LA-UR-22-32684

Approved for public release; distribution is unlimited.

Title:	Coupled Fire-Atmosphere (CFA) tools: opening doors from fire research to prescribed fire applications
Author(s):	Linn, Rodman Ray
Intended for:	9th International Fire Ecology and Management Congress, 2021-11-01/2021-12-03 (Virtual presentation, New Mexico, United States)
Issued:	2022-12-07

Slide 1

Los Alamos NATIONAL LABORATORY EST. 1943

Coupled Fire-Atmosphere (CFA) tools: opening doors from fire research to prescribed fire applications

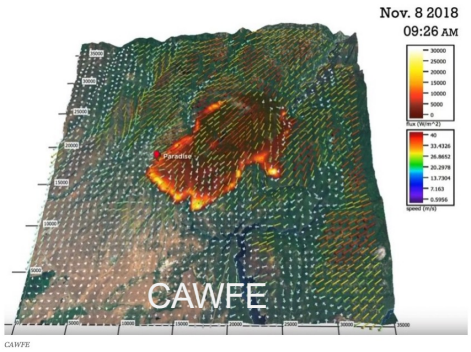
Presenter: Rod Linn

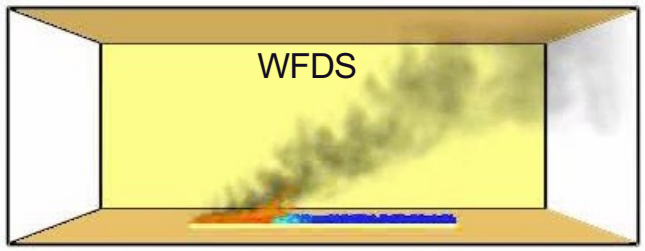
Contributions by a variety of colleagues at LANL, USFS and collaborators at other institutions

Computing resources provided by:
LANL Institutional Computing Program

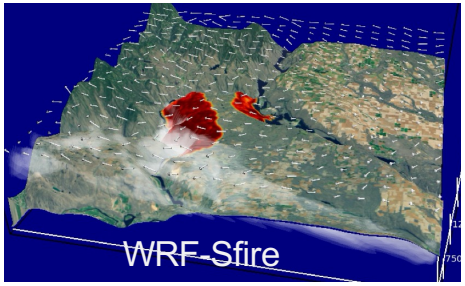
Coupled Fire Atmosphere (CFA) Tools

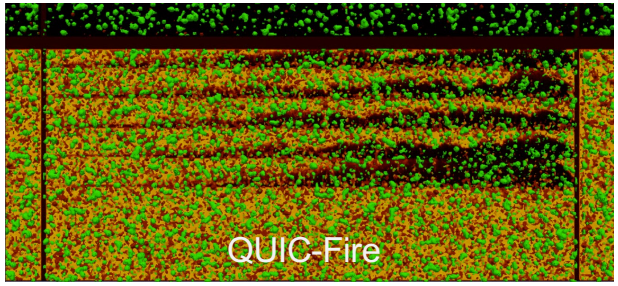
- Explicit representation of atmospheric motions surrounding a fire and feedbacks
- Developed at a variety of scale
  - Weather model scales
  -
  -
  - Submeter scales

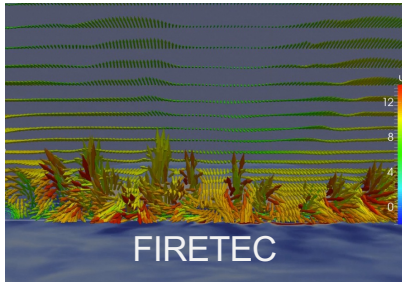




- For a variety of applications
  - Wildfire prediction
  -
  - Prescribed fire planning
  -
  - Science investigations



