Simulation of Wildland-Urban Interface Fires

Overview of Work in Progress

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Areas of Effort

1. Burning of individual bushes and trees.
   - Idealized bush burning experiments of Dupuy
   - Small conifer tree burning experiments at NIST
2. Burning of homogeneous fuels (e.g., grass).
3. Fire spread through mixed vegetative (grass, ladder fuels, crowns) and structural fuels (siding, roofing).
4. Parallel computation.

Validation: Burning Bush

- Experiments of Dupuy *et al.*

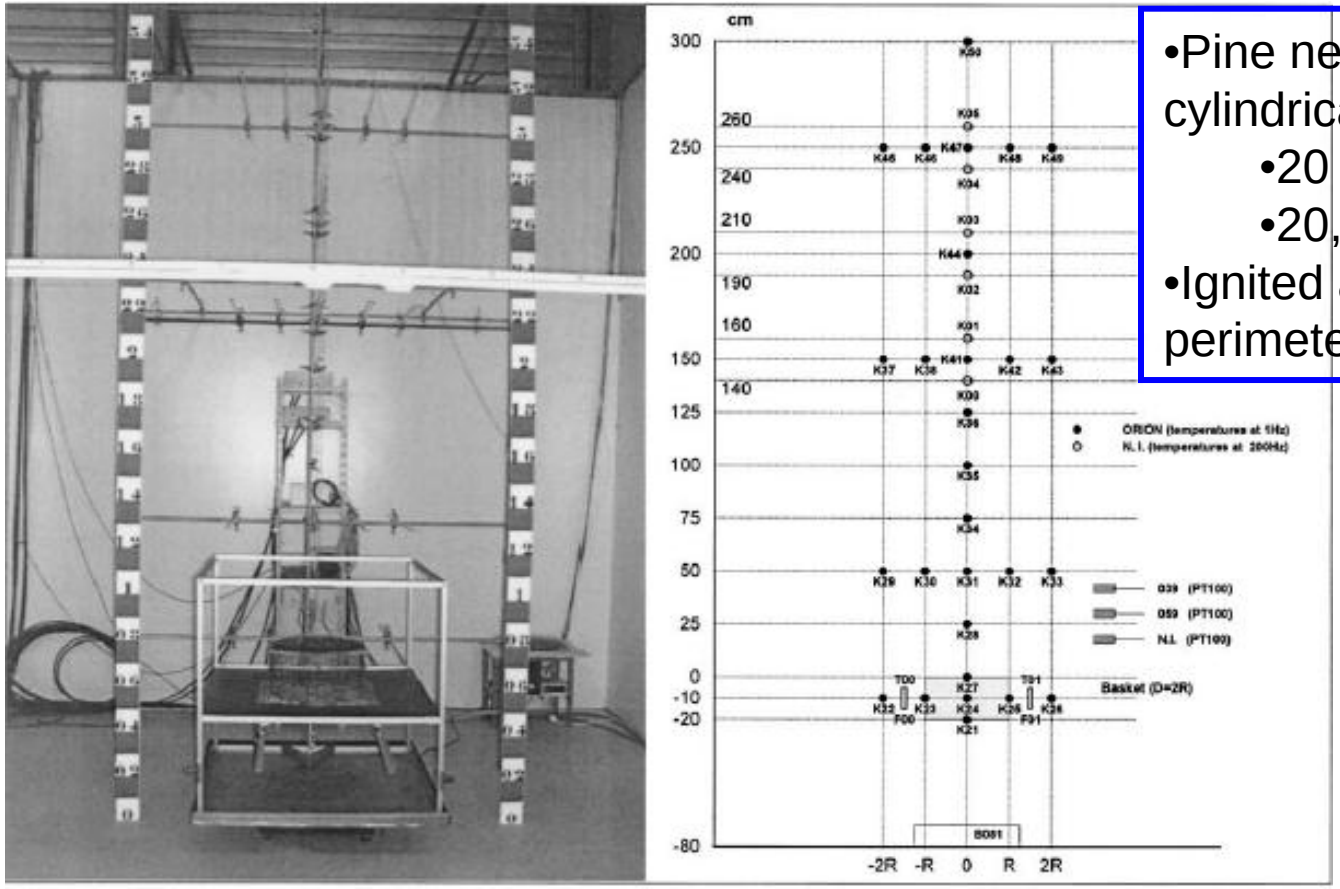


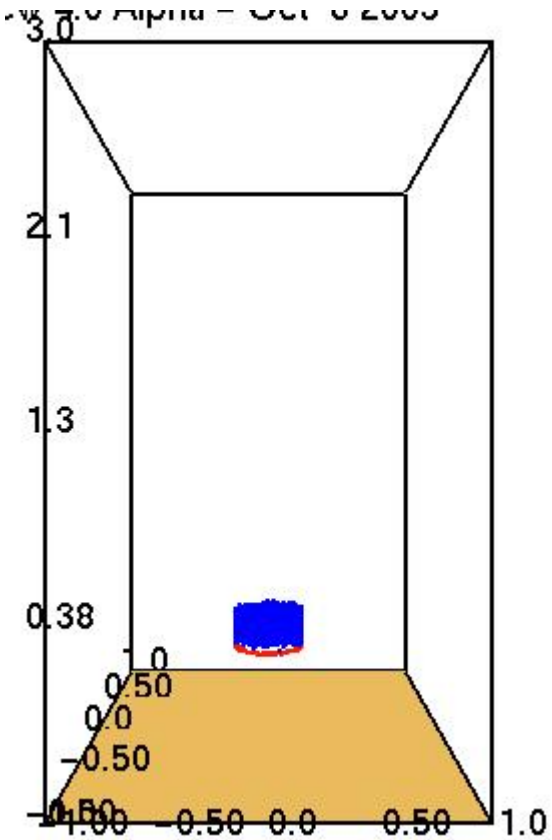
Fig. 1. Experimental apparatus.

