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College of Natural Resources

MULTI-TEMPORAL POINT CLOUD ANALYSIS

CAN 3D NAIP AND 3DEP LIDAR PROVIDE USEFUL MEASURES FOR ESTIMATING SITE INDEX?

EDWARD FLATHERS

WESTERN MENSURATIONISTS CONFERENCE 2025

MOSCOW, ID

17 JUNE 2025

University of Idaho
Department of Forest,
Rangeland and Fire Sciences

PROJECT SUPPORTERS

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THANK YOU!

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Forest Biometrics Research Institute

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MULTI-TEMPORAL POINT CLOUDS

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PROJECT QUESTIONS

- Can we use a time series of 3D point cloud data from 3DEP and 3D NAIP for a specific area to measure change, especially Δh/t?
- Under what conditions will 3D NAIP data support individual tree identification vs canopy/area based modeling?
- Can we locate individual trees in higher density point clouds and co-locate those trees in 3D NAIP data?
- Will height measurements from different instruments, densities, and times support measuring height differences over time?
- Can we use multi-temporal measurements to inform site index computation?

3D NAIP

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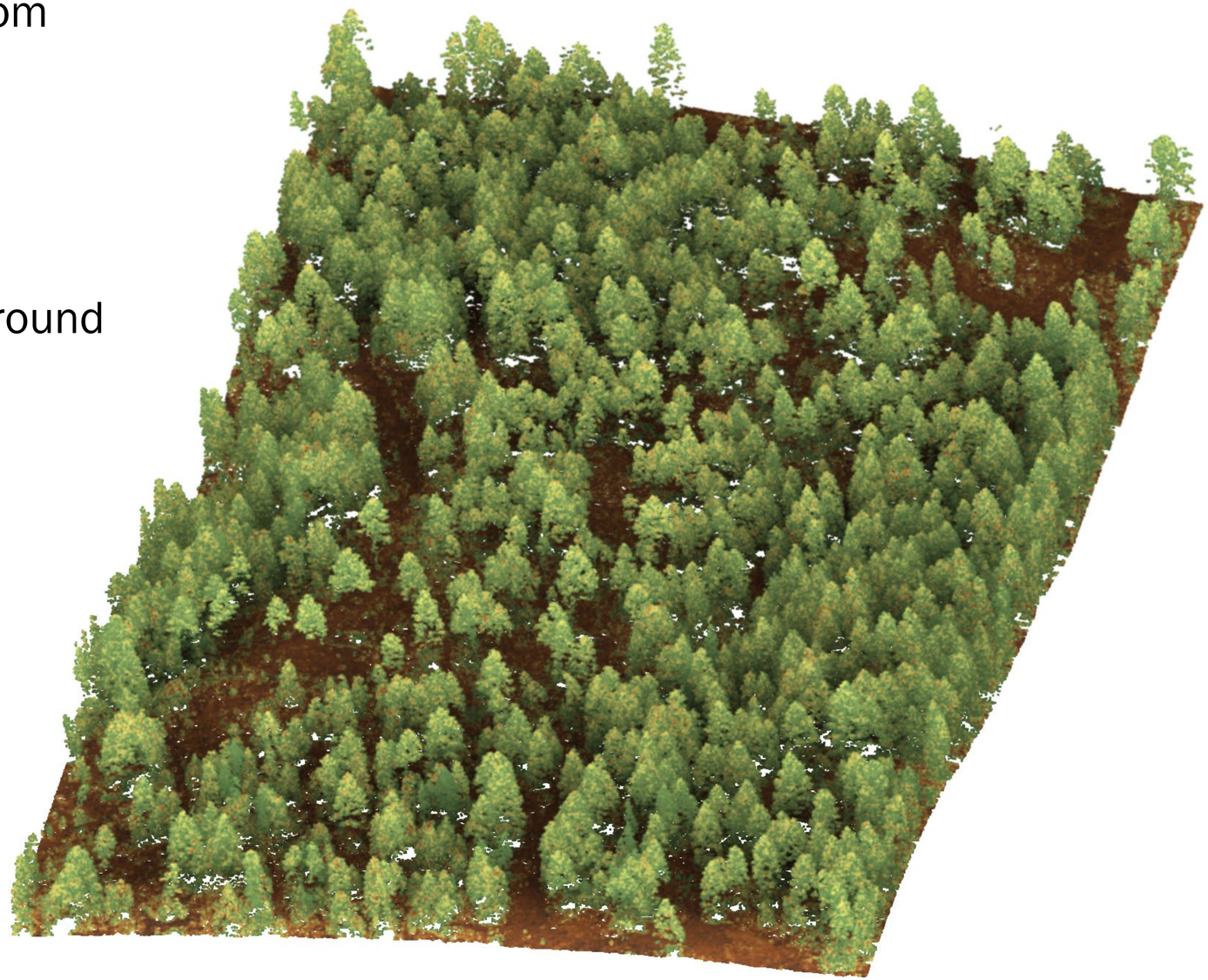
- A 3D point cloud generated using Structure from Motion (SfM) algorithms on overlapping NAIP imagery
- Natural and/or color infrared attributes
- Works best at canopy top and unobstructed ground
- Low point density below canopy



CHALLENGES: DATA AVAILABILITY

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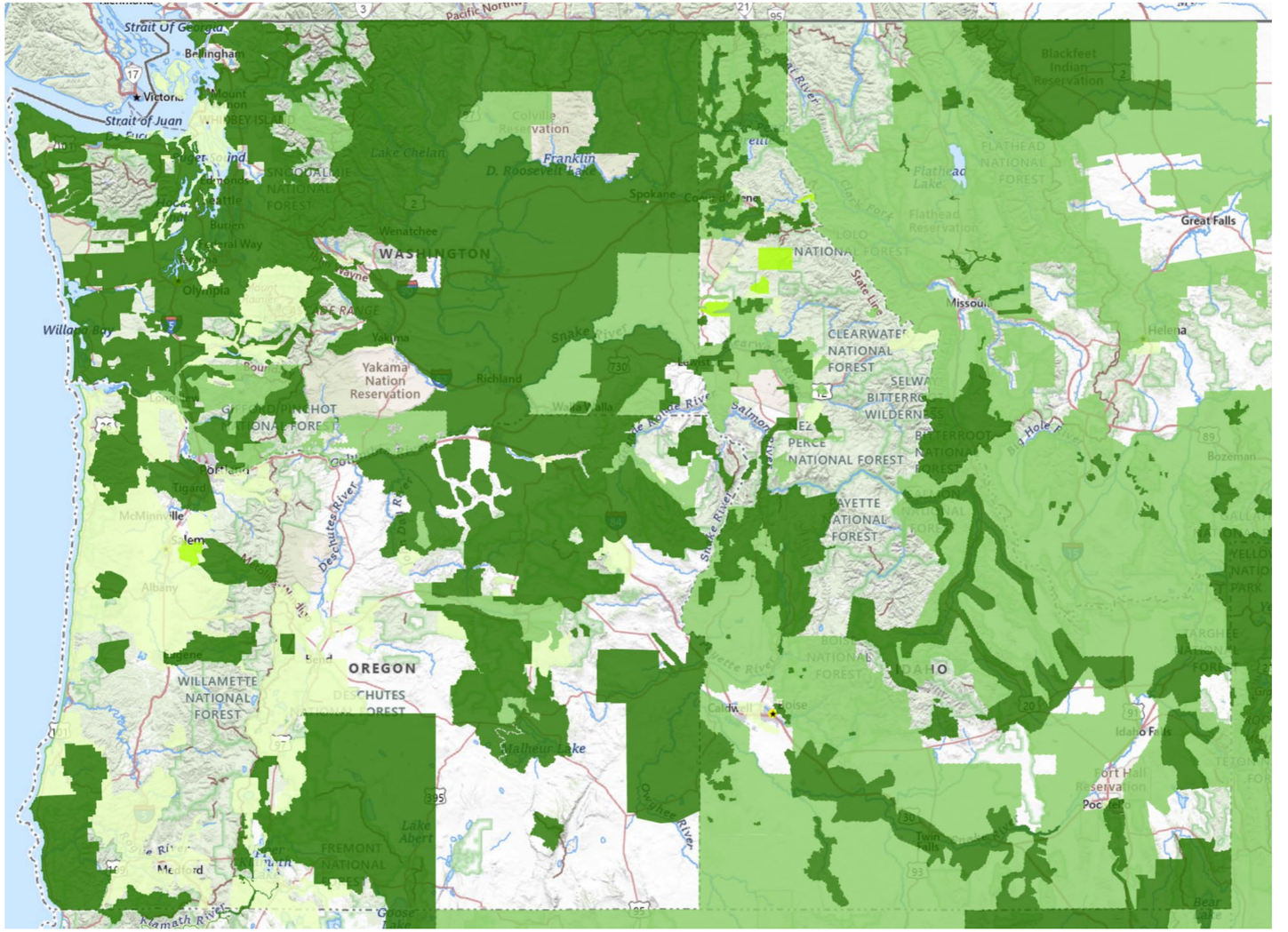
- Statewide 3D NAIP may exist, but may be expensive and encumbered with licensing terms
- 3DEP LiDAR may exist, but are limited in spatial and temporal extents and continuity (USGS 3DEP LidarExplorer, right)
- UAV and other LiDAR sources may not be georeferenced with high accuracy



CANOPY HEIGHT MODELING

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The typical approach:

$$DSM - DTM = CHM$$

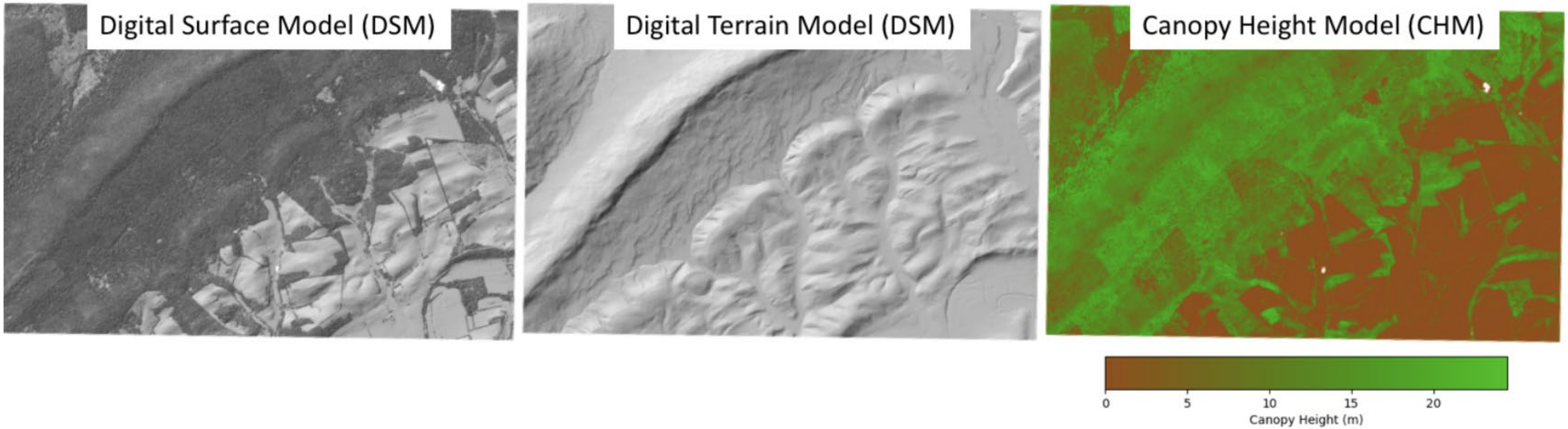

Figure: https://opentopography.org/news/opentopography-releases-canopy-height-model-tool