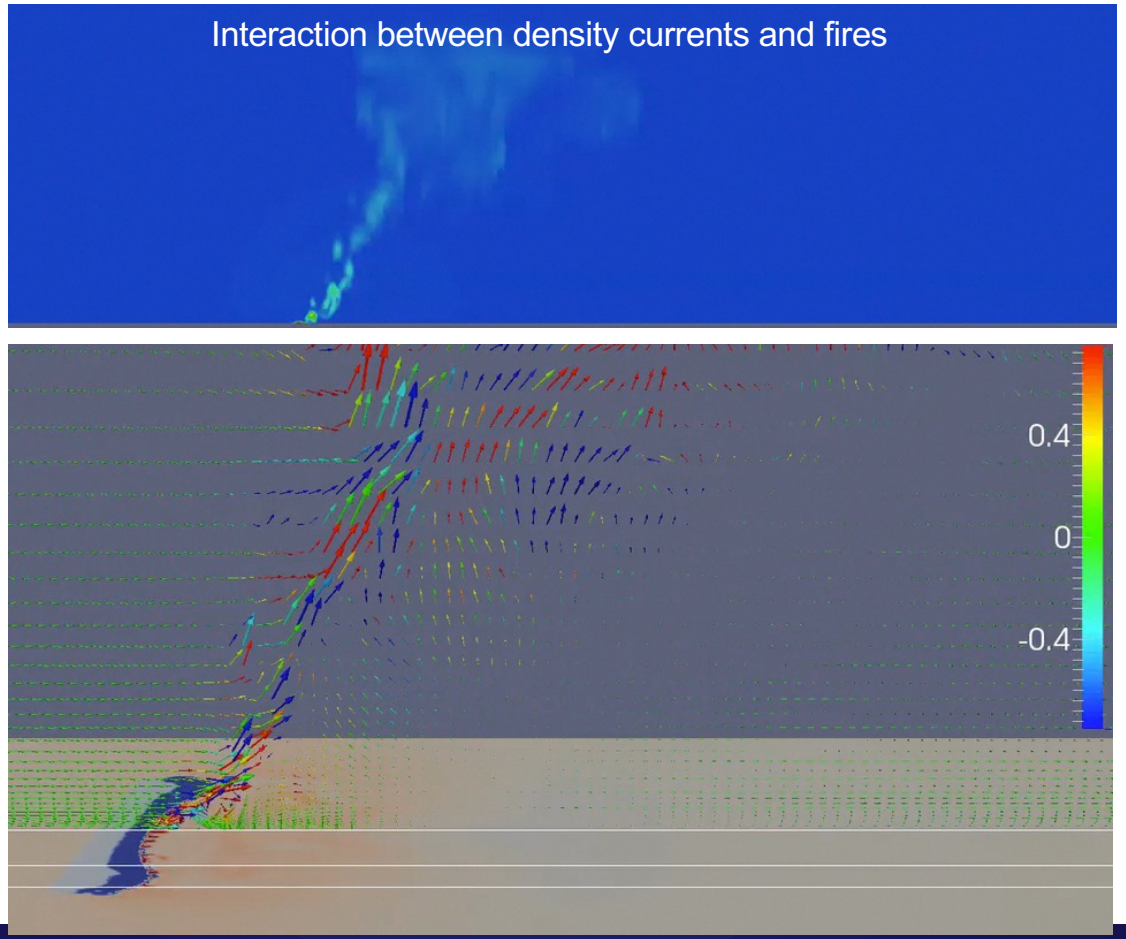




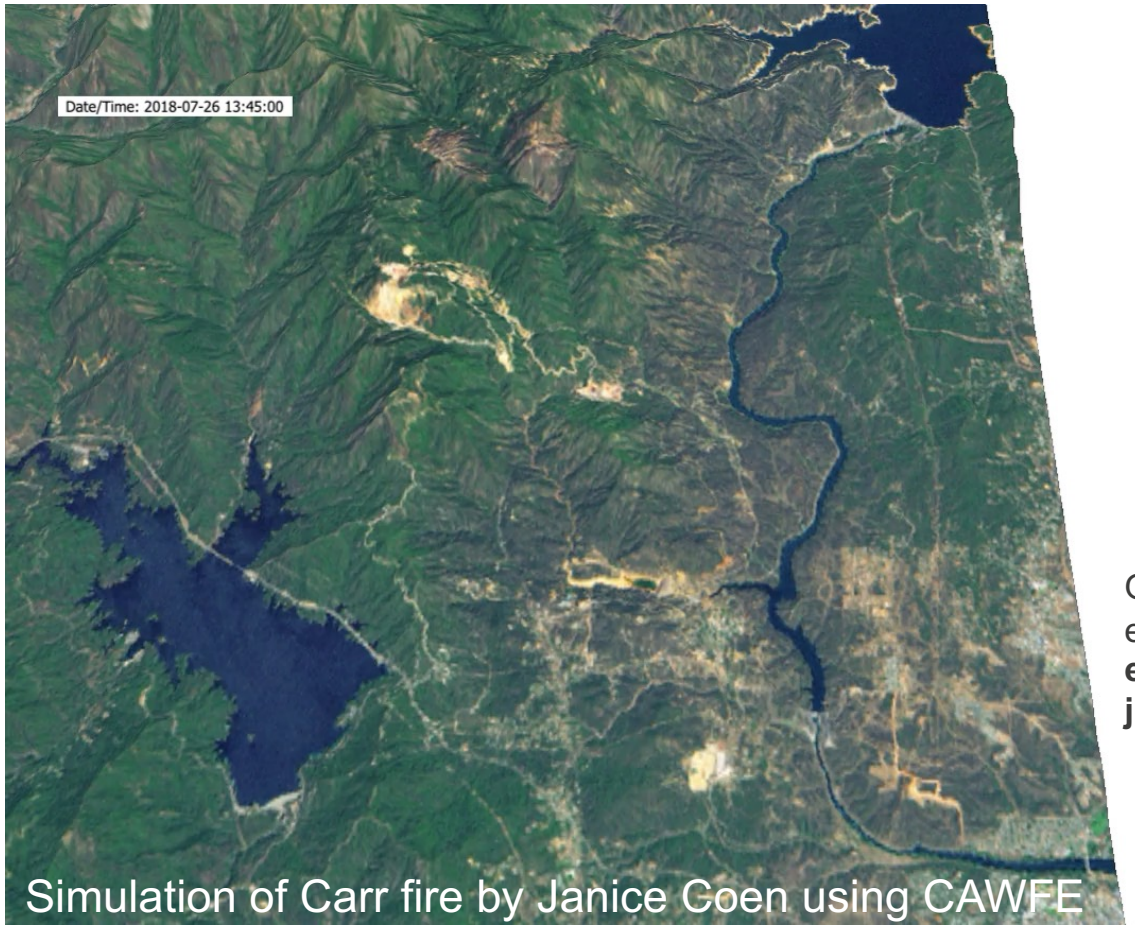
- As with all modeling:
  - It is important to appropriately match models to applications
  - Important to understand the limitations of models

Opportunities for CFA tools:

Exploring fundamental wildland fire behavior



Opportunities for CFA tools:
Event reconstruction



Simulation of Carr fire by Janice Coen using CAWFE

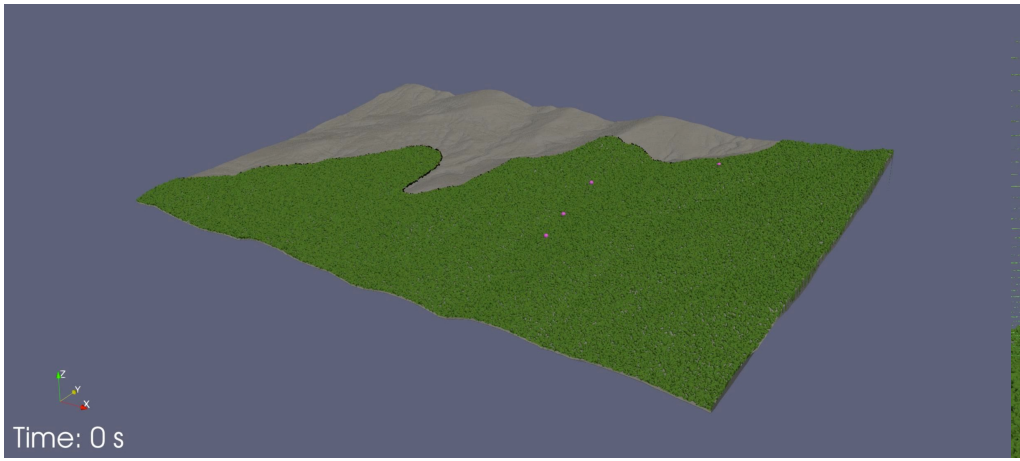
One of the things that Janice has highlighted with her event reconstruction work using CAWFE is that: **evaluation of the coupled models is more than just the net ROS or expansion in perimeter area**

Coen, J., M. Cruz, D. Rosales-Giron, and K. Speer (2022) Coupled Fire-Atmosphere Model Evaluation and Challenges. In: K. Speer & S. Goodrick (Eds.) Wildland Fire Dynamics: Fire Effects and Behavior from a Fluid Dynamics Perspective, in press. Cambridge: Cambridge University Press

