

Field Experiments and Modeling for the Assessment of Fuel Treatment Effectiveness in Reducing Wildfire Intensity and Spread Rate



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Outline

- Background
- Study site
- Experimental measurement protocol
 - Fire behavior
 - Fuel consumption
- Experimental results
 - Year 1 – detailed
 - Year 2 – overview
- Modeling challenges
- Conclusions

Background

- 3-year goal – To study the effectiveness of fuel treatment
 - \$5.6 billion (USD) spent in the past 10 years for hazardous fuel reduction in the United States
 - “The agencies, for example, still lack a measure of the effectiveness of fuel reduction treatments and therefore lack information needed to ensure that fuel reduction funds are directed to the areas where they can best minimize risk to communities and natural and cultural resources” - Government Accountability Office, 2009
- Long-term goal – Improved understanding of wildland fire behavior
- Goals addressed through a combined experimental and numerical approach
 - 2 field experiments
 - Detailed physical Computational Fluid Dynamics (CFD) modeling
 - Wildland-urban interface Fire Dynamics Simulator (WFDS)

Study Site

- New Jersey Pinelands National Reserve
 - 1.1 million acres ~23% of NJ



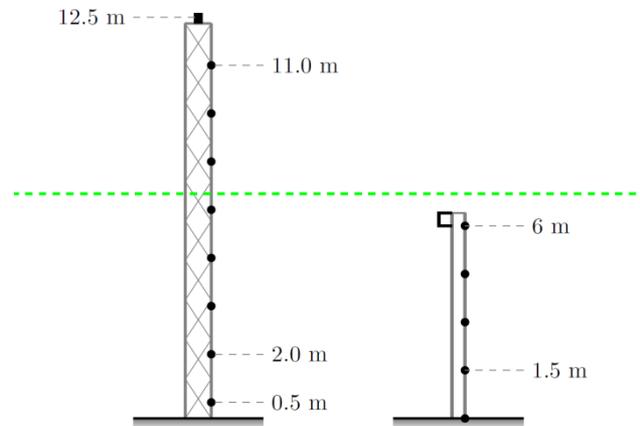
- Averages 1300 wildfires per year (2003-2013)
- Large crown-fire event every 5-10 years
- High level of WUI
 - RxB conducted on 12,000 acres per year

Measurement Techniques

Fire Measurement

Overstory towers

- 8 K-type thermocouples
- 1 3D Sonic Anemometer



Understory towers

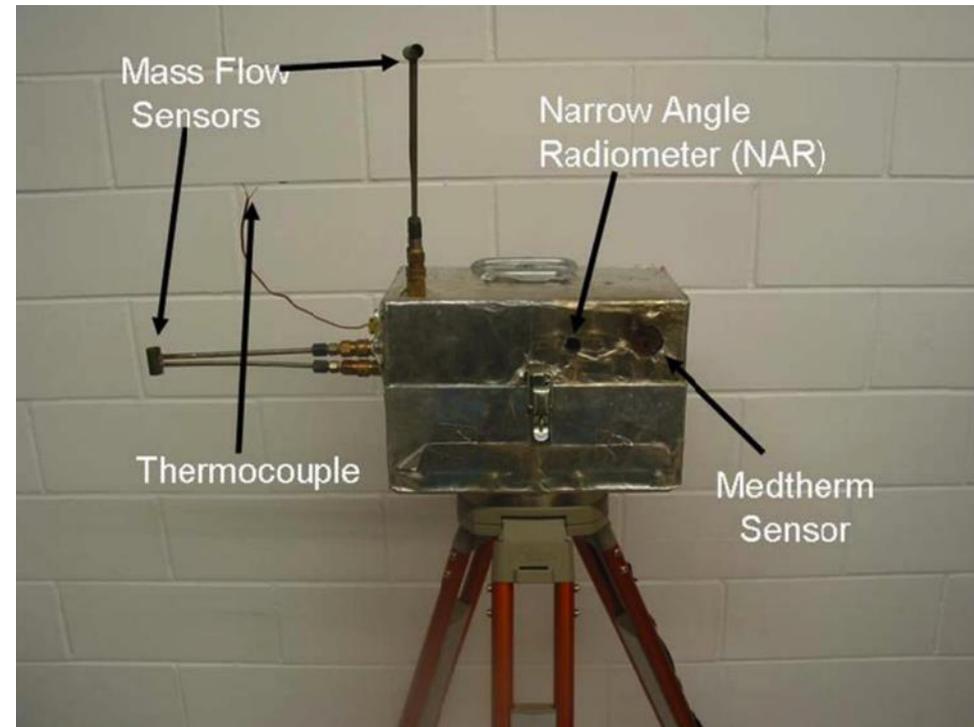
- 5 K-type thermocouples
- 1 vertically oriented flow sensor (pressure)
- 1 vertically oriented dual-band radiometer



Fire Measurement

Fire behavior packages – year 1

- 3 packages developed by USDA Forest Service
- Provide measurements of:
 - Temperature
 - 1 thermocouple
 - Heat flux
 - 1 Medtherm dual heat flux guage
 - 1 narrow angle radiometer
 - Flow
 - 1 horizontal probe
 - 1 vertical probe



Fire Measurement

Fire behavior packages – year 2

- 3 Sites
 - 4 thermocouples (at 60 cm intervals)
 - 6 thin-skin calorimeters (total heat flux)
 - 3 directions of flow velocity



Fire Measurement

Aerial imagery

- Series of stills taken using RIT's Wildfire Airborne Sensor Program (WASP)
 - 3 bands of IR - 640x512 pixel
 - SWIR: 0.9-1.7 μm
 - MWIR: 3-5 μm
 - LWIR: 8-9.2 μm
 - Georeferenced

