Wildfires: Rate of Spread Through The Lens of Models and Simulations

Loren Brink
University of Utah, Department of Atmospheric Sciences

Introduction

There are many different influences on the rate of spread of wildfires including but not limited to fuel type, wind speeds and directions, terrain type and fuel moisture content. The goal of this research project is to look at how these properties influence fire spread in the Balbi Model, the QES Fire Simulation and the SAM Simulation, which all have different assumptions and limitations. We introduce this topic by looking at a prescribed grass fire burn called Fire Flux II and it's rate of spread through time.

Fire Flux II Experiment

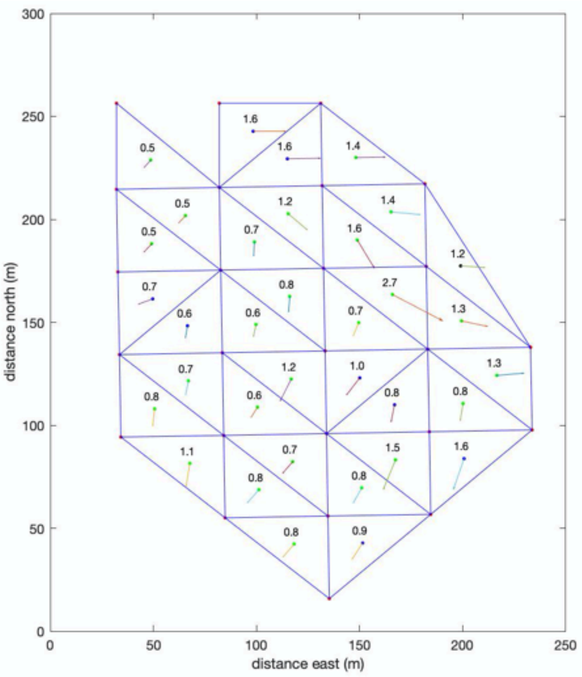
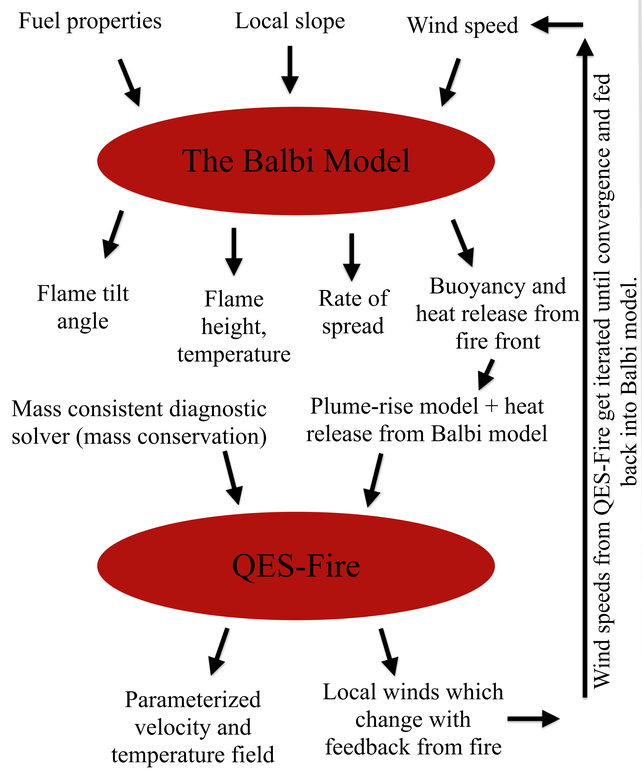


Figure 1: Rate of spread over course of prescribed Fire Flux II burn.

The FFII experiment was a prescribed grass fire burn on flat terrain in south-east Texas. The main purpose of the FFII experiment was to expand on a previous prescribed burn (FFI) and grasp a better understanding of elements in the environment that influence fire spread. By determining the time of arrival of each fire front at each of the 23 data loggers placed in the prescribed burn field, I was able to plot an isochrone of the distances in x and y directions in relation to time passed. I accurately determined the change in rate of spread of the fire in meters per second, shown by the arrows drawn above.

Balbi Model and QES Fire Simulation Case Studies

The Balbi model was developed in 2009 and dynamically couples wind to the rate of spread. It obeys the laws of physics with simplifications. QES Fire couples the atmosphere to the fire line dynamically using heat release from the Balbi model to produce the winds. Below are the inputs and outputs which differ slightly for each model.



A portion of my research included conducting resolution tests using QES-Fire to see how the rate of spread changes when we change properties of the wildfire.

