On the Use of Fire Behavior Models for Decision Support Part II: Additional FARSITE Operational Considerations

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1. INTRODUCTION

This study applies FARSITE (Finney, 2004) to a late spring fire event to further explore its operational capabilities and potential use by National Weather Service (NWS) forecasters as a decision support tool for fire line officers and emergency support personnel responding to developing wildland fires (Huston, 2010). The primary goal of providing fire behavior spread projections during the initial stages of a developing wildfire is twofold: (1) Provide a framework for objective analysis of the developing incident, and (2) Support multiple levels of decision makers formulating and implementing strategic and/or tactical response plans.

Appropriately framing the analysis and formulating an adequate response is strongly dependent upon accurate and timely fire behavior projections. In turn, the accuracy of these projections is subject to, and limited by, the accuracy of the underlying variables used to initialize the model, namely fuel and wind (Rothermel, 1983). The natural variability of these elements in time and space effectively rules out absolute predictability. Thus, graphical *ensemble* depictions will be explored as a means of accounting for this uncertainty while maximizing the potential usefulness of FARSITE as an operational decision support tool.

2. CASE STUDY: HOWARD FIRE - JUNE 17, 2007

a. General Description of Event

On the afternoon of June 17, 2007, a wildland fire started approximately 4 km east-southeast of the Pocatello Regional Airport in the northwest foothills of the northern extent of the Bannock Range at approximately 1402 m MSL (Fig. 1). Strong west winds drove the fire east across the ridge (1770 m MSL) and into the western periphery of the city of Pocatello consuming over 650 hec in a little over 9 hours. Little further growth was observed the following day and the fire was declared contained on June 19, 2007.

b. Geospatial Fuel Distribution

The fuel distribution was predominantly characterized by a mix of grass and sage (see Scott and Burgan, 2005; fuel models GR2, GS2, and SH2), typical of the northern Great Basin.

c. Fuel Conditions

The fuel conditions were characterized as *transitioning* from spring green-up into early summer curing. Grass fuels found on south- and west-facing aspects had completed the transitional phase and had begun curing, while those found on north-facing aspects were still green and flourishing (Fig. 2).

The National Fire Danger Rating System (NFDRS) classified the fire danger as moderate to high across the impacted region (Fig. 3). Observed live fuel moisture readings of 145-160 percent for Basin Big Sagebrush located near Pocatello provided a good representation of the live woody fuel moisture values. Readings at this level typically support moderate fire behavior with a fast continuous rate of spread. However, under windy conditions and low humidity, high fire behavior can be expected requiring indirect fire fighting tactics (Pollet and Brown, 2007).

d. Synoptic Developments

During the afternoon of June 16, 2007, one day prior to the fire ignition, a vigorous low pressure system advanced east across northern Washington (Fig. 4) and into northwest Montana (Fig. 5) by 0600 MDT the following morning. The progression of the low was typical of many late spring storm systems which make landfall in the Pacific Northwest and shift east along the Canadian border. As the low pressure system progressed east across Washington, an associated surface cold front pushed southeast across southern Idaho (Fig. 6) and advanced rapidly into northern Utah by 0000 MDT on June 17 (Fig. 7). A strong postfrontal surface pressure gradient remained across southern Idaho the following day (not pictured) resulting in sustained west-southwest winds in excess of 25 mph with frequent gusts greater than 35 mph.

3. MODEL RESULTS

a. Supporting Data Sets

i. Weather File (WTR)

The data recorded from the Pocatello Regional Airport (PIH) Automated Surface Observing System (ASOS) was used as the basis for the weather inputs for this study due to its close proximity to the fire (Fig. 1). Consideration was also given to the weather data recorded at the Crystal Remote Automated Weather Station (RAWS) which was located a little over 58 km west of the fire.

ii. Broadscale Wind File (WND)

The wind speed data captured at both the Pocatello ASOS and the Crystal RAWS indicated sustained speeds in excess of 25 mph with frequent gusts greater than 35 mph beginning before noon and continuing through 2200 MDT on June 17, 2007. The wind direction was predominantly west-southwest (248 deg) at both locations and varied at times from southwest (225 deg) to west (270 deg) throughout the afternoon and evening. In agreement with the predominant wind direction recorded at the nearby observation sites and without due regard to potential terrain effects, the initial broadscale wind direction was indiscriminately set at 240 deg with speeds ranging from 23 to 27 mph between 1500

MDT and 2200 MDT. After 2300 MDT, the observed wind speed markedly decreased to 6 mph and was represented accordingly in the wind file.

iii. **Gridded Wind File (ATM)**
A mass-consistent microscale wind prediction model (WindNinja) was used to produce the gridded wind files used in this study (Forthofer, 2007). The broadscale winds noted above were used to initiate this microscale model.

iv. **Initial Fuel Moisture File (FMS)**
A set of five seasonal fuel moisture scenarios were objectively constructed based on a blend of the standard fire behavior reference tables found in Scott and Burgan (2005, Table 3 and 4) and climatological Live Fuel Moisture data acquired for both Sage and Juniper from representative fuel sampling sites in close proximity to the fire. These scenarios were classified as *frozen*, *pre-green up*, *green up*, *transitional*, and *cured* and were assigned dates of occurrence consistent with the observed seasonal cycle. The Howard Fire started at the beginning of the seasonal date assigned to the *transitional* fuel scenario. Live fuel moisture observations taken near Pocatello for June 4 through 18, 2007, clearly showed that moisture readings were at their lowest historical value for that time of year and resembled conditions typically observed during mid-summer. Thus, a *custom* fuel scenario was constructed in response to the accelerated seasonal curing observed. This *custom* scenario conservatively maintained the dead fuel moisture values (1-, 10-, and 100-hour) originally assigned to the *transitional* phase while averaging the *transitional* and *cured* live herbaceous and live woody fuel moisture values in an effort to reflect a modest response to the accelerated curing.

b. FARSITE Simulations

i. **Varying Wind Simulations**
The first simulation (Fig. 8) was initiated at 1500 MDT on June 17, 2007 from a point source ignition (stick-pin) following a 3-day fuel conditioning period utilizing the broadscale wind and *custom* fuel moisture data sets noted above. The simulation was arbitrarily terminated at 0300 MDT on June 18, 2010 (yellow line).

A second run was completed using the corresponding microscale gridded wind inputs (cyan line). Gridded microscale wind inputs were expected to provide greater model responsiveness to terrain influences and less dependency on the direction of the broadscale wind regime, resulting in increased fire spread prediction accuracy (Forthofer, 2007 and Finney *et al.*, 2006). The differences between each run were minimal and neither run compared well with the actual observed fire perimeter (red line) which consumed considerably more acreage to the south and east.

Deflection and/or a splitting wind flow around the northern extent of the Bannock Range could be reasonably envisioned given the stable postfrontal environment present across the region (Whiteman, 2000; Rife, 1996). Two similarly sited and independent meteorological platforms, Trail Gulch RAWS located 160 km west-southwest of the fire and Pocatello 6E located 16 km east-southeast of the fire, recorded northwest winds at the time of ignition. Thus, a modest wind direction adjustment to 270 deg was made in the model to compensate for complex terrain induced flows evident across the northern extent of the range. The corresponding broadscale and microscale wind inputs were then used to initiate new simulations (Fig. 9). The results were much improved and both simulations roughly captured the observed fire growth across the northern and eastern sectors of the fire. However, both simulations failed to capture the finger-like details observed across the eastern portion of the fire which were likely the result of the complex fuel moisture distribution noted previously and ongoing fire suppression activities. The broadscale simulation showed a modest extension of fire growth further to the east when compared to the microscale wind simulation which was consistent with lee-side effects noted in Forthofer (2007). The observed fire perimeter still extended further south of the modeled perimeter, which suggested that additional adjustments to the wind direction were warranted.