LA-UR-XX-XXXXX

Opportunities for CFA tools:
Training and lessons learned

Los Alamos NATIONAL LABORATORY EST. 1943

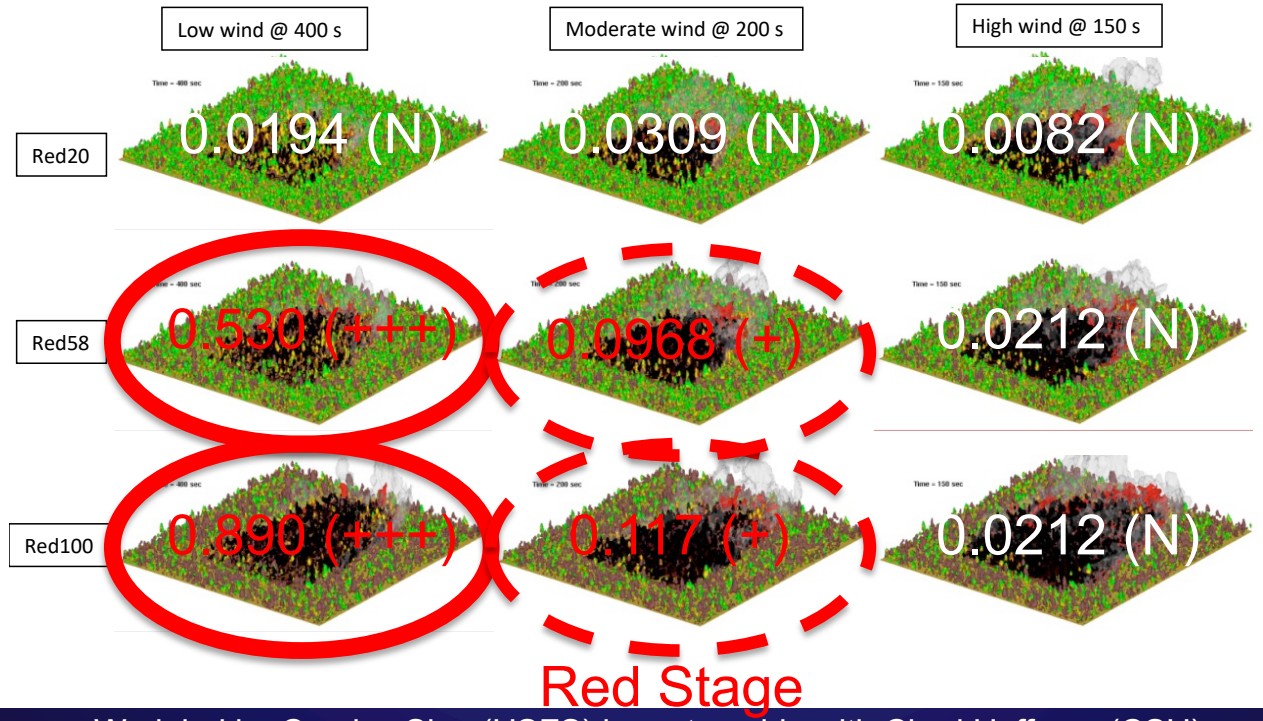


Exploration of density current interaction with fire during the tragic Dude fire

Opportunities for CFA tools:
Understanding the interactions between multiple disturbances

Synergism between bark-beetle mortality and fire in ponderosa pine forest

Syn>0.05 = synergistic interaction (+) (Beetle mortality amplifies fire effects on remaining forest)
-0.05<Syn<.05 = neutral interaction (N) (Two disturbances are ~independent)
Syn< -0.05 = antagonistic interaction (-) (Beetle mortality dampens fire effects on remaining forest)

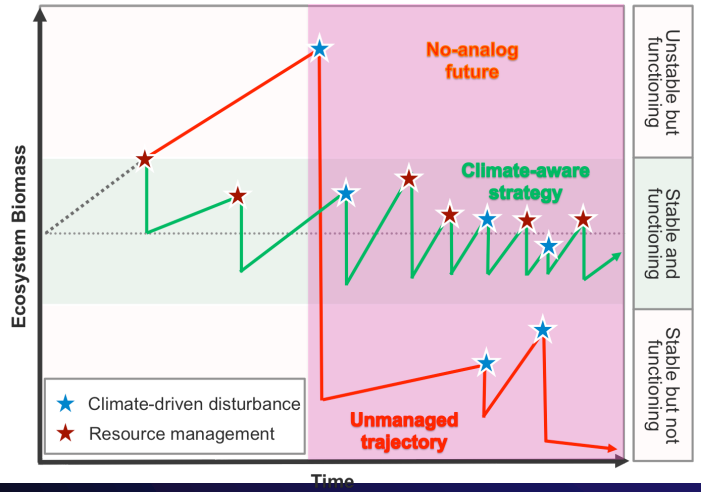


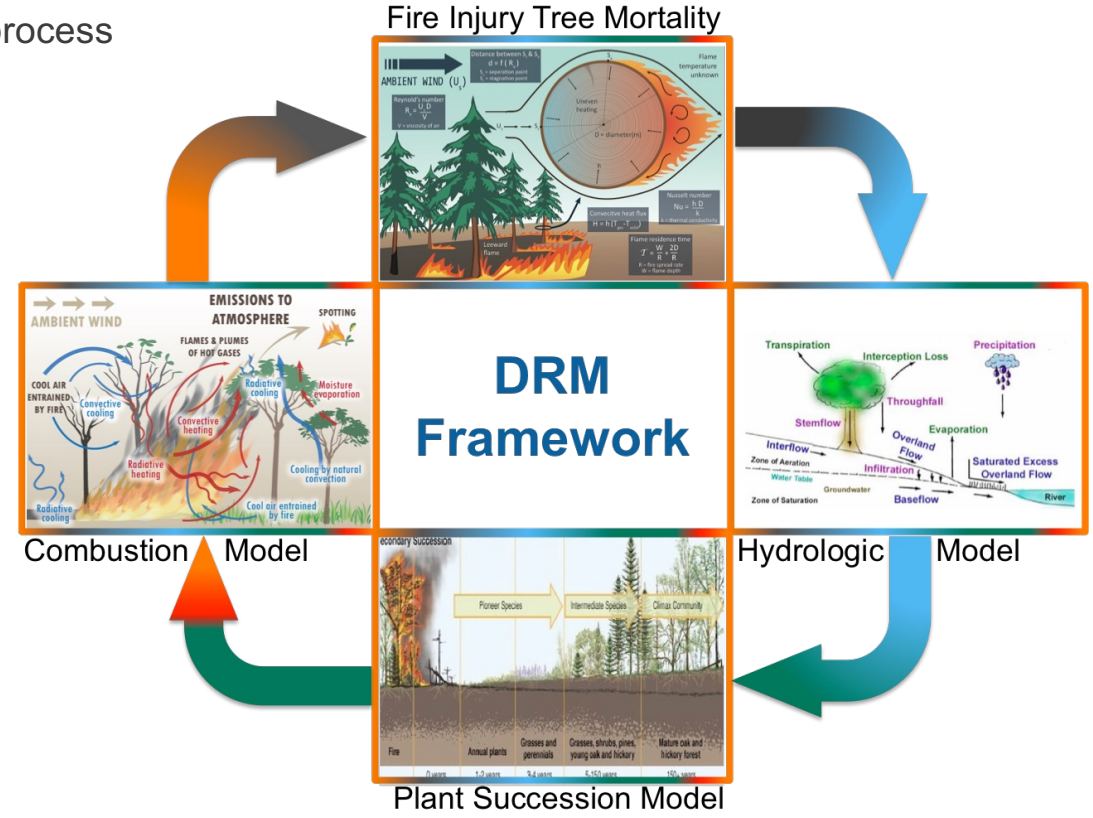
Work led by Carolyn Sieg (USFS) in partnership with Chad Hoffman (CSU)

