Using terrestrial LiDAR to describe fuel elements in a diffuse-form shrub for fire behavior modeling

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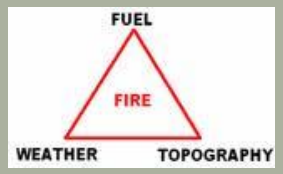
Outline

- Background information
  - Fire behavior and fuels models
  - LiDAR application in diffuse shrubs (chamise)
- Preliminary Findings in using short range LiDAR
- Using Intensity
  - Mass
  - Range
- Mapping a diffuse shrub in three dimensions
  - Burn chamber experimentation
- Further research



Fire Behavior and Fuels Modeling

- Weather
  - Temporally discrete
- Topography
  - Spatially discrete
- Fuels
  - Typically generalized

SH5 (145)

High Load, Dry Climate Shrub

Description: The primary carrier of fire in SH5 is woody shrubs and shrub litter. Heavy shrub load, depth 4-6 feet. Spread rate very high; flame length very high. Moisture of extinction is high.

Fine fuel load (t/ac)	6.5
Characteristic SAV (ft-1)	1252
Packing ratio (dimensionless)	0.00206
Extinction moisture content (percent)	15

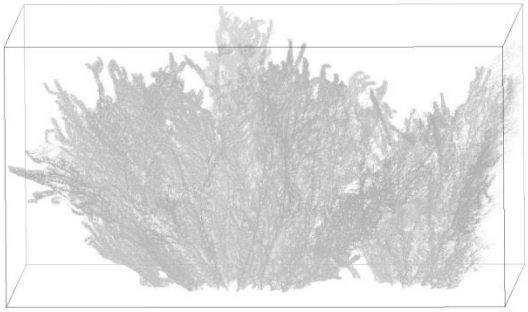
Scott and Burgan 2005

Light Detection and Ranging (LiDAR)

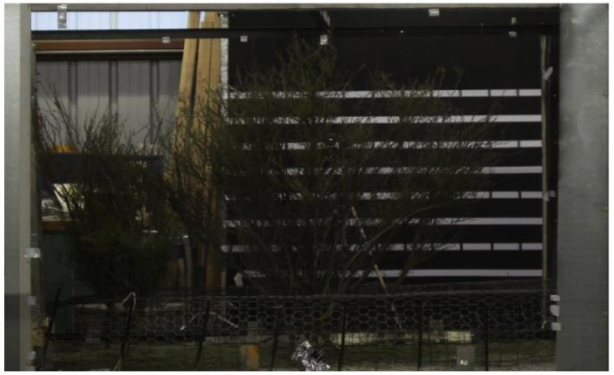
- Terrestrial Laser Scanners (TLS)
  - Emits laser pulse
  - Pulse hits an object, returns to instrument
  - Time of flight until return to unit
- Laser return produces point cloud
  - Point of reflectance
    - Easting, Northing, Elevation (X, Y, Z)
  - Intensity of return
- Function of laser footprint and spot spacing
  - Footprint: ~13mm @ 5 m range
  - Spot spacing: <1 mm

- Optech ILRIS-3_6D Scanner
- Class I Laser (1535 nm)
- Range of 3 m to 1.5 km

Diffuse Shrubs and LiDAR



- In diffuse shrubs such as Chamise (*Adenostoma fasciculatum*), fuel structure not uniform
- LiDAR allows for the mapping of fuel components in three dimensions
- Descriptive, non-destructive measurement



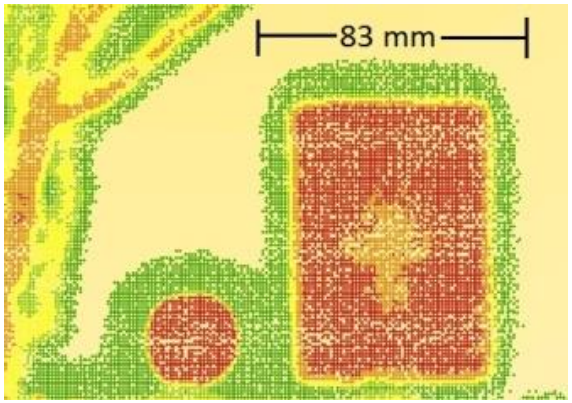
Short Range LiDAR Phenomena

Ghosting: The trans-location of points between two surfaces in the y-direction

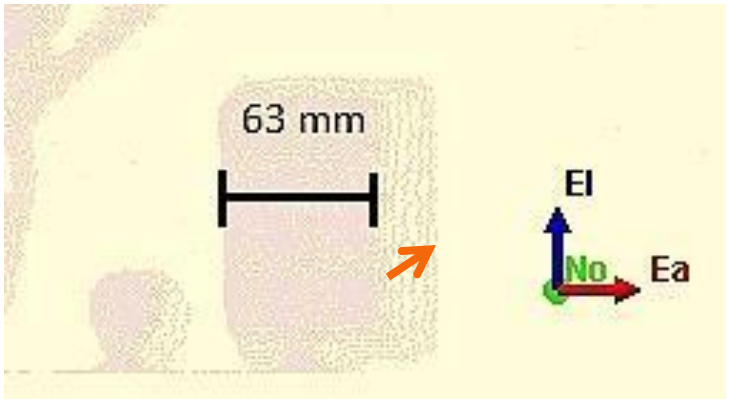
Halo: Edge effect where surfaces are depicted as having wider dimensions than in reality

Ghosting and Halo

- Identified phenomena of TLS
  - Theory: Caused by laser footprint



Halo effect: Card is represented as wider than actual measurement



Ghosting effect: card width measurement is more accurate, but geometry is created behind