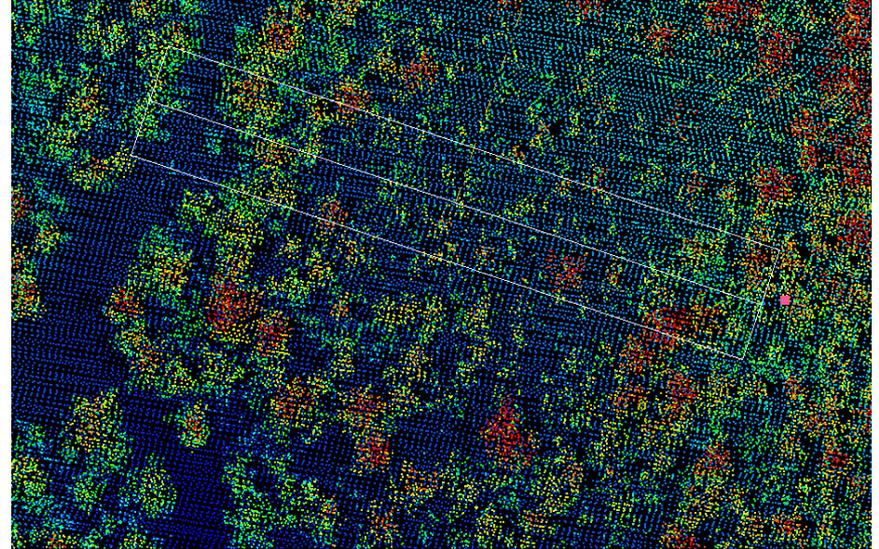
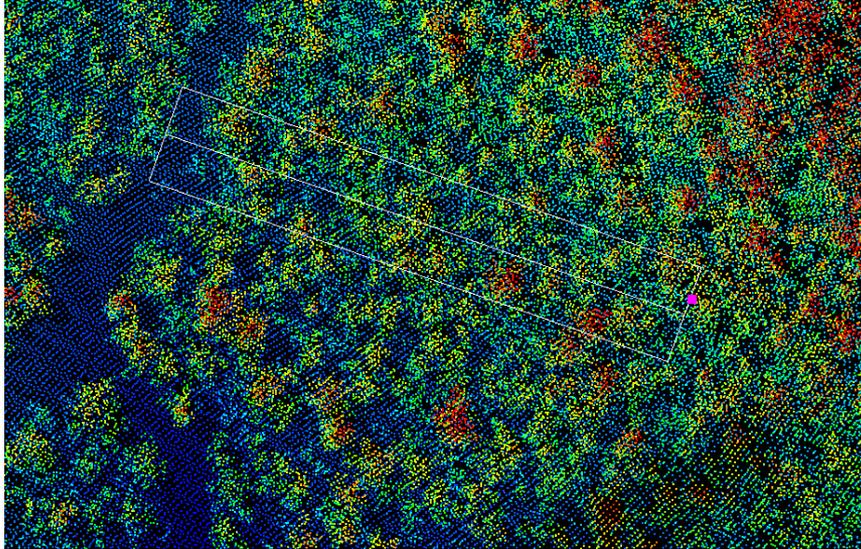


Fuel Measurement

- 36 pre- and post-fire clip plots (3 per understory tower)
- Fuels sampled by size class
 - Forest floor: fine, repro., 1hr, 10hr, 100hr
 - Shrub and Oak layer: 1hr, 10hr (live and dead)



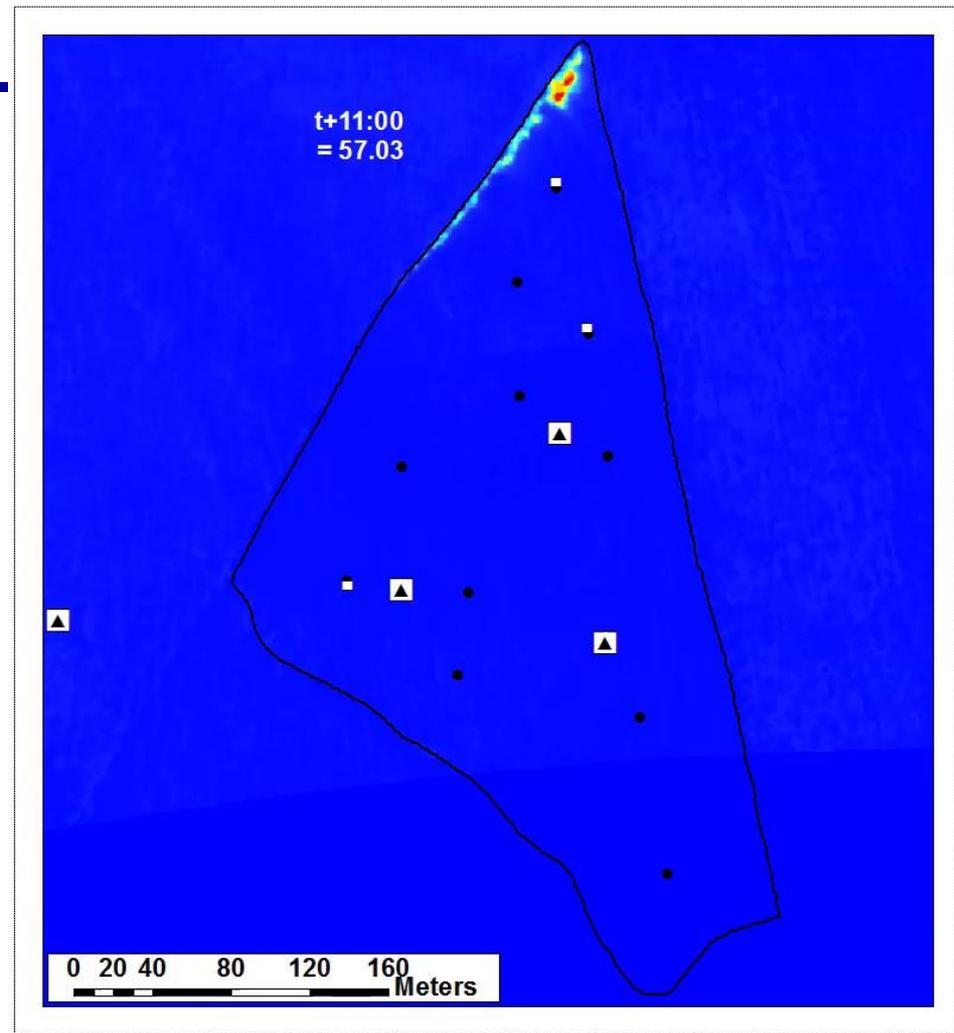
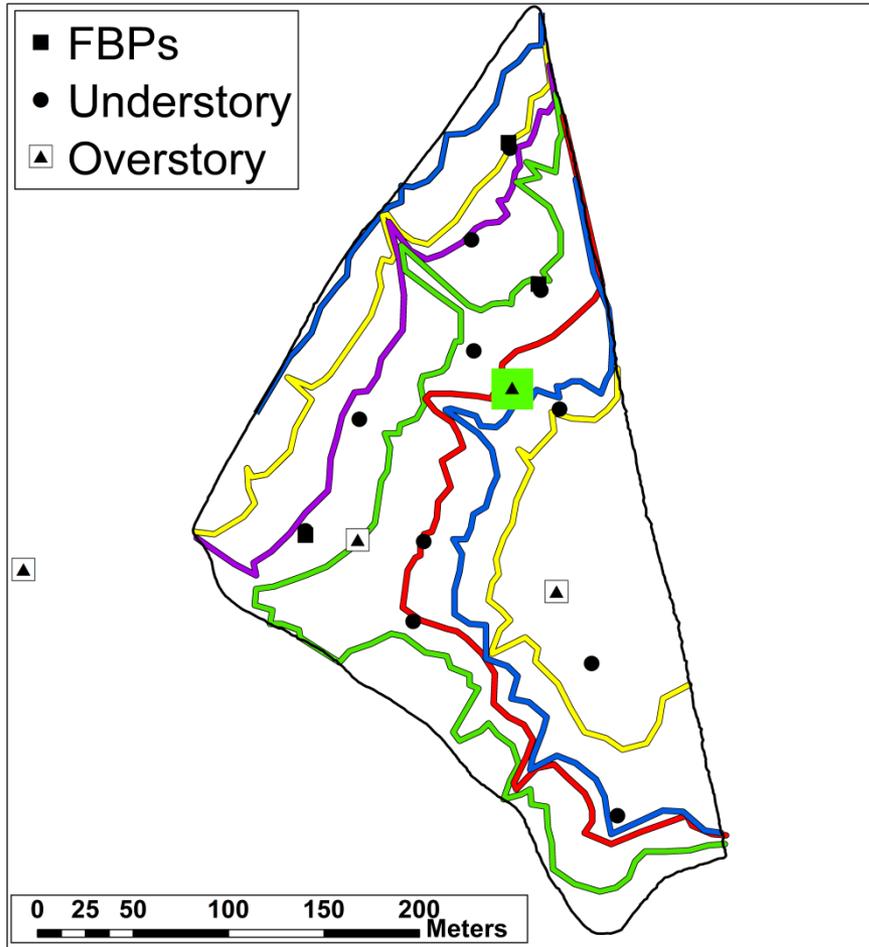
Fuel Measurement



