TrueTrees: A Scalable Workflow for the Integration of Airborne LiDAR Scanning Data into Fuel Models for Prescribed Fire Simulations

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SILVXLABS

Lawrence Livermore National Laboratory

TALL TIMBERS

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UC San Diego

Last days…

Canary Islands

Canary Islands schools close and wildfire revives in soaring temperatures

Heat is forecast to continue as authorities suspend classes on all islands and battle Tenerife blaze

…ve been rekindled in the high
…n deployed. Photograph: Europ

…ed the temporary closur
…e archipelago that have s
Tenerife.

United States

Study: Wildfire Smoke Exposure Has Increased 27-Fold In US

October 9, 2023

The average person in the U.S. has been exposed to more wildfire smoke this year than any other year since 2016. But this problem has been increasing with global warming, with particulate matter exposure from wildfire smoke now 27 times where it was a decade ago.

Canadian wildfire smoke invades Florida choking skies with smoke, unhealthy air quality

Canadian wildfire smoke ended up in Florida due to the combination of a low-pressure system over Florida from this past weekend and a high-pressure system over the eastern U.S., causing the winds around those systems to carry it as far south as Miami.

Wildfires rage in Argentina's Cordoba province amid heatwave

Authorities evacuate people as massive flames surround populated areas in Cordoba province.

Argentina

Argentina wildfires create apocalyptic scene of blazes at city's edge

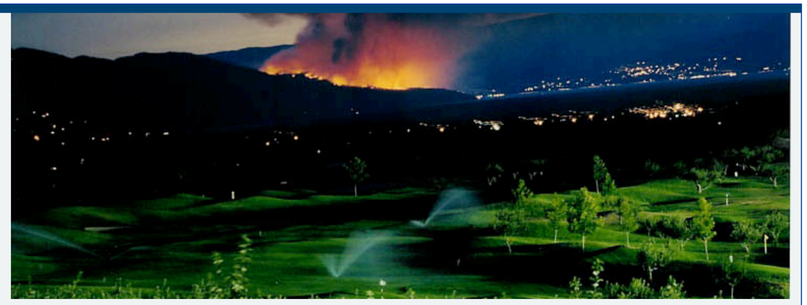
The fires were largely brought under control Wednesday, authorities said

By Scott Dance

Updated October 11, 2023 at 4:37 p.m. EDT | Published October 11, 2023 at 4:23 p.m. EDT

Drone video recorded on Oct. 10 shows a large wildfire approach Villa Carlos Paz, Argentina. (Video: Federico Krypner)

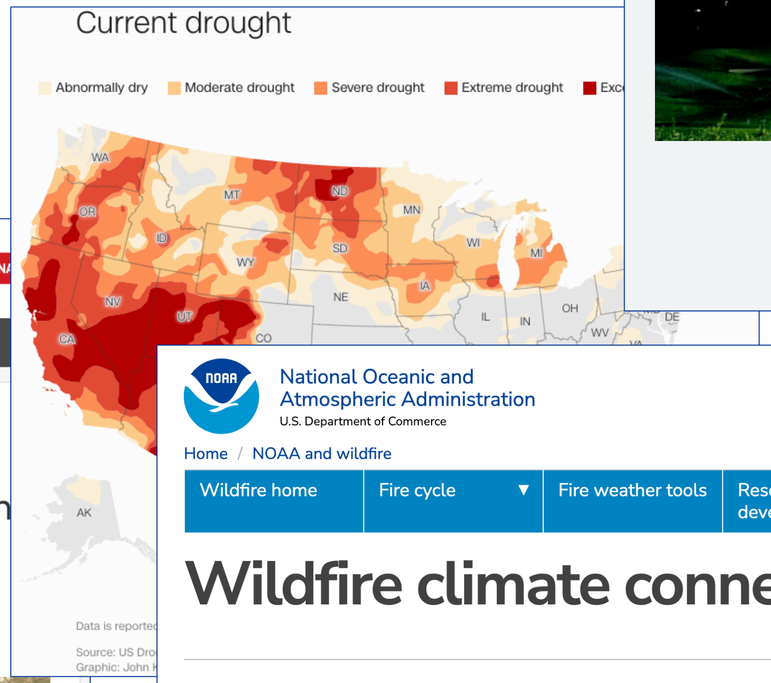
Fire is an inevitable part of nature, but megafires are not.



SCIENCE + TECHNOLOGY

September 14, 2011

Researchers Analyze the Evolving Human Relationship with Fire



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ENVIRONMENT

West Coast Fires: Climate, Forest Management, Lax Rules, Plenty Of Blam To Go Around

September 15, 2020 · 3:15 PM ET

KIRK SIEGLER

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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Wildfire home | Fire cycle | Fire weather tools | Research and development | Climate connection | Partners | News and Stories

Wildfire climate connection

Share:

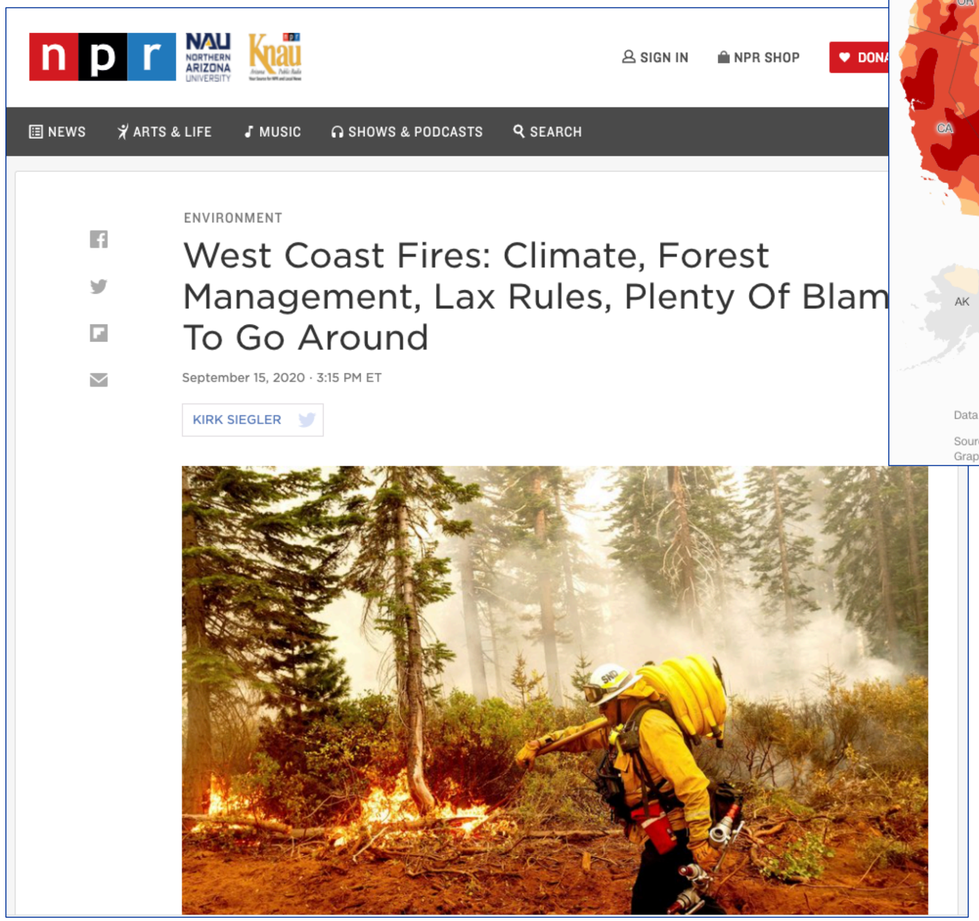
Climate change, including increased heat, extended drought, and a thirsty atmosphere, has been a key driver in increasing the risk and extent of wildfires in the western United States during the last two decades. Wildfires require the alignment of a number of factors, including temperature, humidity, and the lack of moisture in fuels, such as trees, shrubs, grasses, and forest debris. All these factors have strong direct or indirect ties to climate variability and climate change.

