002), the South Canyon Fire (Butler et al 1999) and the Thirtymile Fire (USDA Forest Service 2001). The intended comparison was to be made between a fire growth simulation based on a constant speed and direction wind scenario (selected to most closely match the conditions at the time of the fire) and a second fire growth simulation that used wind information produced from the CFD tool.

2.1 Price Canyon Fire

The constant wind speed and direction for the time period of interest for the first simulation used measurements obtained from remote weather stations in the vicinity. The increase in fire size over time is displayed by the fire perimeters (fig. 3). In this case the fire growth predictions for the conditions on June 30 are compared to the final fire perimeter published by the incident review team (Thomas and Vergari 2002). As shown in the image there is significant under prediction of the fire growth on the north edge of the fire and over prediction of fire growth on the southern edge of the fire. A second set of simulations were completed using gridded (CFD based) wind data for the same period keeping all other factors the same (fig 4). Agreement between the actual and predicted final fire perimeters is much better. The discrepancy between predicted and actual perimeters on the right (west) edge of the fire area is due to a burnout operation that was conducted by the firefighters, and was not simulated in the FARSITE runs.

2.2 South Canyon Fire

Complex mountain winds were cited as one of the most important variables influencing the fire behavior on July 6, 1994 when the South Canyon Fire overran and killed 14 firefighters (Butler et al. 1998). Strong winds in excess of 45 mph developed as the result of a passing cold front. The ensuing combination

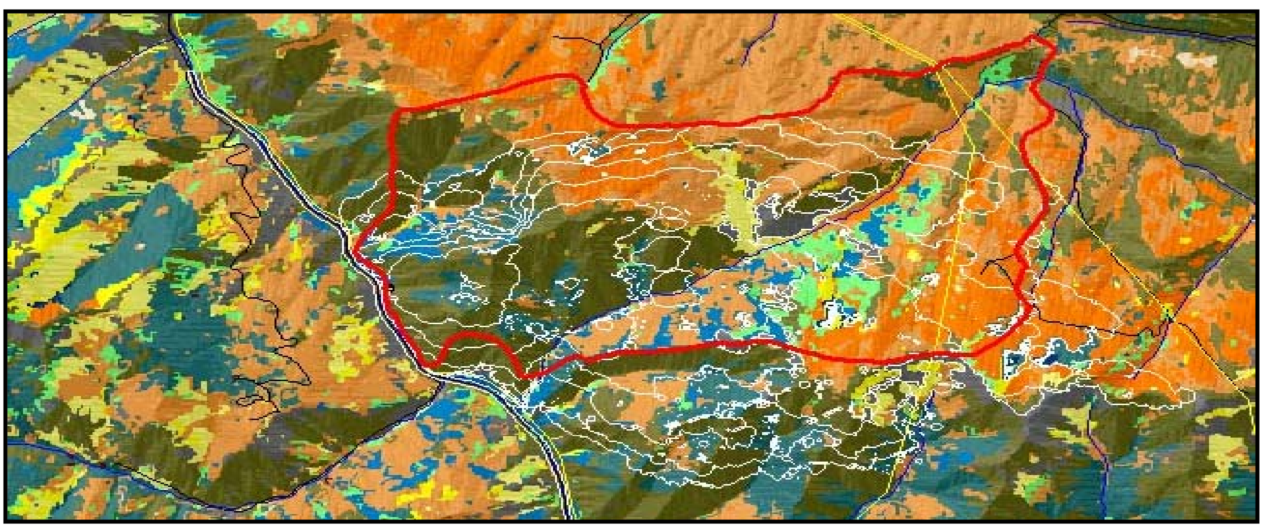

Figure 3 – FARSITE simulation of the Price Canyon Fire assuming uniform wind speed and direction from the left to right (west winds). White lines represent successive fire perimeters produce from the FARSITE simulation, heavy red line represents actual final fire perimeter. Fire started on the extreme left edge of the perimeter along the railroad on canyon floor.

