Investigating fireline geometry processes and fuel pattern impacts with prescribed fire experiments and CFD modeling

International Workshop: New Remote Sensing Techniques for 3D Forest Structure Mapping and Wildfire Modeling
May 21-22, 2024

Chris Moran, Carl Seielstad, Anthony Marcozzi, Marta Jerebets, Anna Vonessen, Mary Brady, Valentijn Hoff, Lloyd Queen, Russ Parsons, Sarah Flanary, etc.!!!

National Center for Landscape Fire Analysis

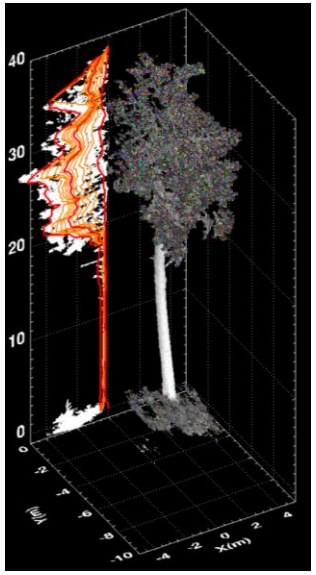
22+ Years of

NATIONAL CENTER FOR LANDSCAPE FIRE ANALYSIS

UNIVERSITY OF MONTANA

Fire Science

- -Remote Sensing
- -Geospatial
- -Fuel Characterization
- -Fire Modeling



Workforce Training

- -Fire and Land Managers
- -Prescribed Fire
- -Graduate Degrees
  - MS and PhD
- -Undergraduate
  - Fire Science Minor

Science and Technology Transfer

- -Incident Management Teams
- -Wildfire Assignments
- -Prescribed Fire
- -Tool and Database Development

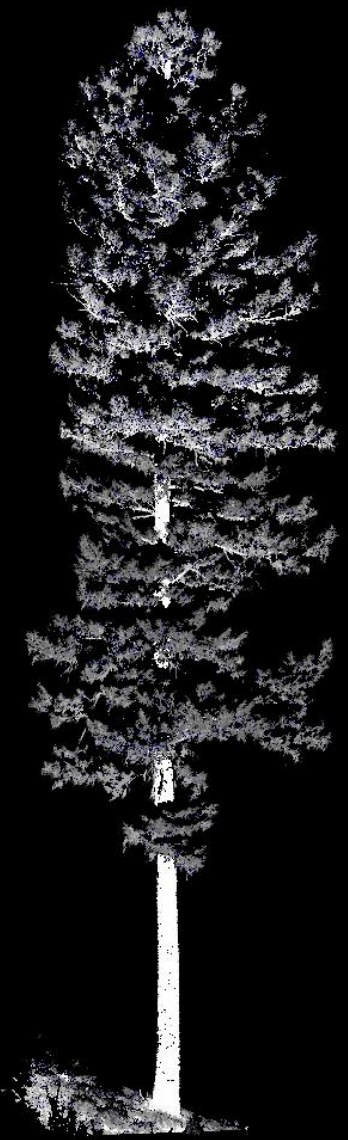
Outline

- Survey of 3D Data and Fuels
- Survey of Fire Behavior Data Collected
- Specifically Address Three Burn Experiments
- Fire Modeling Early Results and Directions

Fire Science

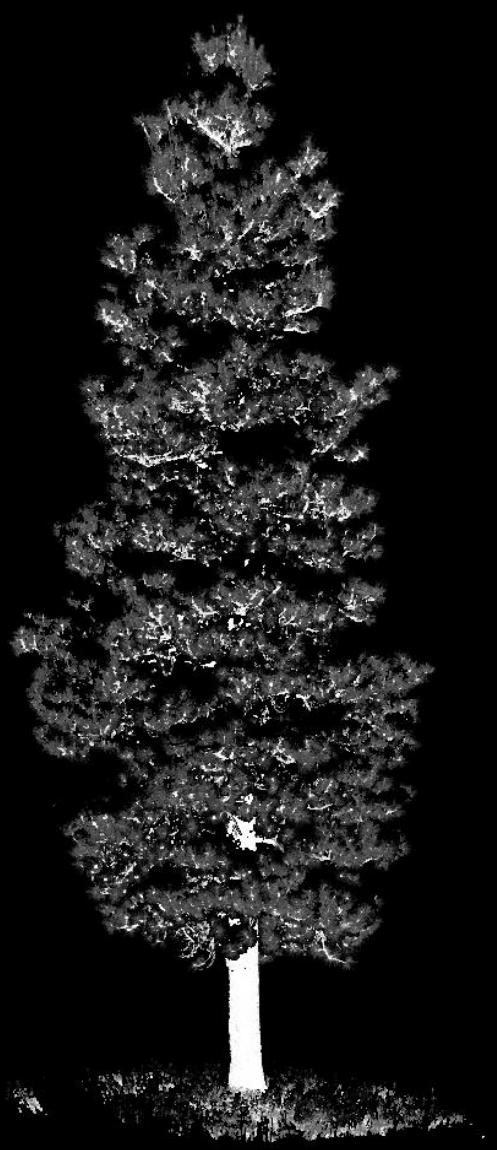
- Remote Sensing
  - LiDAR
    - ALS, TLS, Drone
  - Thermal
    - Drone, Ground-Based
  - Multispectral
    - Satellite, Drone
  - Hyperspectral
    - Drone