The wind direction was once again adjusted further north to 300 deg and each simulation was reinitialized utilizing the respective broadscale and microscale wind inputs (Fig. 10). The results were nearly identical and showed very good performance across the western and southern sectors of the fire. The change also produced a negative impact across the northern sector of the fire where considerably less modeled acreage was consumed compared to the observed fire perimeter.

ii. Seasonal Fuel Moisture Simulations

In an attempt to gauge the suitability of the initial *custom* fuel moisture file, the previous wind cases were rerun using the *transitional* and *cured* seasonal fuel moisture scenarios discussed earlier. The cases that utilized the higher fuel moisture levels indicative of the *transitional* scenario exhibited considerably less modeled fire growth while the drier fuel moisture levels associated with the *cured* scenario resulted in a significant increase in fire spread over the *transitional* and *custom* fuel moisture scenarios (not pictured).

The three fuel scenarios associated with the 240 deg microscale wind input were assembled into one depiction (Fig. 11) for comparison purposes (green – *transitional* fuel; cyan – *custom* fuel; orange – *cured* fuel). Figure 12 and 13 represent similar depictions based on the 270 and 300 deg microscale wind inputs, respectively. The *custom* fuel moisture fire spread simulation based on the 300 deg microscale wind direction (Fig. 13; cyan) performed reasonably well in all areas except the northern sector of the fire as noted previously. The *cured* fuel moisture scenario generated from the 270 deg microscale wind direction (Fig. 12; orange) performed extremely well in all areas with a notable extension of fire growth across the eastern sector of the fire in contrast to the observed fire perimeter. Again, this difference could be attributed to the complex fuel moisture distribution observed across the fire and/or ongoing fire suppression activities.

4. DISCUSSION

a. Broadscale Versus Gridded Wind Results

Based on Forthofer (2007) and Finney *et.al.* (2006), it was expected that the use of gridded microscale wind data would provide greater responsiveness to terrain influences and less dependency on the direction of the broadscale wind regime, resulting in increased fire spread prediction accuracy. This case study and previous work (Huston, 2010) suggest that these findings may be overstated. The comparative results (Figs. 8-10) were mixed with no clear advantage indicated by either methodology.

Secondary tests utilizing WindNinja (not shown) indicated that the model was incapable of resolving mesoscale terrain influenced wind circulations occurring over areas as large as 4 km^2, which was a fraction of the area burned during the fire. Thus, the finer *microscale* detail exhibited in the gridded data set may be useless if the broadscale wind used to produce it is unrepresentative of the mesoscale flow occurring over the fire landscape.

b. Use of Seasonal Fuel Moisture Scenarios

The use of seasonal fuel moisture scenarios helped speed the process of generating a reasonable initial fuel moisture file. In an operational context, the use of seasonally adjusted fuel scenarios may also help to maintain consistency among forecasters. An obvious drawback would be the potential over reliance on the seasonal scenarios when significant deviations occur in observed conditions, as demonstrated in this case study.

c. Impacts Associated with Heterogeneous Fuel Conditions

Great care was taken to initiate each point source ignition from the same grid throughout the entirety of the study. However, the manual point-and-click method of selecting an ignition point within the FARSITE software resulted in sites that fluctuated by as much as one or two grid boxes at times, producing noticeable differences in the final fire spread perimeter when compared to similar secondary runs. The use of a 2.5 hec circular shape file centered on the point of ignition and used to initiate each successive fire would have effectively eliminated this potential anomaly.

The heterogeneous fuel moisture conditions noted between north and south facing aspects undoubtedly impacted the model's ability to replicate the complexities of the observed fire perimeter which were also compounded by ongoing fire suppression activities. FARSITE enables users to define custom fuel types which, when coupled with GIS capabilities, may allow a modeler, with considerable effort, to approximate the complex nature of the fuel moisture distribution across a landscape. This effort would likely be prohibitive given the sparse fuel sampling resolution and time constraints associated with operational product preparation.

d. Ensemble Approach

Clearly, the natural variability of fuel and wind conditions can significantly impact the outcome and accuracy of any single fire behavior modeling simulation. Research has shown that *ensemble* depictions of multiple numerical weather predictions initiated from a perturbed state of initial conditions are a useful means of improving forecast skill (Toth *et.al.*, 1997; Grimit and Mass, 2002). The extension of this technique to fire behavior modeling has been demonstrated by Anderson *et.al*. (2005) and Finney *et.al*. (2010). A composite ensemble depiction of fire spread for the Howard Fire (Fig. 14) was constructed from the numerous simulations presented above for illustrative purposes. Such depictions could prove extremely useful in the process of objectively framing the potential coverage and impact of a developing incident. For example, a number of items have been annotated on figure 14 to demonstrate how these graphics might be used to quickly and efficiently assess potential impacts to transportation, communication, housing, essential public utilities, etc.

e. Decision Support Opportunities

Perhaps the most exciting aspect of producing timely operational fire spread projections is its potential use as a decision support tool during the initial stages of a developing incident. Fire management personnel and a wide spectrum of public and private agencies who are involved in fire support or mitigation efforts could benefit from the specificity and accuracy of model output during their decision making process. Statistics taken from the Wildland Fire Decision Support System (WFDSS) for southeast Idaho during the 2010 season indicated that nearly 70% of all modeling efforts were initiated two or more days *after* initial fire suppression activity had begun. Thus, an opportunity clearly exists to capitalize on the use of fire behavior projections in support of management decisions made during the initial stages of developing incidents.

f. Fire Management Applications

The *Fire Line Handbook* and the *Guidance for Implementation of Federal Wildland Fire Management Policy* (see references) are replete with directives that strongly encourage the use of "the full range of strategic and tactical options…in response to every wildland fire" and "a decision support process to guide and document wildfire management decisions."

This process should include a situational assessment, hazard and risk analysis, and management actions that are “based upon the best available science.”

A basic situational assessment identifying threatened resources, risks to public and fire fighter safety, fire complexity, and planned and alternative response actions could be rapidly accomplished with the aid of timely fire spread projections coupled with ancillary geographic information that is readily available within the WFDSS (e.g. Fig. 14). The use of *ensemble* projections to depict numerous potential fire outcomes could prove useful for assessing fire complexity as well as reducing uncertainty. Furthermore, *ensemble* projections might help identify potential *blow-up* conditions which could be used to increase public and firefighter safety. Model output could also be used as a *yard stick* to monitor fire behavior in an effort to support ongoing situational awareness.

Quantitative and qualitative model output could also be used to inform and support tactical and/or strategic decisions during various stages of the incident. The use of this information might allow initial attack forces to make the leap from the vague notion that *this fire is going to go big* to formulating a specific expectation of *how big*. Fire spread and flame length projections could be used to support decisions to safely conduct burnout operations prior to the arrival of the fire front. Alternatively, observed fire behavior that deviates significantly from modeled projections might provide an early warning that a fire is escalating out of control, necessitating a change in fire management tactics in the face of unanticipated developments. Incident commanders could also use model projections to help identify and anticipate critical support needs, pre-positioning forces in those areas to maximize protection. Model output might even prove useful for deciding when to follow preplanned response actions (e.g. district Fire Management Plans) and when to deviate from those plans based on projected fire severity. These examples and others suggest that timely and objective fire spread projections may provide an element of specificity and precision to initial attack decision support that has not existed before and that judicious use of these projections might result in increased safety with improved fire management outcomes.

5. CONCLUSION

Technological advances in wireless communication coupled with the availability of meteorological and fire behavior prediction have made it possible for wildland fire managers and impacted entities to obtain fire-specific decision support information in the field. Initial results indicate that timely delivery of fire spread projections during the early stages of an incident creates an opportunity for land managers to objectively assess potential fire outcomes, reduce uncertainty, evaluate risk, and formulate strategic and/or tactical plans and alternatives quickly and efficiently. Future work should include a collaborative effort with an incident commander to test and evaluate the usefulness of operational fire-specific decision support projections during the course of an incident.