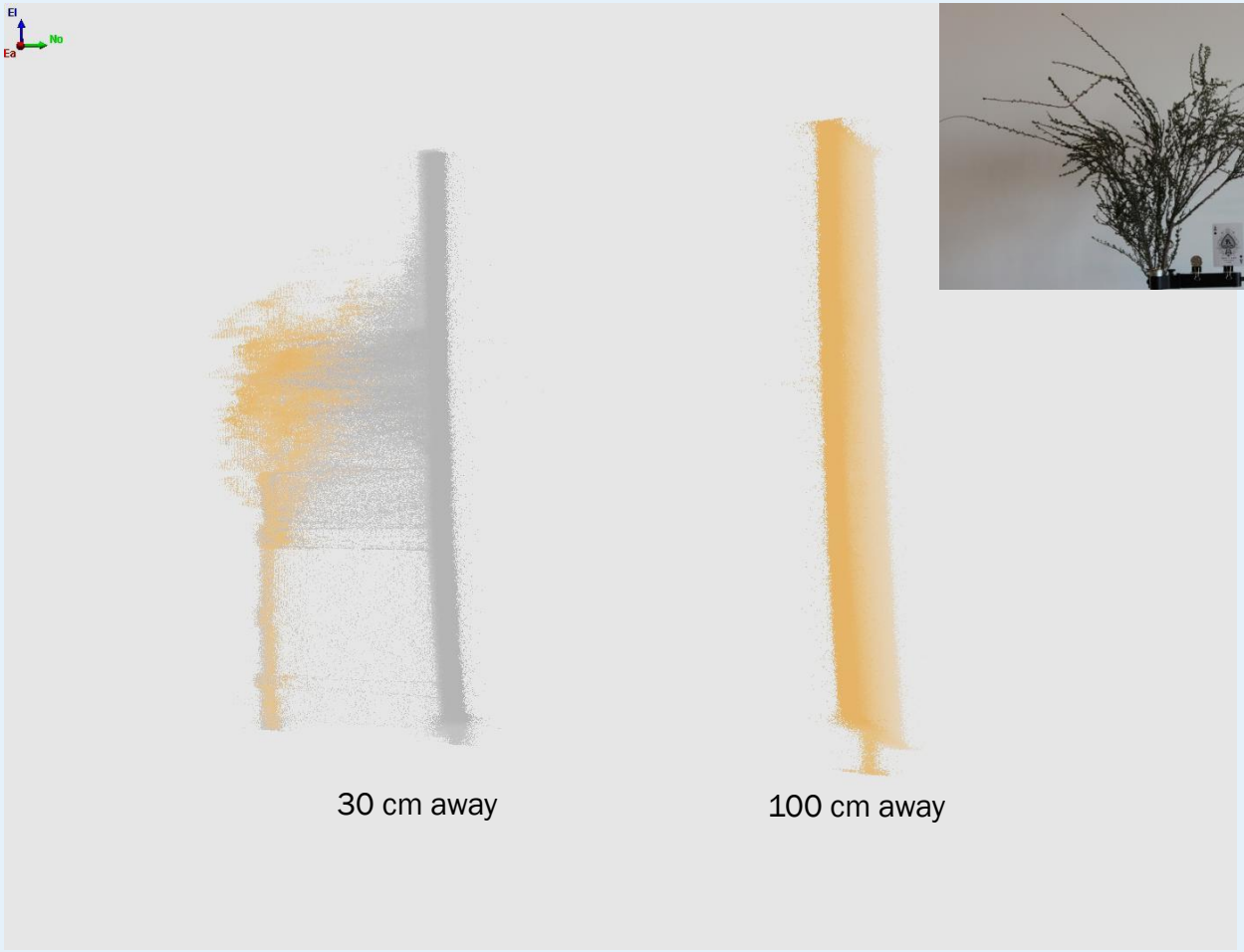
Background Experiment

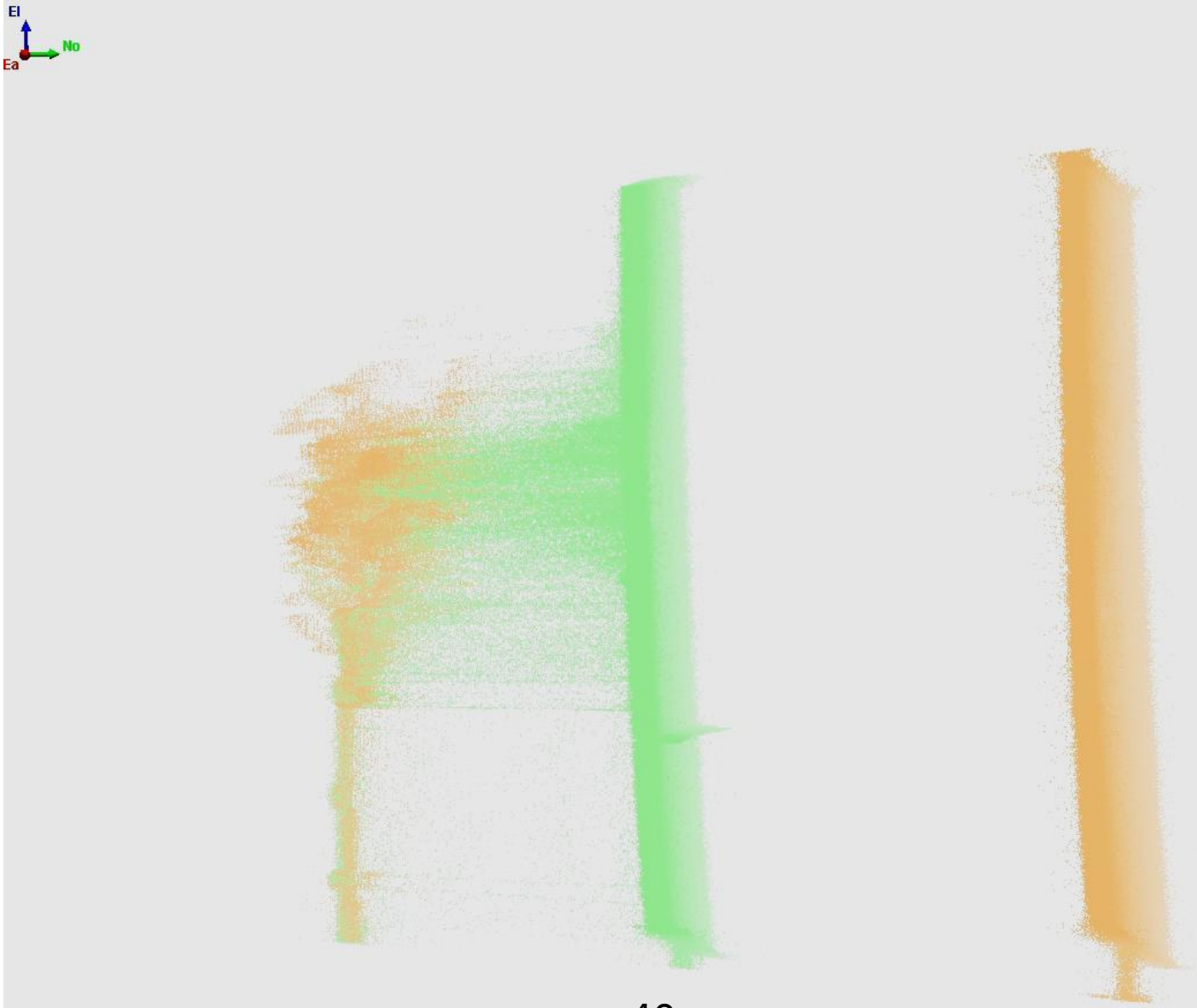
A highly-reflective, discrete background was positioned at varying distances from diffuse and discrete structures

- Target consisted of chamise branches (diffuse), the ace of spades, and a US Quarter (discrete)
  - TLS to target: 5 m
- Background was poster board

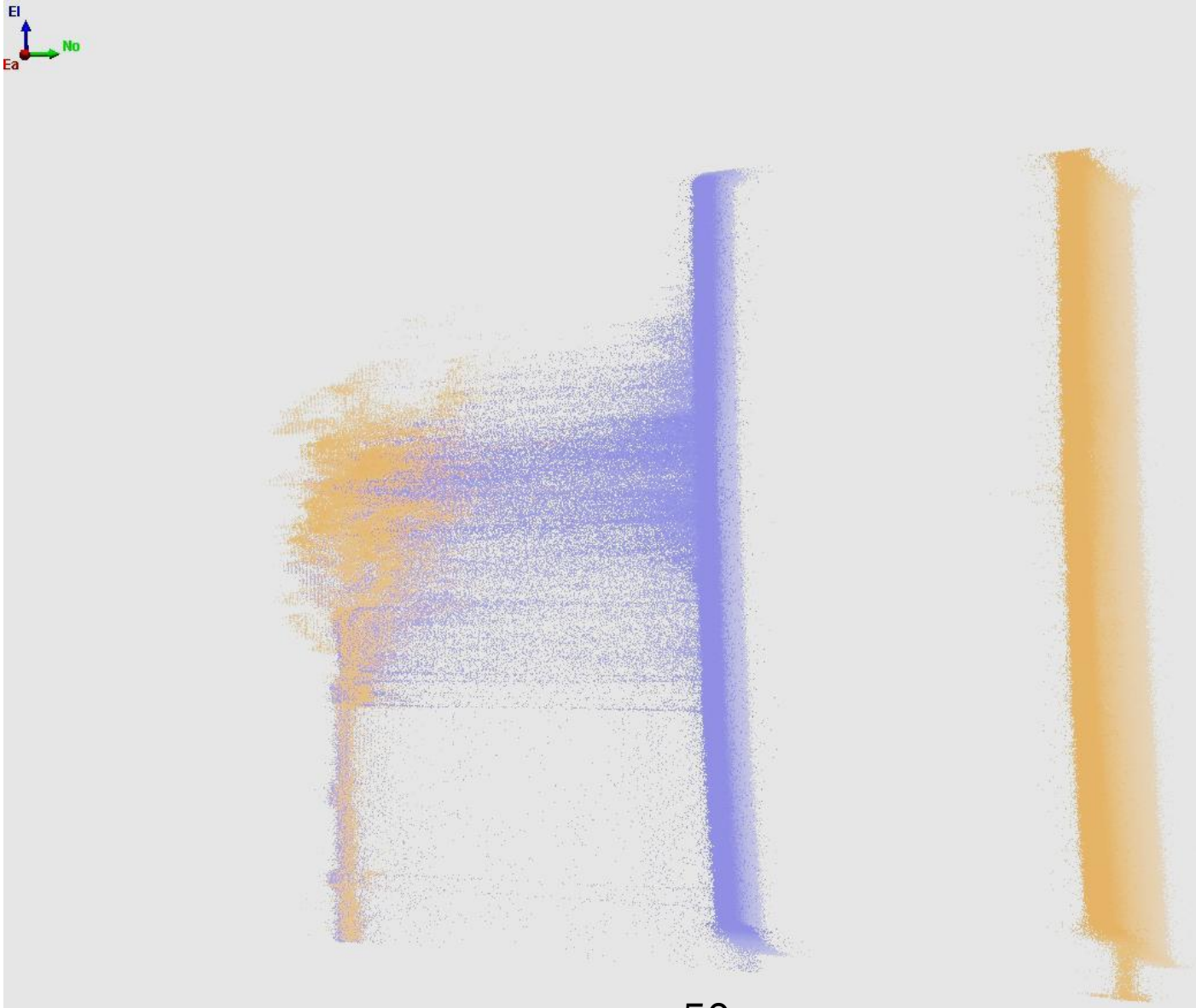
  Background Range:
  - 30-100 cm by 10 cm
  - 100-500 cm by 50 cm
- Control scan with no background