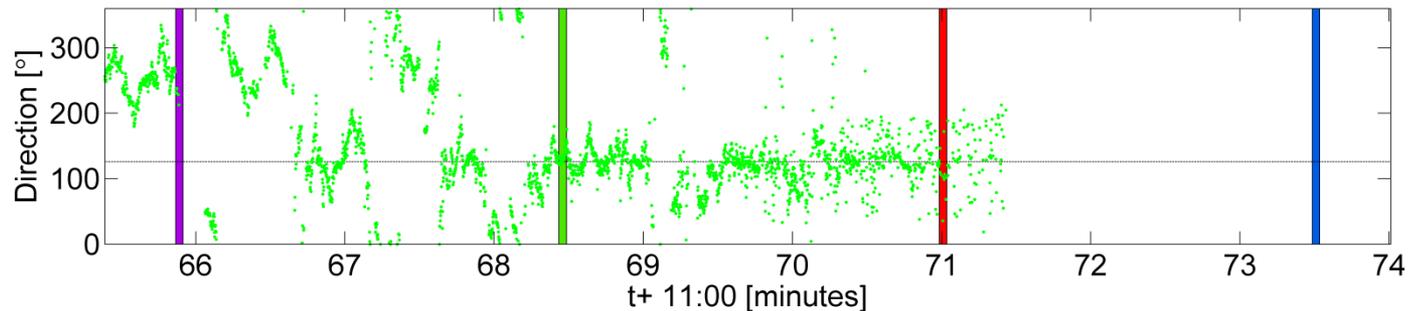
- Pre- and post-fire flights of Airborne Laser Scanning data (ALS)
 - Collected at 400 kHz, with a pulse density ca. 5.12 points m⁻²
- Will provide canopy height profiles and canopy bulk densities (calibrated by upward sensing LiDAR)
- Resolution of 10 x 10 x 1 m

Year 1

Fire Front Progression



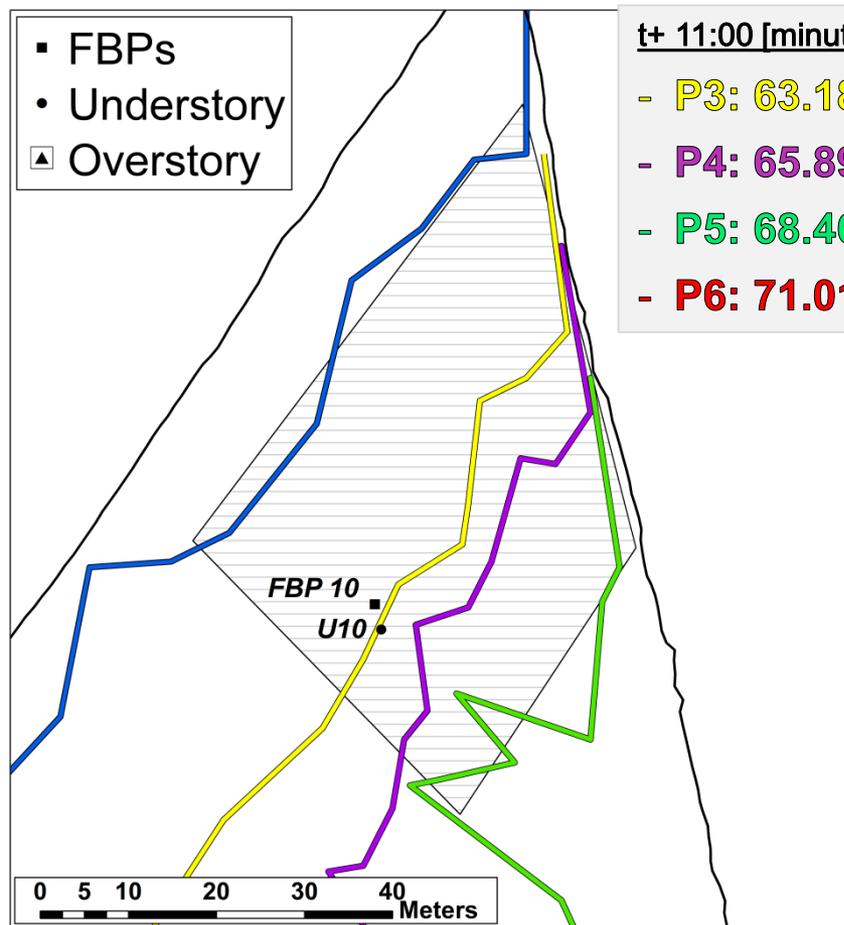
North



- FBPs
- Understory
- ▲ Overstory

t+ 11:00 [minutes]

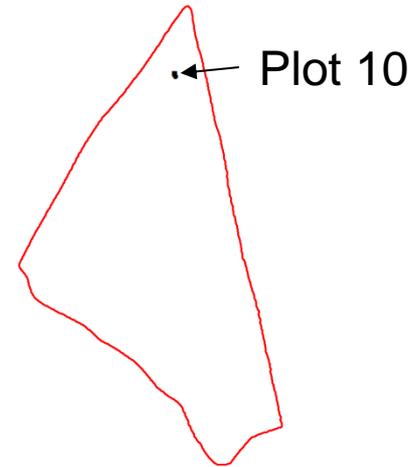
- P3: 63.18
- P4: 65.89
- P5: 68.46
- P6: 71.01



$$\text{Fireline Intensity } I_f = ROS \cdot \Delta m \cdot h$$

~500-1300 kW·m⁻¹

Plot 10



- Large fuel sizes had low/sporadic distributions – only fine and 1hr fuels were considered

