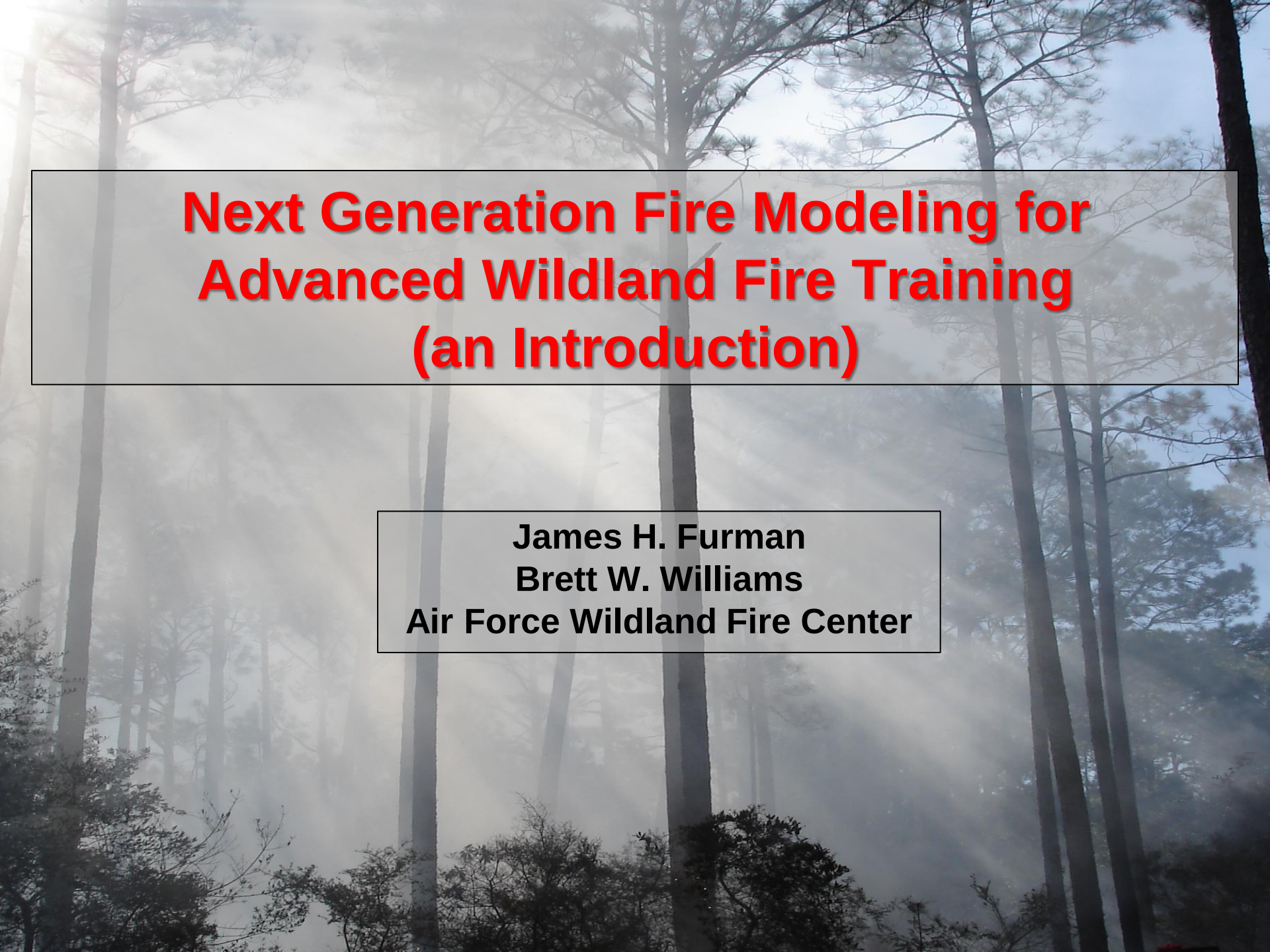


Next Generation Fire Modeling for Advanced Wildland Fire Training (an Introduction)

James H. Furman
Brett W. Williams
Air Force Wildland Fire Center

Question:

- Have you ever been involved in aerial ignitions as Burn Boss or Firing Boss?

Question:

- Have you ever witnessed 360 degree in-drafts on a prescribed burn?

Question:

- How many have witnessed the “doughnut hole of death” in the center of a burn unit from this phenomenon?

Scenario

You are Burn Boss. It is 1400 & you are ½ way through firing a 1,700 acre aerial ignition unit, flying perpendicular to the wind igniting ~4 fires/ac. It is early February, 72 degrees, 45% RH with 20' winds at 8 mph. Forecast DI is 40 and 1 for the evening. Fire intensity is getting higher than desired, particularly in the center of the ignited area. There is no way to shut down the burn, no cutoff points.

To moderate intensity and finish the burn, should you:

A. Increase density of ignitions?
B. Decrease density of ignitions?
C. Don't know

NEXT GENERATION FIRE MODELING FOR ADVANCED WILDLAND FIRE TRAINING - AN INTRODUCTION

Project Focus

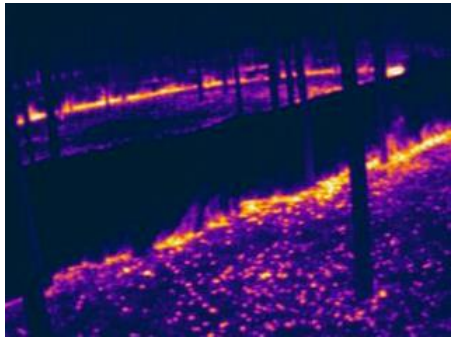
- *Demonstrate ability of FIRETEC, a physics-based, fluid dynamics wildland fire spread model, to simulate fire behavior from prescribed fires in southeastern fuels.*
- *Use FIRETEC to explore fire behavior sensitivities as related to variable vegetation structure, ignition type and pattern, and wind speeds.*
- *Simulate prescribed fire scenarios that answer real-world questions of prescribed fire practitioners*
- *Disseminate project results to prescribed fire practitioners in order to accelerate learning and increase successful prescribed fire outcomes*

Project Team

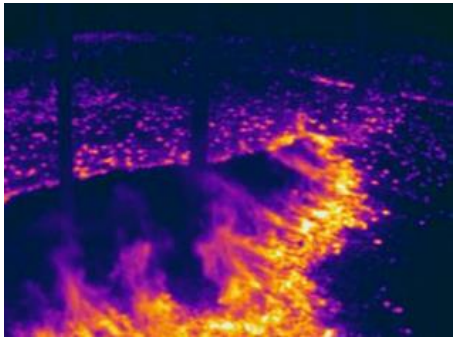
- *James Furman, U.S. Forest Service, Air Force Wildland Fire Center*
- *Brett Williams, Air Force Wildland Fire Center, Eglin AFB*
- *Dr. Rodman Linn, Los Alamos National Laboratory*
- *Dr. Judith Wintercamp, Los Alamos National Laboratory*
- *J. Kevin Hiers, Tall Timbers Research Station*

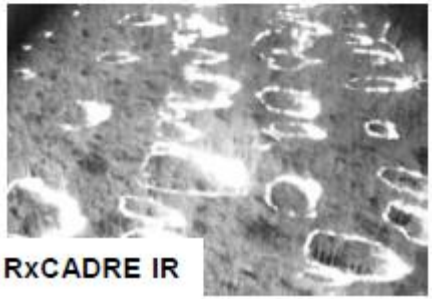
Problem Statement

- Large-scale prescribed-fire tactics utilize and rely on coupled interaction between fire and atmosphere.
- Commonly-used operational fire-behavior models (BehavePlus, FlamMap, FARSITE, FSPro)
  - ♦ do not account for the two-way fire-atmosphere feedbacks
  - ♦ Incapable of describing the interactions between multiple fires or fire's response to common prescribed fire tactics
- Poor understanding of fire/atmospheric interactions:
  - ♦ compromises success of burn operations
  - ♦ puts resources, personnel and mission at risk



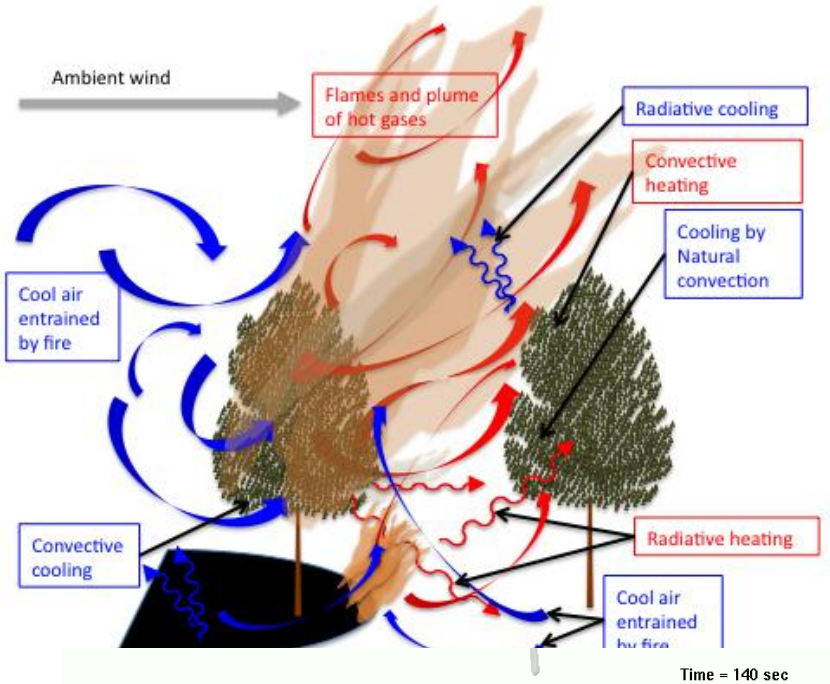
Rx-Fire Interactions

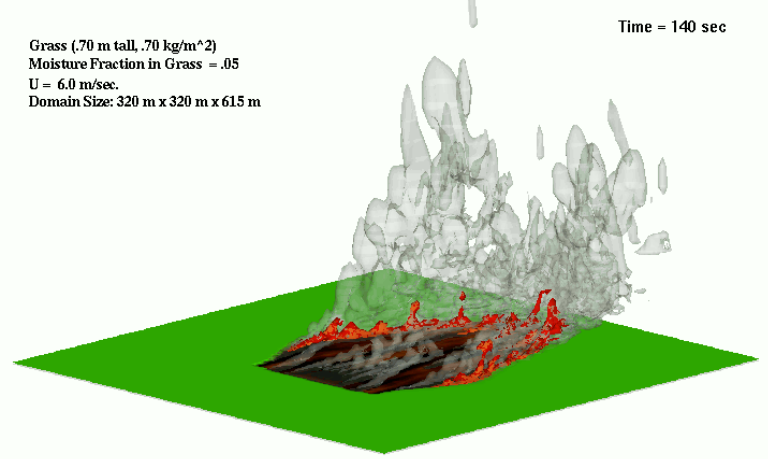




FIRETEC

- Physics-based coupled fire/atmosphere behavior model, which is fully coupled to HIGRAD
- Designed for 3-D landscape-scale fire simulations
- Captures the dynamic interaction between wildland fire and its environment by modeling critical physical processes in a CFD model , including
  - Multi-phase fluid/solid interaction
  - combustion
  - heat transfer (convective and radiative)
  - aerodynamic drag turbulence
- Solves a set of coupled partial differential equations for conservation of mass, momentum, energy, chemical species and turbulence
- Local conditions (i.e. solid and gas temperatures, wind speed and direction, turbulence, oxygen, etc.) are computed as functions of time at millions of locations in a 3D terrain-following mesh