Subalpine Fir

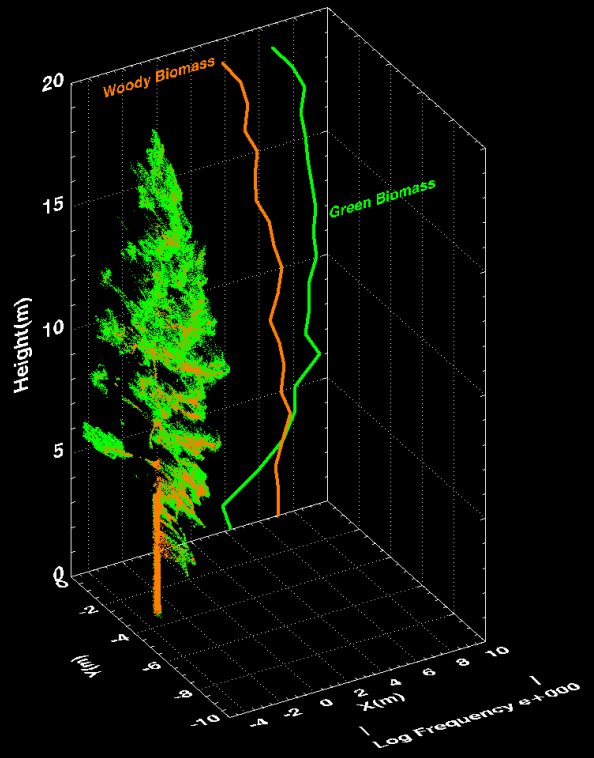


Douglas Fir

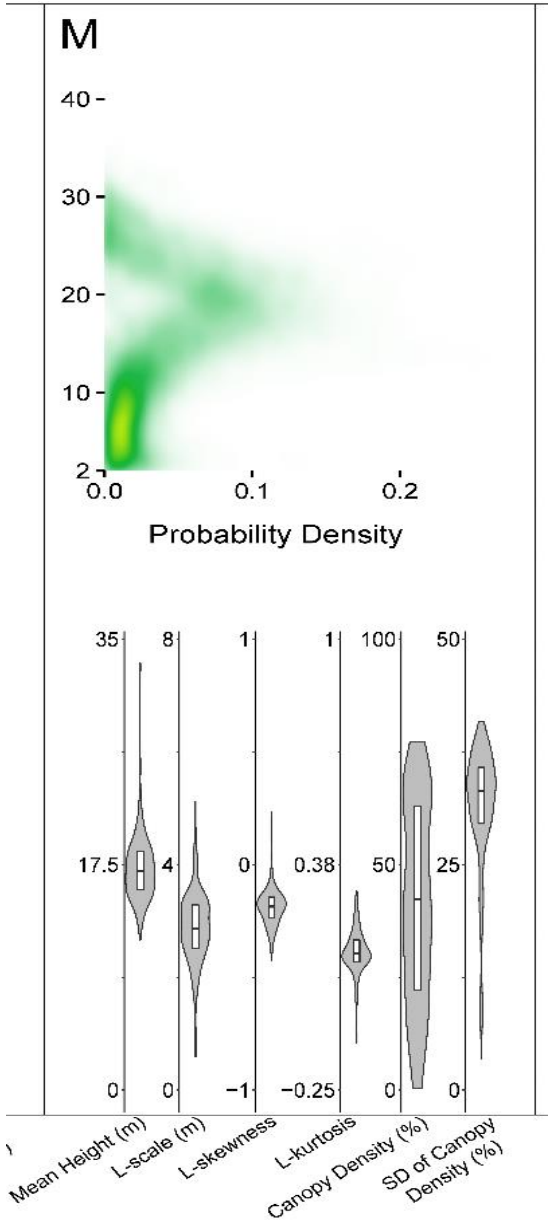
Grand Fir

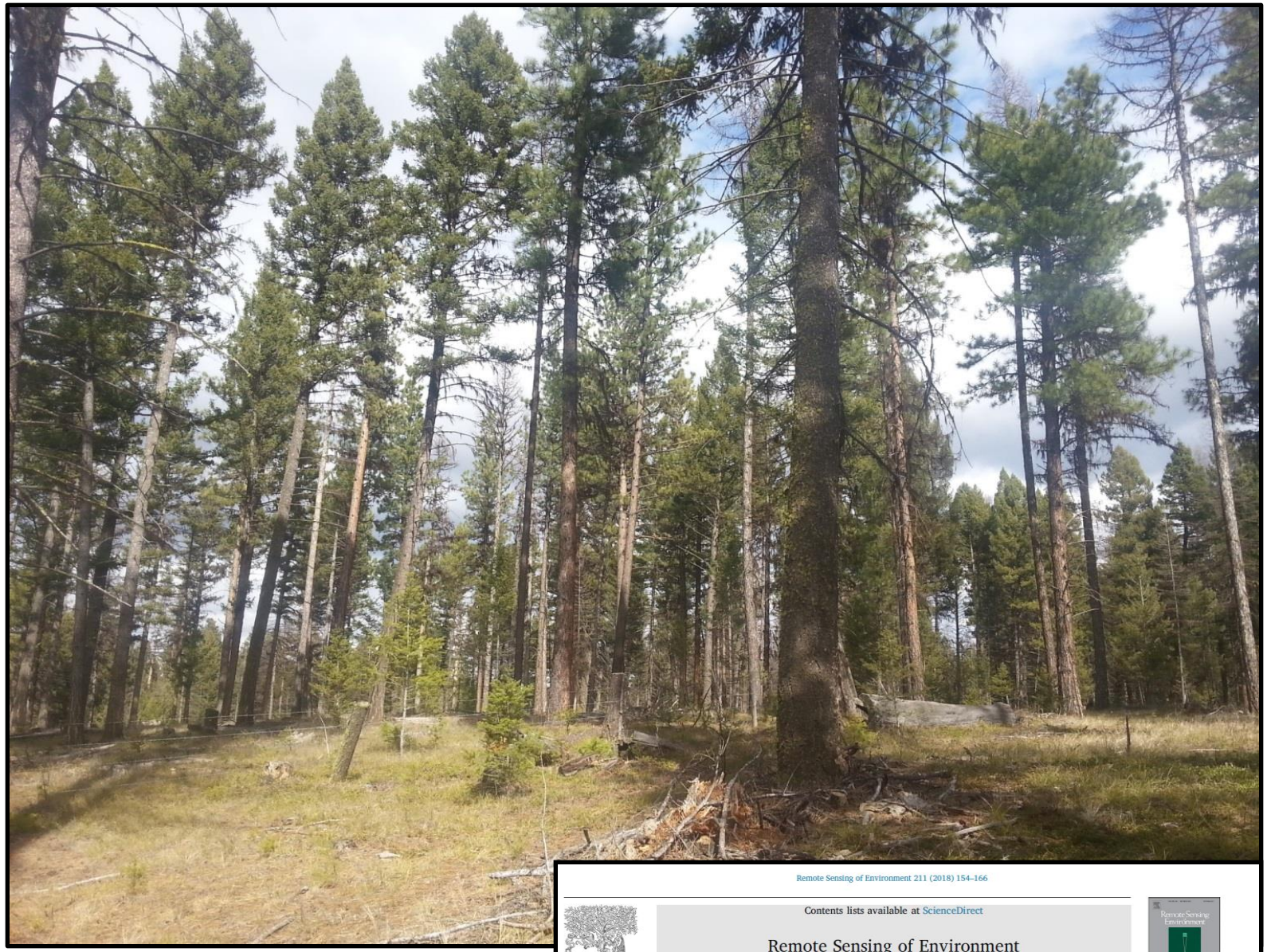


Ponderosa Pine



Ferrarese et al. 2015





Remote Sensing of Environment 211 (2018) 154–166

Contents lists available at ScienceDirect

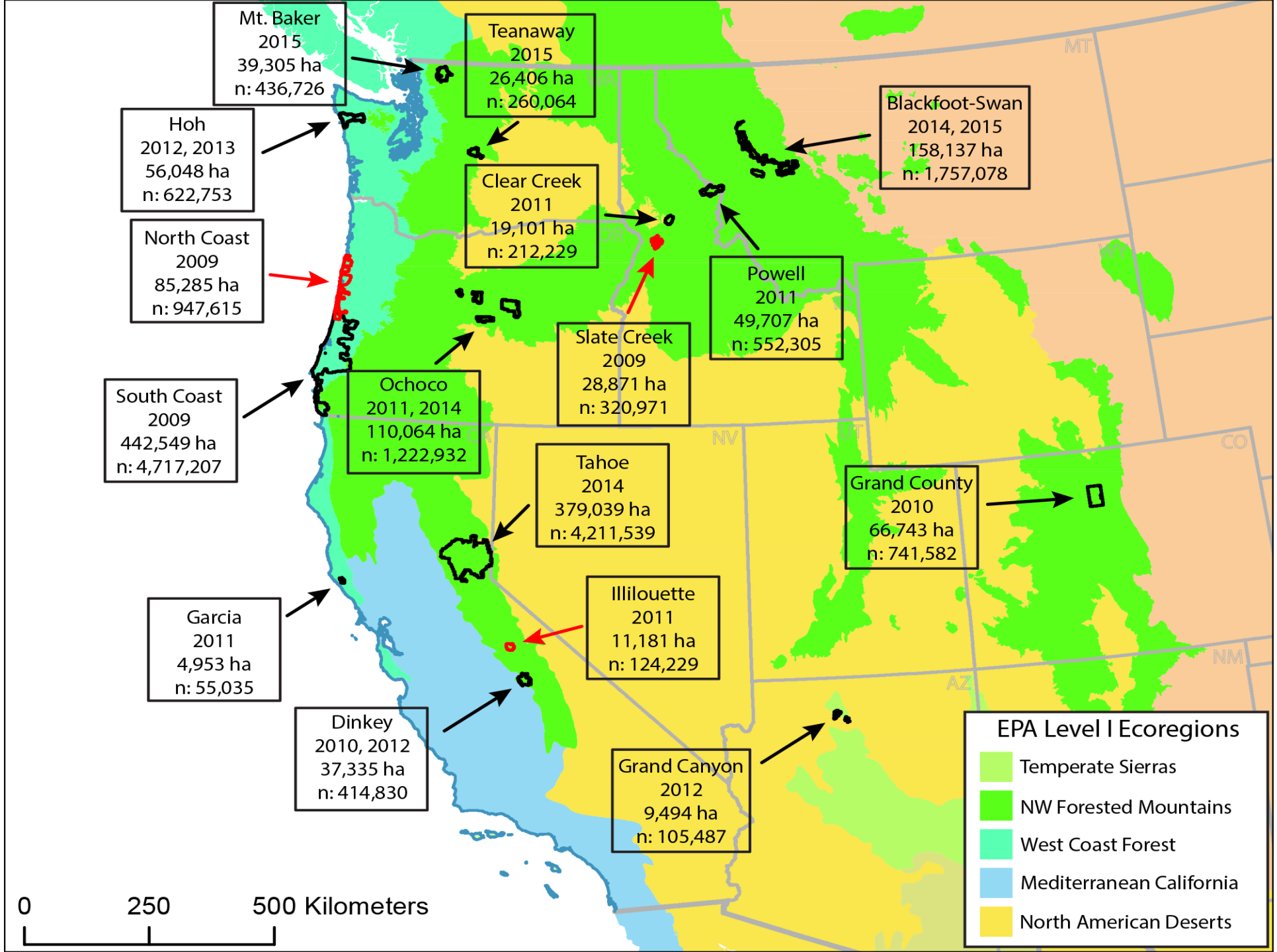
Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

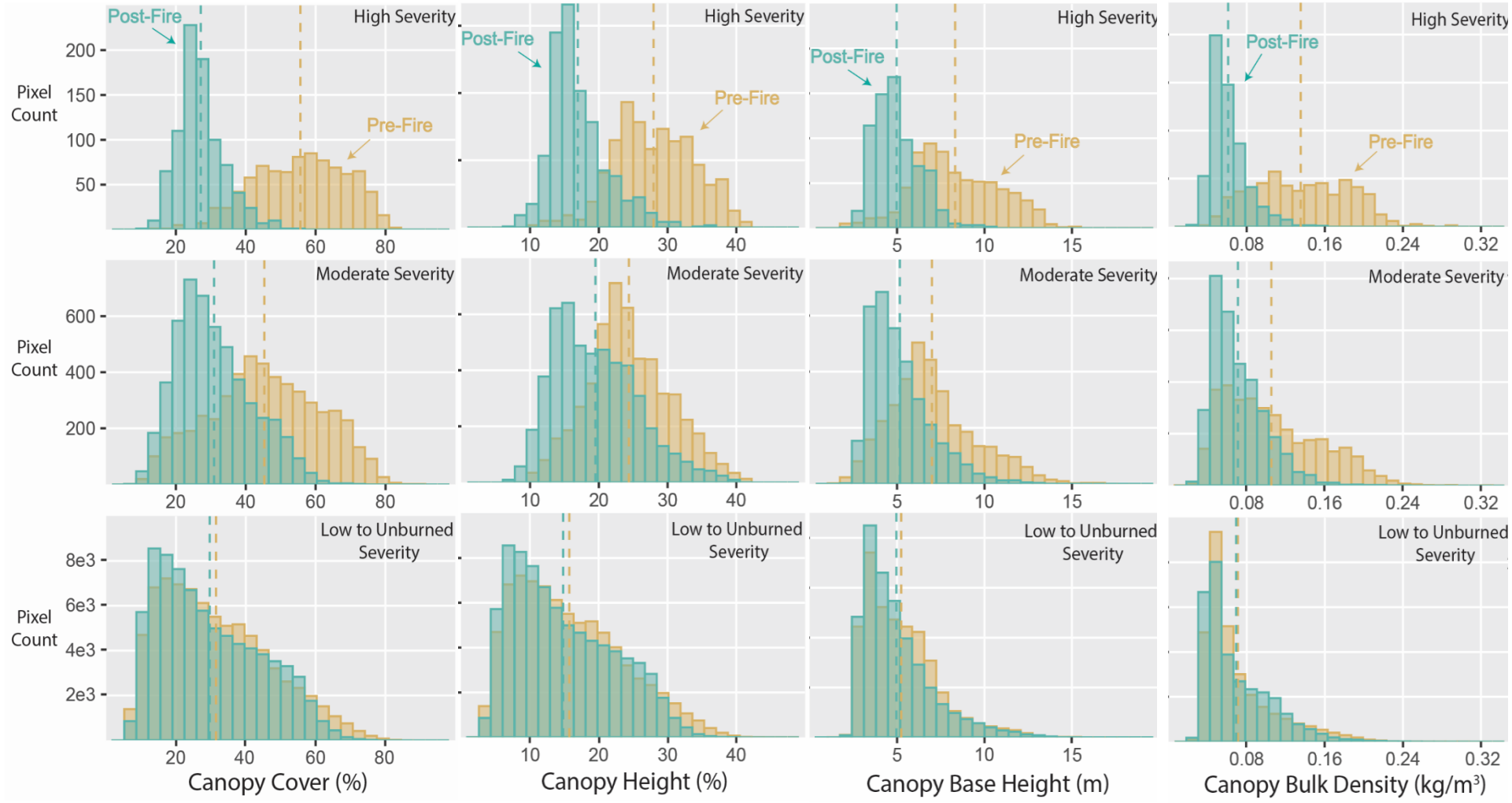
A data-driven framework to identify and compare forest structure classes using LiDAR

Christopher J. Moran*, Eric M. Rowell, Carl A. Seielstad

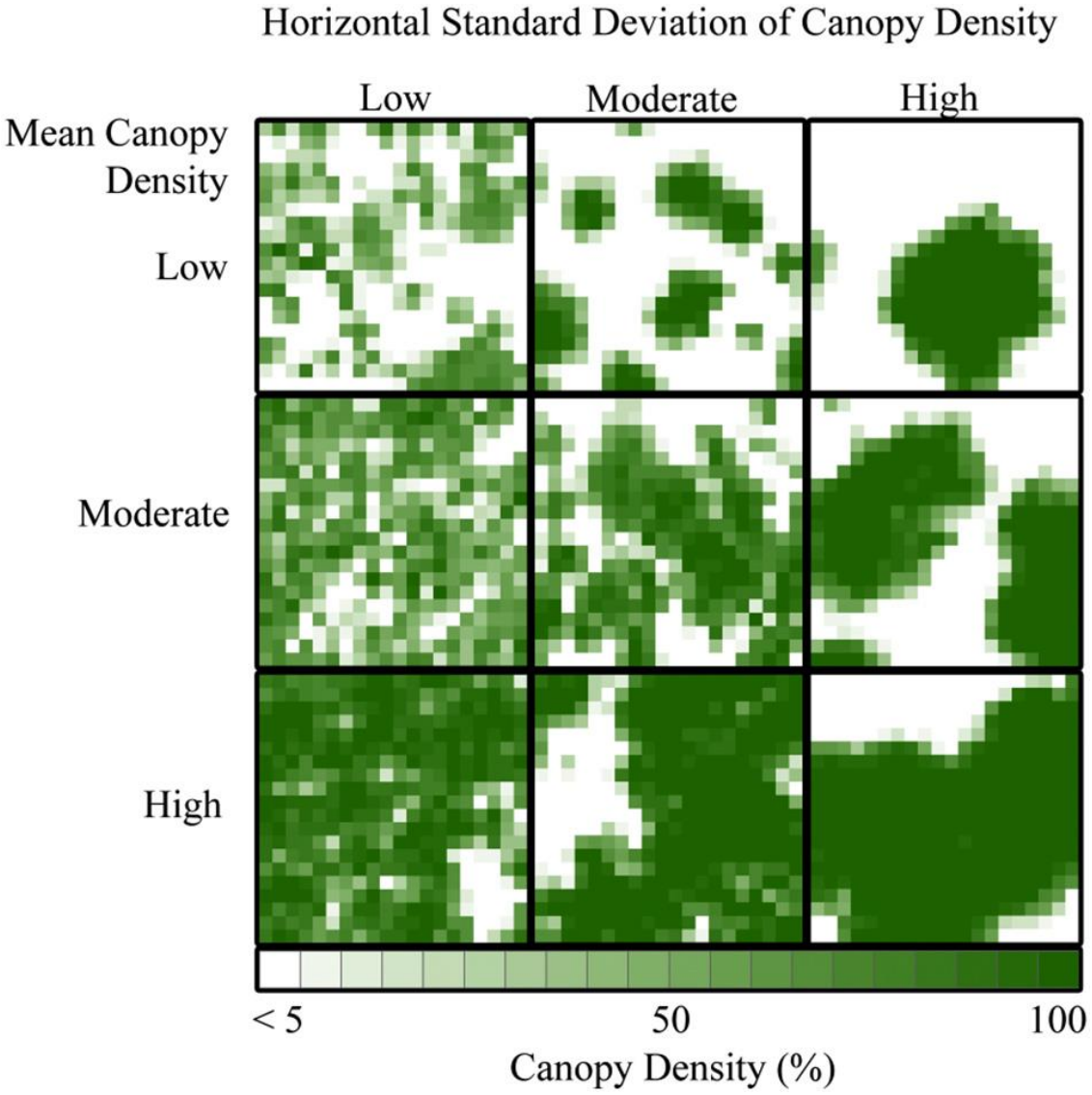
National Center for Landscape Fire Analysis, University of Montana, Missoula, MT, United States


Mt. Baker
2015
39,305 ha
n: 436,726
Teanaway
2015
26,406 ha
n: 260,064
Blackfoot-Swan
2014, 2015
158,137 ha
n: 1,757,078
Hoh
2012, 2013
56,048 ha
n: 622,753
Clear Creek
2011
19,101 ha
n: 212,229
North Coast
2009
85,285 ha
n: 947,615
Powell
2011
49,707 ha
n: 552,305
Slate Creek
2009
28,871 ha
n: 320,971
Ochoco
2011, 2014
110,064 ha
n: 1,222,932
South Coast
2009
442,549 ha
n: 4,717,207
Tahoe
2014
379,039 ha
n: 4,211,539
Grand County
2010
66,743 ha
n: 741,582
Illilouette
2011
11,181 ha
n: 124,229
Garcia
2011
4,953 ha
n: 55,035
Dinkey
2010, 2012
37,335 ha
n: 414,830
Grand Canyon
2012
9,494 ha
n: 105,487
MT
WA
OR
WY
ID
NV
UT
CO
AZ
NM
0
250
500 Kilometers
EPA Level I Ecoregions
Temperate Sierras
NW Forested Mountains
West Coast Forest
Mediterranean California
North American Deserts

