New Scientific Investments & Approaches to Fire Modeling

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Outline

- Current state of fire modeling
- Examples of limitations of the current models
- Examples of physics-based modeling
- What measurements are important

Where are we now?

Behave / Farsite form the basis of fire behavior modeling applications in the U.S.

They are based on the (semi)empirical Rothermel surface fire ROS equation.

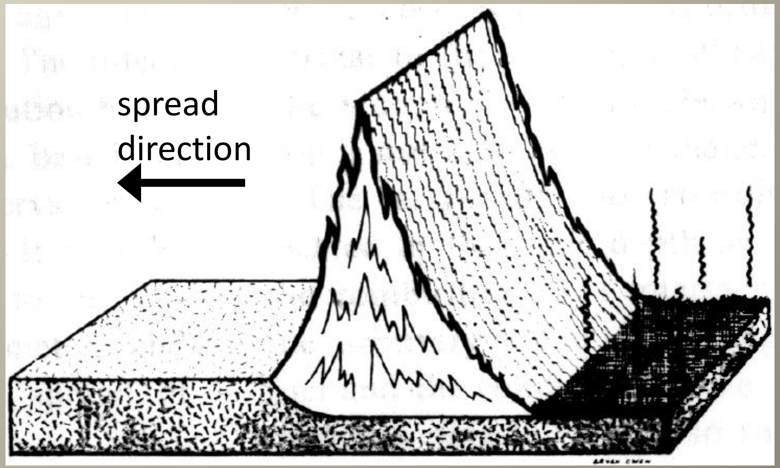
Anderson/Frandsen Model Assumptions

(theoretical basis of Rothermel model)

Frandsen, 1971 formulated a model for quasi-steady rate of spread, motivated by Fons (1946).

Required conditions:

1. Constant ambient wind
2. Constant fuel bed properties
3. Constant slope



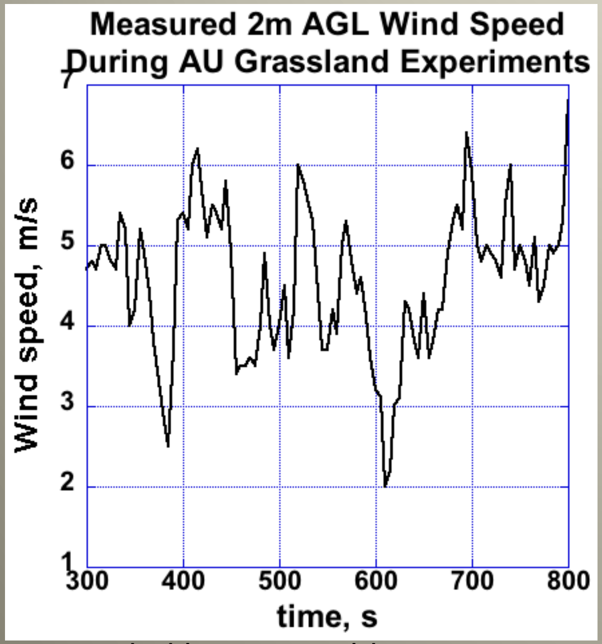
Frandsen, 1971

Examples of Problems Beyond the Scope of the Frandsen/Rothermel Physical Assumptions

- Fire through raised fuels
- Fuel treatment effectiveness
- Unsteady fire behavior (e.g., fireline acceleration up a drainage)
- Fire behavior in the WUI (firebrands, complex fuels)
- Smoke generation and transport
- Fire fighter safety (heat flux & smoke exposure)
- Fire effects and structure ignition (heat and firebrand fluxes)

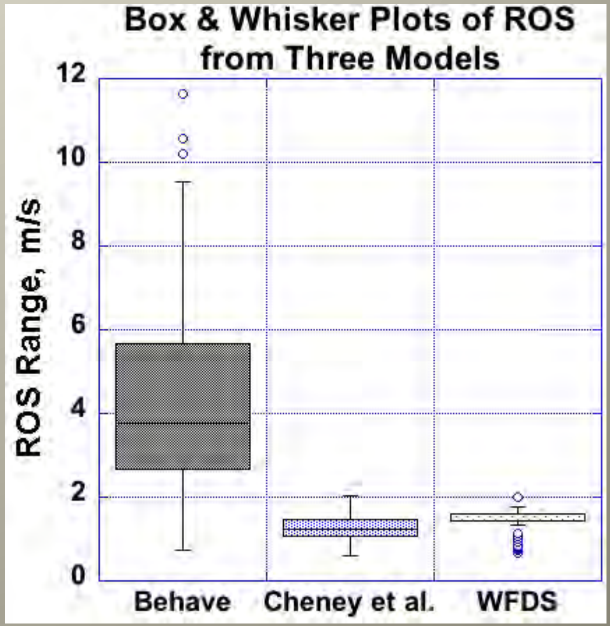
Limited by Dataset of Origin

An empirically derived ROS is restricted to the environmental conditions that are consistent with the dataset of origin.