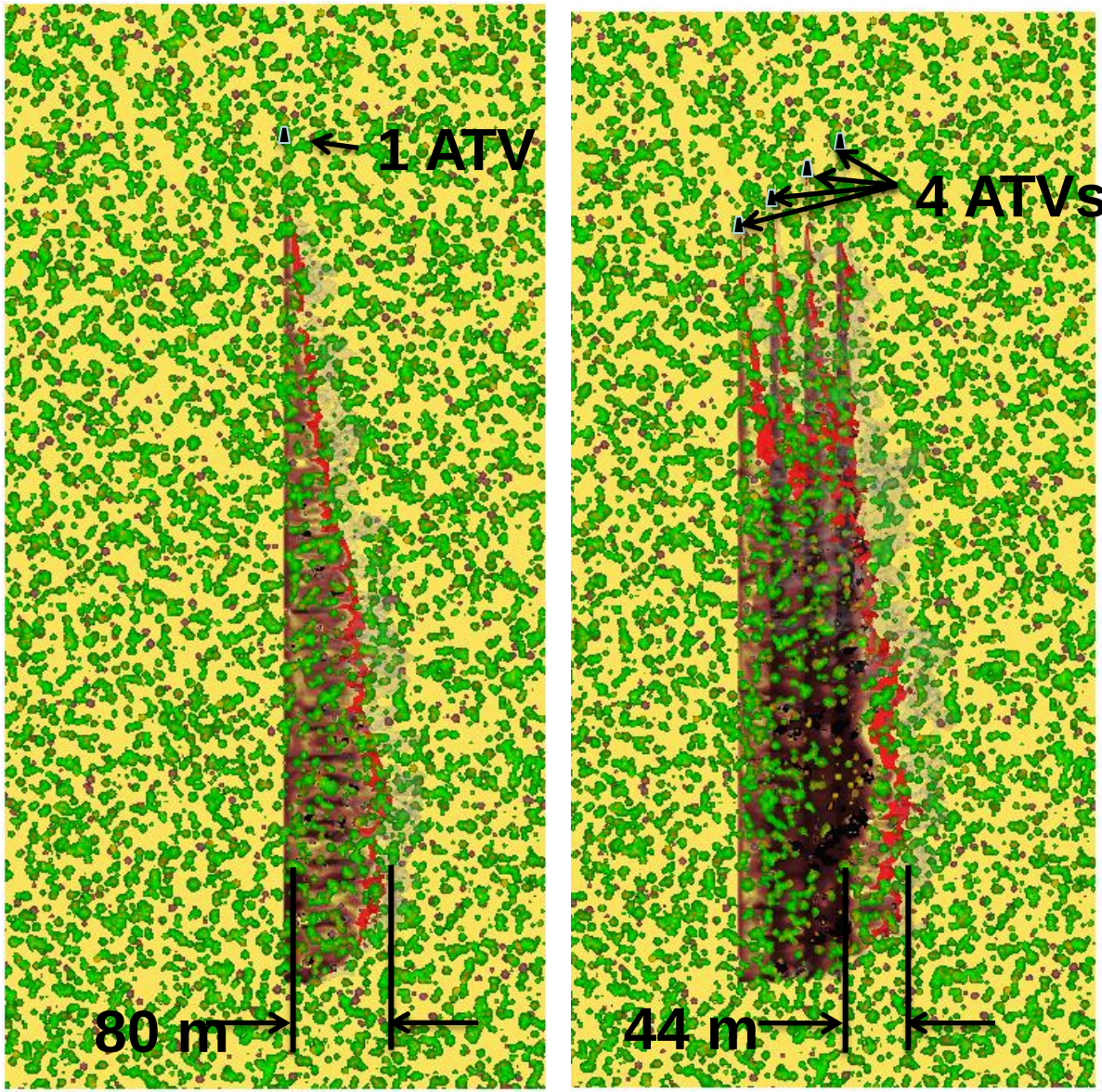


Early Proof of Concept

Proof of concept Rx-fire simulations derived from Eglin-sponsored seed project.

In these FIRETEC simulations, the ignition of three upwind strip ignitions decreased the downwind spread rate, but the interactions between the lines produced intense burning in some areas.

Single and multiple strip-fire ignitions



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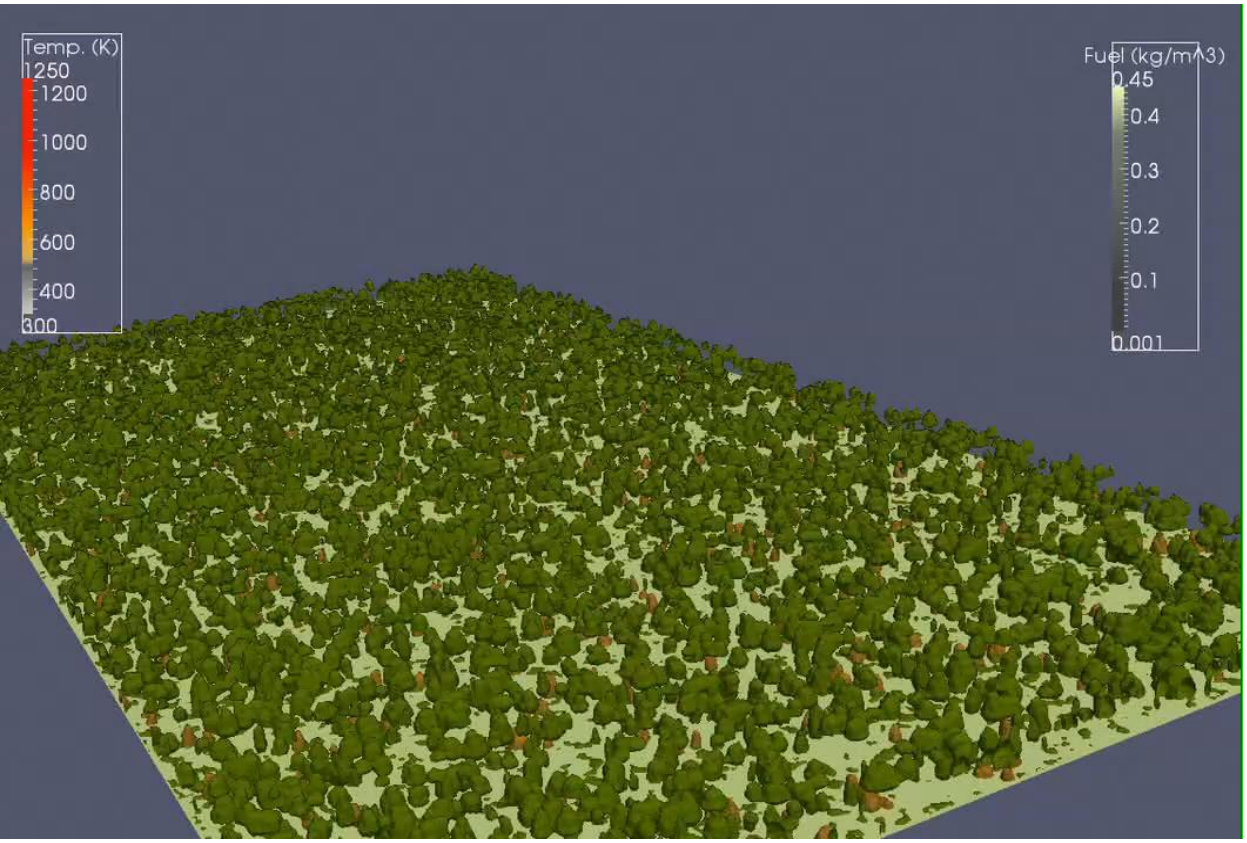
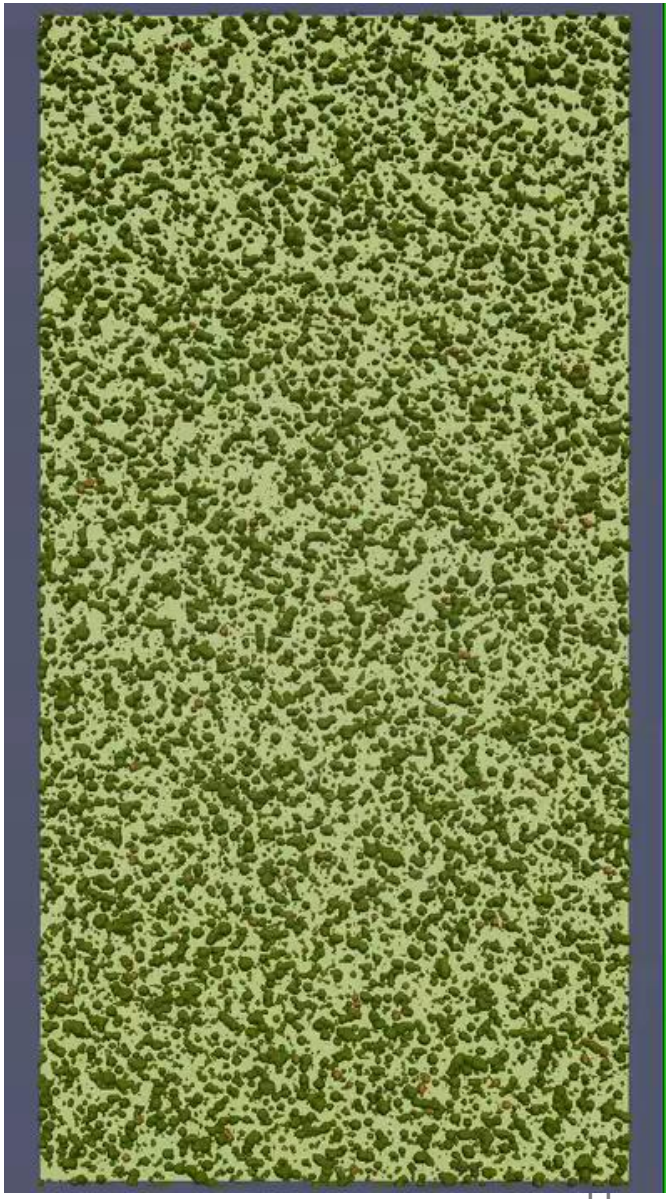
- atv4_top_paraview.mp4 (movieA.mp4)
- atv4_sw_paraview_mp4.mp4 (movieB.mp4)