Opportunities for CFA tools:

Exploring strategies and trade-offs for proactive fire management

- Effectiveness of fuels treatments
- Coupling between fire and ecologic/hydrologic process
  - Fire effects
  - Impacts of fire frequency on ecosystem stability
  - Watershed security
- Smoke trade-offs
- Landscape-level planning





DRM work being led by Adam Atchley

Not all fires are the same

Spectrum of fires

Intense wildfires

- Often have strong drivers
  - Strong winds
  - Dense, continuous or extremely dry fuels
  - Topography
- Contributing factors are often landscape scales
- Resilient to fine-scale heterogeneity on fuels or short-term lulls in the wind

.

.

.

Marginal fires

- Lack strong drivers
- Depend on localized conditions for their sustainability
- Influenced by small scale (meters or smaller) gaps in fuels or momentary wind fluctuations
- Correlations between transient events and fuel heterogeneities matters

Qualities of prescribed fires

Prescribed fires are often performed in ways/locations/times when strong drivers do not exist or can be managed

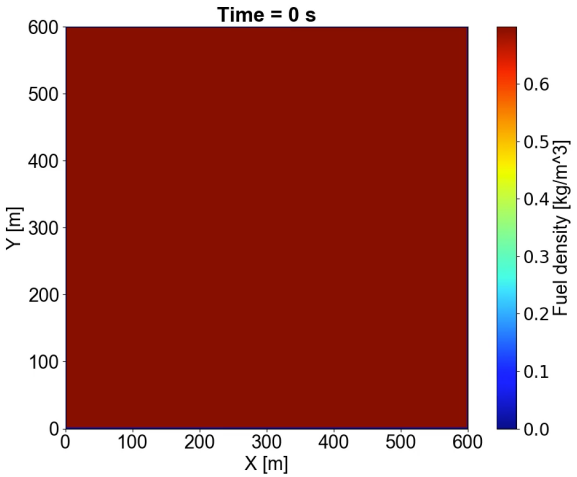
- Moderate and/or heterogeneous fuels
- Light and/or variable winds
- Tactical burn operations can be used to manage fuel or topography hazards
- Burn operations often create the drivers for fire behavior

Purposefully-designed dynamic ignition pattern influence fire behavior and smoke lift

- Tailored to fit weather, fuel and topographic conditions
- Change fire activity compared with natural fire progressions
- Adjustable in real time
- Designed to meet burn objectives
  - Wildfire risk reduction
  - Ecological benefits

Multi-scale fire and fuels context is crucial

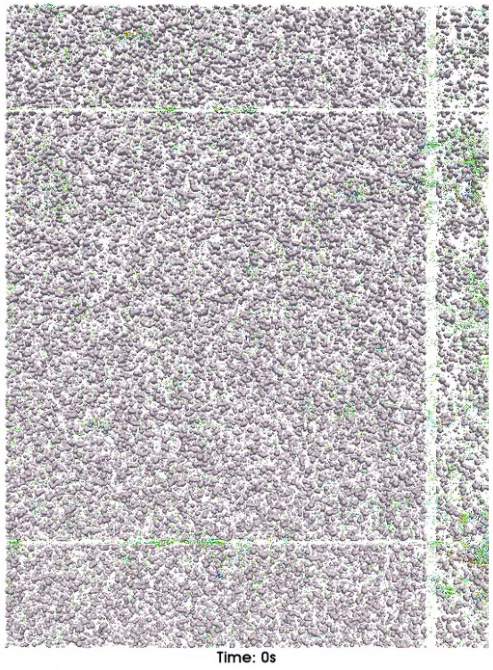
Importance of the interaction between multiple fires



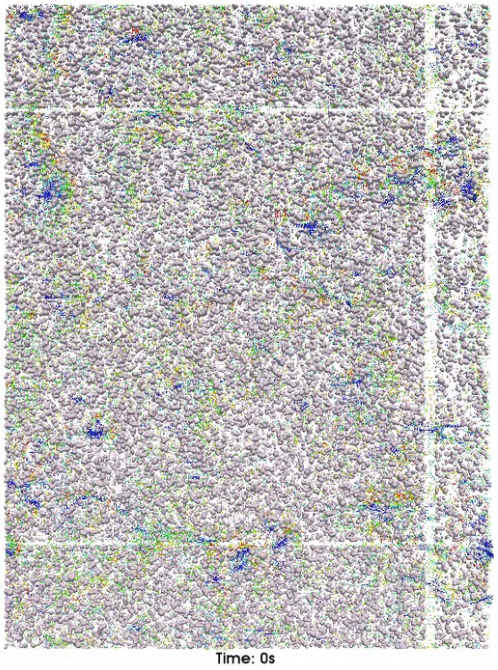
Example:
Difference in wind paradigms: prescribed fire vs. wildfires

low-intensity prescribed fire (aerial ignitions) (5.6 m/s ambient. Wind above canopy)