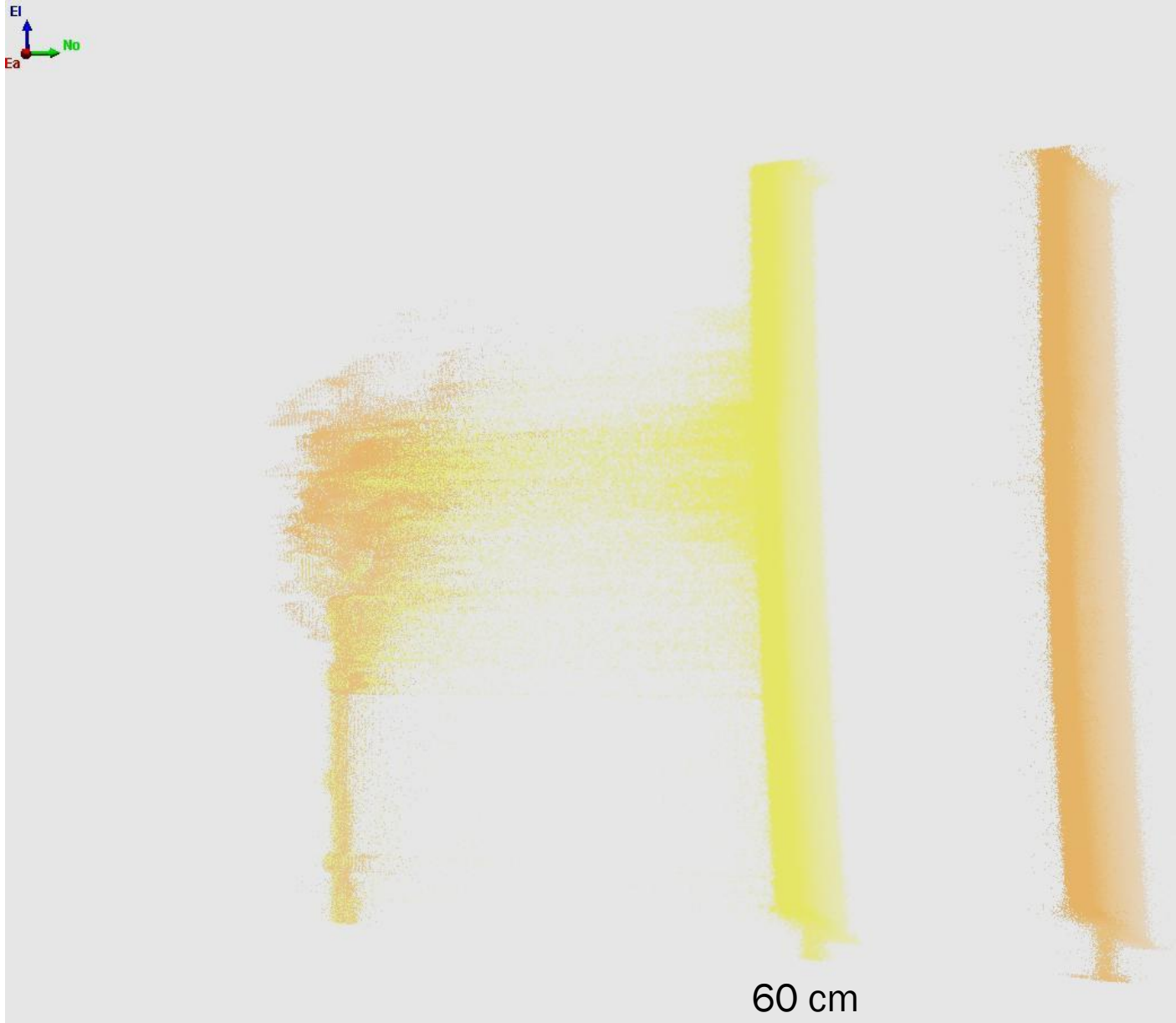
Ghosting Visualized

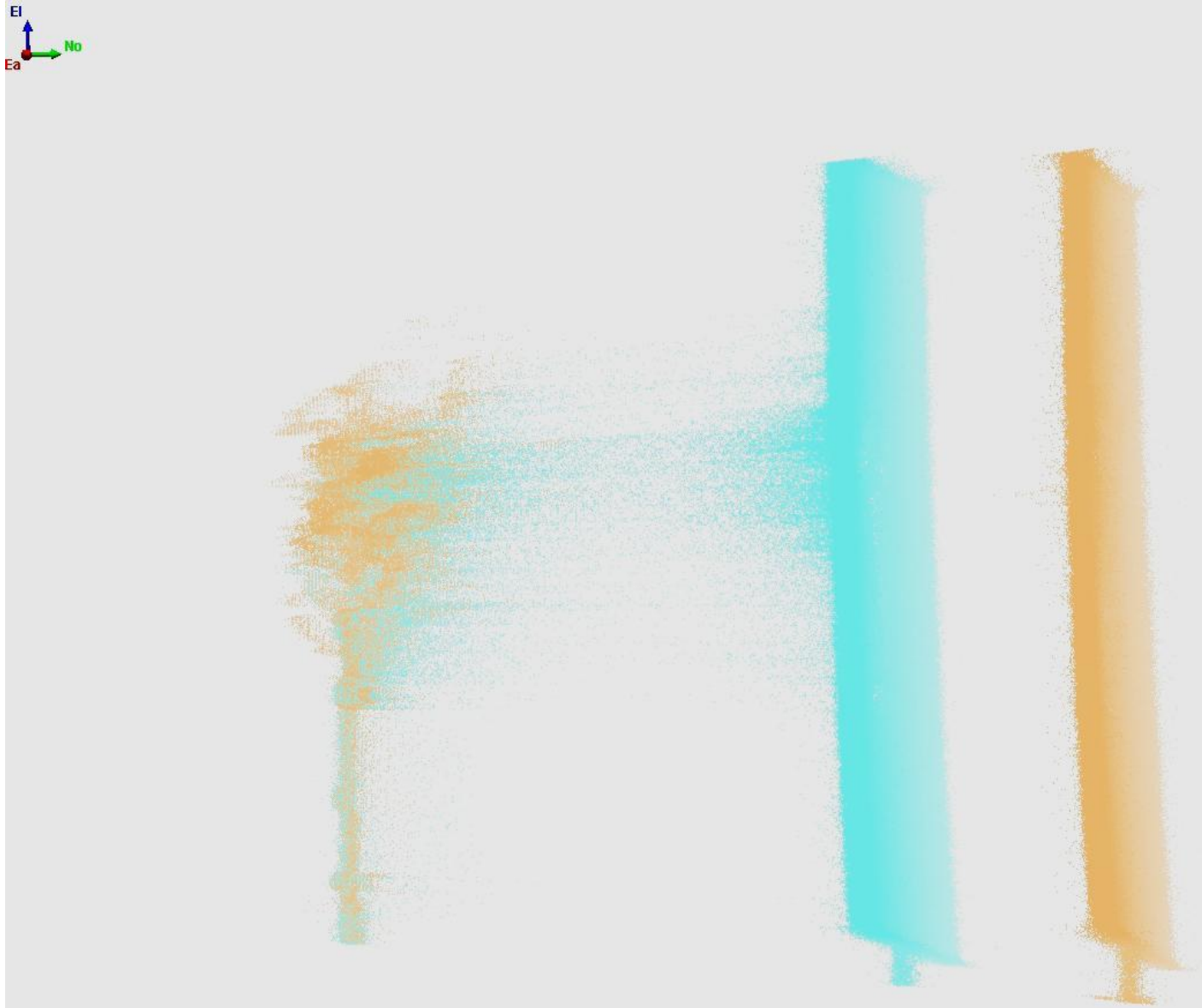


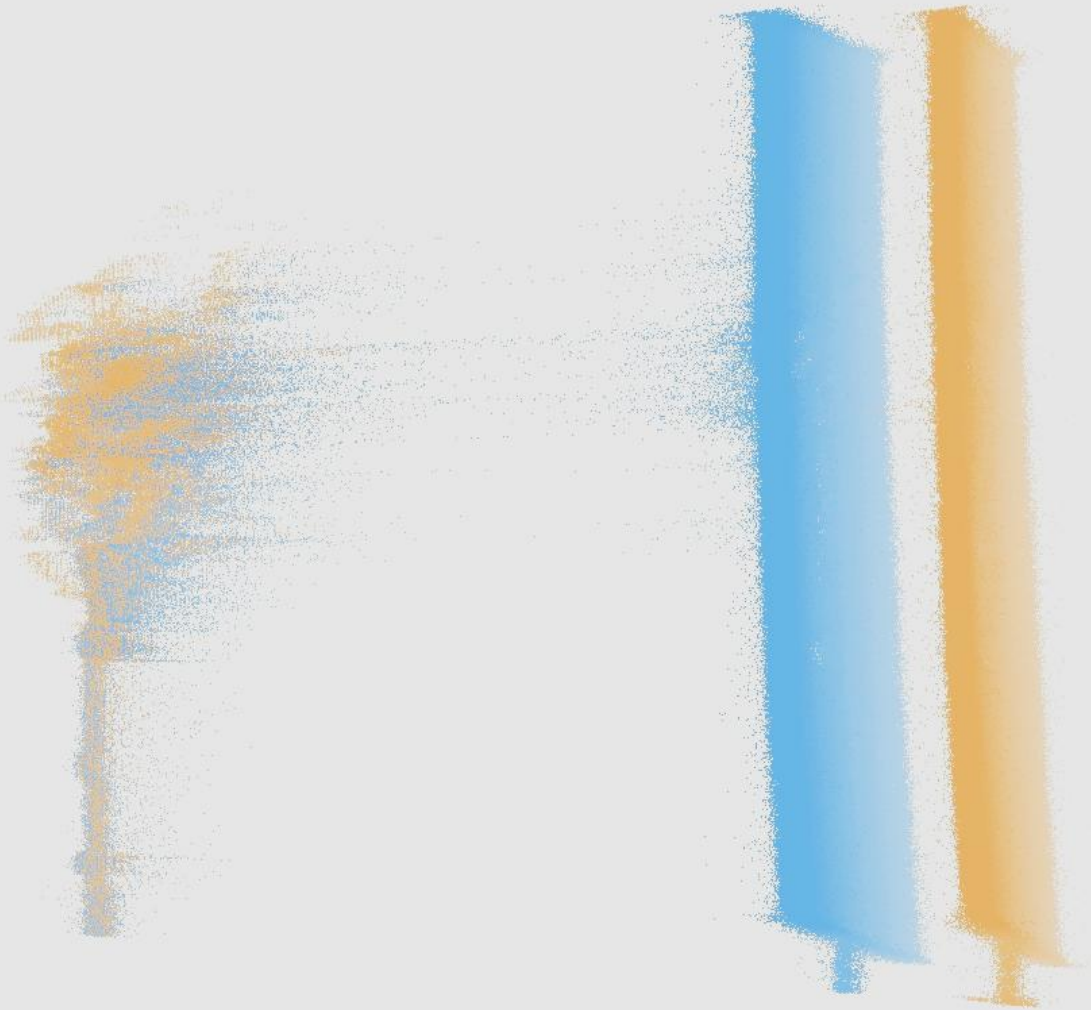