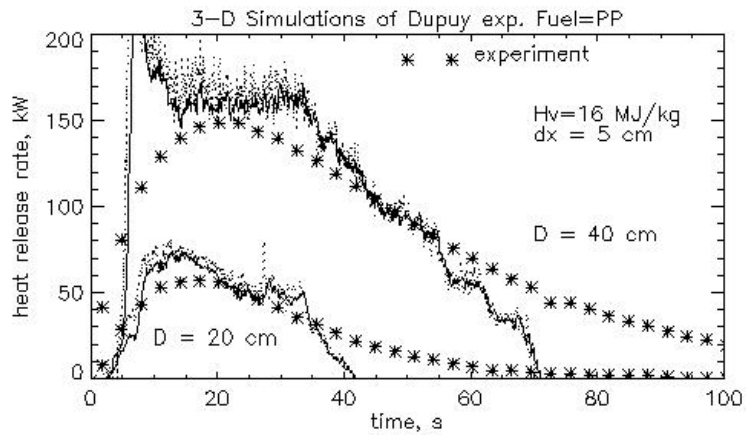
- Pine needles in a cylindrical basket of
  - 20 cm height
  - 20, 28, 40 cm diameter
- Ignited along bottom perimeter

Burning Bush/Tree Simulation Approach

- Sub-grid fuel elements represent pine needle fuel
- Fuel particle properties used: moisture, density, surface-to-volume ratio, specific heat, temperature of ignition, heat of vaporization
- Fuel bulk properties used: fuel loading, height, bulk density.

Burning Bush Simulation Example



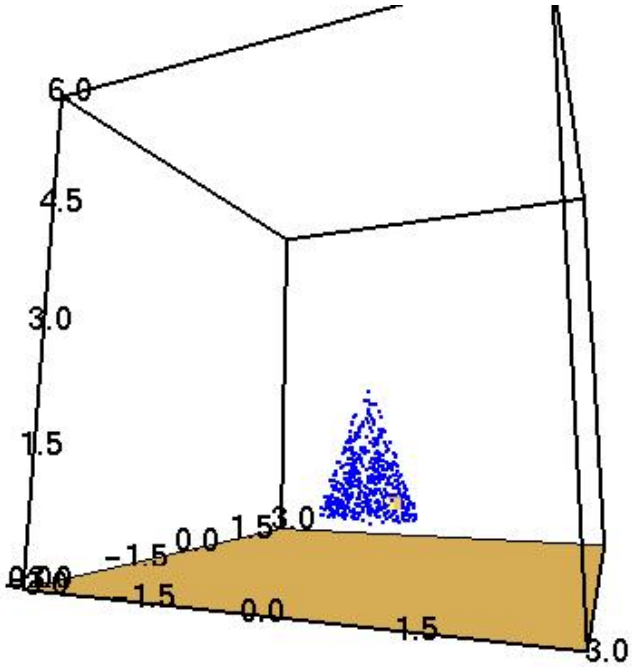


• Note: heat release rate (HRR) as determined by combustion model (solid line) agrees with HRR determined from solid fuel vaporization (dotted line):

