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Mathematical Modeling of Community-scale Fires

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Mathematical & Computational Science Division (MCSD)
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Technology Administration, U.S. Department of Commerce

OUTLINE

- What distinguishes WUI fires? - Buildings
- What is the role of burning structures in WUI fires?
- Measurement of ignition & HRR for WUI fuels – landscape trees and structures – Lab & Full Scale
- PC-based fire model – neighborhood scale
- Web-based fire risk tool for use by property owners

We welcome input to help move this work forward.

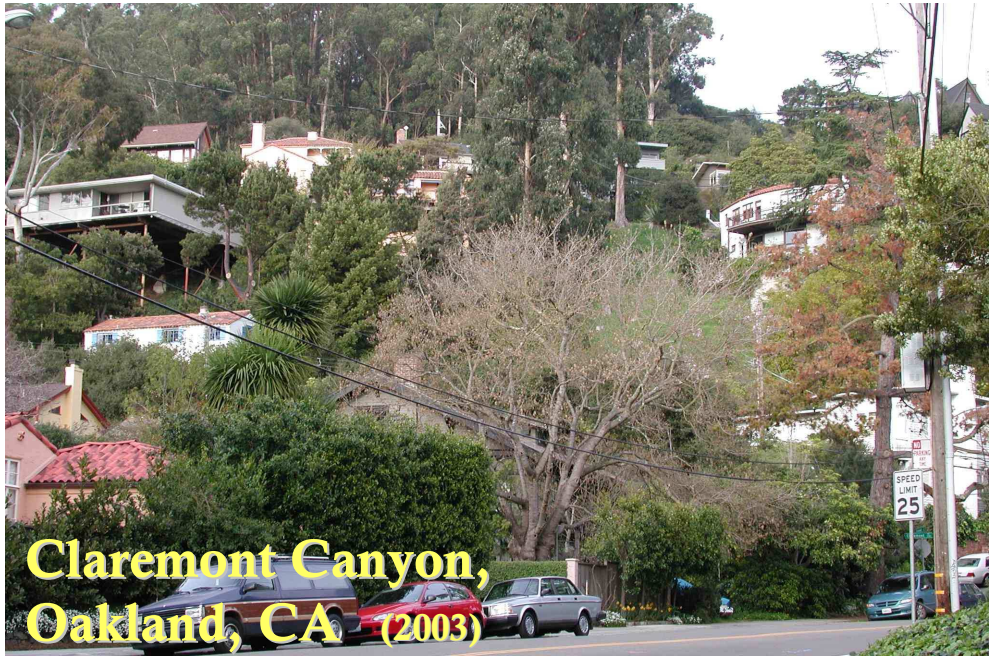
NIST ó Building Fires R Us

Forest Fire

WUI Fire (Summerhaven 2003)

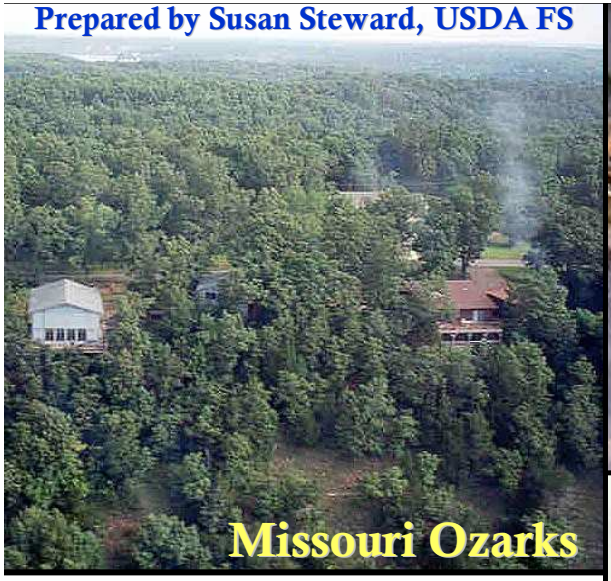
WUI fire models must consider individual fuel elements.

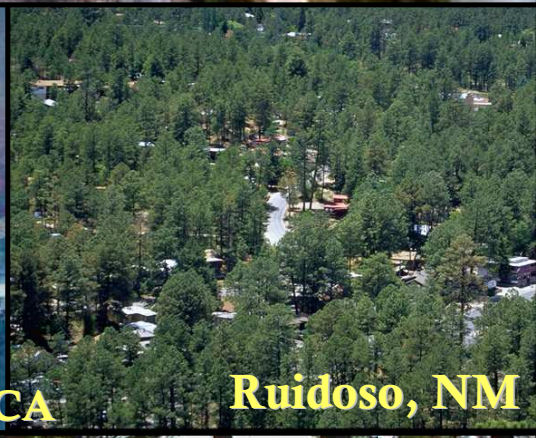
The technical challenge is to resolve fire spread at the scale of individual land parcels and buildings



Claremont Canyon, Oakland, CA (2003)

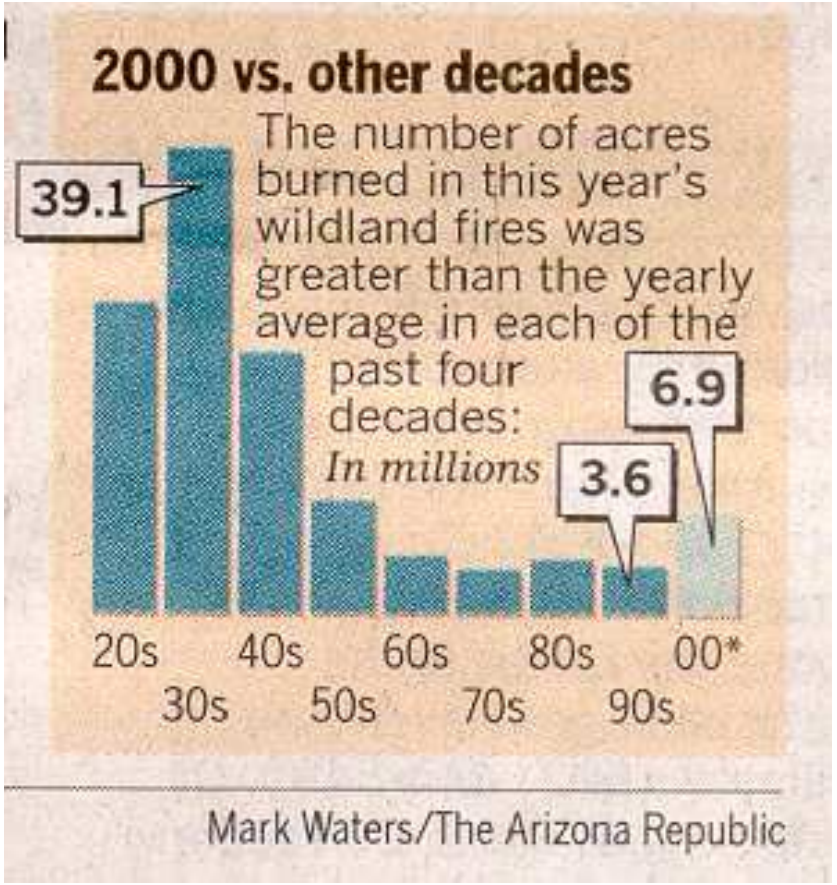
36% (42 million) U.S. homes are in the WUI