40 cm

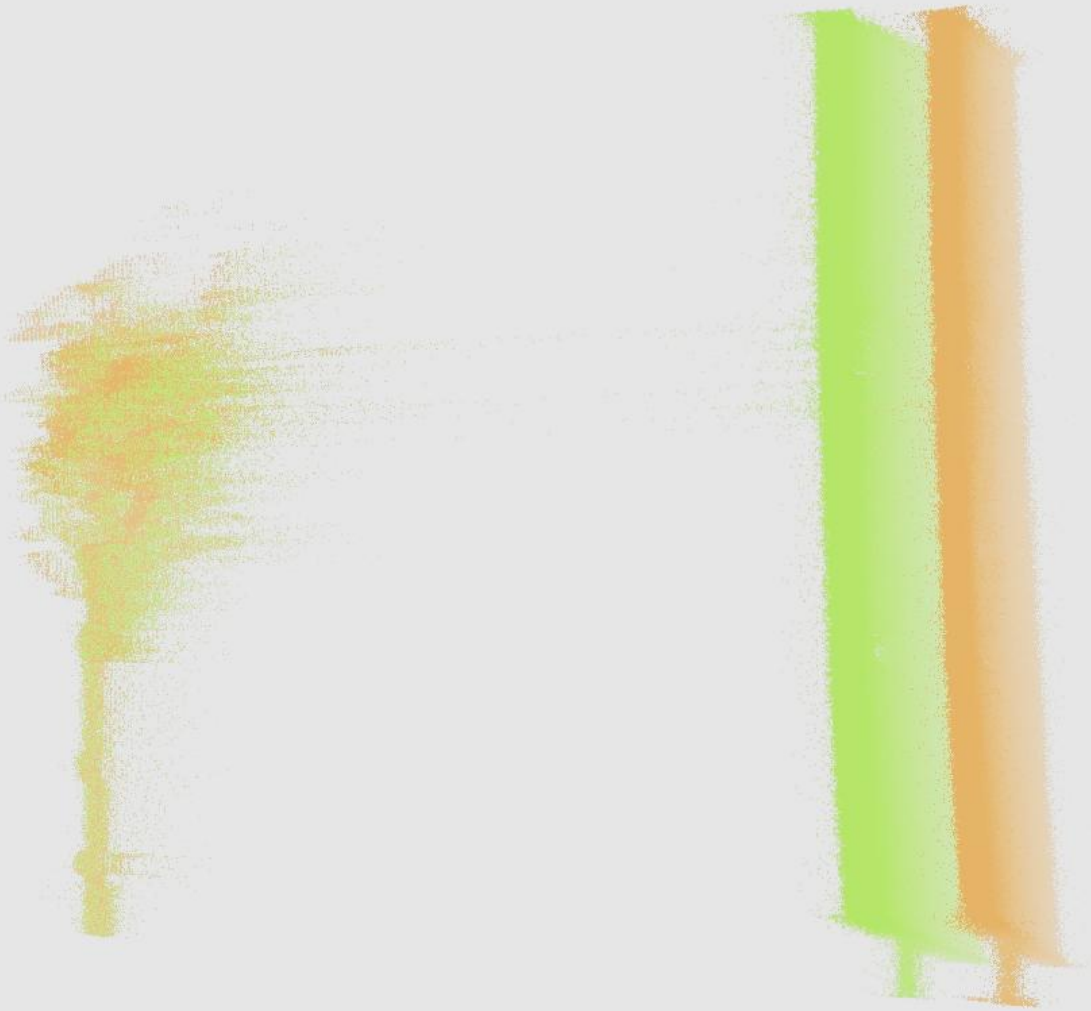

El
No
Ea
50 cm


El
No
Ea
60 cm


El
No
Ea
70 cm



