



3D modelling of hilly terrains for security operations using airborne LiDAR and ortho-images

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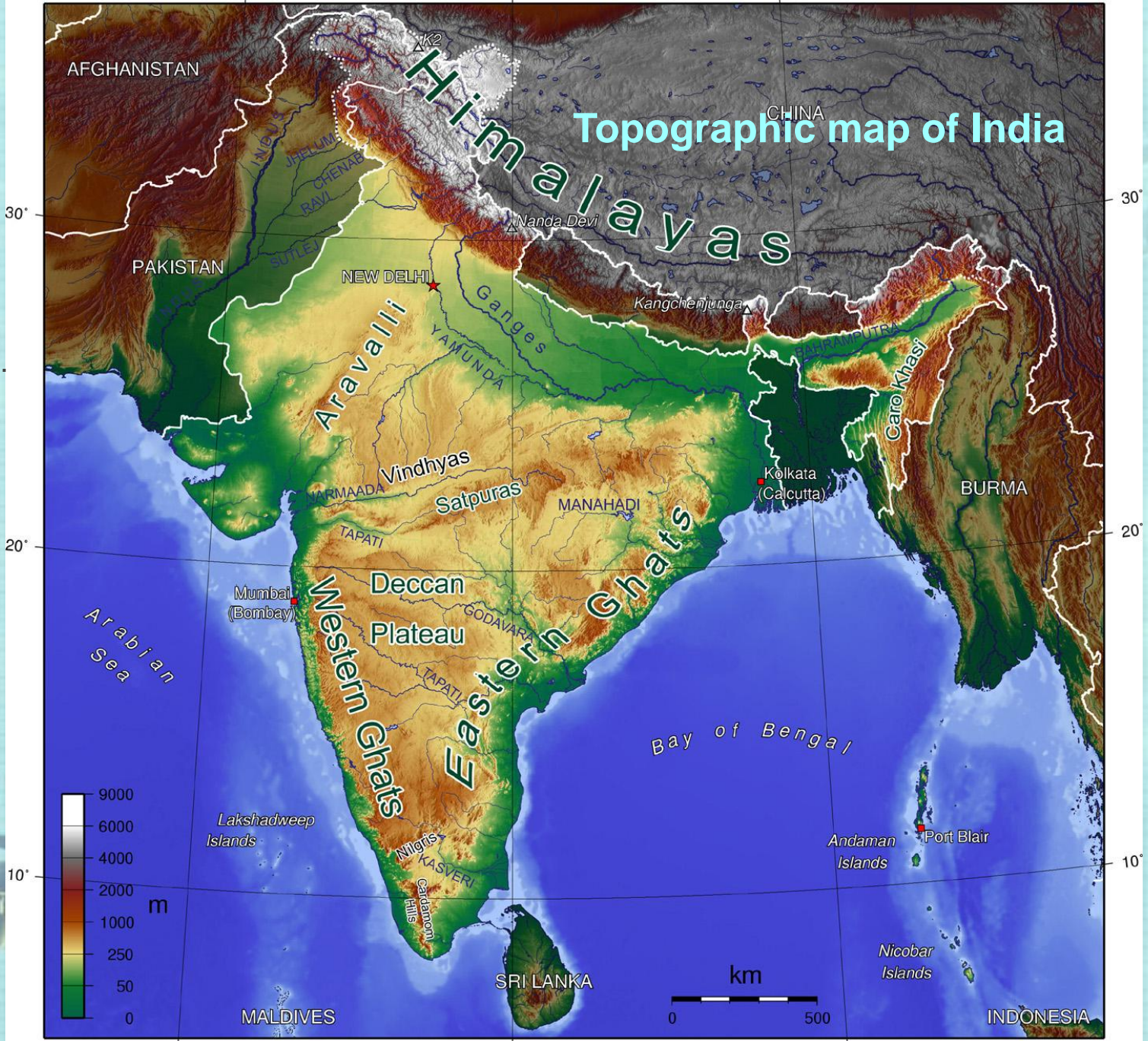
Model 1

(for overview of large area)

