The Effect of Complex Terrain on Fire Progression Using QES-Fire

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I. Introduction

Wildfires in the western US are a threat to human health and infrastructure. Forecasting wildfires is important for forest management and smoke forecasting, which allow us to effectively conduct prescribed burns and predict high PM2.5 events. QES-Fire is a 3-D fire simulator that uses a parametrized mass-conserving wind solver, simplified rate of spread model, and plume-merging model to couple the atmosphere and fire front (Moody et. al., 2022). Wind is understood to be the main driver of wildfires, but terrain plays an important role in both the shape and rate of spread (ROS) of fires. The scope of this study is to analyze the behavior of fires over more complex terrain, which includes a uniform inclined plane and a normalized gaussian type hill.

Wildfire in the Medicine Bow-Routte National Forest, September 2018

II. Methods

- QES-Fire uses the parametrized wind solver QES-Winds, the Balbi *et al*. (2020) fire ROS model, and a plume merging model to couple the atmosphere with the fire front and account for fire-plume generated winds (Moody *et al*., 2022).
- 20m line fires were initiated on inclined plane geotiff files over a 50 x 50m domain and allowed to run for 180s.
- 40m line fires were initiated on gaussian hill geotiff files over a 100m x 100m domain and allowed to run for 240s.
- All simulations had 5m/s winds and 1m x 1m x 1m resolution

III. Results

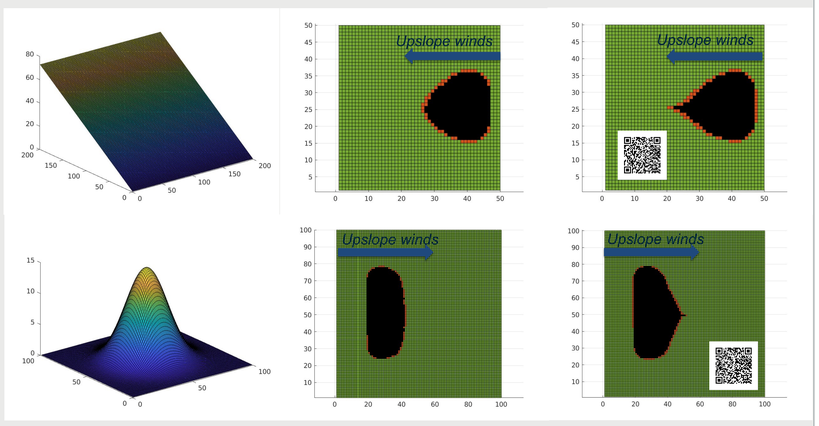

Figure 1. The surfaces and their respective burns. The final burn area of the flat plane and shortest hill is given in the middle column, and the steepest plane and highest hill in the right column. The middle columns show the common parabolic shape, while the steeper slopes develop a pointed front. Use the QR codes to see an animation of the fire front.

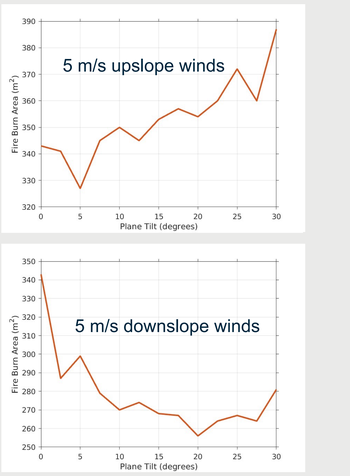

Figure 2. The relationship between plane tilt and burn area with upslope (top) and downslope (bottom) winds.

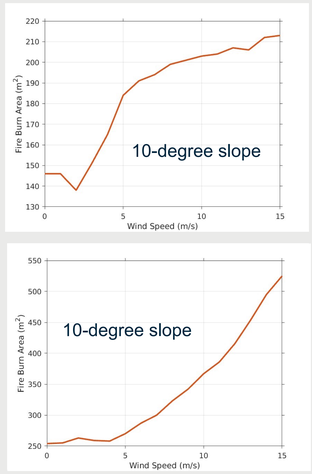

Figure 3. The relationship between wind speed and burn area for upslope (top) and downslope (bottom) winds.

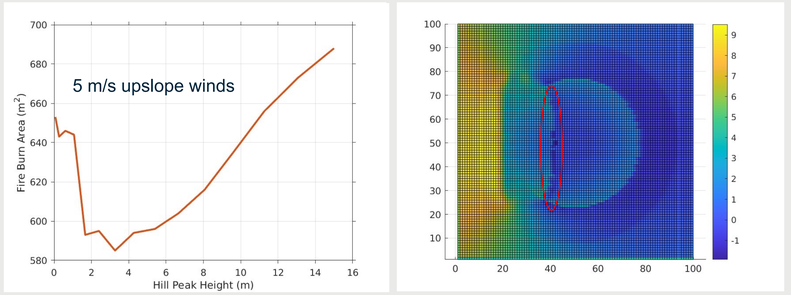

Figure 4. The simulations over the gaussian hills demonstrate the importance of coupling the fire with the atmosphere. The heat from the fire front creates a plume that pulls air from around the fire, which induces winds around the fire front. The x-component winds of the ~3m hill (pictured right) demonstrate this phenomena and explain the valley in the graph. The fire induced winds are significantly slowing the rate of spread, especially at the centerline of the hill, which does not happen to the same extent in the taller and shorter hills. The graph of total burn (left) has a valley where the fire induced winds are the main fire driver.

III. Summary and Conclusions

- There is a moderately strong linear relationship between slope angle and total burned area, with an r-squared value of .745 for upslope winds. All other results show a non-linear relationship.
- Total area burned as a function of upslope and downslope winds behave as expected, with a concave down relationship for the former and a concave up relationship for the latter .
- There is a blocking phenomena that occurs at the low to moderate heights of the gaussian hills.

IV. Acknowledgements and Citations

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Moody M.J. *et al.* (2022) QES-Fire: a dynamically coupled fast-response wildfire model. *International Journal of Wildland Fire* **31**, 306-325.

Balbi J.H. *et al.* (2020) A convective–radiative propagation model for wildland fires. *International Journal of Wildland Fire* 29(8), 723–738. doi:10.1071/WF19103

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