CHALLENGES: NO 3D NAIP DTM

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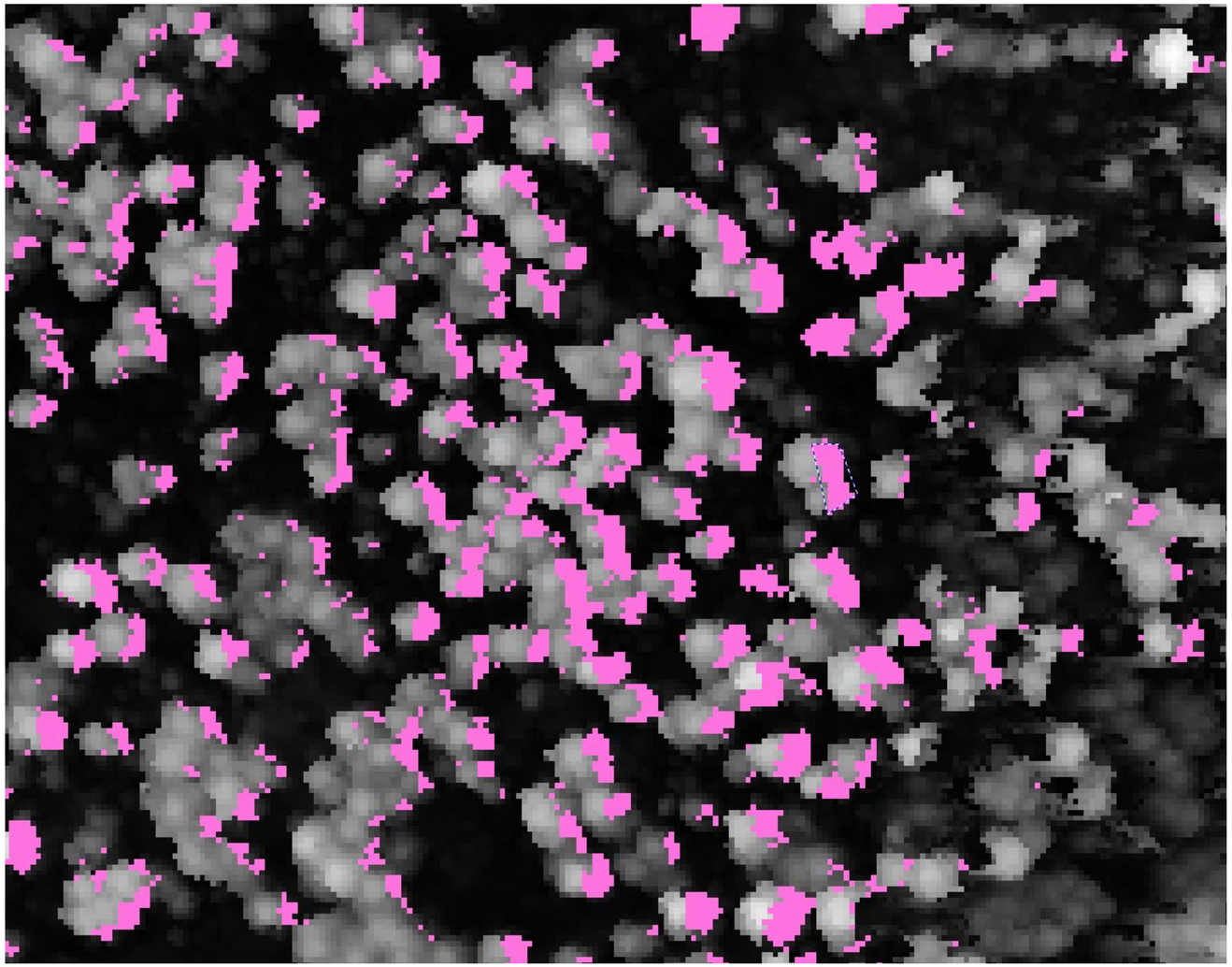
- Ground area occluded by canopy are sparse/missing. This would include most ground area directly beneath trees.
- Ground area in deep shadow (pink areas, right) are sparse/missing. These data voids can be >100m^2.
- With so many large areas of missing ground, a useful DTM cannot be generated from 3D NAIP.



CANOPY HEIGHT MODELING

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A hybrid approach is necessary:

$$DSM_{NAIP} - DTM_{3DEP} = CHM_{hybrid}$$

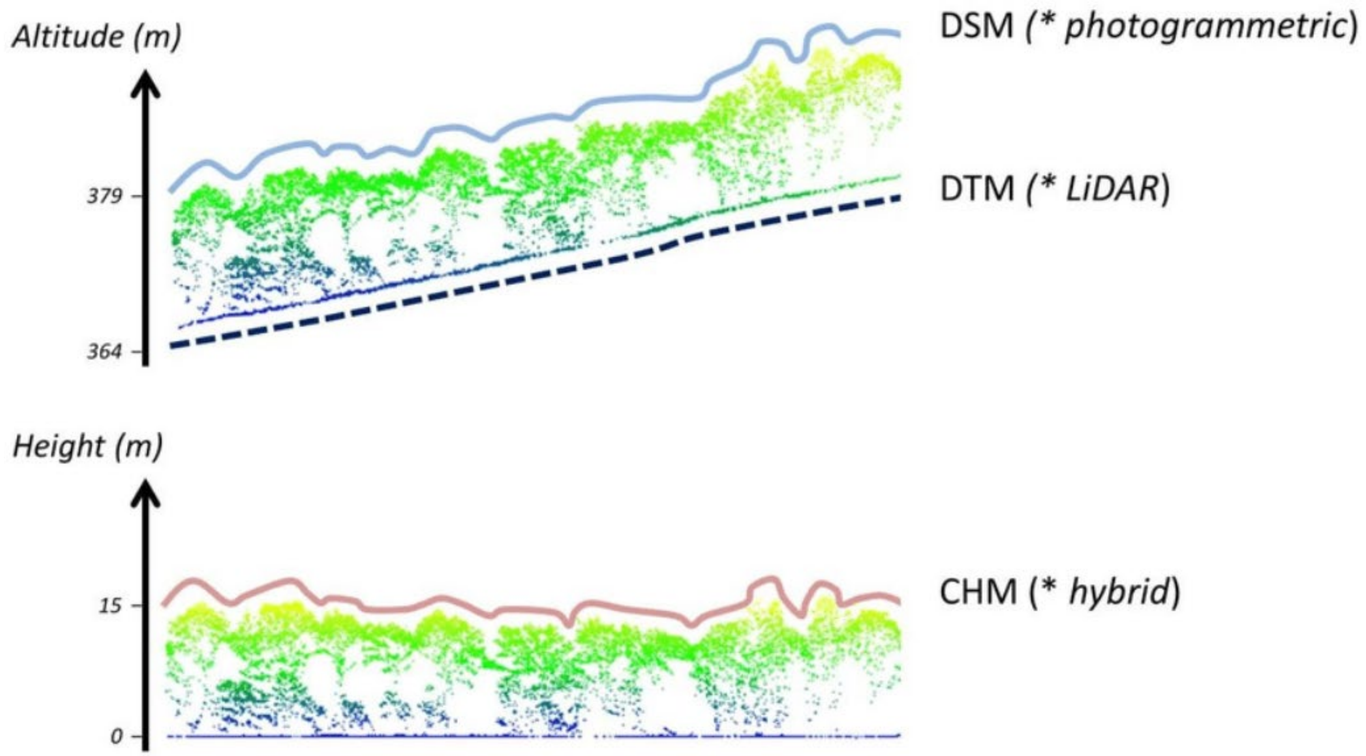

Figure: Adrien, Michez. (2016). Caractérisation multi-échelle des bandes riveraines des cours d'eau wallons par télédétection active et passive. DOI:10.13140/RG.2.2.17433.62569

CHALLENGES: HYBRID CHM

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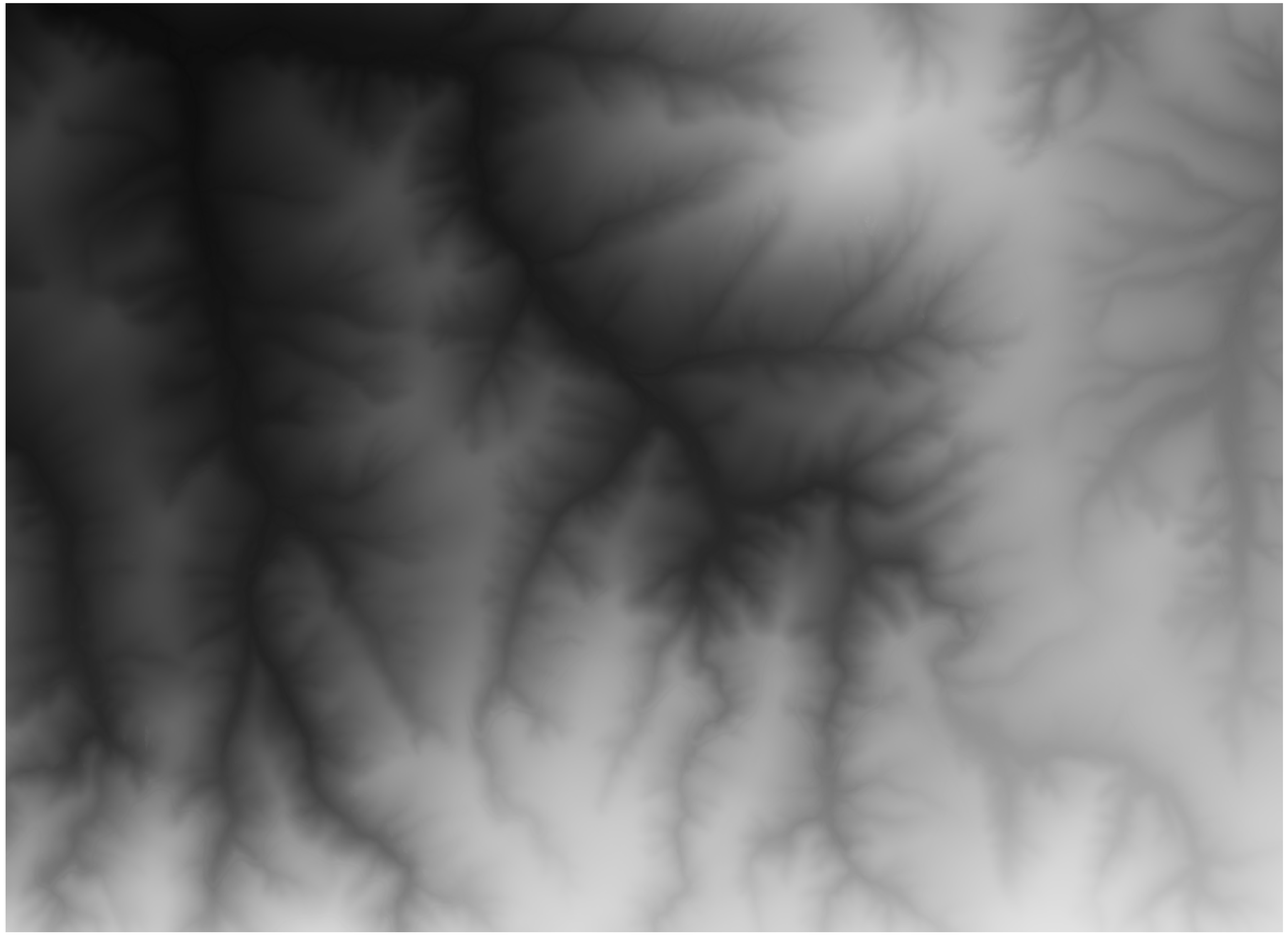
- Need a high-resolution, high-quality DTM
- Can be acquired from National Elevation Dataset or built from 3DEP (or other) LiDAR, if available
- Coordinate system differences are inevitable
- Data of different vintages almost certainly are based upon different geoid models for Z dimension
- Depending on geographic location, geoid differences could be on the order of single centimeters to tens of meters
- 3D NAIP point cloud must be closely coregistered with the DTM and/or its source data
- If any condition is not met, height estimation is degraded