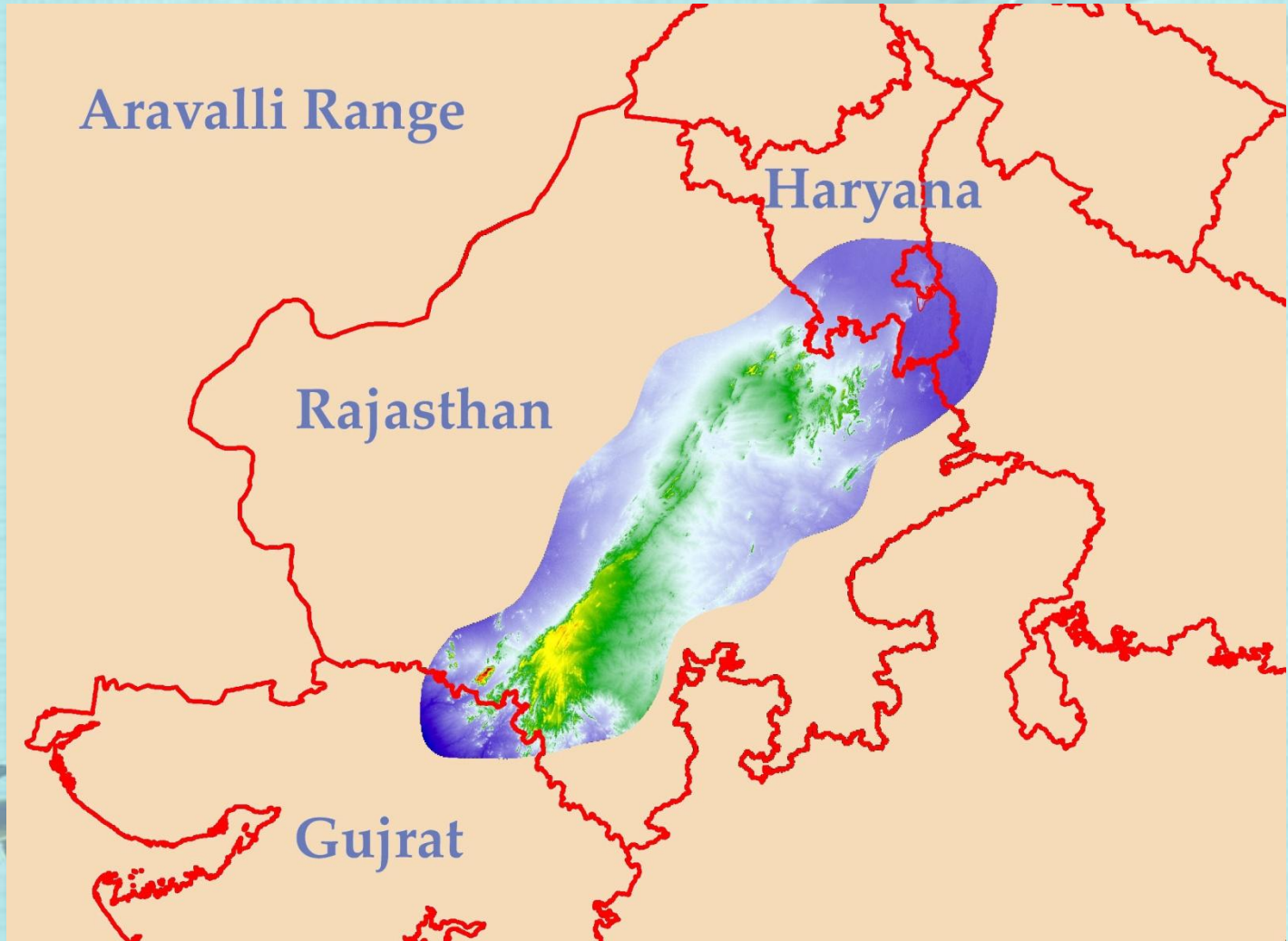
Modelling Aravalli hill range



Topographic map of India



Aravalli Range



Aravallis

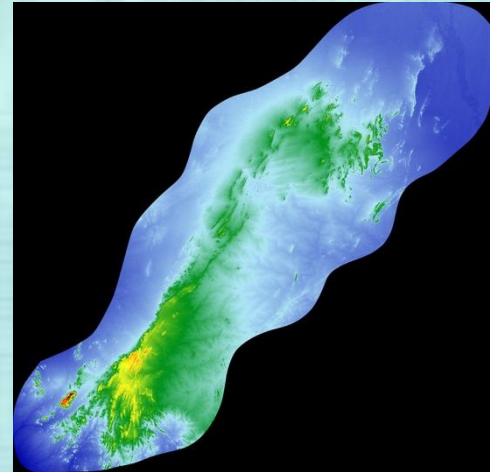
- Means--- Line of Peaks
- Oldest mountains
- Running over 800 KM from Indian states Gujarat, Rajasthan, Haryana and New Delhi
- From Palanpur in Ahmadabad to Northern Delhi ridge