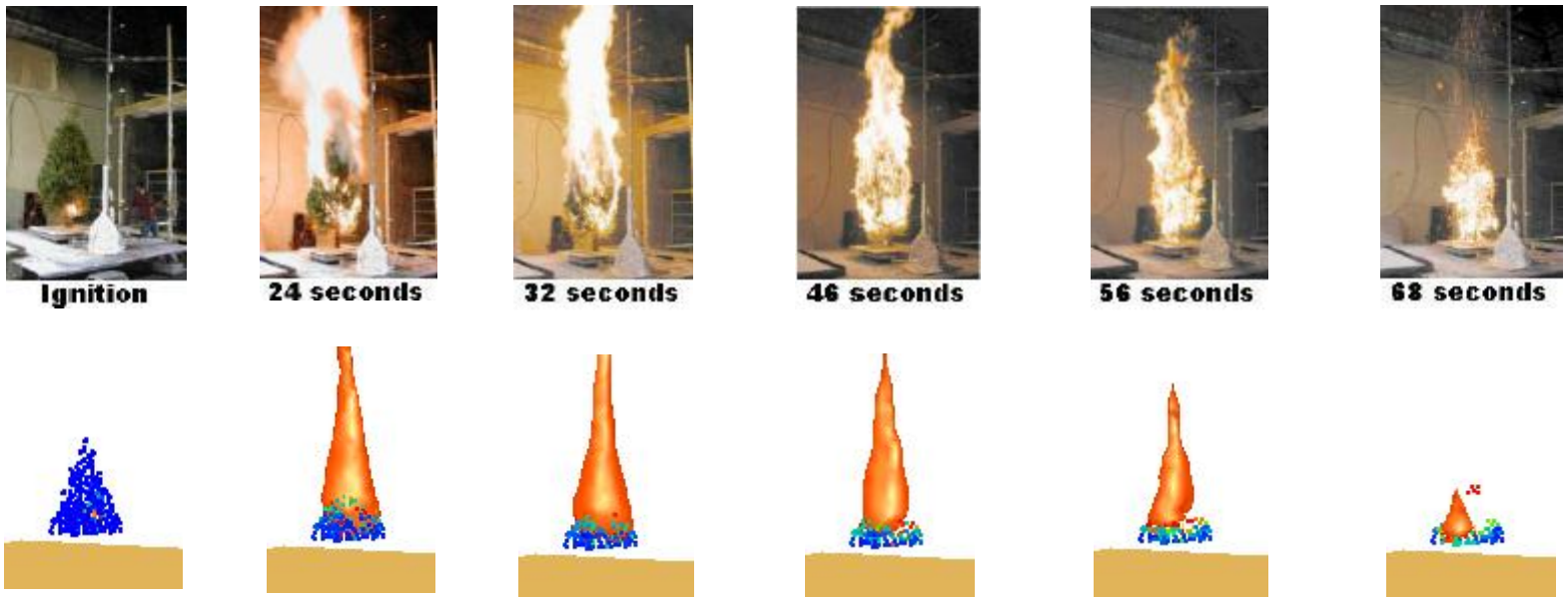
$$(\mathrm{HRR}_{\mathrm{comb}})_{\text{gas phase model}} = H_{\mathrm{comb}}(\dot{m}_{\text{Fuel gas}})_{\text{solid model}}$$