The heterogeneous nature of fuel moisture coupled with the spatial variability of meteorological conditions clearly rules out absolute fire spread predictive capability. The accuracy of the fire spread projections presented in the current work also shows a strong dependency on well forecast wind parameters. Providing quality wind forecasts in complex terrain under varying meteorological conditions in time and space is a delicate proposition. However, research suggests that short-term meteorological ensemble depictions may improve forecast skill, which in turn may allow one to effectively frame and capture the most probable outcome and potential impacts of a developing wildland fire. Unfortunately, FARSITE does not allow for a range of meteorological inputs and the manual production of ensemble members would likely prove much too time consuming for operational consideration. Still, trial production of ensemble fire spread projections evaluated against observed fire perimeters may help to substantiate the use and accuracy of an ensemble approach which in turn may support a change to the FARSITE code to enable this capability.

A number of modest efficiencies and/or improvements supporting the use of areal ignitions, broadscale winds, and climatological initial fuel moisture files were demonstrated in the current study. These improvements could be incorporated into a production process which may help to enhance and support the potential use of FARSITE as an operational decision support vehicle.

6. ACKNOWLEDGMENTS

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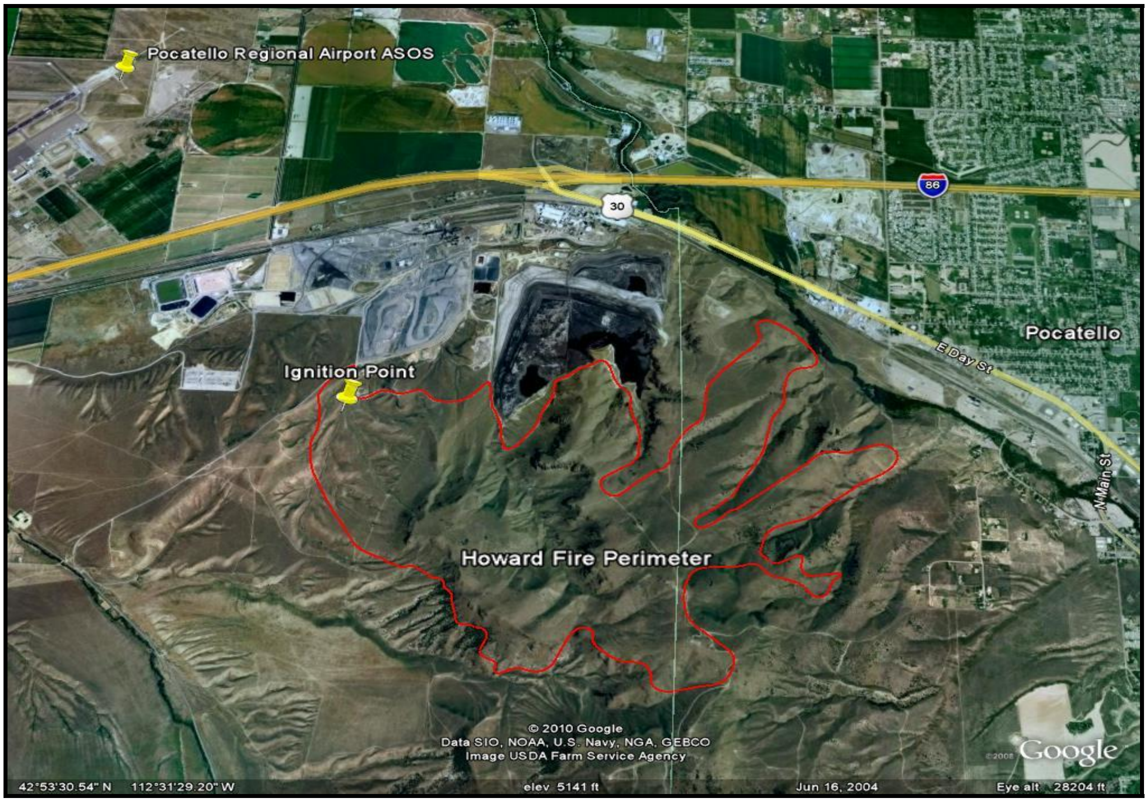

Fig. 1. Google Earth image with the perimeter of the Howard Fire overlaid in red.

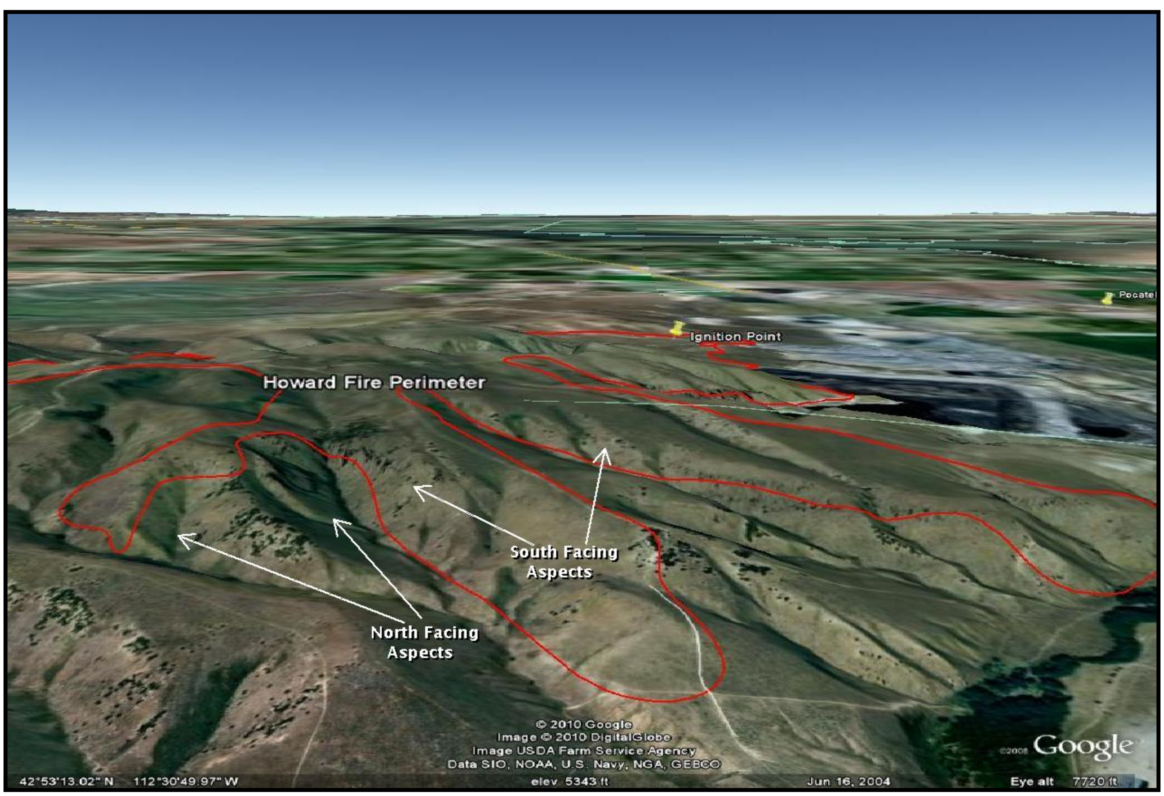

Fig. 2. Google Earth image looking west across the Howard Fire. Perimeter overlaid in red. North and south facing aspects annotated for reference.

