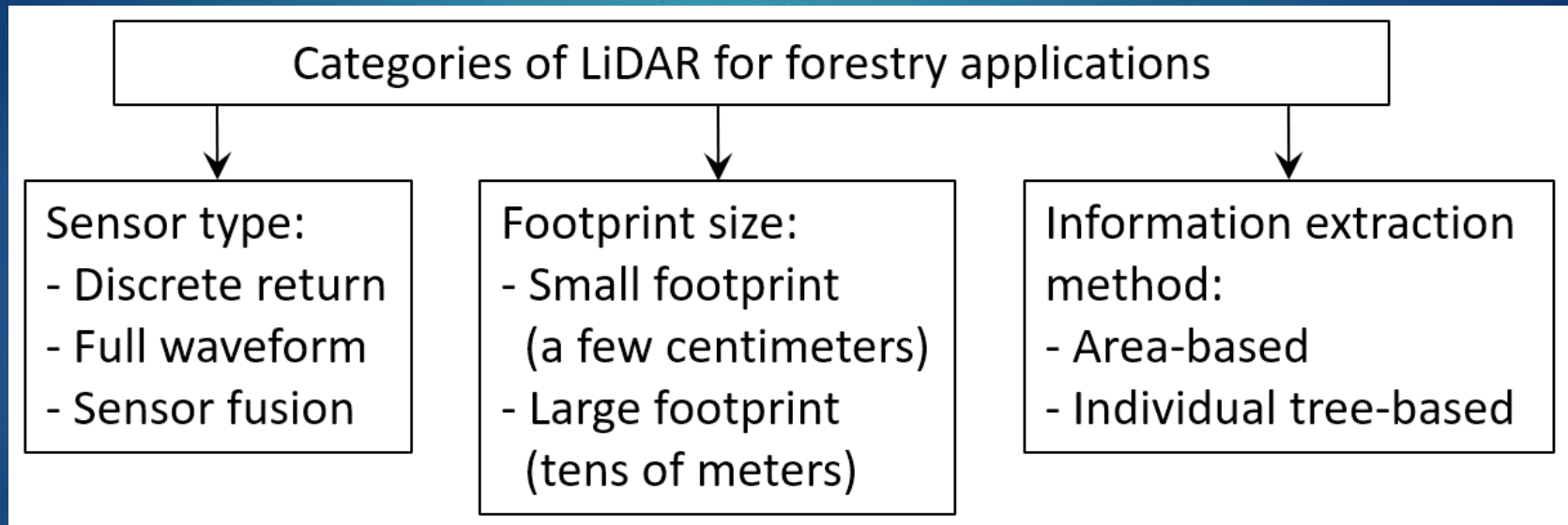




Vegetation Mapping and Measurement Using LiDAR (1)

- 
- 4.1 Introduction
 - 4.2 Canopy Surface Height Modeling and Mapping
 - 4.3 LiDAR Metrics for Vegetation Analysis
 - 4.4 Individual Tree Isolation and Mapping
 - 4.5 Area-based Modeling and Mapping
 - 4.6 Modeling, Mapping, and Estimating Biomass

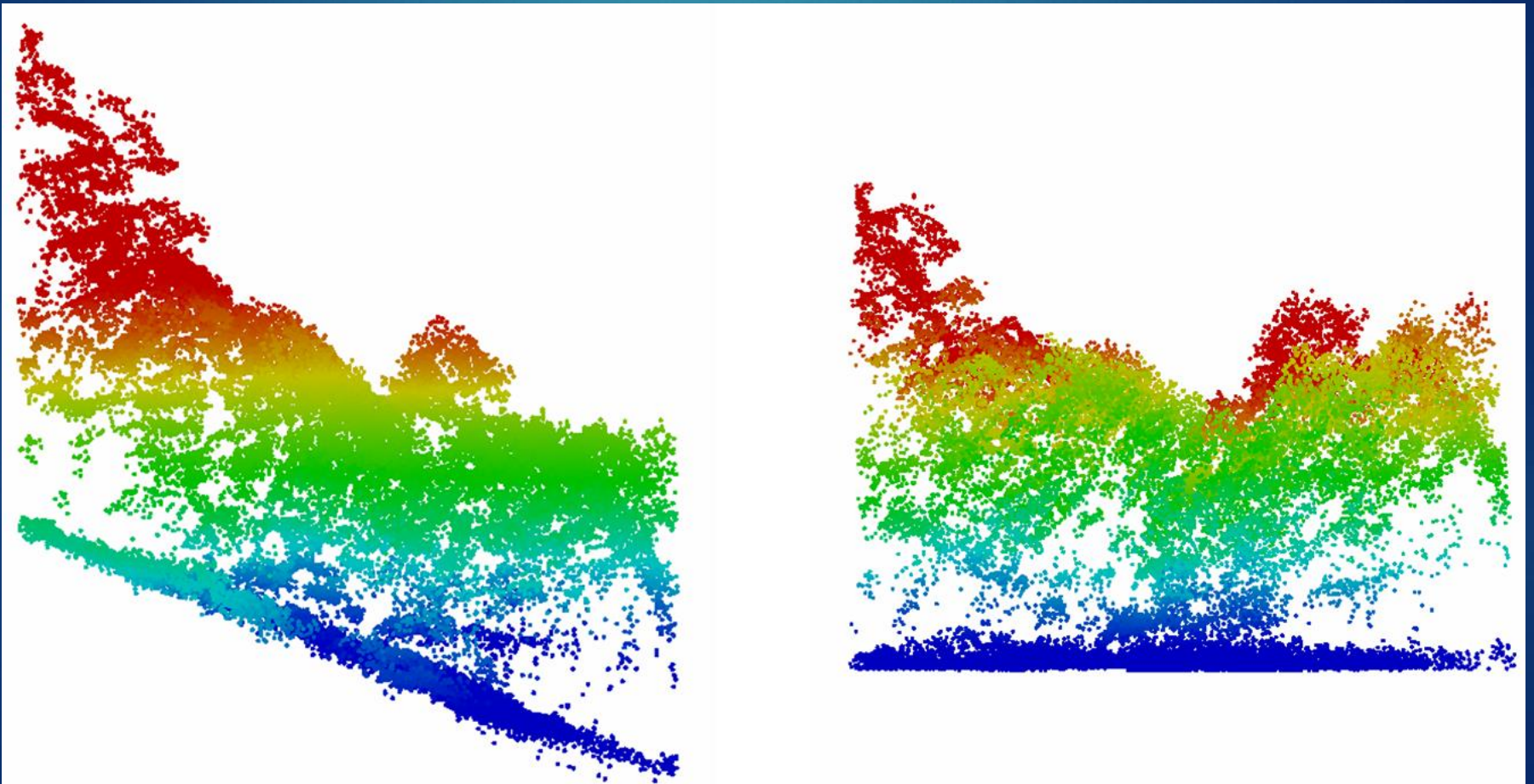
Categories of LiDAR for Forestry Applications