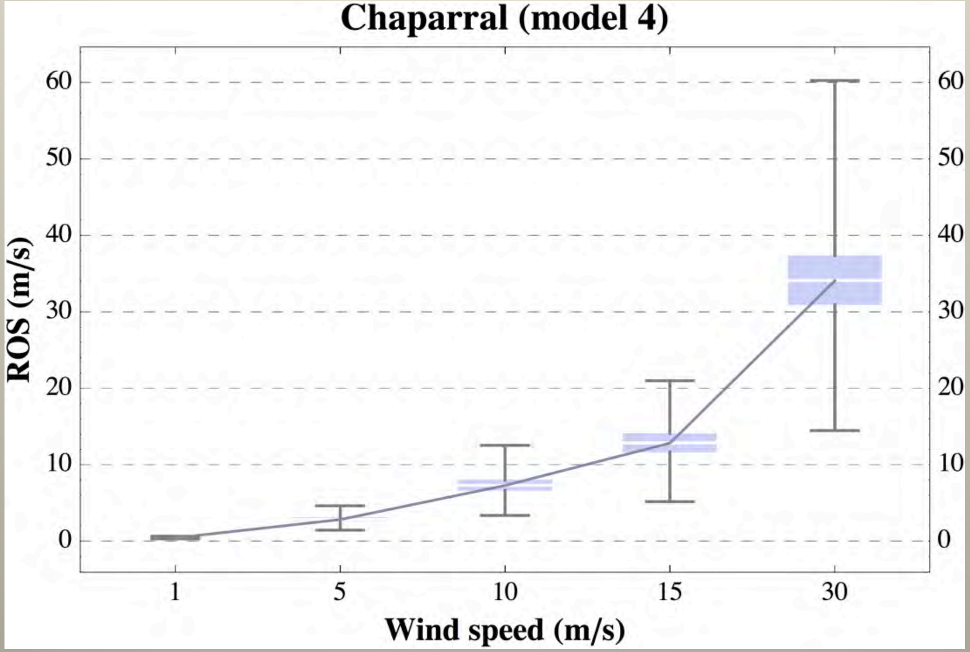


Provided by Jim Gould

Input into model with AU grassland fuels



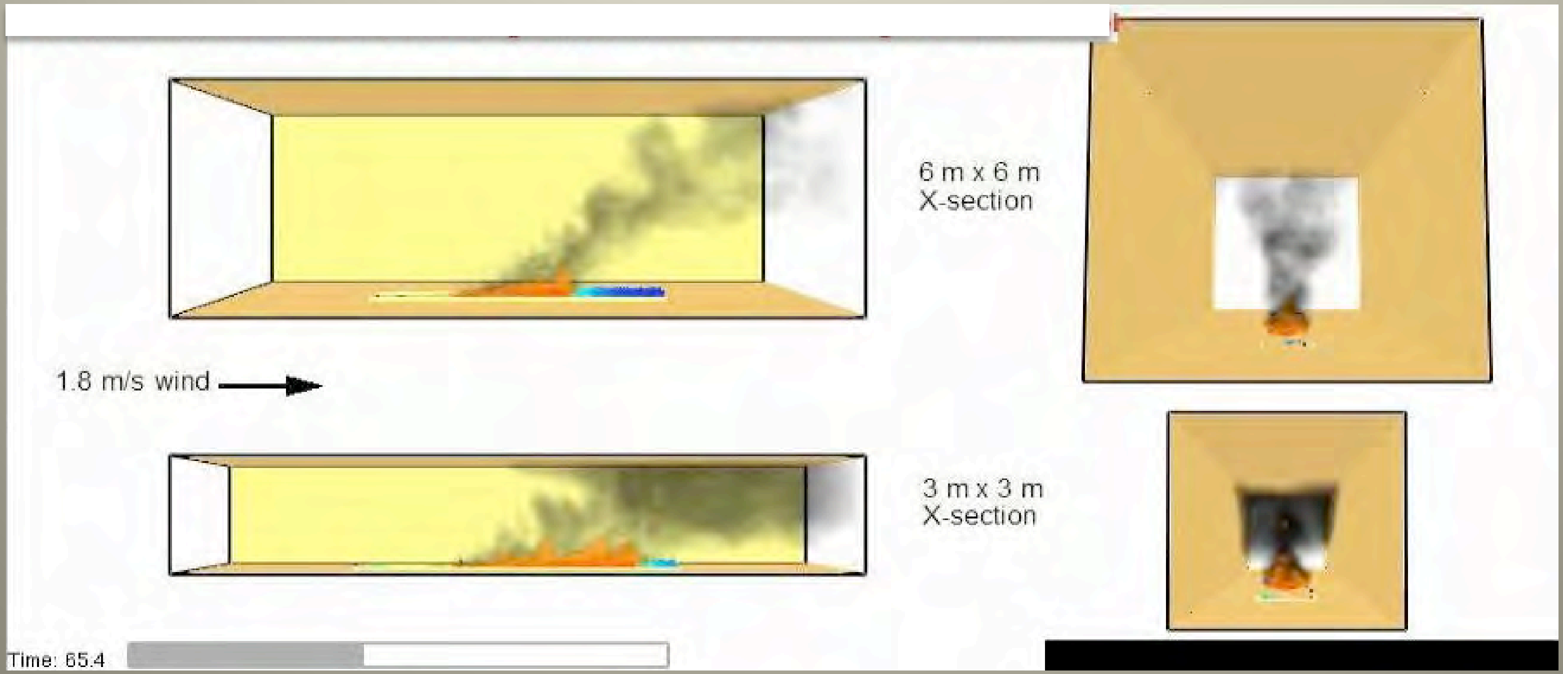
Box & Whisker of ROS variation at different wind speeds



Influence by Scale/Configuration of Experiment

-Laboratory experiments are not always representative of real-scale.

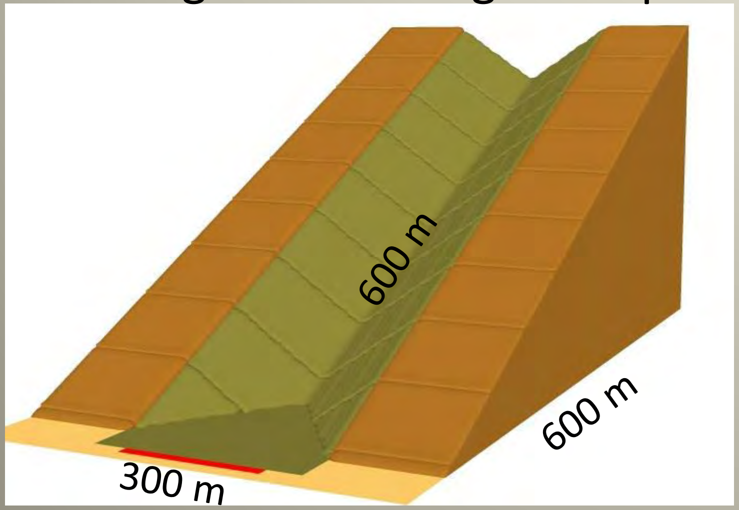
- Important processes may not be present or may be prohibited.

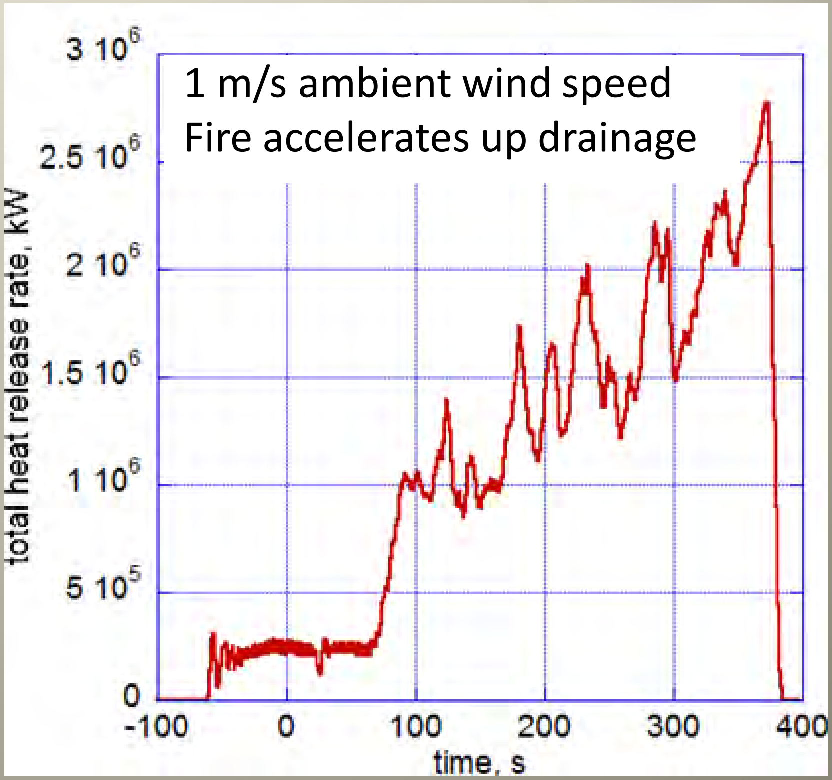


Limited by Quasi-steady ROS Assumption

Fireline acceleration up a drainage cannot be directly accounted for by a Frandsen/Rothermel-type formulation.