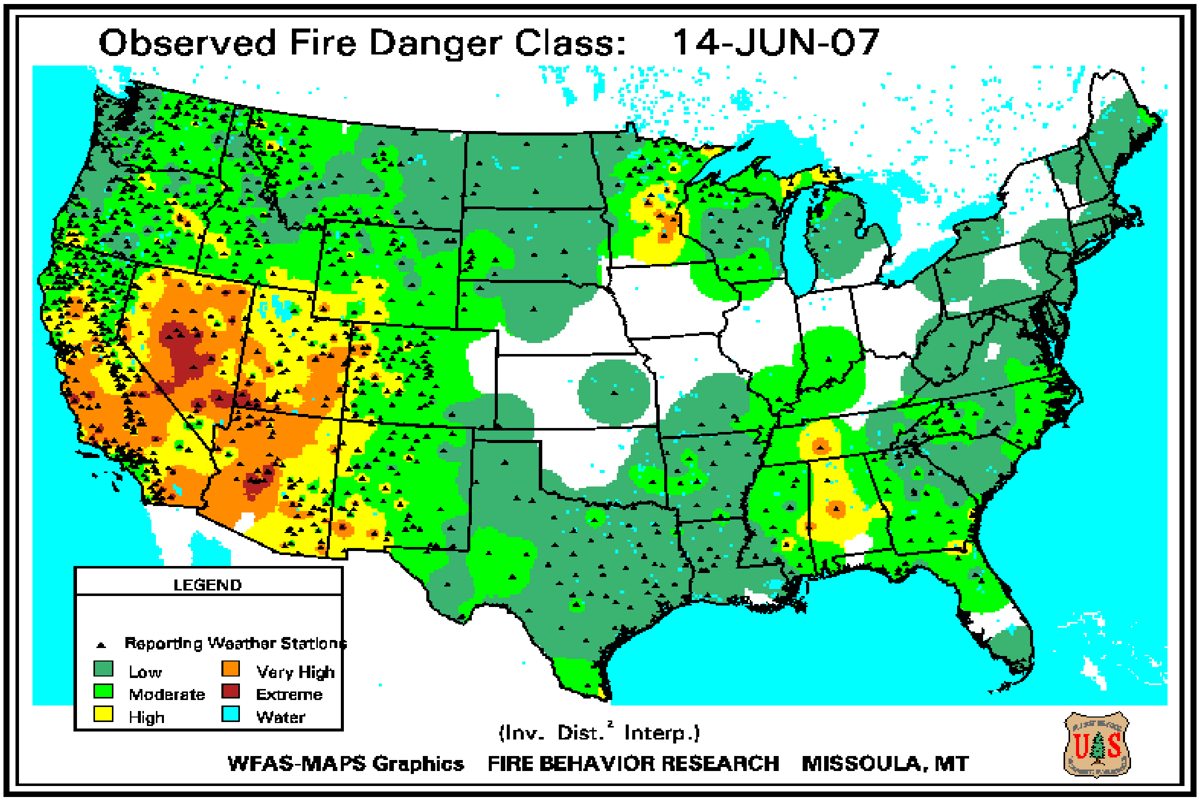

Fig. 3. Observed Fire Danger Class for June 14, 2007. Moderate to High Fire Danger is indicated for southeast Idaho.

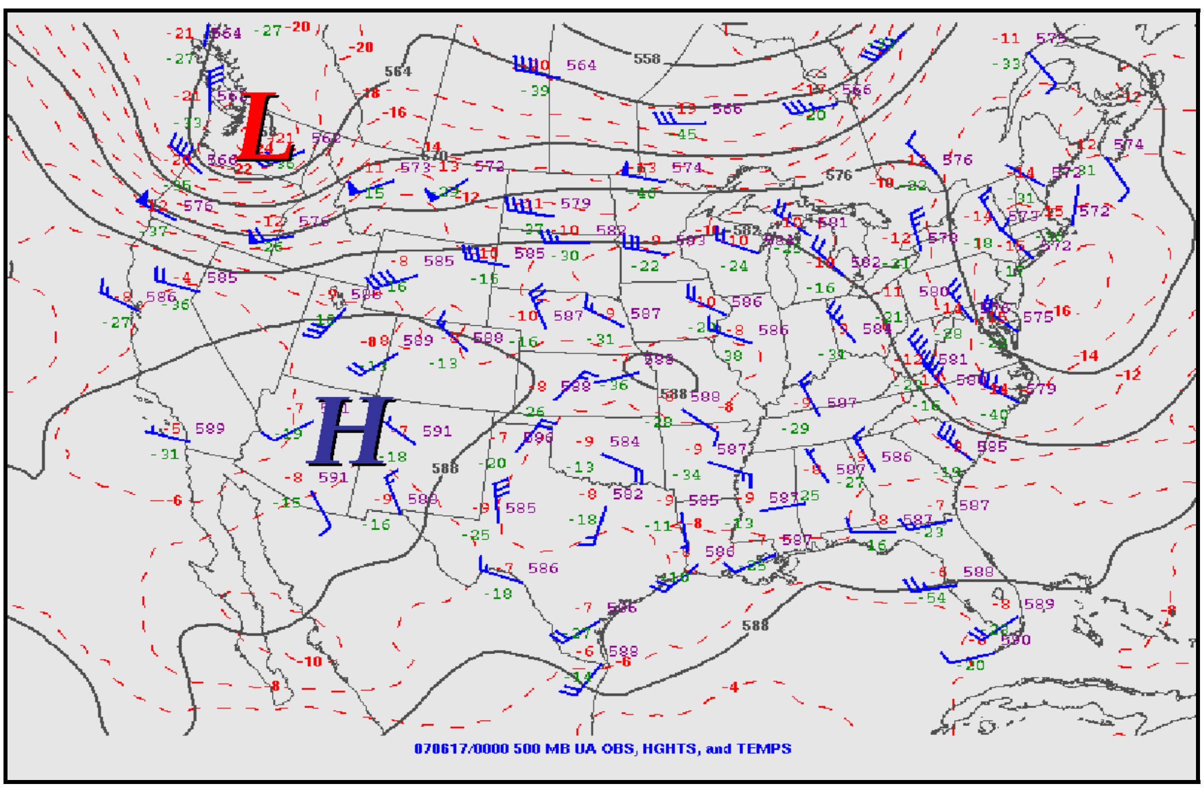

Fig. 4. Observed 500 hPa height (purple, solid black line with contour interval 60 meters), wind (blue wind barbs in knots), and temperature (red, dashed red line with contour interval 2 ^{o}C) for June 16, 2007 at 1800 MDT.

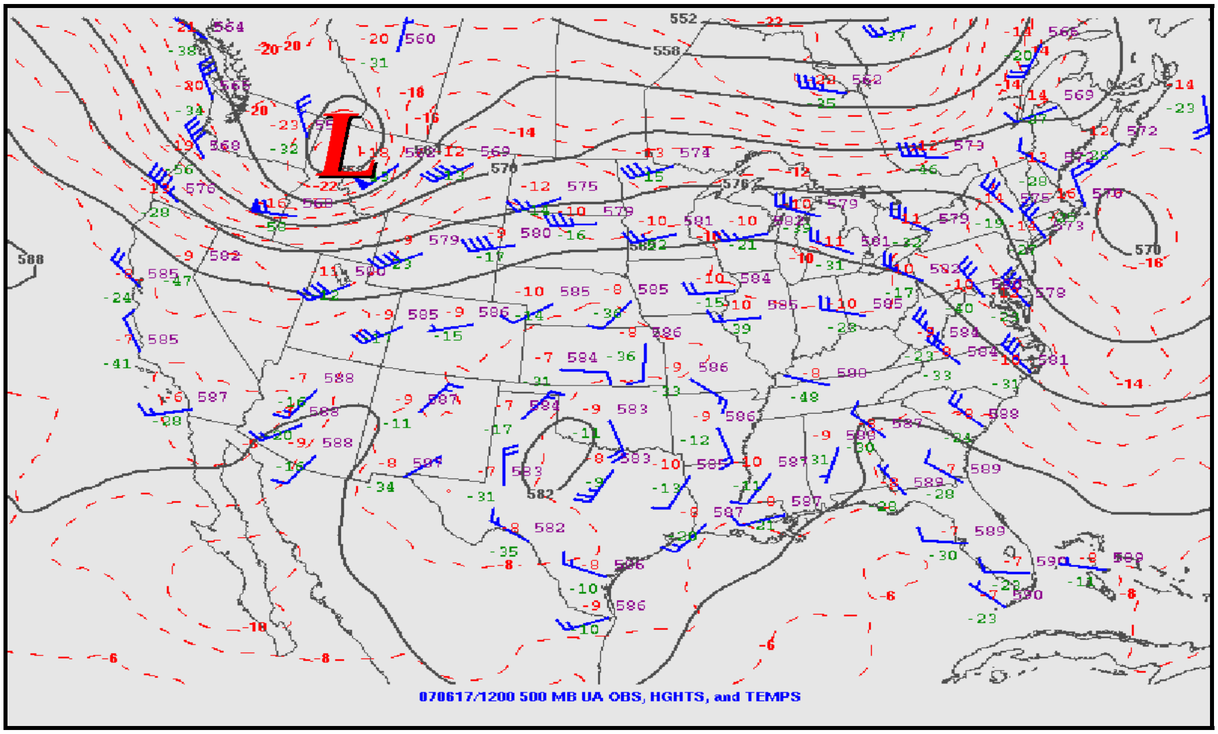

Fig. 5. Observed 500 hPa height (purple, solid black line with contour interval 60 meters), wind (blue wind barbs in knots), and temperature (red, dashed red line with contour interval 2 ^{o}C) for June 17, 2007 at 0600 MDT.