Canopy Gaps



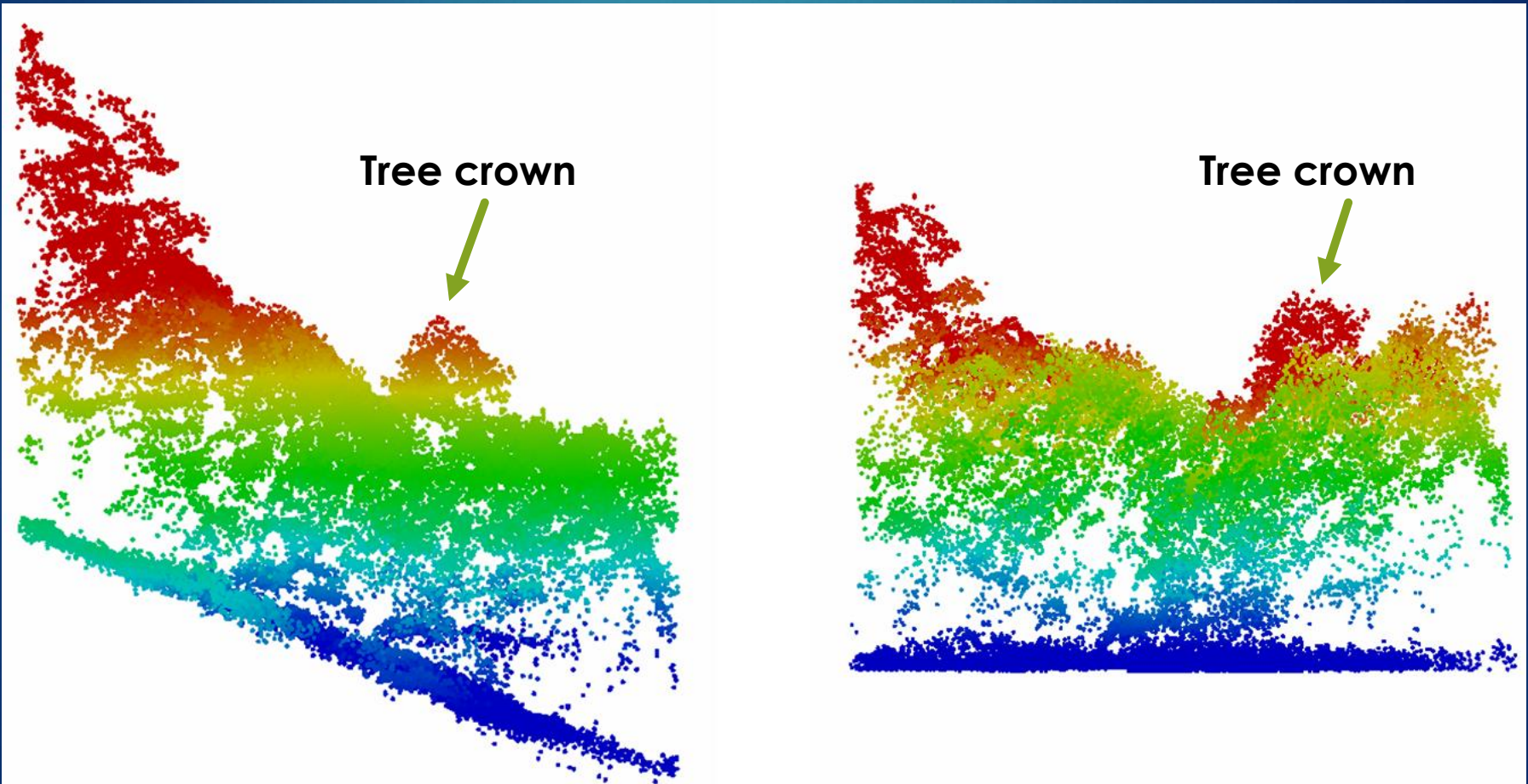
LiDAR point cloud before (left) and after (right)
height normalization.



Height Normalization: Pros and Cons

Pros: Canopy heights are readily available, and the canopy height model (CHM) can be used in other models.