Wildland Fires 2000

- 80,000 fires
- 7 million acres
- $10 Billion loss

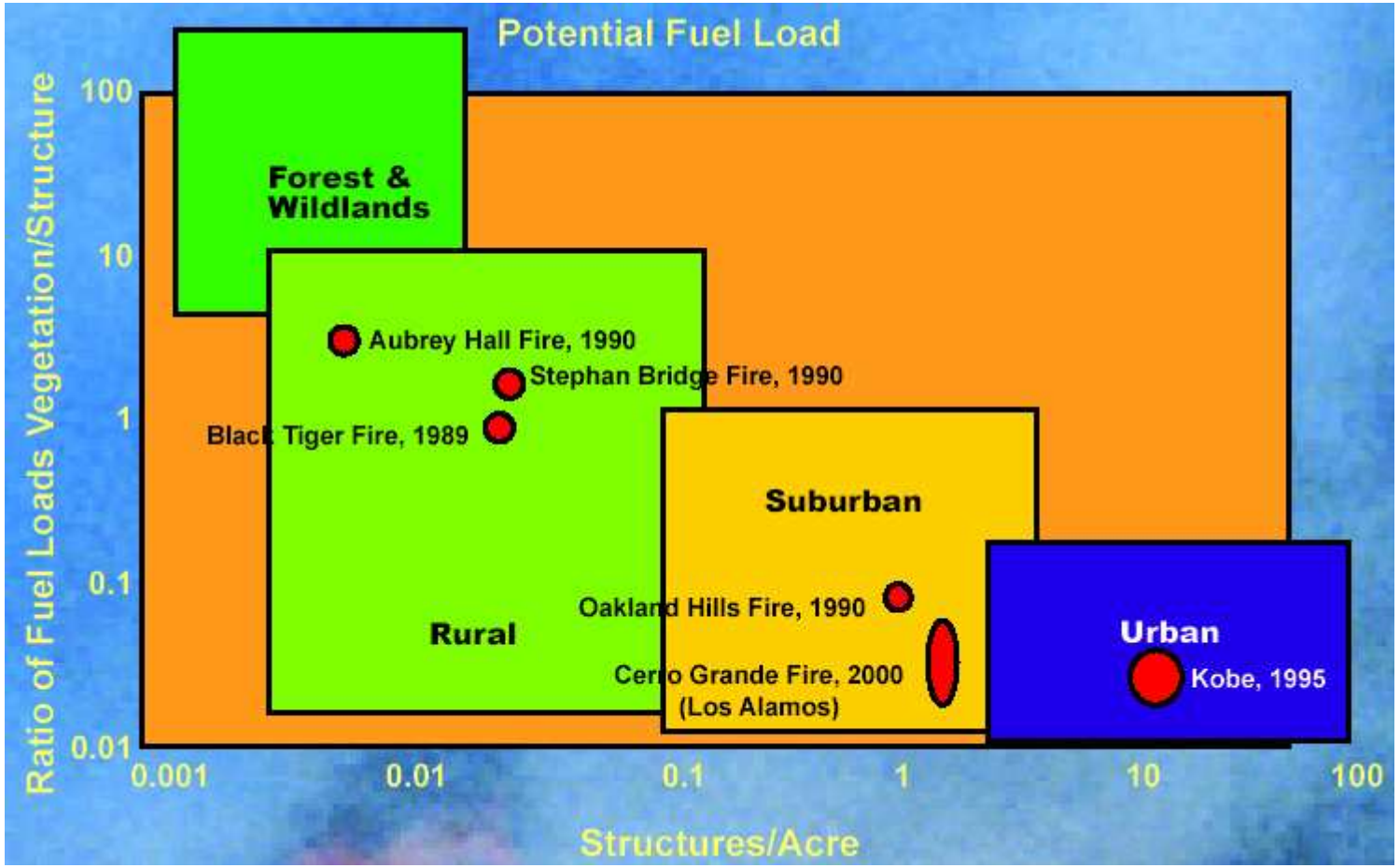


Wildland-Urban Interface (WUI)

- **WUI increasing rapidly**

- **Wildland fires also increasing rapidly**

Structures vs. Vegetation Fuels



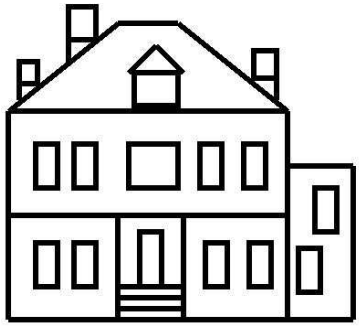
> Potential fuel load from a structure is large compared to wildland fuel load

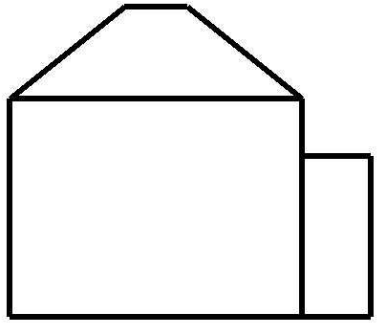
Model Approximations

- Hydrodynamics: (rectangular grid only)
  - Low-Mach-Number Approx.
  - Large-Eddy Simulations (LES)
- Combustion: Flame-sheet Approx.
- Radiative transport: Finite volume method
- Vegetation model (Thermally thin)
- Smoke: ALOFT - Taylor Approx. also

Mathematical Models

Caricatures





$1.

$.25

$.05

Complex Model: Computationally & Data Intensive

Approximate Model: Small Computational & Data Needs

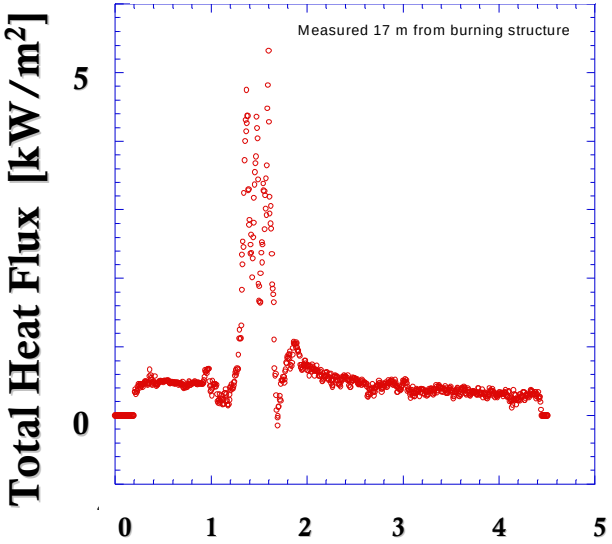
MEASUREMENTS

- **Full-scale fires – outdoors**

- **Laboratory fires**
  - **NIST Large Fire Laboratory**
  - **Fires up to10 MW**