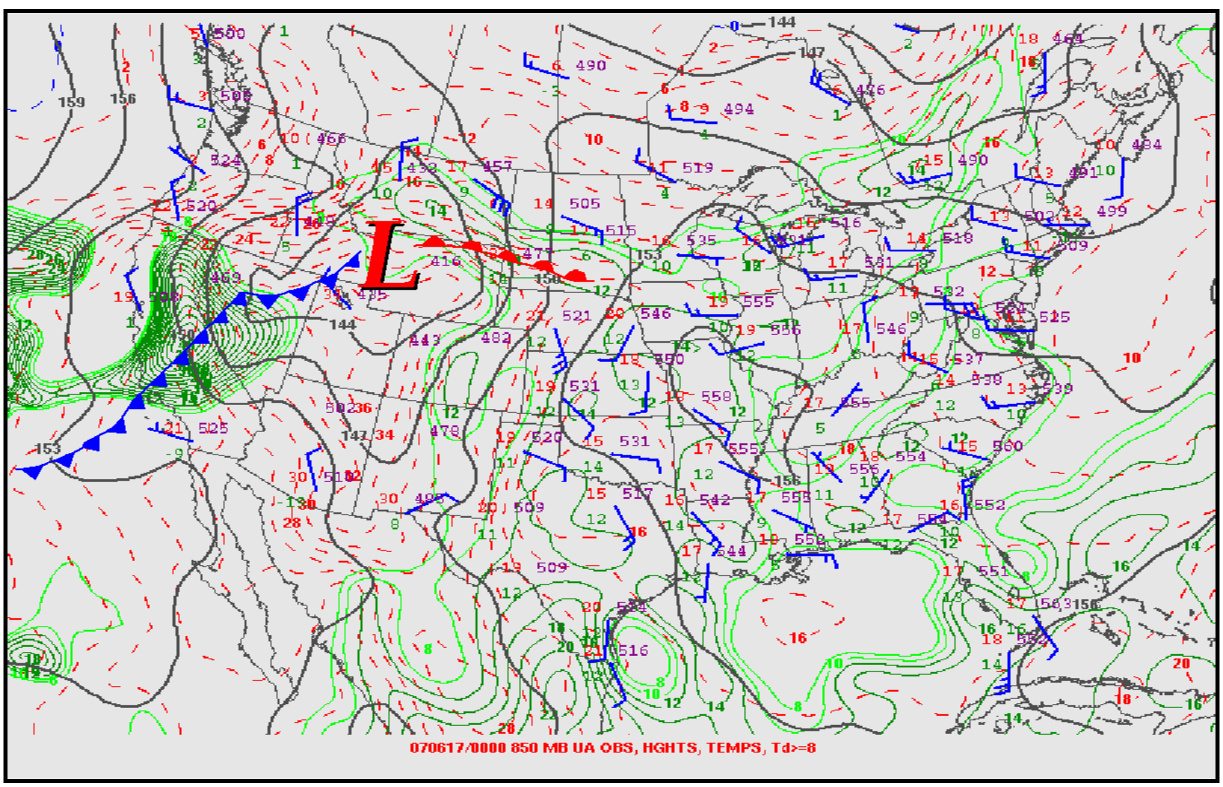

Fig. 6. Observed 850 hPa height (purple, solid black line with contour interval 30 meters), wind (blue wind barbs in knots), and temperature (red, dashed red line with contour interval 2 ^{o}C) for June 16, 2007 at 1800 MDT.

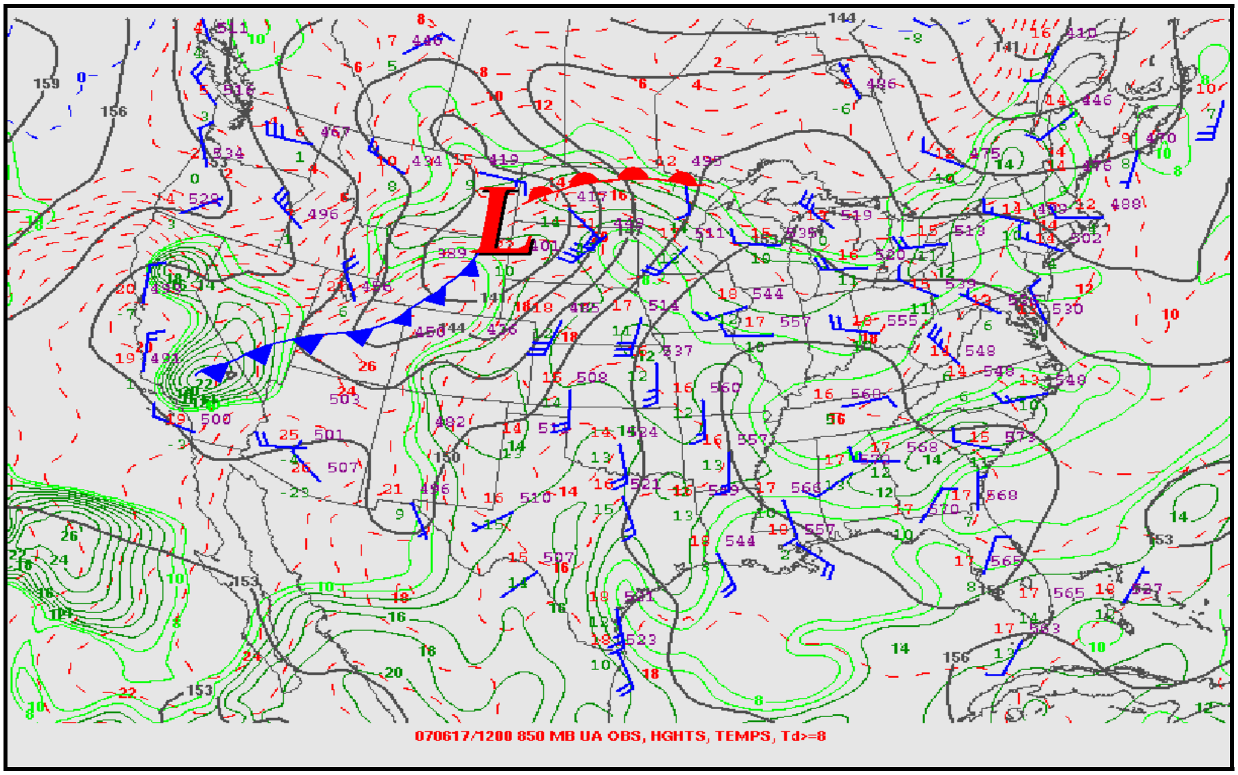

Fig. 7. Observed 850 hPa height (purple, solid black line with contour interval 30 meters), wind (blue wind barbs in knots), and temperature (red, dashed red line with contour interval 2 ^{o}C) for June 17, 2007 at 0600 MDT.