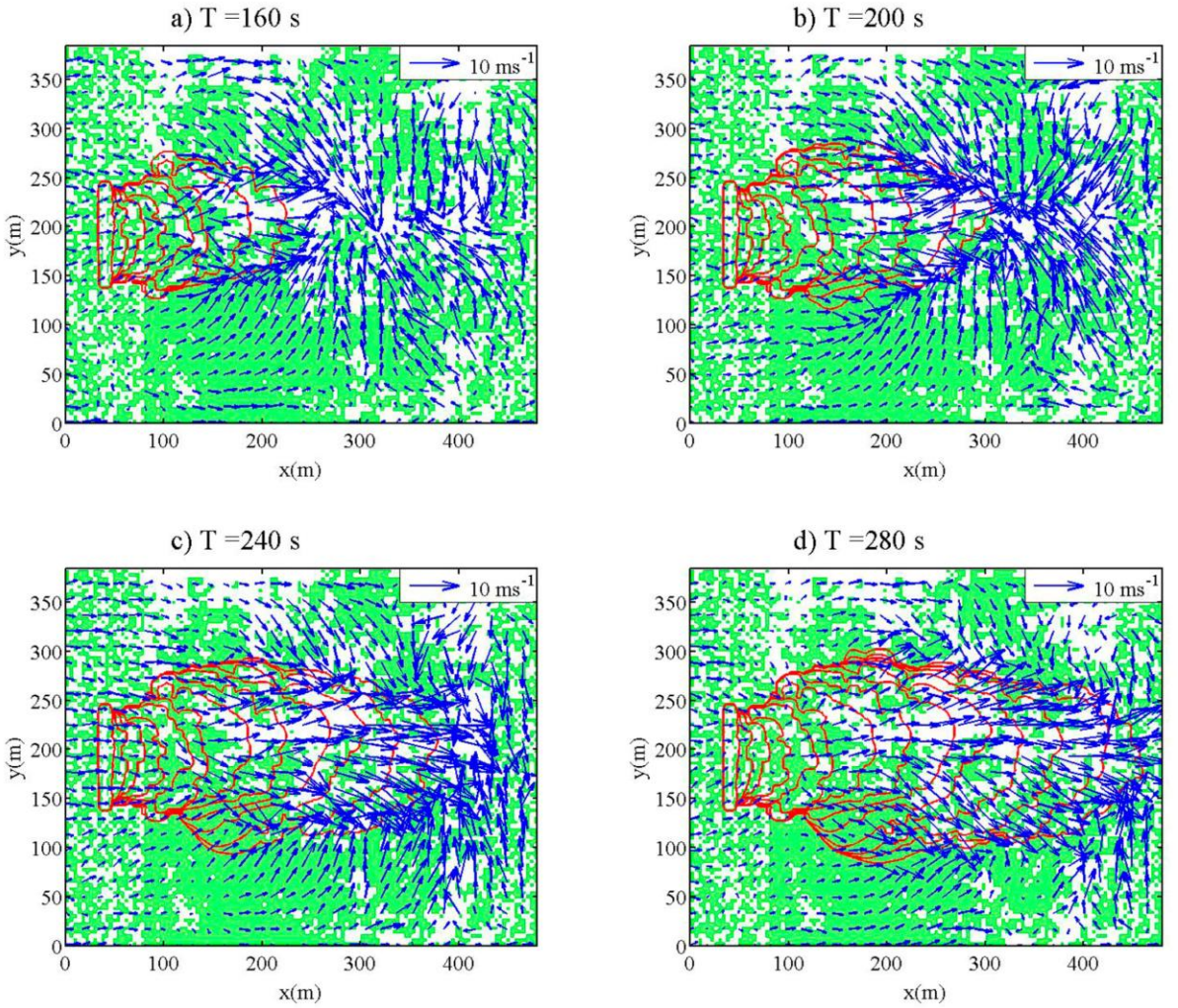
Model Response to Fire



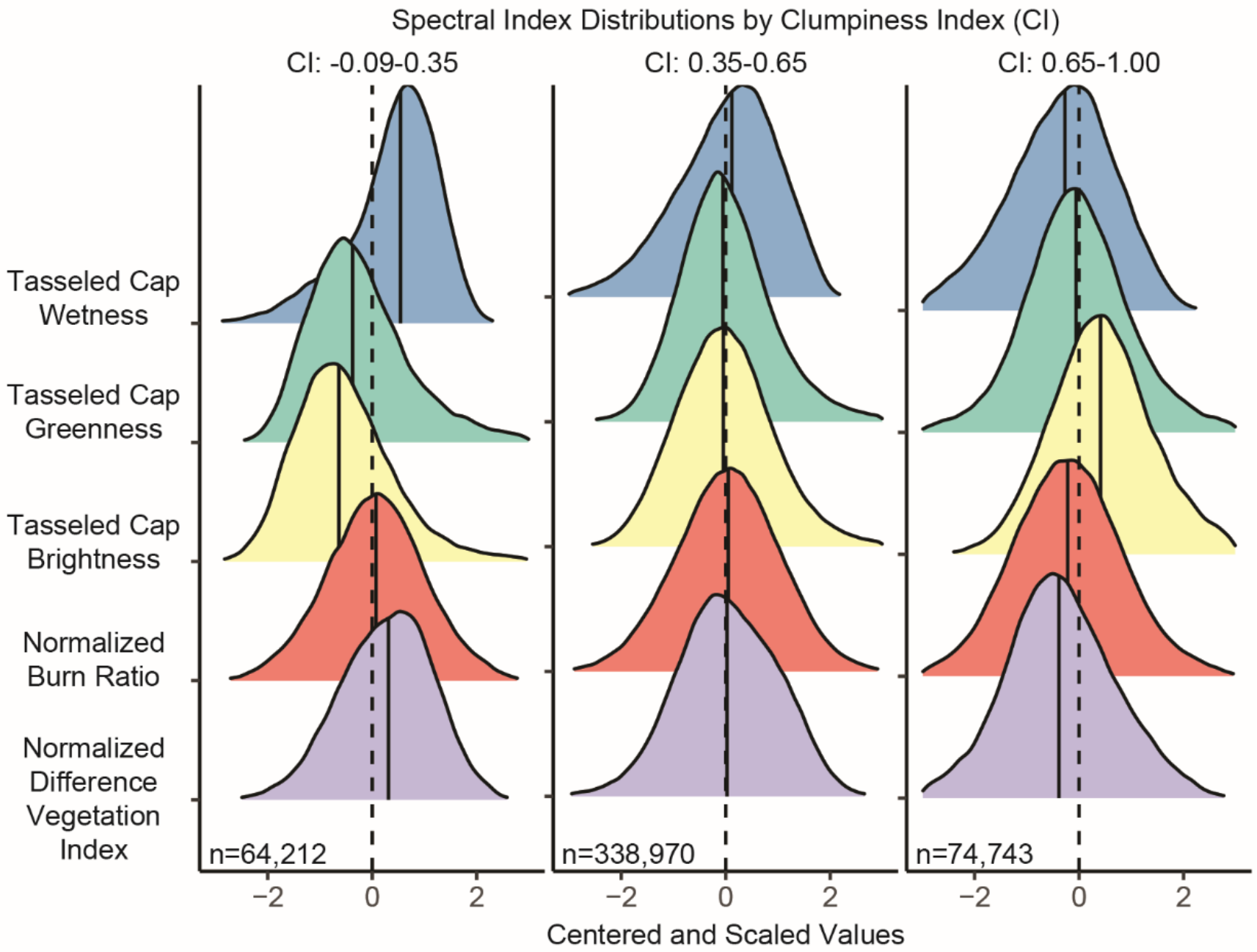
Moran et al. 2020



Moran et al. 2018

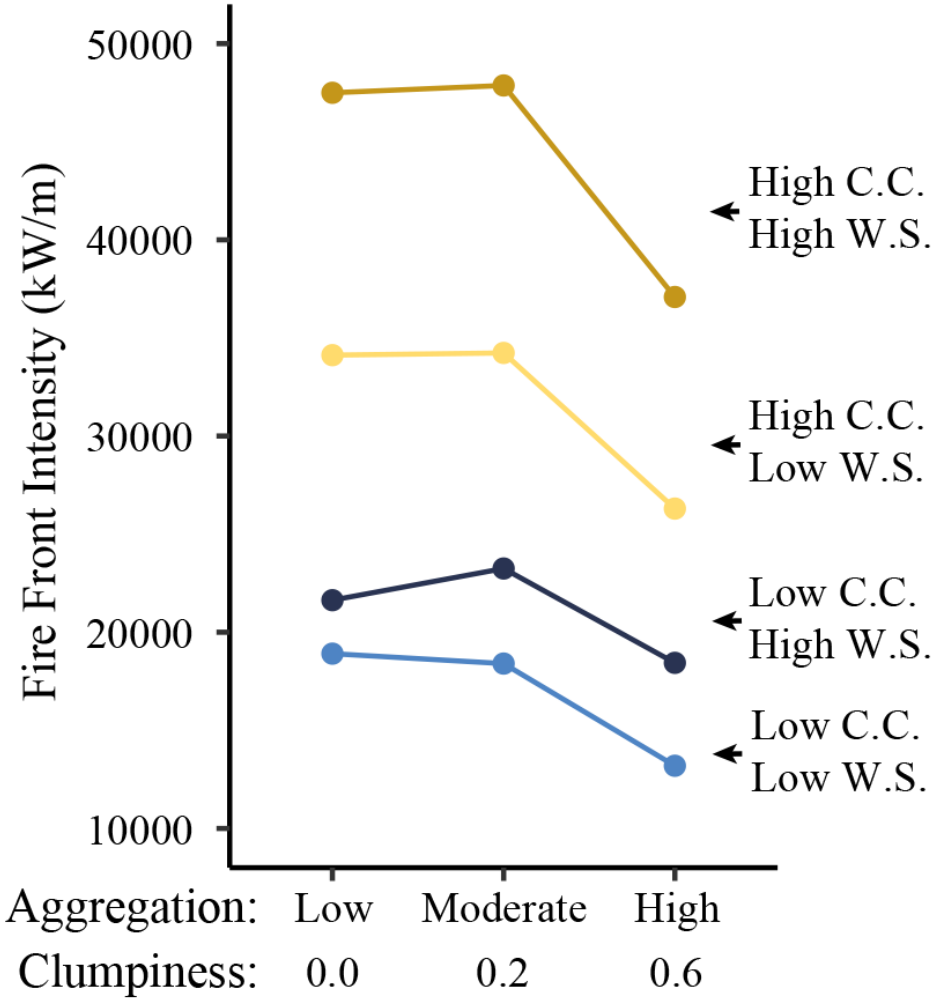


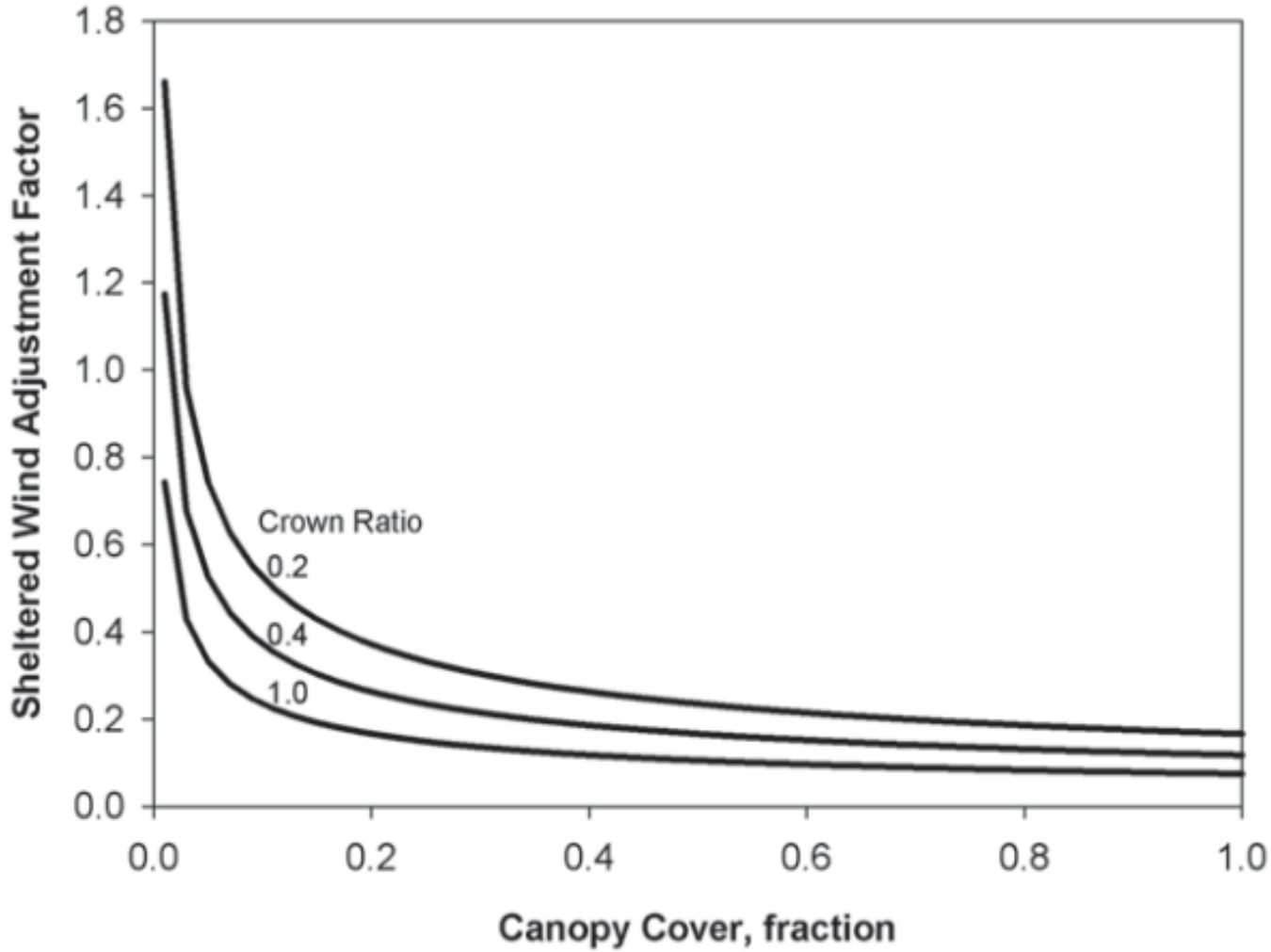
Parsons et al. 2017



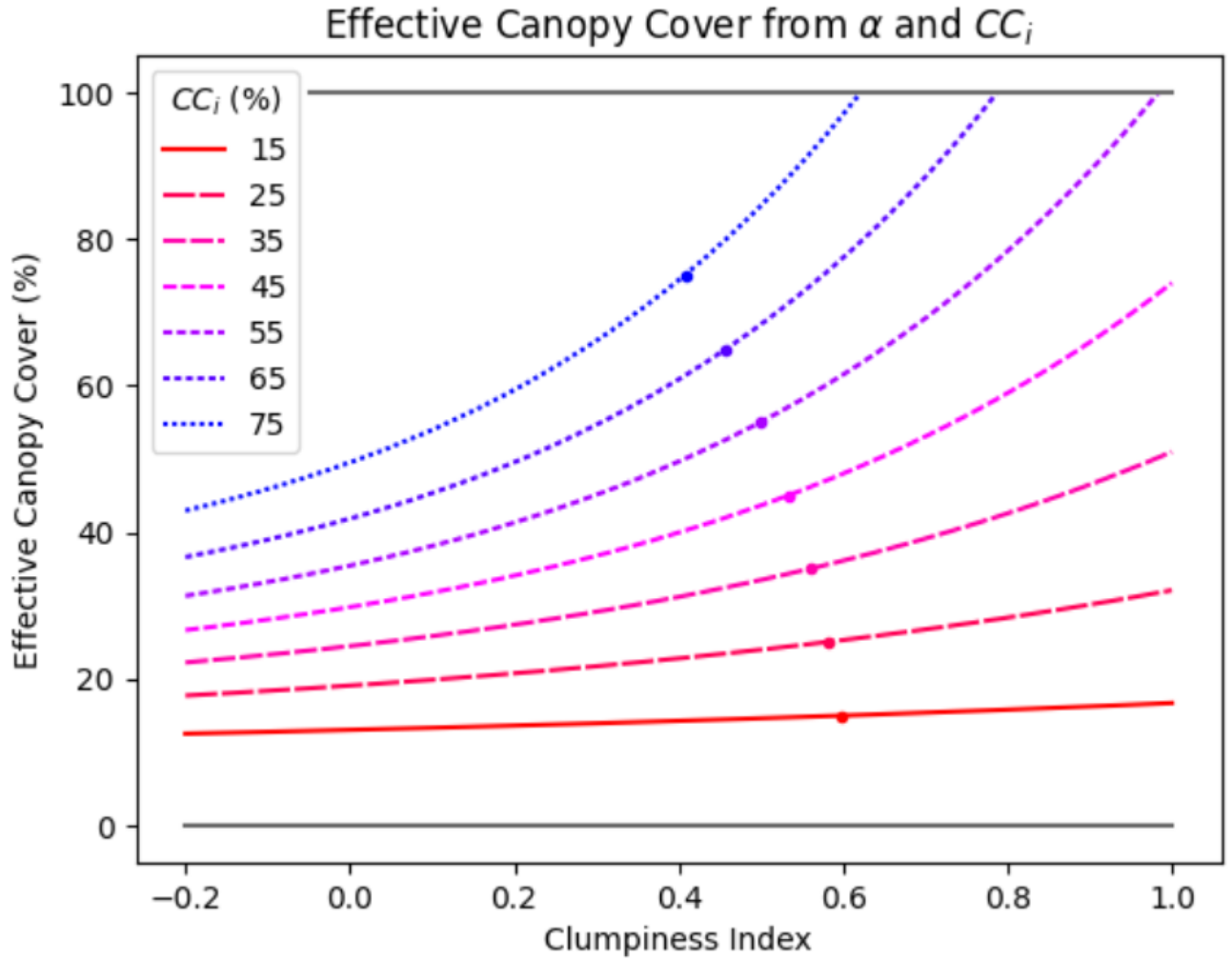
There is a Landsat spectral signal for the spatial arrangement of tree canopy

Application in Current Operational Fire Models





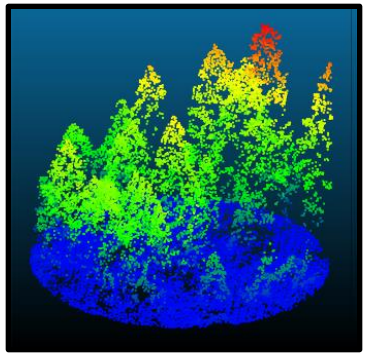
Modify Canopy Cover (CC) to represent the expected change in intensity based on CC arrangement



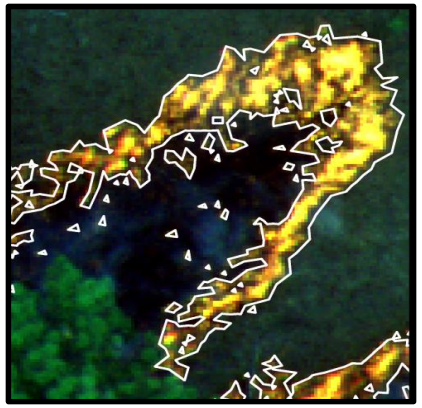
Conceptual Framework

"…understand the causes and consequences of pattern" - Levin

3D Fuels and Forest Structure

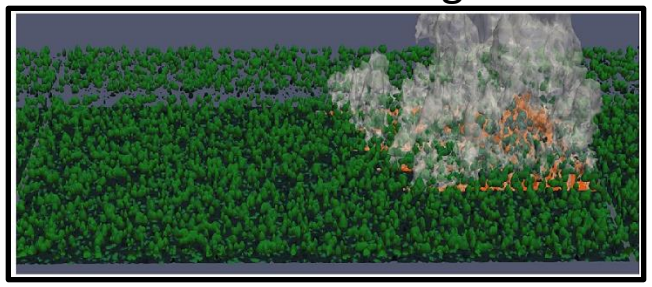


Fire Behavior



