Application of a Vegetation Canopy Parameterization to Wildland Fire Modeling

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Motivation

- Smoke dispersion from wildland fires is a critical health and safety issue
- Over past 10-20 years, focus on prediction has been on smoke dispersion from intense fires
- Ability of current smoke dispersion modeling systems (e.g., Bluesky) to handle local dispersion (i.e., 1-2km away) from low-intensity burns is poor

Modeling of Smoke Dispersion from Low-Intensity Fires

- Particularly challenging due to the effect on dispersion of critical factors such as
  - near-surface meteorological conditions
  - local topography
  - vegetation
  - atmospheric turbulence within and above vegetation layers
- Important: Exchange of particles through vegetation canopy

Overall Modeling Strategy

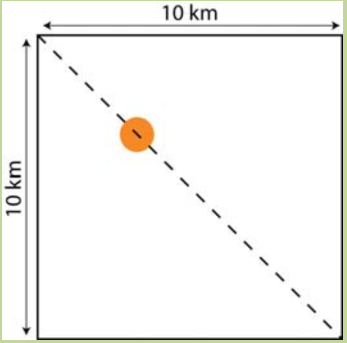
- Obtain fine-scale atmospheric dispersion modeling systems
  - Weather Modules: Advanced Regional Prediction System (ARPS), WRF, RAFLES
  - Dispersion Module: Flexpart
- Evaluate performance of models with existing datasets & recent burn data
  - e.g. Silas Little Experimental Forest: Feb/Mar 2011
- **ARPS: examine sensitivity of flow in and above canopy to low-intensity fire**

Modifications to ARPS

- Canopy parameterization
  - Neutral BL (Dupont and Brunet 2008,2009)
    - Momentum Equation: Pressure and Viscous Drag force term: $-C_d A_f \sqrt{u_j u_j} u_j$
    - TKE Equation: Wake energy cascade term: $-2C_d A_f \sqrt{u_j u_j} e$
  - Modification for Convective BL (Shaw and Schumann 1992) – downward decaying vertical heat flux: $Q(z) = Q(h)\exp(-\alpha F),\ F = \int_z^h A_f dz \qquad \alpha \approx 0.6$

Modifications to ARPS

- Fire parameterization
  - Prescribe surface heat flux fixed in space & time
    - Kiefer et al. (2009)
  - Account for attenuation of thermal radiation from fire by soot
    - Sun et al. (2006) : $I/Io = \exp(-KL) \quad K \approx .038$
  - Surface heat fluxes tested: 400, 600, 800, 1000 W m^{-2}