- Highest Peak: 1722 mts Guru Shikhar, Mt Abu
- Rivers: Banas, Luni, Sahibi, Sakhi and Sabarmati



3D Flythrough Aravalli Model



Data used: Landsat Imagery, 2015 15mts
Aster DEM 30mts

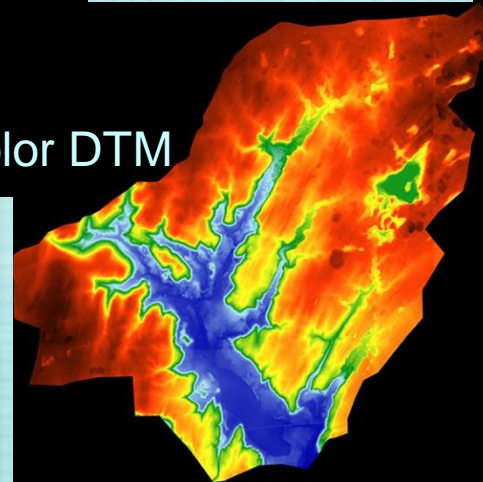
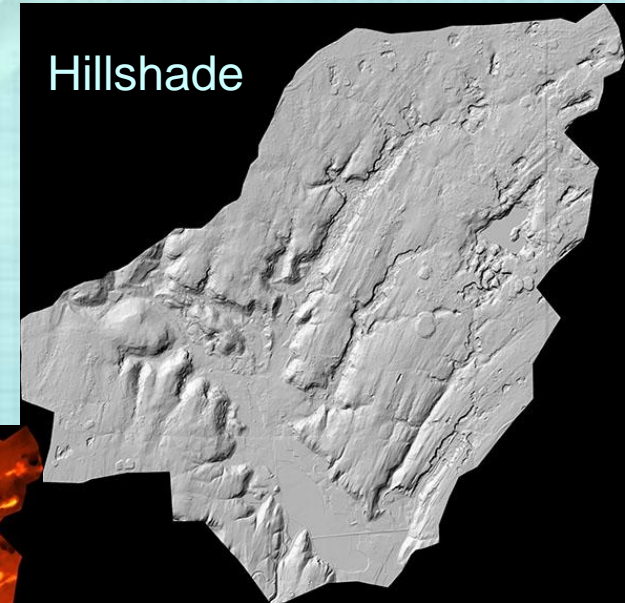
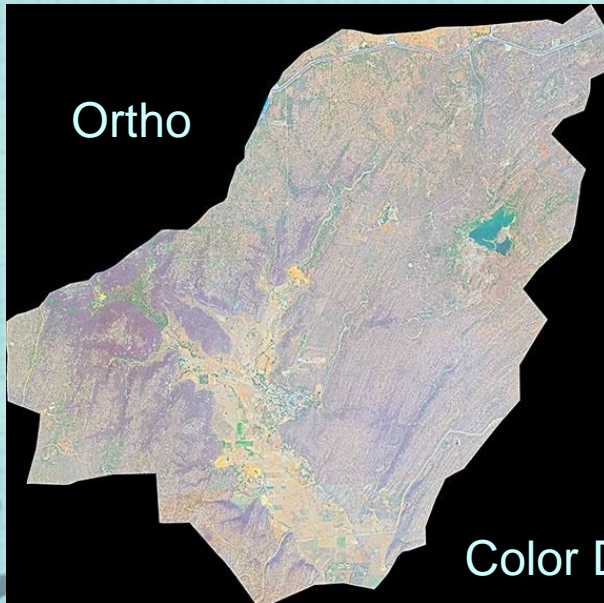