Small Conifers

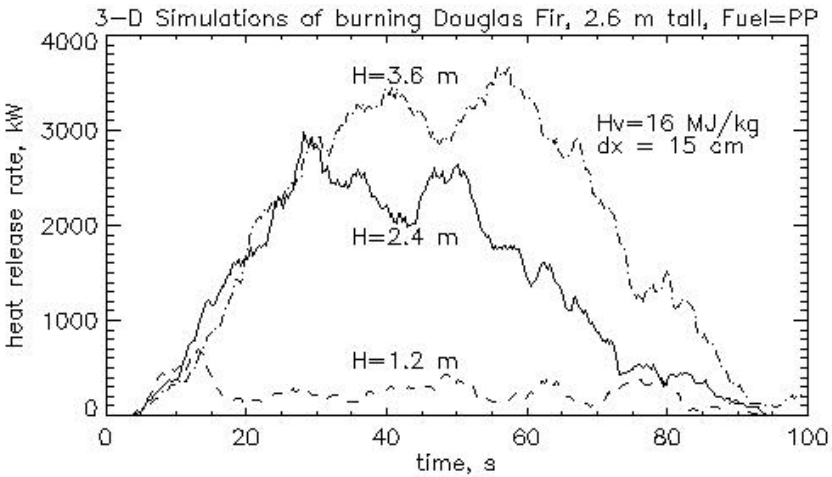
- Experiments at NIST
  - 1.2 m, 2.4 m, 3.6 m tall
- Simulations of each tree were run assuming M=29%
  - Smokeview



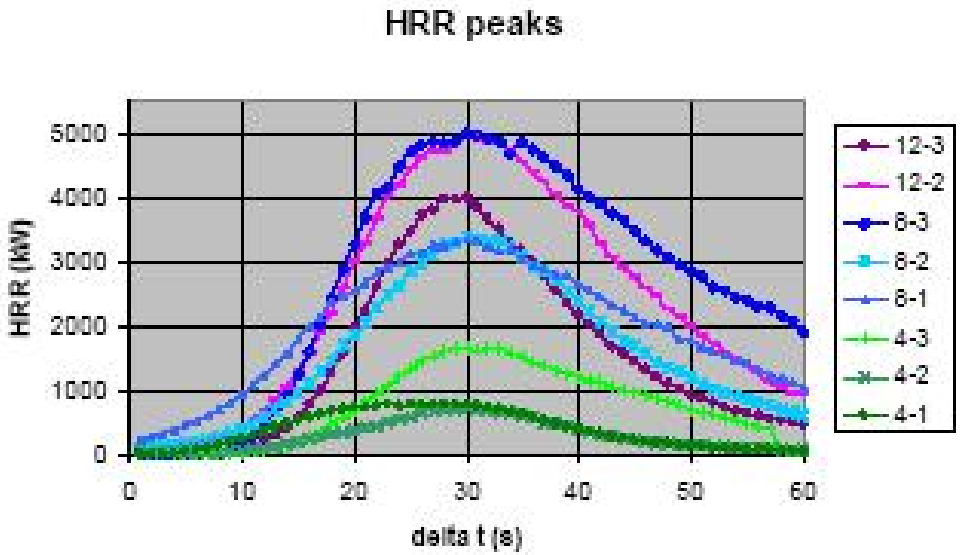
Snapshots of experiment and simulation of 2.4 m tall conifer



HRR vs time for different tree heights



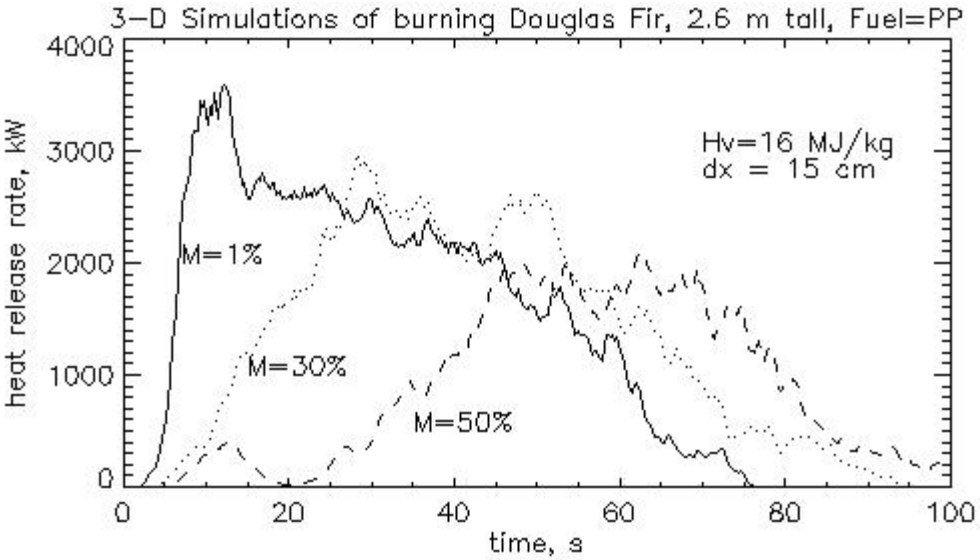
FDS simulation



NIST experiments

- Simulations were a first attempt, M = 29%
- Cases will be rerun with correct parameters when NIST report on experiments is obtained.