STUDY AREA: MOSCOW MOUNTAIN

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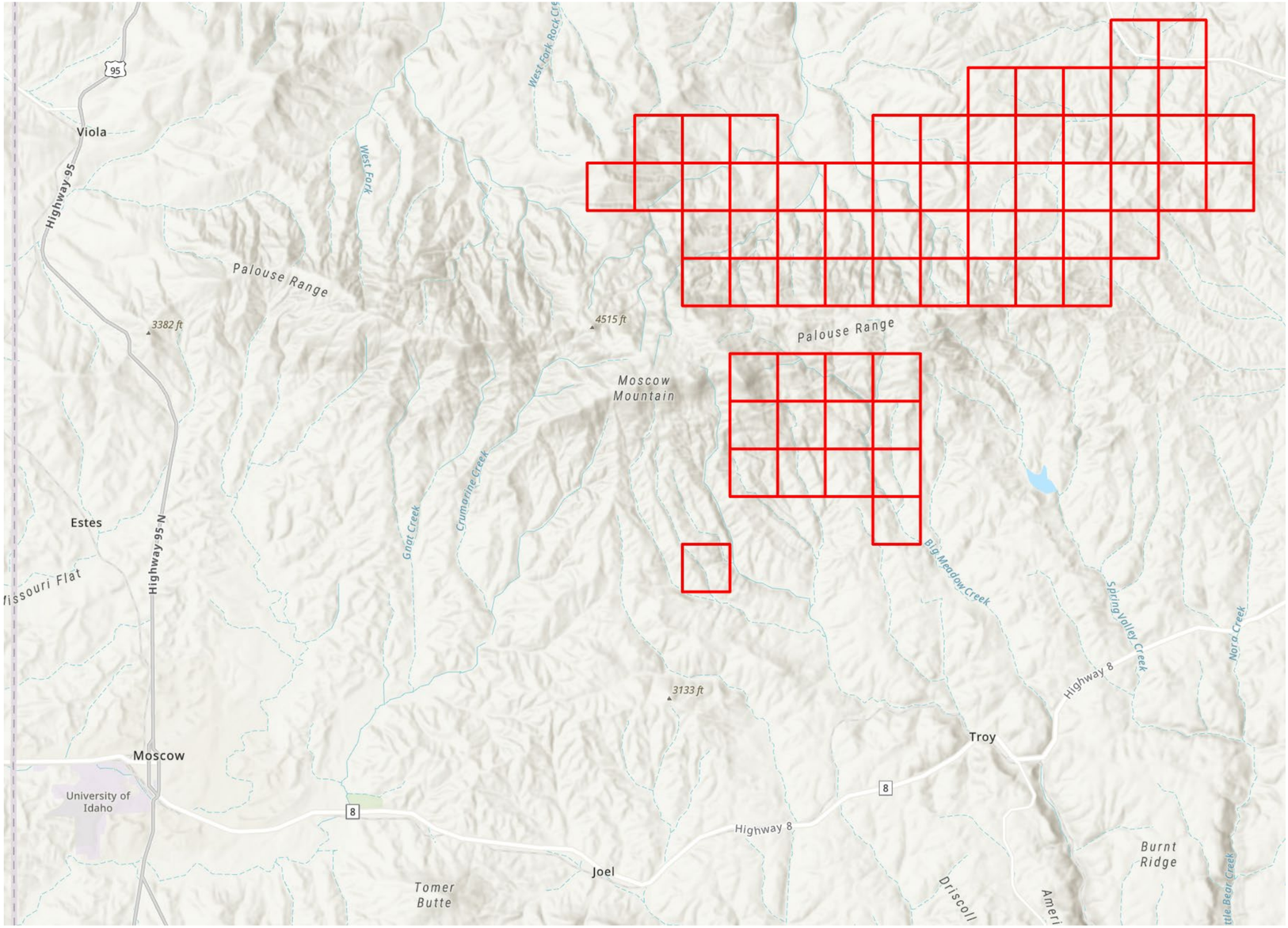
- Data available
  - 2023 3D NAIP
  - 2023 Geiger LiDAR
  - 2022 3DEP LiDAR
  - 2016 3DEP LiDAR
  - Stem mapped plots



DATA PROCESSING

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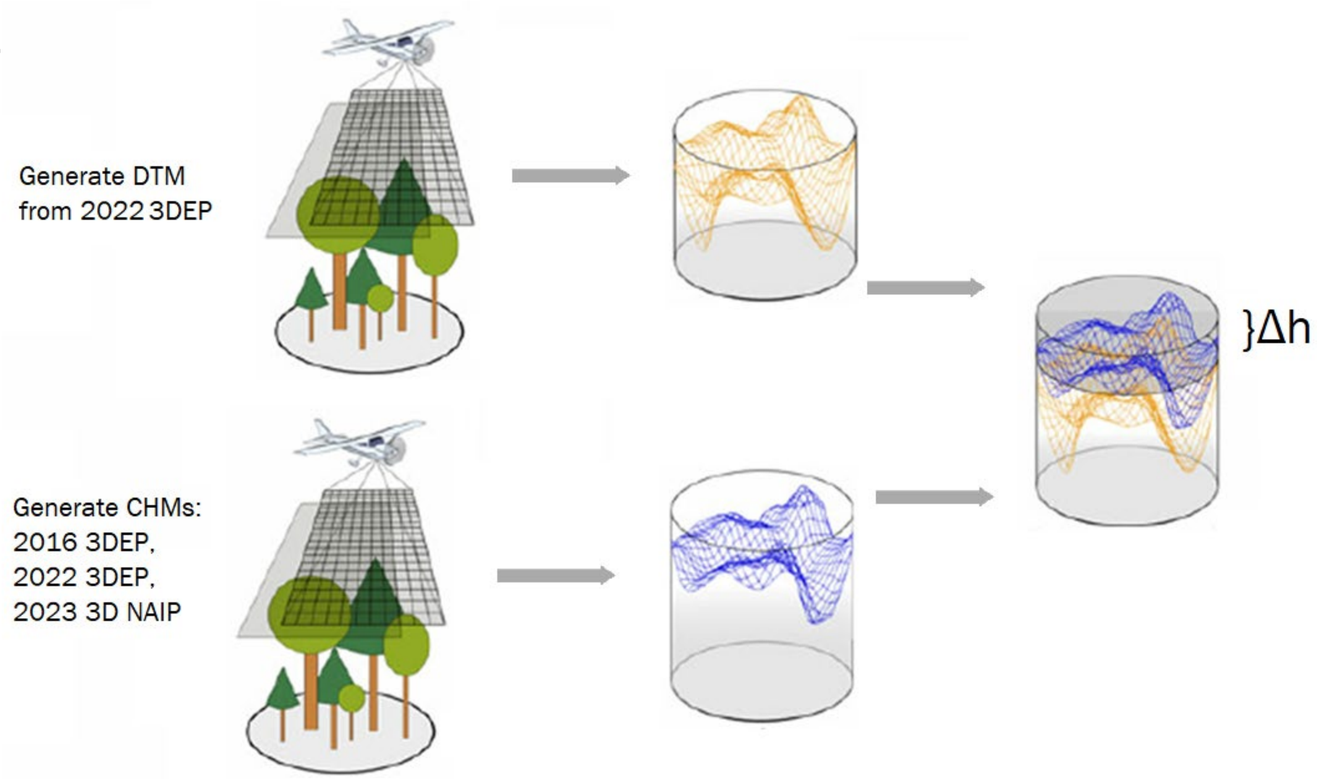
- Generate 30 cm DTM using 2022 3DEP L
- Generate 30 cm CHMs using
  - 2016 3DEP LiDAR
  - 2022 3DEP LiDAR
  - 2023 3D NAIP
- $\Delta h_{NAIP} = CHM_{2023} - CHM_{2016}$
- $\Delta h_{3DEP} = CHM_{2022} - CHM_{2016}$
- $h_{diff} = CHM_{2023} - CHM_{2022}$



STUDY AREA: MOSCOW MOUNTAIN

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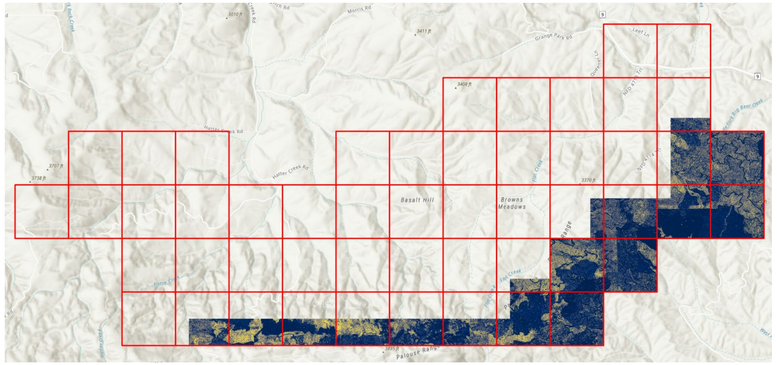
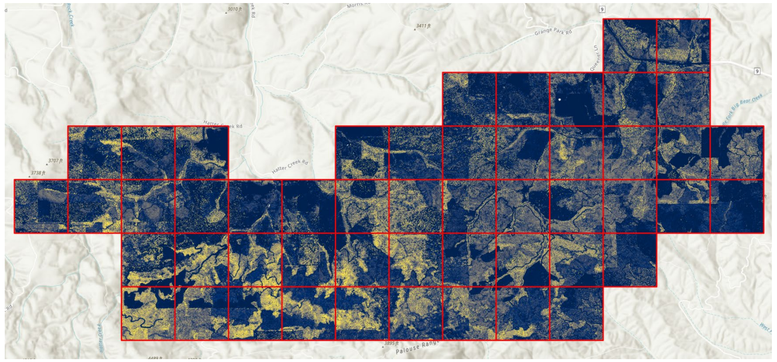
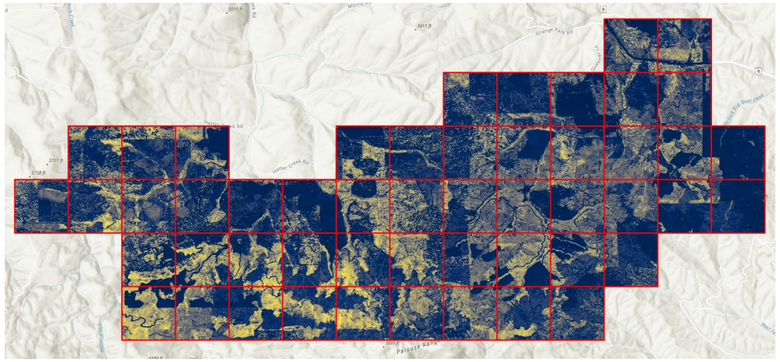