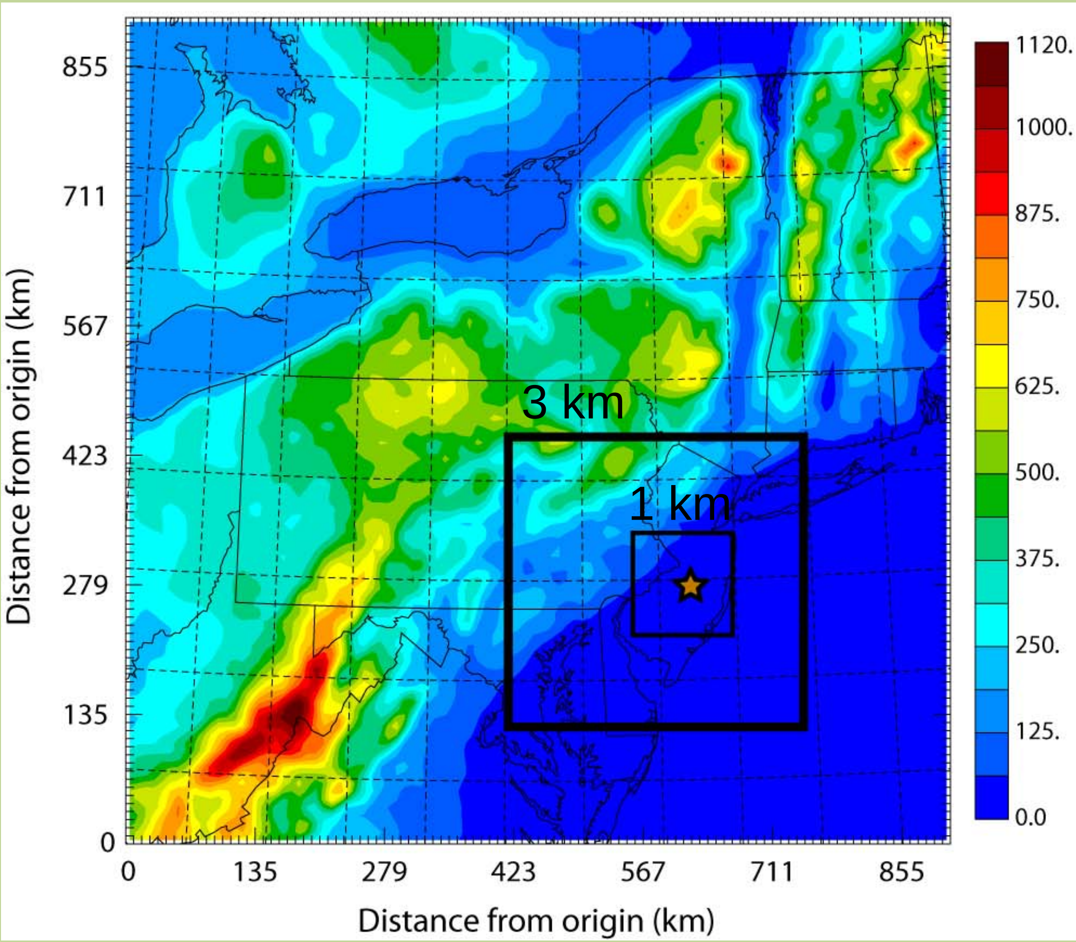


ARPS Nesting Strategy

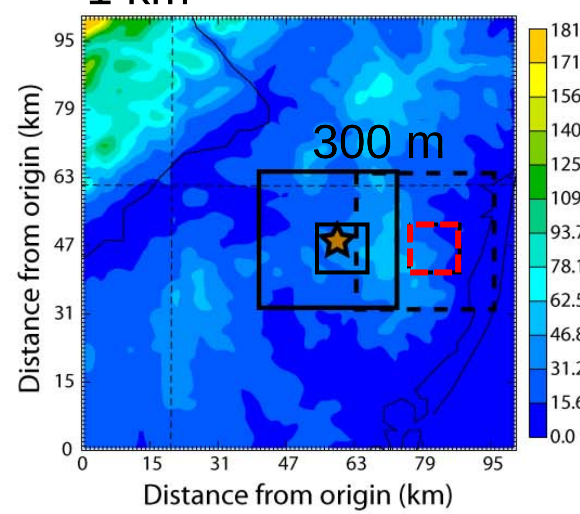
Test case: Double Trouble State Park wildfire 2 June 2002