Prescribed Fire *Experiments*

Next Generation Fire Modeling



“Standard” Fire Data Collection

Pre-Fire

- 3D Point Clouds
  - SfM – RGB & Multi-spec
  - LiDAR
  - TLS
- Fuels Data
  - Photo Load
  - Clipped and Weighed
  - Moisture

During-Fire

- Thermal
  - Flir 7-14 micron
- Multi-Spectral
  - Micasense Rededge
- Weather Station

Post-Fire

- 3D Point Clouds
  - SfM – RGB & Multi-spec
  - LiDAR
  - TLS
- Fuels Data
  - Not much
  - Consumption on one burn

“Standard” Fire Data Collection

- 55 Plots: most 1 ha in area, with some pre-, during-, and post-fire data

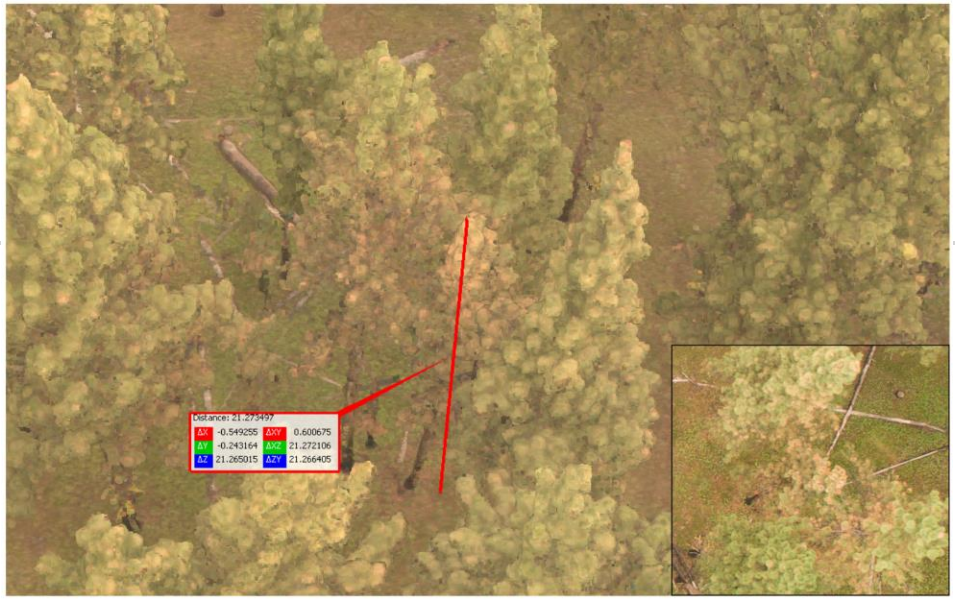
Minority have the "full-suite" - lots of tech

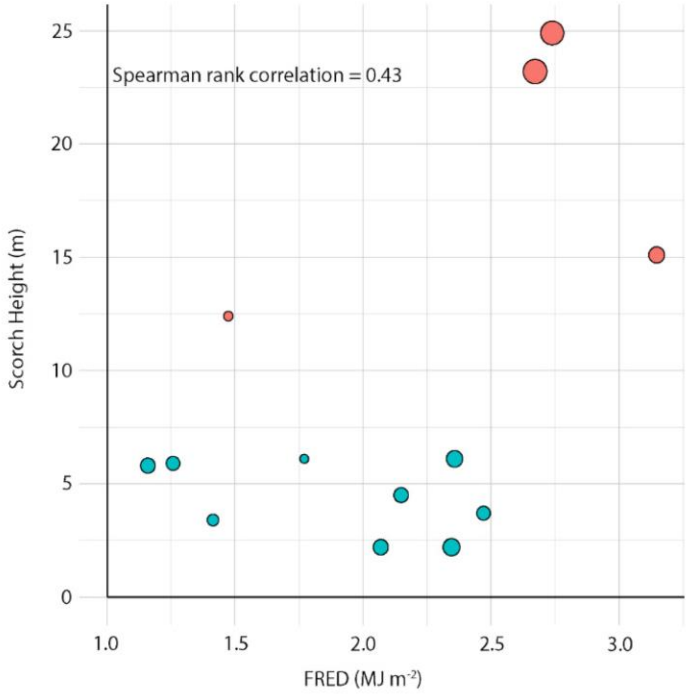
FastFuels UAS on-ramp research will translate to fuel inputs