Model 2 (for specific areas with land parcel details)

3D Fly through model of Mangar, Faridabad

Data used: Worldview 2 Imagery, 50cm

DEM 1m from the stereo pair of WV2 data

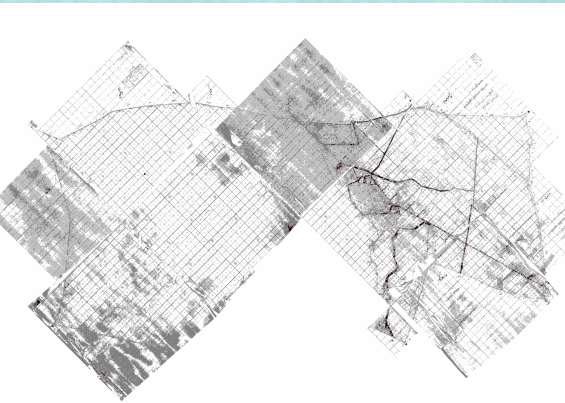


Preparing Geo-referenced maps with land parcel details

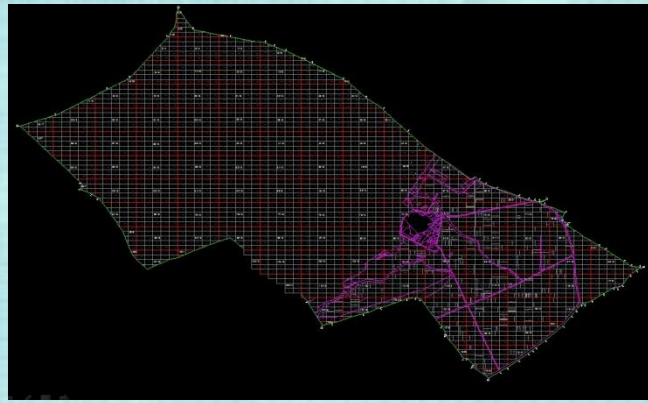
e.g. Village Badkhal

Process of preparing Geo-referenced maps

- Scanning cadastral maps
- Digitizing cadastral maps
- Geo-referencing digitized map
- Overlaying with high resolution imageries