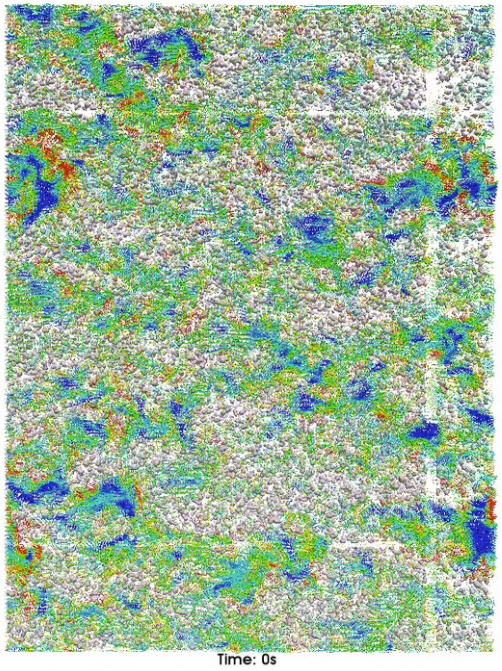
Wind-driven
wildfire scenarios



Winds at height=2.5 m



Winds at height=10 m



Winds at height=30 m

Colors indicate vertical winds, Blue=2 m/s downward, Green=Horizontal winds, Red=2 m/s upward
Black indicates burned surface fuel

Essential factors for simulating prescribed fire behavior

Prescribed fires are often performed in ways/locations/times when strong drivers do not exist or can be controlled

- Moderate and/or heterogeneous fuels
- Light and/or variable winds
- Tactical burn operations can be used to manage fuel or topography hazards
- Burn operations often create the drivers for fire behavior

Purposefully-designed dynamic ignition patterns influence burn patterns and smoke lift

- Tailored to fit weather, fuel and topographic conditions
- Adjustable in real time
- Designed to meet burn objectives
  - Wildfire risk reduction
  - Ecological benefits

Multi-scale fuel heterogeneities and transient wind and fuel conditions can be important factors

Importance of the interaction between multiple fires

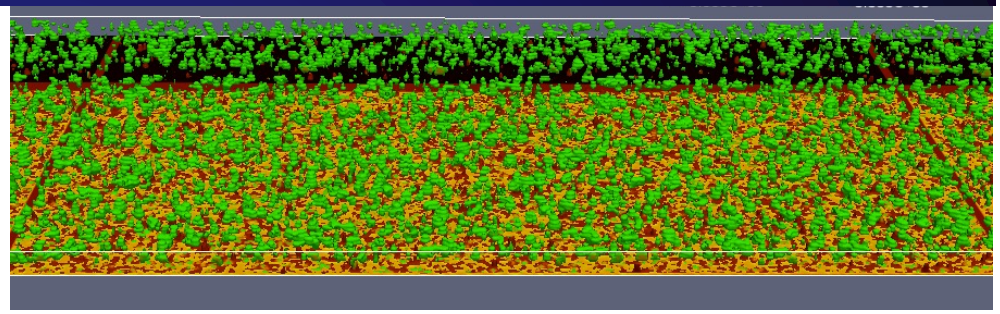
Use what we learn from research tools to Develop fast-running tools to assist planners and practitioners

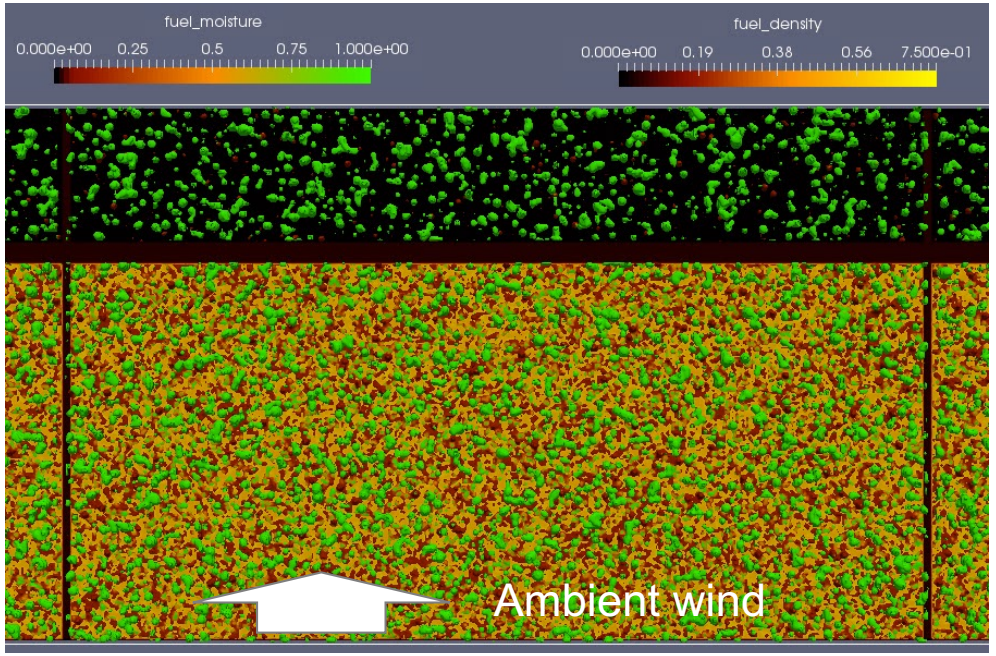
Critical to incorporate two-way coupled fire/atmosphere/fuels interaction

- Fast-running diagnostic wind model
  - Combines influences of ambient wind and fire influences
  - Influenced by vegetation structure and topography
- Reduced-order fire spread model
  - Fire spread and intensity
  - Heterogeneous fuels
  - Impact on local wind field

Example:

- Use of a fast-running CFA tool to simulate 5-ATV ignition in Eglin AFB fuels
- Things to notice
  - 3D fuels
    - green live canopy fuels
    - Brown and tan colors illustrating heterogenous moisture in dead shrubs and surface fuels (dormant season)
    - “Black” region downwind wind of burn block
  - Dynamic ATV ignition pattern based on practitioner design
  - Heterogeneous consumption of canopy