- 2016 3DEP LiDAR – significant missing data



- 2022 3DEP LiDAR – full coverage



- 2023 3D NAIP – full coverage

MOSCOW MOUNTAIN: HARVESTED AREA

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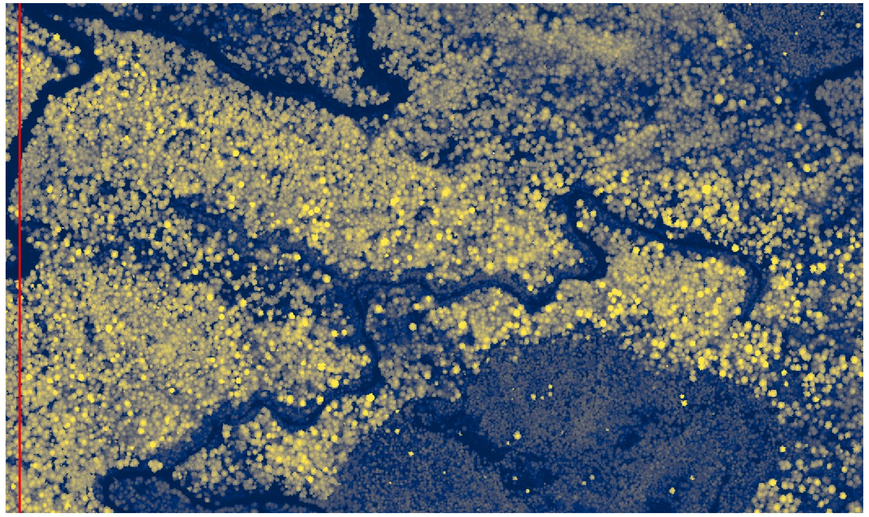
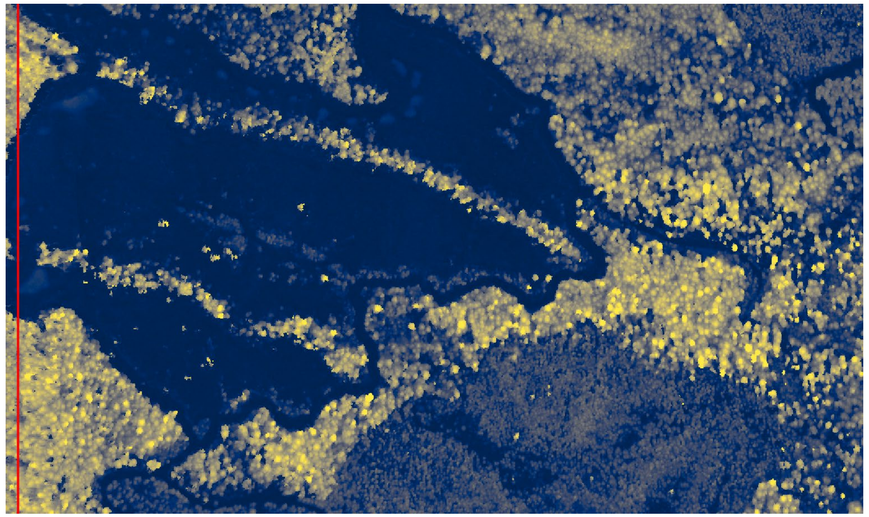
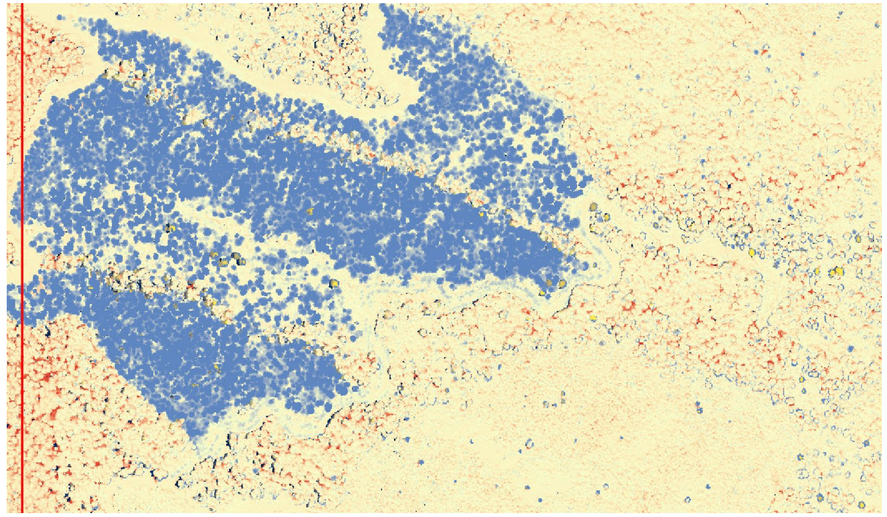
- 2022 3DEP LiDAR (CHM_{2022})

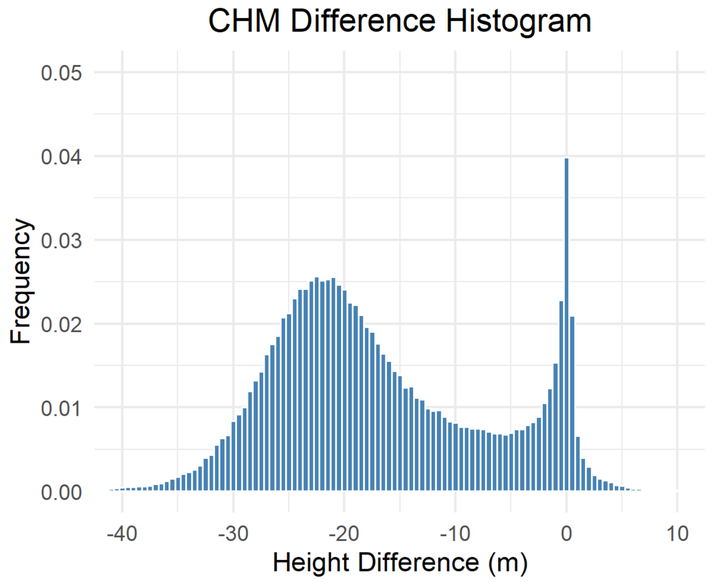


- 2023 3D NAIP – postharvest (CHM_{2023})



- $h_{diff} = CHM_{2023} - CHM_{2022}$





MOSCOW MOUNTAIN: MATURE AREA

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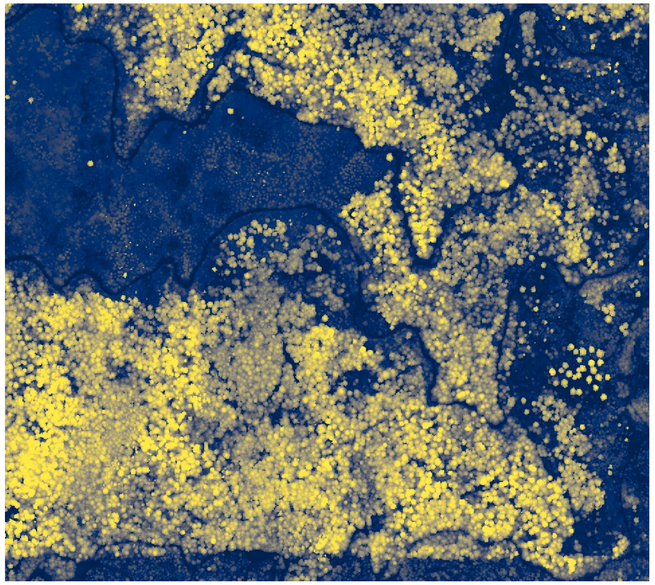
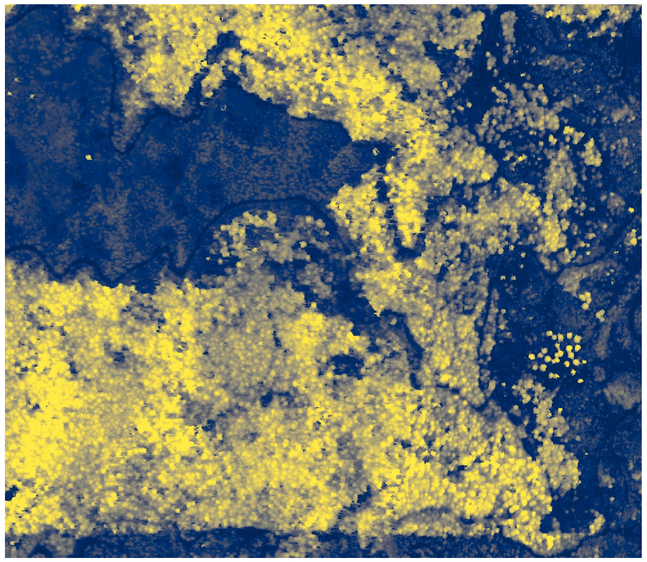
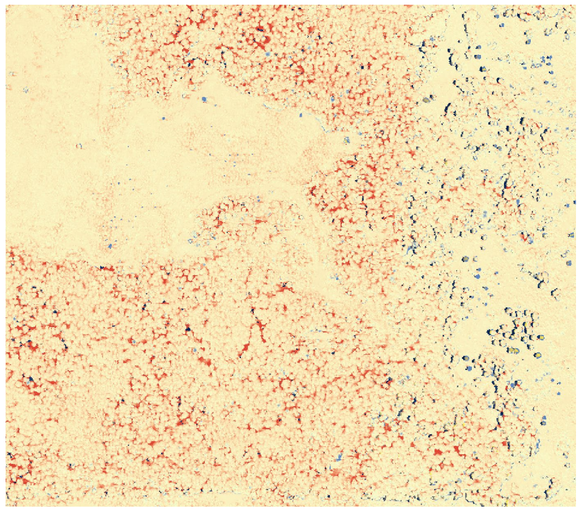
- 2022 3DEP LiDAR (CHM_{2022})

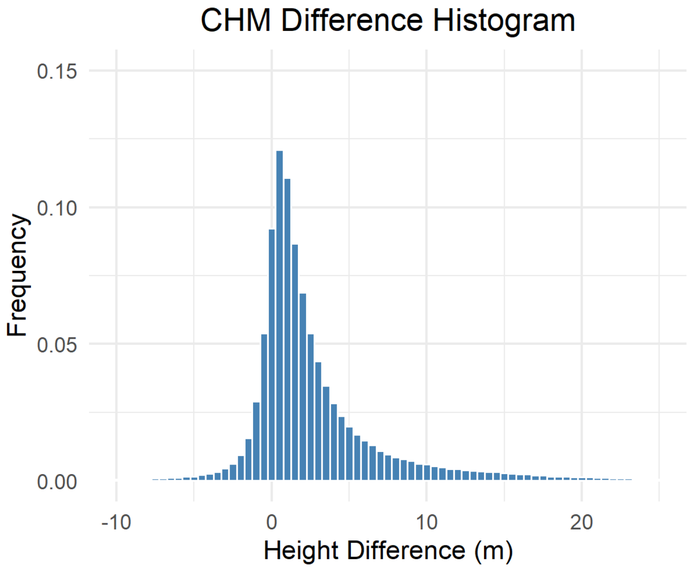


- 2023 3D NAIP – mature (CHM_{2023})