Scanning Musavis



Digitization

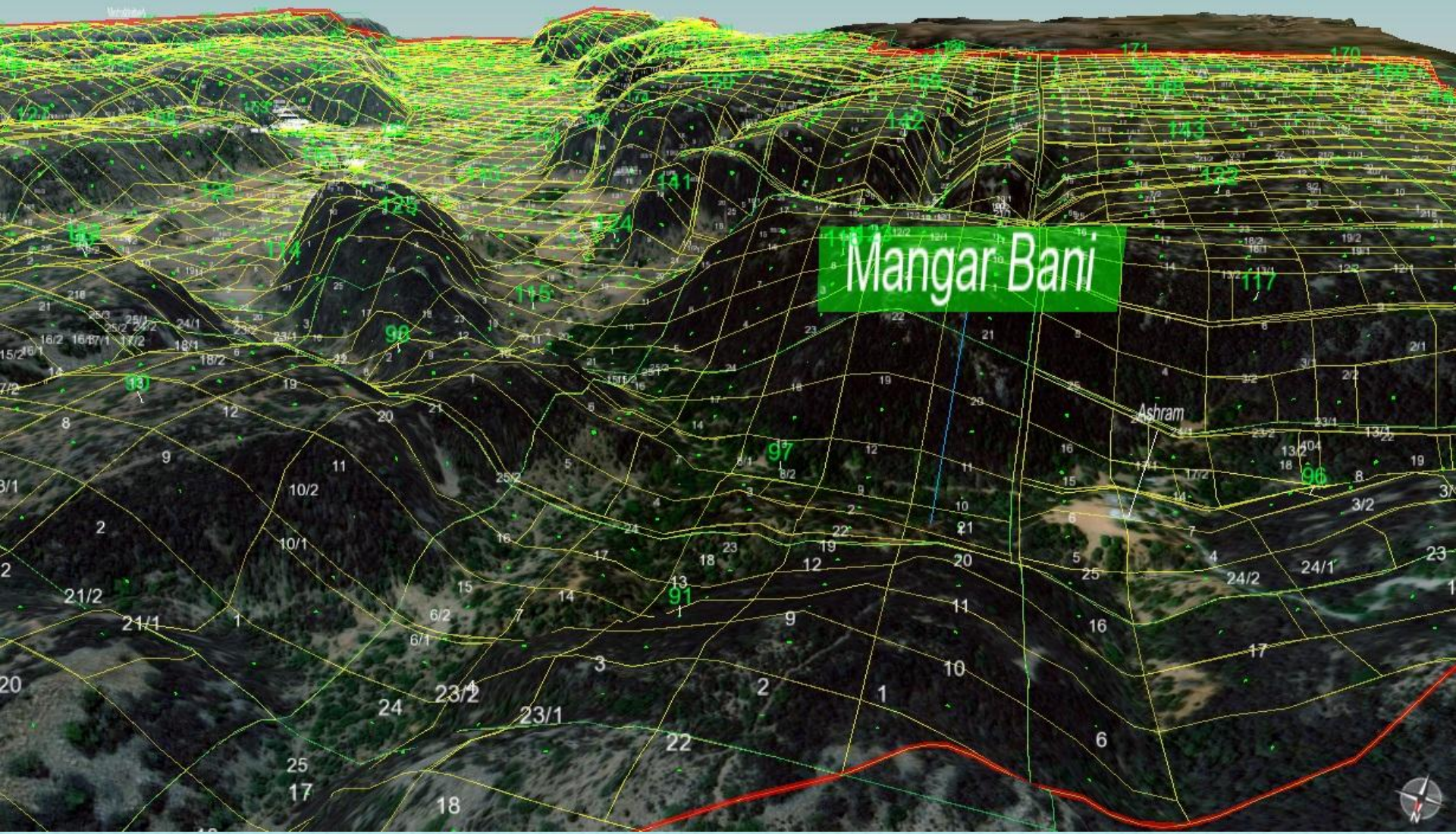


Georeferencing

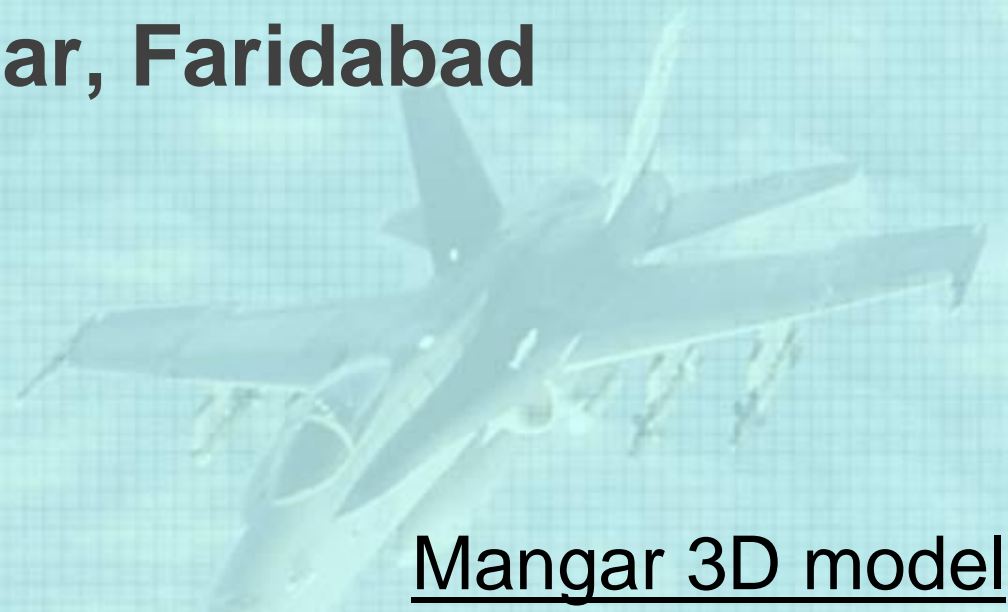
3D mapping of Mangar, Faridabad