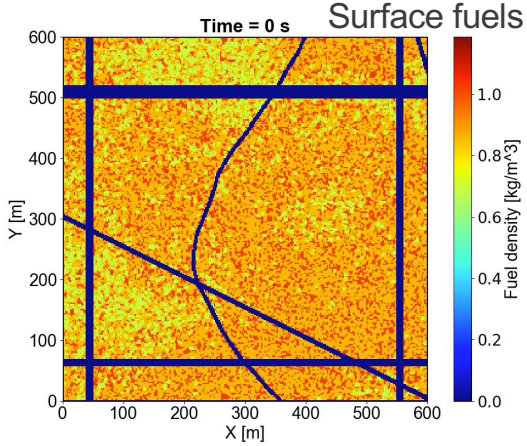




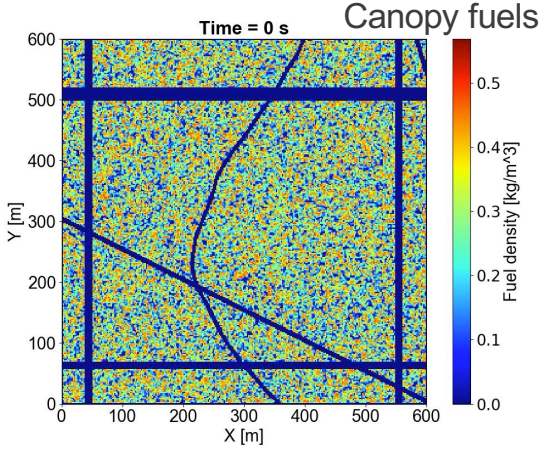
Exploring influences of ignition techniques in NJ forest

Aerial vs. ATV ignition

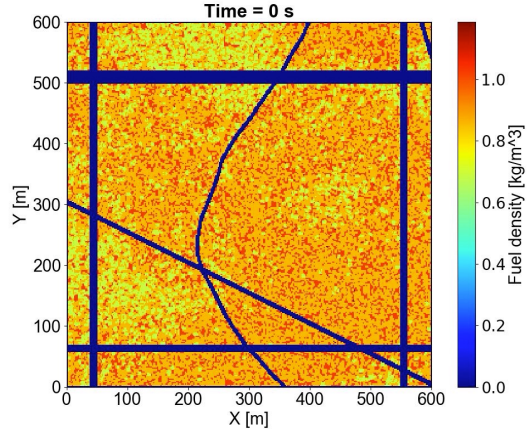
Surface fuels (0-1m)

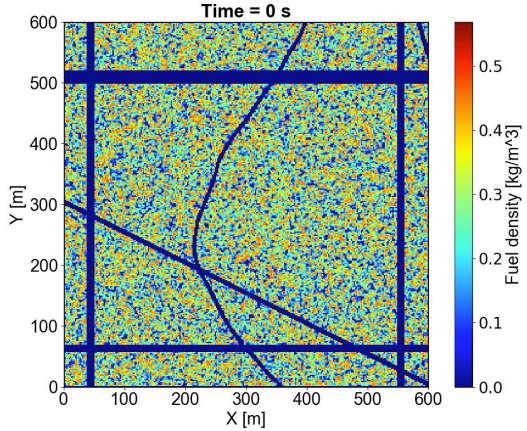


Canopy fuels (4m-5m)



- 5 ATVs
- ATV speeds = 2.68 m/s (6 mph)
- Space between lines = 100m
- Delay time = 9 s or 24 m
- Winds varying between 2 and 10 mph



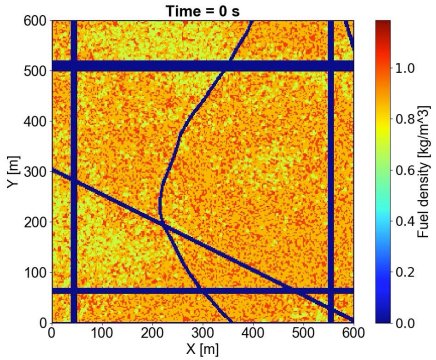


- 12 helicopter passes
- Travel speeds = 26 m/s (50 knots)
- Space between lines = 25 m
- Space between drops =25 m
- Winds varying between 2 and 10 mph

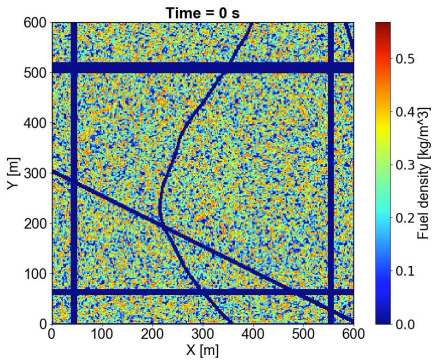
Simulations tied to investigations led by M. Gallagher and N. Skowronski (USFS-NRS)

Influences of changes in fuel conditions

Surface fuels (z=0-1m)



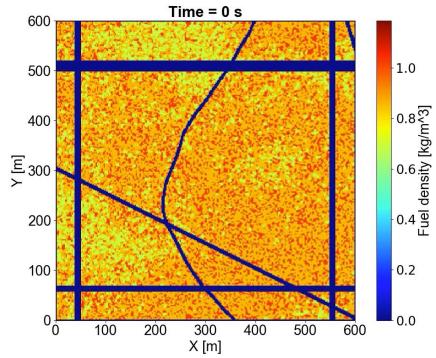
Canopy fuels (z=4m-5m)

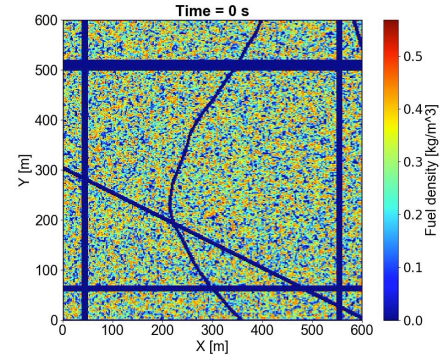


User-specified conditions

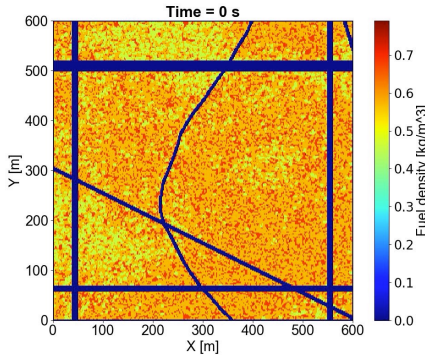
Aerial ignition

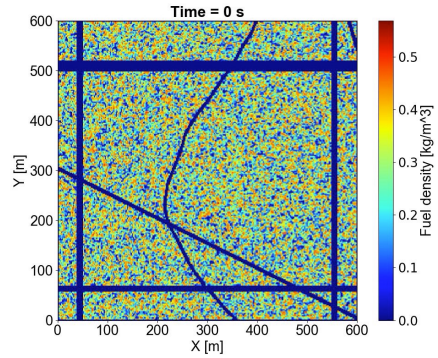
- 12 helicopter passes
- Travel speeds = 26 m/s (50 knots)
- Space between lines = 25 m
- Space between drops =25 m
- Winds varying between 2 and 10 mph