Forest floor – U10

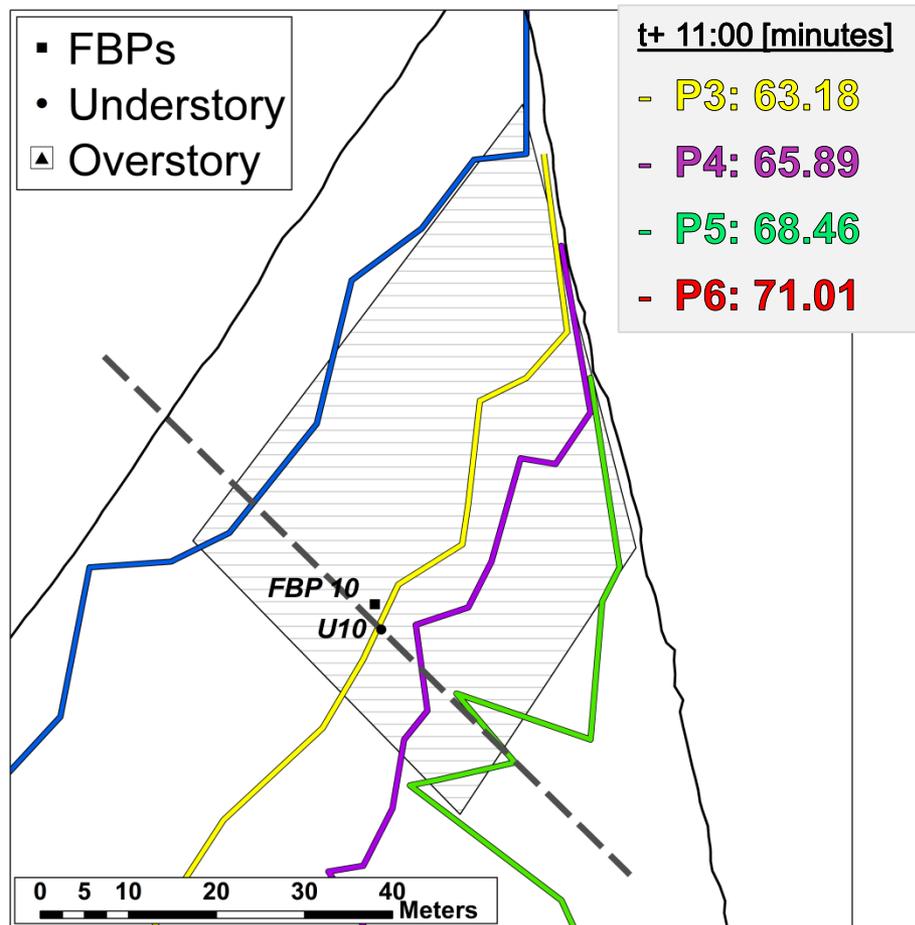
	fine	wood 1hr	FF total
mean consumption [g·m ⁻²]	440.2	131.3	571.5

Shrubs and Oaks – U10

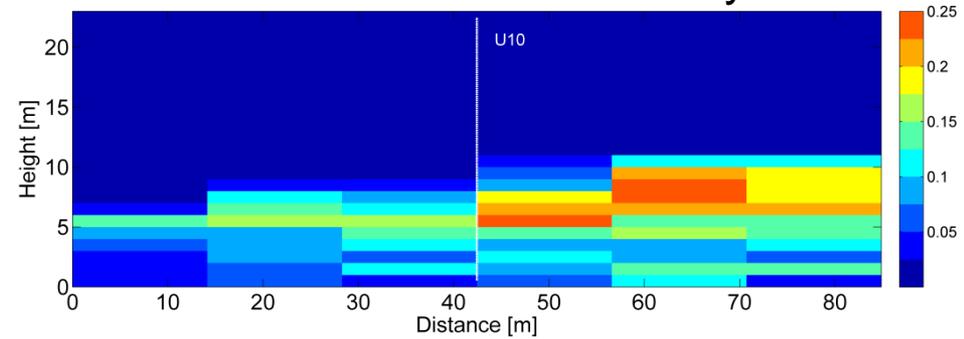
	1hr L+D
mean consumption [g·m ⁻²]	154.3