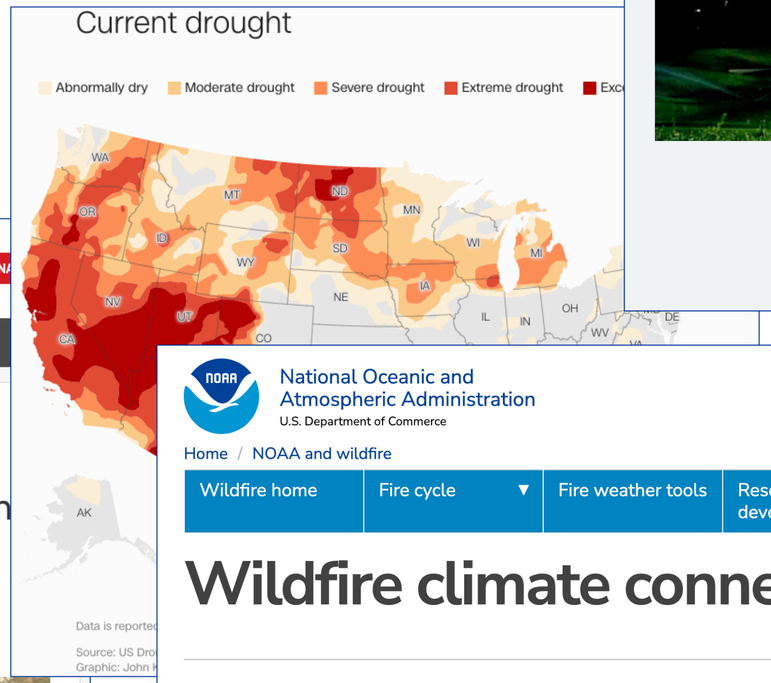
A 2016 study found climate change enhanced the drying of organic matter and doubled the number of large fires between 1984 and 2015 in the western United States. A 2021 study supported by NOAA concluded that climate change has been the main driver of the increase in fire weather in the western United States.

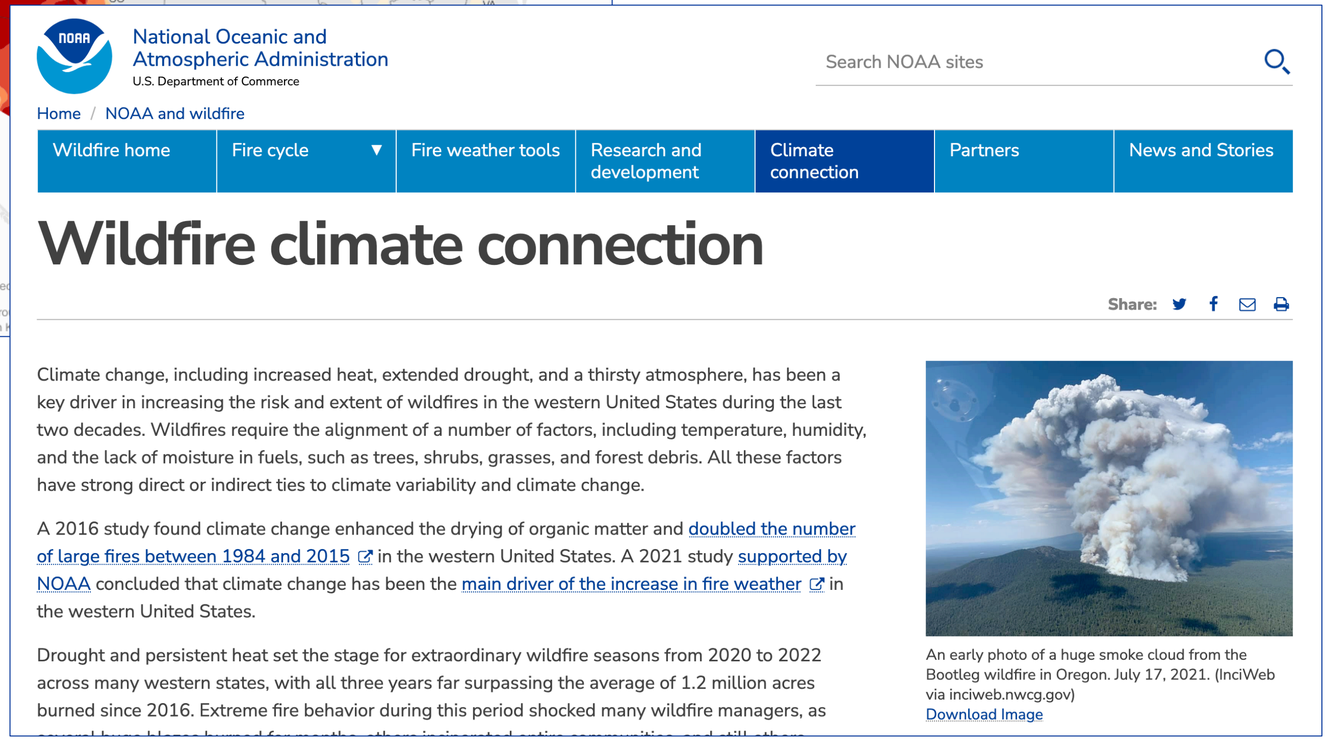
Drought and persistent heat set the stage for extraordinary wildfire seasons from 2020 to 2022 across many western states, with all three years far surpassing the average of 1.2 million acres burned since 2016. Extreme fire behavior during this period shocked many wildfire managers, as

An early photo of a huge smoke cloud from the Bootleg wildfire in Oregon. July 17, 2021. (InciWeb via inciweb.nwcg.gov)
Download Image

There are many reasons for the megafires we are having today.







A century of fire suppression!

Too few good fires (low intensity)
and
too many bad fires (high intensity.)

Fire deficit!

Wildland Fire Deficit

- Apocalyptic wildfires have become the norm. The 2021 Dixie fire was the largest single-source wildfire in CA history.

- A policy of wildfire suppression has resulted in fuel accumulation, increasing the risk of severe wildfires during fire season.

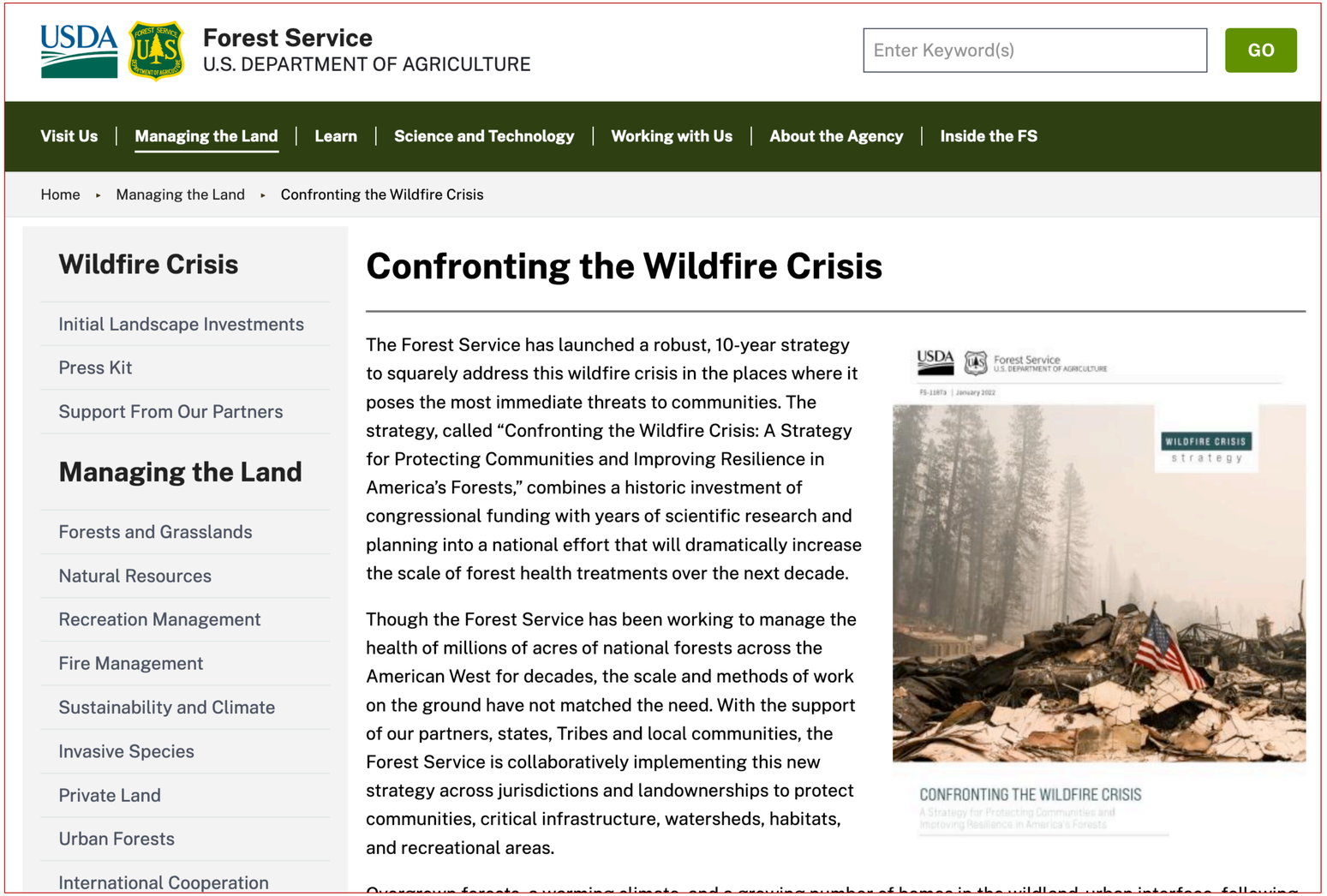
- Climate change (megadroughts, heatwaves) and invasive species exacerbate the problem

The solution:

Proactive wildfire risk mitigation through **prescribed burns**.