Field Burns – Buildings of Opportunity

Out-building Burn with Odenton Maryland Volunteer Fire Department, 8/11/02



Estimated Peak HRR ≈ 23 MW

Simulation of Structure to Structure Fire Propagation

LFF – Asphalt shingle siding wall burn

Over 100 years of
Building fire safety
studies
by NIST – NBS

Fully involved exterior wall fire

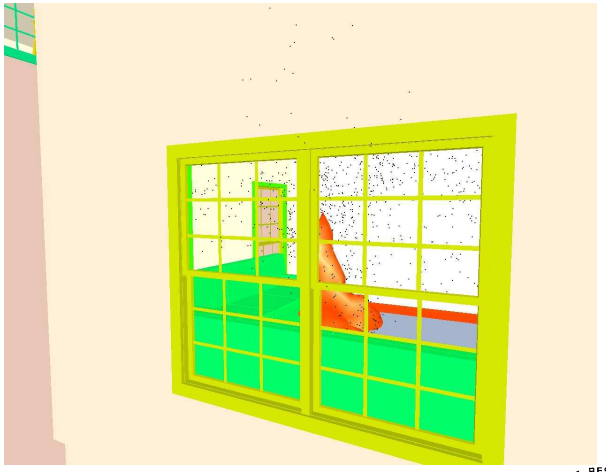
LFL Structure to Structure Fire Spread

House to House Spread

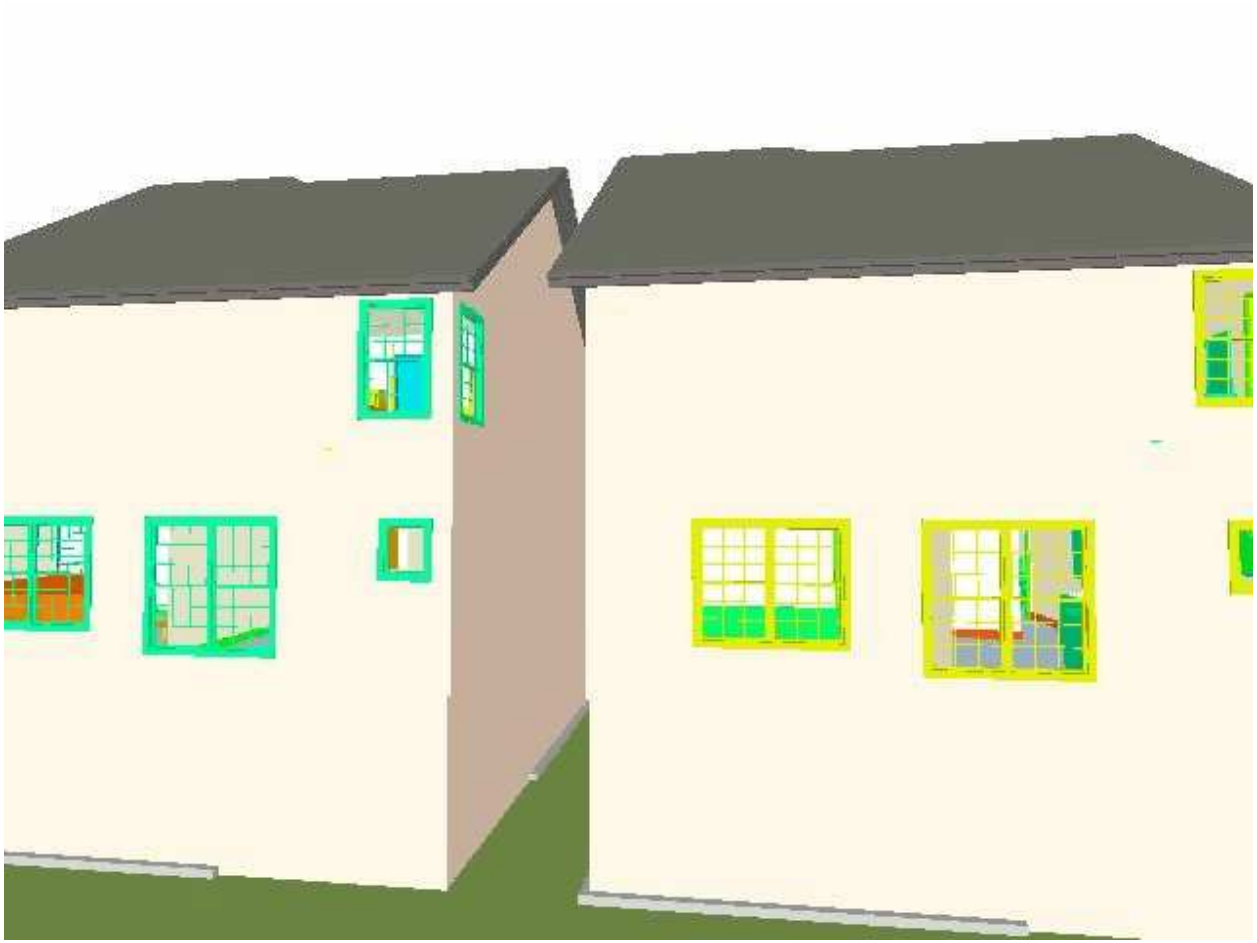
Front

Back

Ignition
right house

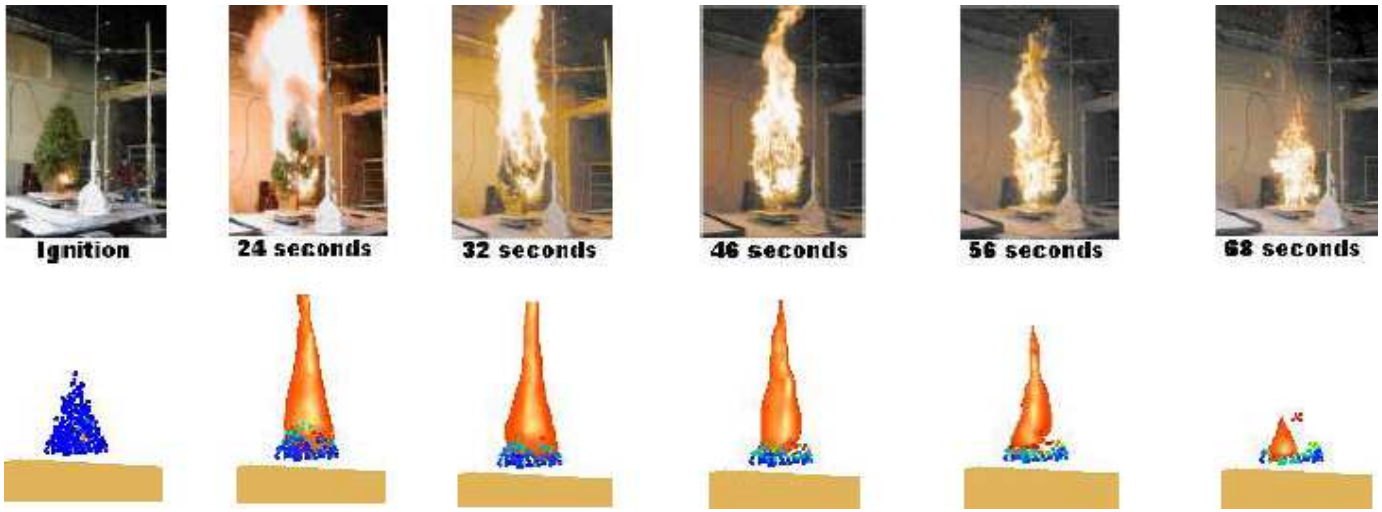


House to House Spread

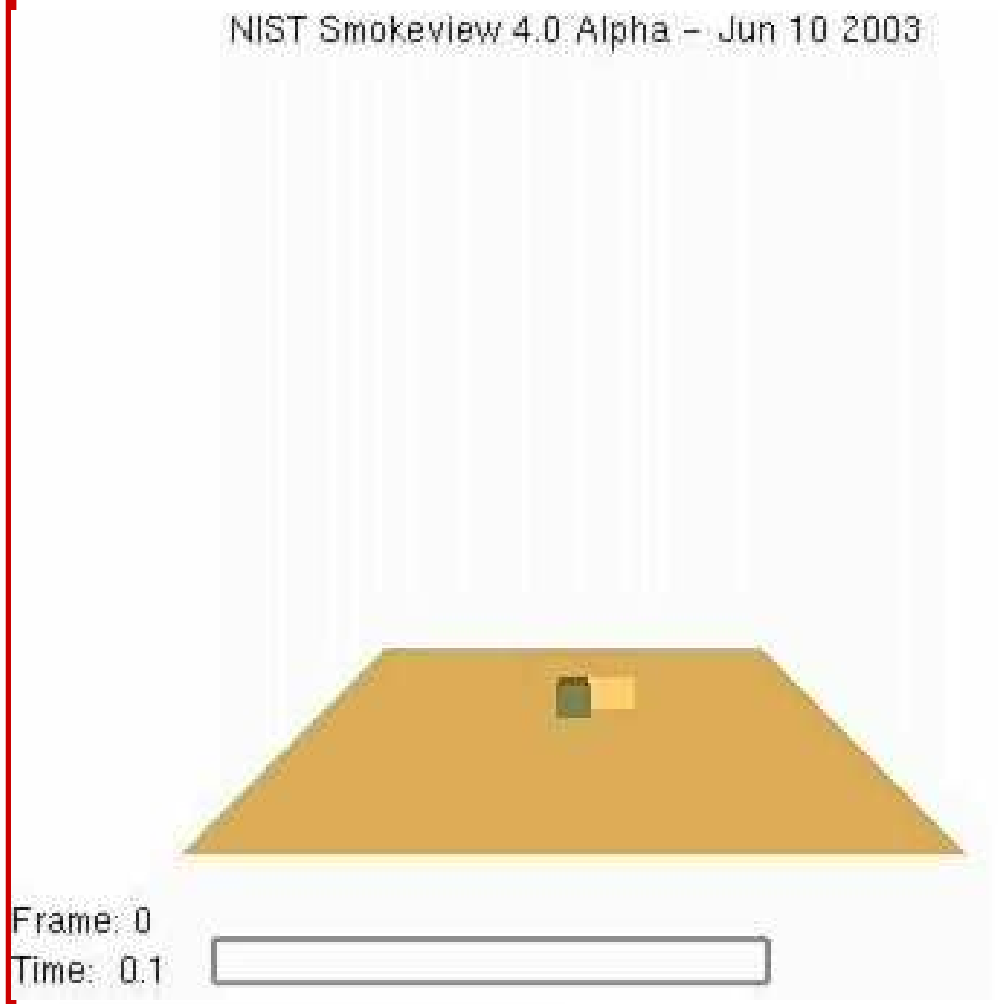


Simulation of Burning Wildland Fuels

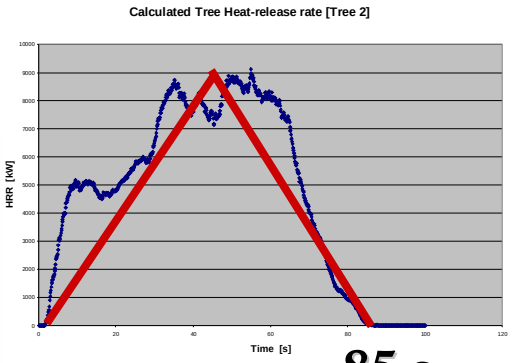