Simulated heat release rate time history for different moisture contents



- All simulation are for a 2.2 m tall tree
- The flame self extinguished in both the experiment and simulation for M > 50%.

Peak HRR vs. Moisture Experiment and Simulation

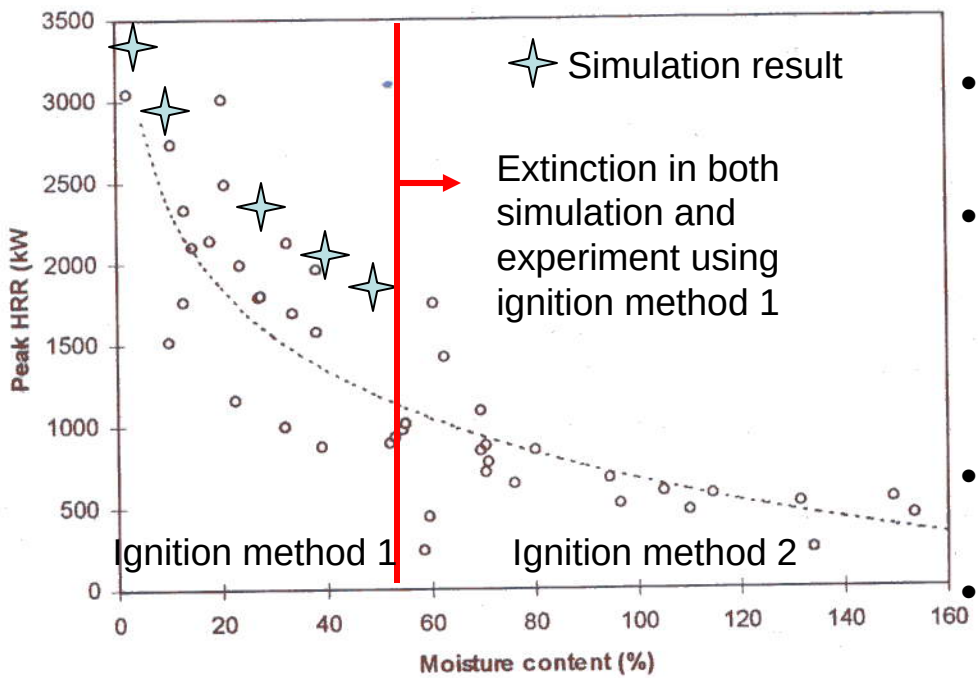
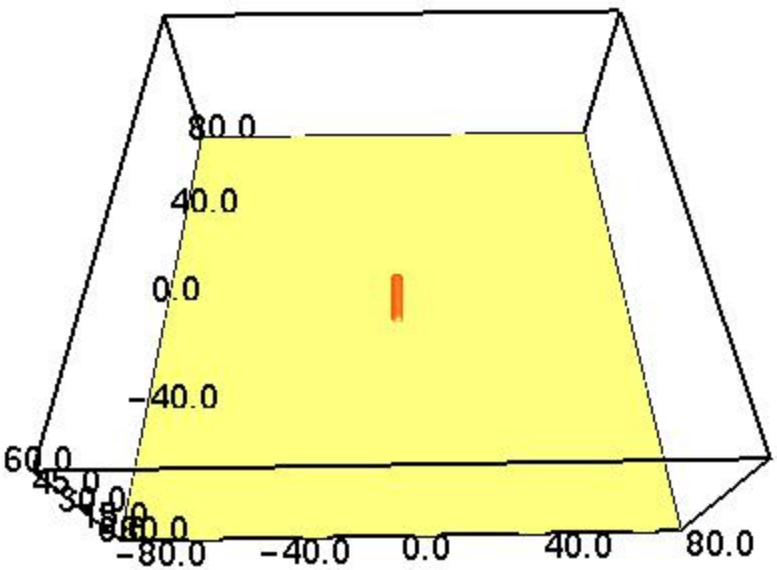