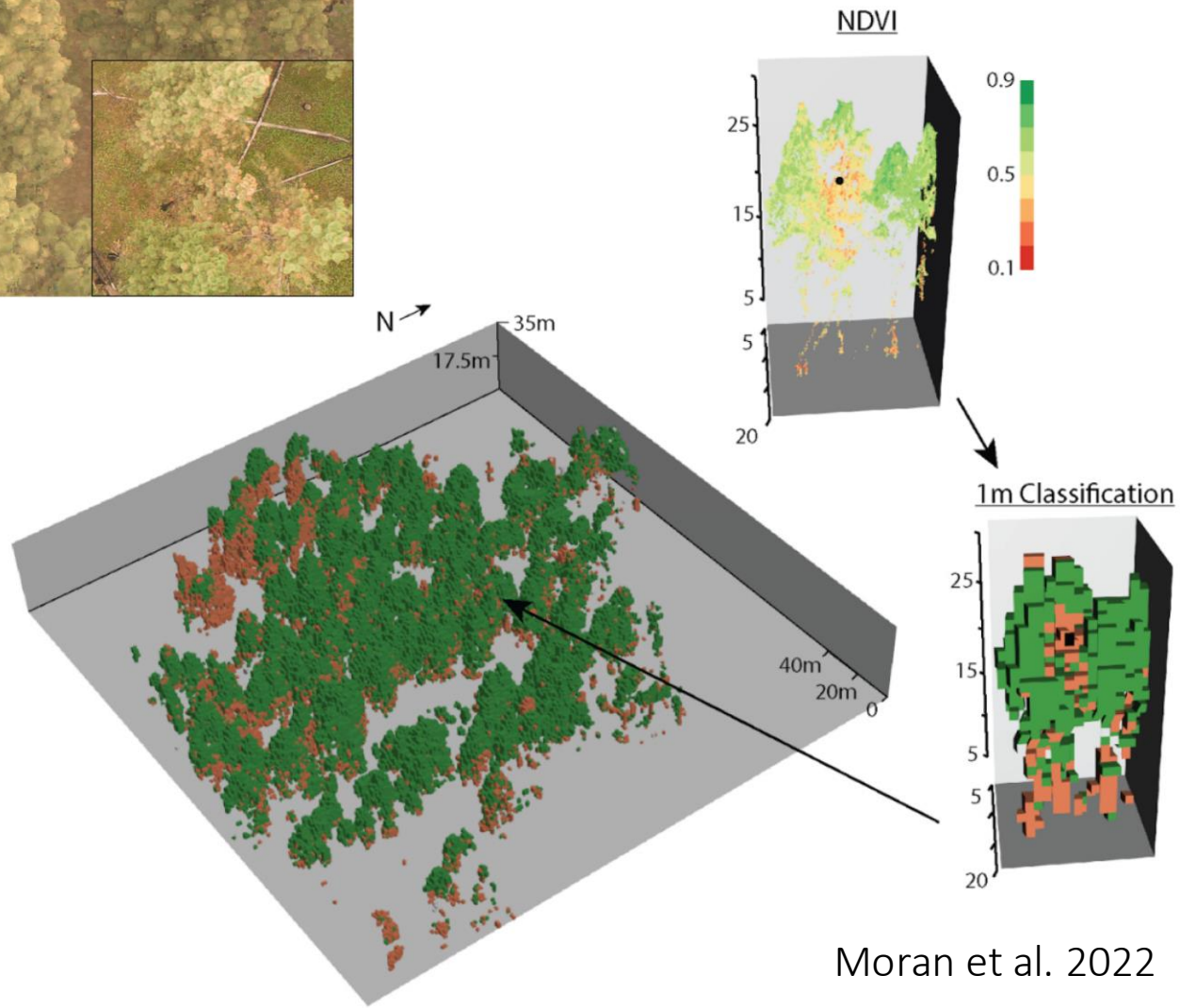
Fine-scale weather much more difficult....

Post-Fire

-







Moran et al. 2022

Data Useful for Modeling

A note on Validation:

~~Pixel-to-Pixel or Progression Matching~~

Pattern-Process Interactions We Care About

Prescribed Burn Experiments

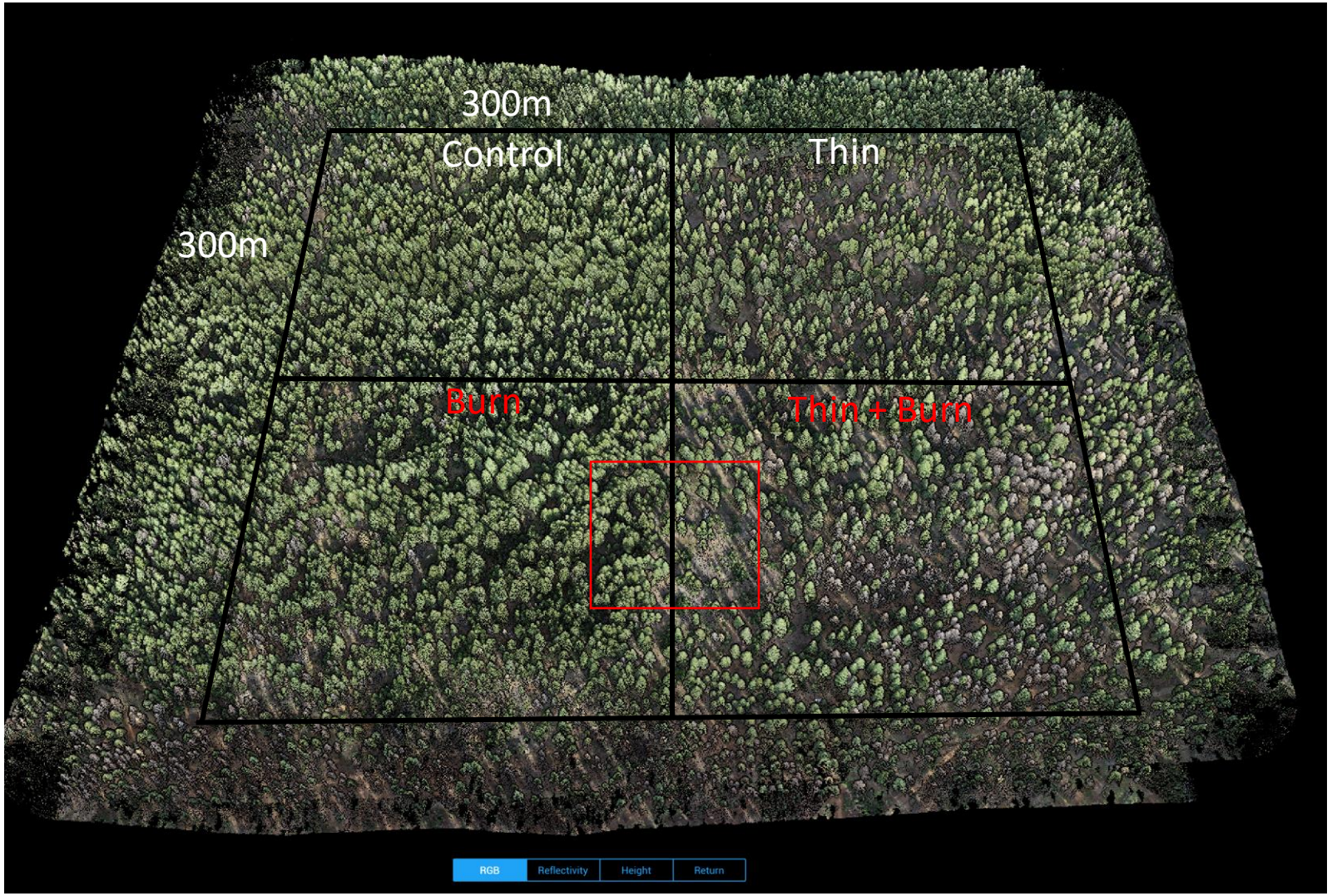
Crop Circles

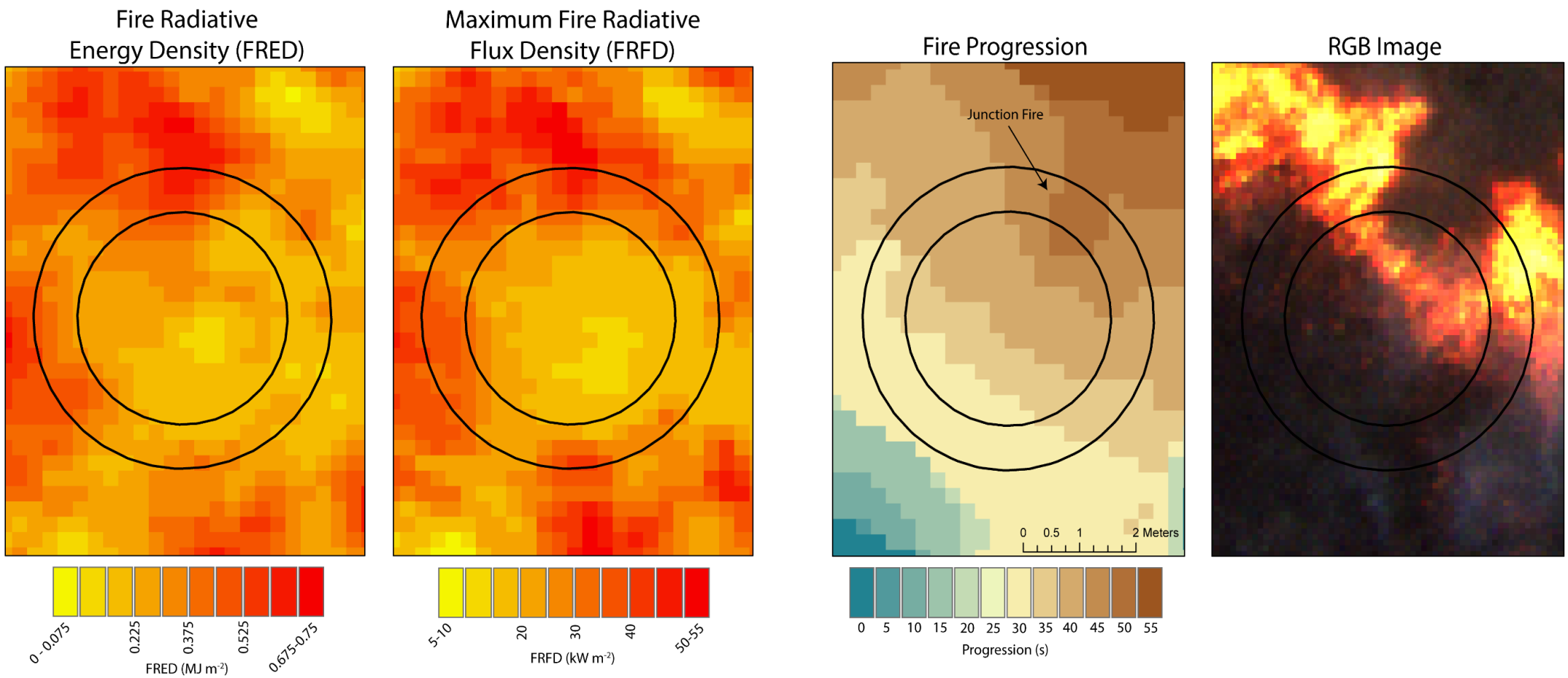
Chevrons

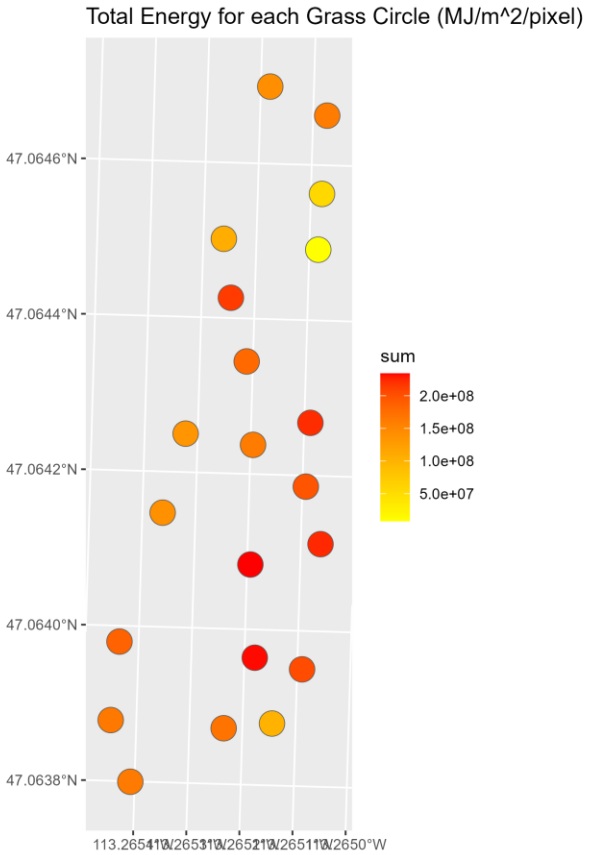
Fire-Fire Surrogate

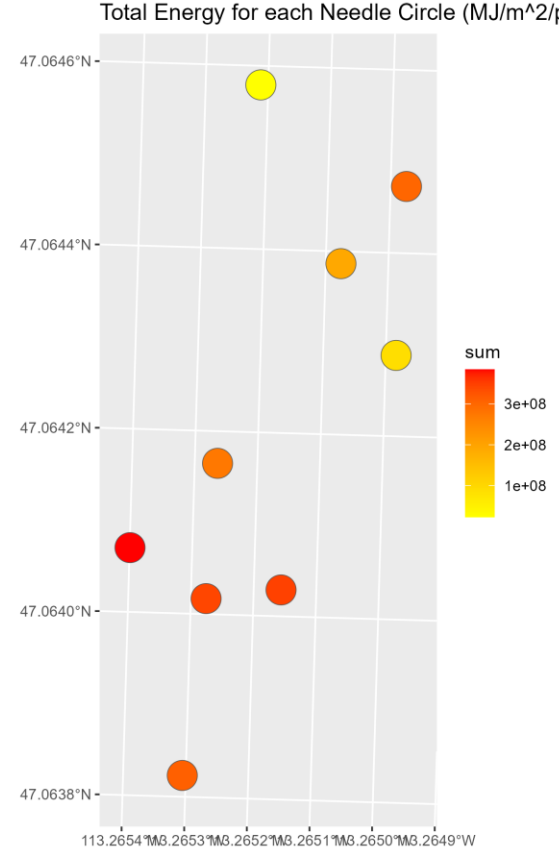
Lubrecht Fire-Fire Surrogate

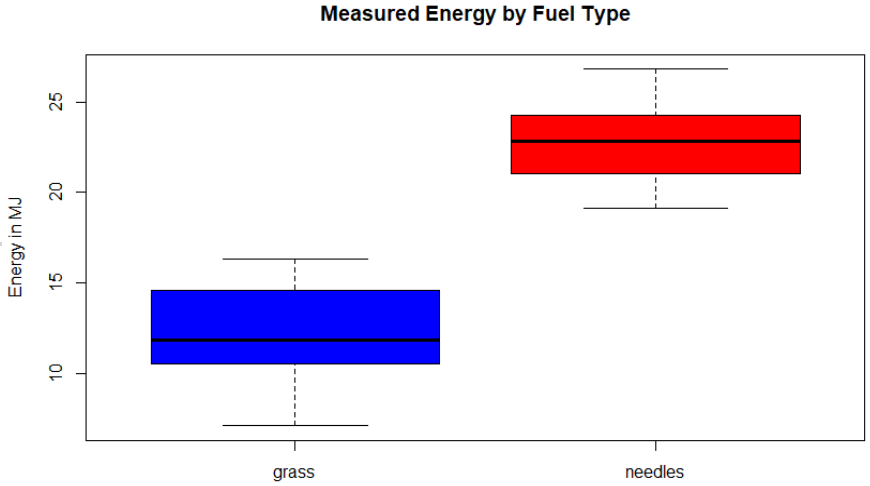
- Four treatment blocks, three replicates
  - Ongoing experiment originally conceived 20 years ago
  - Significant field data collected
  - Thinning Completed in 2023
  - Burns Completed Spring 2024