Early Eglin
FIRETEC Simulation



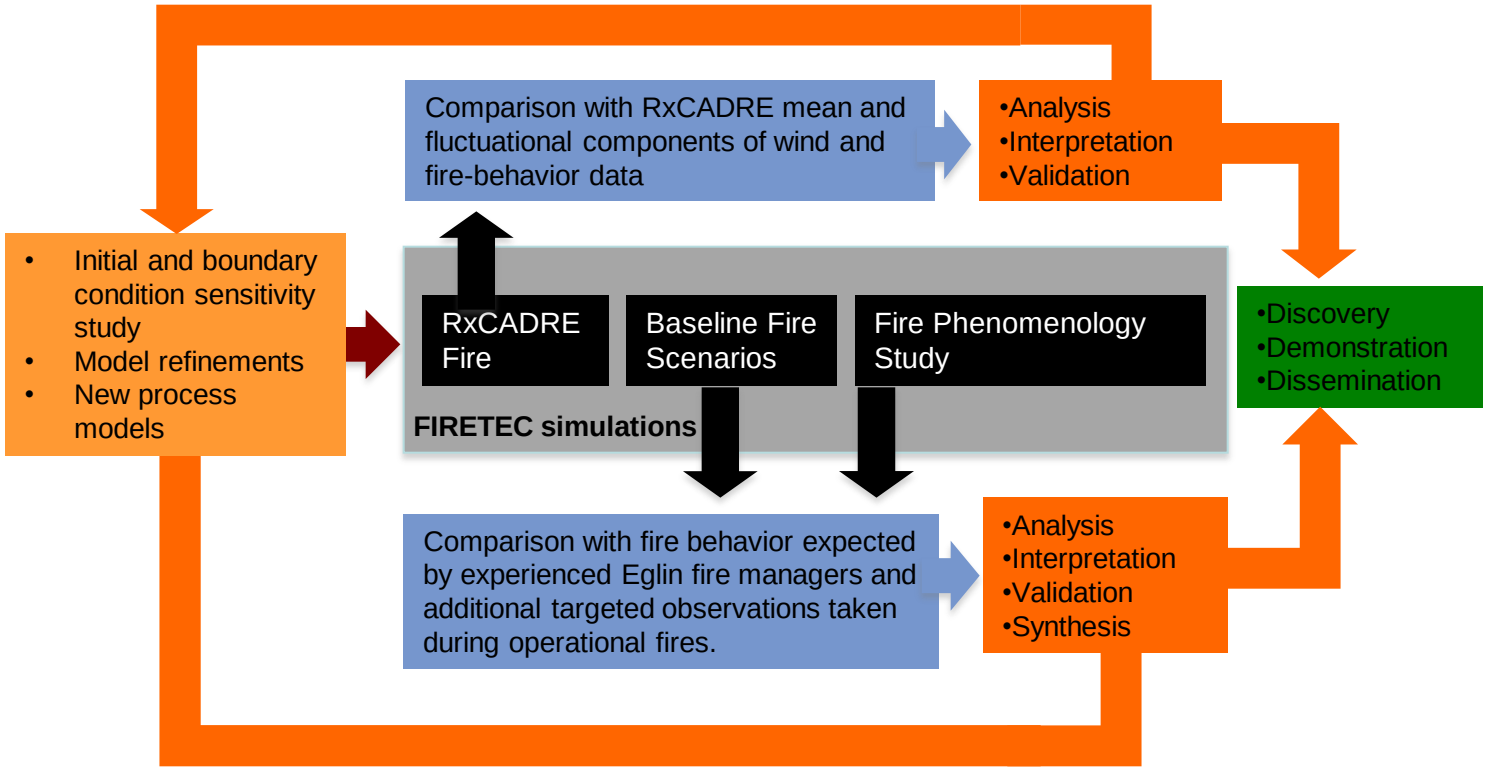


Project Focus

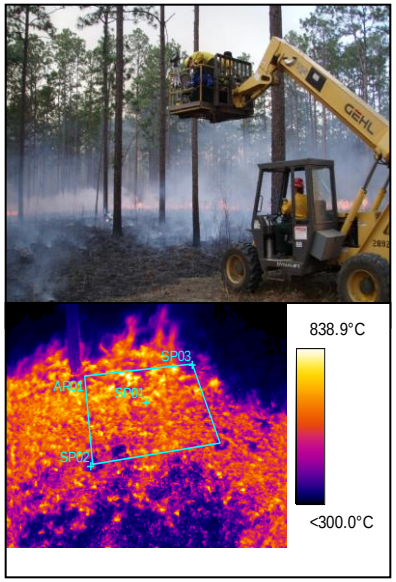
ADDRESS "BURNING QUESTIONS" OF FIRE MANAGERS:

- How do we understand fire behavior as related to:
  - Low (5 mph) vs. Moderate (12 mph) Winds
  - Open vs. Midstory Stand Conditions
  - Varying Firing Patterns
    - Strip Head
    - Closed vs. Open Flanks
    - Short (6m) Dash Ignition
    - Longer (14m) Dash Ignition
    - In-line vs. Staggered Ignitions
    - Aerial Point Source Ignition
    - Varying Density of Ignition Points
- How do we quickly train proficient fire managers?
- How can we more effectively meet Rx fire objectives?

Technical Approach

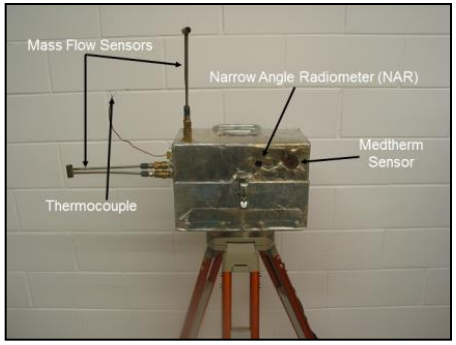


RxCADRE



Demonstrate FIRETEC's capacity to model Rx-fire phenomenology using RxCADRE & Eglin AFB datasets

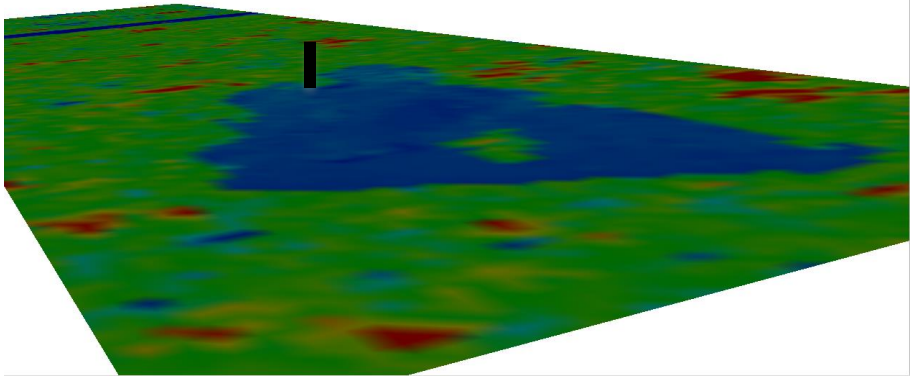
- RxCADRE burns conducted at Eglin AFB
  - Most highly instrumented wildland fires on record with large datasets available for:
    - Indrafts, updrafts and plume rise
    - Fuel structure and loading
    - Fire behavior including spread rates, patterns & heat release
- Simulate fires using RxCADRE conditions to compare FIRETEC outputs to RxCADRE data:
  - Comparison against measured data
    - Fire-influenced winds and turbulence
    - Heat release
    - Fire spread rate, direction & patterns