2022

US launches a new ten-year strategy to proactively confront the wildfire crisis by **ramping up prescribed burns by 4X!**



https://www.fs.usda.gov/managing-land/wildfire-crisis

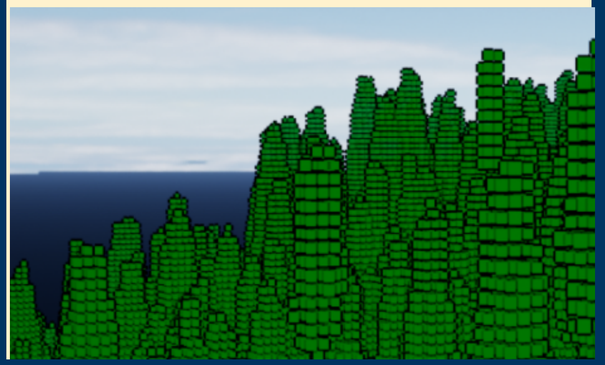
BurnPro3D

- BurnPro3D is a decision-making tool to plan safe and effective prescribed burns
- It uses a coupled fire/ atmosphere model to capture the interaction between user-defined ignition patterns and environmental (weather, fuel) conditions.
- Powered by the Wifire Data and Models Commons and led by Dr. Ilkay Altintas

Four Pillars of BurnPro3D

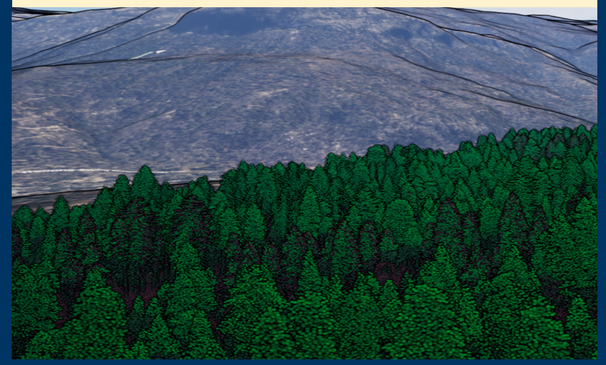
FastFuels

3D Fuels for Fire Models



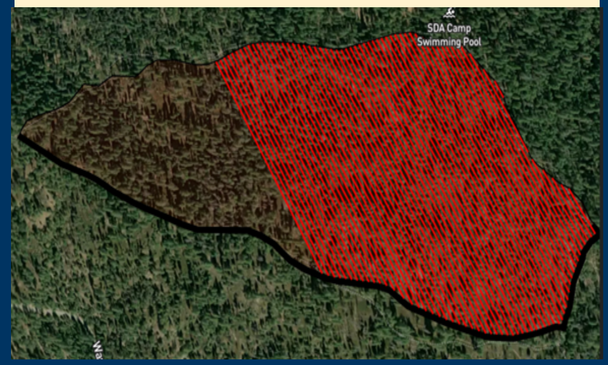
TrueTrees

Lidar-Derived Tree Positions and Heights



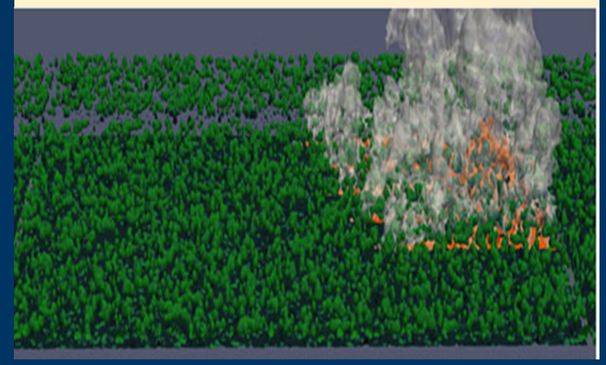
DripTorch

Custom Ignition Patterns

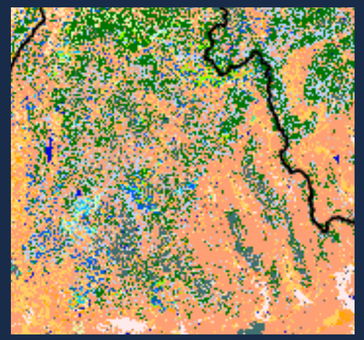


QUIC-Fire

Prescribed Fire Simulator

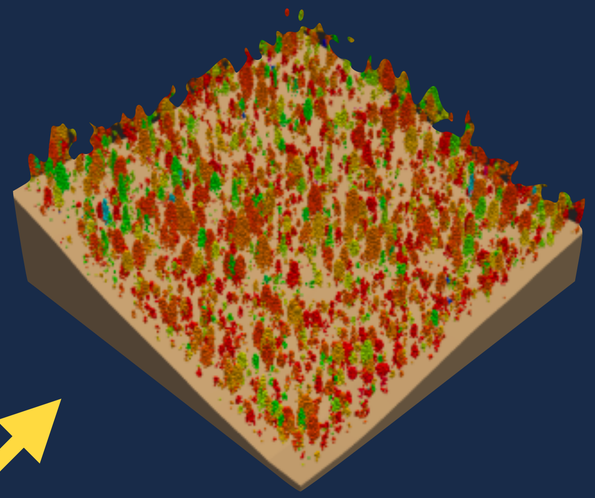


Landfire



2D (30 m resolution)

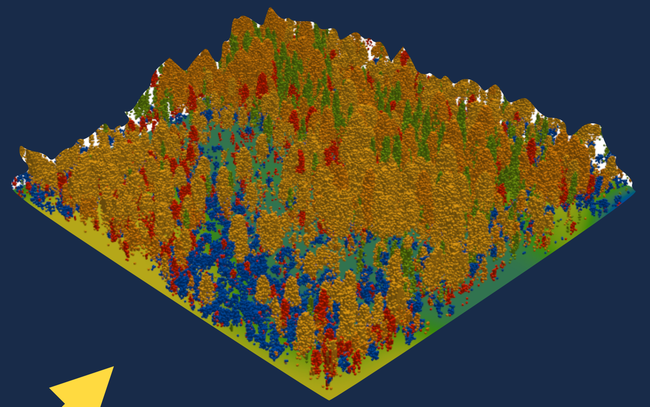
FastFuels



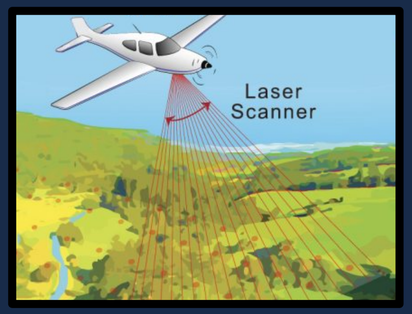
3D (1m resolution)
Statistically modeled tree parameters

FIA DB

TrueTrees



3D (1m resolution)
Lidar-observed tree paramete



FastFuels is “a 3D fuels super-highway” that accelerates the use of 3D fire models.

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TrueTrees represents an ”on-ramp” to this superhighway that integrates ALS observations into 3D fuels.

Tree Parameters (Dendrometrics) in FastFuels and TrueTrees

Tree Parameter	FIA Symbol	FastFuels	TrueTrees
Position [m]	X, Y	Modeled from forestry data	Measured by Lidar
Height [m]	HT		
Crown radius [m]	CR		
Diameter [m]	DIA		Modeled from Lidar and forestry data
Species code	SPCD		
Crown base height	CBH		
Statuscode	STATUSCD	N/A	N/A