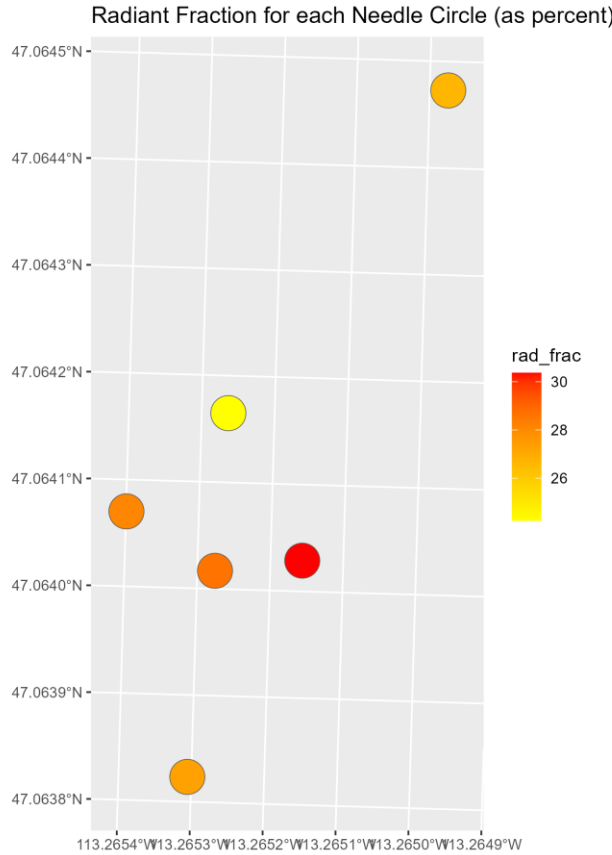



Fire Radiative
Energy Density (FRED)
Maximum Fire Radiative
Flux Density (FRFD)
Fire Progression
RGB Image
Junction Fire
0 0.5 1 2 Meters
0 - 0.075
0.225
0.375
0.525
0.675-0.75
FRED (MJ m-2)
5-10
20
30
40
50-55
FRFD (kW m-2)
0 5 10 15 20 25 30 35 40 45 50 55
Progression (s)


Total Energy for each Grass Circle (MJ/m^2/pixel)
47.0646°N
47.0644°N
47.0642°N
47.0640°N
47.0638°N
sum
2.0e+08
1.5e+08
1.0e+08
5.0e+07

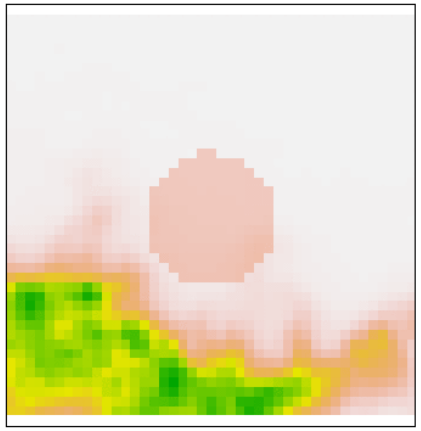

Total Energy for each Needle Circle (MJ/m^2/pixel)
47.0646°N
47.0644°N
47.0642°N
47.0640°N
47.0638°N
sum
3e+08
2e+08
1e+08


Measured Energy by Fuel Type
Energy in MJ
25
20
15
10
grass
needles

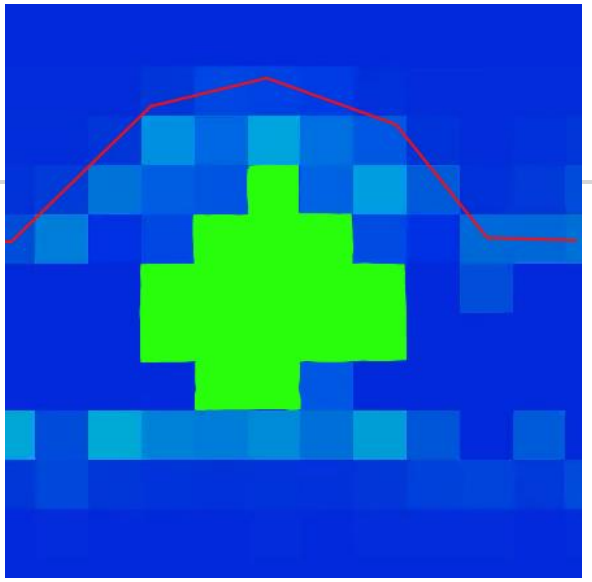

Radiant Fraction for each Needle Circle (as percent)
47.0645°N
47.0644°N
47.0643°N
47.0642°N
47.0641°N
47.0640°N
47.0639°N
47.0638°N
rad_frac
30
28
26