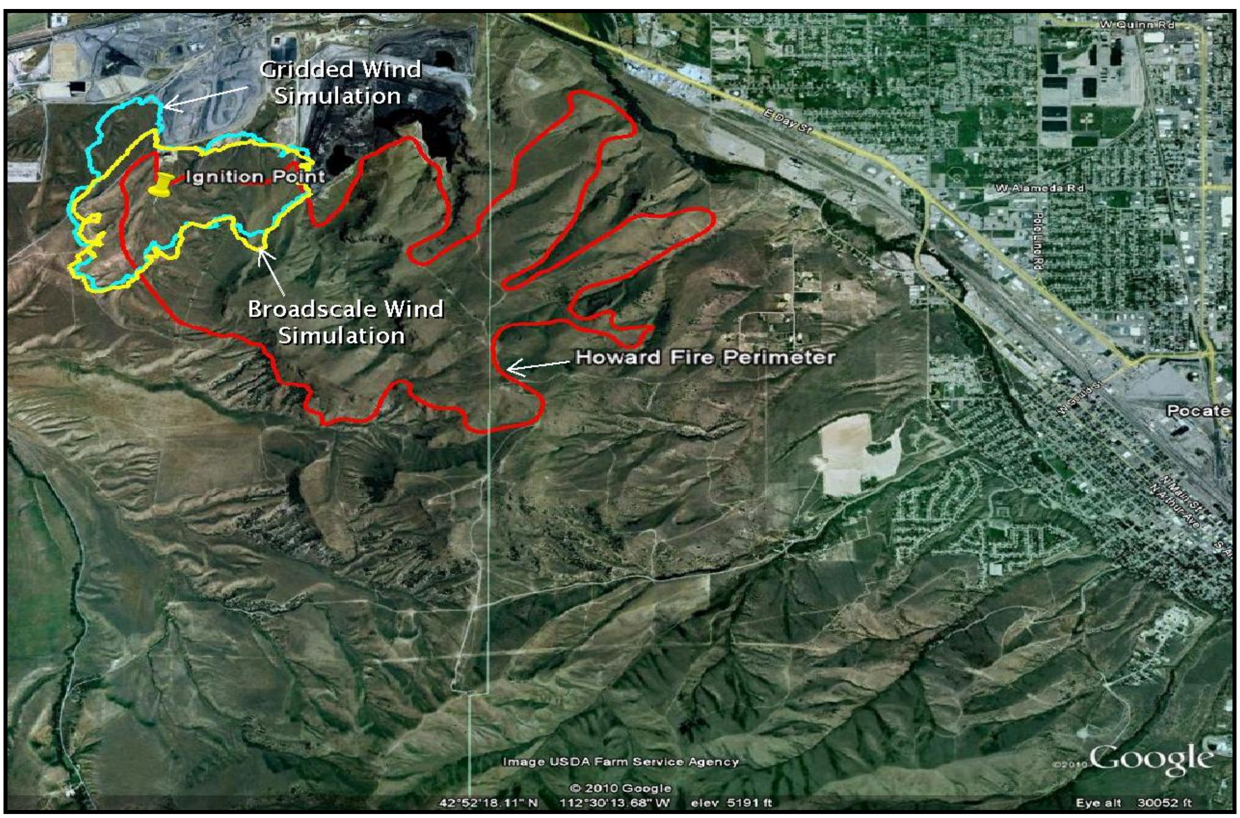

Fig. 8. Google Earth image of observed fire perimeter (red), FARSITE broadscale wind simulation (yellow), and FARSITE gridded wind simulation (cyan) from 240 deg.

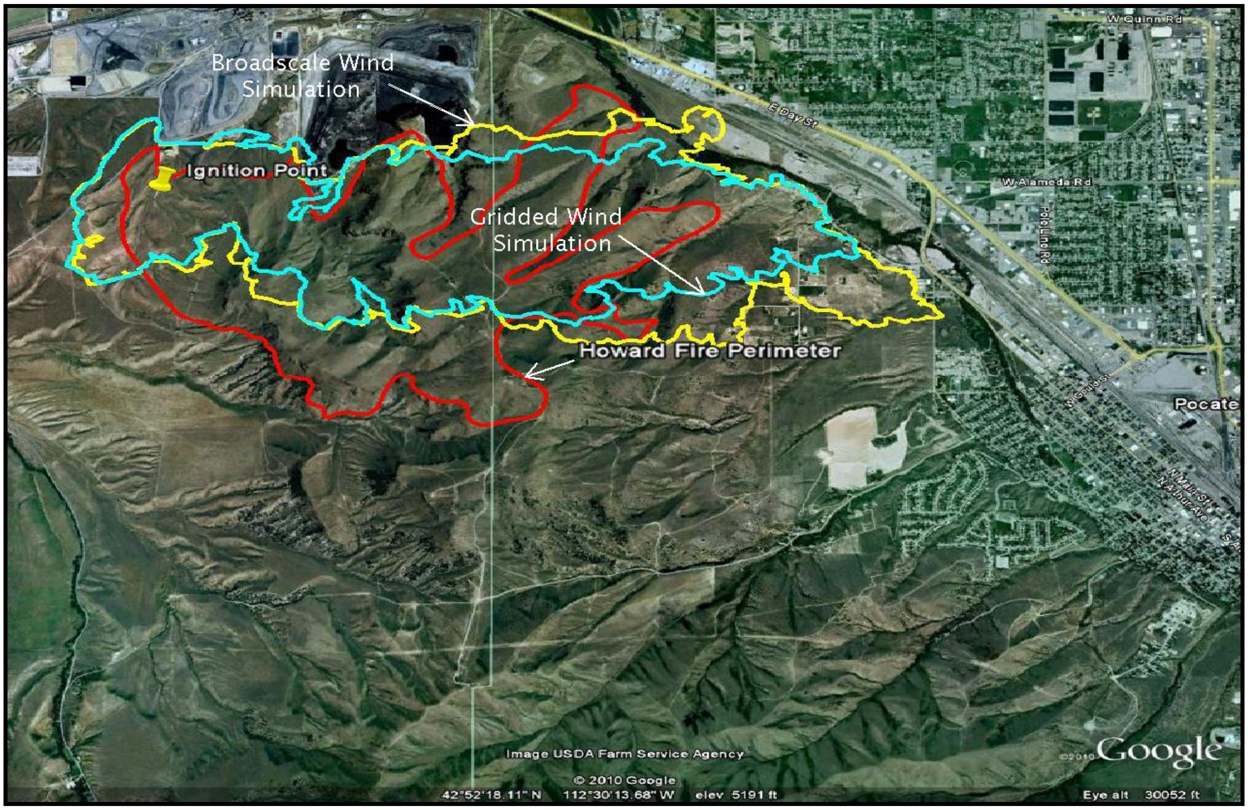

Fig. 9. Google Earth image of observed fire perimeter (red), FARSITE broadscale wind simulation (yellow), and FARSITE gridded wind simulation (cyan) from 270 deg.