3D mapping of Mangar, Faridabad

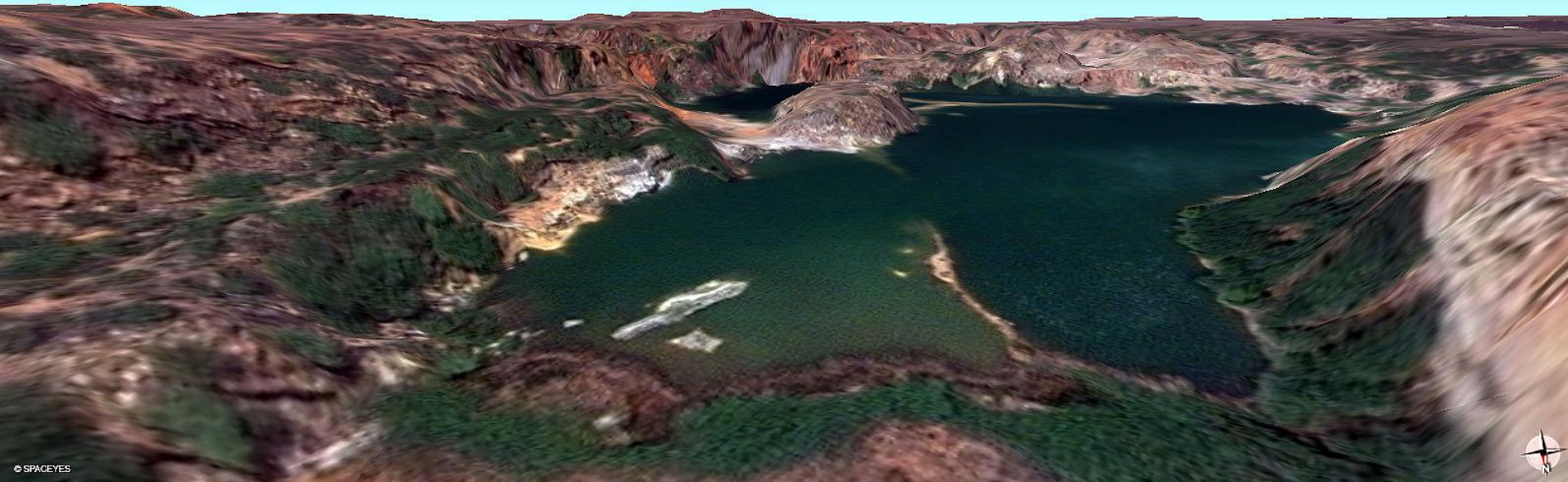


3D mapping of Mangar, Faridabad



Mangar 3D model

Mining Lake, Mangar

