Examining Convective Froude Number as a Fire Spread Rate and Plume Structure Predictor Using WRF Model

Nichola Maynard[1, 2], Masih Eghdami[3]

[1]University Corporation for Atmospheric Science, Boulder CO, [2]University of Maryland, College Park MD, [3]National Center for Atmospheric Research, Boulder CO

Introduction & Research Goal

- ❖Wildfires are unpredictable and dangerous, especially to the firefighters working on the frontlines.
- ❖They cost billions of dollars every year in both destruction and loss of life.
- ❖Wildfires tend to behave in an erratic and unpredictable manner, making it hard to produce proper forecasts and warnings for frontline workers.
- ❖We use the Froude Number as a predictor for wildfires plume structure and rate of spread.
- ❖The goal is to have better predictions of wildfire behavior so firefighters can be safe.

WRF-Fire Model

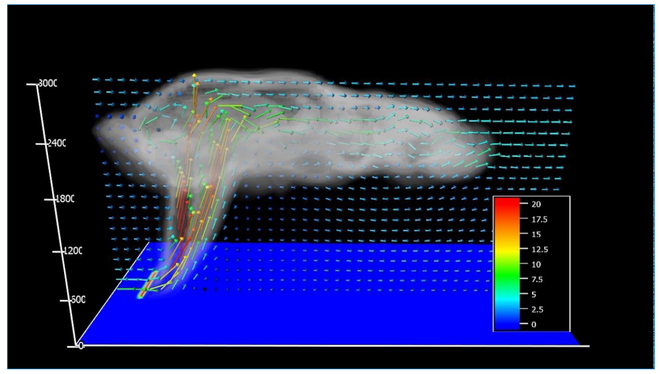

Figure 1. A visual representation of the WRF-Fire model.

- ❖ We make use of the Weather Research and Forecasting (WRF) Fire model (Coen et al., 2012).
- ❖ 18 3-hour simulations were conducted.

Methods

$$F_c = 1.29(u - r)\left(\frac{\rho c_p \theta}{gI}\right)^{1/3}$$

- ❖ The Froude Number is a dimensionless convective number used to consider the interaction of the horizontal dynamic forces of the wind flow over the fire with the vertical buoyant forces of the fire.
- ❖ It allows us to categorize fires with a singular value that gives us information about the plume structure and spread rate of the fire (Sullivan, 2007).

Simulations

Wind Speed	Heat Flux	Fuel Type & Fire Wind Level	Relative Humidity
5 m/s	Convective: Φ_{TKE} = 0.200 W/m^2	1)Grass @1m 2)Dormant brush @2m 3)Medium logging slash @3m	0%
5 m/s	Convective: Φ_{TKE} = 0.200 W/m^2	1)Grass @1m 2)Dormant brush @2m 3)Medium logging slash @3m	50%
5 m/s	Convective: Φ_{TKE} = 0.200 W/m^2	1)Grass @1m 2)Dormant brush @2m 3)Medium logging slash @3m	75%

Plume Cross-Section Plots

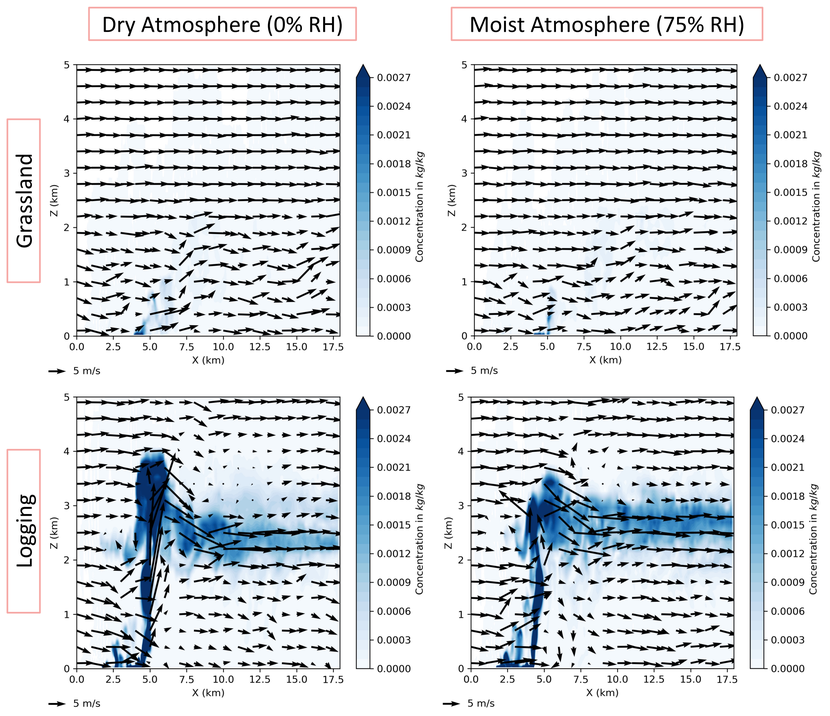

Figure 2. Vertical plume cross-section plots for a dry atmosphere (0% relative humidity; left column) and a moist atmosphere (75% relative humidity; right column) and for grassland (top row) and logging (bottom row). The arrows indicate wind speed and direction, and the plume is represented by the smoke concentration in color.

Froude Number

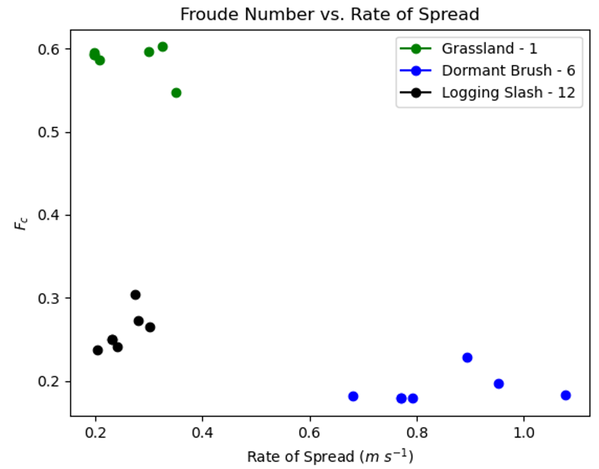

Figure 3. The Froude Number as a function of the rate of spread.

Results and Discussion

- ❖ Dormant brush has the highest rate of spread
- ❖ Grassland has the highest Froude Number
- ❖ A lower froude number can be indicative of a more erratic fire based on wind speeds
- ❖ Relative humidity slows down the rate of spread

References and Acknowledgements

- ❖ Patricia DeRepentigny – Writing Mentor
- ❖ Julie Malmberg – Community Mentor
- ❖ Amy Barfield – Community Mentor
- ❖ Rebecca Porter – Peer Mentor

Coen, J. L., Cameron, M., Michalakes, J., Patton, E. G., Riggan, P. J., & Yedinak, K. M. (2012, January 1). WRF-fire: Coupled weather-wildland fire modeling with The Weather Research and Forecasting model. *US Forest Service Research and Development*. https://www.fs.usda.gov/research/treesearch/41760#. Accessed 18 July 2023

Sullivan, A. L. (2007). Convective Froude Number and Byram's energy criterion of Australian Experimental Grassland fires. *Proceedings of the Combustion Institute*, *31*(2), 2557–2564. doi:10.1016/j.proci.2006.07.053

This material is based upon work supported by the National Science Foundation under Grant No. AGS-1641177 (SOARS). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.