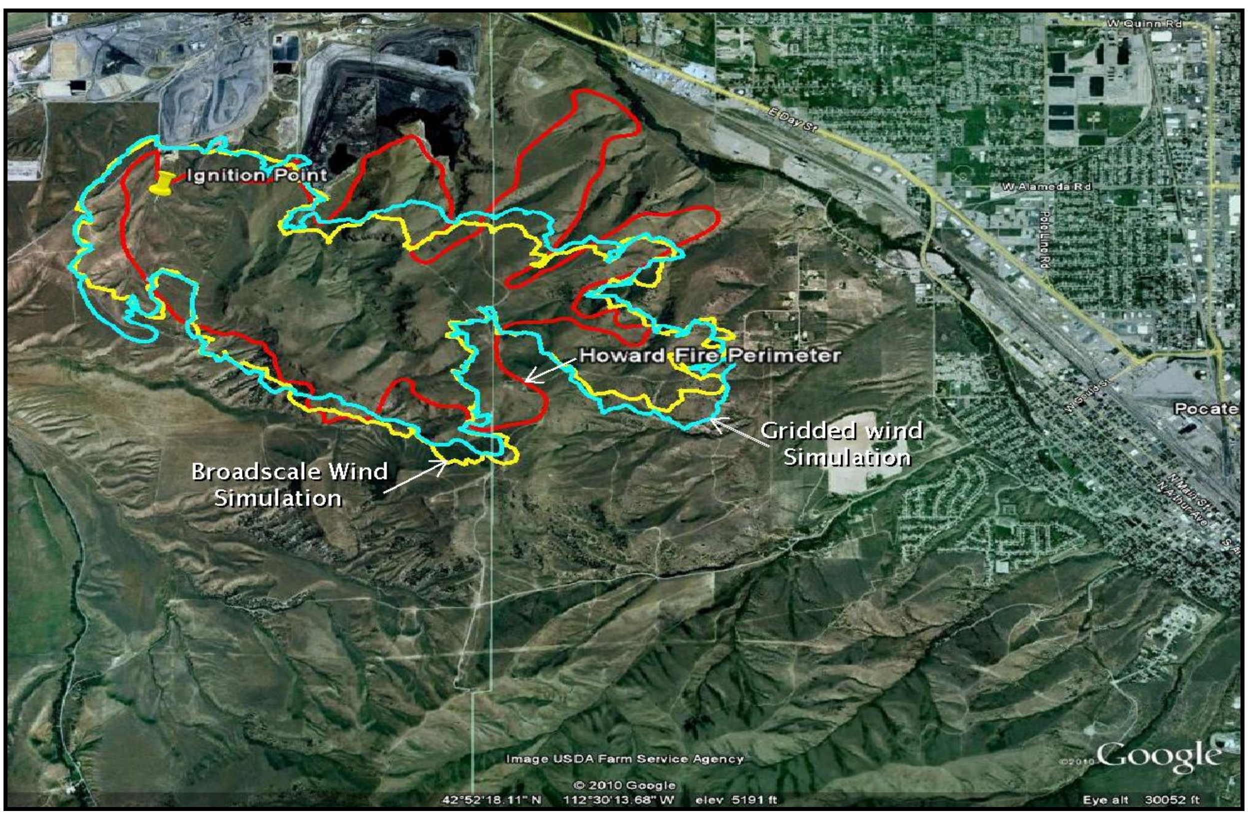

Fig. 10. Google Earth image of observed fire perimeter (red), FARSITE broadscale wind simulation (yellow), and FARSITE gridded wind simulation (cyan) from 300 deg.

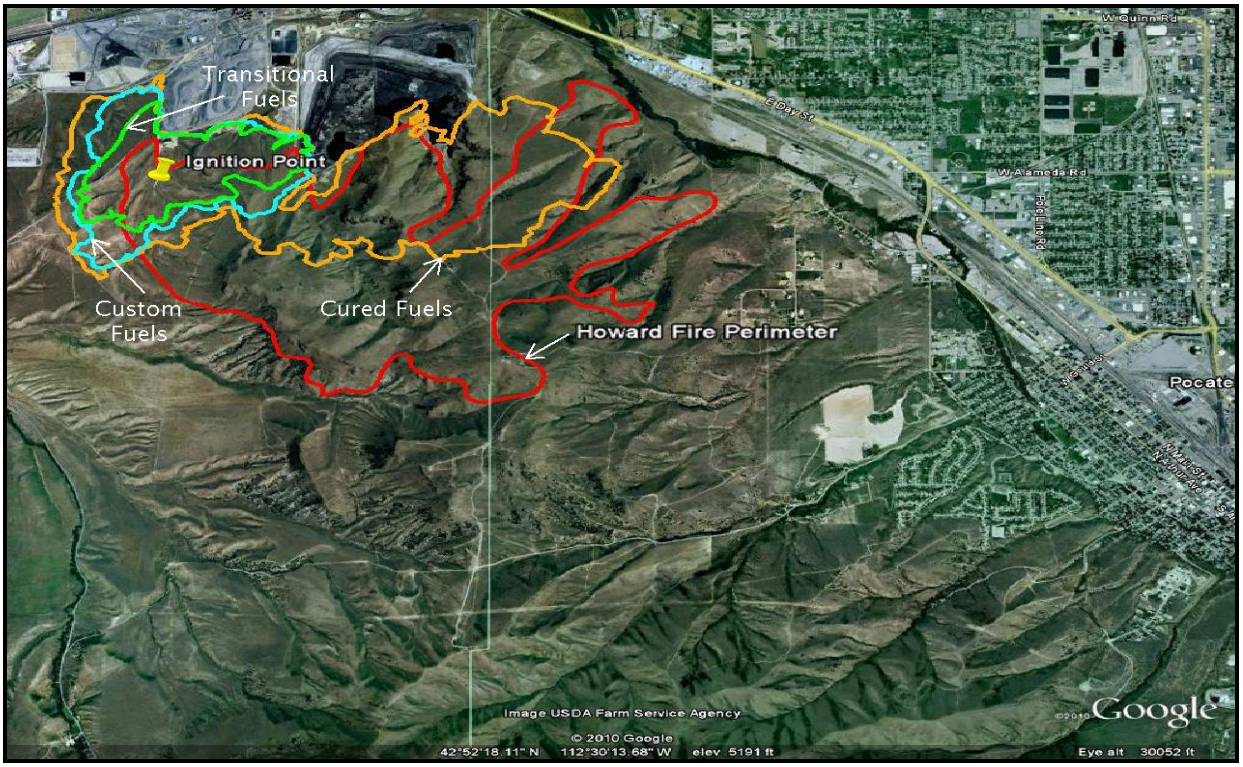

Fig. 11. Google Earth image of observed fire perimeter (red) and FARSITE gridded wind simulation from 240 deg for the transitional fuel moisture scenario (green), custom fuel moisture scenario (cyan) and cured fuel moisture scenario (orange).