Plot 10

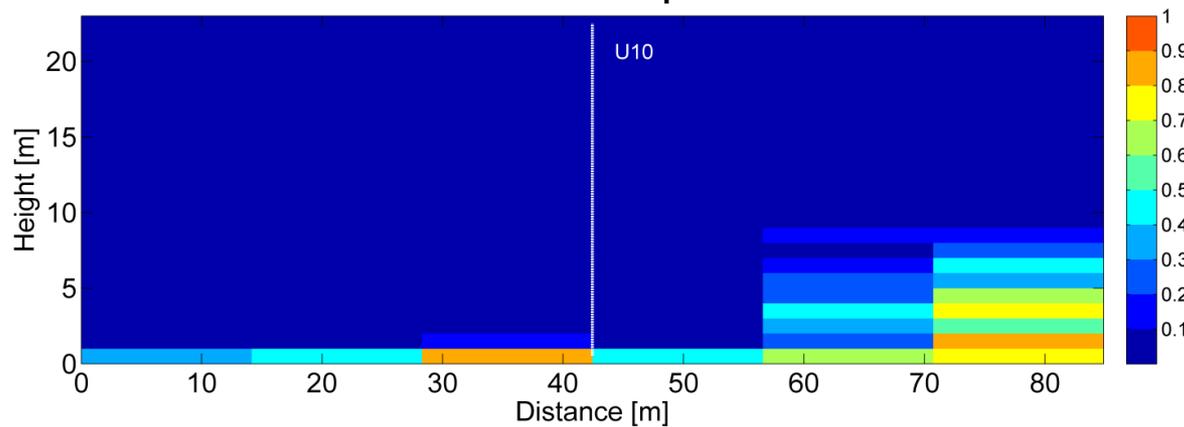
Un-calibrated LiDAR



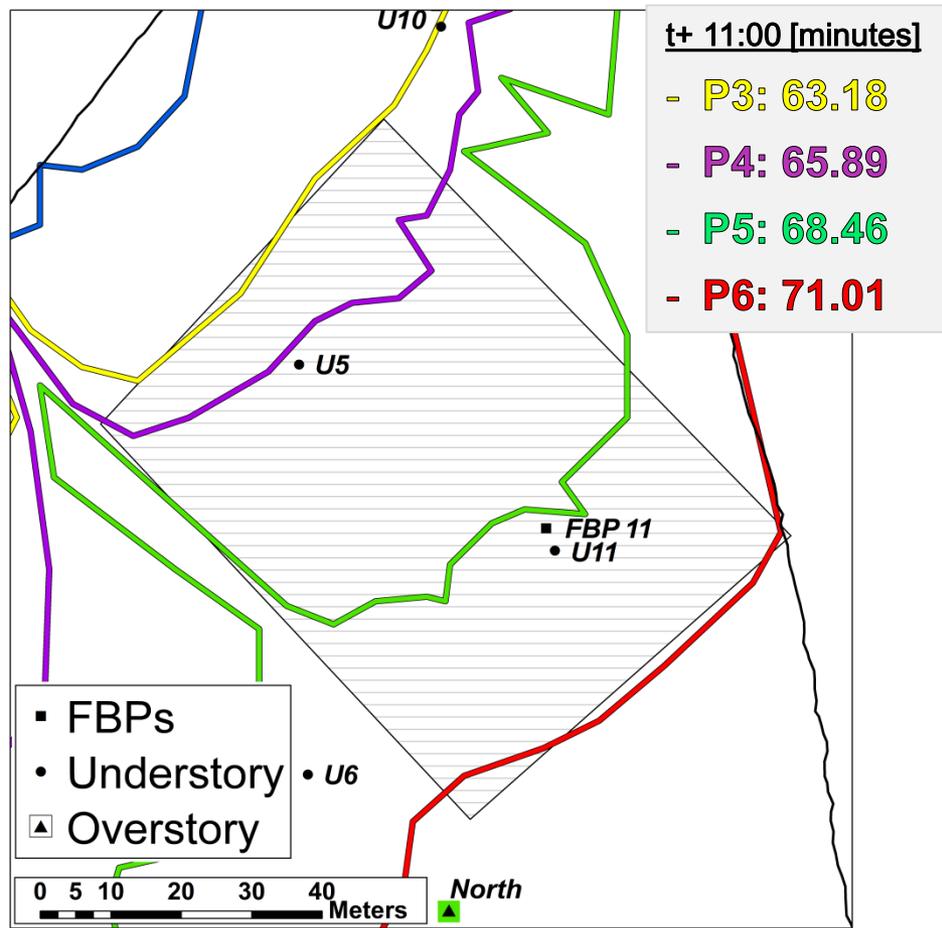
Pre-Fire Bulk Density



% Consumption



Plot 5 & 11



Plot 5 → Plot 11

Forest floor – U5

	fine	wood 1hr	FF total
mean consumption [g·m ⁻²]	575.7	-0.7	575.0

Shrubs and Oaks – U5

	1hr L+D
mean consumption [g·m ⁻²]	324.0

Forest floor – U11

	fine	wood 1hr	FF total
mean consumption [g·m ⁻²]	507.4	391.7	899.1

Shrubs and Oaks – U11

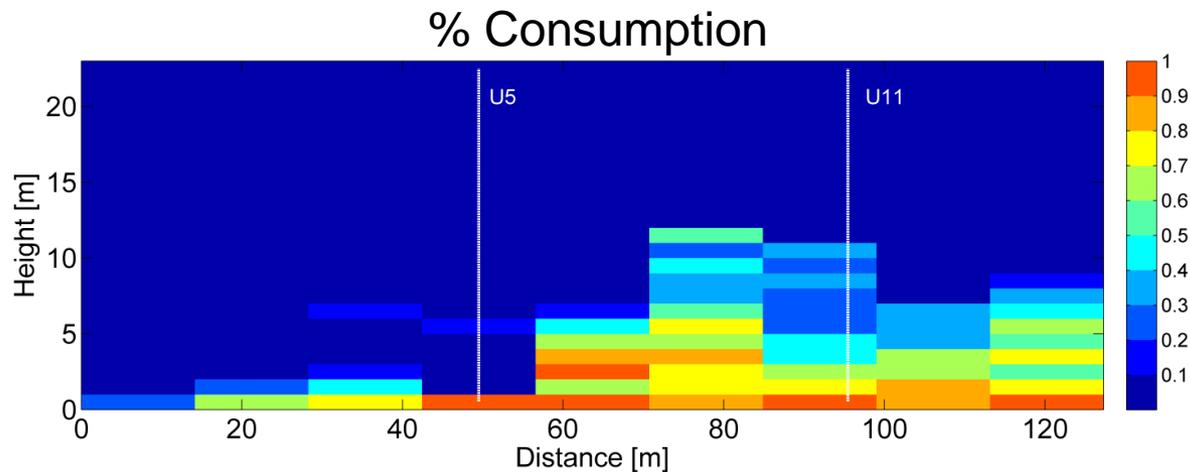
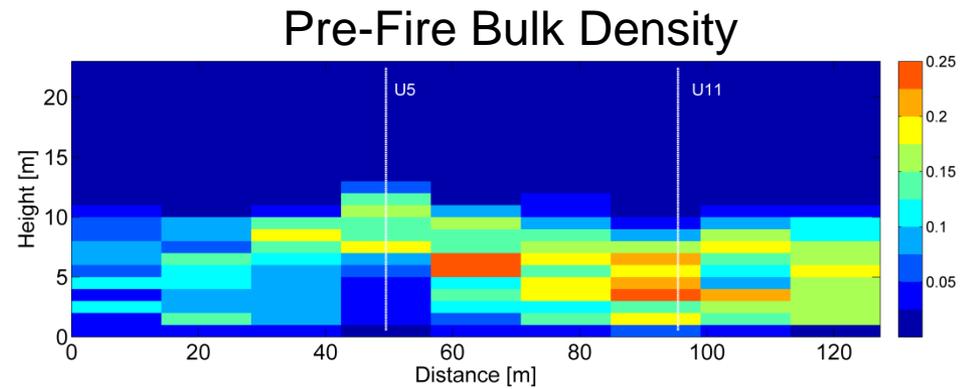
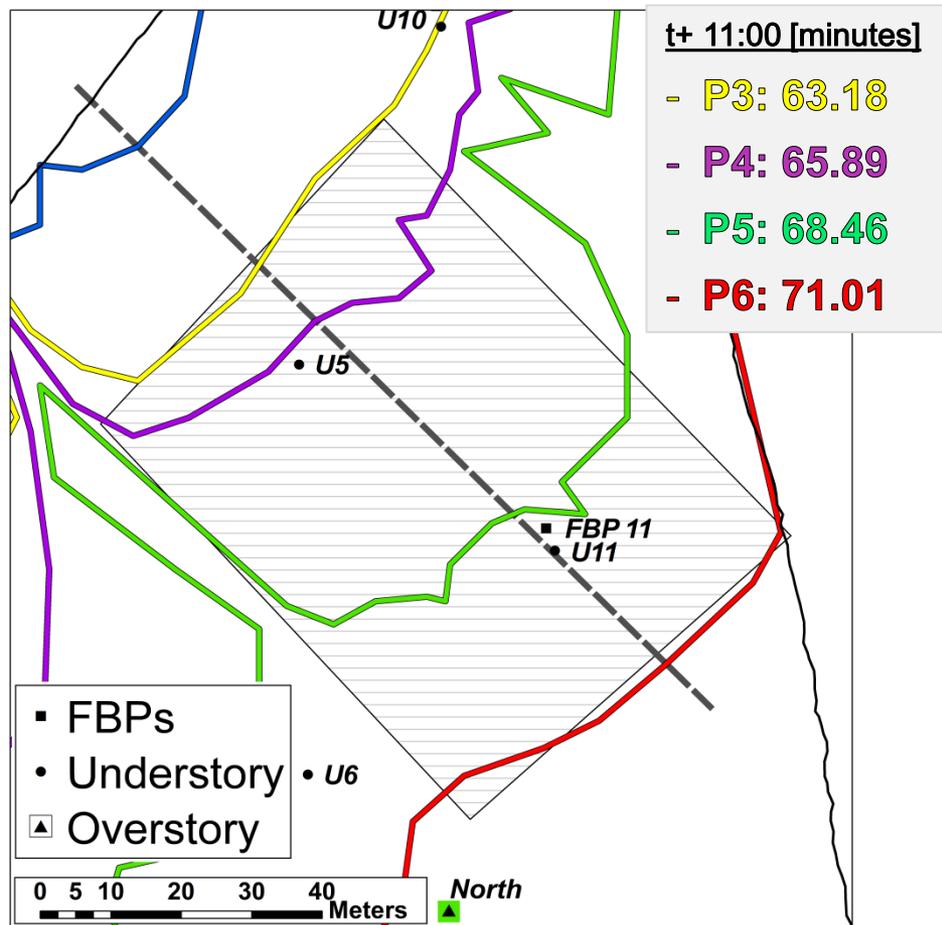
	1hr L+D
mean consumption [g·m ⁻²]	419.7