Figure 3 The relation between MC and HRR

- Douglas fire ~ 2.17 m tall (same as previous slide)
- Two ignition methods:
  1. Small flame, M < 50%
  2. Burning gift packages at base of tree, M>50%
- Only method 1 was used in the simulations to date.
- Note large variation in experimental values due to differences in how the mass is distributed in a tree (size of trunk, branches, …)

Grass Fires: Movies

- Grass fire cases in Rod's IJWF paper
  - link to web page
  - No wind sv, qt
  - Delayed ramp up to 6 m/s wind
    - One processor sv, qt (10 cpu h)
    - Four processors sv (2.6 cpu h)



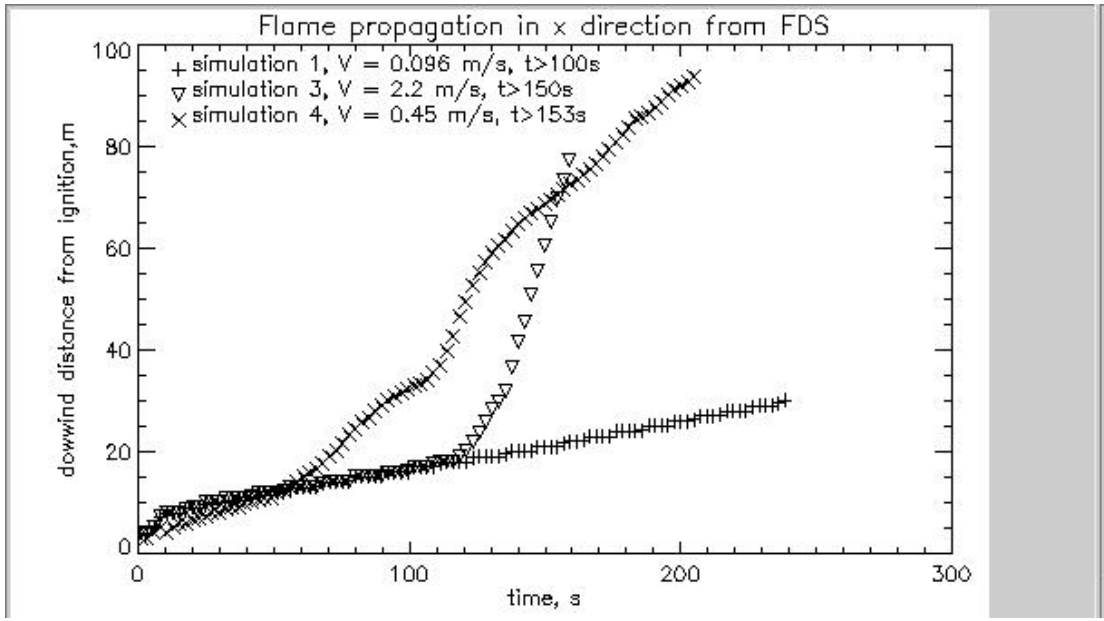
Computational specs:

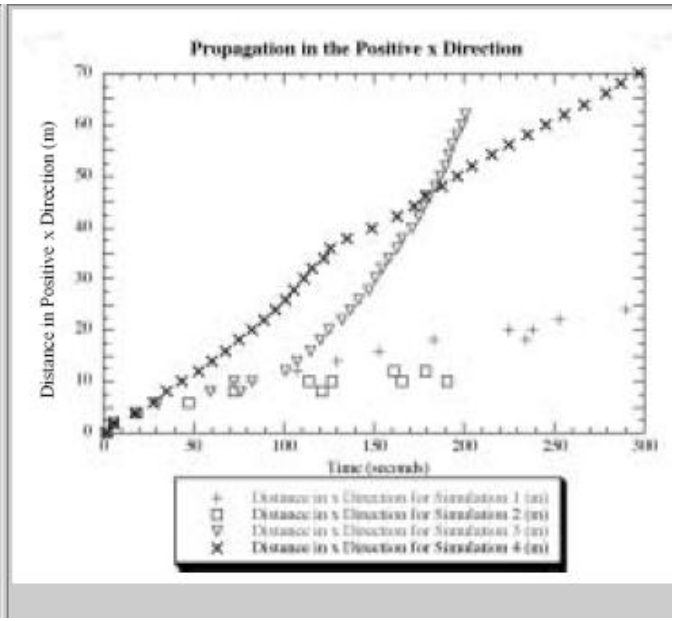
160x160x30 grid points; 160x160x60 m; 1m resolution; 5 minutes simulated time

