New Statistical Descriptions of Fire Behavior

Daryn Sagel[1,2], Kevin Speer[1], Bryan Quaife[1,2]

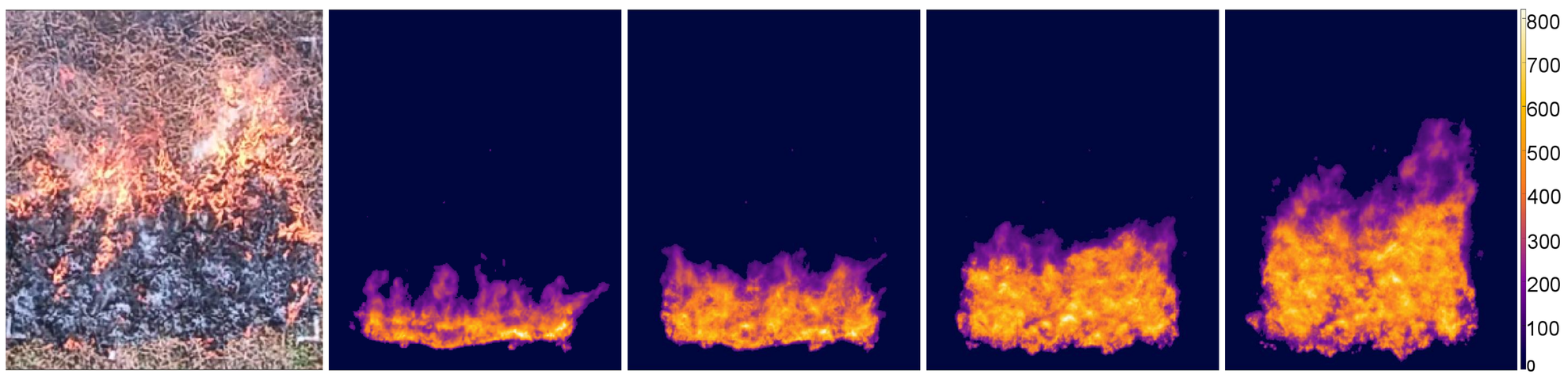
[1]Geophysical Fluid Dynamics Institute, [2]Department of Scientific Computing at Florida State University

Abstract

When fire propagates through a fuel bed, there are a variety of structures and behaviors we wish to better understand. Two examples are (1) small-scale fire spread through a porous pine straw bed, commonly found in nature, and (2) large-scale interactions between the fire, plume, forest canopy, and atmosphere. I have developed techniques that combine computer vision and graph theory to track such behaviors. Due to the turbulent nature of fire, a statistical approach is used to analyze data obtained through my method. This analysis reveals behavior of the fire and plume dynamics, heat transport, and fire-atmosphere coupling. In this poster, I showcase analysis from an infrared video that captured fire spread in a pine straw plot.

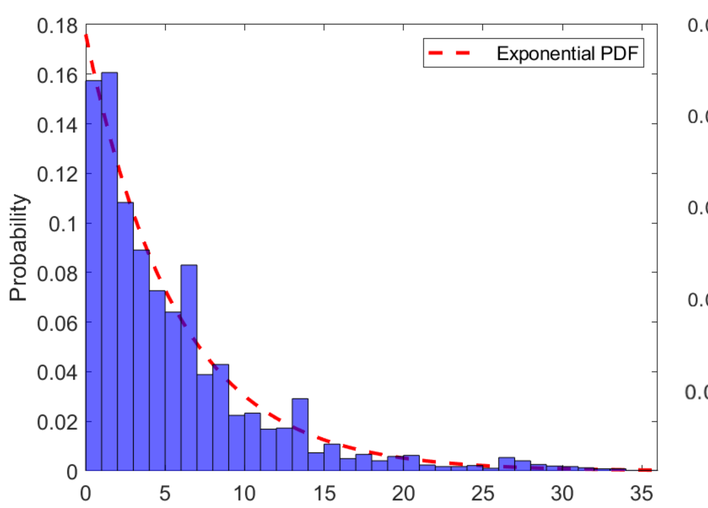
Data

Below are sample images of fire spreading across a 2m x 2m plot of pine straw. On the left is a visual reference frame showing the plot and pine straw setup, and on the right is a progression of infrared images. Video was recorded by cameras looking straight down at the plot. Infrared image temperature is given in degrees Celsius.

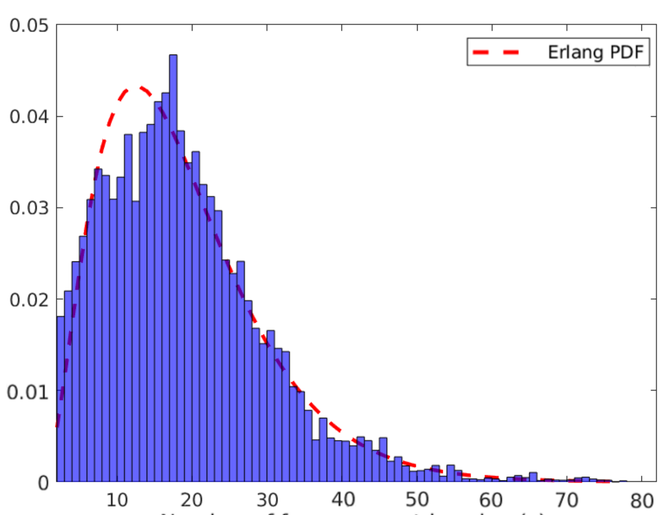


Results

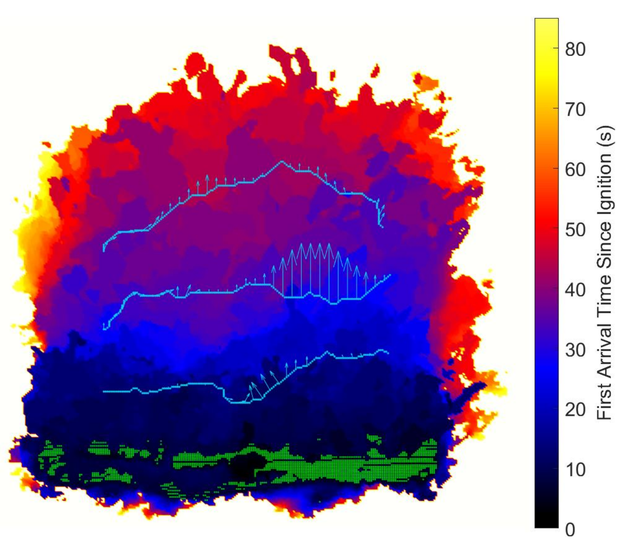
Analysis of the infrared images yields information about transverse and longitudinal velocity components of the fire's spread, spatially and temporally varying forward rates of spread, fuel consumption rates, and first arrival time rates of spread. Focusing on the forward spread distribution and burn time properties:



Distribution of forward rates of spread fit with an exponential distribution. Suggests that small-scale fire behavior can be modeled as a random, memoryless process.



Distribution of pixel burn times fit with an Erlang distribution. This implies that burn time relies on multiple exponential factors, like spread rate.



Map of the time each pixel exceeds ignition temperature with initial ignition pattern in green and sample isotherms in blue. First arrival time rate of spread is 2 - 4cm/s.

Application

Example of the calculated forward spread rate (from the exponential distribution above) implemented using a Fast Marching Level-Set Method.

Reference

Sagel, D., Speer, K., Pokswinski, S., & Quaife, B. (2021). Fine-Scale Fire Spread in Pine Straw. *Fire*, *4*(4), 69.