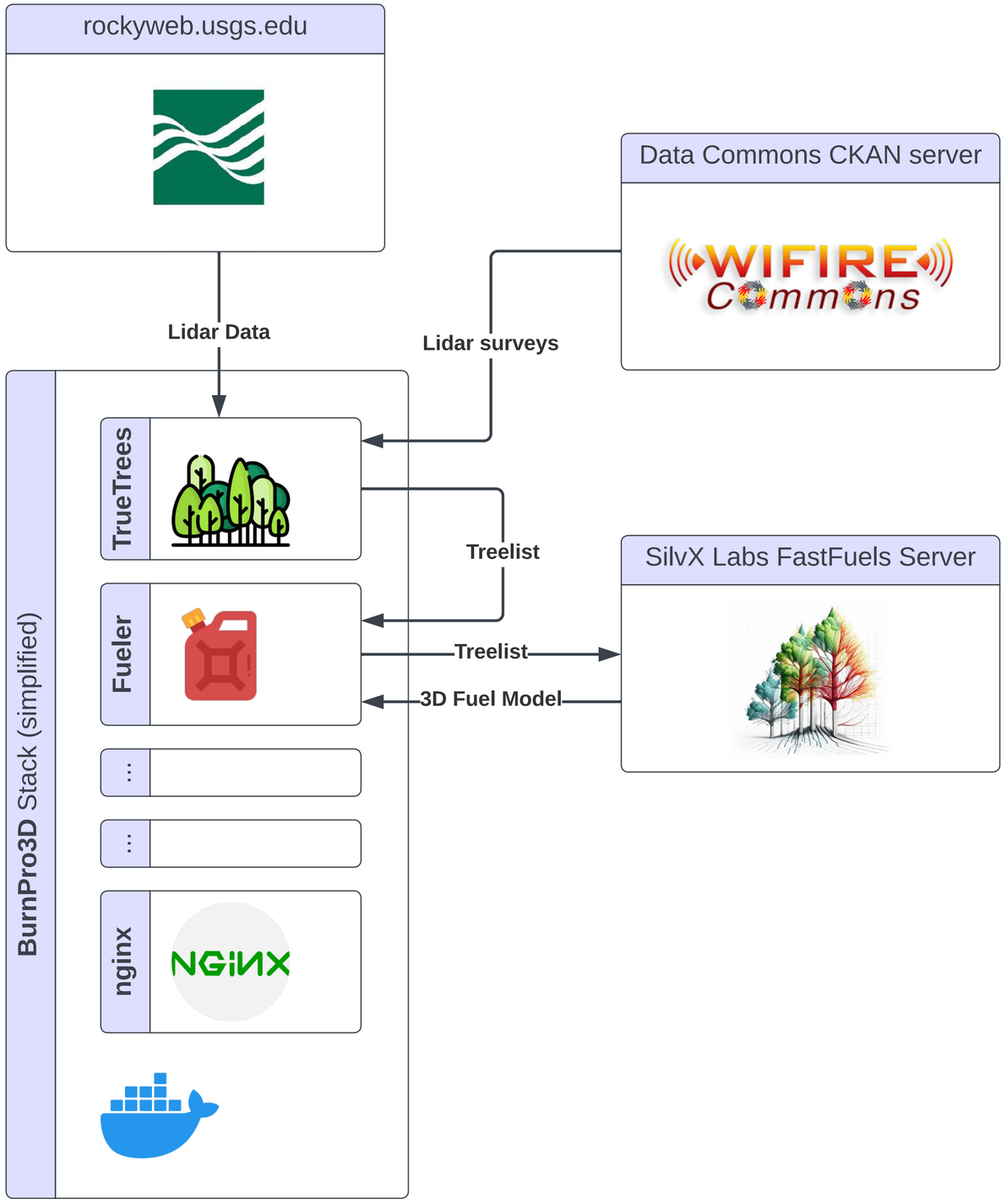
TrueTrees is a scalable, automatic workflow that carries out two main tasks:

1. Raw Lidar point cloud data query, retrieval and treelist extraction.
2. Modeling of tree parameters that can not directly be determined by Lidar.

TrueTrees interacts with multiple external data sources and services:

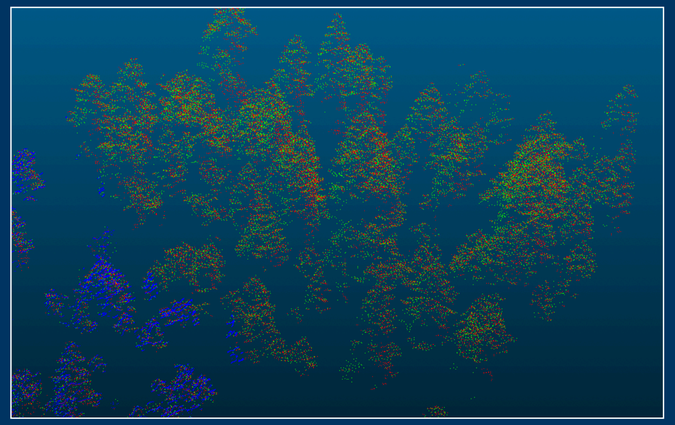
- USGS 3DEP Lidar data repository (Rockyweb)
- WIFIRE Commons Data catalog (Lidar metadata)
- FastFuels Server (SilvX Labs)

TrueTrees workflow is integrated in BurnPro3D software stack.



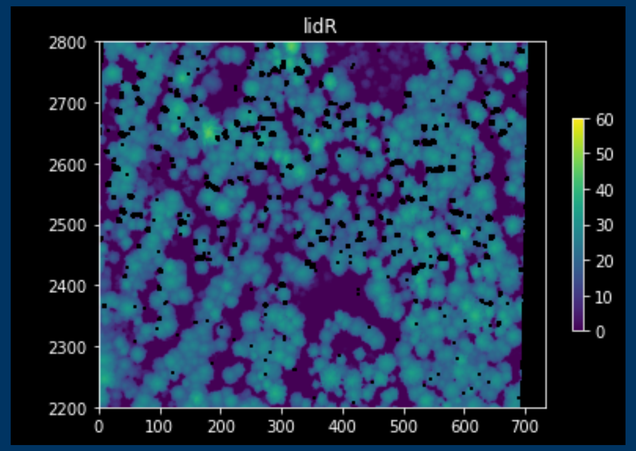
Treelist Extraction from Lidar Point Cloud Data

ALS Point Cloud Data



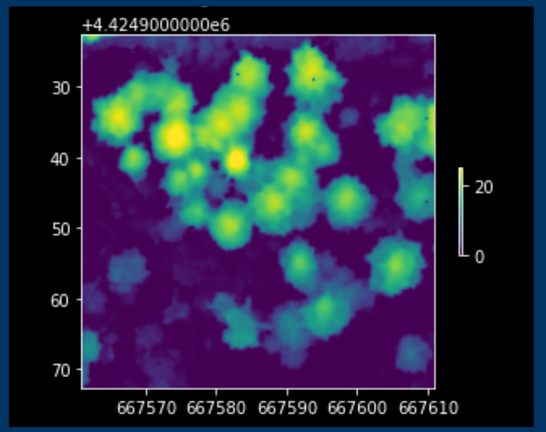
Noise filtering
Normalization

Pit-free canopy height model



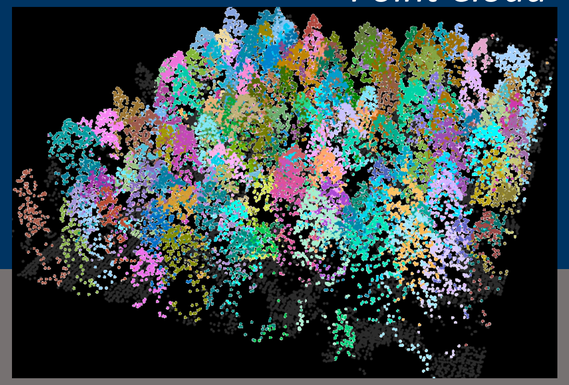
Height-based filtering

Smoothed CHM



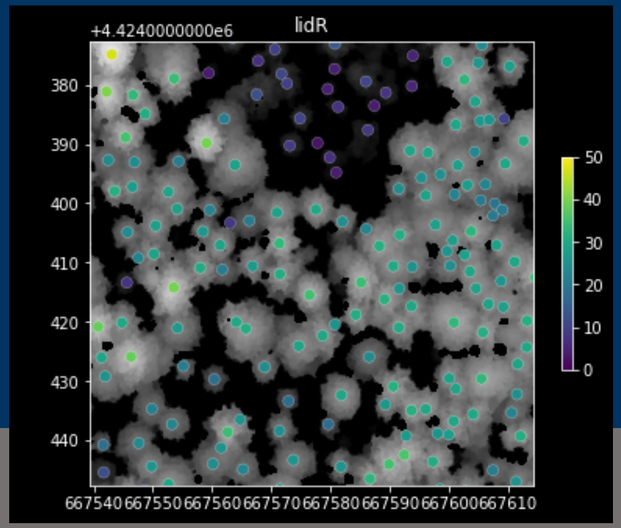
Tree segmentation (Watershed algorithm)