Full case: Silas Little Experimental Forest burn Feb/Mar 2011

Δx = 9 km



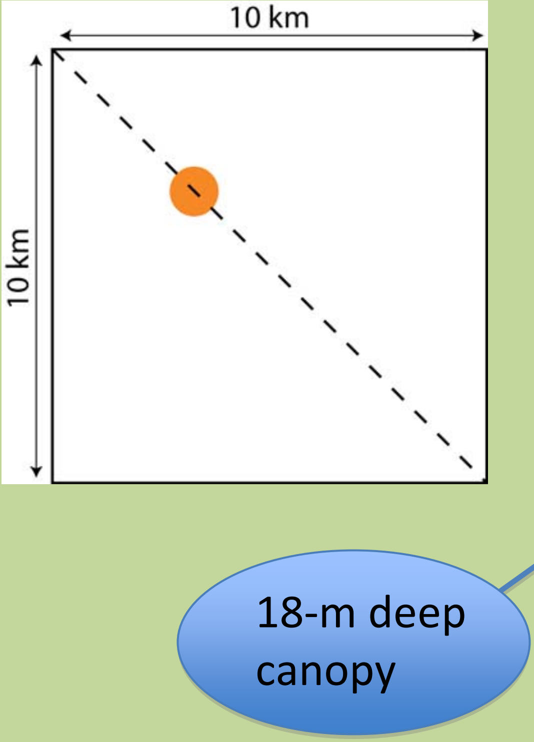
1 km

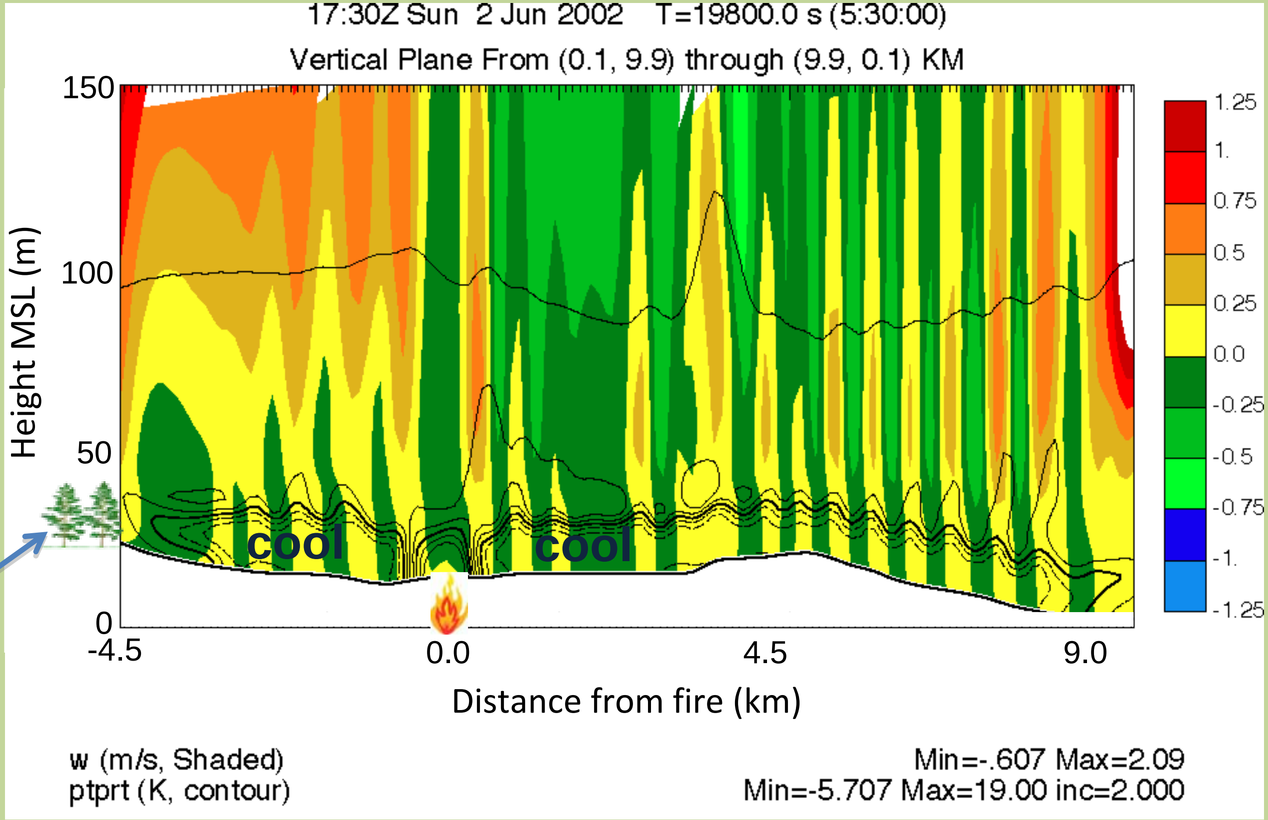


Innermost nest: horizontal grid spacing is 100 m, and vertical grid spacing is 2 m