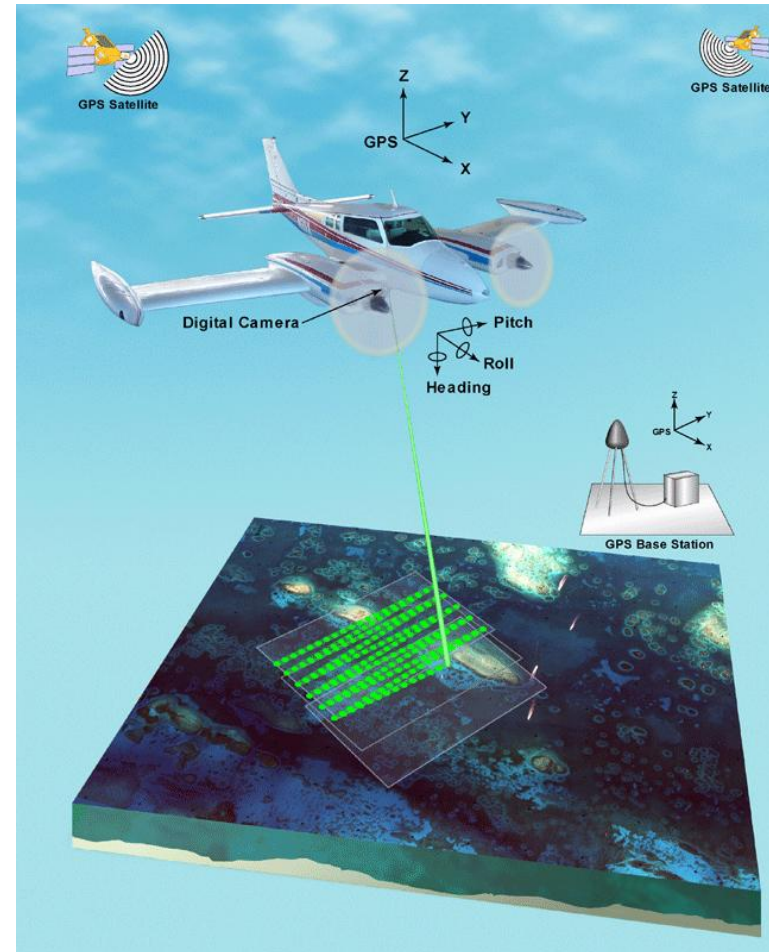


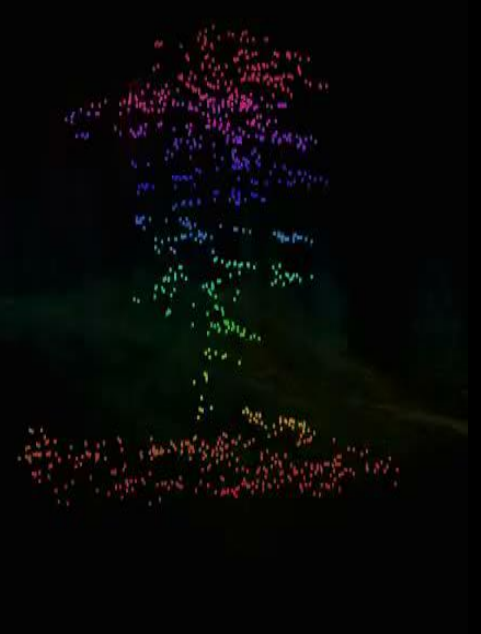
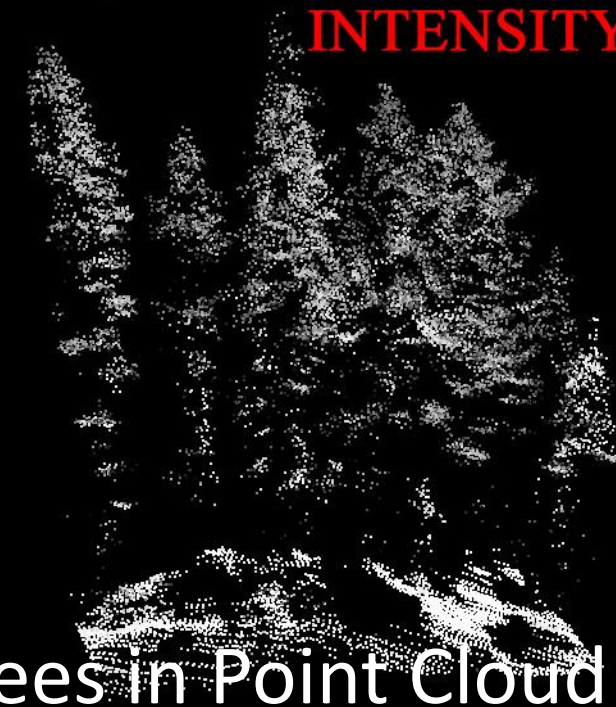
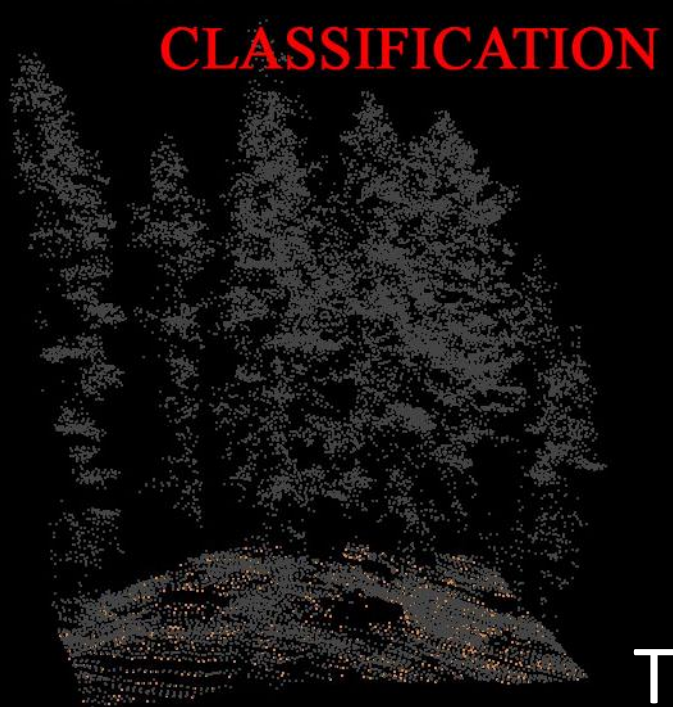