Decreased surface fuel load

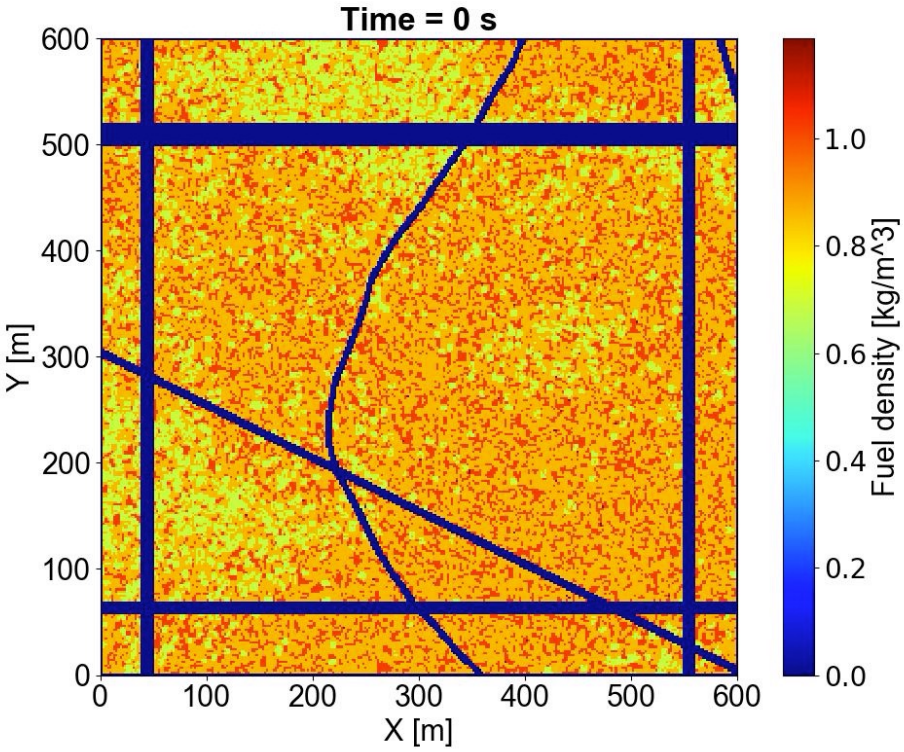


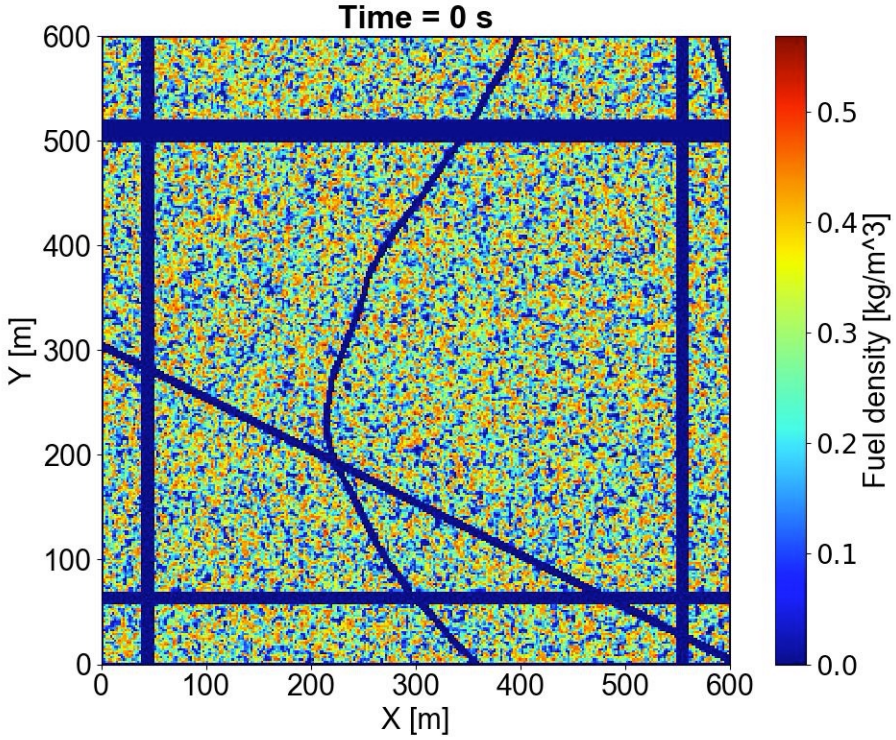


Increased surface moisture content

Simulations tied to investigations led by M. Gallagher and N. Skowronski (USFS-NRS)

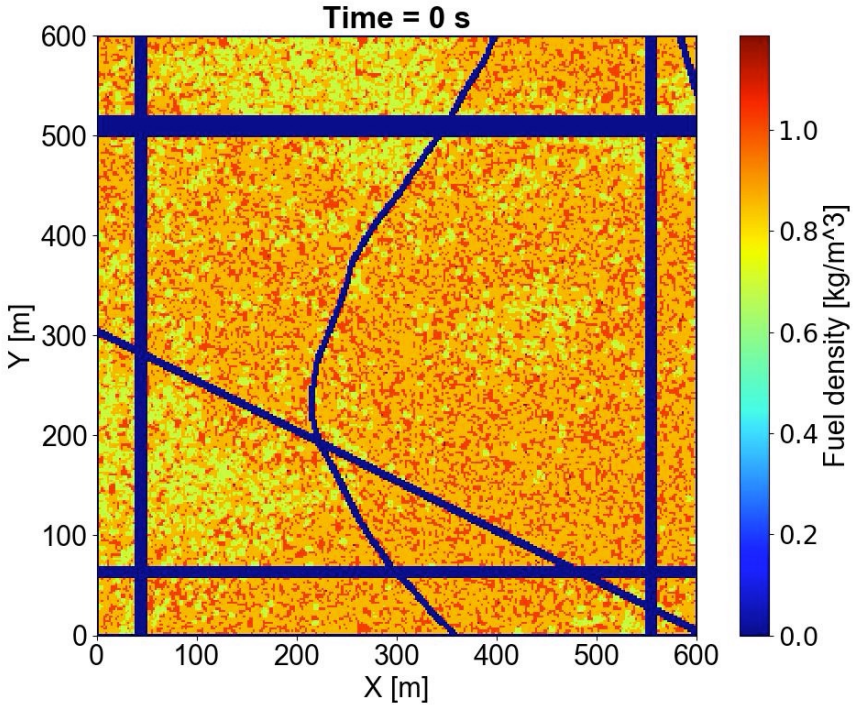
Use of ignition patterns to drive canopy consumption in a NF Forest