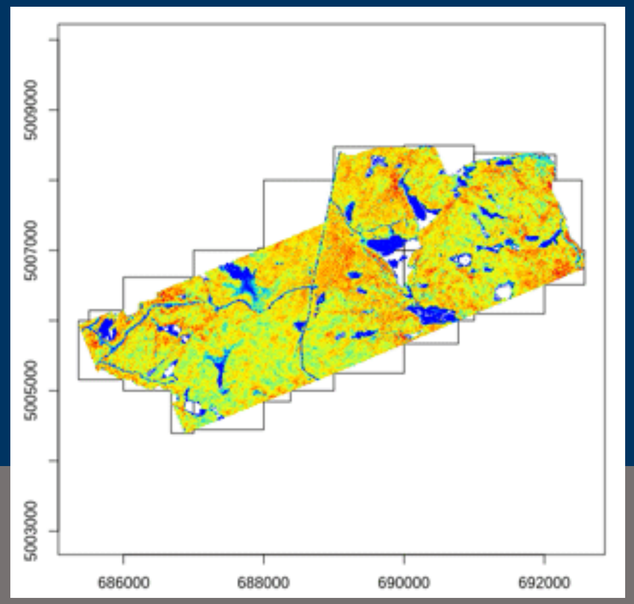
Labeled Point Cloud



Tree extraction

Tree list





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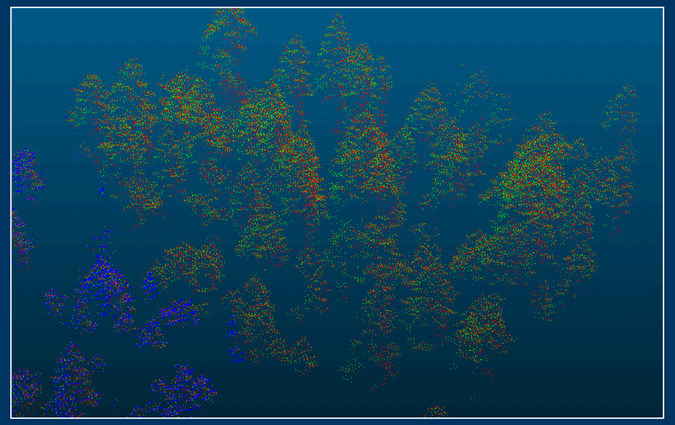

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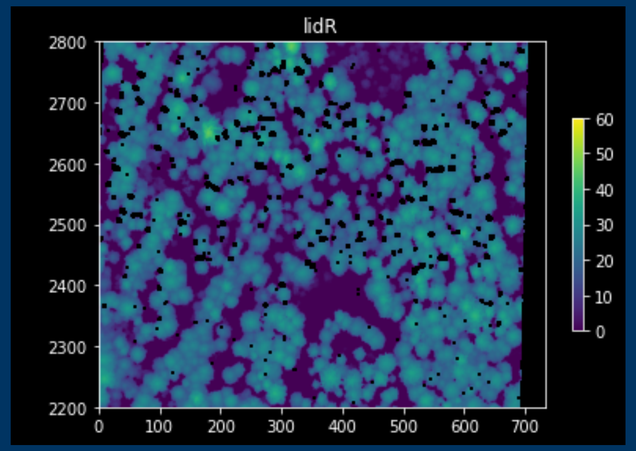

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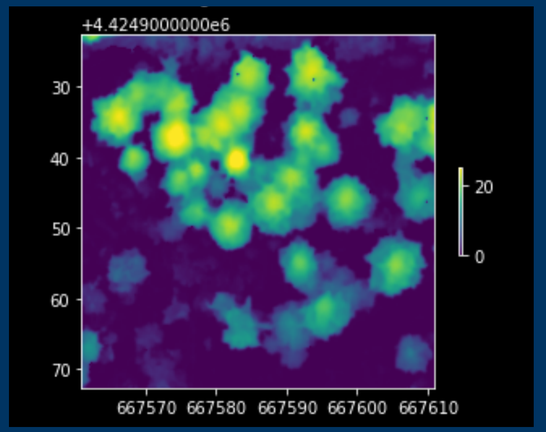

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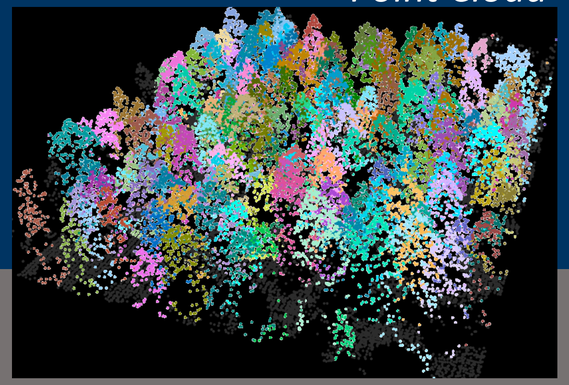

Tree extraction

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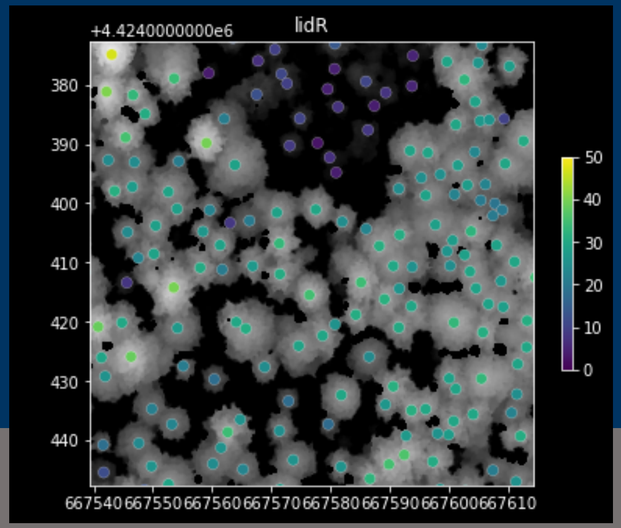
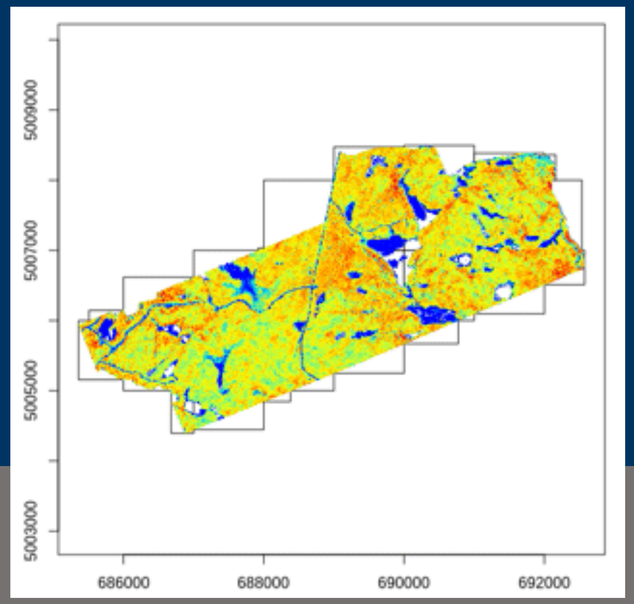
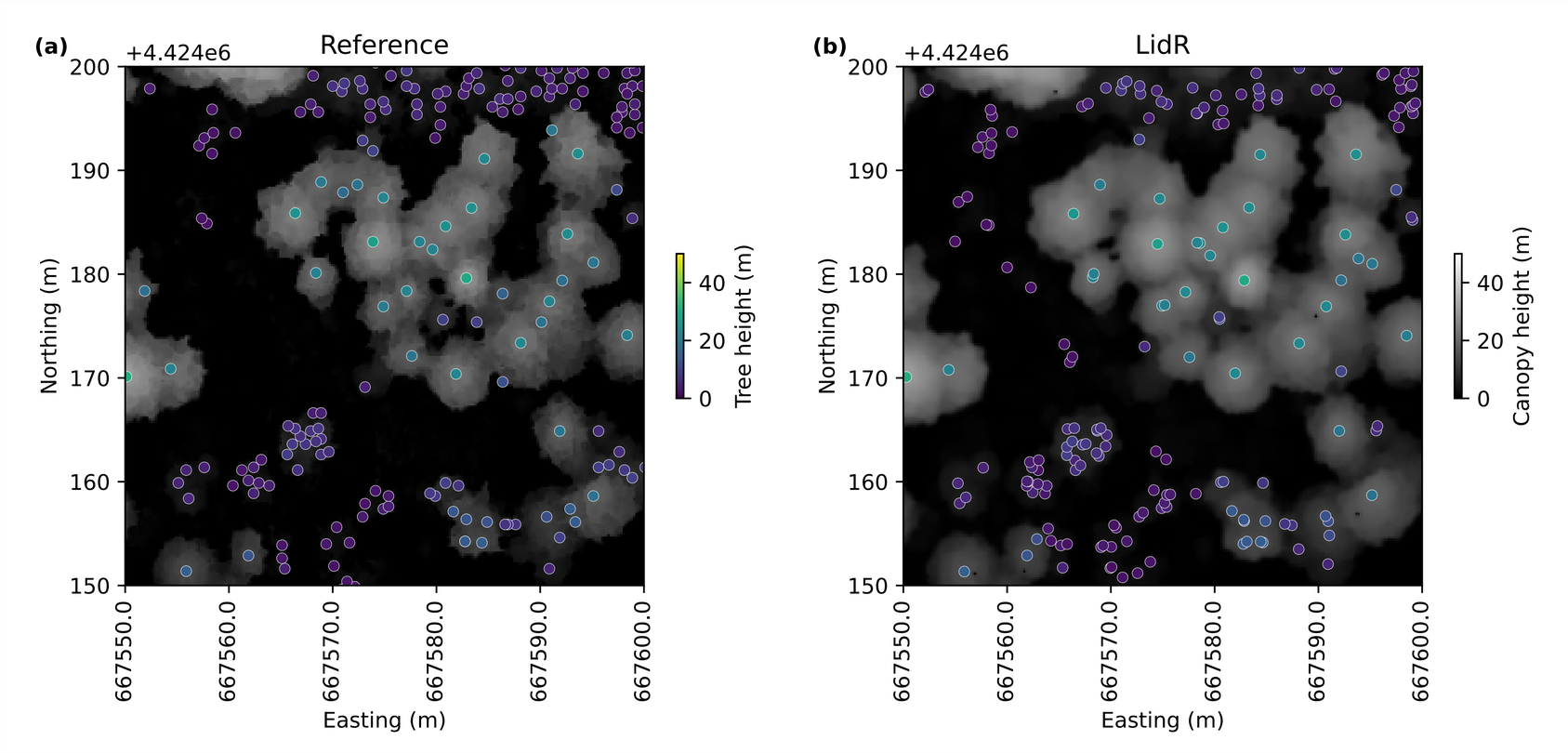