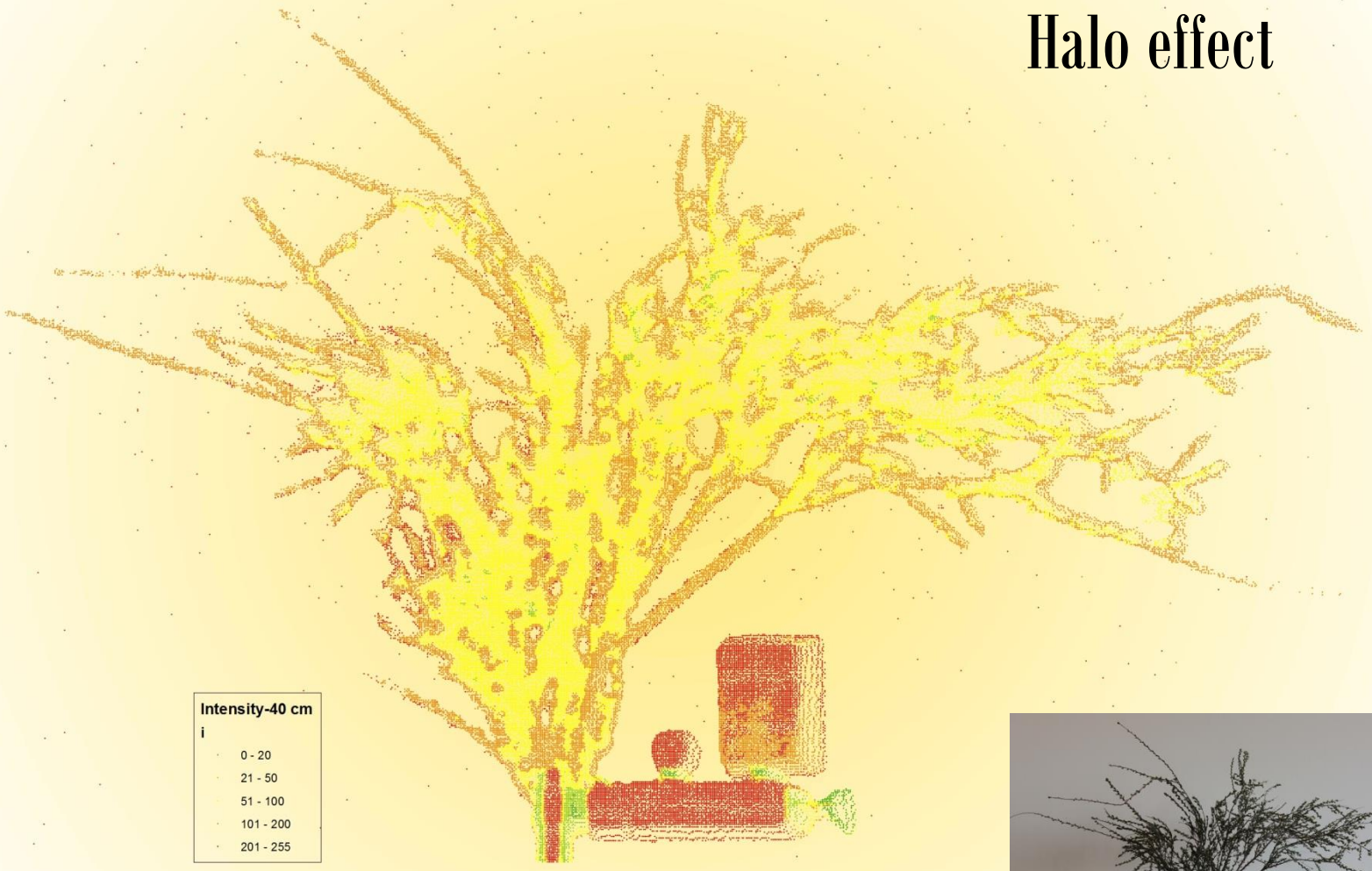
80 cm



90 cm

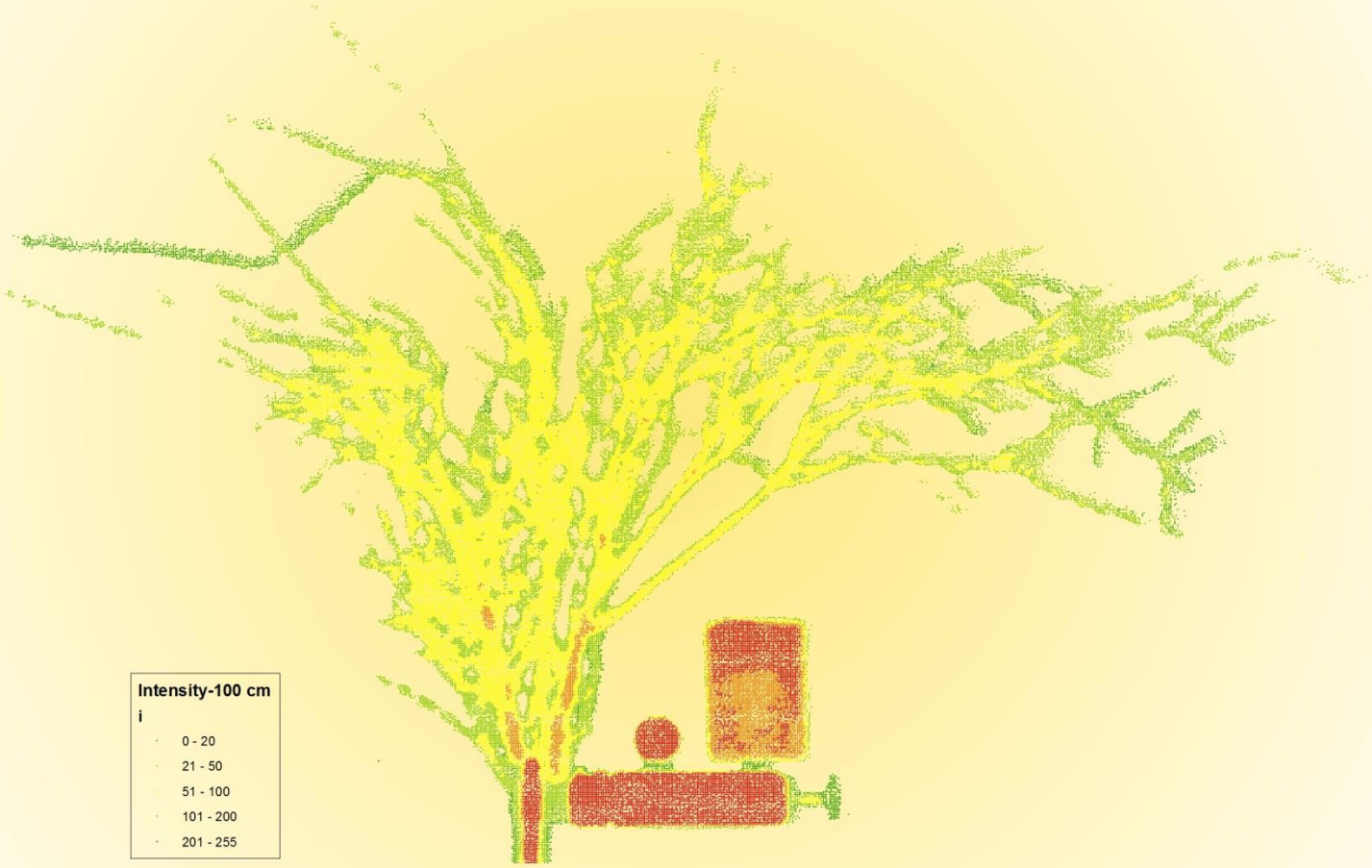
Intensity returns with background at 40 cm