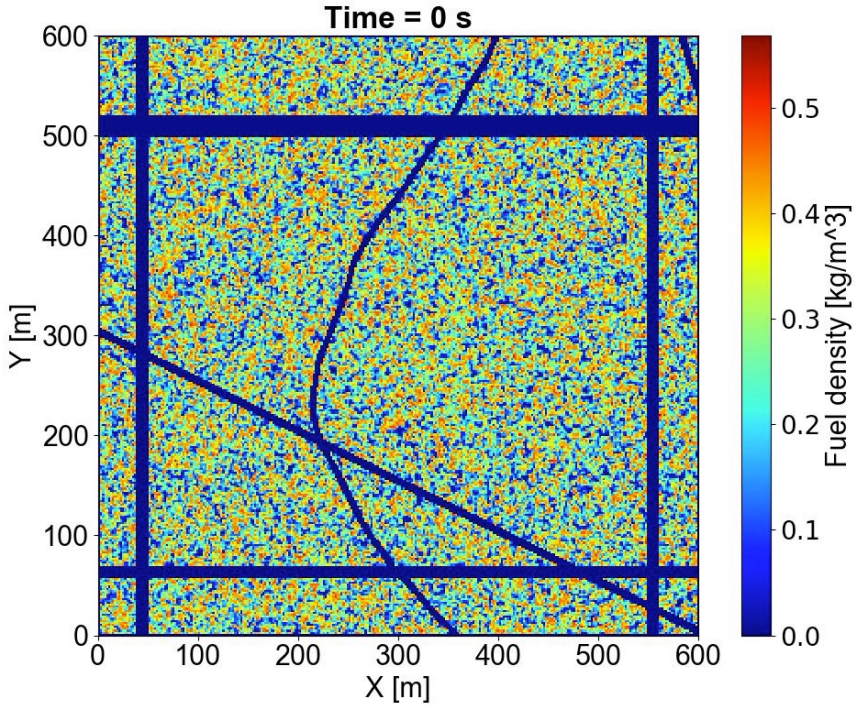




Simulations tied to investigations led by M. Gallagher and N. Skowronski (USFS-NRS)

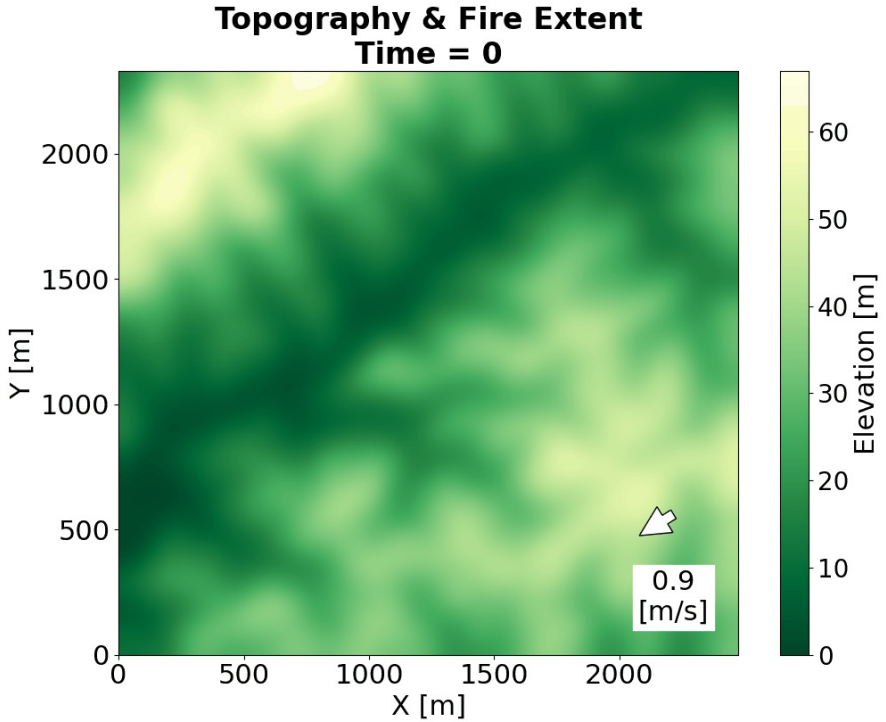
Exploration of mitigation efforts ”catchers mitt”

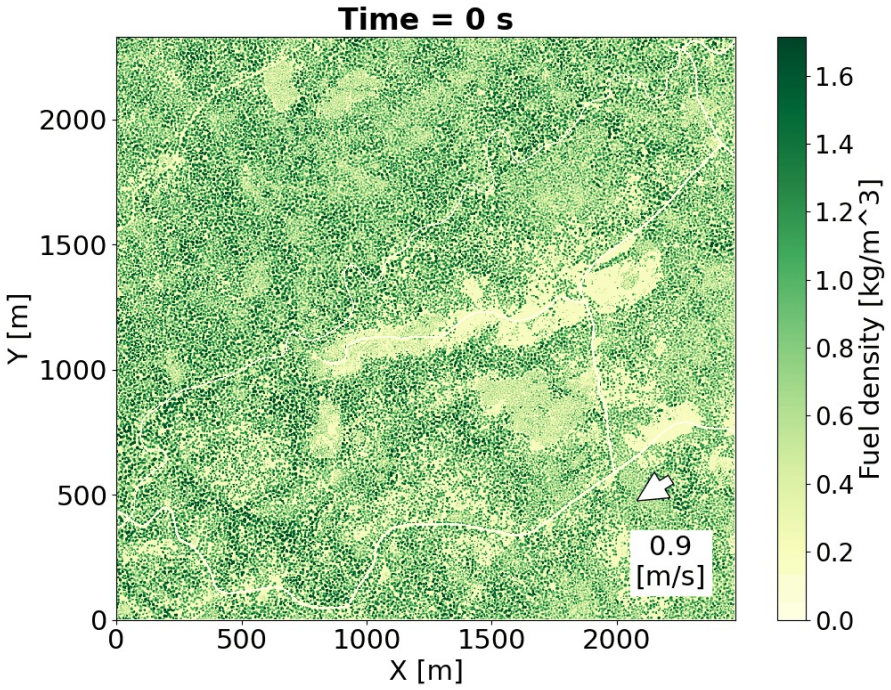




Simulations tied to investigations led by M. Gallagher and N. Skowronski (USFS-NRS)

Influences of realistic dynamic and heterogeneous ignition patterns





Simulation performed by Daniel Rosales and Zach Cope (TT) based on ignition data provided by John Wallace (USFWS) from Hitchiti prescribed fire


Questions?