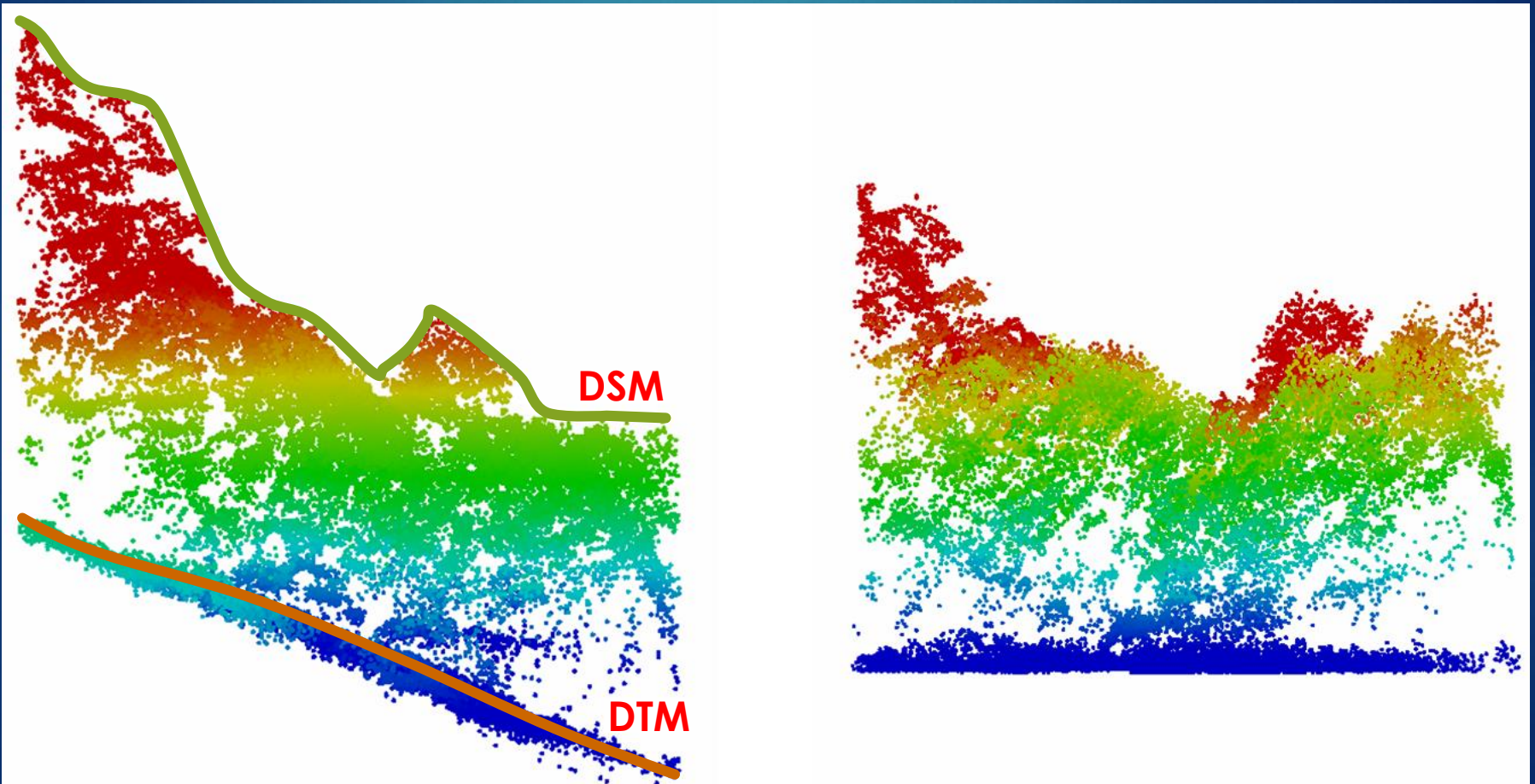
Cons: Crown shapes of individual trees may be distorted.



Canopy Height Model (CHM)

- A Digital Height Model (DHM) in a forest

$$\text{CHM} = \text{DSM} - \text{DTM}$$





Two major problems of traditional interpolation methods for generating canopy height models (CHM):

1. Noises in CHM;
2. Under-estimation of tree height.

Soquel Demonstration State Forest (SDSF), California (2011)



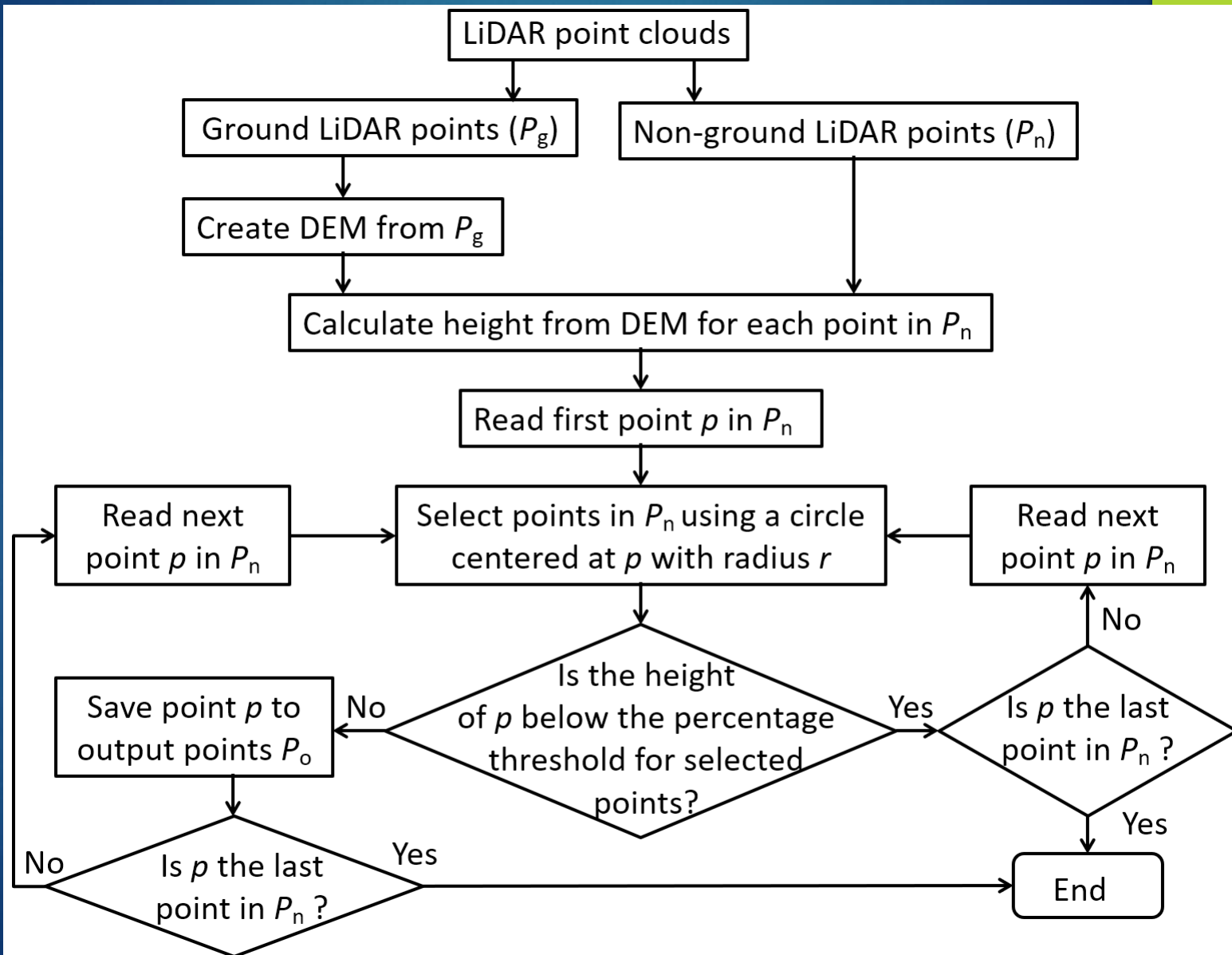
Soquel Demonstration State Forest (SDSF), California (2011)



