

# Large Eddy Simulation of Canopy Structure Effects on Smoke Dispersion

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## Abstract

This paper presents results from high-spatial resolution modeling of air quality and smoke dispersion from a simulated low-intensity prescribed burn in the New Jersey Pine Barrens. We used the Regional-Atmospheric-Modeling-System (RAMS)-Based Large Eddy Simulation (RAFLES) model<sup>(1)</sup> to simulate the effects of canopy structure on within and above canopy smoke dispersion. The RAFLES model incorporates 3-D heterogeneous effects of tree canopies on wind flow and turbulence in the atmospheric boundary layer at very high spatial resolution (1 m<sup>3</sup>). It includes a stochastic-Lagrangian dispersion of prescribed scalars and particles, including heavy particles. The shaved grid cell method is used to represent physical obstructions to the flow from tree stems. Model parameters include leaf density, tree stems, the vertical distribution of leaf density, and the horizontal differences between individual tree crowns. For the present study, the detailed 3D canopies and fuel layers were created with the Virtual-Canopy Generator (V-CaGe)<sup>(2)</sup>, using information obtained from airborne light detection and ranging (LiDAR) observations of the New Jersey forest. Smoke emission and heat were prescribed as a dynamic, spatially heterogeneous forcing. Virtual experiments were conducted with several different canopy structures (e.g., sparser or denser) and fuel-canopy combinations to understand the interactions between canopy structure, ejection height, and near-source concentrations of the smoke plume.

### References

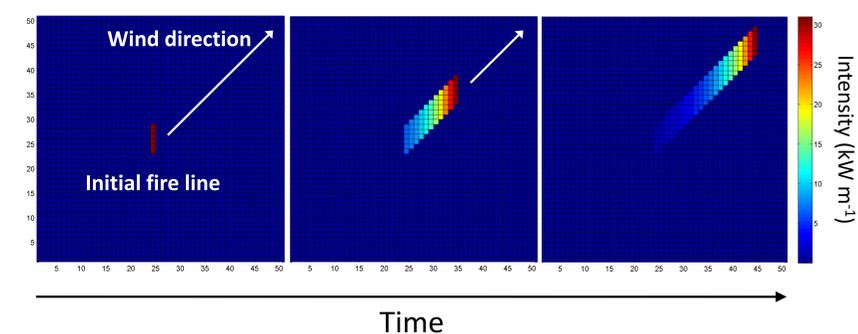
- (1) Bohrer, G. et al. 2009. *Boundary Layer Meteorology* 132: 351–382. || (2) Bohrer, G. et al. 2007. *Tellus B*, 59: 566-576. || (3) Deardorff, J.W. 1980. *Bound. Layer. Meteorology* 18: 495-527. || (4) Bhushan S., Warsi ZUA. 2005. *Int. J. Numer. Methods Fluids*, 49: 489-519. || (5) Bohrer, G. et al. 2008. *Journal of Ecology*, 96: 569-580.

### Acknowledgements

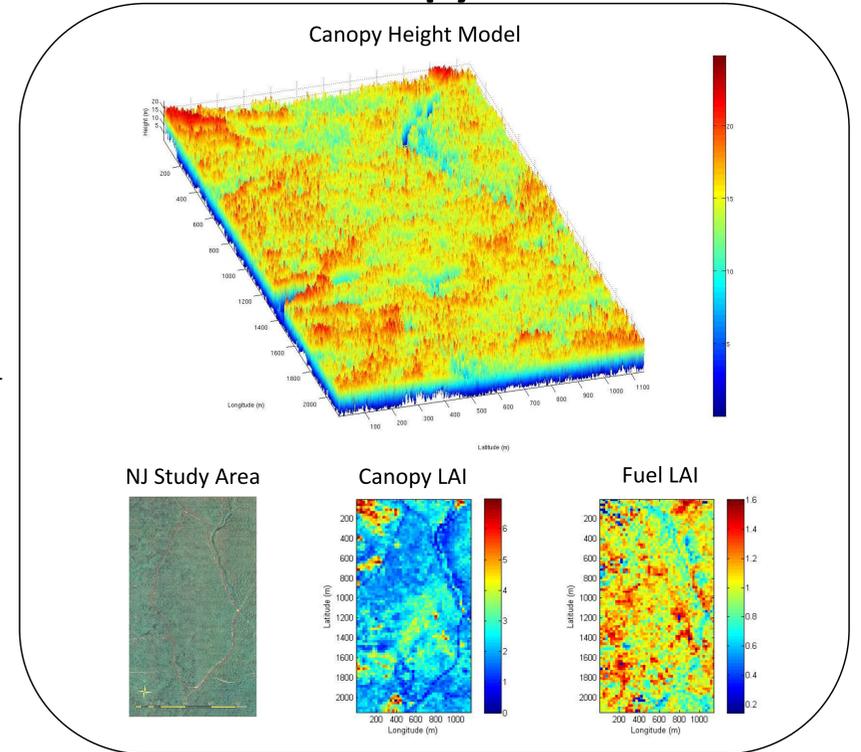
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## Fire Model