- $h_{diff} = CHM_{2023} - CHM_{2022}$





MOSCOW MOUNTAIN: REGEN AREA

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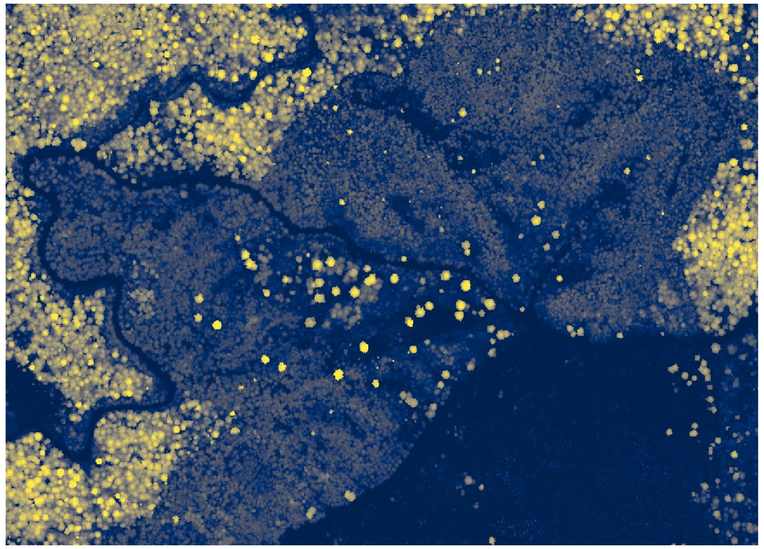
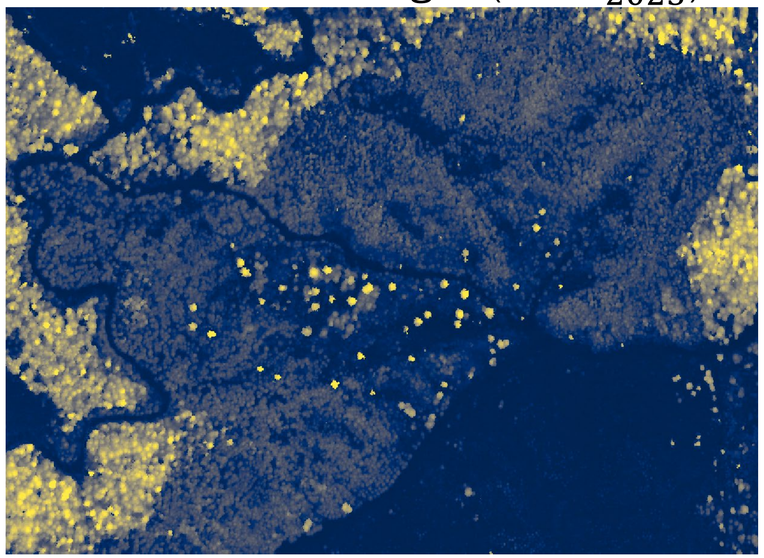
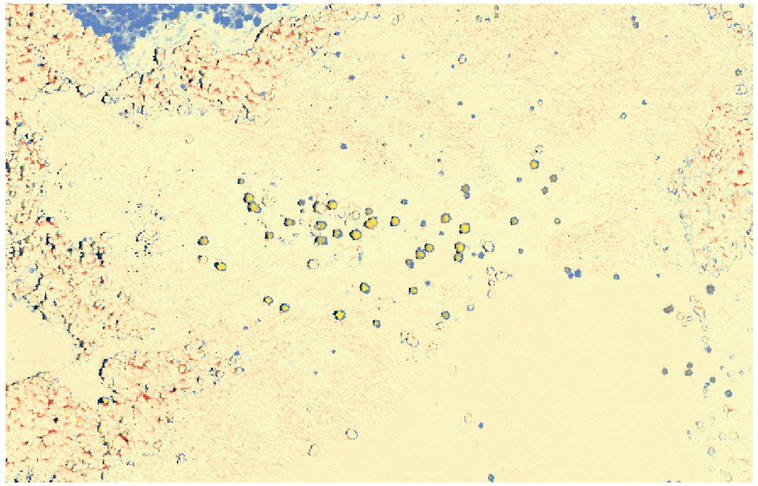
- 2022 3DEP LiDAR (CHM_{2022})

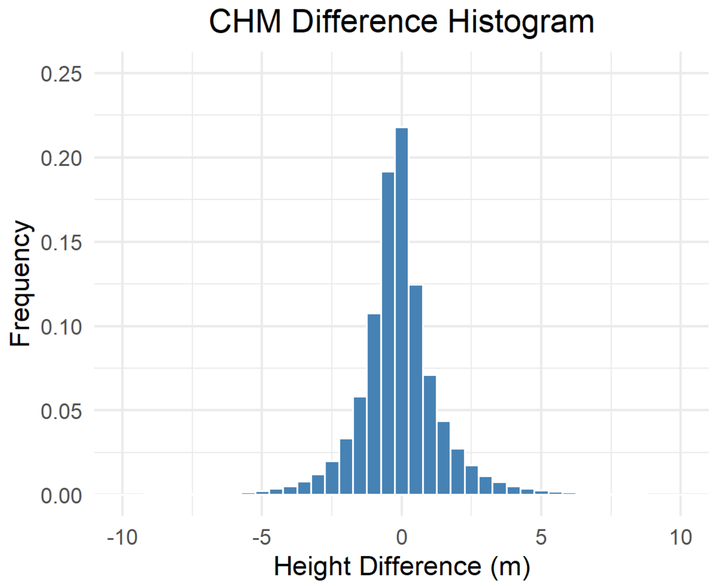


- 2023 3D NAIP – regen (CHM_{2023})



- $h_{diff} = CHM_{2023} - CHM_{2022}$





MOSCOW MOUNTAIN: 3D NAIP VS 2016 3DEP

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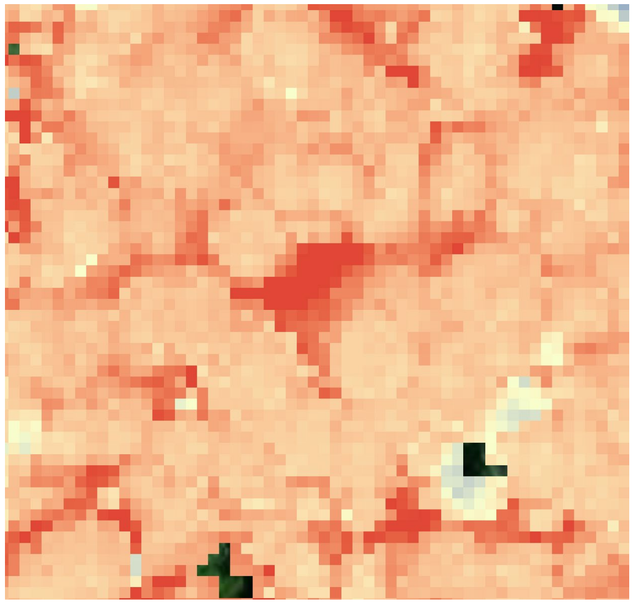
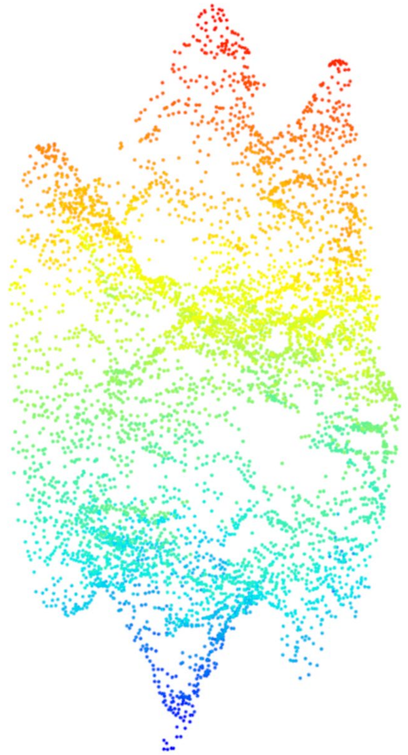
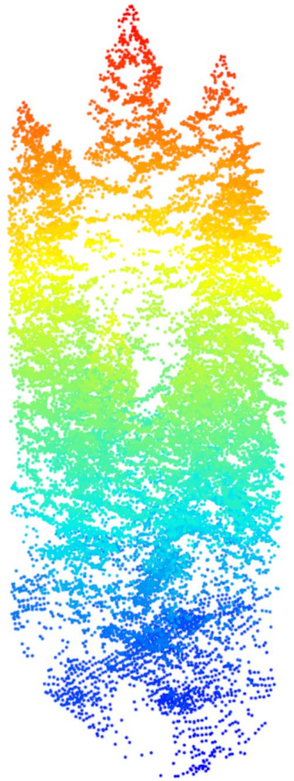
- Shadows cause problems: $h_{diff} = CHM_{2023} - CHM_{2016}$







- From left: h_{diff}; NAIP imagery; 2023 3D NAIP; 2022 3DEP
- 3D NAIP failed to find the opening in the shadow
- Significant height overestimations in canopy gaps

MOSCOW MOUNTAIN: 3D NAIP VS 2016 3DEP

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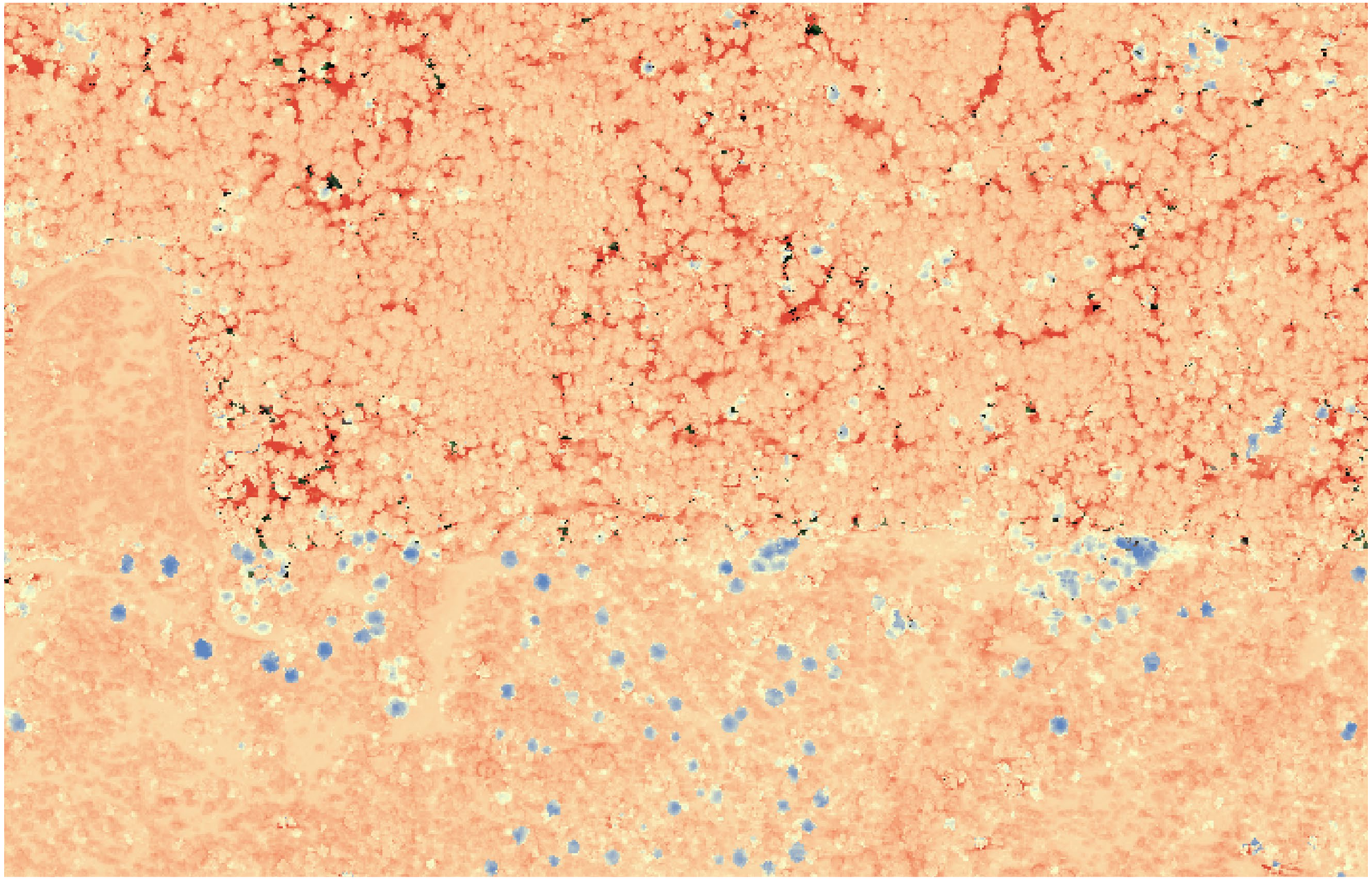
- Almost all extreme high values in h_{diff} are incorrect due to shadows
- CHM/area based statistics are invalid
- Potential solution: NAIP imagery-derived shadow filter