Drainage on a 27 degree slope

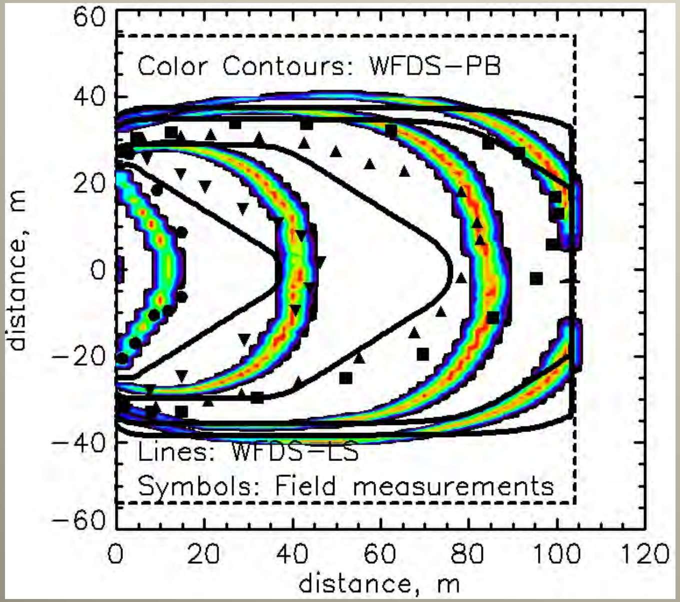


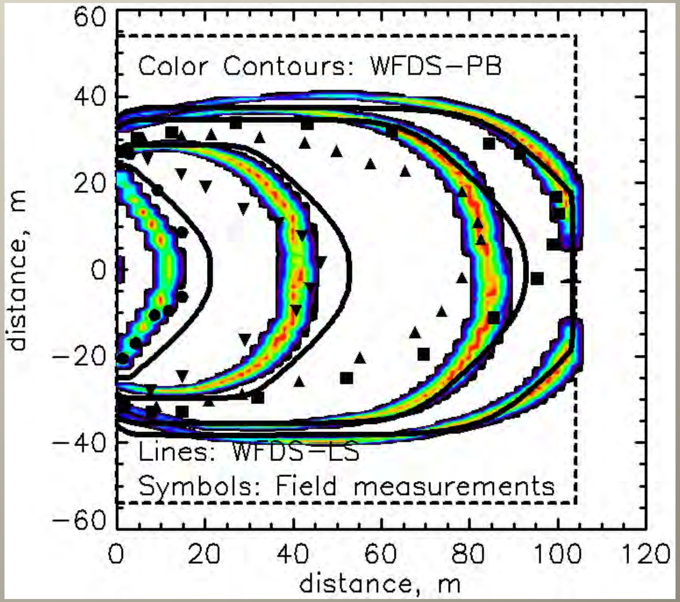


Limitation: Quasi-steady ROS Assumption Example from Australian Grassland Experiments

Cheney et al.

Solid lines: WFDS Level Set ~ Farsite
Color contours: WFDS Physics Based
Symbol: measured fire perimeter location

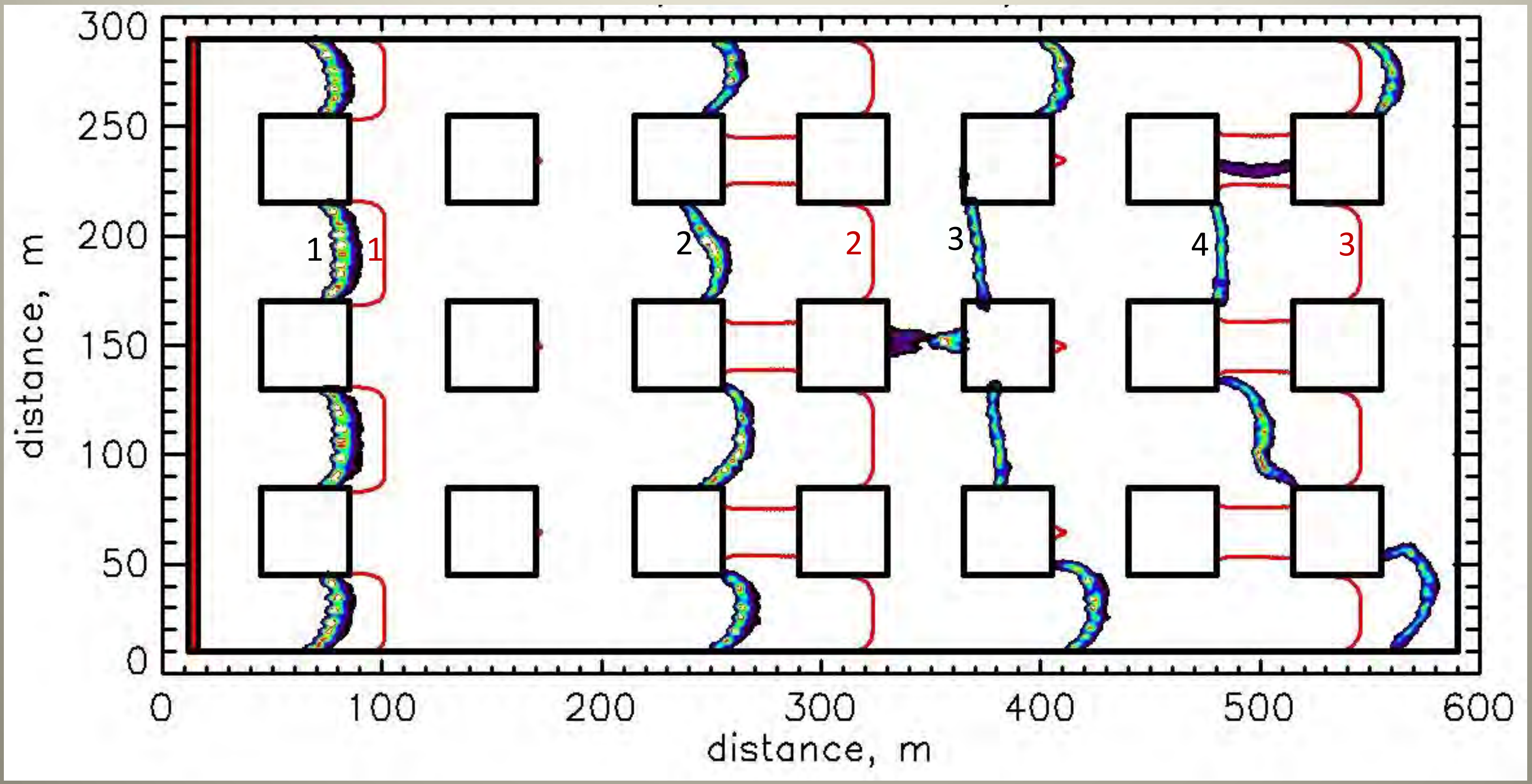




Time of firelines: 27 s, 53 s, 85 s, 100 s after ignition was completed.