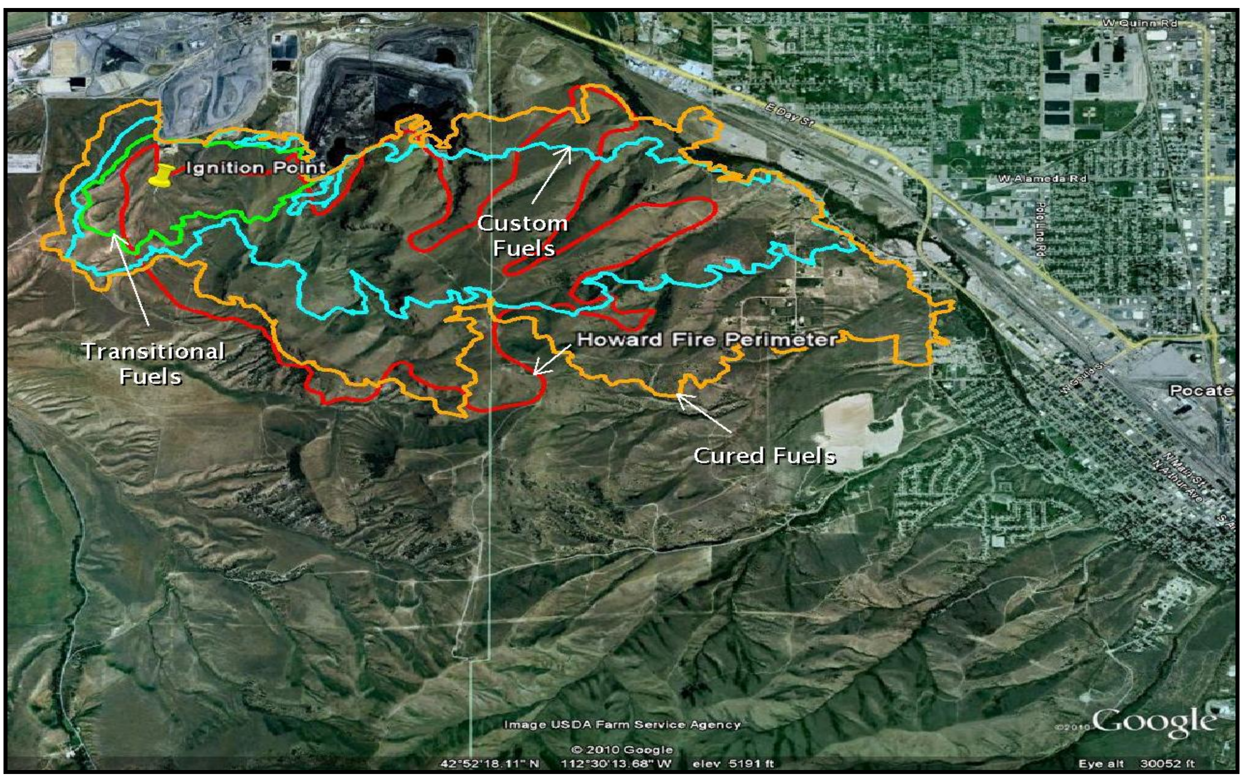

Fig. 12. Google Earth image of observed fire perimeter (red) and FARSITE gridded wind simulation from 270 deg for the transitional fuel moisture scenario (green), custom fuel moisture scenario (cyan) and cured fuel moisture scenario (orange).

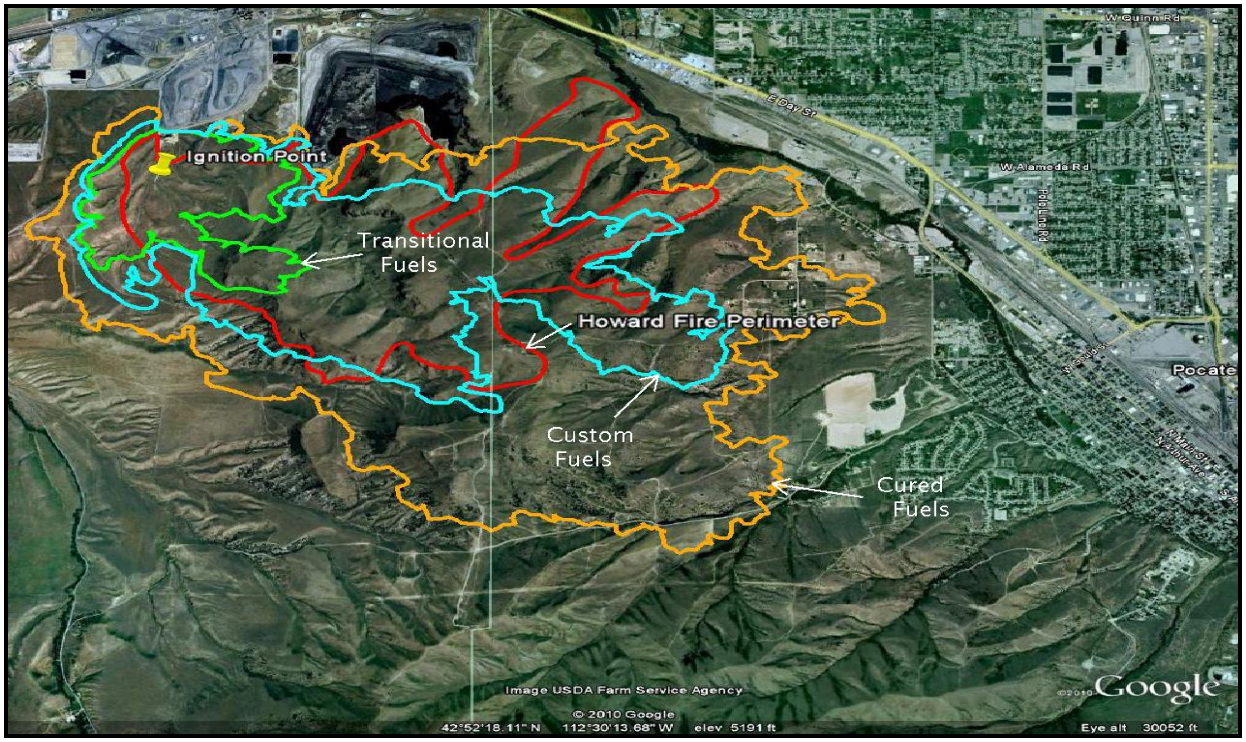

Fig. 13. Google Earth image of observed fire perimeter (red) and FARSITE gridded wind simulation from 300 deg for the transitional fuel moisture scenario (green), custom fuel moisture scenario (cyan) and cured fuel moisture scenario (orange).

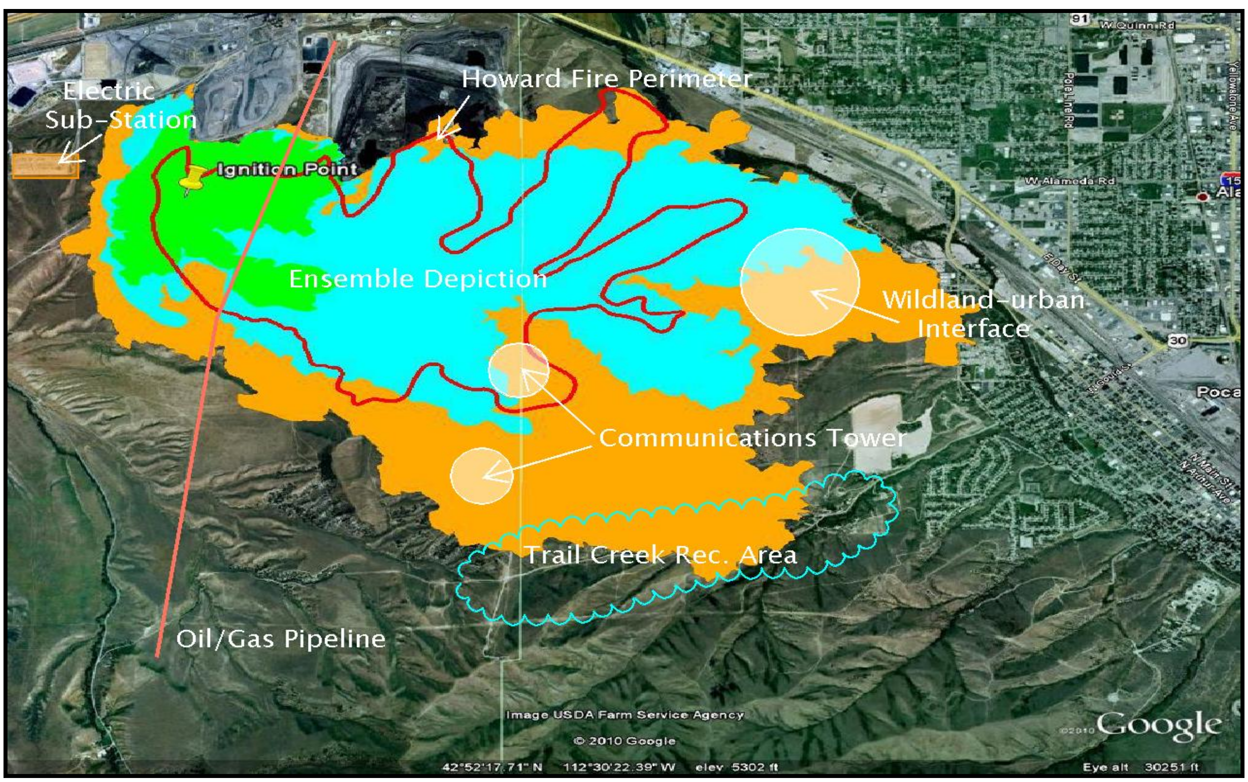

Fig. 14. Google Earth image of observed fire perimeter (red) and a composite ensemble depiction of FARSITE gridded wind simulations from 240 deg, 270 deg, and 300 deg for the transitional (green), custom (cyan), and cured (orange) fuel moisture scenarios.