MOSCOW MOUNTAIN: CHM VS FIELD DATA

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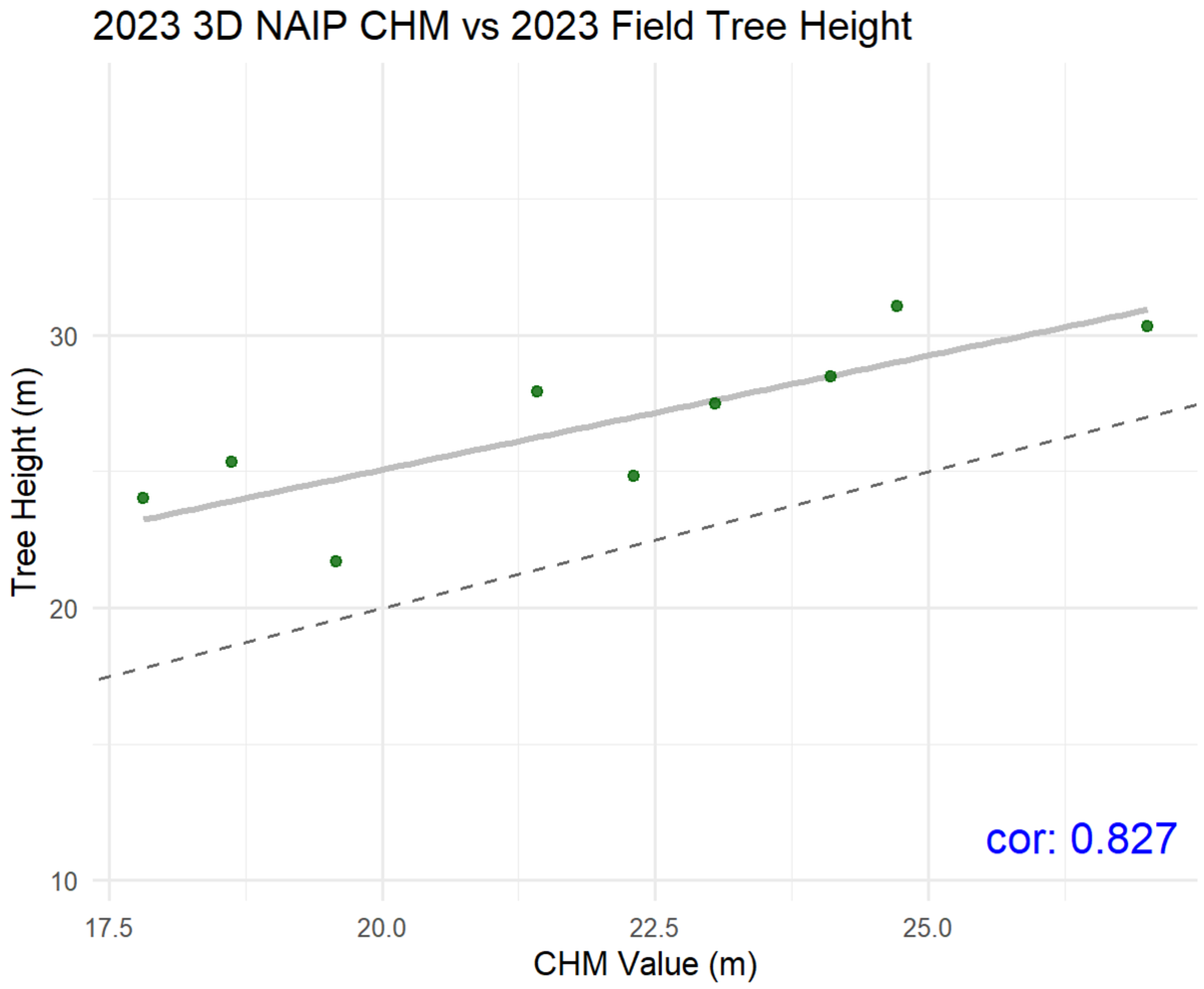
- Plots were stem mapped summer 2023
- CHM derived from 2023 3D NAIP vs field measured tree heights
- Could be improved with better point/CHM coregistration
  - Snap points to lidar treetops
  - Buffer points and find neighborhood max height



MOSCOW MOUNTAIN: CHM VS FIELD DATA

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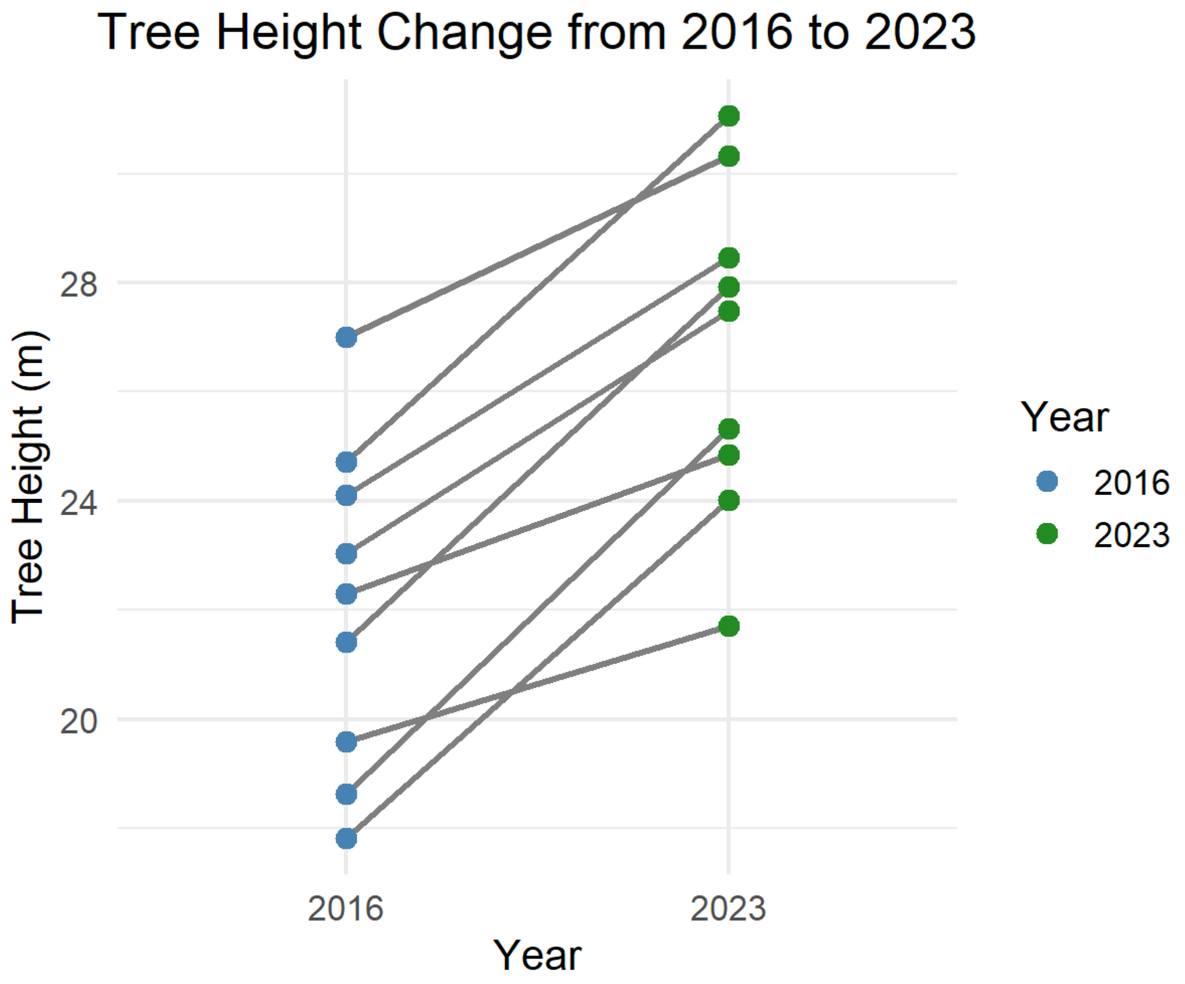
- CHM values from 2016 3D NAIP
- 2023 height values from field measurements