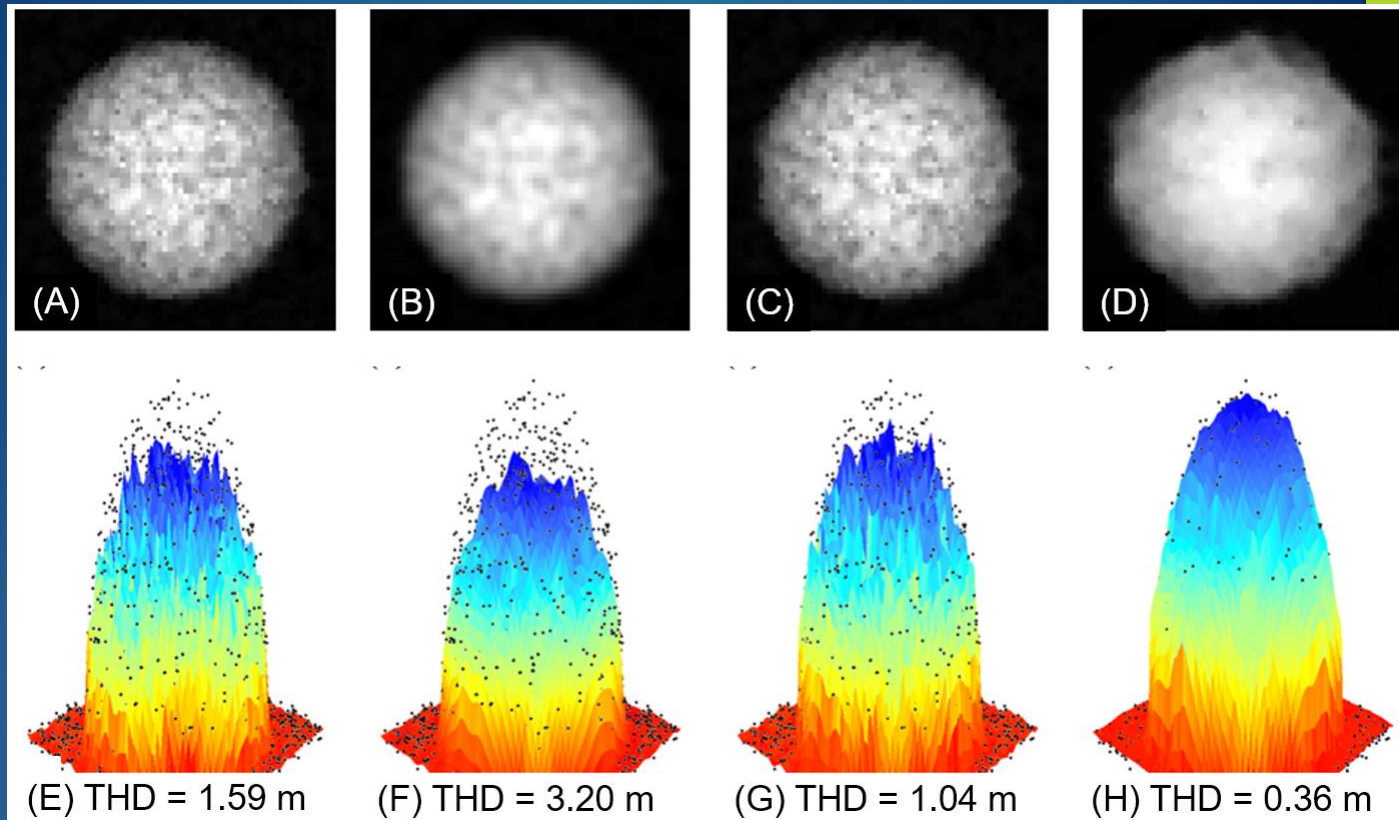
Soquel Demonstration State Forest (SDSF), California (2011)



A New Method for Generating CHMs (Liu and Dong, 2014)