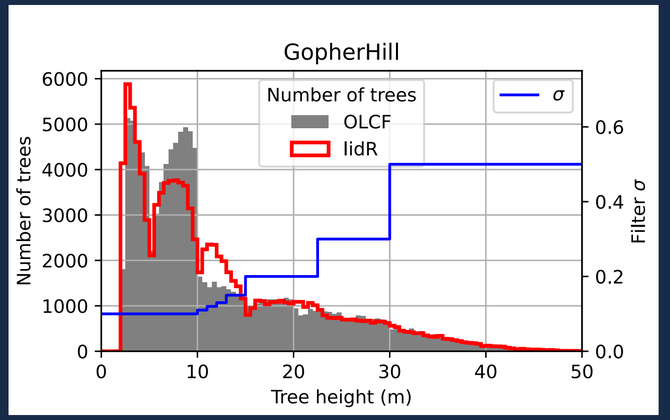


Verification of Tree Extraction Workflow

Reference tree extraction result:
U.S. Forest Service Lidar survey for northern CA forests, reported by Xu *et al.* (2018)



Length of height-based filter (Pitkänen et al., 2004) adjusted by trial-and-error.



Tree Extraction Workflow Weak Scaling

- R/Future for distributed processing of data chunks
- Deployed on Nautilus Kubernetes cluster using persistent or ephemeral volumes for shared data

Ft. Stewart Survey

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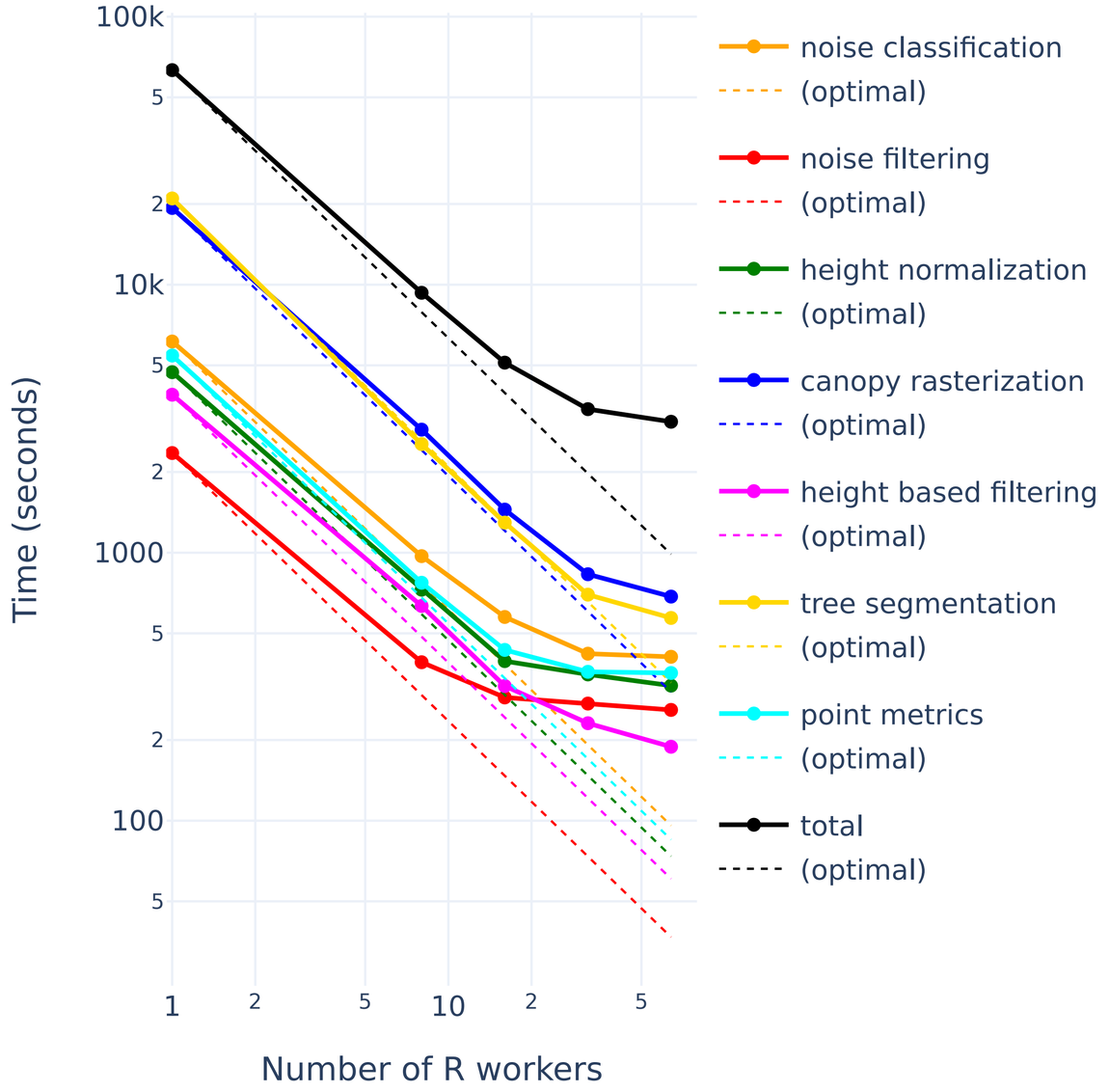
Ft. Stewart Survey