Halo effect



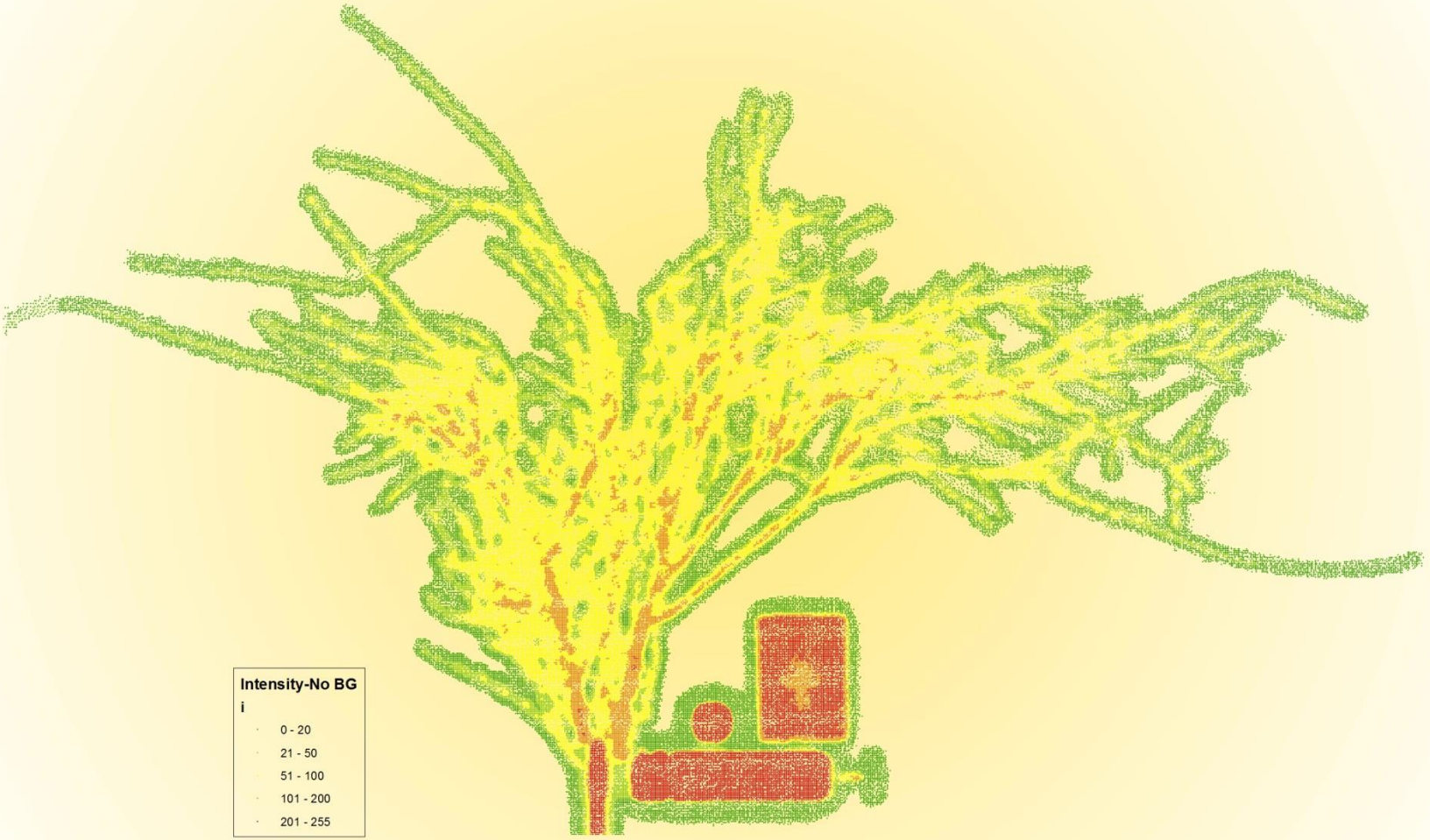
Intensity returns with background at 80 cm

Intensity returns with background at 100 cm

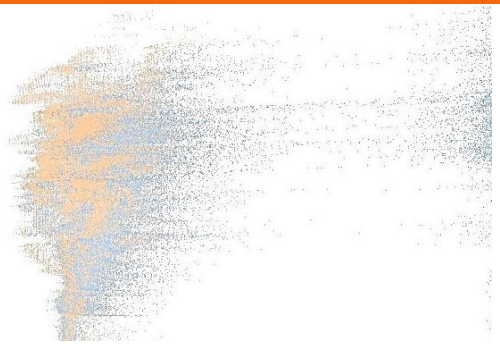


Intensity returns with background at 150 cm

Intensity returns with no background



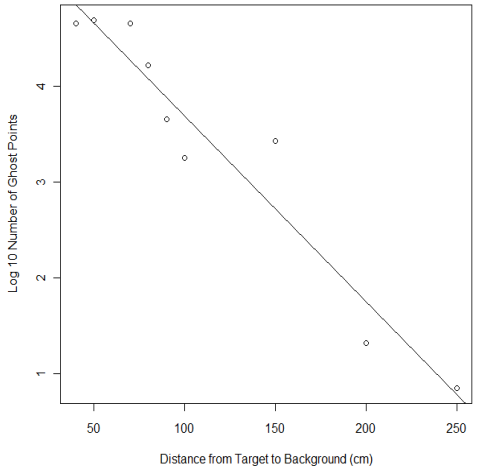
Ghosting vs. Halo



This brief study showed that both are related to the distance from a discrete background.

Ghosting

- Pro: Accurate measurement on plane perpendicular to laser
- Con: Creates geometry behind object that should not be there



Halo

- Pro: All partial returns occur within the volume of the target
- Con: Gaps within target geometry can not be seen

Using Intensity

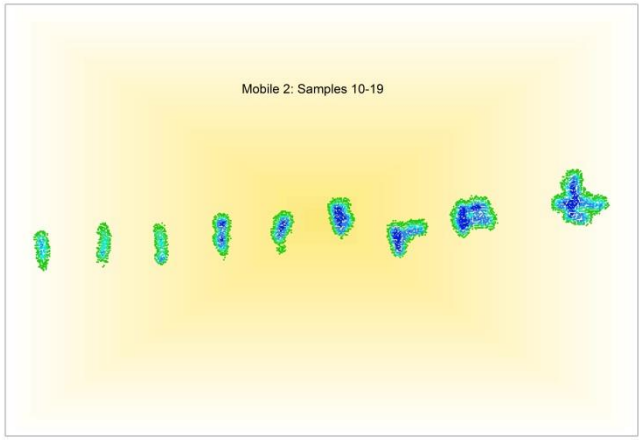
"…a measure of the return strength of the lase pulse that generated the point…based, in part, on the reflectivity of the object struck by the laser pulse."