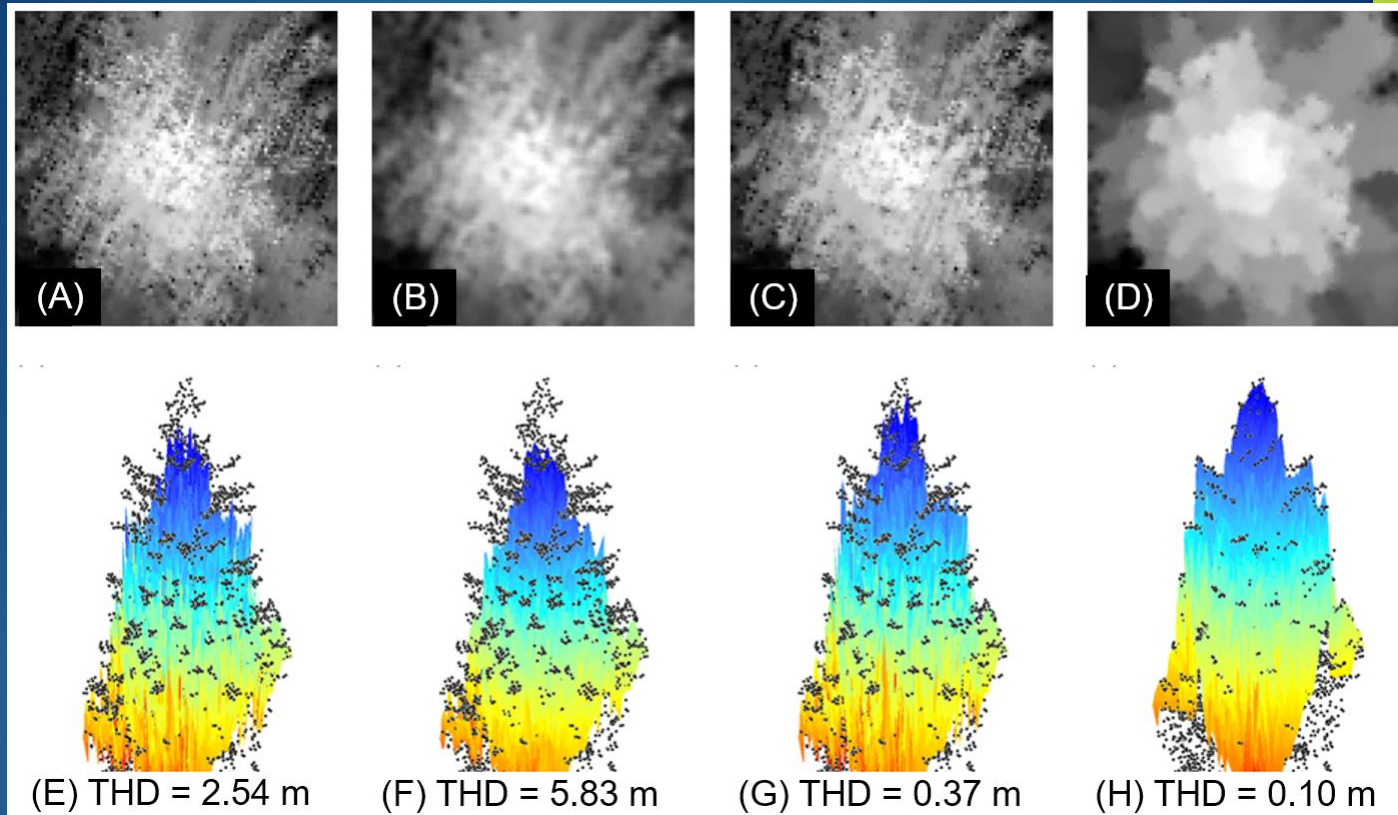
CHMs from Simulated LiDAR Points



- (A) IDW interpolation of original non-ground points;
- (B) Median filtering of (A);
- (C) IDW interpolation using the highest points method;
- (D) IDW interpolation using the new method;
- (E) – (H) are perspective views of (A) – (D).

THD – Treetop height difference between treetop point and raster surface.

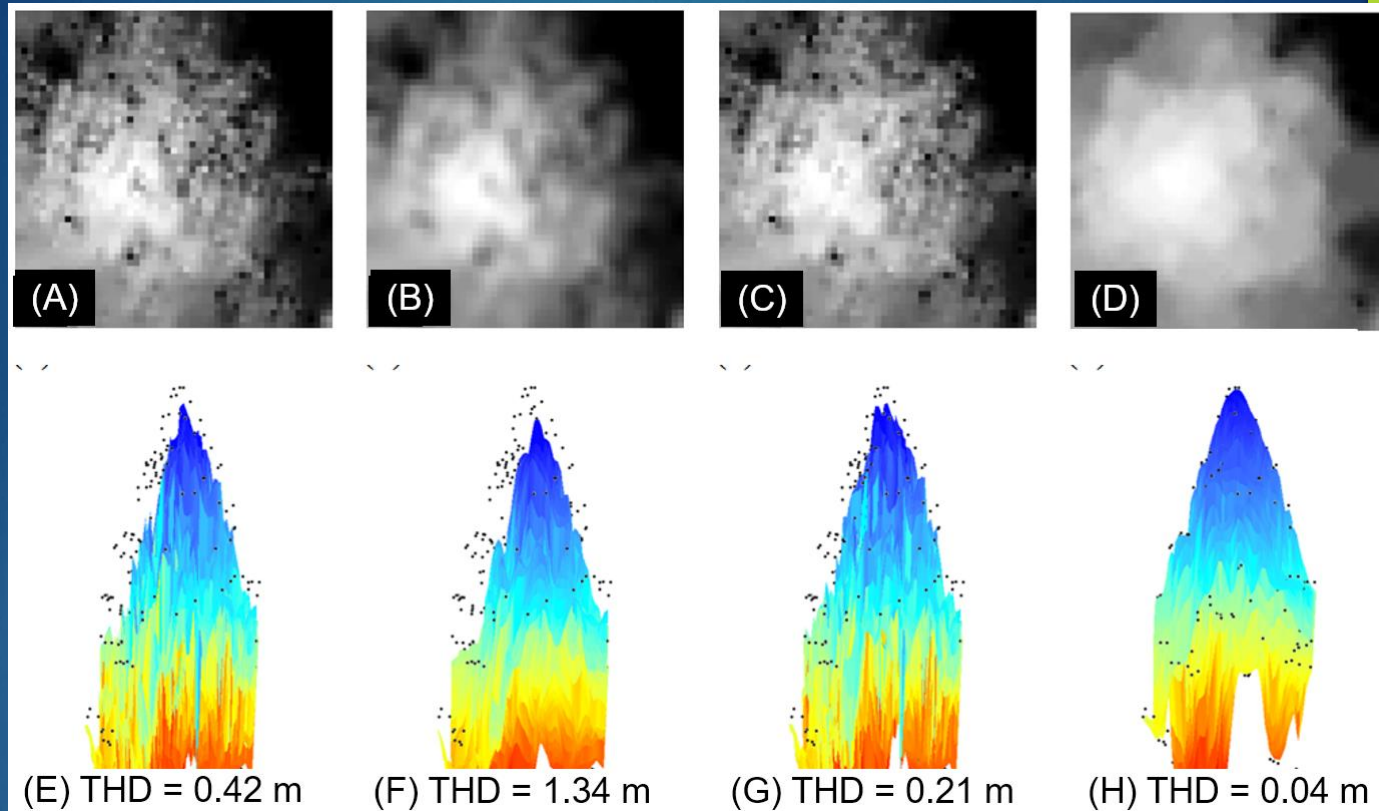
CHMs from Real LiDAR Points (1)



- (A) IDW interpolation of original non-ground points;
- (B) Median filtering of (A);
- (C) IDW interpolation using the highest points method;
- (D) IDW interpolation using the new method;
- (E) – (H) are perspective views of (A) – (D).