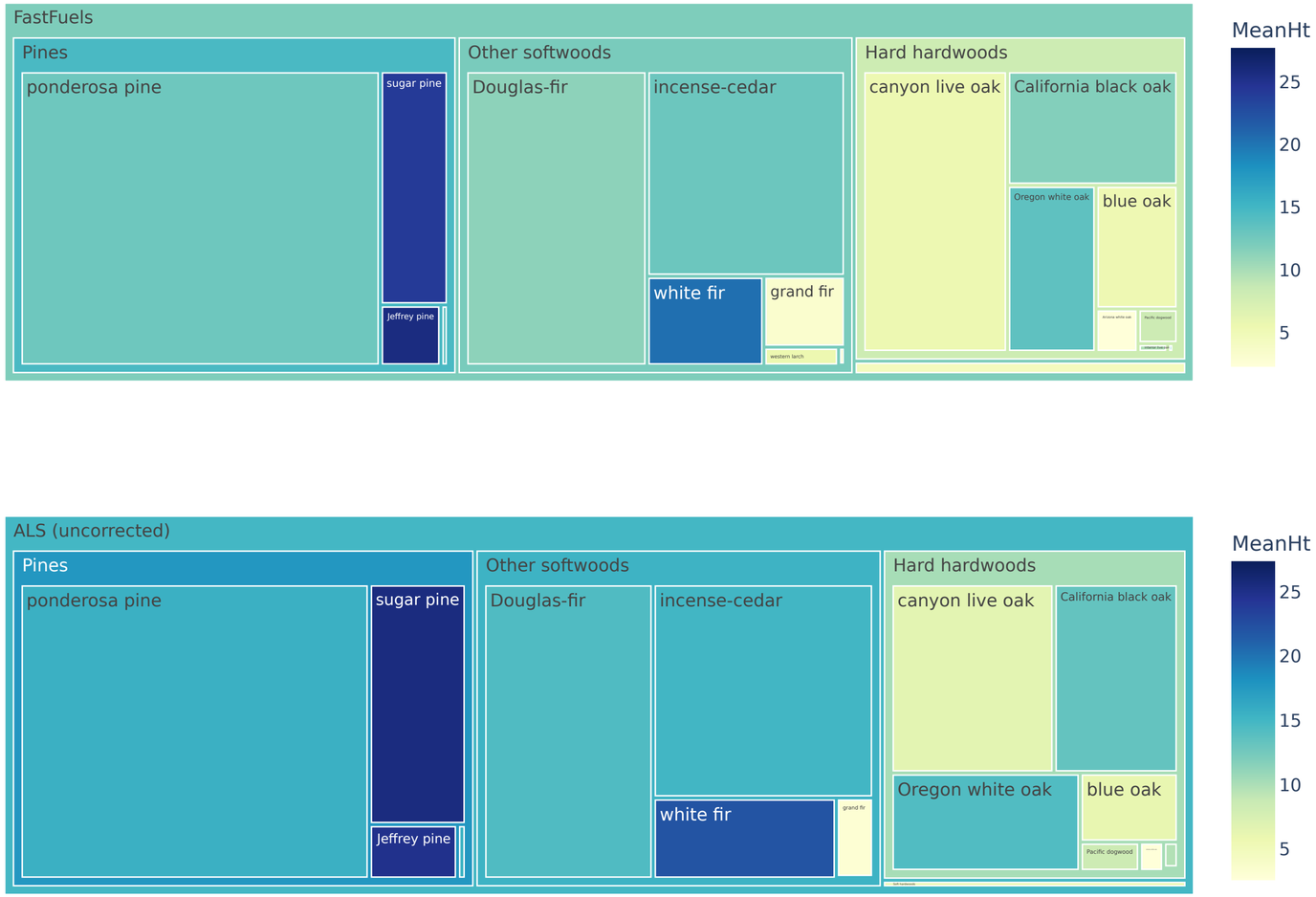
Storrie survey



Gaussian NB Classifier for Species Imputation

- Probability that tree of height X belongs to species k:

$$p(C_k|z=X) = \frac{p(C_k)\ p(z=X|C_k)}{p(z=X)}.$$



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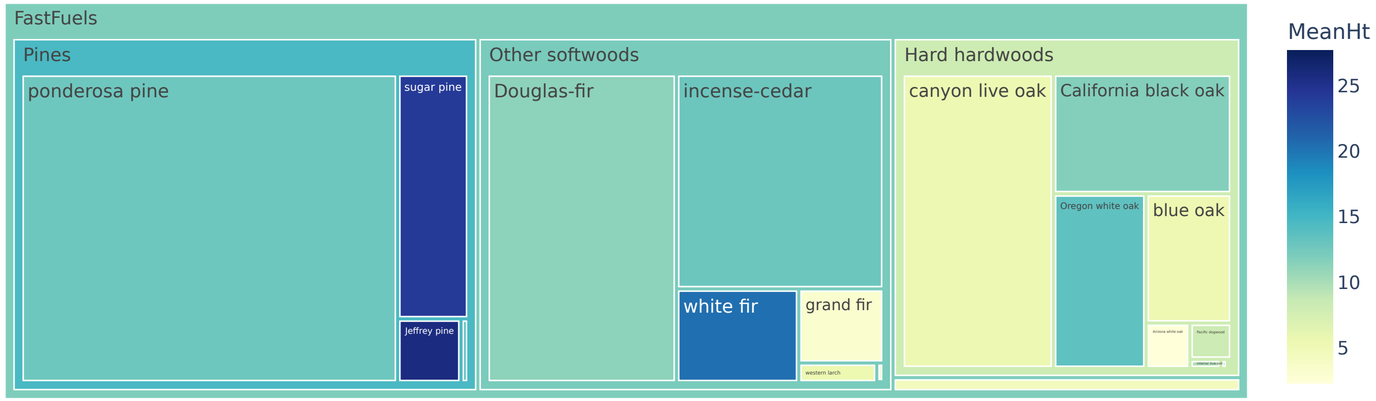
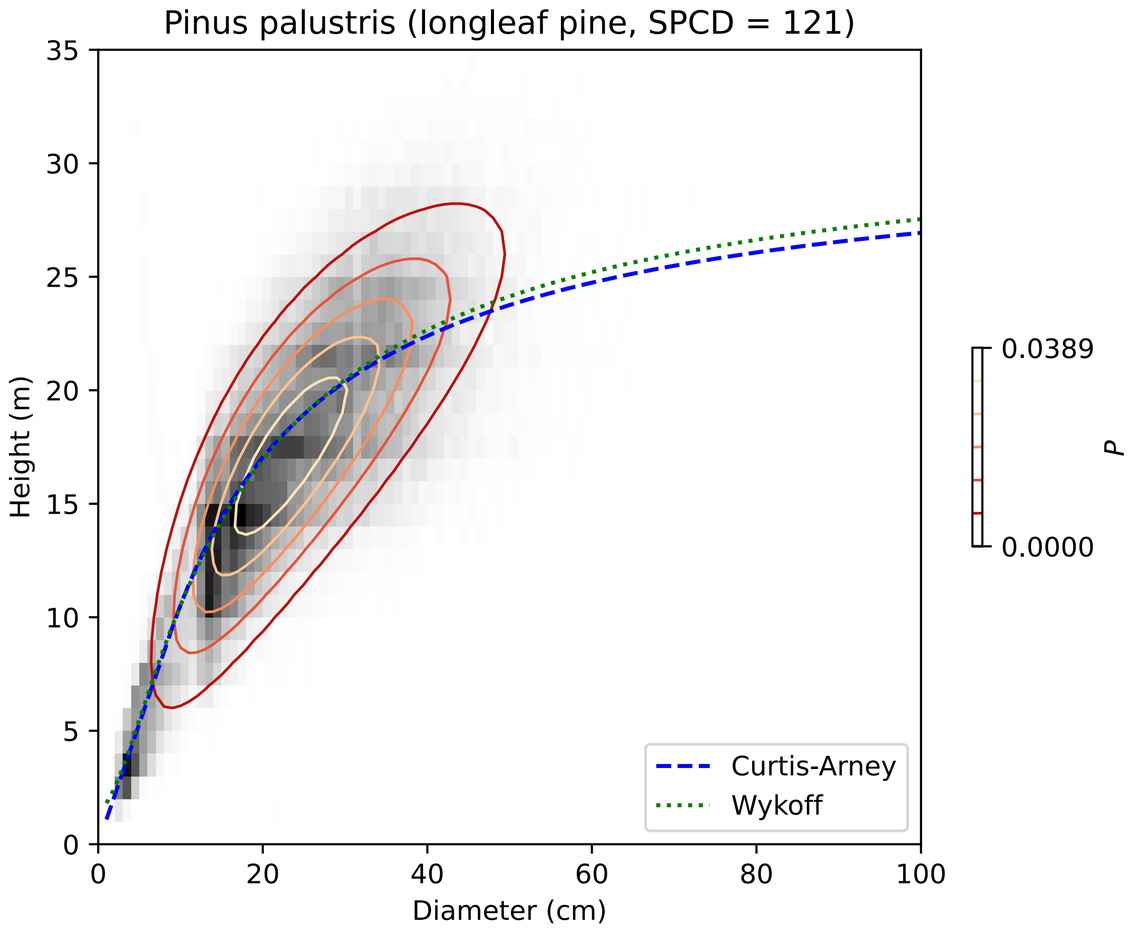
- Correction factor is applied to priors to reproduce species composition in forest inventory data