The fire rate of spread ( $m s^{-1}$ ) and direction of spread is driven by horizontal wind velocity. The amount of fuel in each grid cell ( $kg m^{-2}$ ) is generated with V-CaGe using LiDAR-derived estimates of understory Leaf Area Index. Fire line intensity ( $kW m^{-1}$ ) is calculated at each time step and is used to calculate heat flux ( $W m^{-2}$ ) and scalar mixing ratios ( $g kg^{-1} s^{-1}$ ).

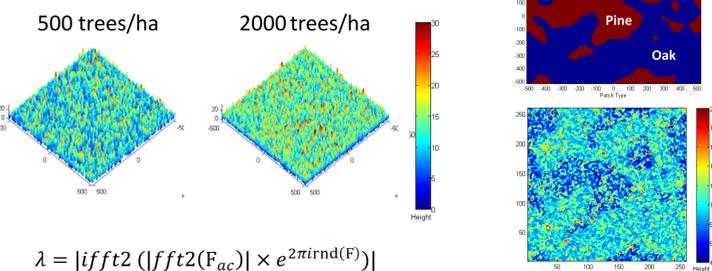


## LiDAR Canopy Structure



## V-CaGe

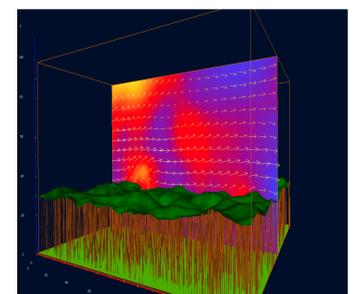
### Simulating canopy structure



$$\lambda = |\text{ifft2}(|\text{fft2}(F_{ac})| \times e^{2\pi i \text{rnd}(F)})|$$

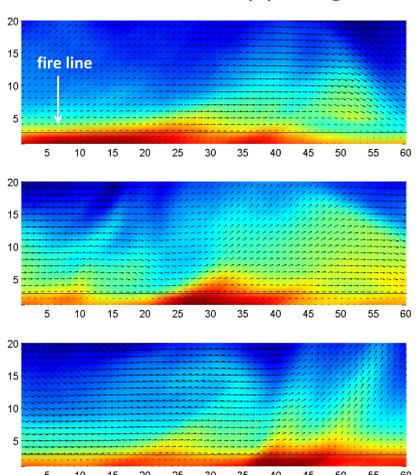
## RAFLES

RAFLES resolves wind flow inside and above 3D heterogeneous tree canopies. The model is initialized and forced with horizontal wind, temperature and humidity. It uses the Deardorf sub-grid scale TKE parameterization<sup>(3)</sup> with a Bhushan backscatter scheme<sup>(4)</sup>. Incoming solar energy is calculated by the Fu-Liou radiation scheme. It includes Eulerian-Lagrangian particle dispersion<sup>(5)</sup>.

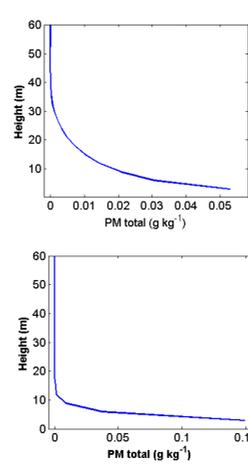
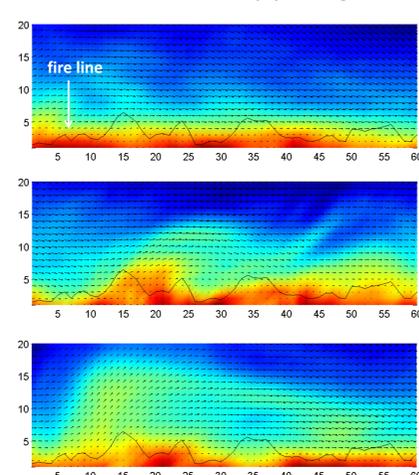


## Results

### Uniform Canopy Height



### Variable Canopy Height



### Smoke Dispersion