NIST's LFL Tree Burns



Calculated 4.0 m Tree Burn- HRR



9000 kW



85 s

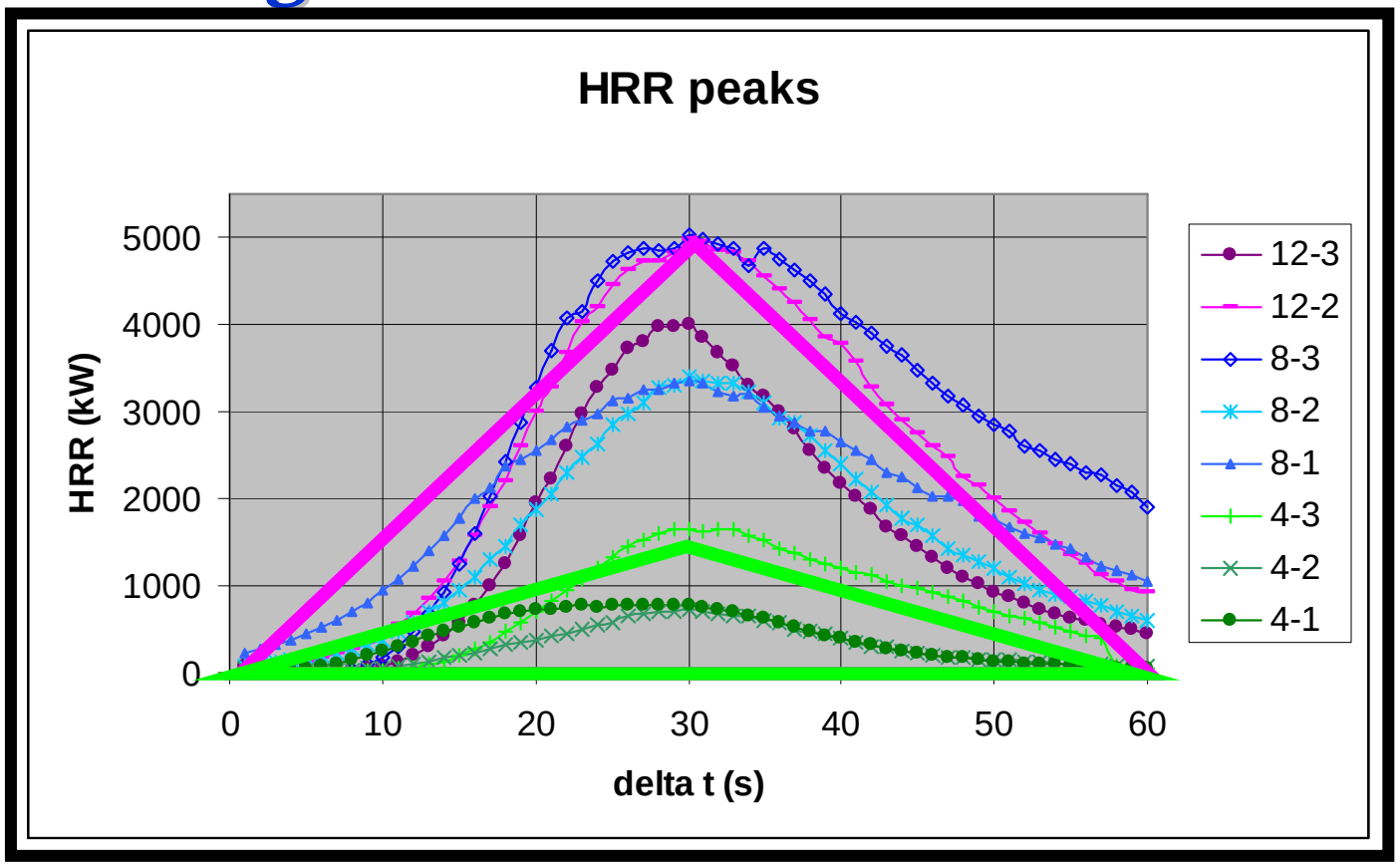
LFF Douglas Fir Burns

1.2 m tall

3.6 m tall

Measurement of total heat release rate, burning rate, radiative flux, flame height, and burn duration.

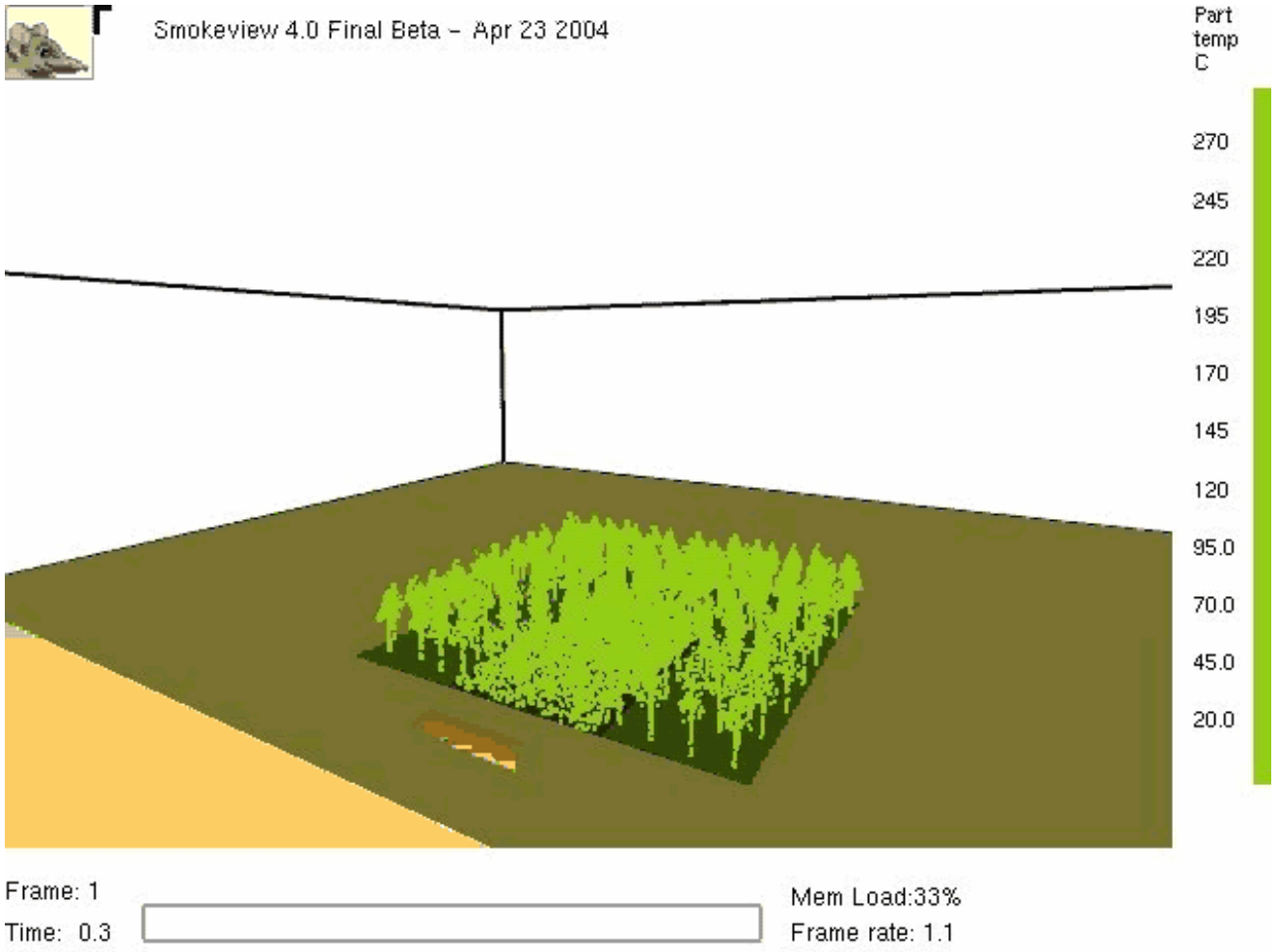
Total Heat Release Rate
Douglas Fir trees 1.2 to 3.2 m