FDS Level Set 4

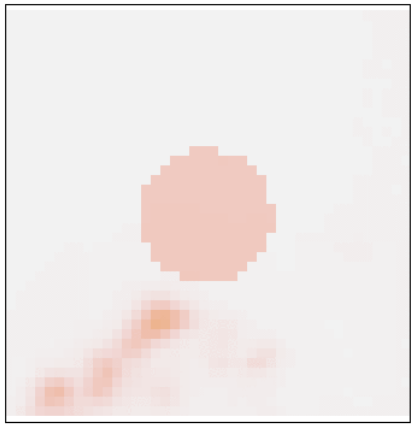
Comparable Observation

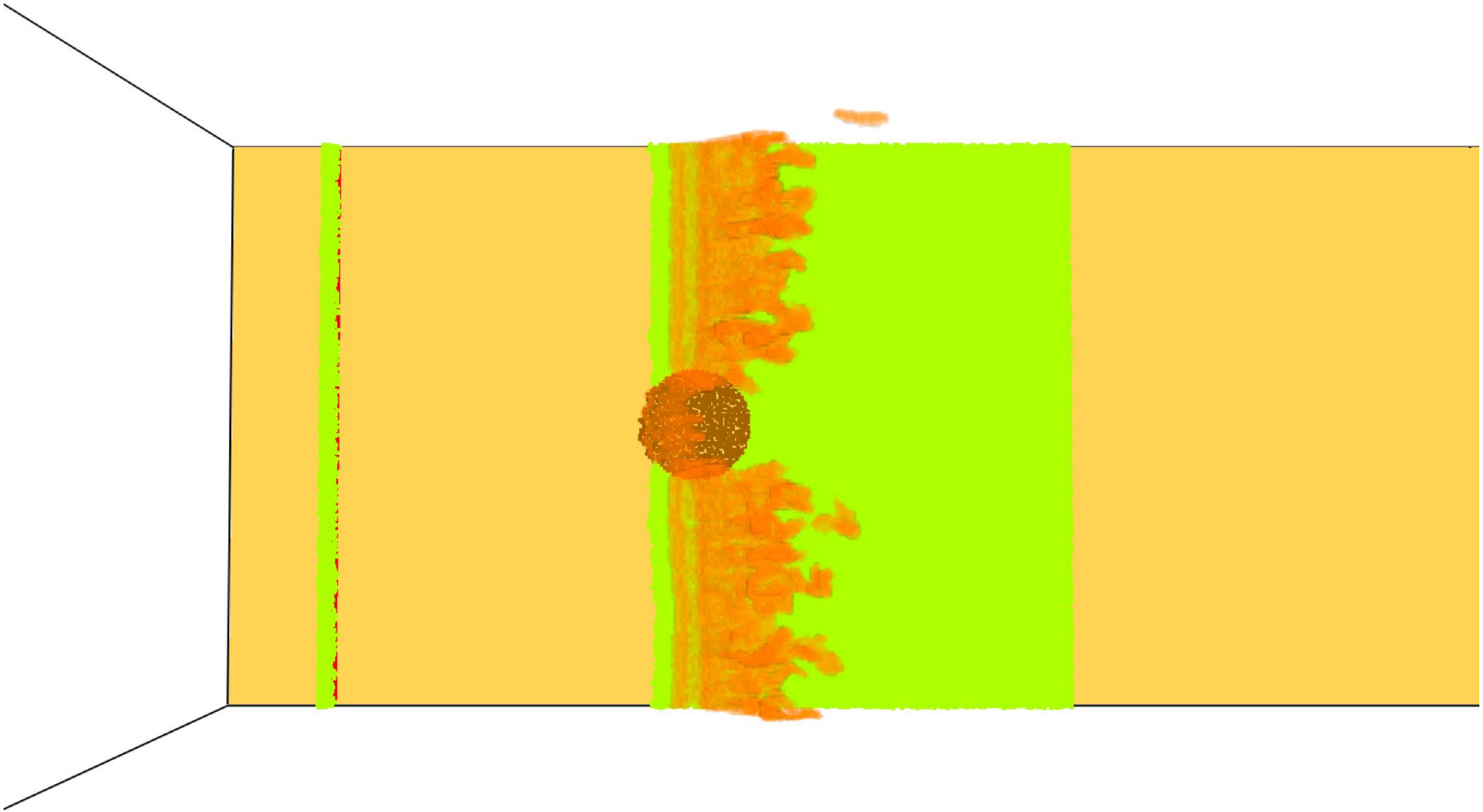


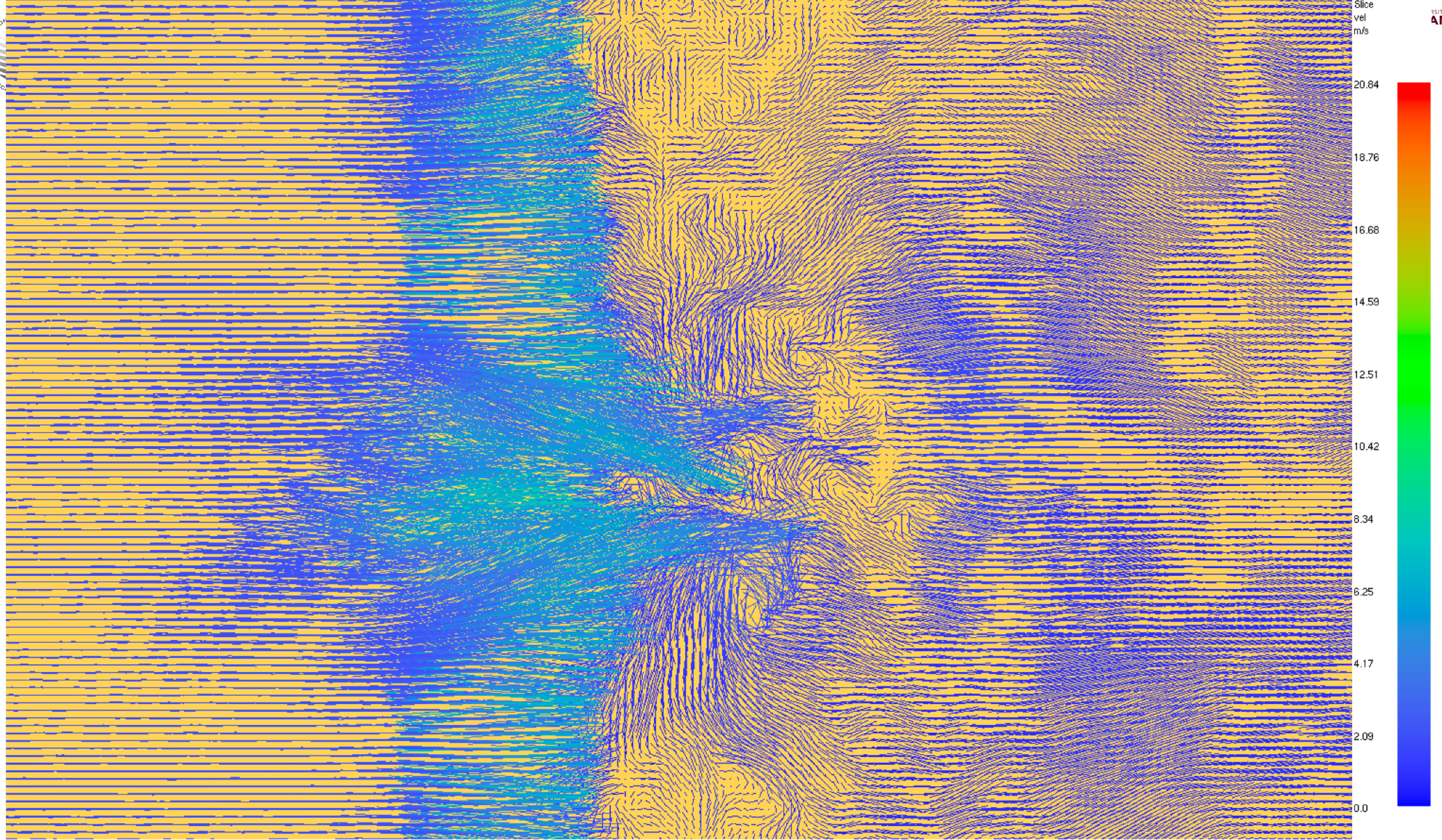
Full FDS



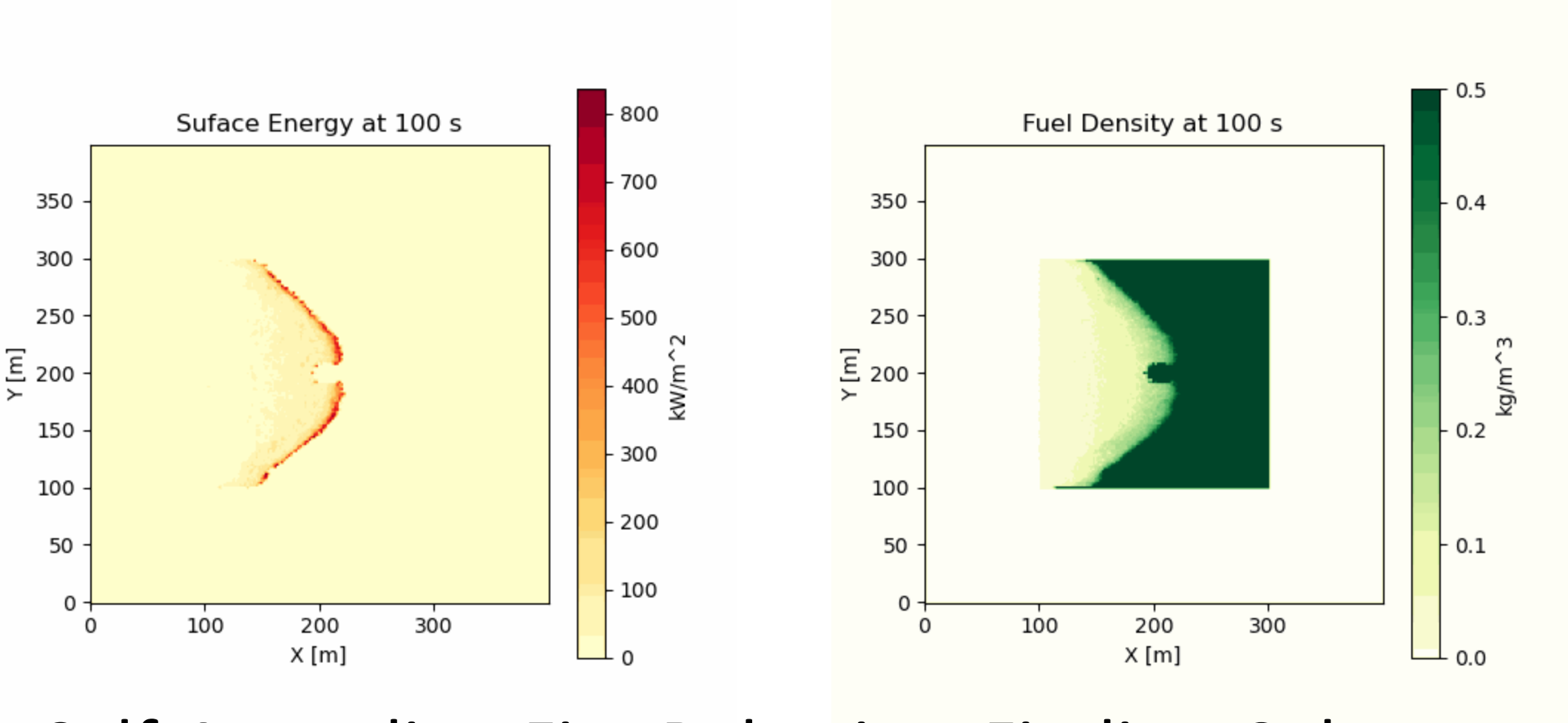
Comparable Observation






Slice
vel
m/s
20.84
18.76
16.68
14.59
12.51
10.42
8.34
6.25
4.17
2.09
0.0

Equivalent Quic-Fire Simulations



Self-Annealing Fire Behavior: Fireline Coherence

Next Steps

Expand experiments in modeling space

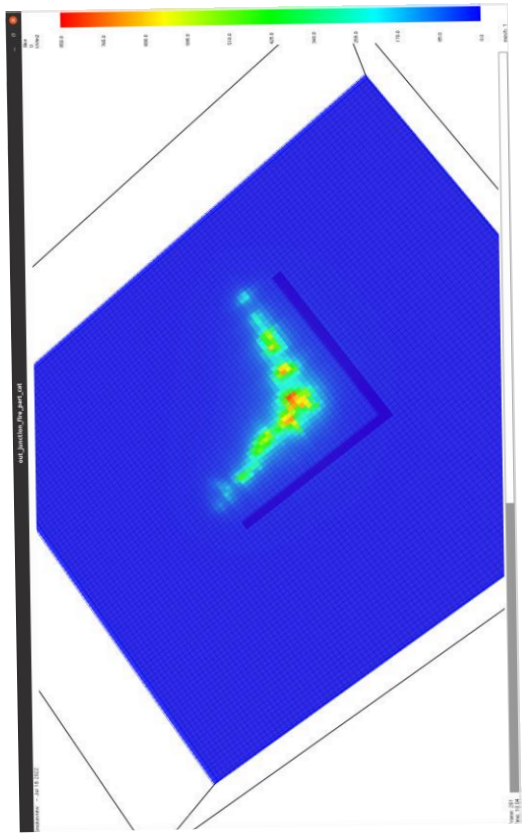
- Circle Size Thresholds
- Weather and Fuel Mass Impacts
- Spatial Arrangement