RxCADRE S-5 Simulation

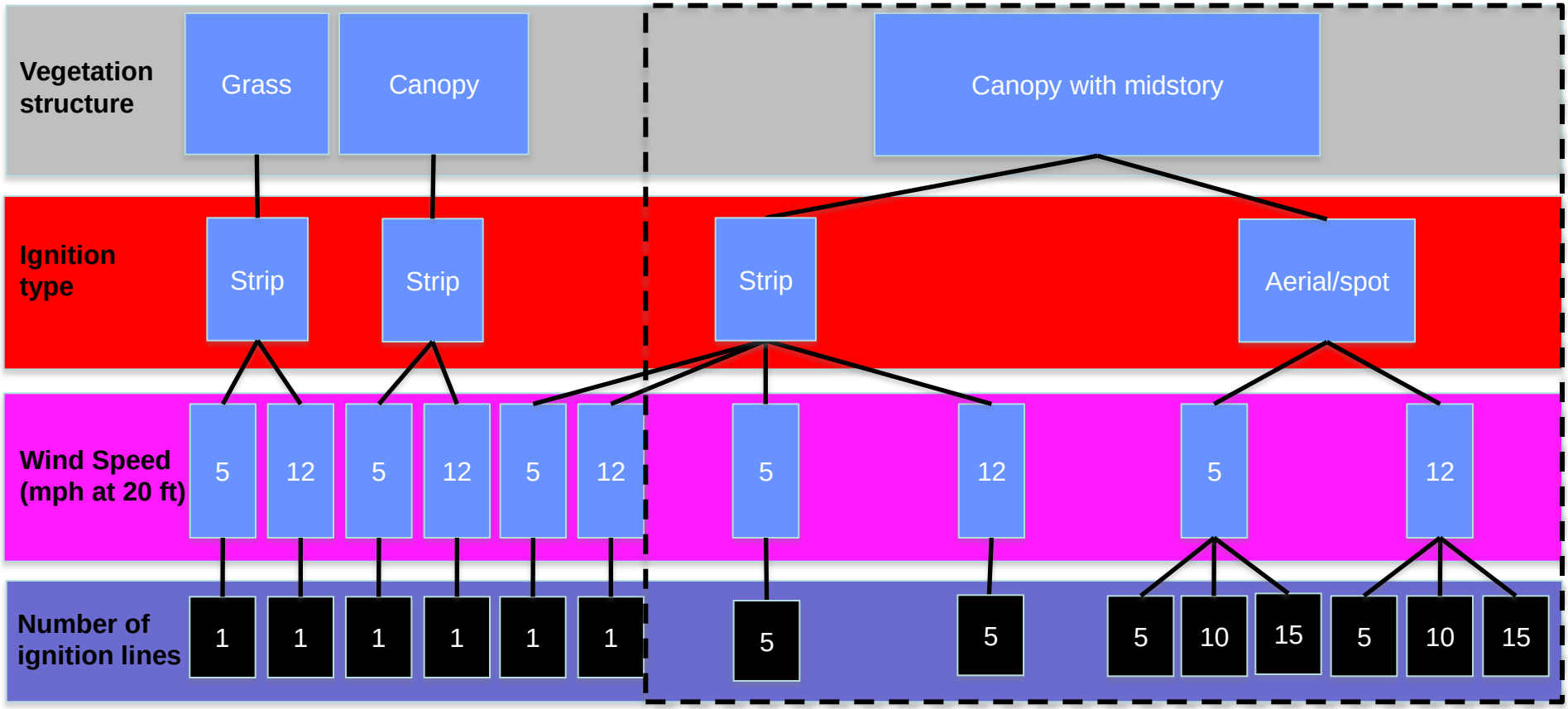
- Developed new methodology to generate realistic fuel beds in FIRETEC
- Obtained anemometer wind measurements for S-5 perimeter
  - ♦ Verify that simulated winds at tower locations are of similar magnitude, direction and fluctuation strength
- FIRETEC simulations with surface winds specified by 5 single anemometers were used to assess the impact of measurement variability
- Simulated fire-behavior under various composite wind fields
- Compared range of shapes and rates of spread with experiment

Winds from 8-sensor nearest neighbor algorithm



Baseline Fire Scenarios

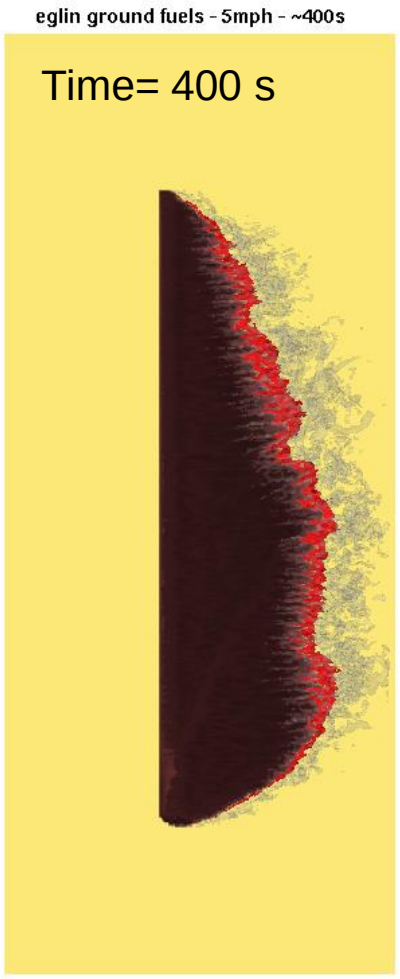
Simulations designed to demonstrate sensitivity of prescribed fire practices (ignition type and distribution) to key environmental conditions (wind and fuels)



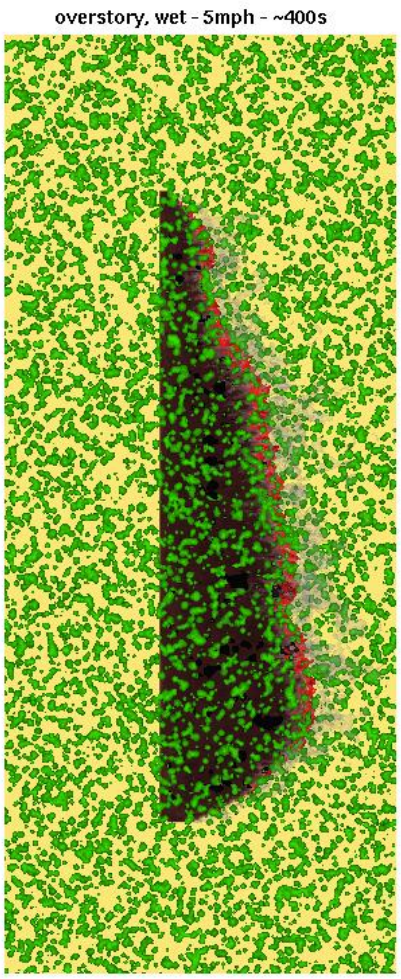
Bottom boxes: FIRETEC simulations with conditions denoted above it in its tree

Baseline Fire Scenarios

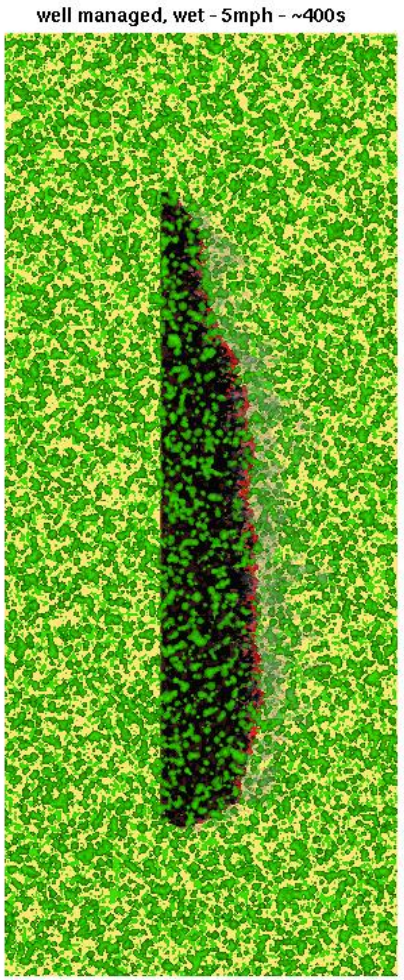
Influence of Canopy and midstory in low (5 mph) winds



- Single ATV line
- 5 mph wind
- Understory fuel only



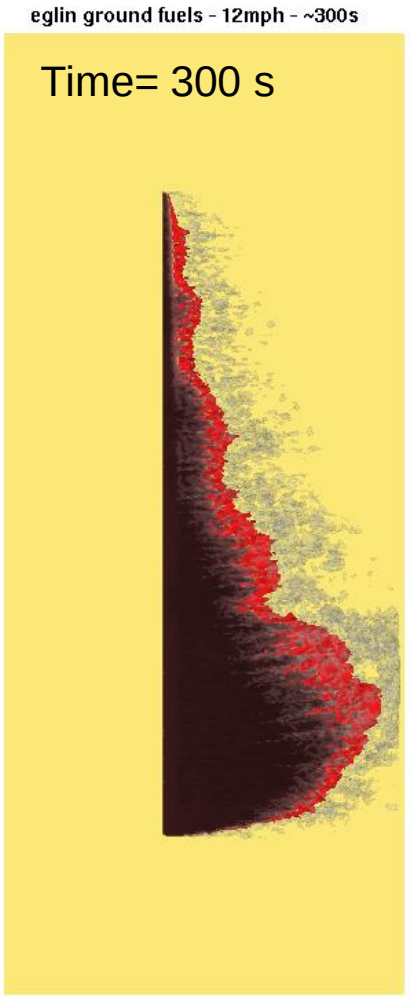
- Single ATV line
- 5 mph wind
- Canopy fuels added



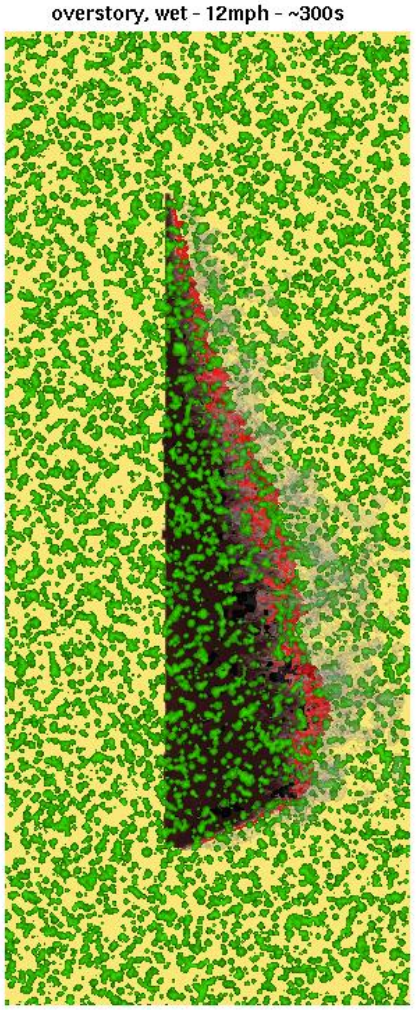
- Single ATV line
- 5 mph wind
- Mid-story added