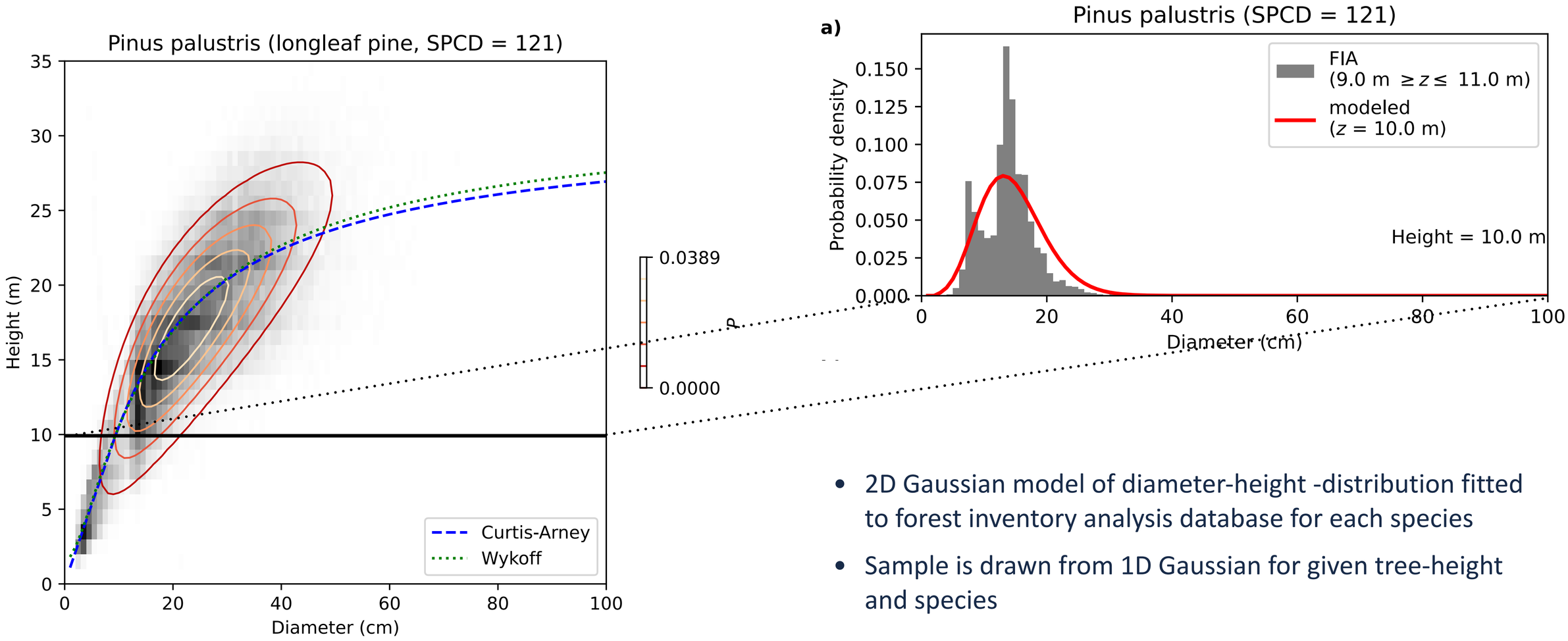


Tree Diameter Modeling



- 2D Gaussian model of diameter-height -distribution fitted to forest inventory analysis database for each species

Tree Diameter Modeling



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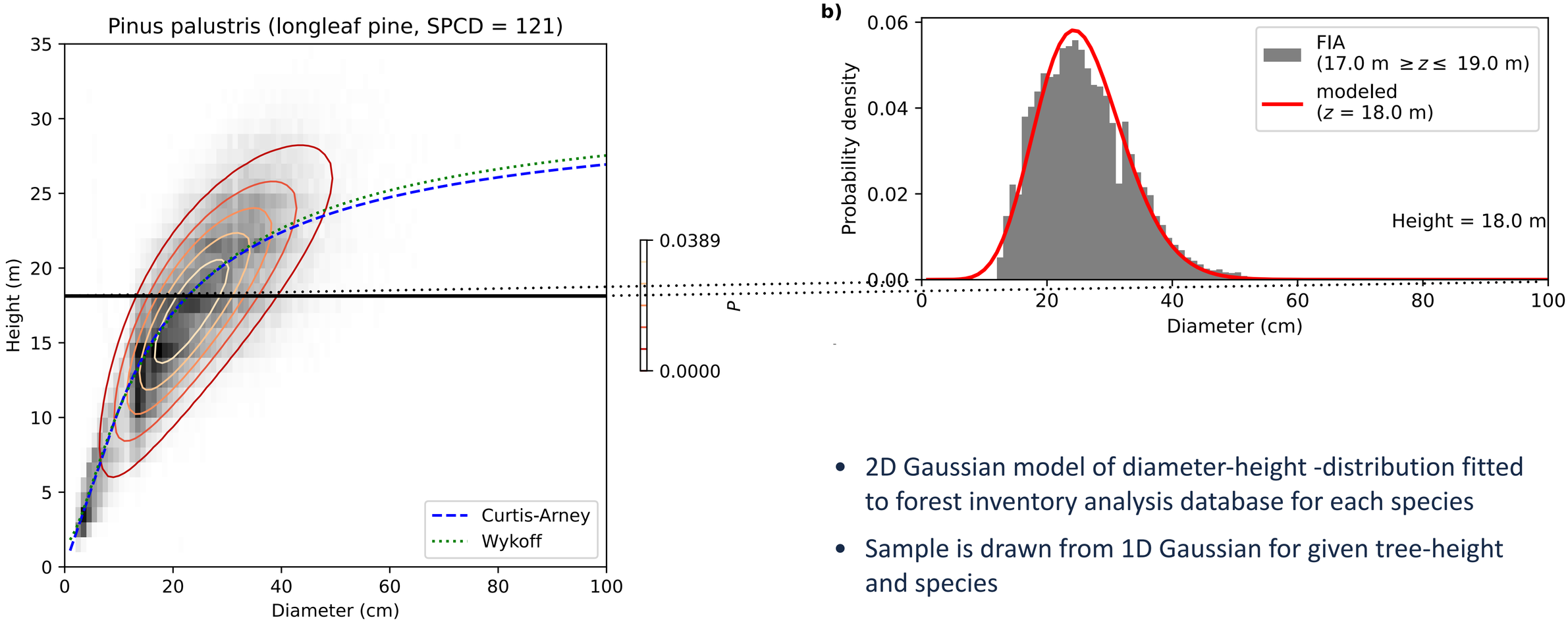
Tree Diameter Modeling



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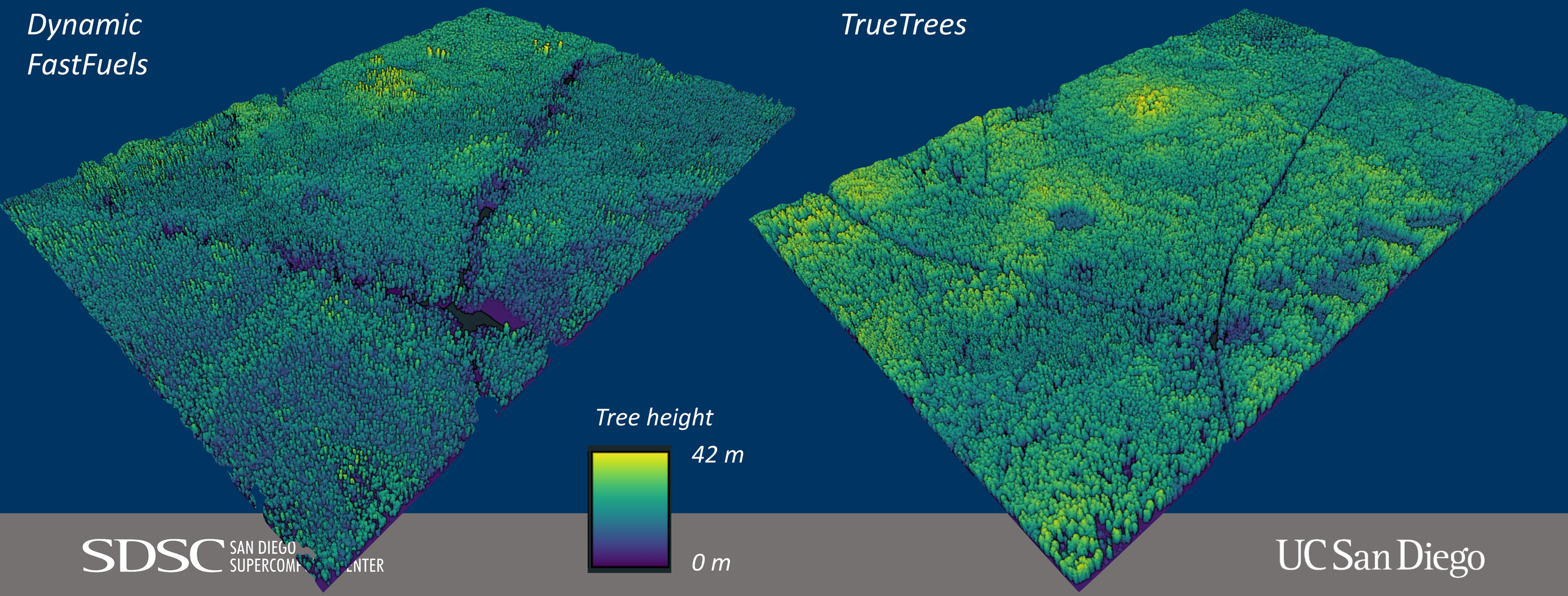
3D Fuel Model Comparison

Ft. Stewart Burn Unit, GA

Dynamic FastFuels

TrueTrees



Summary

- Prescribed burns are a proven way to mitigate wildfires in the face of heatwaves, megadroughts and fuel accumulation.
- BurnPro3D is a prescribed burn planning tool that combines advanced fire simulations and the 3D fuel models FastFuels to identify safe burn conditions.
- TrueTrees is an on-ramp to FastFuels that replaces randomly generated tree parameters in FastFuels with Lidar observations.
- A scalable, automatic workflow was developed to automatically identify available Lidar surveys, extract tree parameters from raw point cloud data and models and models missing parameters.
- The workflow is integrated in the BurnPro3D application stack.

Acknowledgements

- WIFIRE team at SDSC
- Andy Hudak (USFS)
- Qing Xu (ICRB)
- NSF 2040676 and 2134904
- Nautilus

Questions?

E-mail d1roten@ucsd.edu

More info:

2023 eScience conference paper:

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