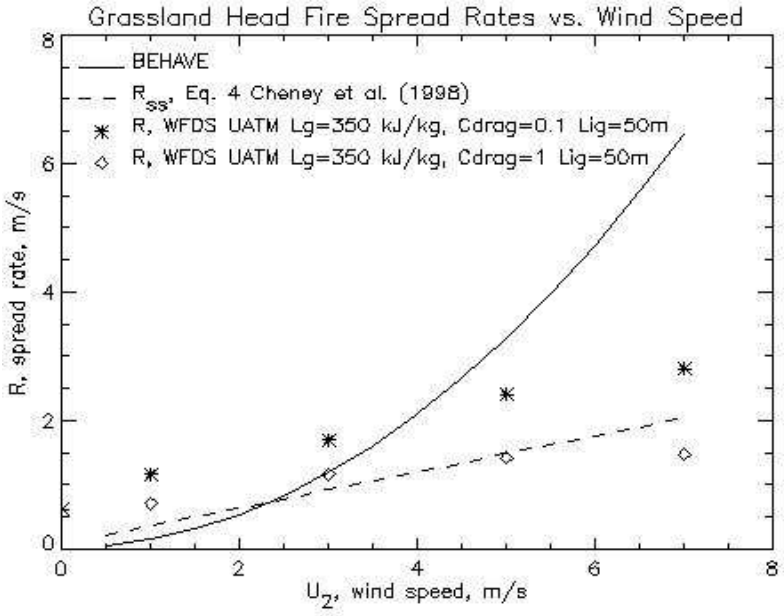
3.6 m — 1.2 m

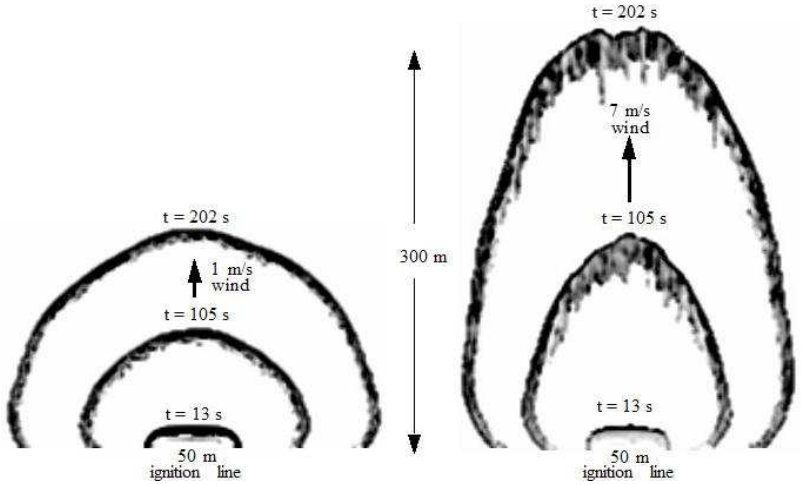
Triangle Approximation for Tree HRR

Fuel Treatment



Wildland Fire Simulation
Australian Grassland Experiments





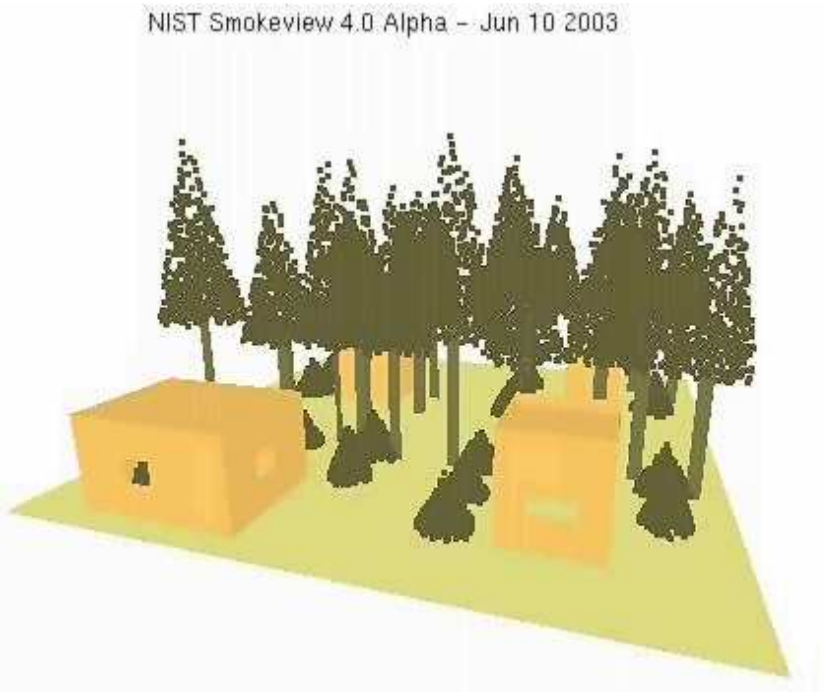
Wildland & Structure Fires

Wildland-Urban-Interface (WUI) Fires

Physics-based wildland-urban fire spread model using FDS

PC based fire model

Predicted fire spread from fuel element to fuel element.



> Ignition of ladder fuel
> Fire spread to tree crowns
> Structures ignited by radiation
> Trees burn differently from houses
> House interiors and exteriors burn
> Fuel is consumed and burns out

FDS & Smokeview are software for PC available for free download at www.fire.nist.gov