-ArcGIS 10.1

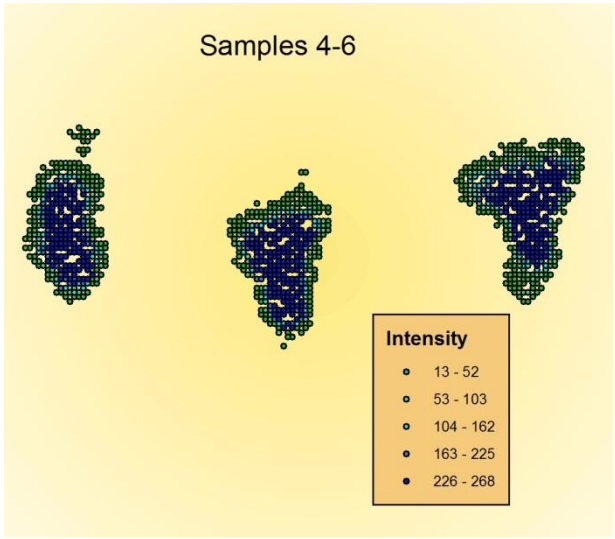
2 cm experiment

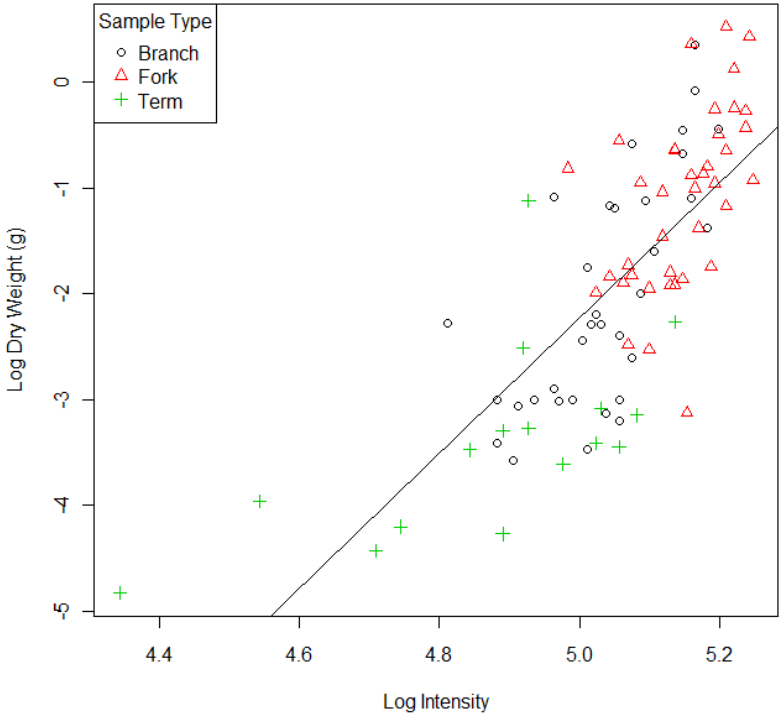
2 cm samples of chamise were scanned to relate intensity to mass

- 10 samples at a time
- 9 replications
  - n=89
- 4 m range to target
- Background >2.5m behind targets



Intensity and Mass



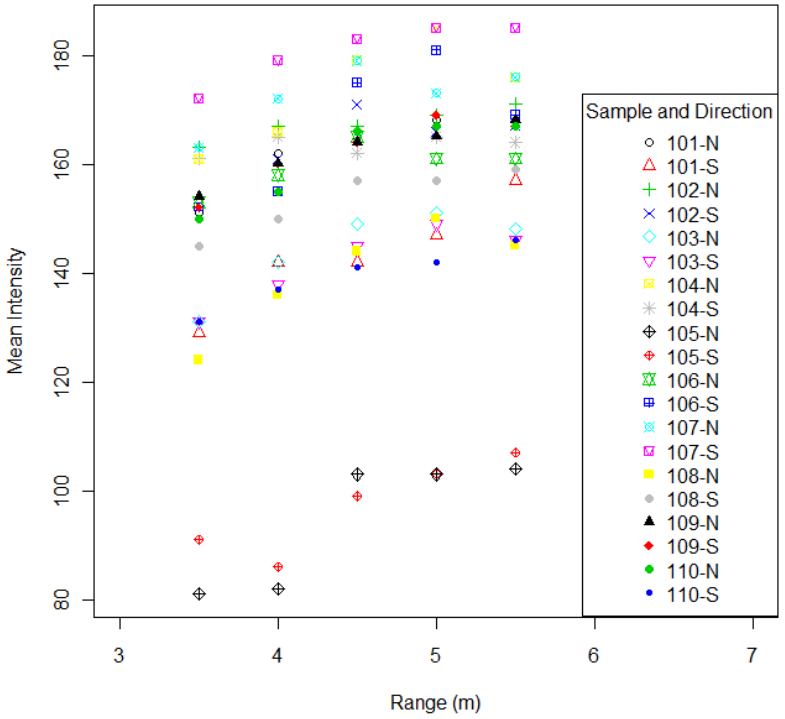


R-Squared: 0.57, F-stat:115, P:<.001

Intensity and Range

The relationship is well understood beyond 15 m, but less so within.

- Scanner head moved in 50 cm increments
  - 3.5 -5.5 m
  - From 2 directions
- 10-2cm samples of chamise
- Mixed Effects Model
  - n=100 with 20 groups



Slope: 7.73
t-value:11.87, p-value: <0.01

Burn Lab Experiments

USFS Pacific Southwest Riverside Research Station

December 16-20, 2012

13 chamise 'shrubs' burned

- Psuedo-random construction of 'realistic' chamise shrub within burn chamber
- Fuel moistures: 6-20%

Collection Site

- San Bernardino National Forest
- 33.8 N by 116.9 W
- 3600-3900 FT ASL

Data Collection and Processing

Laboratory Data Collection

- Scan from 3 angles,
  - Pre- and post-burn
  - 4-5 m range, 1.0 mm spot spacing
- High speed video
- Thermal camera
- Thermocouple array
- Pre- and post-mass