Baseline Fire Scenarios

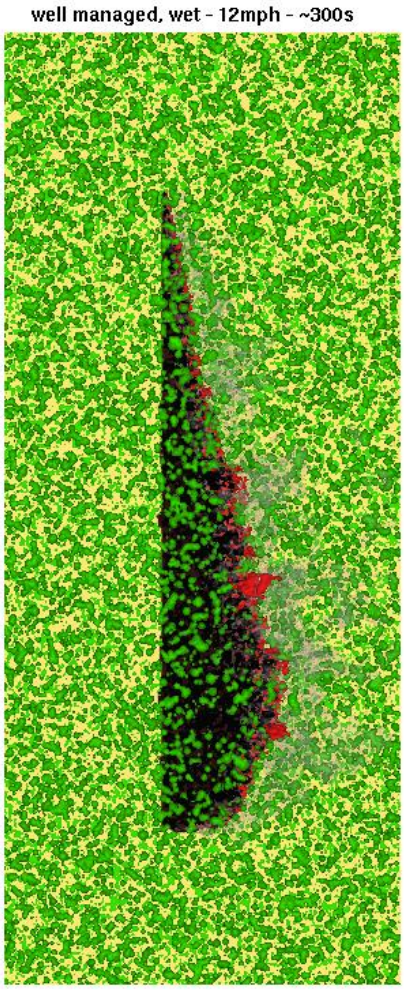
Influence of Canopy and midstory in moderate (12 mph) winds



- Single ATV line
- 12 mph wind
- Understory fuel only



- Single ATV line
- 12 mph wind
- Canopy fuels added

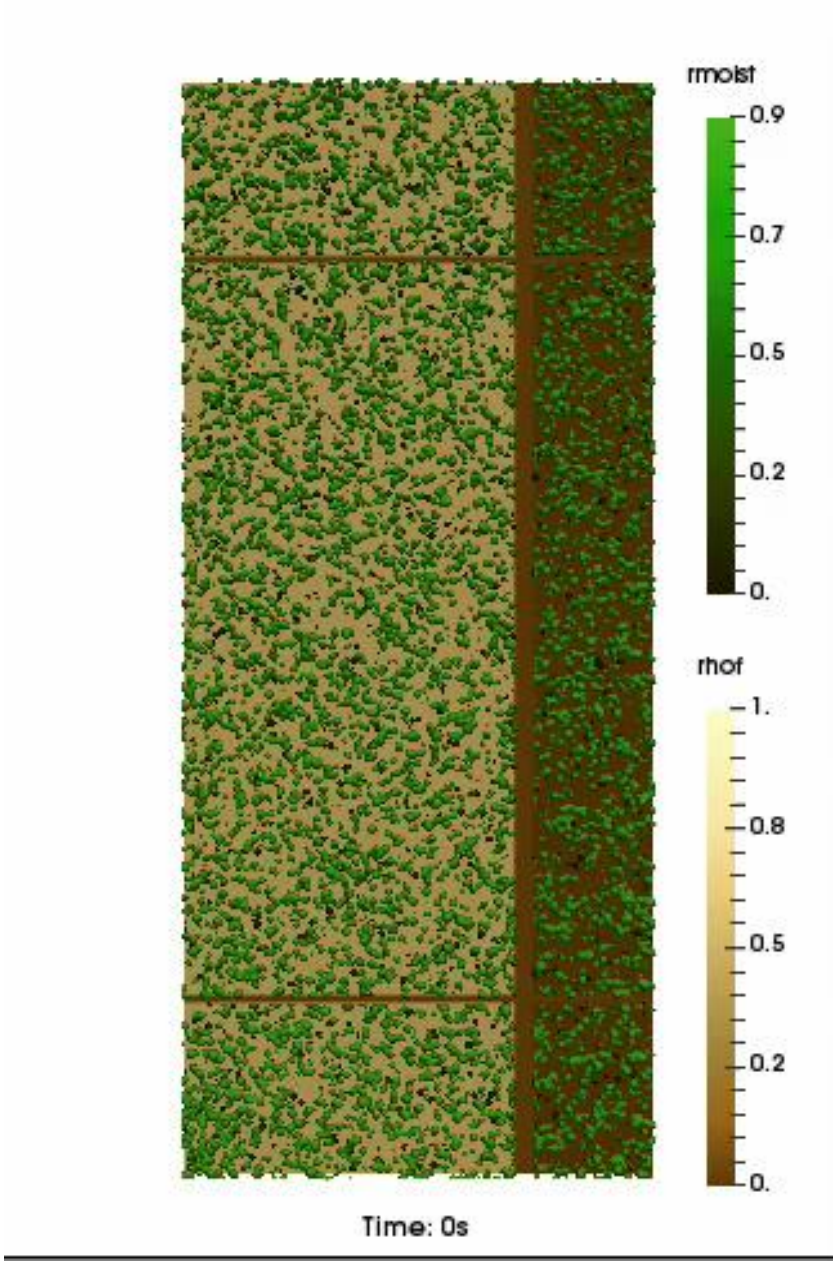


- Single ATV line
- 12 mph wind
- Mid-story added

Ground Ignition

75 acre unit
5 “ATVs”
Rate = 7.5 MPH
Midstory component
150’ between lighters

Temp = 80^0 F
Surface loading = 3.5 T/Acre
Grass/Litter FDFM = 8%
Midstory FDFM = 15%

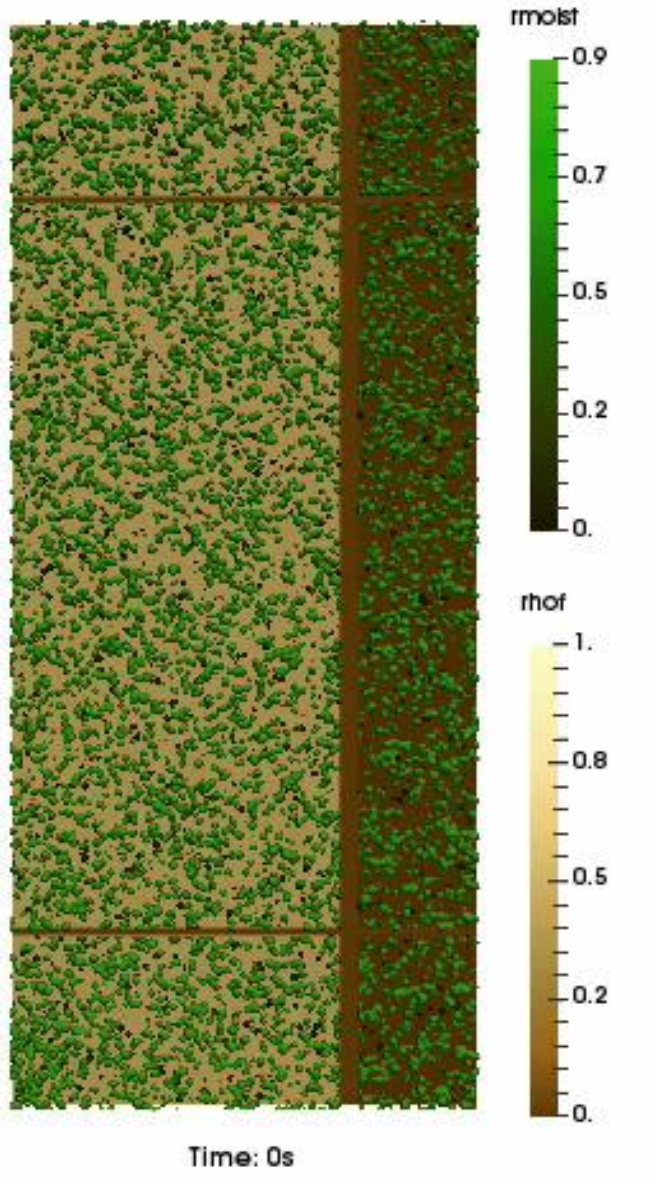


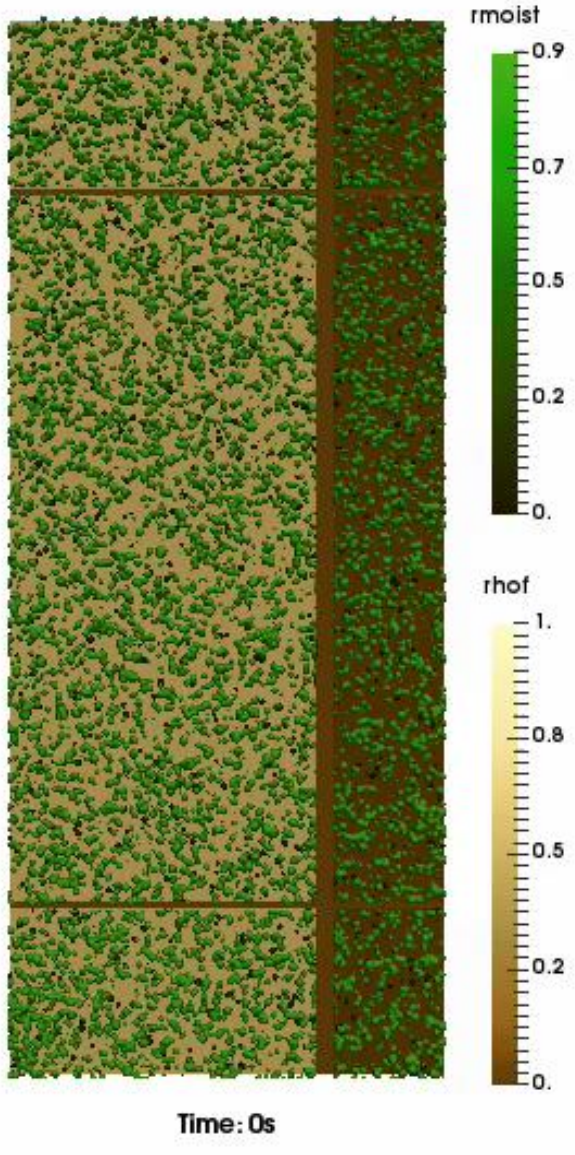
Videos on next slide; run concurrently

- Midstory.5mph.5line.mp4 (movieC.mp4)
- Midstory.12mph.5line.mp4 (movieD.mp4)