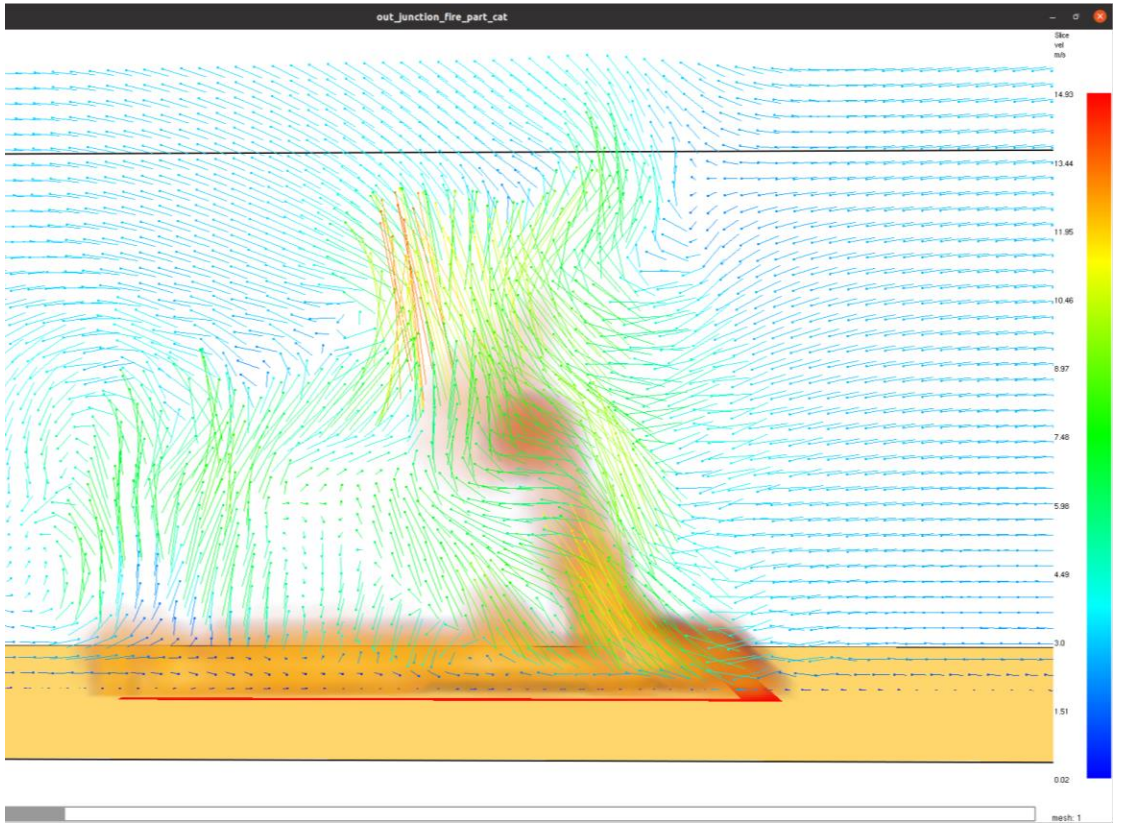
<u>Example Application</u>

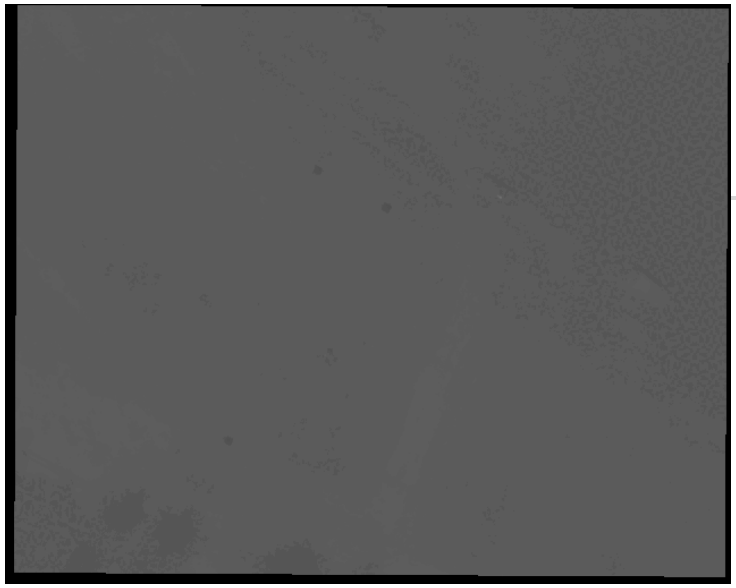
Precision Fuel Treatments

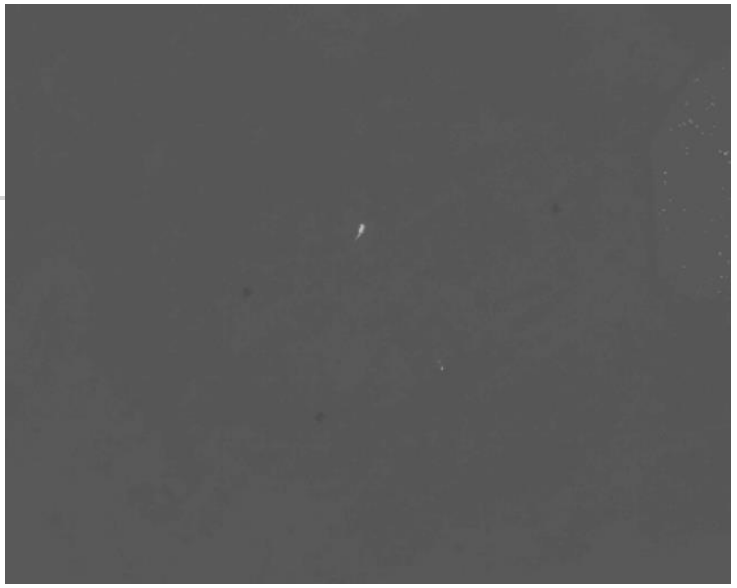
Xyloplan.com

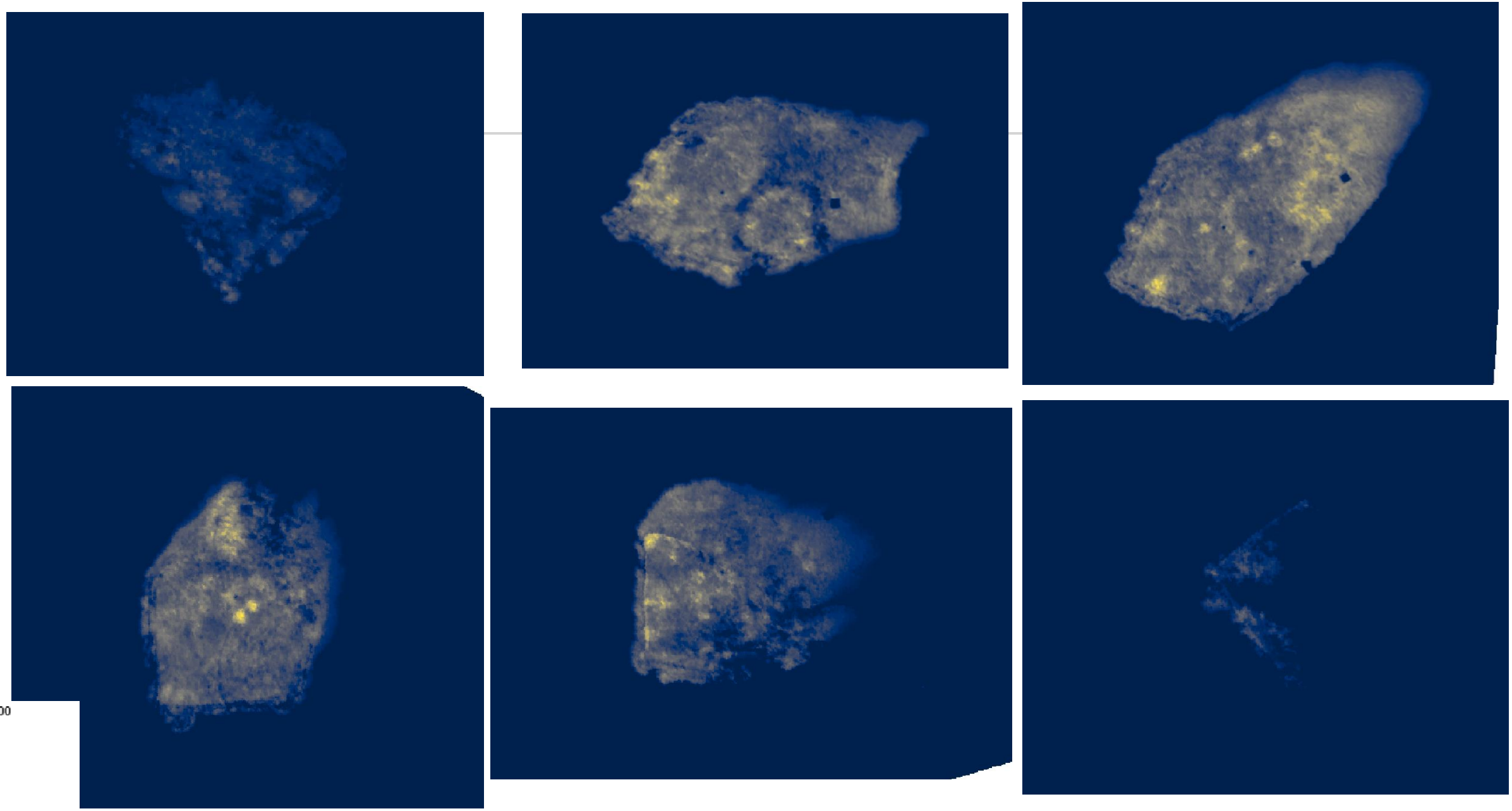
Fire Dynamics – Interacting Firelines





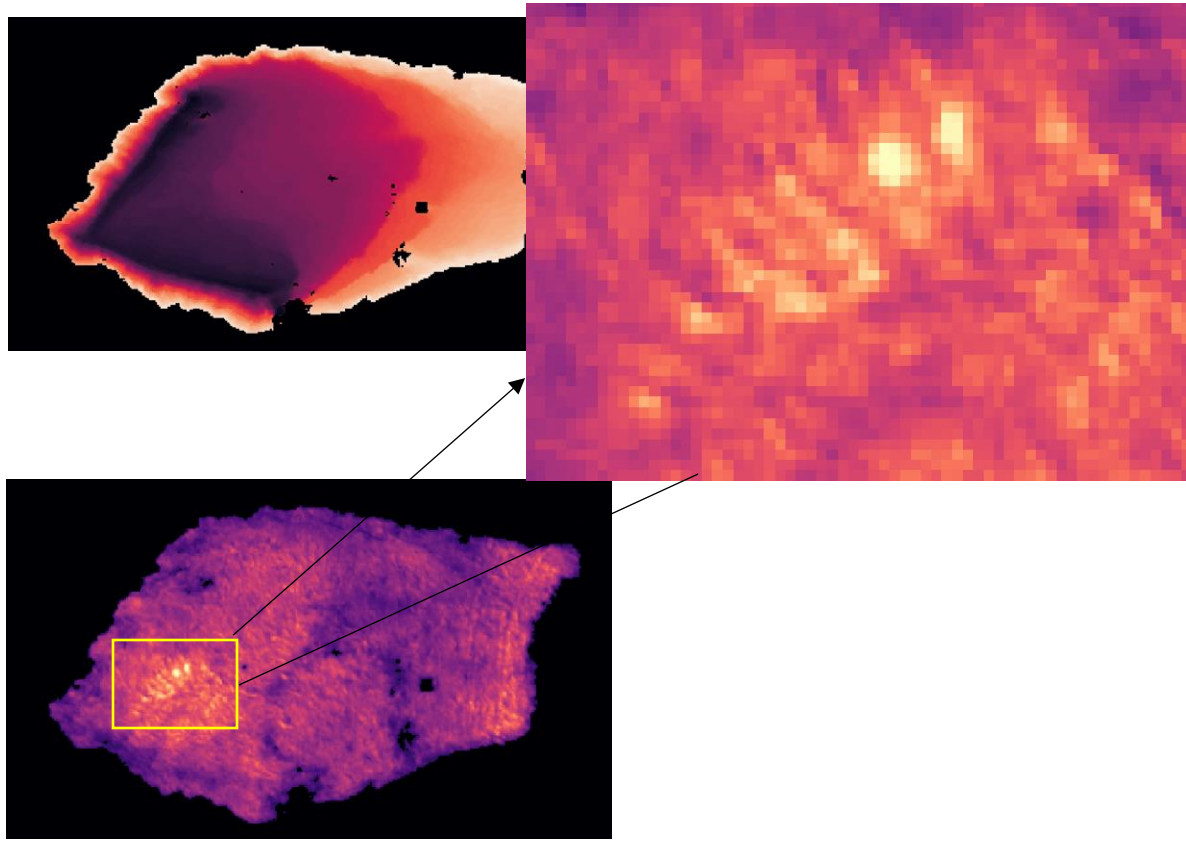


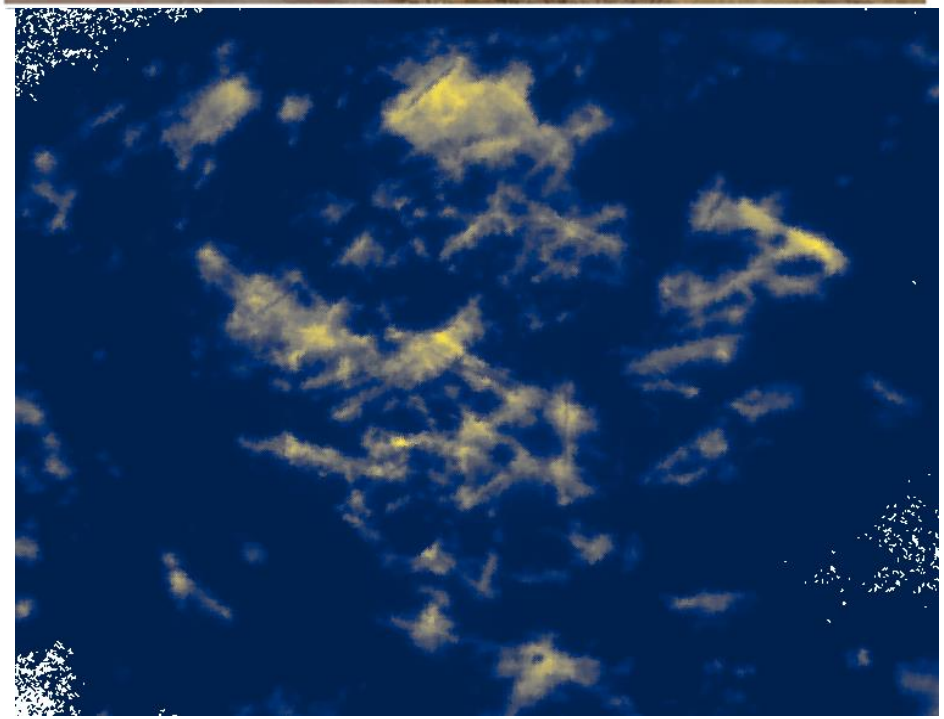


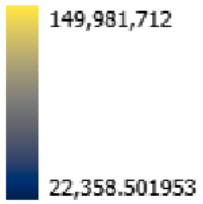

J/m2
1,400,000
0

Initial Results

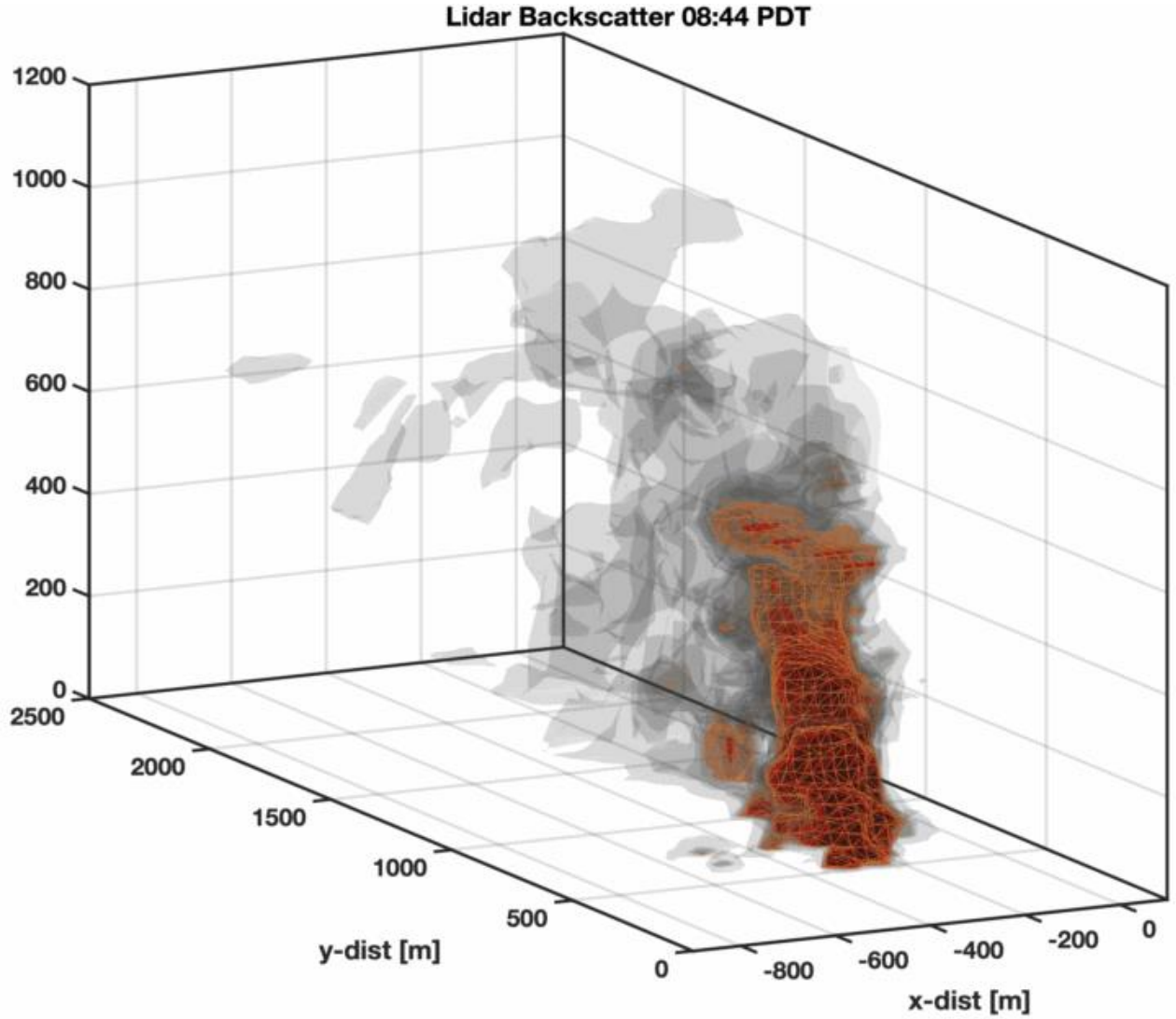
1 of 6 chevrons showed strong interaction
Stronger intensity, consistent wind speed and wind direction alignment







J/m^2



Video: Tyler Salas, UNR grad student

Next Steps

Identify conditions that reliably produce Increased fire behavior with variable Ignition geometry

- Through volume, many chevrons in A single burn
- Weather and Fuel Mass Impacts
- Spatial Arrangement

<u>Example Application</u>

Mixed Severity Prescribed Burning

Thanks!

Funding Acknowledgments

U.S. National Science Foundation

SERDP ESTCP