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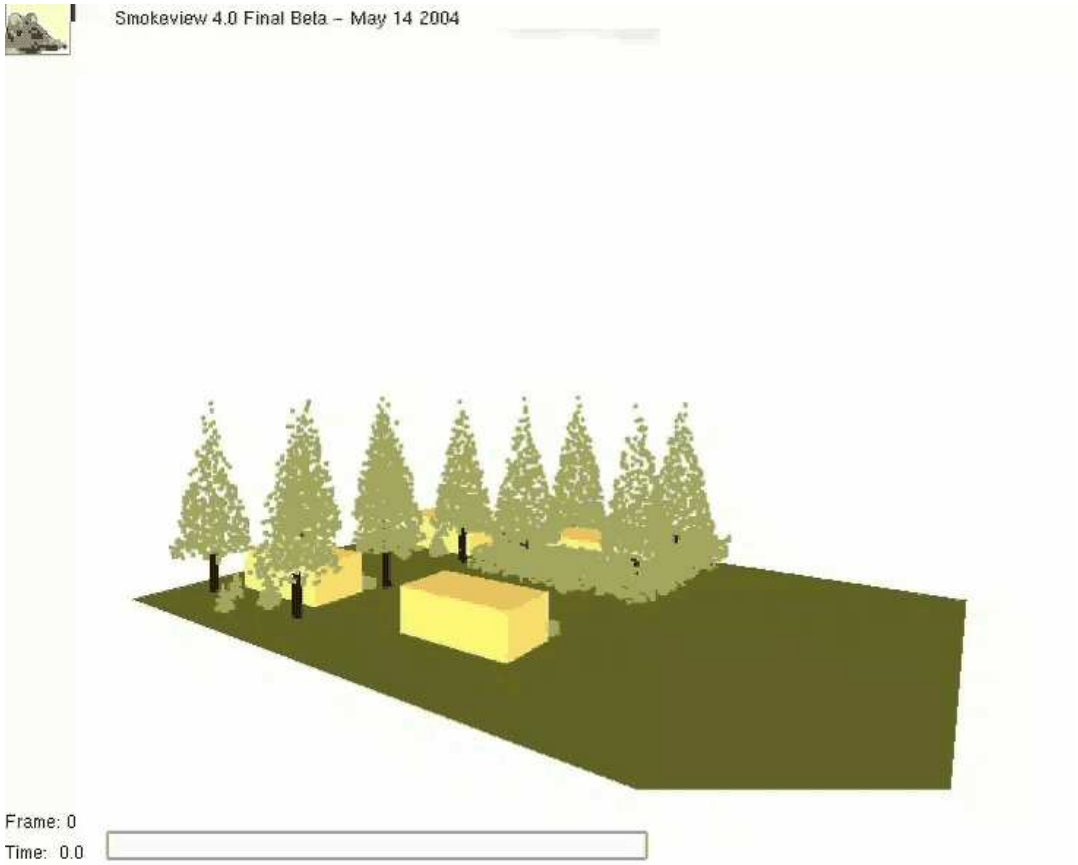
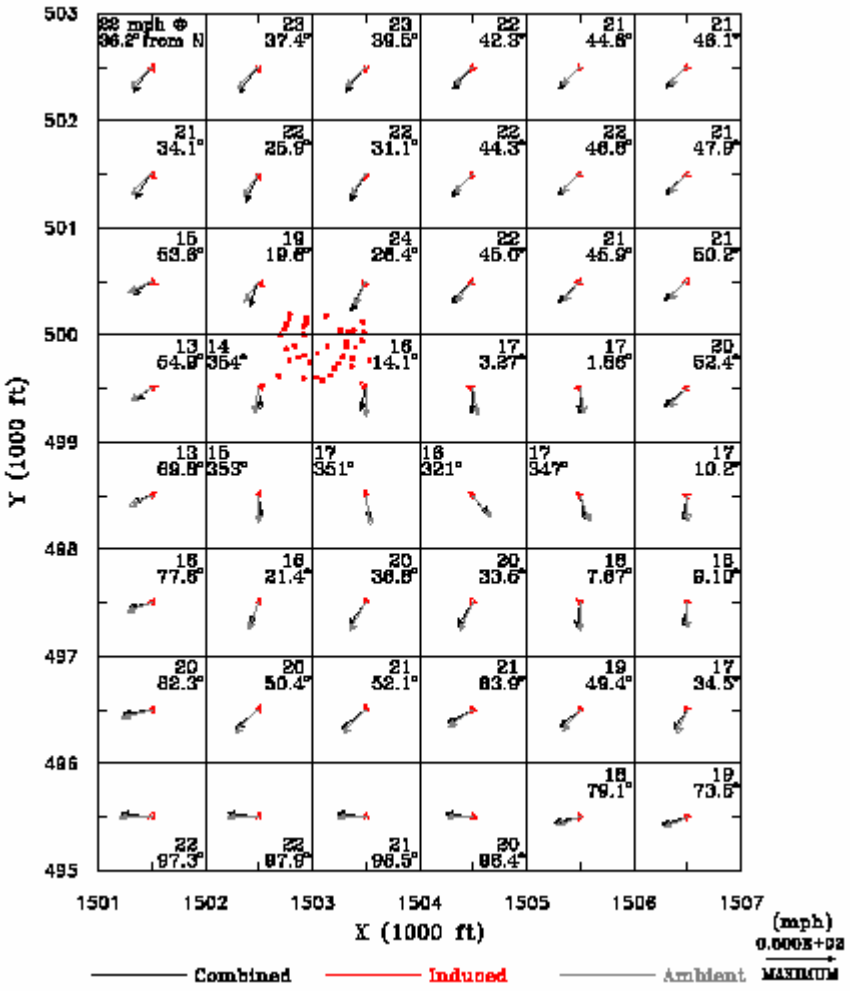
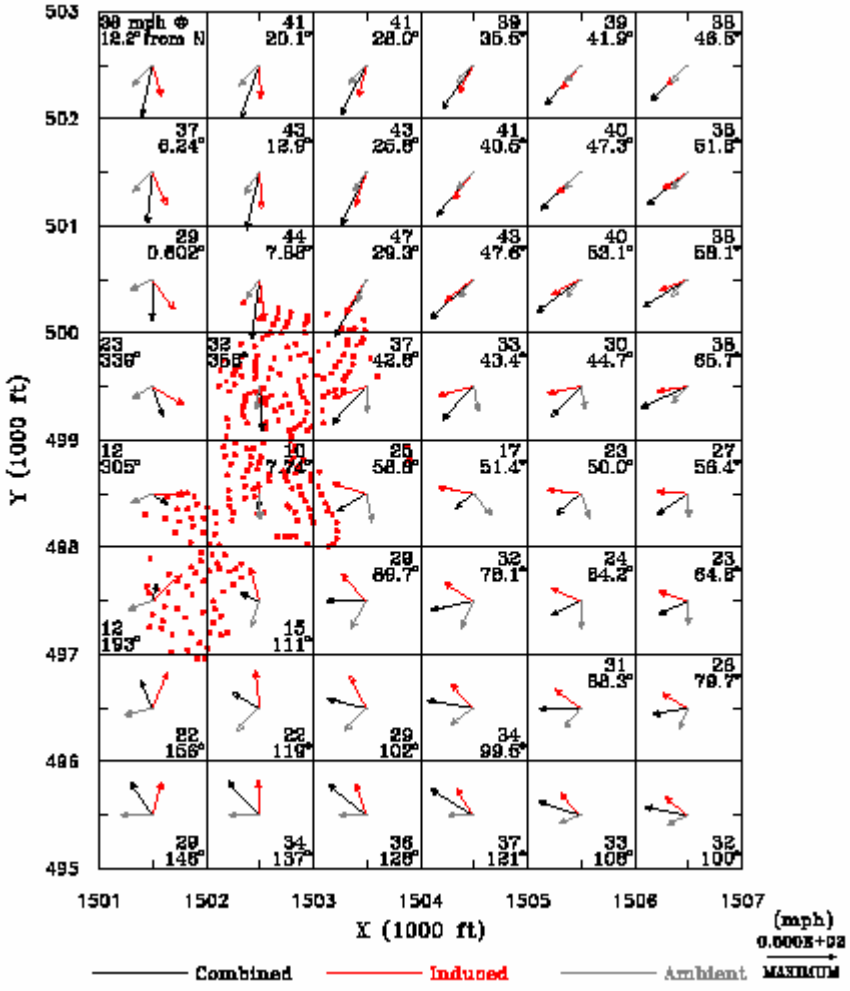
Fire line invading a community



Horizontal Ambient & Fire-Induced Winds at Two Times during the 1991 Oakland Hills Fire