Baseline Fire Scenarios:

Strip Ignition, 5 lines; 5 mph vs. 12 mph wind

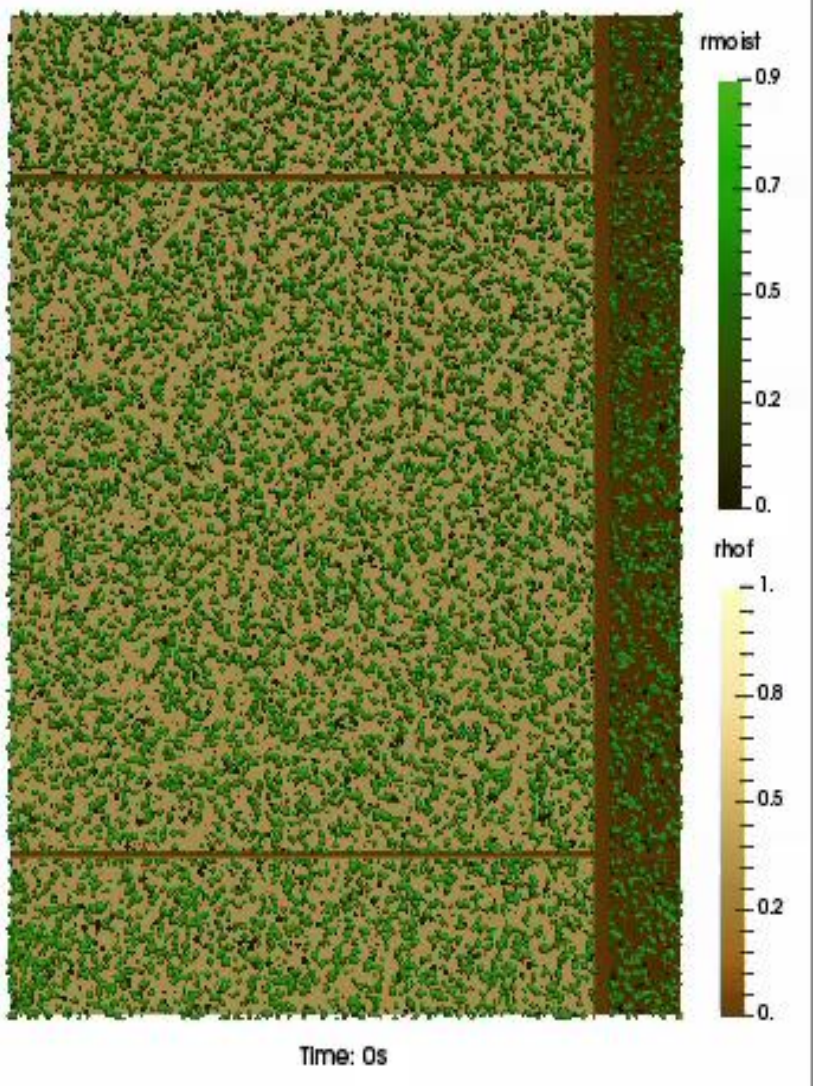




Aerial Ignition

800m x 1200m
~237 acre unit
100’ between spheres
150’ between drifts
3 ignitions/acre

Temp = 80^0 F
Loading = 3.5 T/Acre
Grass/Litter FDFM = 8%
Midstory FDFM = 15%

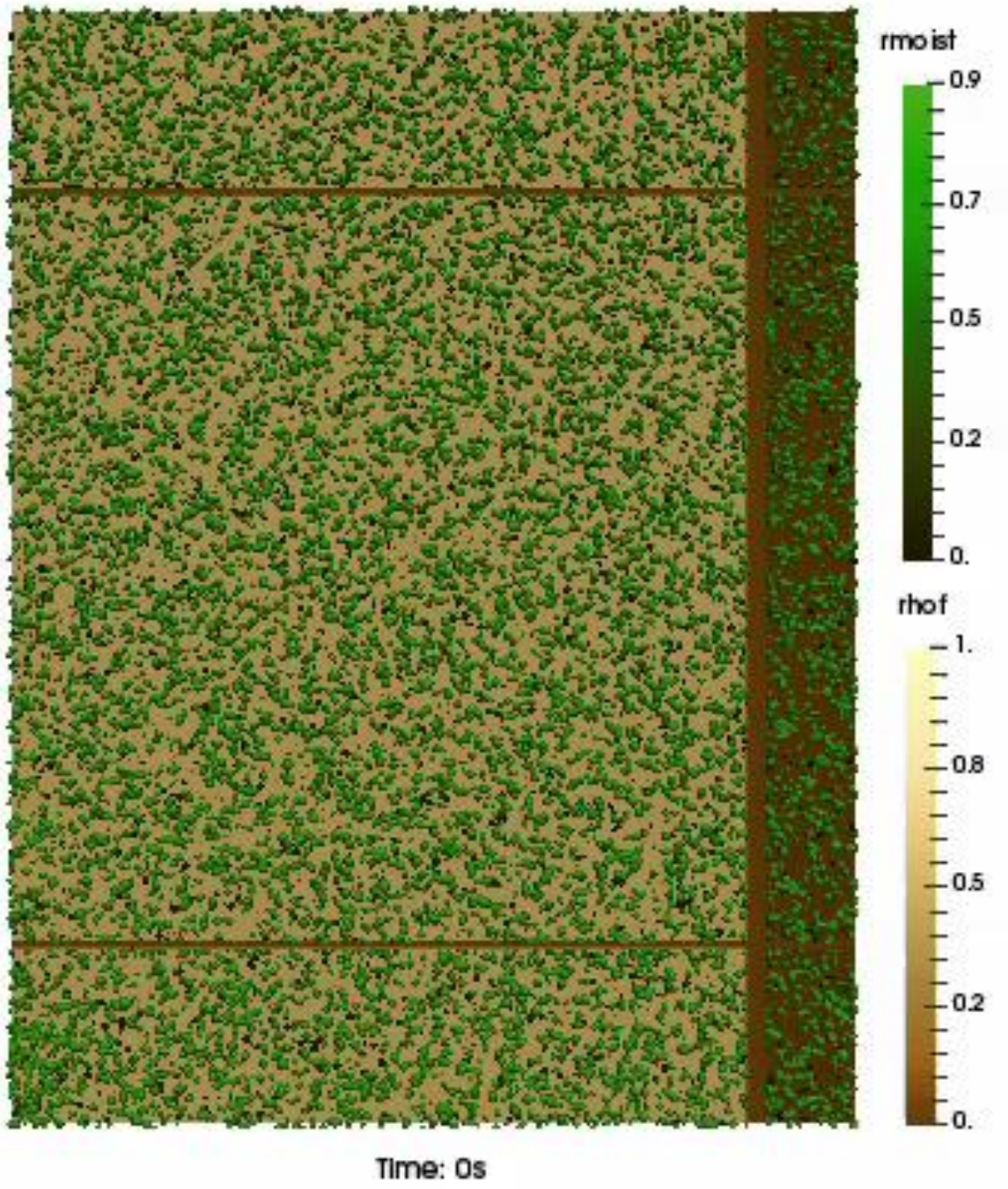


Video for next slide:

midstory.dry.5mph.4cell.450x600.aerial_15line.mp4
(movieE.mp4)

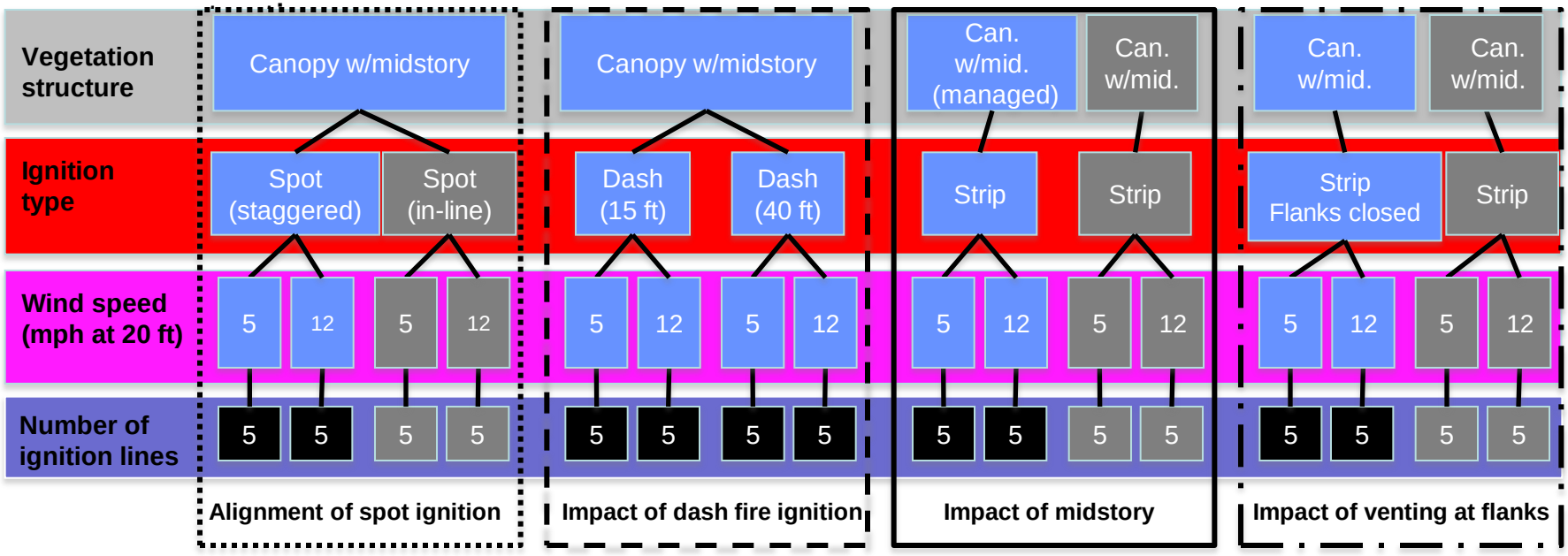
Baseline Fire Scenarios:

Aerial Ignition
5 mph wind



Fire Phenomenology Study

Addressing key questions concerning coupled fire/atmosphere phenomena controlling the effectiveness of prescribed fire



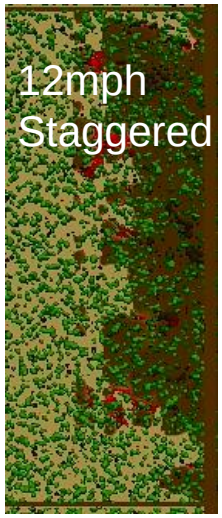
10 Black boxes: additional FIRETEC simulations to explore critical prescribed fire questions

Grey boxes: FIRETEC simulations leveraged from Baseline Simulations described previously

Additional FIRETEC simulations will be performed as needed to further explain key findings

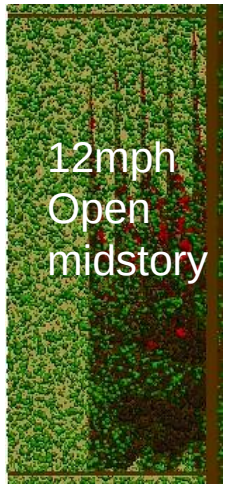
Fire Phenomenology Study

Alignment



Dash Length

Midstory



Venting Flanks

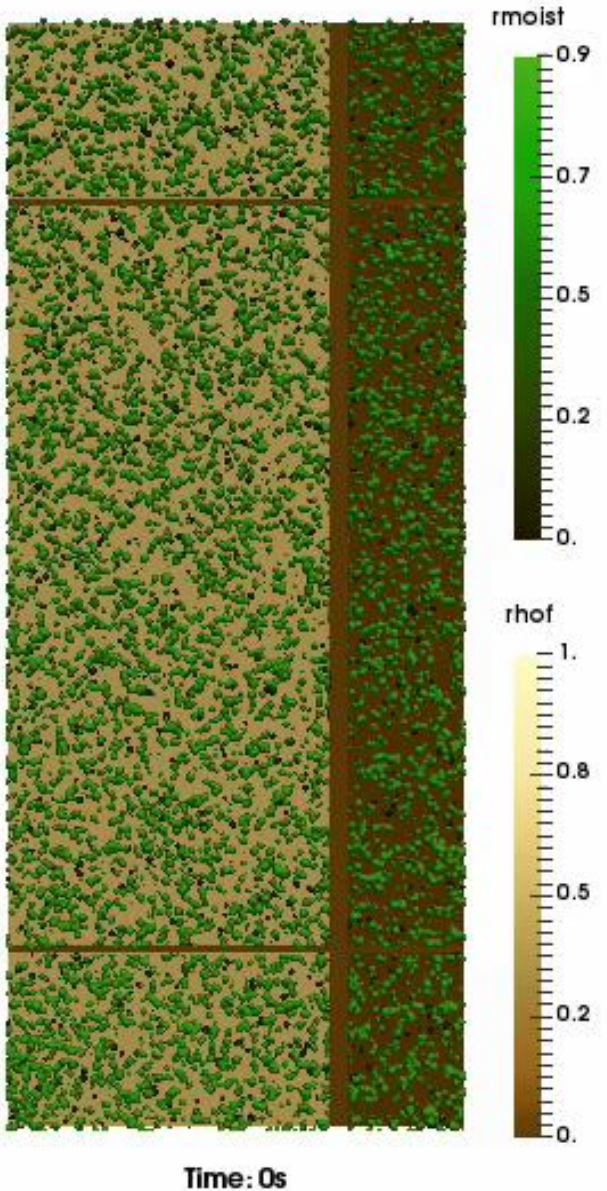
Videos on next slide; run concurrently

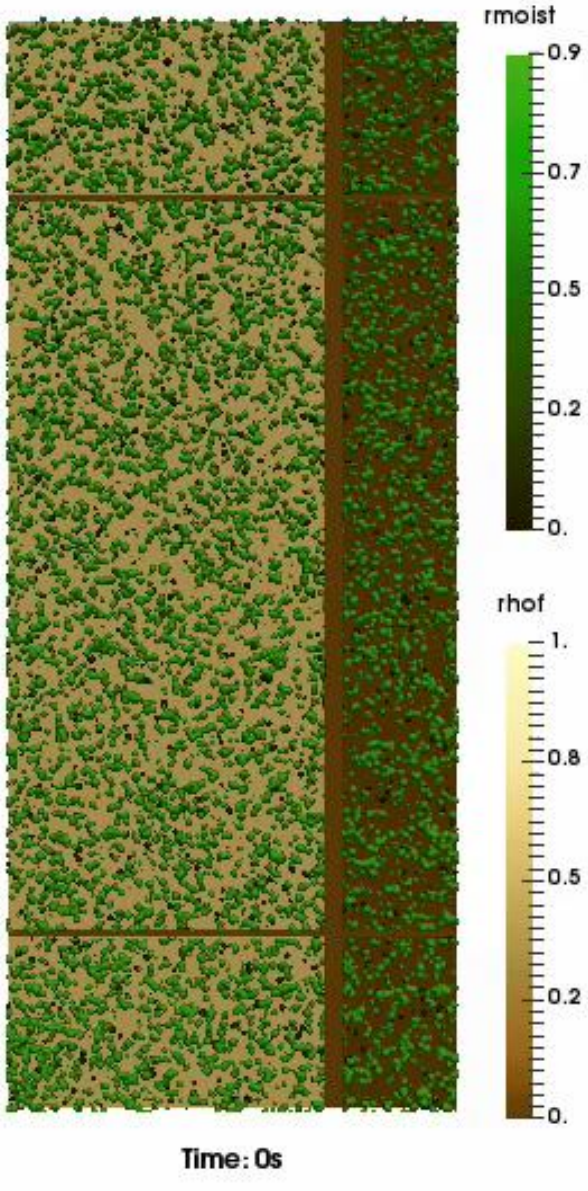
- midstory.12mph.dash14m.mp4 (movieF.mp4)
- Midstory.12mph.5line (movieD.mp4)

Phenomenology Study:

14m dash ignition compared with strip head fire

12 mph wind



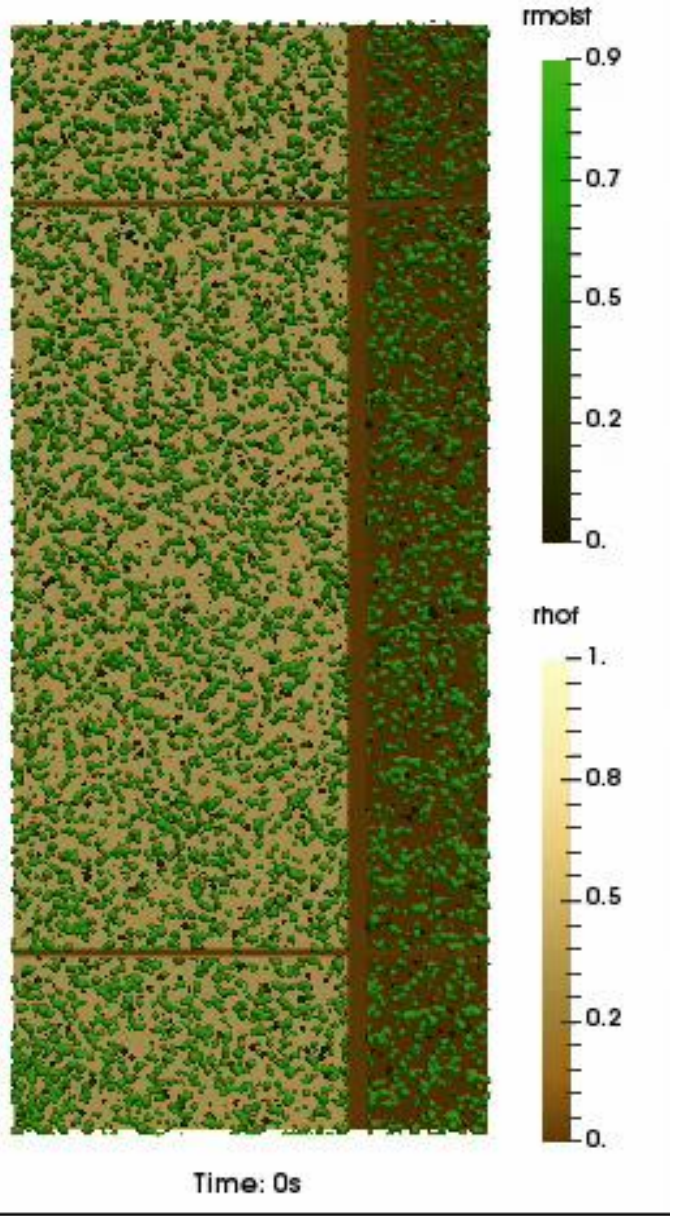


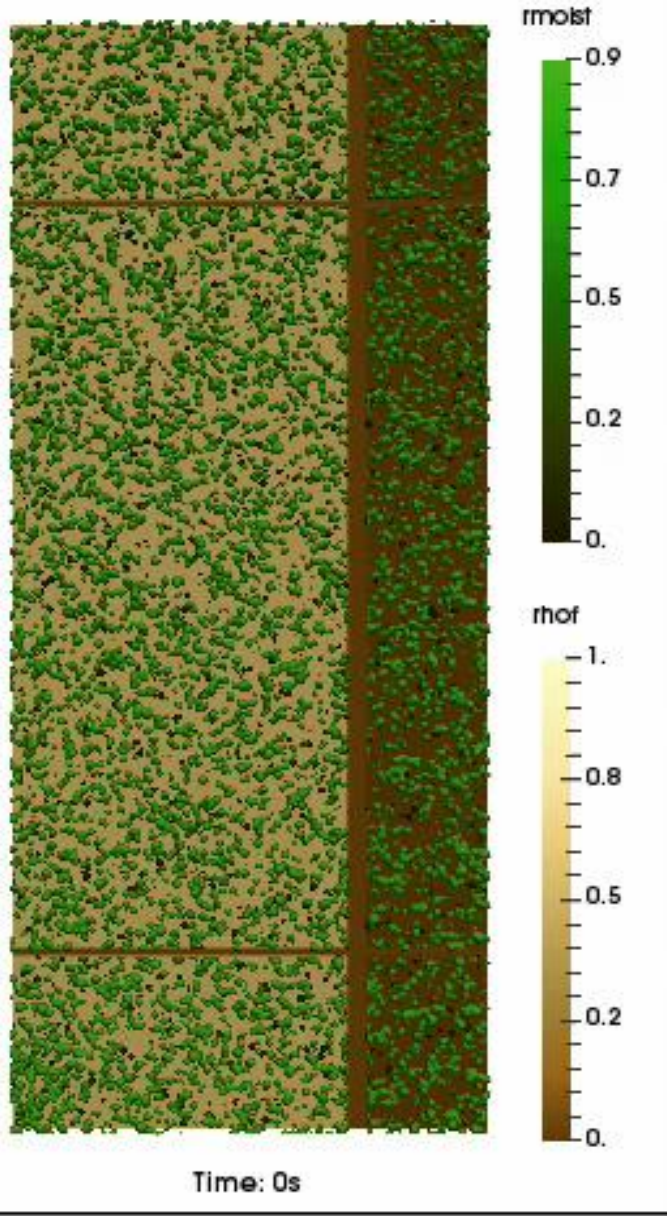
Videos on next slide; run concurrently

- midstory.5mph.closed_flanks.mp4 (MovieG.mp4)
- Midstory.5mph.5line.mp4 (MovieC.mp4)