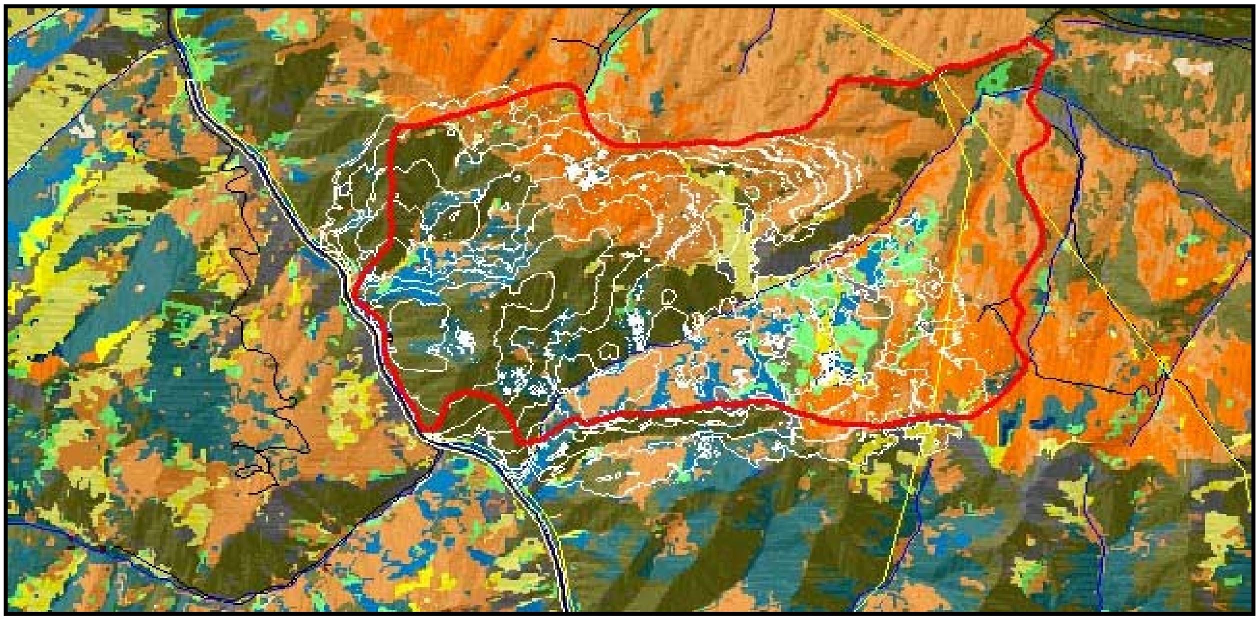

Figure 4 - FARSITE simulation of the Price Canyon Fire using gridded wind data from CFD-based simulation. General wind flow input to CFD was from the left to right (west winds). White lines represent successive fire perimeters produce from the FARSITE simulation, heavy red line represents actual final fire perimeter. Fire started on the extreme left edge of the perimeter along the railroad on canyon floor.

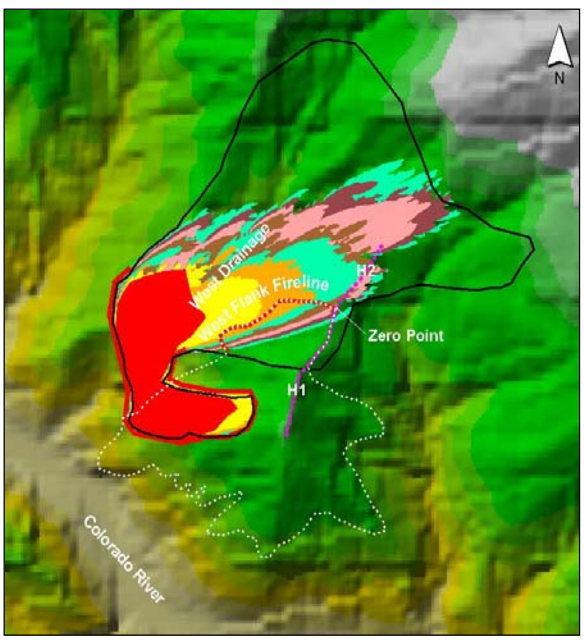

Figure 5 - FARSITE simulation using uniform winds of 33 mph from 245 degrees. The simulated perimeters shown are 3 minutes apart, ending at 1628. The red polygon and bold red line indicate the ignition polygon and barrier used. The actual fire perimeter for 1623 is shown in black.