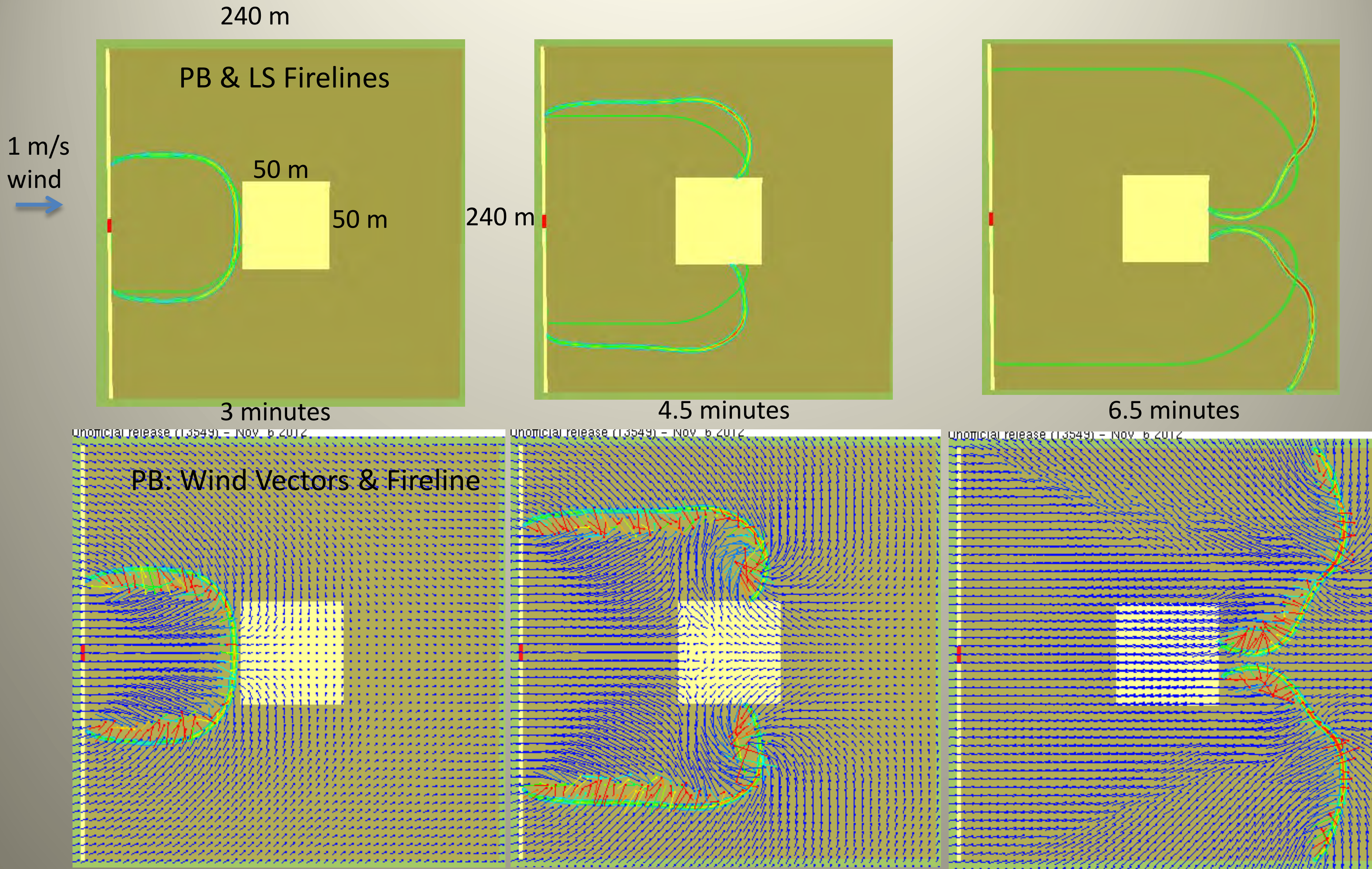
Limitation: Quasi-steady ROS Assumption

Wind=5 m/s, 21 40 m x 40 m fuel breaks; times = 73 s (ignition), 120 s, 240 s, 360 s, 480 s (only for WFDS-physics-based)



Limitation: Quasi-steady ROS Assumption

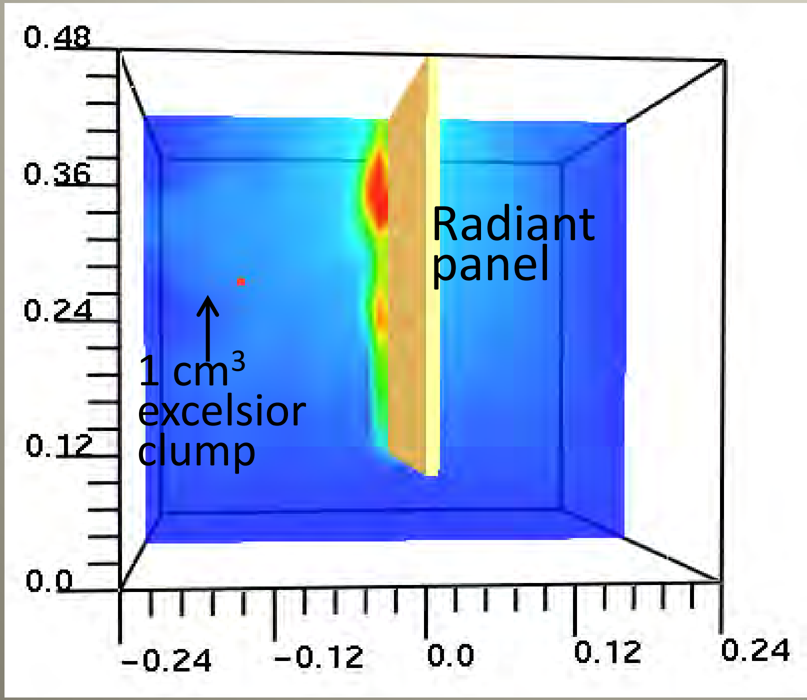
(8 m line ignition)