Single 1.7 GHz processor:10.4 cpu hours, 15.4 micro cpu s / step / cell

Four 1.7 GHz processors: 2.6 cpu hours, 3.2 micro cpu s / step / cell

Grass Fires: Spread Rate

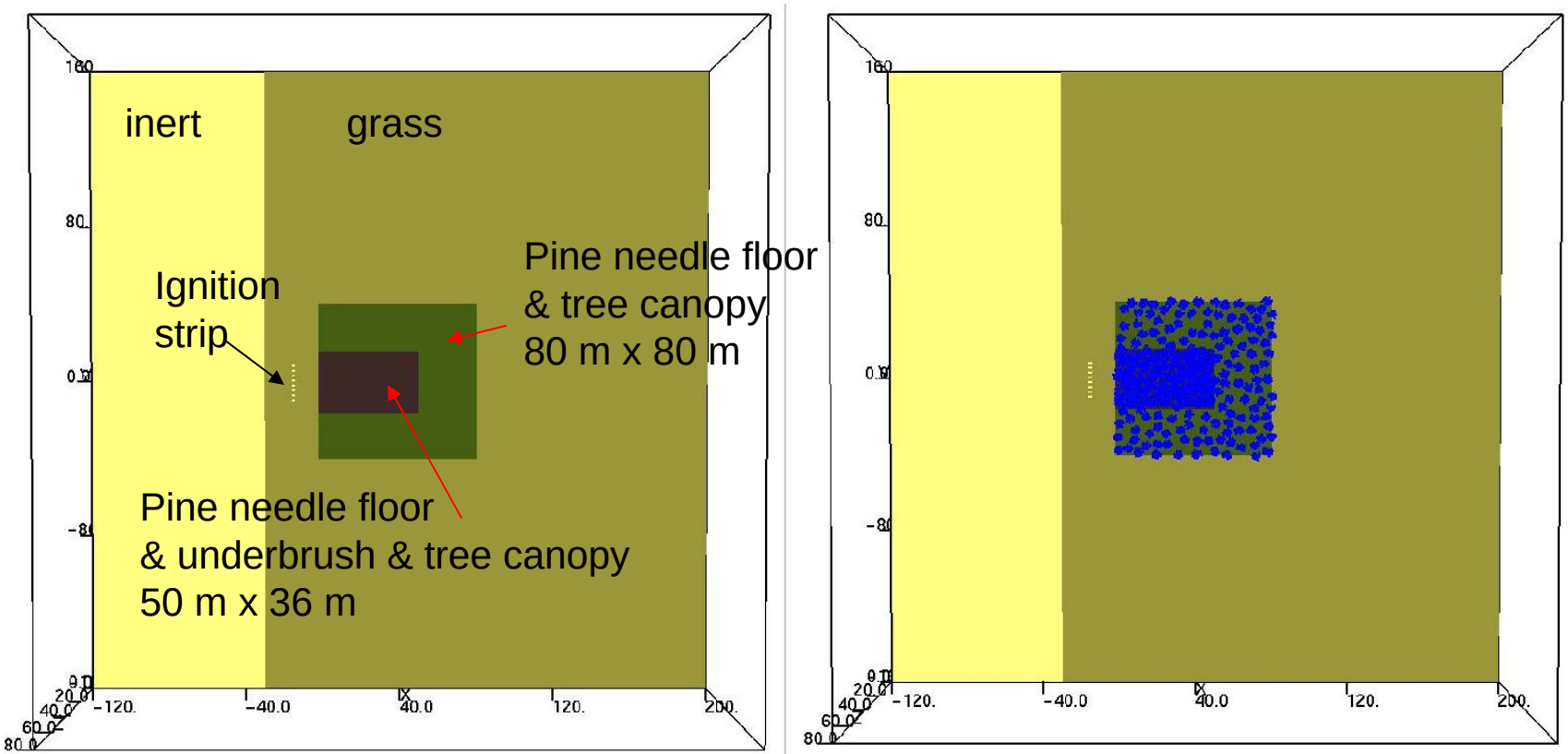




Case	FDS spread rate (no moisture)	FIRETEC spread rate (5% moisture)
Simulation 1 0 wind, grass	0.1 m/s	0.05 m/s (~0.03 m/s BEHAVE)
Simulation 3 0 wind to 100 s Ramp to 6 m/s in from 100 to 106 s	2.2 m/s	1 m/s (~2.5 m/s BEHAVE)
Simulation 4 Wind ramped to 3 m/s over 0 to 40 s Forest present downwind	0.45 m/s after 153 s	not reported

Mixed Vegetative Fuels

Plan view