$$\text{Fireline Intensity } I_f = ROS \cdot \Delta m \cdot h$$

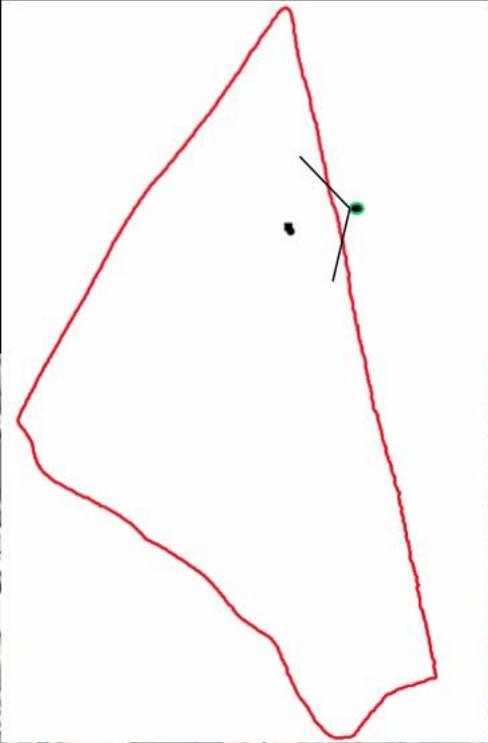
U5: ~1500-4100 kW·m⁻¹ U11: ~4700-6000 kW·m⁻¹

Plot 5 & 11

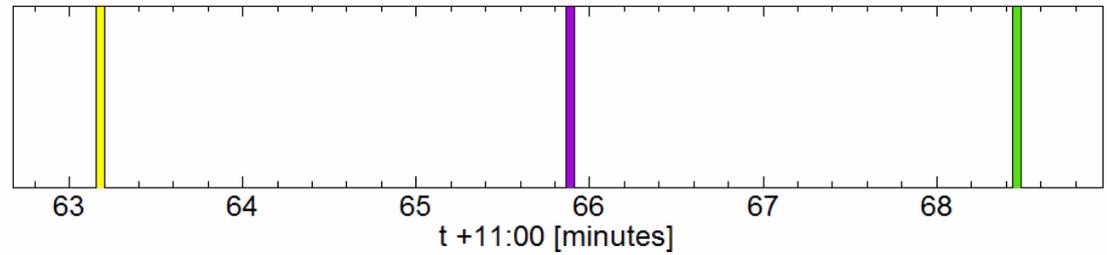
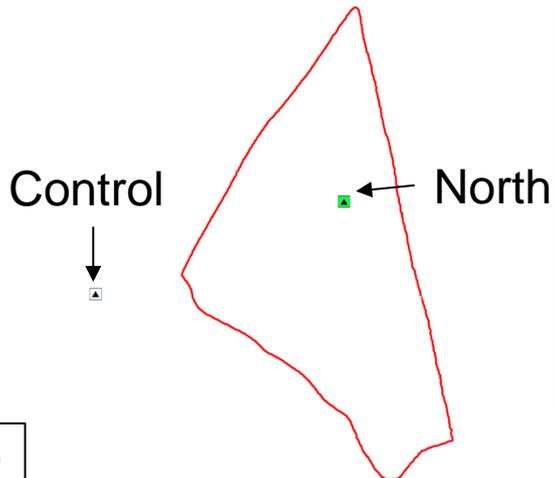
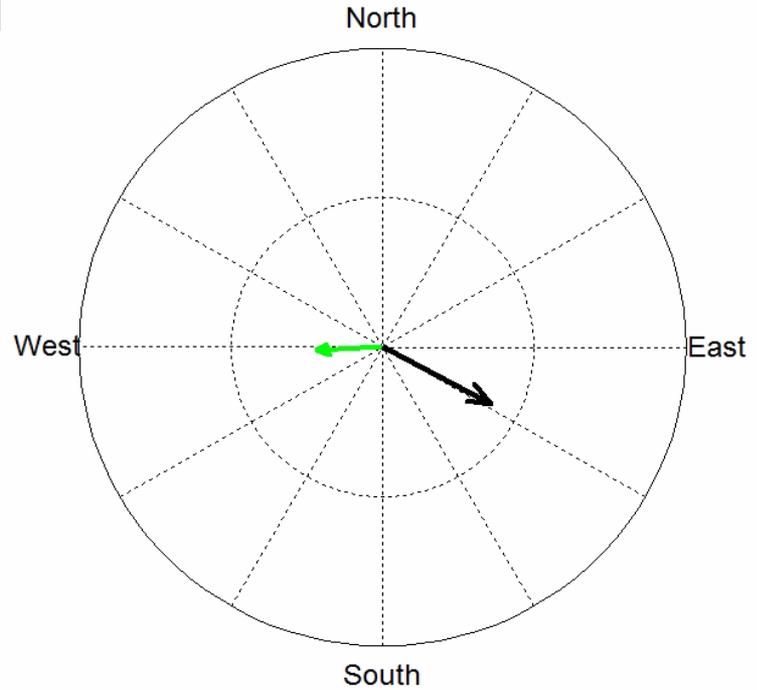
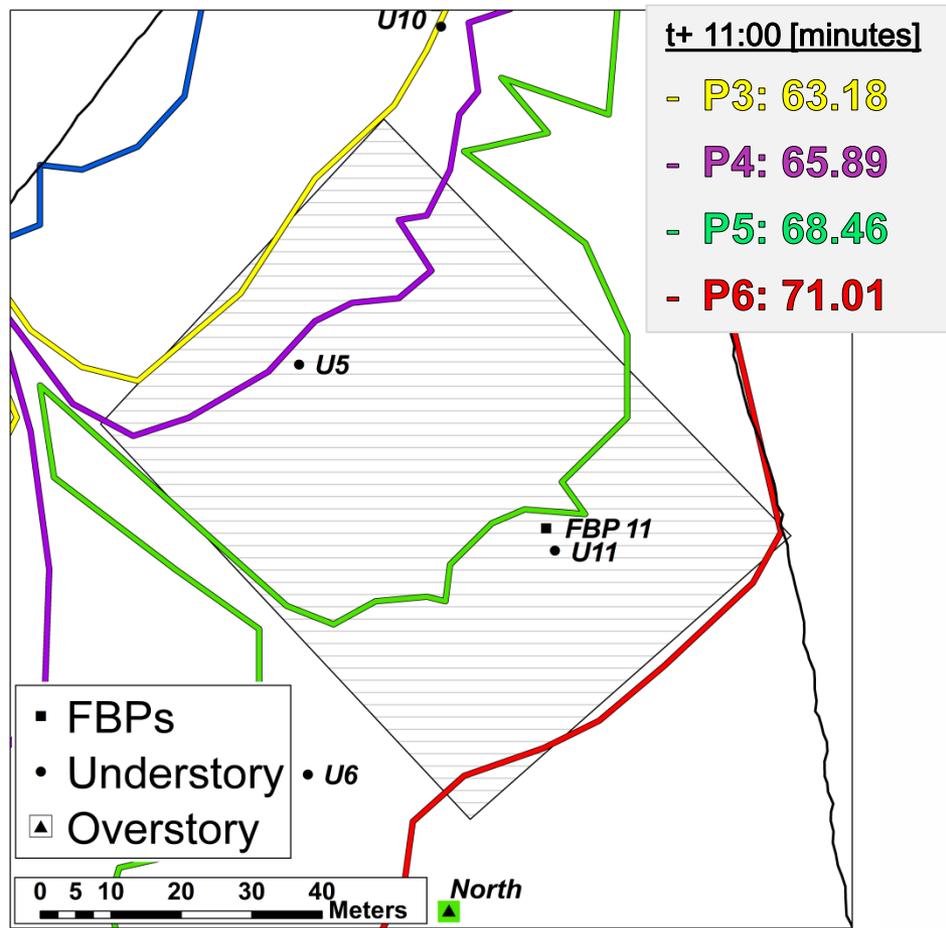
Un-calibrated LiDAR