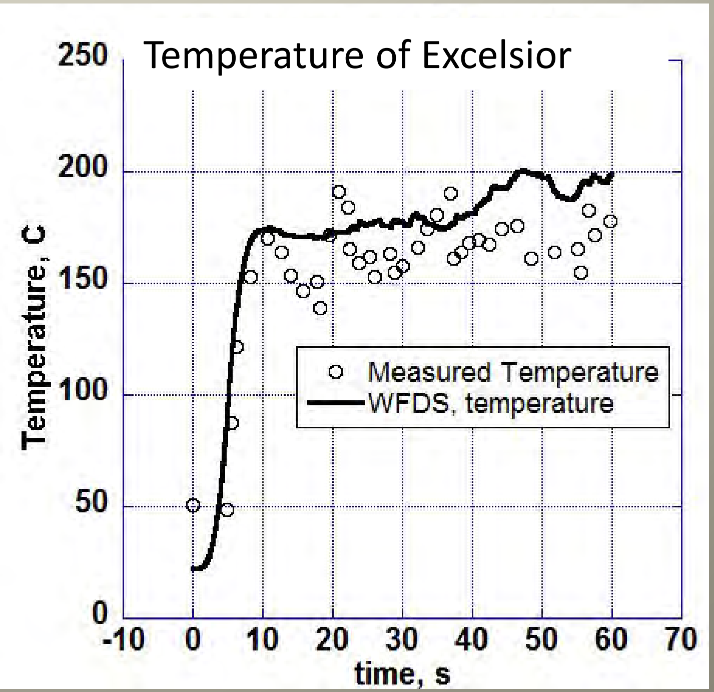


Example of Lab-Scale use of Physics-Based Models

Fuel particle heating during fire spread
(Cohen and Finney 2010)

Heating of a clump of excelsior subject to external radiant flux

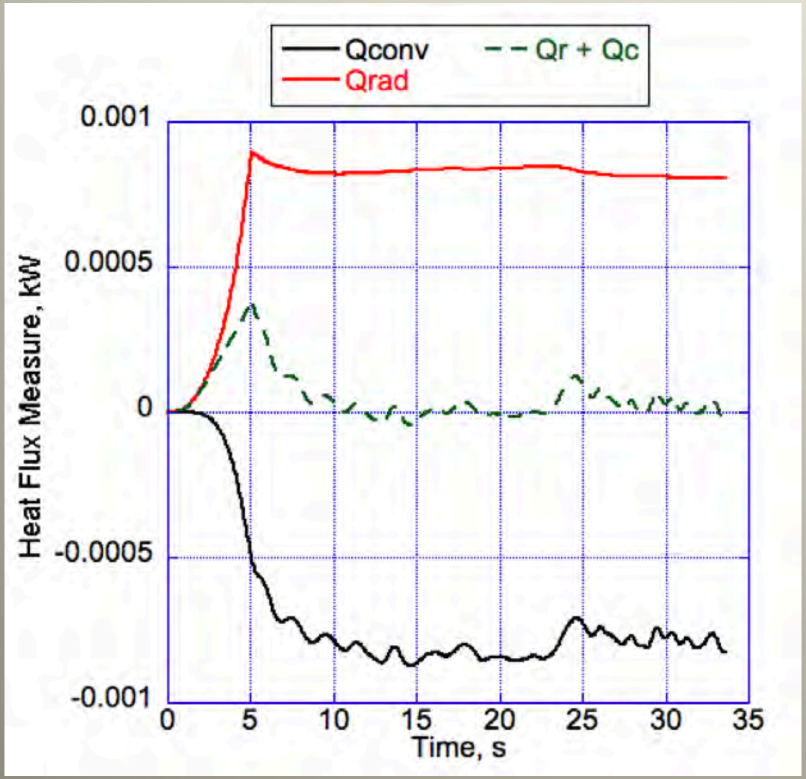




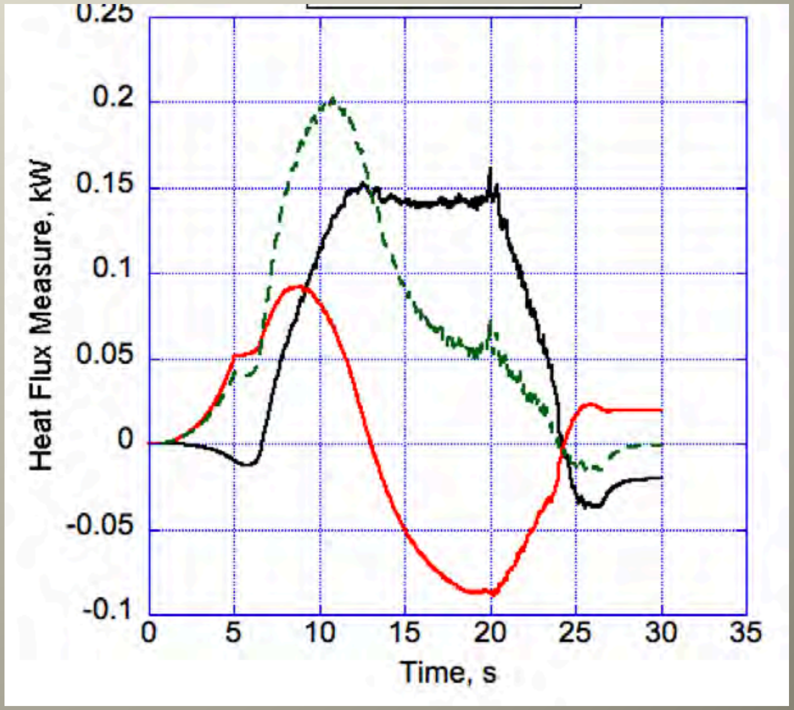
Measured data from Cohen & Finney, 2010.