THD – Treetop height difference between treetop point and raster surface.

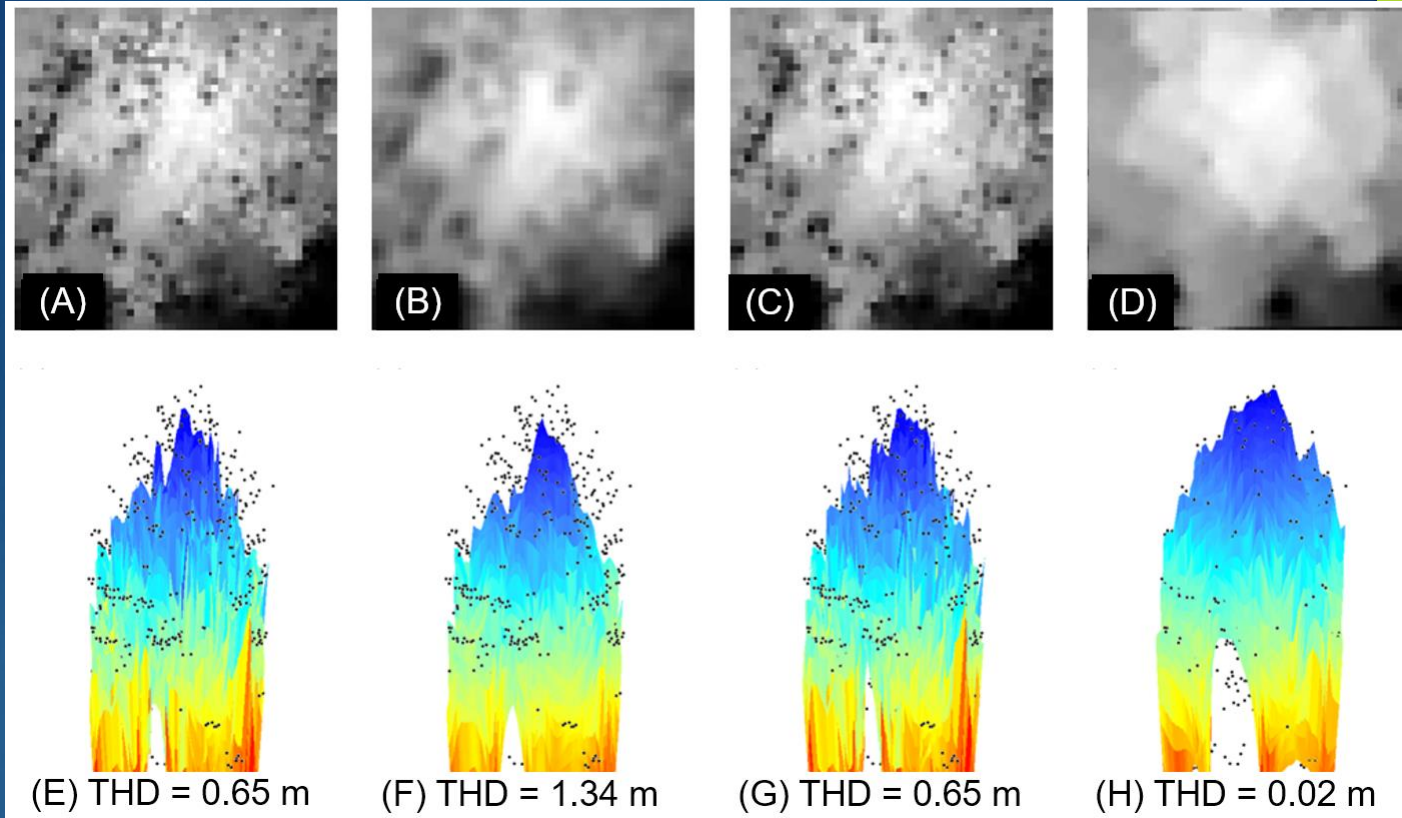
CHMs from Real LiDAR Points (2)



- (A) IDW interpolation of original non-ground points;
- (B) Median filtering of (A);
- (C) IDW interpolation using the highest points method;
- (D) IDW interpolation using the new method;
- (E) – (H) are perspective views of (A) – (D).

THD – Treetop height difference between treetop point and raster surface.