TLS Data Processing

Parse binary data file into X, Y, Z, I

↓

Apply range and intensity correction

↓

Align and merge scans

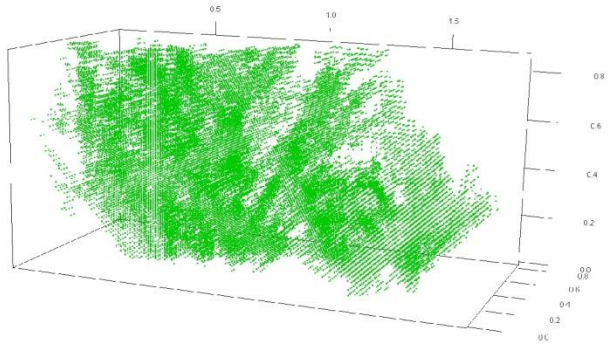
↓

Manually clip excess geometry

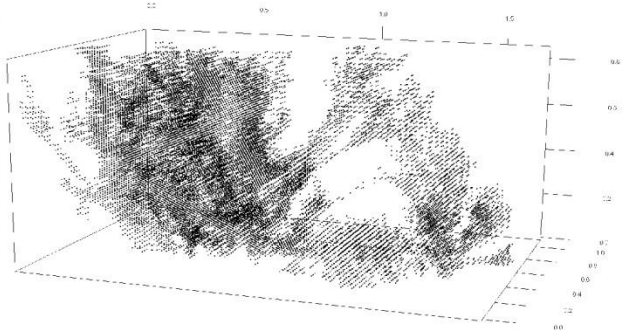
↓

Create 2cm voxel array

Shrub 1

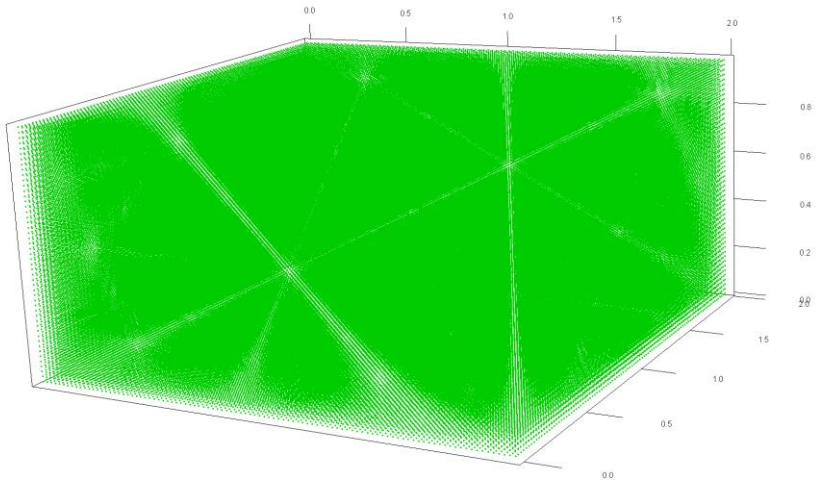


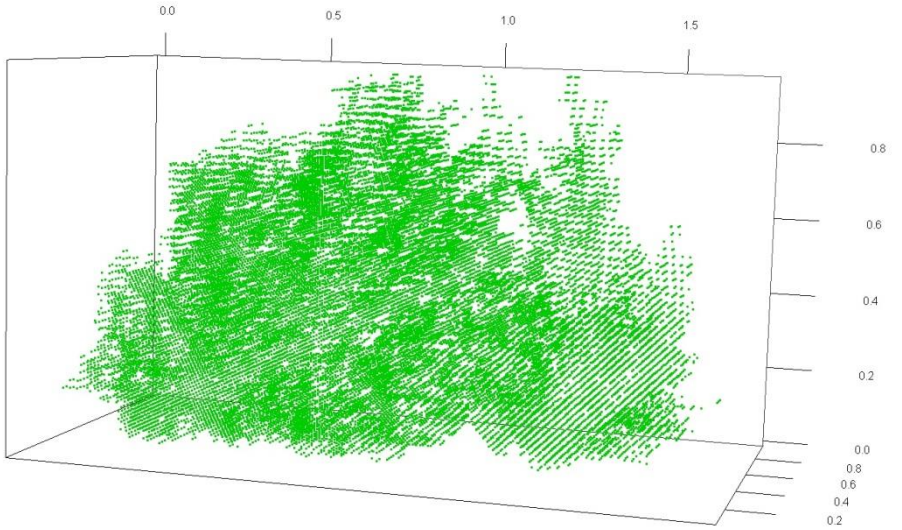
Pre-burn experimental shrub (left)
and voxel array depicting shrub (right)



Post-burn

Shrub 2





Shrub Weight: 6638 g

Generalized Volume: 2 m^3

0.003 g/cm^3

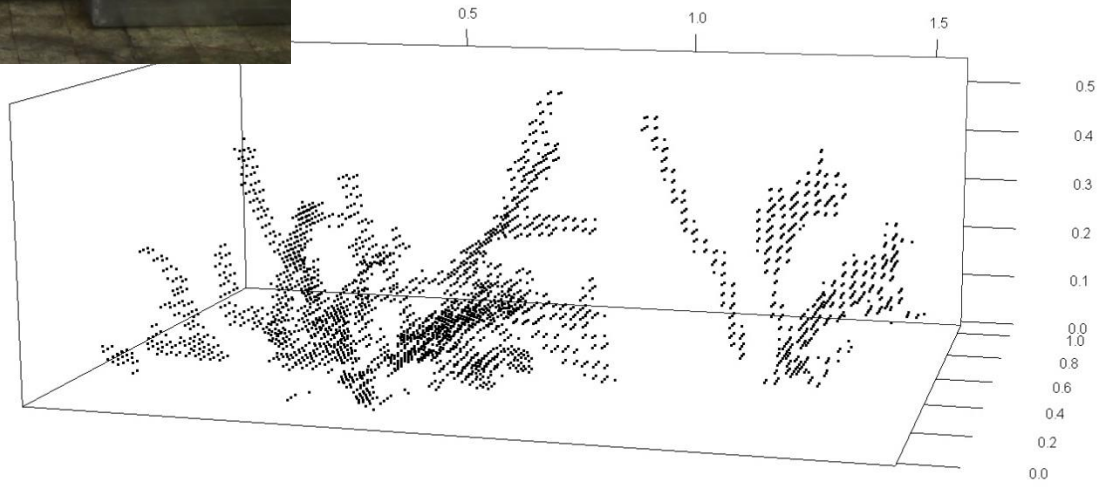
Voxel Volume: 0.24 m^3

0.028 g/cm^3

Shrub 2

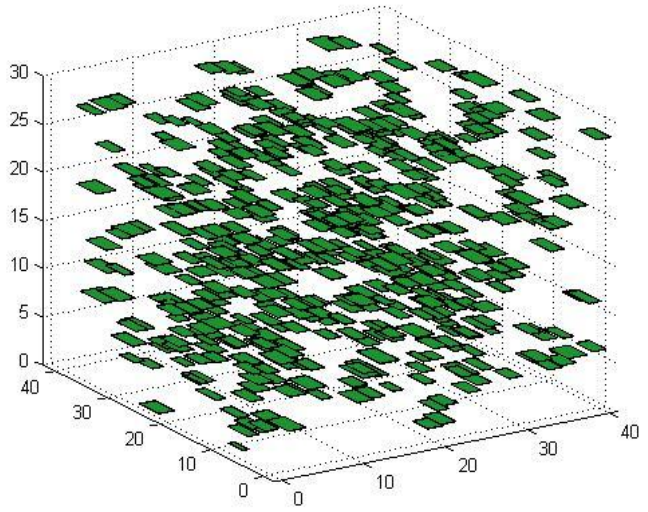
Post-weight: 3548 g
Mass-loss: 3090 g

General Volume: 1 m^3
0.003 g/cm^3
Voxel Volume: 0.09 m^3
0.039 g/cm^3



Fire Modeling in Three Dimensions

- Brigham Young University
  - Chemical Engineering Department
- Statistical, multi-leaf shrub combustion model
  - Uses: experimentally derived flame height and duration
  - Predicts: burning rate, fire path, flame height, flame angle, and ignition characteristics

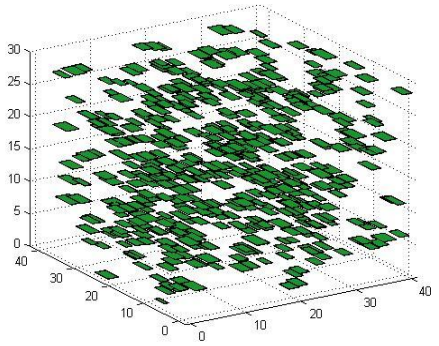


Depiction of randomly assigned leaf locations and dimension (Andersen et. al, In Progress)

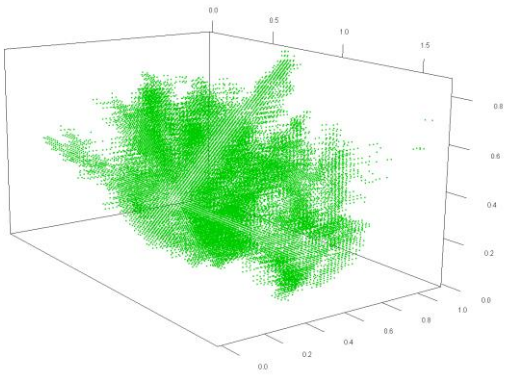
The Next Step

Apply Voxel Array

- Replace



- With



- Attribute values to each voxel
  - Mass
  - Flame Height/Duration
- Apply in a 3D model environment
  - Dr. Tom Fletcher
  - '*Semi-empirical Fire Spread Simulator for Utah Juniper and Chamise Shrubs*' P 29.
  - '*Fuel Element Combustion Properties for Live Wildland Utah Shrubs*' P 49.

Further Research

- Expand data set
  - Multiple species
    - Sagebrush
    - Manzanita
- Validate model predictions
  - Mapped inputs compared to random inputs
- Scale up
  - Landscape mapping and predictions

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