Heat Fluxes Histories

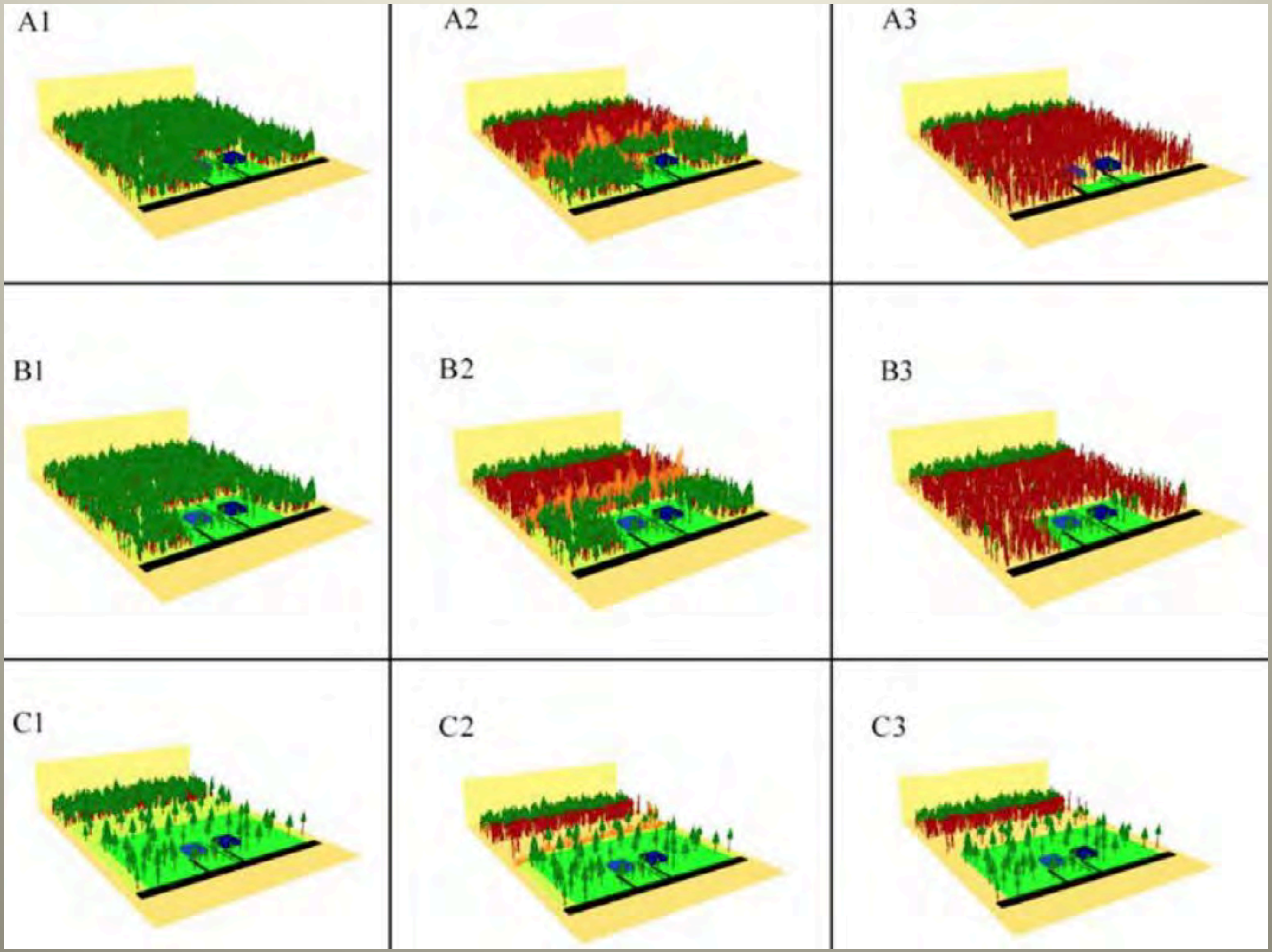
Small Clump of Thermally Thin Material



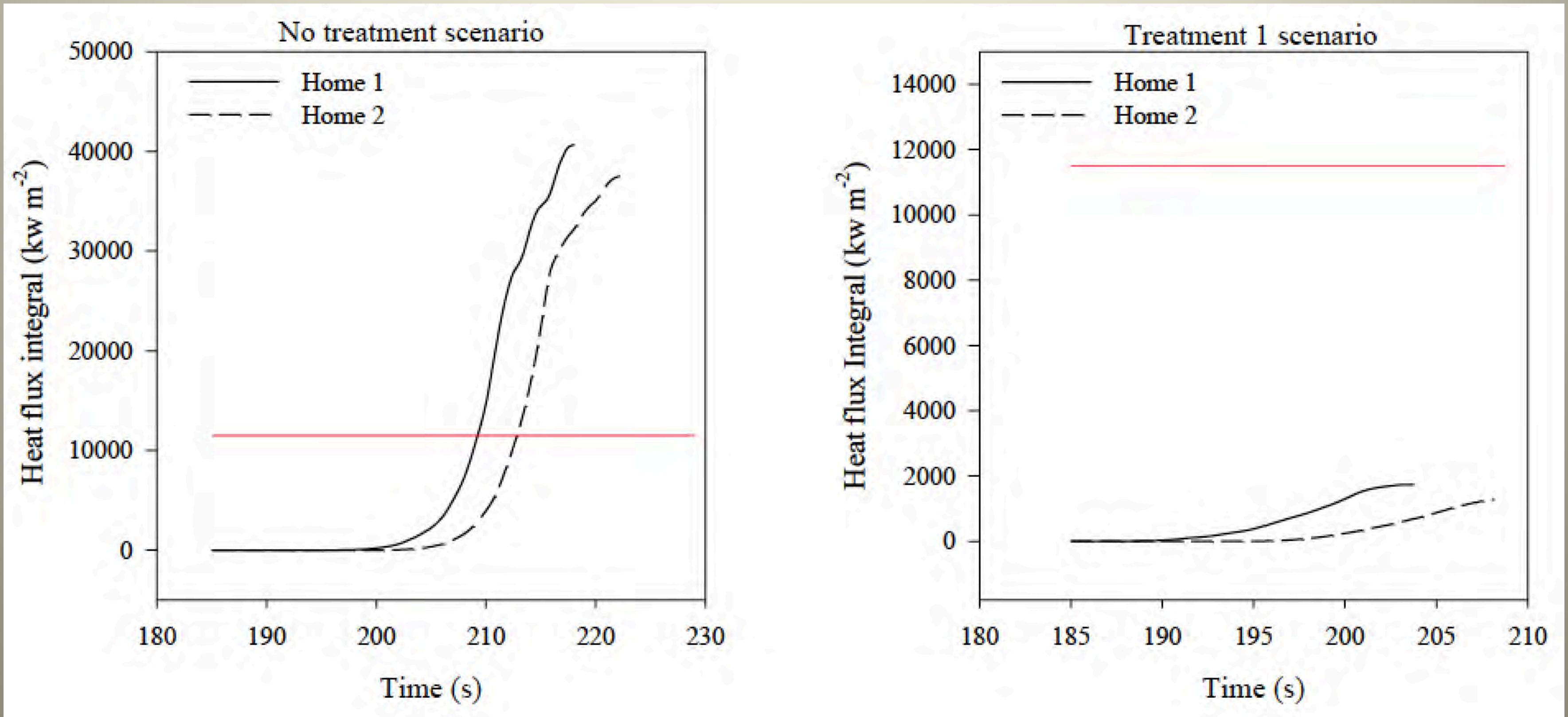
Large Clump of Thermally Thin Material



WUI Fuel Treatment Demonstration



Wood Ignition Criteria



What type of models are needed?