Phenomenology Study:

Strip Head Fire; 5 mph wind, Open vs. Closed Flanks





Technology Transfer

- Dissemination directly to wildland fire managers via
  - Training material to be produced and presented in various forums
    - AF Wildland Fire Center at Eglin AFB
      - Facilitated workshop for DoD personnel in SE U.S., i.e. Tyndall AFB, Ft. Stewart, Camp LeJeune, Camp Blanding, Ft. Bragg, Moody AFB, Avon Park AFR, Ft. Benning, etc.
      - Interagency Prescribed Fire Training Center attendees visiting Eglin AFB
      - DoD and other "pyro-tourists" training at AF Wildland Fire Center
    - Southern Fire Exchange sponsored webinar(s)
    - National Advanced Fire and Research Institute (NAFRI) Advanced Fire Effects, Rx-510 course (PI and Co-PI serve on instructor cadre)
    - Submission of material to NIFC for potential inclusion in next revision of "Interagency Aerial Ignition Guide", NFES #1080
- Dissemination of papers and instructional materials via internet
    - Wildland Fire Lessons Learned Center (www.wildfirelessons.net)
    - JFSP Knowledge Exchange Regional Consortia
    - Coalition of Prescribed Fire Councils, Inc.
    - Fire Research and Management Exchange System (FRAMES) (www.frames.gov)
- Findings presented to various audiences/venues
  - Posters and presentations to fire behavior and fuels conferences, American Meteorological Society, fire council meetings, state and regional fire supervisors, etc.

Technology/Methodology Transfer

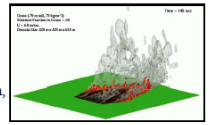
NEXT GENERATION FIRE MODELING FOR ADVANCED WILDLAND FIRE TRAINING

OVERVIEW

The Air Force Wildland Fire Center (AFWFC) at Eglin AFB, in collaboration with Los Alamos National Lab (LANL), have initiated a project to demonstrate and validate the capabilities of a physics-based, fluid dynamics wildland fire spread model, FIRETEC, to simulate fire behavior from prescribed fires in southeastern fuels. Funded by the Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP), this project proposes to (a) validate the FIRETEC model by comparing model simulations to measured values of fire-induced wind velocities and heat release from experimental prescribed fires, (b) demonstrate the ability of FIRETEC to predict realistic fire phenomenological response to heterogeneous forest structure, wind speed, and firing pattern scenarios, and (c) disseminate modeling results and lessons learned to fire managers and practitioners.

WHAT IS FIRETEC?

Current fire spread models are inadequate for predicting the complex influences of atmosphere, forest structure, and self-generating fire processes on wildland fire behavior. FIRETEC is a physics-based, three-dimensional computer code, developed by LANL, designed to capture what is a constantly changing, *interactive* relationship between wildland fire and its environment. To accurately represent such interactive fire processes, FIRETEC combines physics models that represent combustion, heat transfer, aerodynamic drag, and turbulence with a computational fluid-dynamics model that represents airflow and its adjustments to terrain, vegetative obstructions, and the fire itself.



WHY EGLIN AFB?

- ESTCP is DoD's environmental technology demonstration and validation program whose goal is to identify and demonstrate the most promising innovative and cost-effective technologies that address DoD's high-priority environmental requirements.
- The AF Wildland Fire Center at Eglin AFB possesses an extremely active and successful wildland fire program, annually managing over 250 wildland fire incidents either prescribed or wildfire, as well as an extensive fuels monitoring program.
- The Prescribed Fire Combustion and Atmospheric Dynamics Research Experiment (RxCADRE) took place at Eglin AFB in 2008, 2011, and 2012 and will provide invaluable validation datasets for FIRETEC model runs.

FIRETEC SIMULATIONS TO ADDRESS "BURNING" QUESTIONS

Figure 1 illustrates the baseline series of numerical simulations that will be used to illustrate fundamental sensitivities associated with vegetation structure, ignition type, wind speed, and number of ignition lines on fire behavior. In this figure, each of the **18 small black boxes** at the bottom represents a simulation that will have the conditions indicated by the number of ignition lines shown in the black boxes and the wind speeds, ignition type, and vegetation structure shown in blue boxes above the black boxes in the tree. To explore and demonstrate the impacts of vegetation structure on fire behavior, three different vegetation conditions will be simulated: **grass**, **canopy**, and **canopy with midstory**. For each of these vegetation conditions, fire will be simulated with a single strip ignition under both moderate (**12 mph**) and low (**5 mph**) wind speeds. A much more extensive series of simulations will be performed to explore basic prescribed fire sensitivities in the **canopy w/midstory** fuel type, shown within dashed lines in Figure 1. For the canopy w/midstory simulations, both **aerial/spot** and **strip ignitions** will be simulated and a variety of ignition lines will be simulated: **5, 10 and 15 lines for aerial/spot** and **2, 4, and 6 lines for strip ignition**. These patterns were chosen as representative of actual ignition patterns based on inputs from Eglin AFB fire managers.

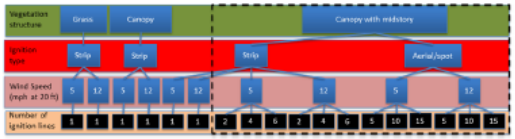
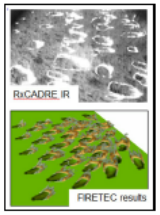


Figure 1. Eighteen baseline FIRETEC simulations. Each black box represents a separate model run.

Following the baseline simulations, additional simulations will be performed to identify key phenomenology that should be considered when making decisions about prescribed fire ignition strategies and techniques. Some of the simulations associated with these studies are illustrated in Figure 2, in which the grey boxes indicate simulations that will be leveraged from the baseline scenarios in Figure 1. Black boxes in Figure 2 represent additional simulations. With these simulations specifically focused on prescribed fire techniques and their implications, the project will answer such questions as:

- What is the effect of distance between ignition points on fire intensity and plume lofting?
- How does spot ignition moderate fire intensity as compared to "dash" or "line" ignition patterns?
- How does lighting unit boundaries affect fire behavior/effects in the burn unit?
- What is the effect of ignition point orientation (in-line vs. staggered) with regard to wind direction?
- How does forest structure affect wind fields and resulting fire behavior with various ignition patterns?
- How do the effects of the above ignition patterns change under varying wind conditions?



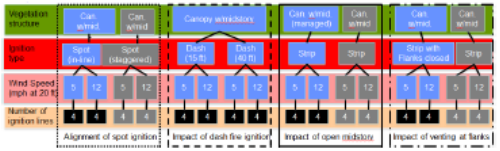


Figure 2. Prescribed fire ignition strategy simulations

EXPECTED OUTCOMES

FIRETEC will produce short "video clips" of fire behavior for modeled simulations. These will be utilized to develop video and training materials for fire managers which will be shared via:

- Facilitated workshops at DoD installations in southeastern U.S. and other locations upon request
- Interagency Prescribed Fire Training Center
- DoD and other "pyro-tourists" training at Air Force Wildland Fire Center
- Rx-510 Advanced Fire Effects Course hosted at National Advanced Fire and Research Institute (NAFRI) (Upon Invitation)
- Wildland Fire Lessons Learned Center (www.wildfirelessons.net)
- Joint Fire Science Program Knowledge Exchange Regional Consortia (e.g., Southern Fire Exchange)
- Coalition of Prescribed Fire Councils, Inc.
- Fire Research and Management Exchange System (FRAMES) (www.frames.gov)
- Additionally, scientific papers will be produced and shared with the fire science community

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Current Project Focus

- Further analysis/comparisons of completed FIRETEC simulations (Baseline and Phenomenology Study)
  - Fire intensity as measured by comparative “scorch” percentages and patterns (quantitative comparison)
- Point source ignition density simulations
  - Varying spacing between ignitions in line
  - Varying distance between lines
- Additional simulations to explore questions raised by current FIRETEC simulations
- Continue outreach activities, including publications

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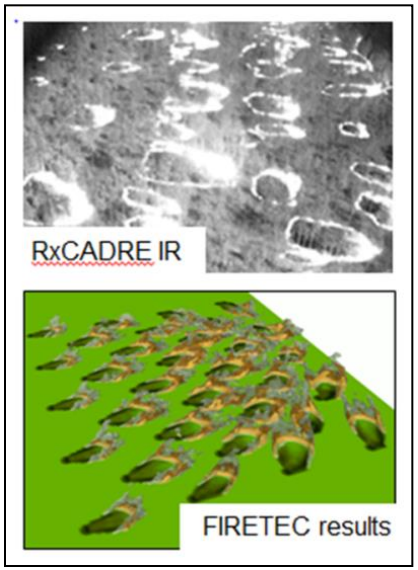
Tall Timbers Research Station for technical expertise and general support

Southern Fire Exchange for support of webinar(s) and outreach efforts




Questions?