INDIVIDUAL TREE COMPARISONS

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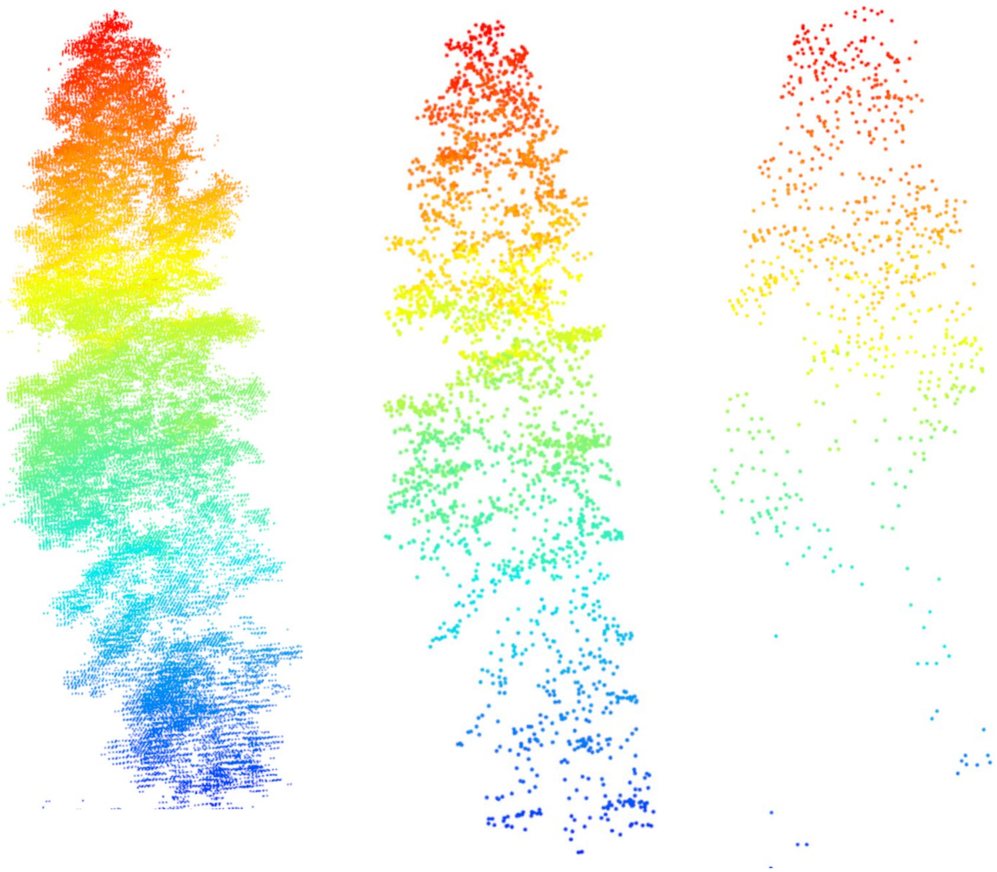
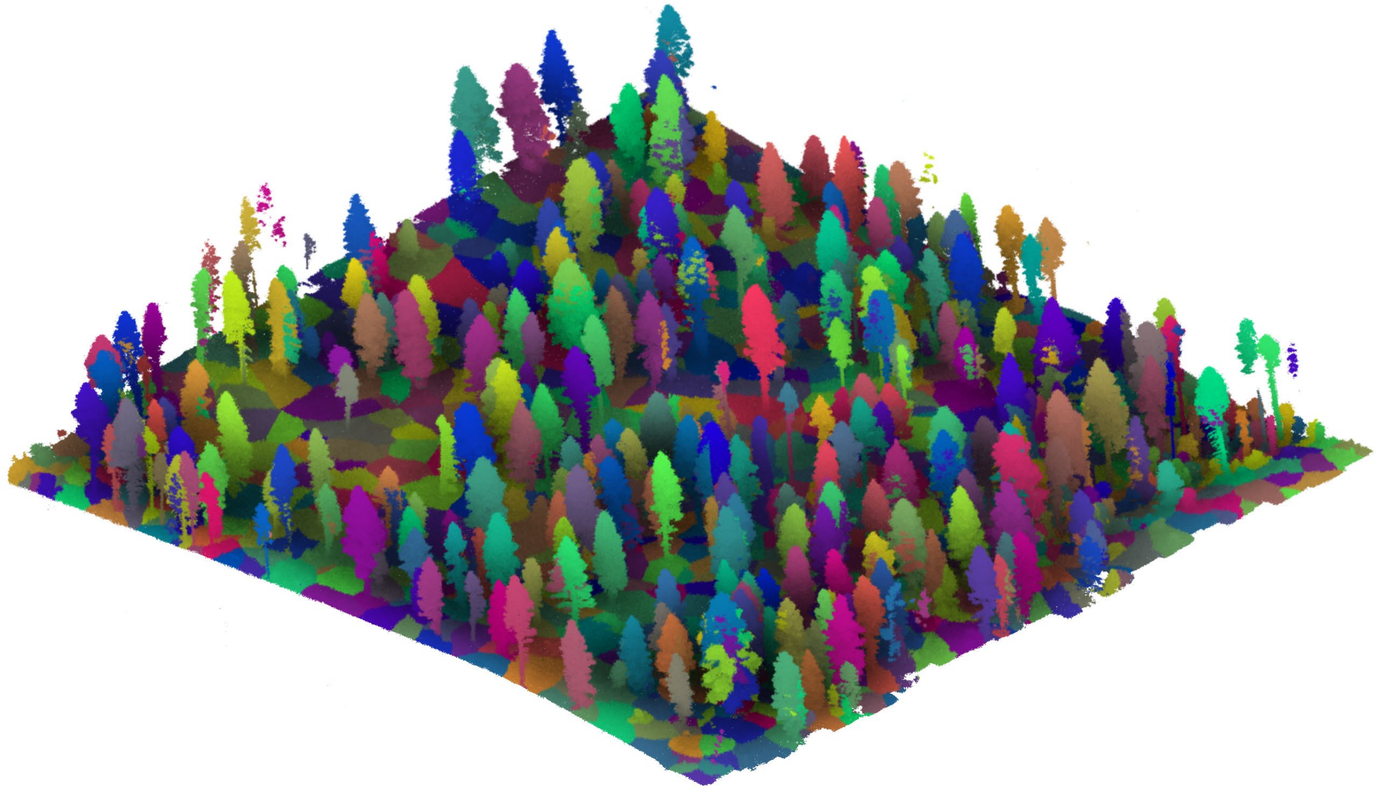
- 3D NAIP data aren't great for segmentation, especially on smaller trees
- Can we get good x,y locations for trees from other sources?





2023 GEIGER VS 2023 3D NAIP

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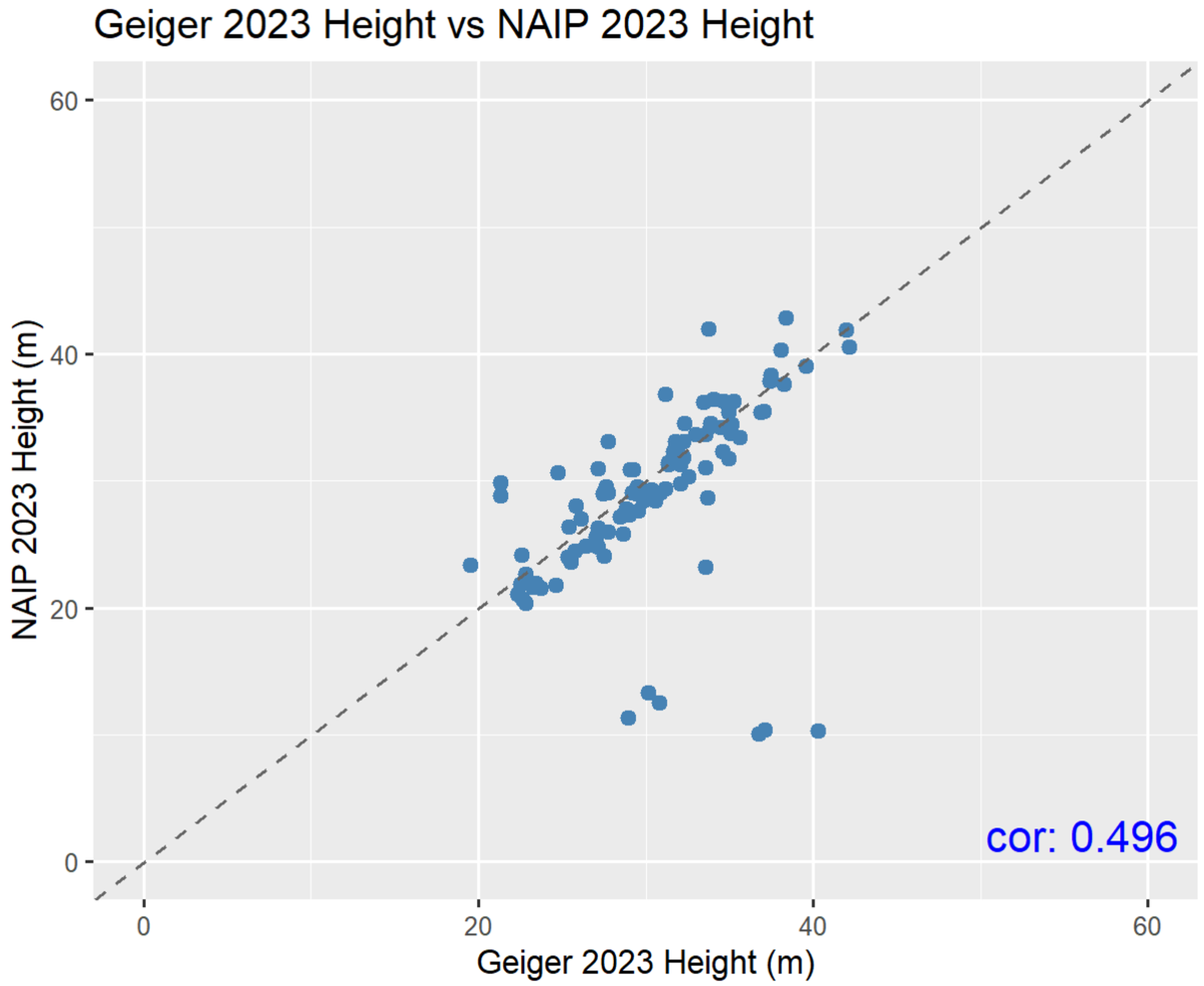
- 100 trees were segmented from Geiger LiDAR
- X,Y locations were used to extract tree points from 3D NAIP
- Low outliers are influential



CHALLENGES: MISSING TREES

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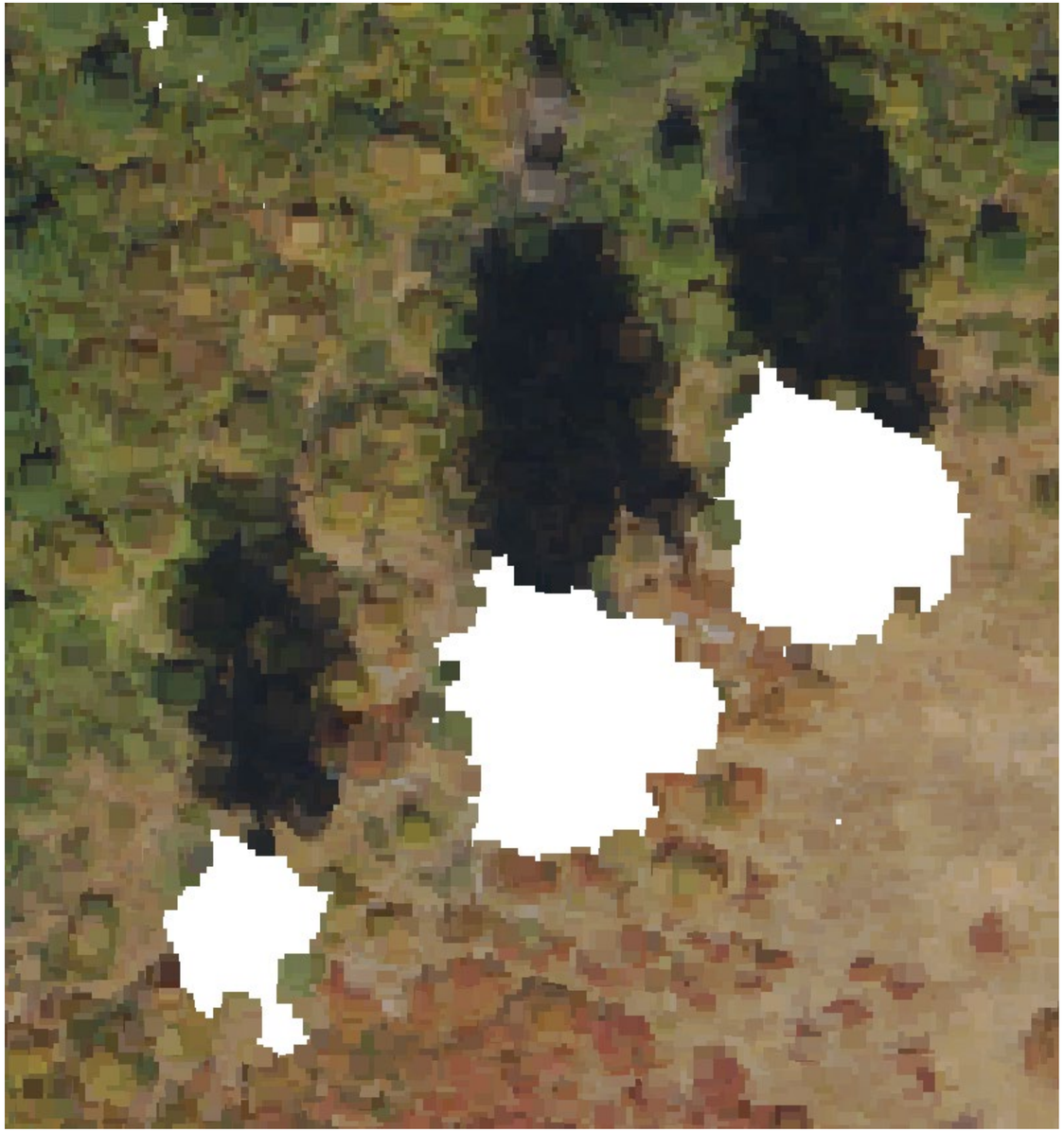
- Reconstruction voids are areas where the SfM algorithm failed to reconstruct the 3D structure using available data.
- An open area with three trees. The white areas are where the trees should be and the dark areas are shadows cast by the trees. The SfM system was unable to reconstruct the trees, leaving voids.