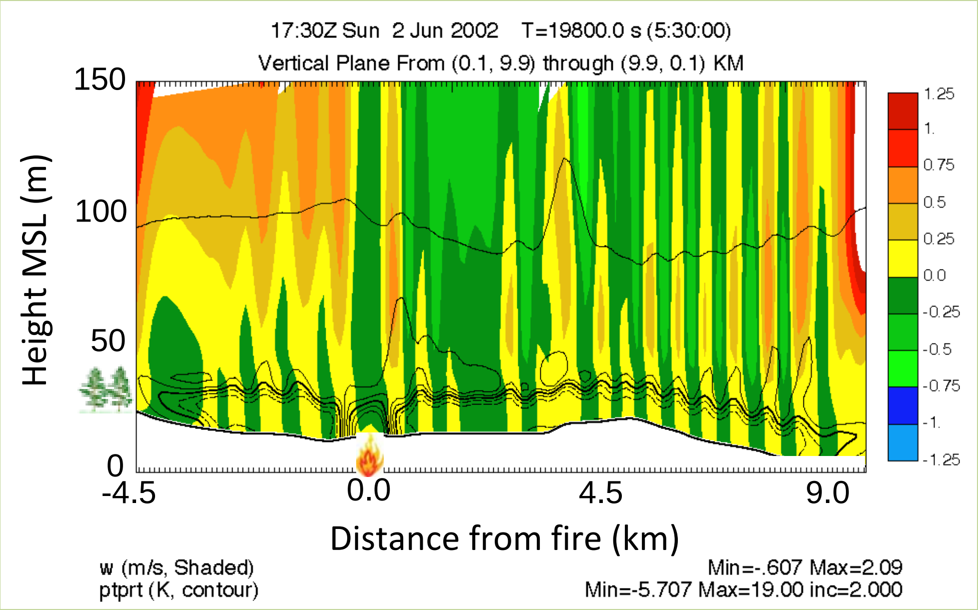
DT case: Plume Cross-Sections

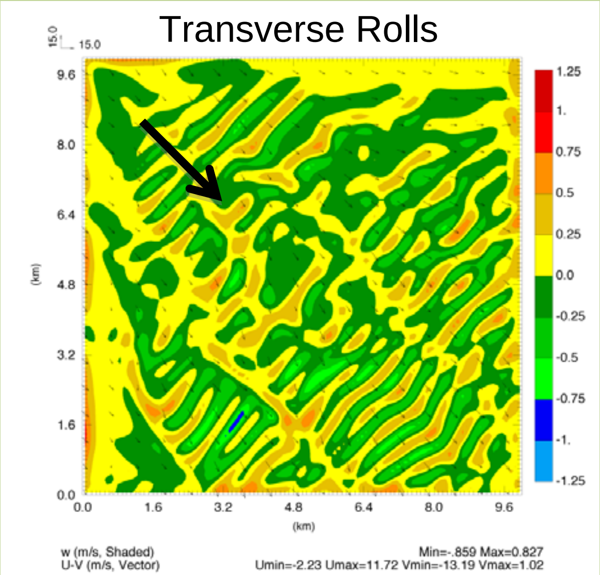
Fire ignited in model at 1700 UTC 2 June 2002