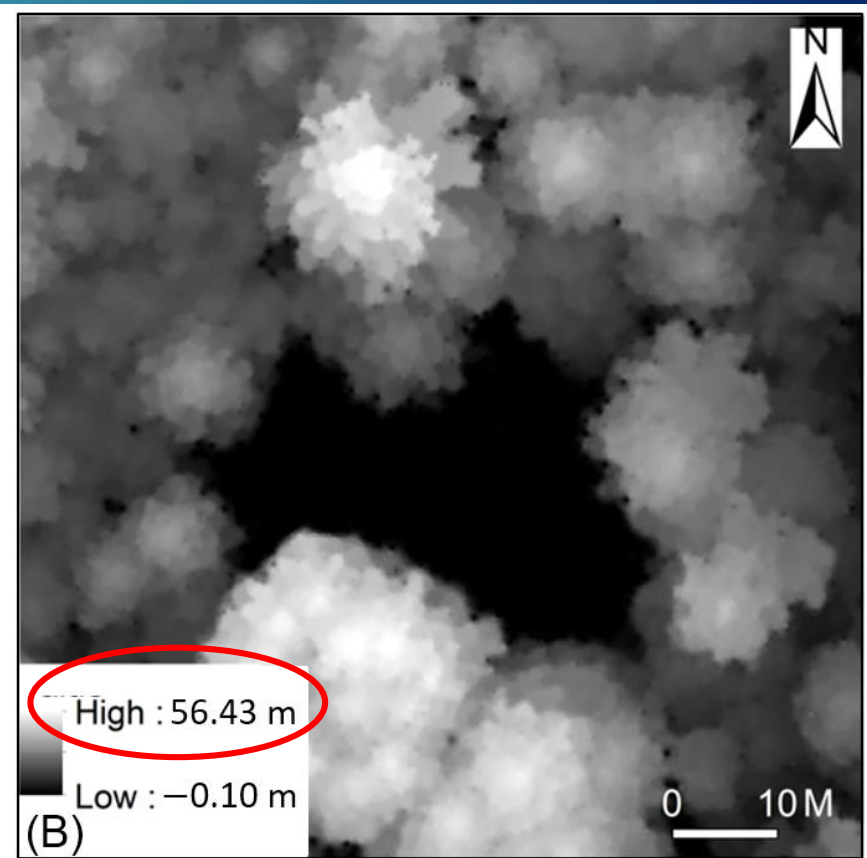
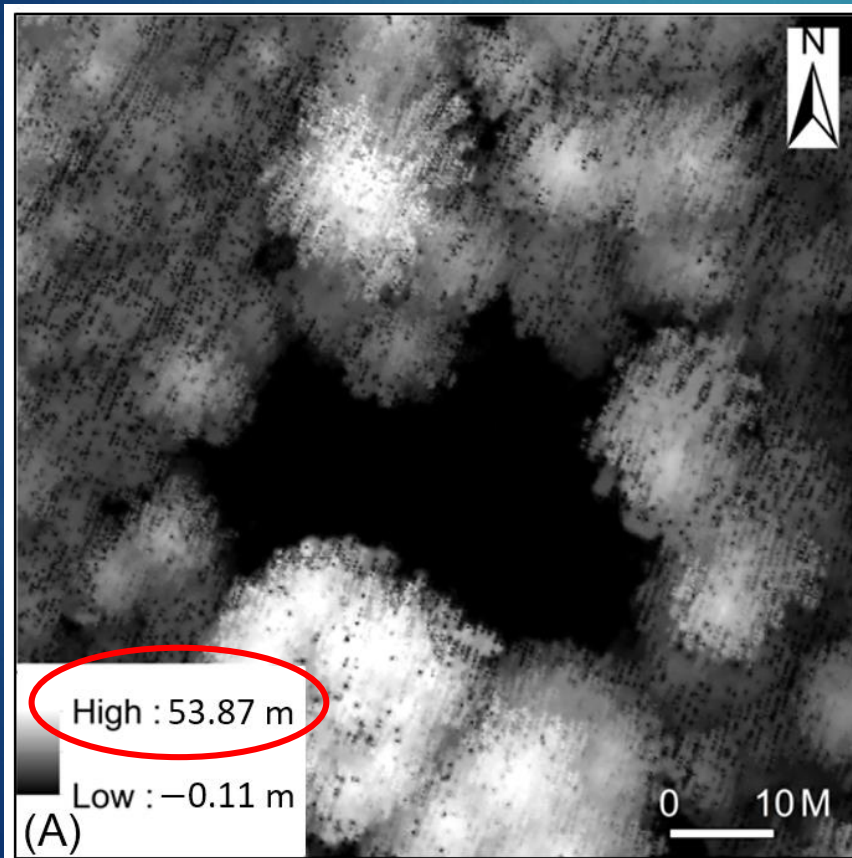
CHMs from Real LiDAR Points (3)



- (A) IDW interpolation of original non-ground points;
- (B) Median filtering of (A);
- (C) IDW interpolation using the highest points method;
- (D) IDW interpolation using the new method;
- (E) – (H) are perspective views of (A) – (D).

THD – Treetop height difference between treetop point and raster surface.

Comparison of canopy height models created from IDW interpolation of (A) all points and (B) remained points filtered by the new method.