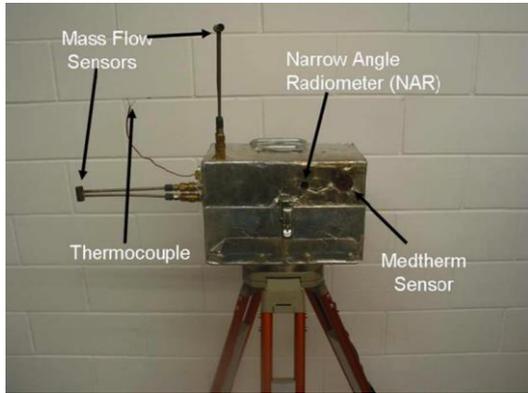
Plot 11



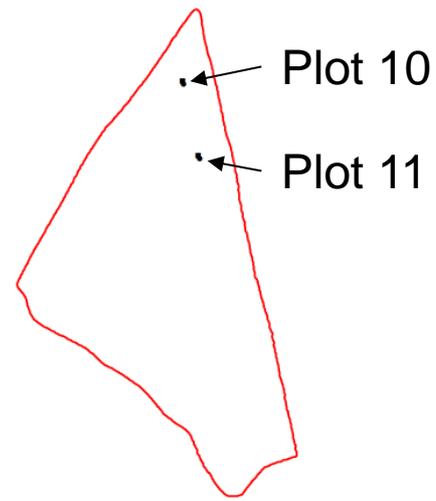
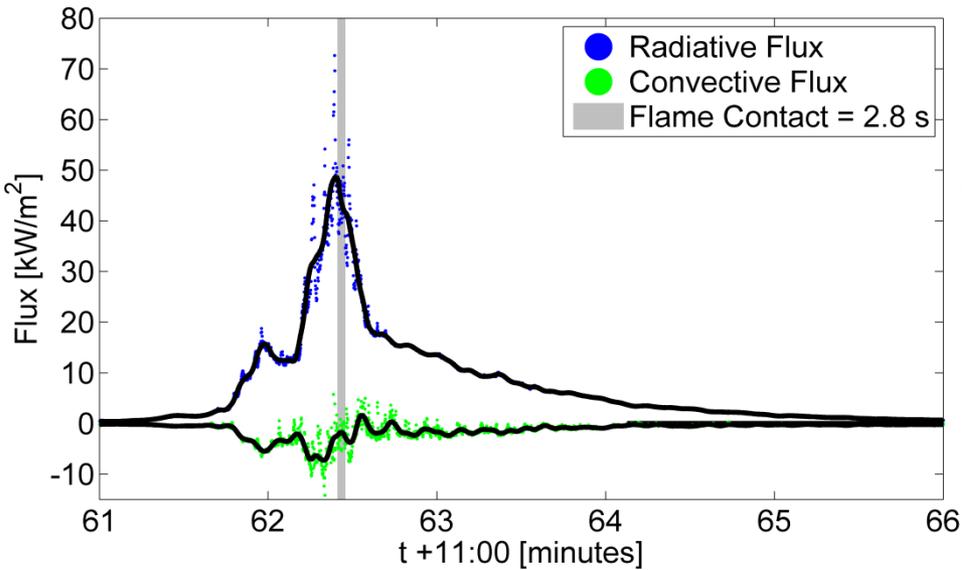
Plot 5 & 11