of weather, fuel and terrain created extreme fire conditions that lead to the tragedy. The wind

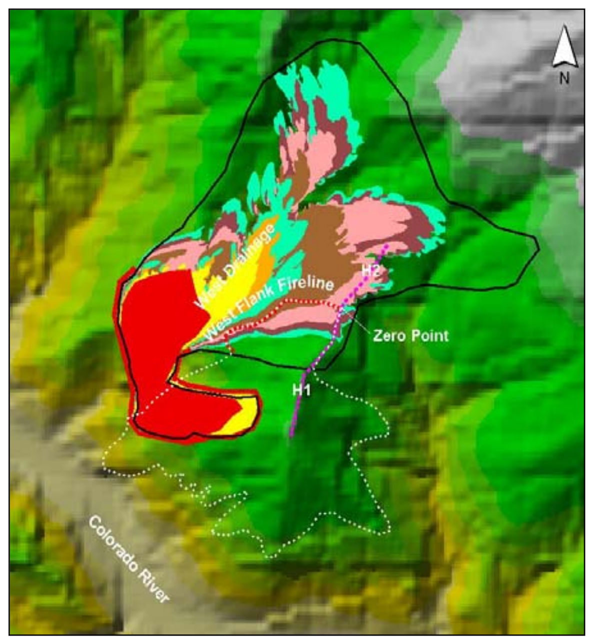

Figure 6 - FARSITE simulation using uniform winds of 33 mph from 245 degrees. The simulated perimeters shown are 3 minutes apart, ending at 1628. The red polygon and bold red line indicate the ignition polygon and barrier used. The actual fire perimeter for 1623 is shown in black.

conditions and abundance of published information concerning this fire make it an excellent candidate for study using gridded wind.

The temperature used for the simulations was 85 degrees F and the relative humidity was 8 percent. For the uniform wind case, 33 mph wind from 245 degrees gave the best results (figure 5).

A wind simulation for the fire area was done to match observations along the main ridge fireline. The upper level flow for the simulation was from 260 degrees. The results indicate channeling up the West Drainage.

The simulated fire spread for the uniform and gridded wind cases are shown in Figures 5 and 6. The approximate fire perimeter at 1623 from witness accounts is shown in black for comparison purposes. The FARSITE runs were started from the 1607 polygon shown in red. A barrier was used in the simulation to prevent fire spread over the previously burned area. During all simulations, a spread rate adjustment factor of 1.5 was used for all fuel models. Despite this, spread rate in all cases was still slower than the actual fire spread rate. The final simulation perimeters shown are for 1628, yet the actual fire perimeter shown in black is for 1623. Deficiencies in the fuel models used or in the fire spread model may be to blame for these slower than actual spread rates

It seems that the gross behavior of the South Canyon Fire was simulated more accurately using gridded wind than with uniform wind. The bifurcation of the fire front up the drainage to the North and over the ridge near H2 was simulated well with gridded wind. The uniform wind simulation did not show any spread to the North. It appears that the channeling of wind up the West Drainage was a crucial element affecting fire behavior.

2.3. Thirtymile fire

Simulations for the thirtymile fire were not completed by the publication deadline. However, preliminary results indicate that wind flow patterns within the drainage were subject to extreme turbulence during the fire event and consequently near ground air flow did not necessarily follow intuitive directions.

3. Conclusions

One major benefit of this methodology is that the user can generate high resolution wind information (~100m) for any number of wind scenarios using a laptop computer. While these initial test cases are not conclusive they suggest that surface wind modeling based on commercial CFD software captures variations in wind speed and direction at the 100 m scale and that wind information at this scale increases the accuracy of short term (< one day) fire growth simulations

4. Acknowledgements

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