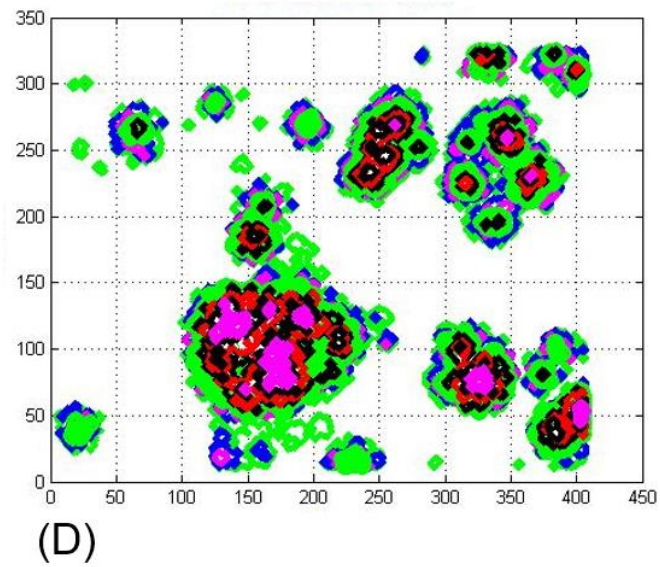
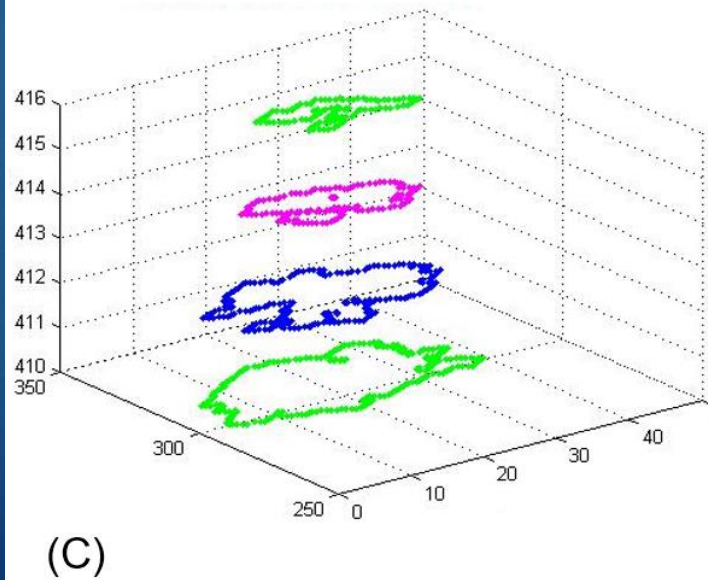
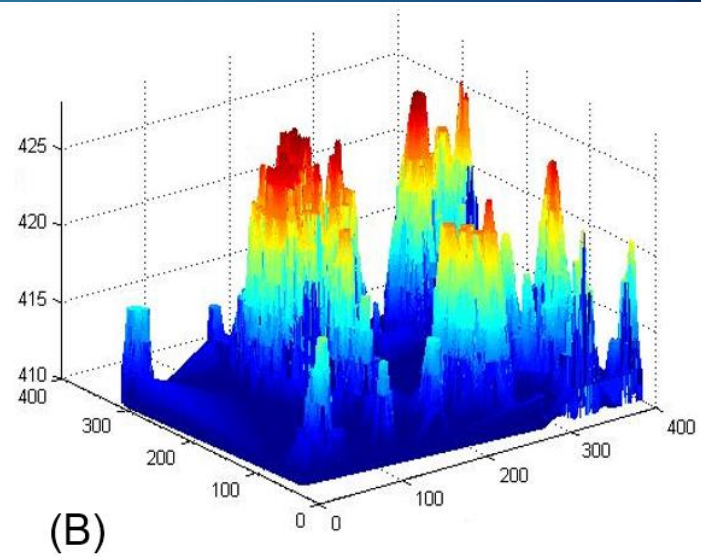
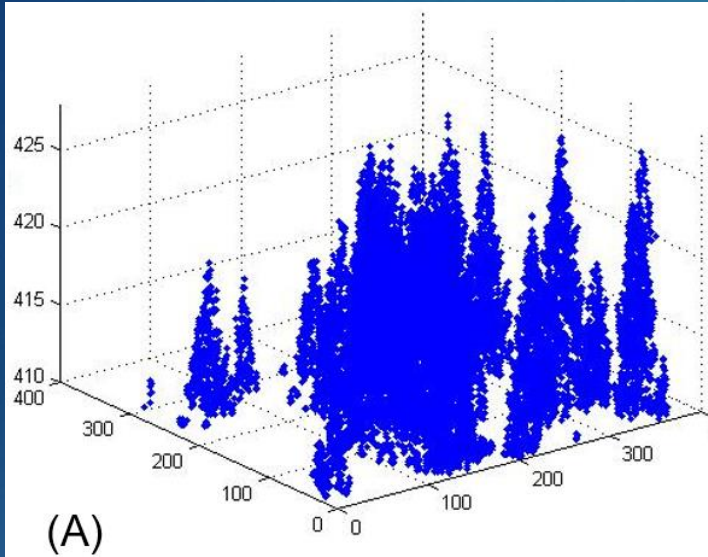
Region-based level set method for 3D canopy reconstruction

(Tang, Dong, and Buckles, 2013)

Minimizing the following function F based on the level set function $\phi(t, x, y)$:

$$\begin{aligned} & F(c_1, c_2, \phi) \\ &= \mu \int_{\Omega} \delta(\phi(x, y)) |\nabla \phi(x, y)| dx dy \\ &+ v \int_{\Omega} H(\phi(x, y)) dx dy \\ &+ \lambda_1 \int_{\Omega} |u_0(x, y) - c_1|^2 H(\phi(x, y)) dx dy \\ &+ \lambda_2 \int_{\Omega} |u_0(x, y) - c_2|^2 (1 - H(\phi(x, y))) dx dy \end{aligned}$$

3D Surface Reconstruction



LiDAR Metrics for Vegetation Analysis

1. Minimum;
2. Maximum;
3. Range: (max – min);
4. Arithmetic Mean: $\mu = \frac{\sum_{i=1}^N x_i}{N}$;
5. Standard Deviation (σ);

6. Variance (σ^2);

7. Percentiles: 5th, 10th, 25th, 50th, 75th, and 95th percentile values (x);

8. Median Absolute Deviation from Median:

$$\text{median}_i(X_i - \text{median}_j(X_j));$$

9. Dominate Mode: Value of the dominate mode in a kernel density estimate (x);

10. Skewness:
$$\frac{\sqrt{n} \sum_{i=1}^n (x_i - \mu)^3}{(\sum_{i=1}^n (x_i - \mu)^2)^{3/2}}$$

11. Kurtosis: $\frac{\frac{1}{n} \sum_{i=1}^n (x_i - \mu)^4}{(\frac{1}{n} \sum_{i=1}^n (x_i - \mu)^2)^2} - 3$

12. Interquartile range: 75th percentile (x) – 25th percentile (x);

13. Coefficient of Variation: $(\sigma/\mu) \cdot 100$;

14. Number of Modes: Number of modes from a kernel density estimate (x);

15. Difference between Min and Max Mode:
(maximum mode – minimum mode) from a kernel density estimate (x);

16. Canopy Relief Ratio: $\frac{\mu(\text{height}) - \text{Min}(\text{height})}{\text{Max}(\text{height}) - \text{Min}(\text{height})}$;

17. Percent of returns that are first, second, third,

etc.: $\frac{[n_i | \text{return number}]}{N} \cdot 100$;

18. Texture: $\sigma(n_i | > \text{height}(0) \text{ and } \leq \text{height}(1))$;

19. Number of ground returns;

20. Number of non-ground returns;



21. Density: $\frac{[n_i | \text{nonground}]}{N} \cdot 100$; and

22. Stratified Density: $\frac{[n_i | >x_1 \text{ and } <x_2]}{N} \cdot 100$