- The previous slides show examples of the use and range of physics-based modeling.
- Suite of models is needed, with physics-based supporting the improvement of simpler (faster) operational models and field guidance.

Important Considerations

- New measurements lead to model improvement, not only to a new, separate, model
  - Experimentalists and modelers work together
- Operate with known limitations over a range of scenarios and scales.

Some New Wildland Fire Models (U.S.)

Scale	Desirable Measurements	Models WFDS physics	FIRETEC	WRF-FIRE	FARSITE	WFDS level set
Bench (fuel elements)	▪ Heat flux ▪ HRR* ▪ Mass loss rate	✓ ✓ ✓				
Laboratory (individual tree; small surface fire)	▪ *same as above* ▪ Spread rate ▪ Fireline depth	✓ ✓ ✓				
Field (forest stand & WUI Community)	▪ Fire perimeter evolution ▪ Fireline depth	✓ ✓	✓ ✓	✓	✓	✓

- HRR = Heat Release Rate (kW) from oxygen consumption calorimetry
- D. Morvan, *Fire Technology* 2010 (FIRELES, U. of California, Riverside; U. of Alabama FIRESTAR, U. of Aix-Marseille)

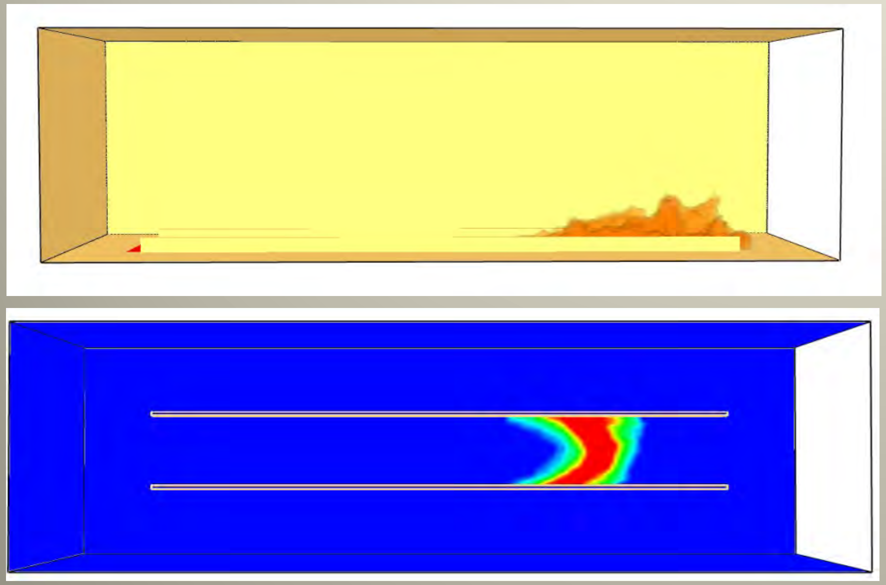
What's the status of physics based (fire-focused) models?

- Capability exists for general (slower than real time) application
- Useful as research tools
- They are largely unproven for application to operational problems
- Suitable field and lab measurements are needed.

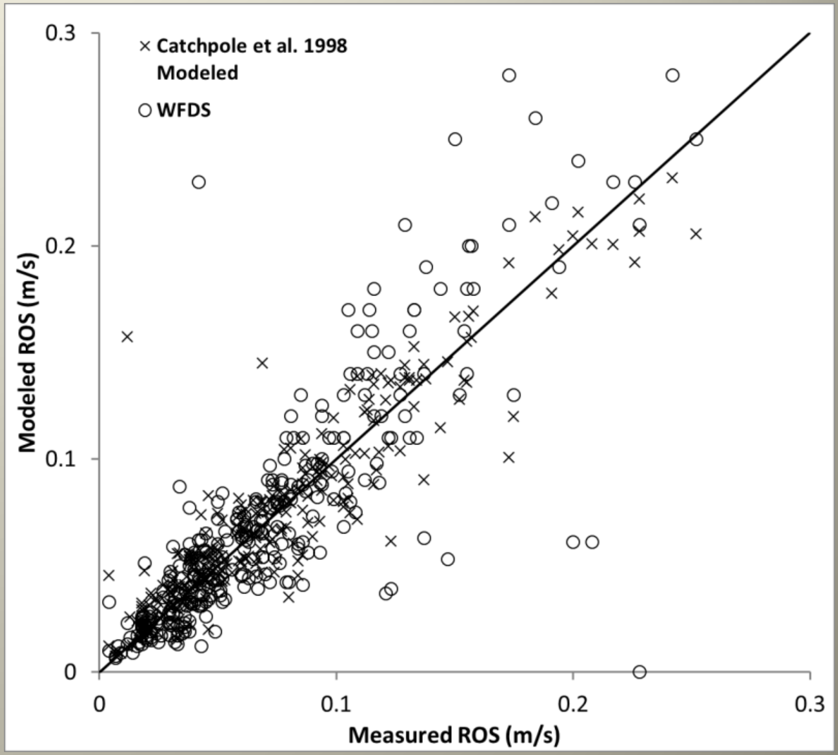
Lab experiments can be a stepping stone

Surface fire spread Catchpole et al. 1998 (290 comparisons)

Comparisons for PIPO needles, 2 types of excelsior range of MC, wind and fuel loading



WFDS ROS vs Measured ROS



Hoffman & Bova

- WFDS mean abs. error = 29%
  (90% of simulations within 50% of experiments)
- Catchpole et al. (1998) empirical model mean abs. error = 27%
- Rothermel (1972) mean abs. error = 53%

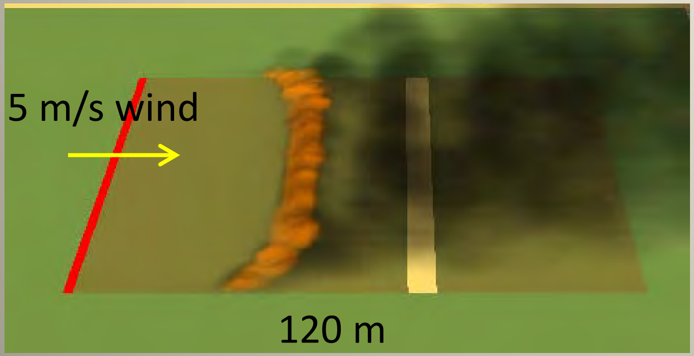
Desirable Laboratory-Scale Studies

- Momentum drag in vegetation
- Radiant absorption
- Thermal degradation of vegetation
  - Live vs. dead
  - Different heat flux environments
  - Ignition
- Heat release rates of different vegetation
- Suitable for testing lab-to-field extrapolation
  - Fireline acceleration

