The Utility of Disparate Large-Eddy-Simulation Models in Revealing Complex Flow Characteristics due to Wildfires.

Moisseeva, N., Howard, R., Stull, R.

Department of Earth, Ocean and Atmospheric Sciences,
The University of British Columbia
Corresponding author: nmoisseeva@eoas.ubc.ca

The final rise height of a smoke plume as well as the vertical distribution of emissions in the atmosphere have a strong influence on downwind pollutant concentrations, and provide key input into global and regional chemical transport models. Most air quality forecasting systems and wildfire smoke modelling frameworks, such as BlueSky, rely on traditional Briggs smoke-stack plume rise equations to estimate forest-fire plume height. Yet evaluation studies comparing operational BlueSky-modelled plume rise heights with observational data show they are only weakly correlated.

One of the obstacles to the development of new plume rise parameterizations has been the scarcity of detailed simultaneous observations of fire-generated turbulence, entrainment, smoke concentrations and fire behavior. Our research, therefore, relies on using synthetic smoke plume data to understand the underlying plume dynamics.

We employ two different numerical models: the Dutch Atmospheric Large-Eddy Simulation (DALES) model, and a more specialized coupled fire-atmosphere semi-empirical model, WRF-SFIRE, configured in large-eddy mode. By comparing model output, we examine the effects of varying the level of idealization of the fire line on near-surface flow and vorticity.

The two models have different dynamics, physics, and numerics. They are each unique enough that when simulations from the two models agree with each other, it adds confidence to the findings. Differences also provide important clues to which processes are or are not important, and often trigger new ideas on how wildfire smoke-plume rise works.

We use sensitivity studies to investigate the effects of ambient conditions, such as atmospheric wind profiles, static stability, boundary-layer depth and fire-generated surface heat flux on updraft and smoke plume behavior. Using model output, we characterize the vertical distribution of fire emissions and smoke injection height. Our ultimate goal is to parameterize these two factors for timely operational use in air quality models.

We found that the length and curvature of the fire line have a strong influence on the three-dimensional flow dynamics. Specifically, in the absence of near-surface lateral inflow for infinitely-long fire lines, which are representative of very large wildfires, the return flow is strong and smoke recirculates to the ground surface. However, for finite or shorter fire lines, near surface lateral convergence reduces return flow and results in less recirculation of smoke towards the surface in the downwind direction.

Our results demonstrate the utility of multi-LES-based methods for studying several aspects of wildfire plume dynamics. They also aid development of a new approach to estimating the vertical distribution of smoke concentrations in the atmosphere.