

Modeling and Analyzing a Fire Plume in a Crosswind

Zachery Ozols, Class of 2028

Wildfires are becoming more frequent, severe, and pose a threat beyond the front of the fire. Firebrands, embers lofted by turbulent air, can unpredictably fly over wildfire containment measures, potentially igniting spot fires which endangers lives and infrastructure. In an effort to predict firebrand transport, large eddy simulations (LES) are employed to resolve the coupled dynamics of fire plumes, crosswinds, and the associated turbulent structures that govern particle trajectories. My objective this summer was to create and analyze a control model; a high-temperature plume interacting with a steady crosswind *without* particles in order to establish a baseline flow field for subsequent firebrand transport research.

I began the project by reading papers on LES firebrand transport and wildfire dynamics while learning Python for data manipulation and visualization. Afterward, I went through extensive pages of PALM—a turbulence-resolving LES software—documentation, presentations, and example models, compiling reference materials for the numerous variables and namelists. These resources allowed me to adjust input files for wind speeds, surface heat flux, boundary conditions, and target output variables for efficient simulations and subsequent output extraction for analysis. To execute these files, I gained an understanding in Linux and high-performance computing (HPC) environments, enabling the submission of these simulation files on the University of California, Irvine’s HPC cluster. In culmination of this research, I ran a two billion cubic meter simulation with a localized high-heat-flux patch (5000W/m^2) representing the fire source. The interaction between the plume and the steady 10 m/s crosswind produced shear layers and turbulent structures, enough to carry simulated firebrands unpredictably far and wide: the basis for the next research stage.

The next stage is to include the Lagrangian particle model (which simulates particle behavior and trajectories in a flow field) and modify it for realistic firebrand release rates based on experimental observations. Currently, many models utilize a structured ember release rate at prescribed heights and intermittency, deviating from natural probabilities. We aim to see the significance of realistic ember release conditions and their connection to firebrand settling distance.

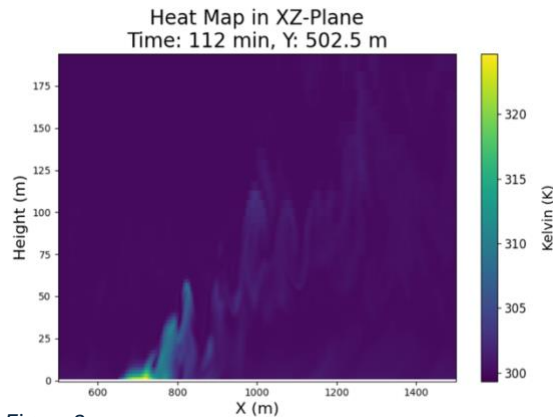


Figure 2

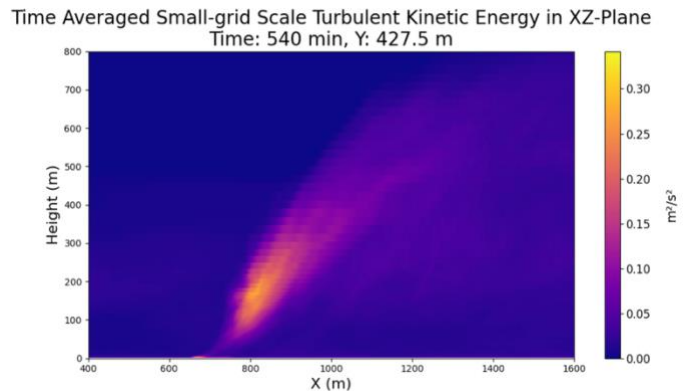


Figure 1

Figure 1. Temperature map in the XZ plane. Plume source is visible in from x coordinates 650m to 750m and y coordinates 450m to 550m. The crosswind impact is also evident in the rightward flow of heat.

Figure 2. (10 minute) time averaged small-grid scale turbulent kinetic energy (TKE) depicts smaller TKE than the computational boxes can solve. Following the visible flow, the high TKE patch on the ground leads into a low TKE section before showing a high and wide TKE flow. This pattern is caused by the replacement of rapidly rising hot air with cooler air at the bottom of the plume, “pinching” the high TKE air at the bottom and a wider plume at greater Z heights.

Faculty Mentor: Alec Petersen

Funded by the Burns Fellowship