Time: 11:45
38 Burning Structures

Time: 12:00
259 Burning Structures

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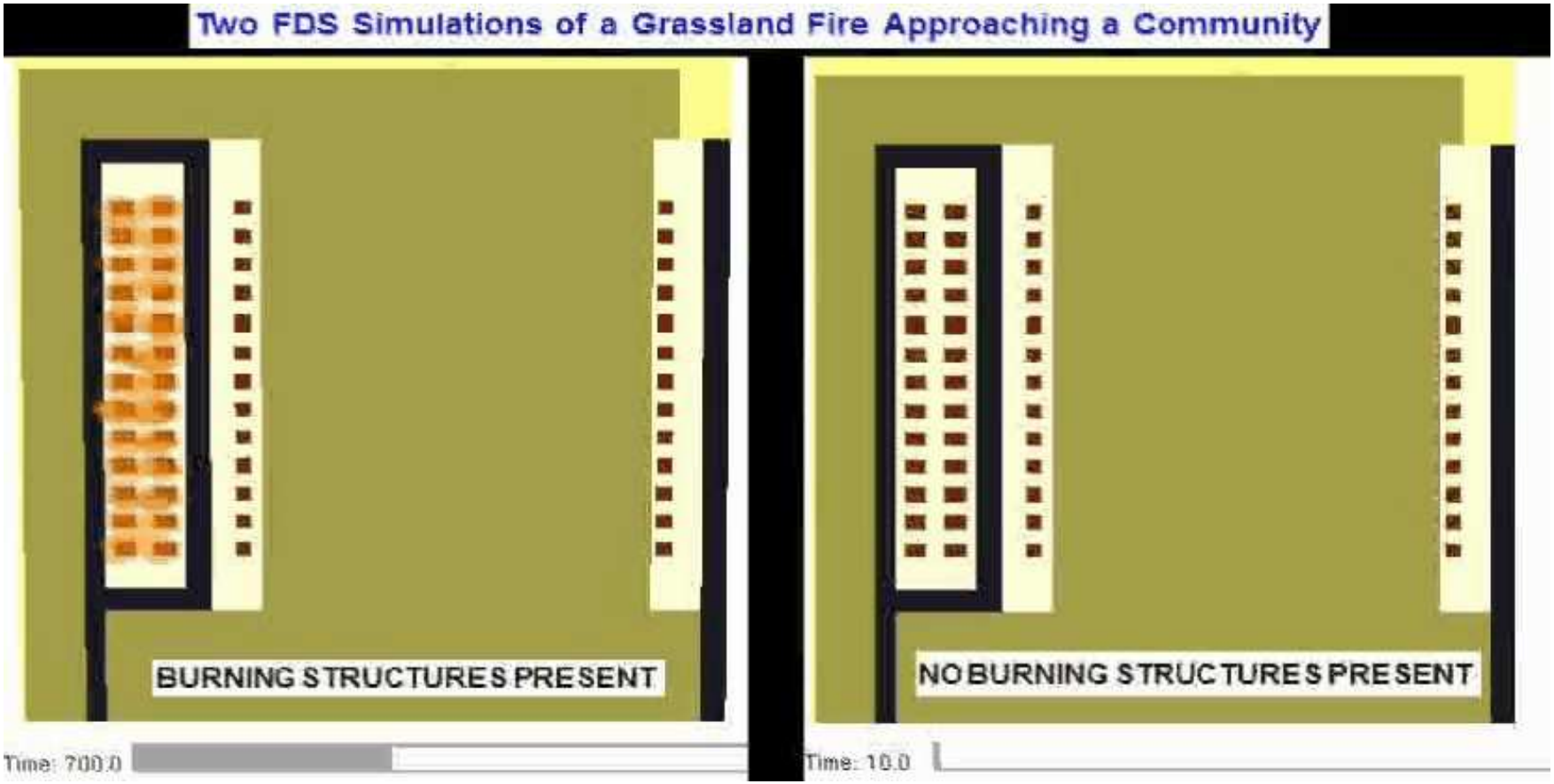
Effects of Burning Structures on Fire-spread



Closing 1

3D, transient physics-based models needed for wildland & WUI fires
data and computational-resource intensive

FDS simulates wildland, structure and WUI fires **Efficiently** - with visualization tool Smokeview

LFL & full-scale data needed for wildland & WUI models

Closing 2

WUI fire models must consider the different burning characteristics of vegetation and structures.

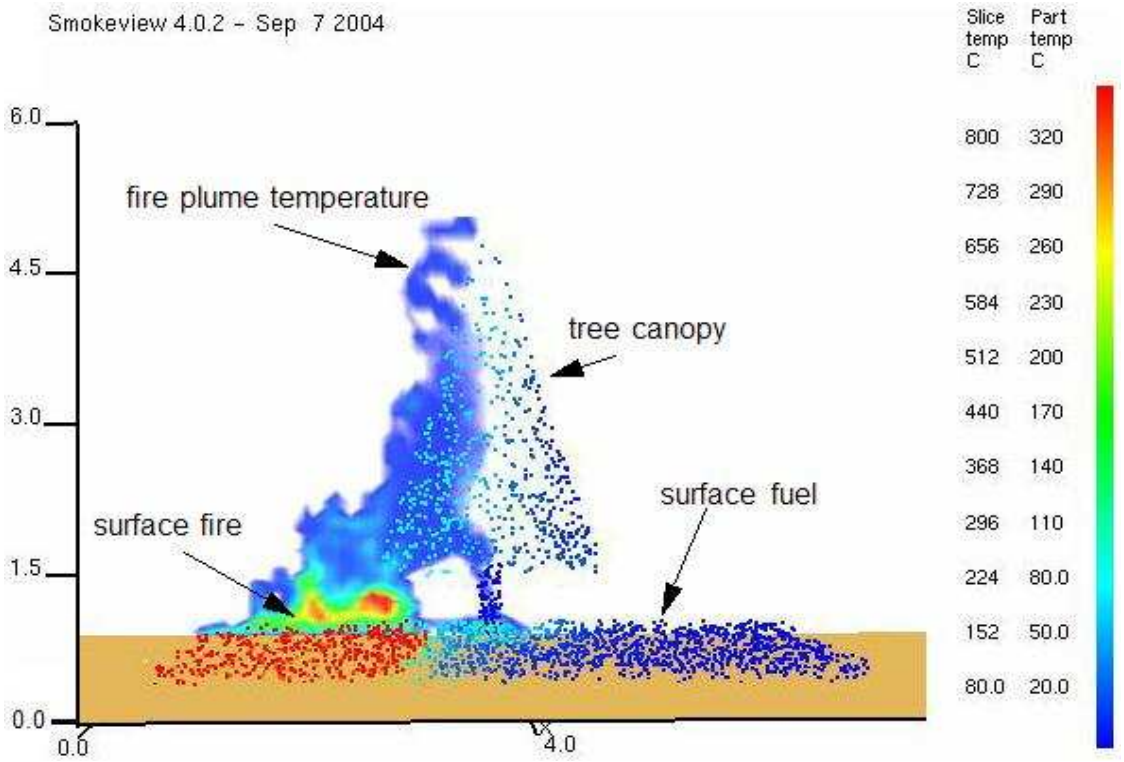
Fuel bed / type modeling assumptions that have been used successfully for wildland fire spread predictions are not sufficient for WUI modeling.

WUI modeling requires a detailed understanding of fuel element ignition and burning that presently does not exist. (ignition time, HHR)

Thank you

Questions

Simulations for Fire Effects



Wind Tunnel Simulation