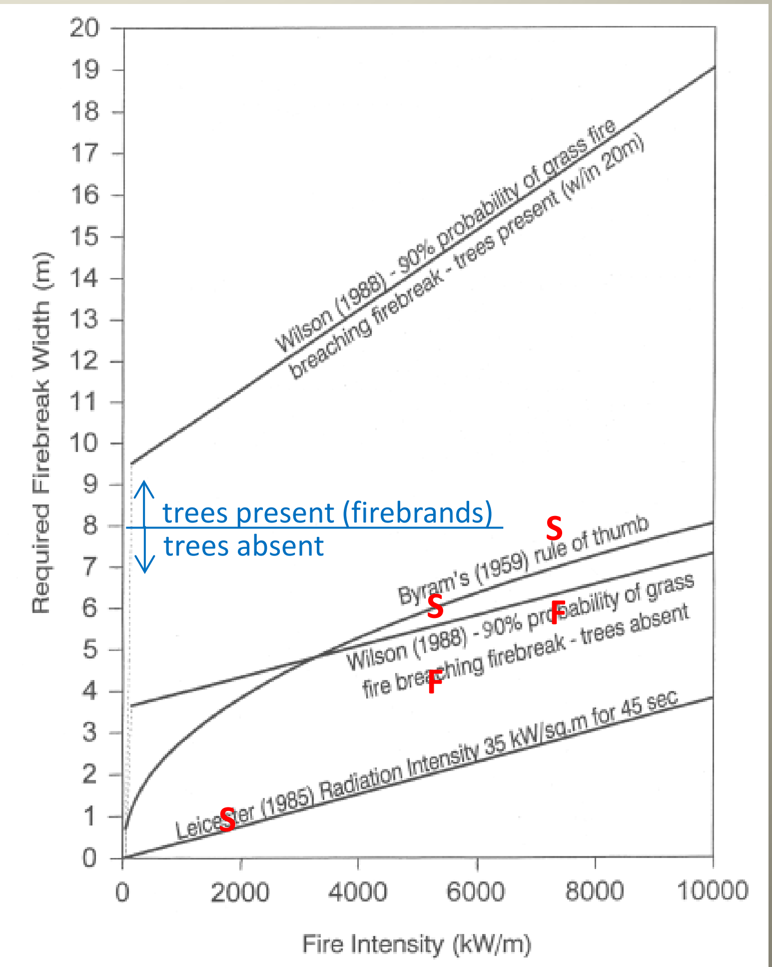
A Field Measurement Need

- Firebreaks & firebrands

Firebreak size vs. Fireline Intensity



WFDS results:
F = firebreak Failed
S = firebreak Successful

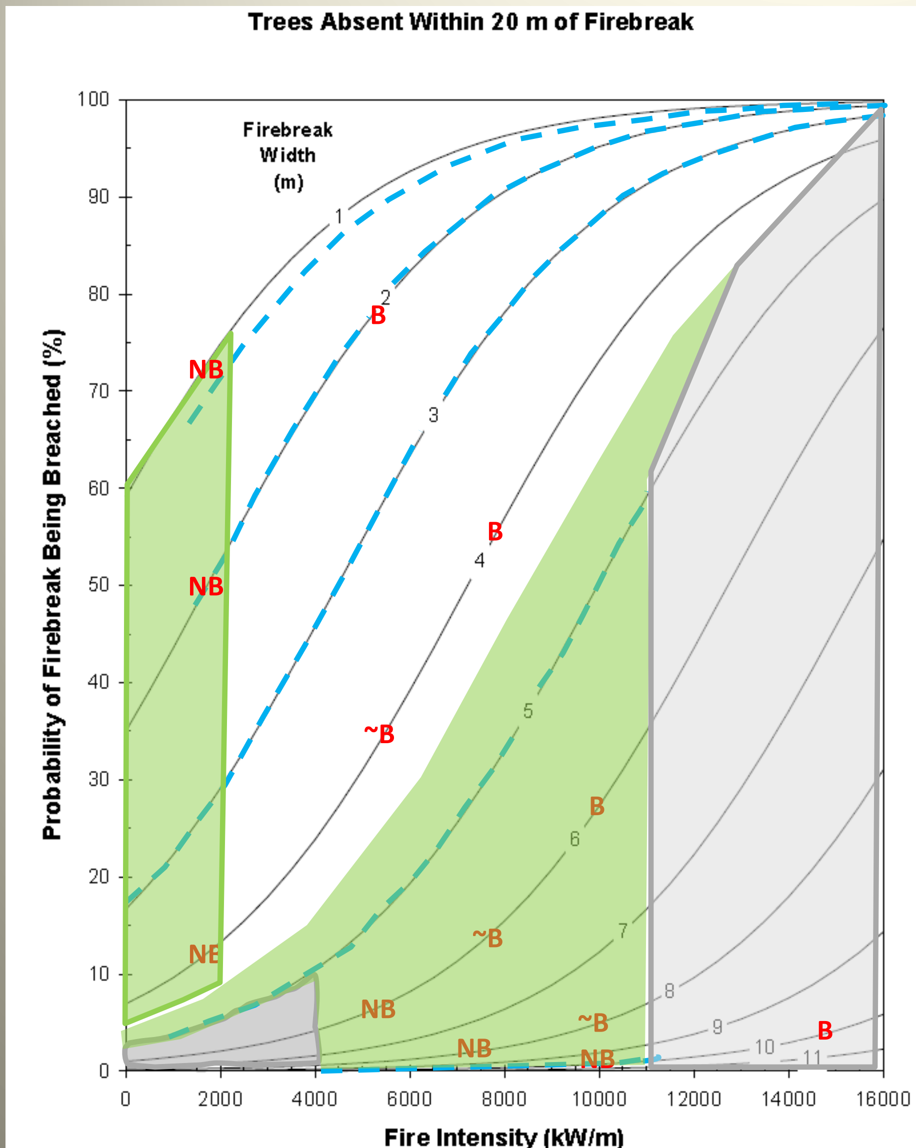


Alexander et al., 2004

Thank you

Field Measurement Needs

- Field
  - Fire:
    - Time evolution and dimension of entire fireline and locally at specific sites
    - Heat fluxes
  - Plume
    - Smoke concentration
    - Plume rise and height
  - Fuels:
    - Size class distribution of mass (foliage, roundwood)
    - Spatial distribution
  - Wind:
    - Near ground around burn plot
    - Farfield around burn plot
    - Terrain & forest influence
  - Firebrand production and deposition
  - Firebreaks



WFDS 9977 bndry fuel results:

B = (full breach) fire breached all along fuel break

~B = (partial breach) fire breached at portions or spots across fuel break

NB = No breach of fuel break

No field data

No breach in field

Firebreak size and I In field exp

Figure and field data from:
ME Alexander (2008) "Proposed revision of fire danger class criteria for forest and rural areas in New Zealand. 2nd Edition. National Rural Fire Authority, Wellington, in association with the Scion Rural Fire Research Group, Christchurch. 62 p.