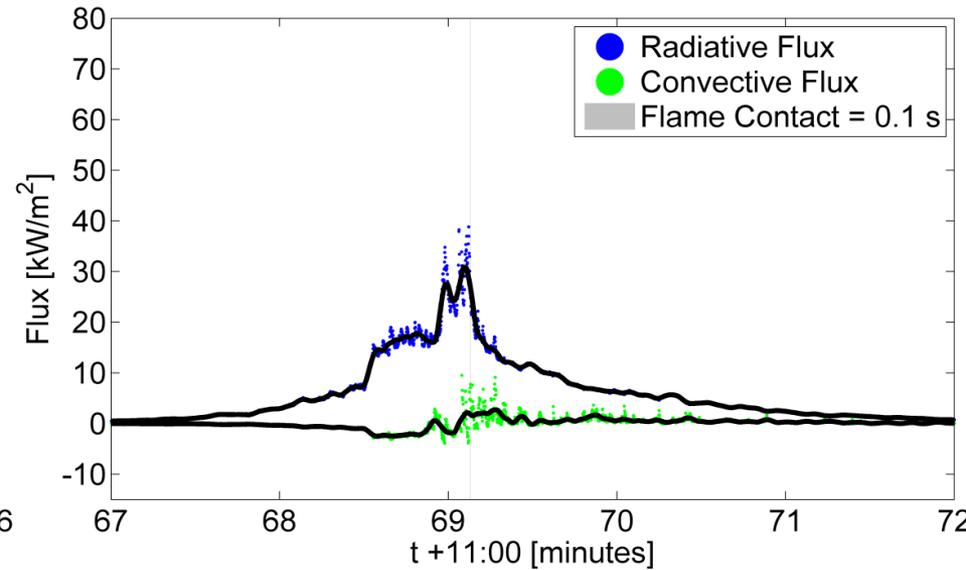
Local Heat Flux



Plot 10



Plot 11

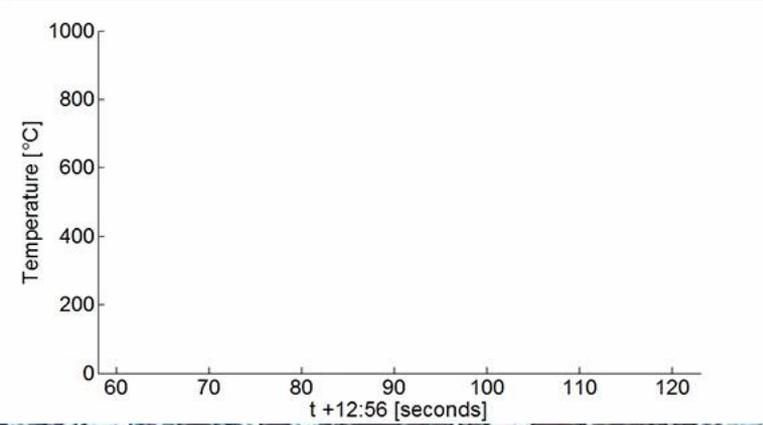


Year 2

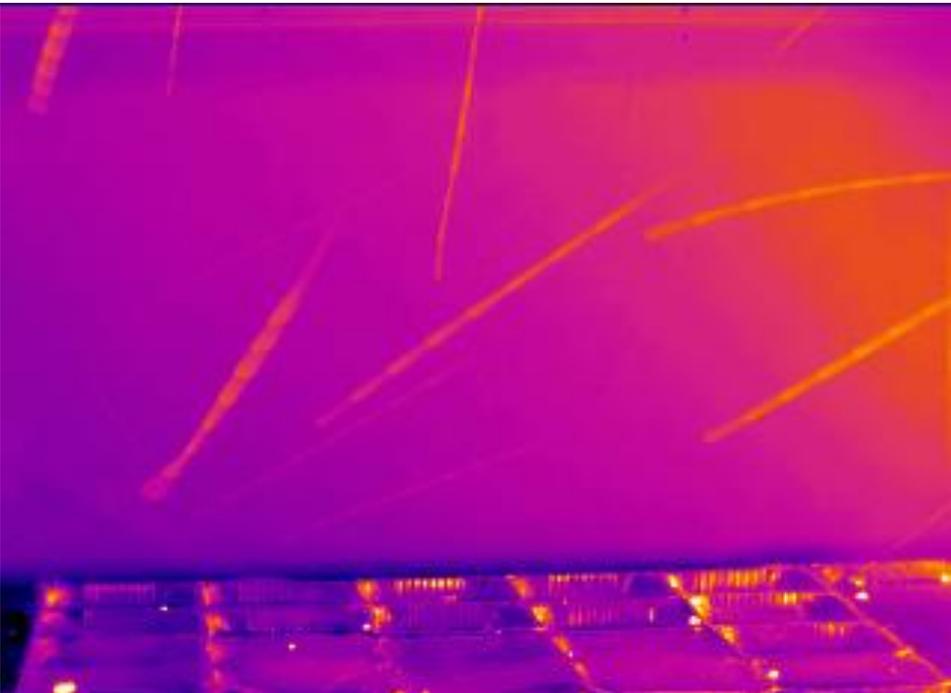
Preliminary Visual Results



Preliminary Visual Results



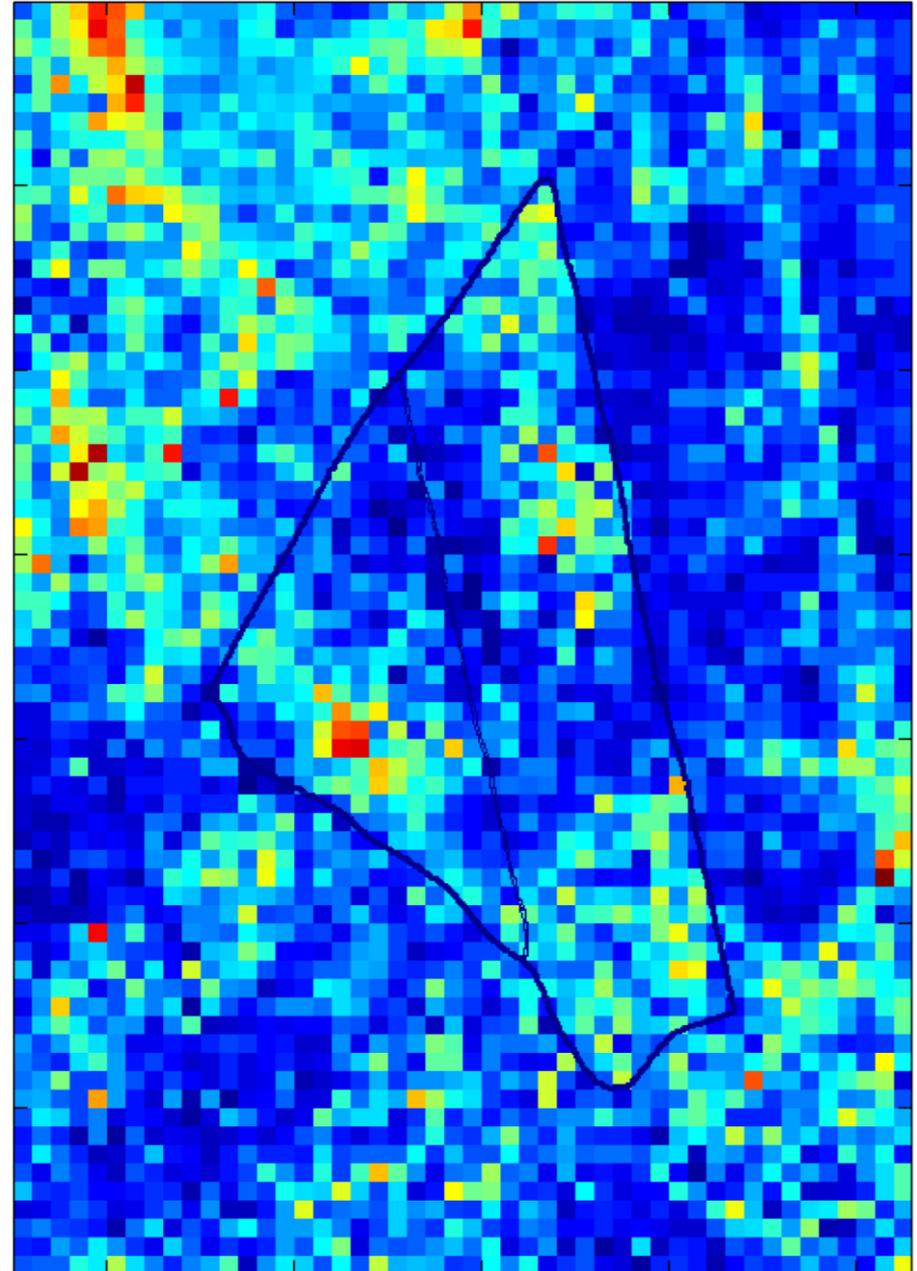
Other Investigations



Future Work and Conclusions

Modeling Challenges

- Numerical simulation requires higher spatial resolution than LiDAR data provides
 - Simple subdivision vs. linear interpolation vs. other (using canopy height model)??



Conclusions

- Experimental
 - Valuable data collected on fire behavior in a forested environment
 - Particularly as it relates to pre-fire fuel loading
 - Much more work to be done to thoroughly analyze results from both years
 - Both fire progression/behavior and total fuel consumption
- Numerical
 - Still in preliminary stages
 - Biggest challenge is the specification of fuel distribution

Questions?



Thank you to JFSP and NJFSS

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