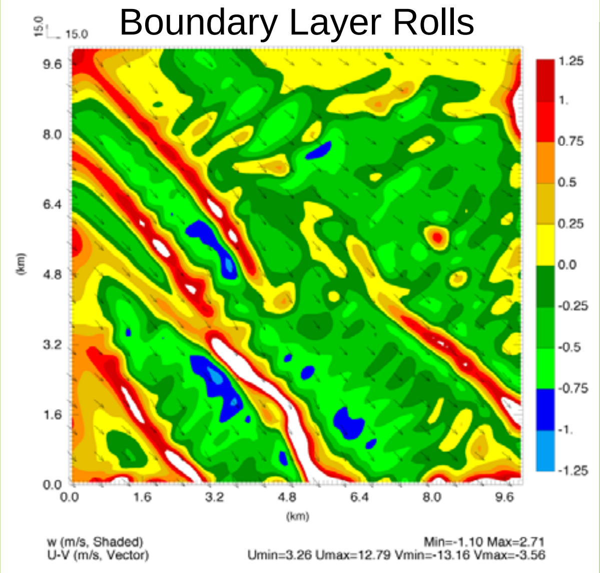


DT case: Plume in a Convective BL



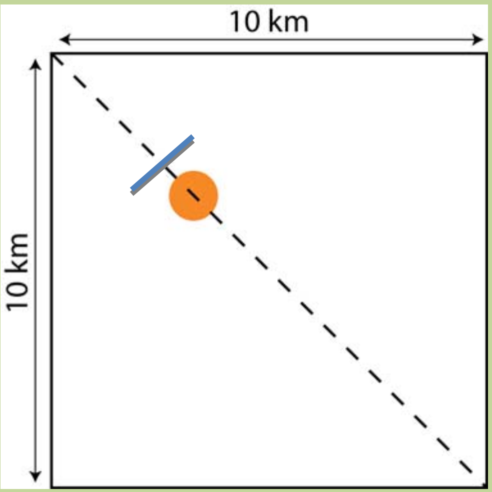


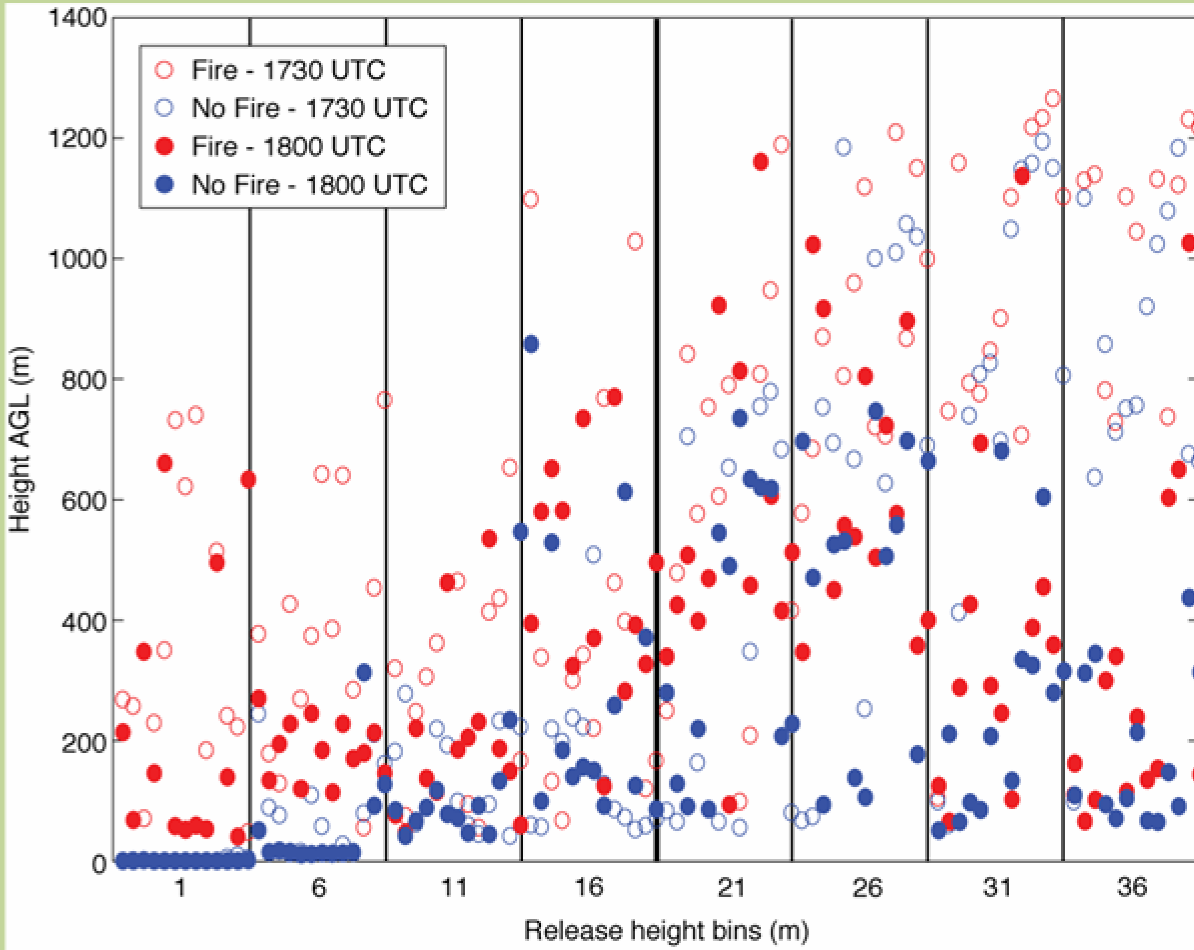
37 m AGL



167 m AGL

DT case: Maximum Parcel Height





More sensitive to fire

More sensitive to release time

Summary

- ARPS modified to include canopy parameterization for convective BL
- ARPS fire parameterization improved
- Preliminary simulations of Double Trouble case reveal:
  - Low-intensity fire critical to vertical exchange of air parcels through canopy
  - Buoyant plume from fire may interact with multiple scales of convective roll in boundary layer

Ongoing Efforts

- Run numerical simulations of low-intensity burn cases
  - ARPS, WRF, RAFLES
- Pass meteorological fields to dispersion module
- Evaluate performance of models against available datasets
- **ARPS: examine sensitivity of flow in and above canopy to low-intensity fire**

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http://www.geo.msu.edu/firesmoke