CHALLENGES: MISSING TREES (AGAIN)

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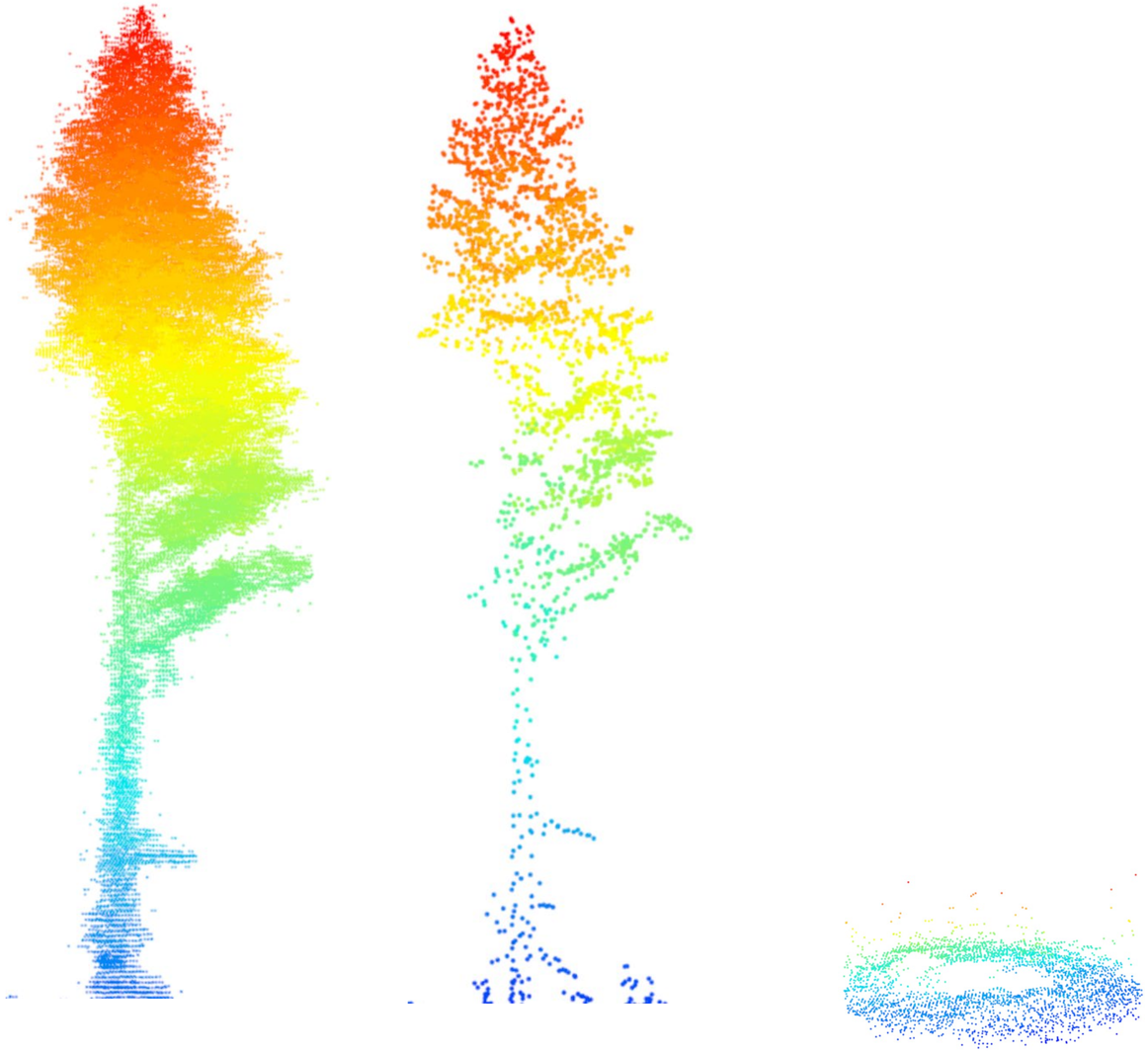
- Tree 1159 in Geiger, 3DEP, and 3D NAIP



CHALLENGES: MISSING TREES

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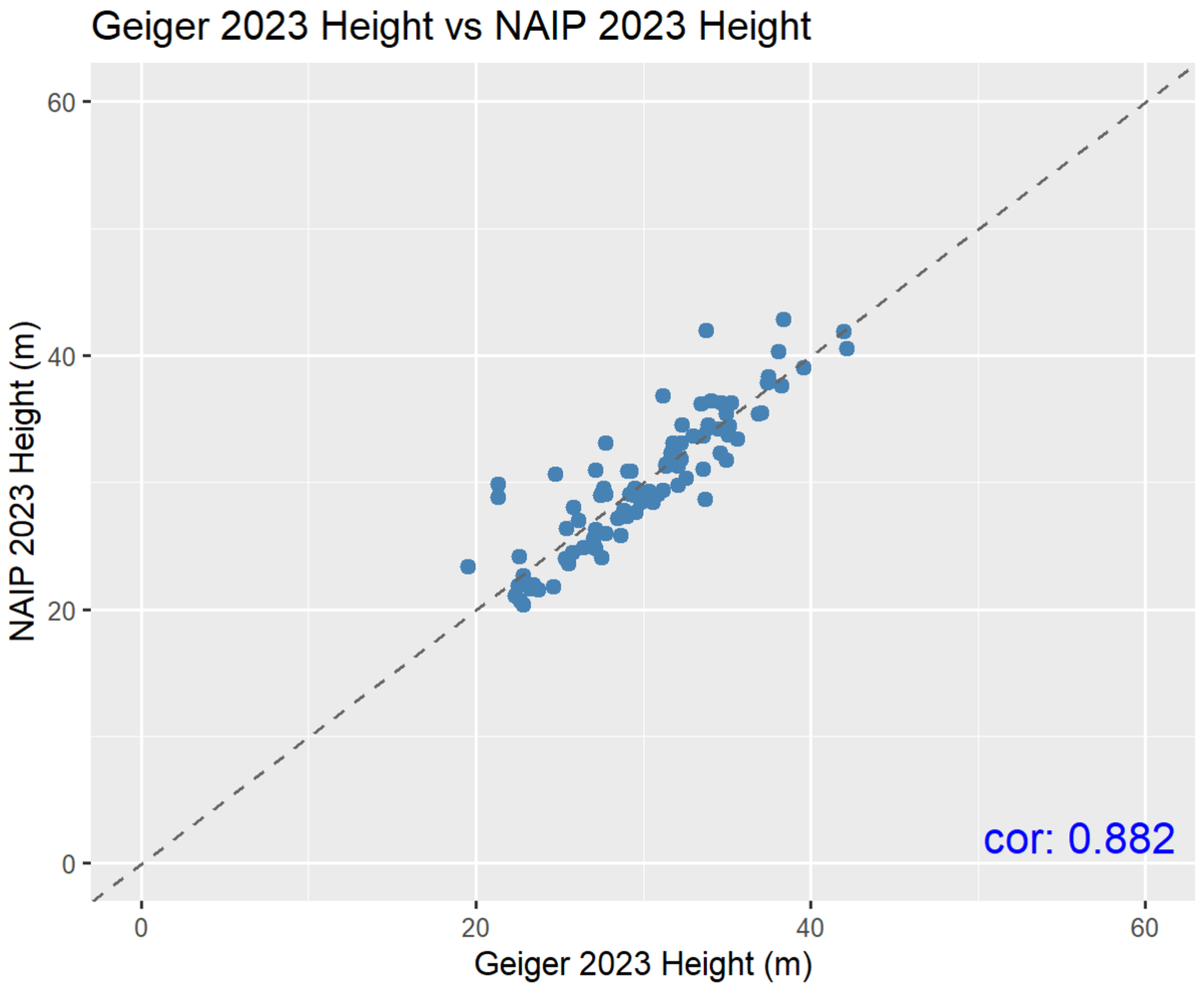
- 7 reconstruction voids were removed
- Difficult to distinguish from genuine disturbance
- Cross-check with NAIP CHM for voids



OBSERVATIONS

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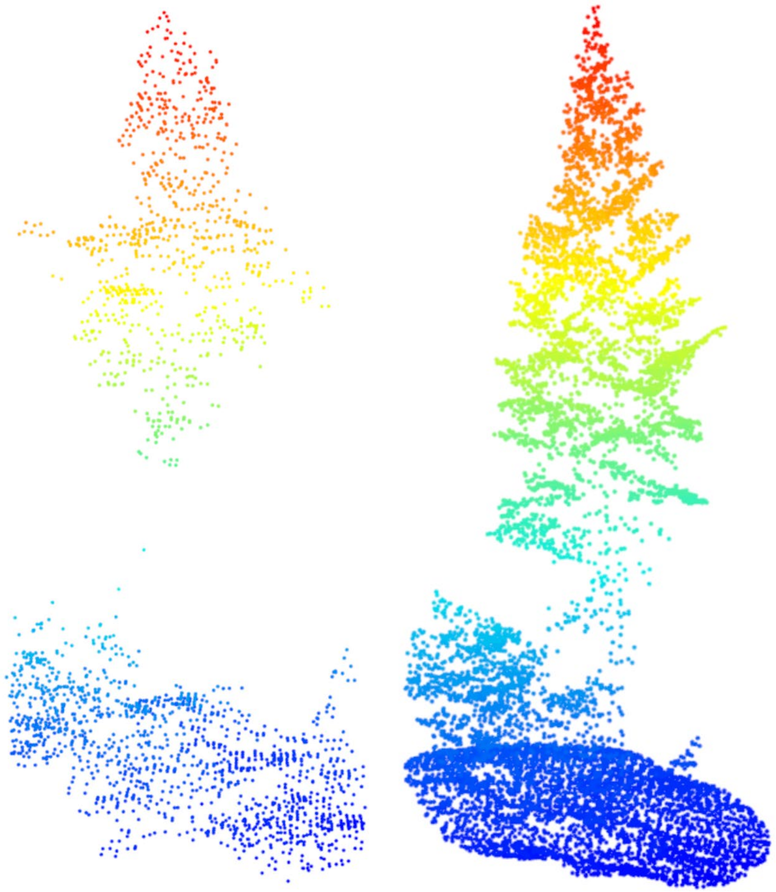
- Combine and hybridize data to leverage strengths of multiple approaches
- CHMs derived from 3D NAIP contain artifacts due to shadow and SfM errors but can be used at known point locations
  - Points could be from stem maps, LiDAR tree tops, canopy segmentations, etc.
- Point cloud extracts at known locations can be used to find trees in 3D NAIP
  - Subtract DTM from max(z) for tree height
- When individual tree locations are known, $\Delta h = CHM_{NAIP} - CHM_{LiDAR}$ is approximately true
- What is the vertical error structure? All components of the system have vertical error; how do they interact?



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LIDAR HYBRIDIZATION

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- Different LiDAR instruments and platforms have different strengths and weaknesses
- Combine and hybridize data to leverage strengths of multiple approaches

	SLAM	UAV	Airborne	3D NAIP	Field Data
X,Y	✅	✅	⚠️	⚠️	⚠️
Z	❌	✅	✅	⚠️	⚠️
Area	❌	⚠️	✅	✅	❌
DBH	✅	❌	❌	❌	✅
$/Acre	❌	⚠️	✅	✅	❌