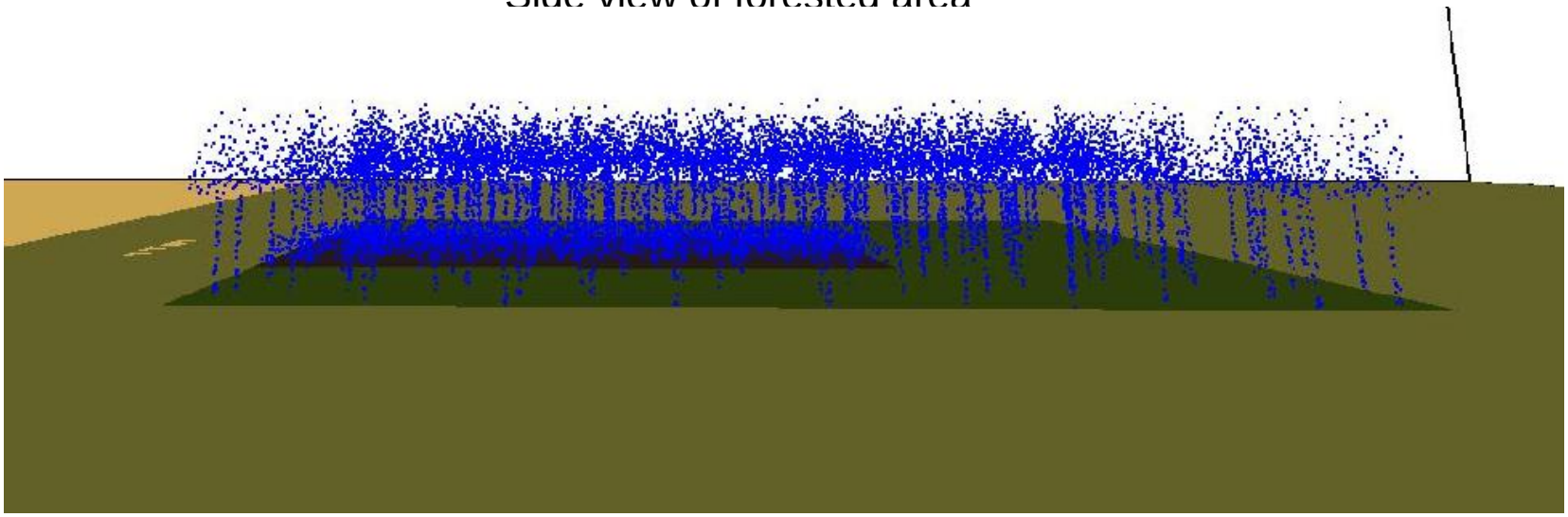


6 m/s wind

Computational specs:
160x160x20 grid points; 320x320x80 m; 2 m resolution
3 minutes simulation time required 5.5 cpu hours on Dell M6 laptop, ~ 2 hours with four 1.7 GHz processors

Mixed Vegetative Fuels

Side view of forested area



- Grass: NFFL fuel model 3 “Tall Grass”
- pine needles: Pinus Pinaster, 5 cm depth, 20 kg/m^3 bulk density
- underbrush: height = 0.5 m to 2 m, 1 kg/m^3 bulk density
- canopy: height = 7 m to 14 m, 0.24 kg/m^3 bulk density (160 trees)
- quicktime movie of flame and tree temperature (sv)