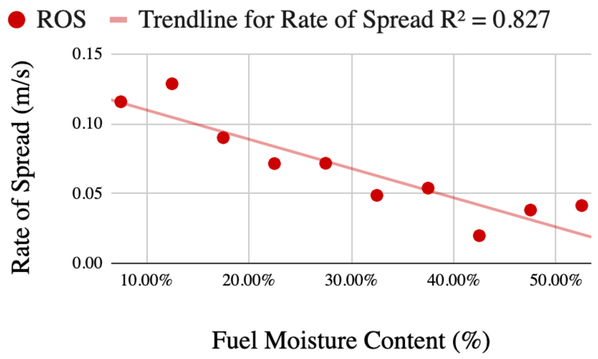


Figure 2: Negative linear relationship between rate of spread and fuel moisture content on flat terrain

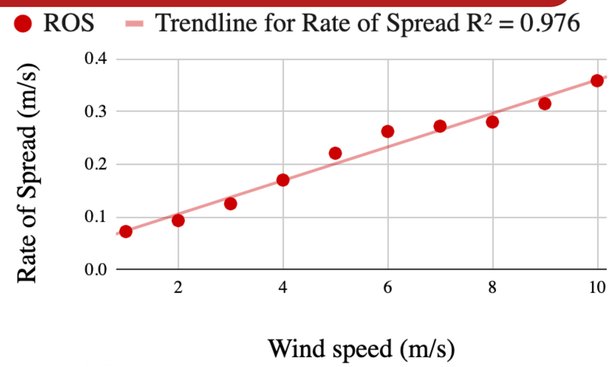


Figure 3: Positive linear relationship between wind speed and rate of spread on flat terrain

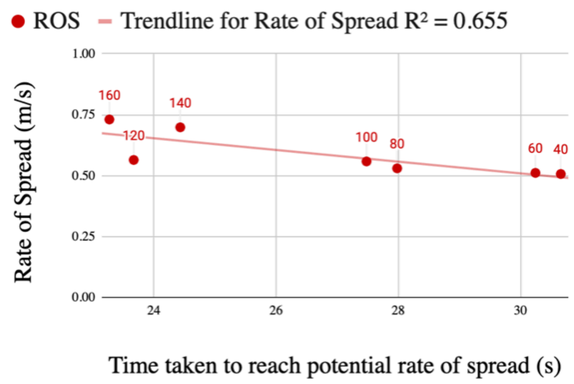


Figure 4: Time taken to reach potential rate of spread with increasing fire line width on flat terrain. Data labels show width in meters.

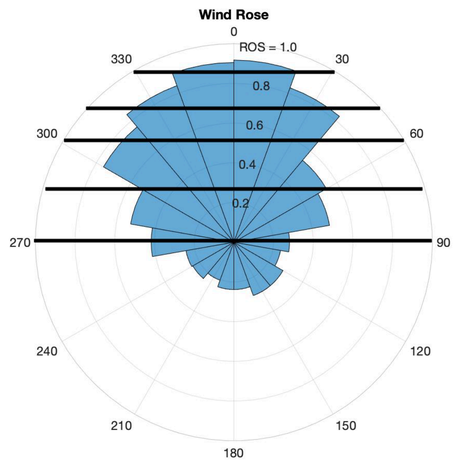


Figure 5: Compass rose depicting rate of spread of a wildfire with winds coming from different directions.

The fire line width case from QES-Fire was also run for SAM, which is discussed in the next section. The SAM resolution study uses a different fuel type, which leads to a greater ROS. However, the SAM study uses a smaller wind speed, which may compensate for this.
*Note: Results are preliminary

SAM Simulation

The System for Atmospheric Modeling, known as SAM, is a 3D dynamical atmospheric model. SAM goes through the same steps as the Balbi Model and QES-Fire but then saves the wind field and uses it as an input. Below is a flow chart of the differences between the Balbi Model and QES Fire versus SAM.

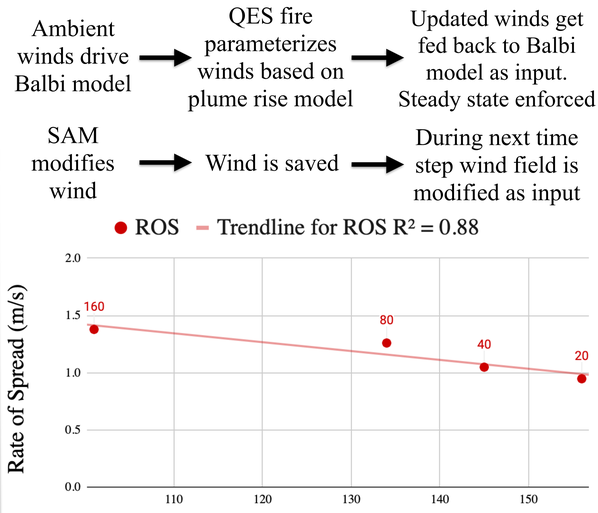


Figure 5: Time taken to reach potential rate of spread with increasing fire line width on flat terrain using SAM. Data labels show width in meters.

Conclusion

The Fire Flux II experiment was recreated in MATLAB in order to further learn about the calculation of rate of spread of a wildfire. I was able to match the measured rate of spread expected from the information provided in the Clements paper listed in the references section of this poster using this code.

The resolution studies which were tested on fuel moisture content, wind speed, wind direction and width of the fire line matched what I expected to see based off of previous research and knowledge of wildfires. The fire line width resolution study was followed up by a similar study using SAM to further our understanding and compare models. A similar relationship was observed.

References

Cheney, Phil & Sullivan, Andrew. (2008). Grassfires: Fuel, Weather and Fire Behaviour. 10.1071/9780643096493.
Clements et al. 2019. The FireFlux II experiment: a model-guided field experiment to improve understanding of fire-atmosphere interactions and fire spread. International Journal of Wildland Fire. 28: 308-326.