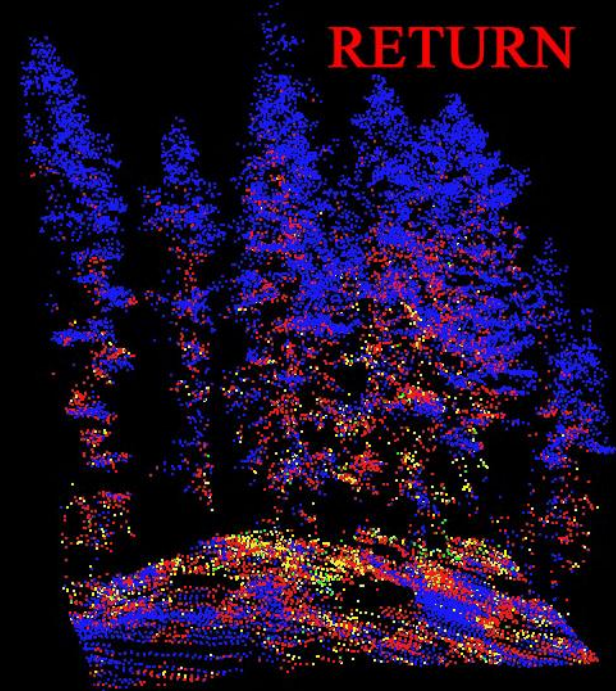
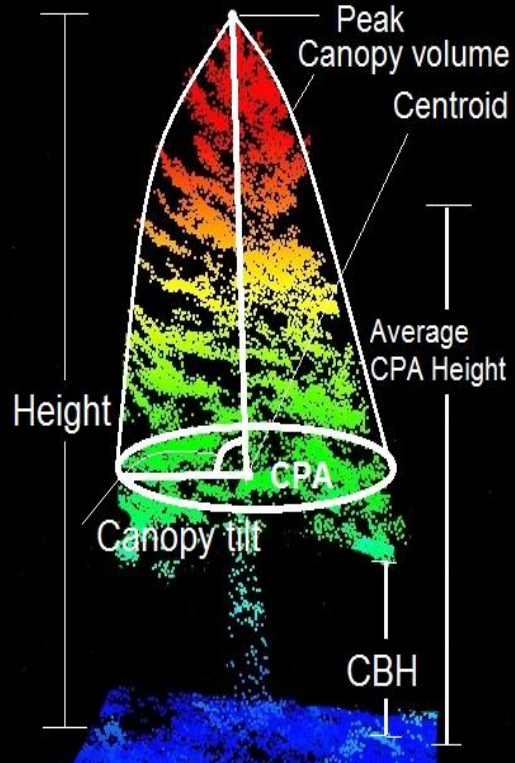
Model 3, Walkthrough models from LiDAR



LiDAR Technology (Light Detection And Ranging)

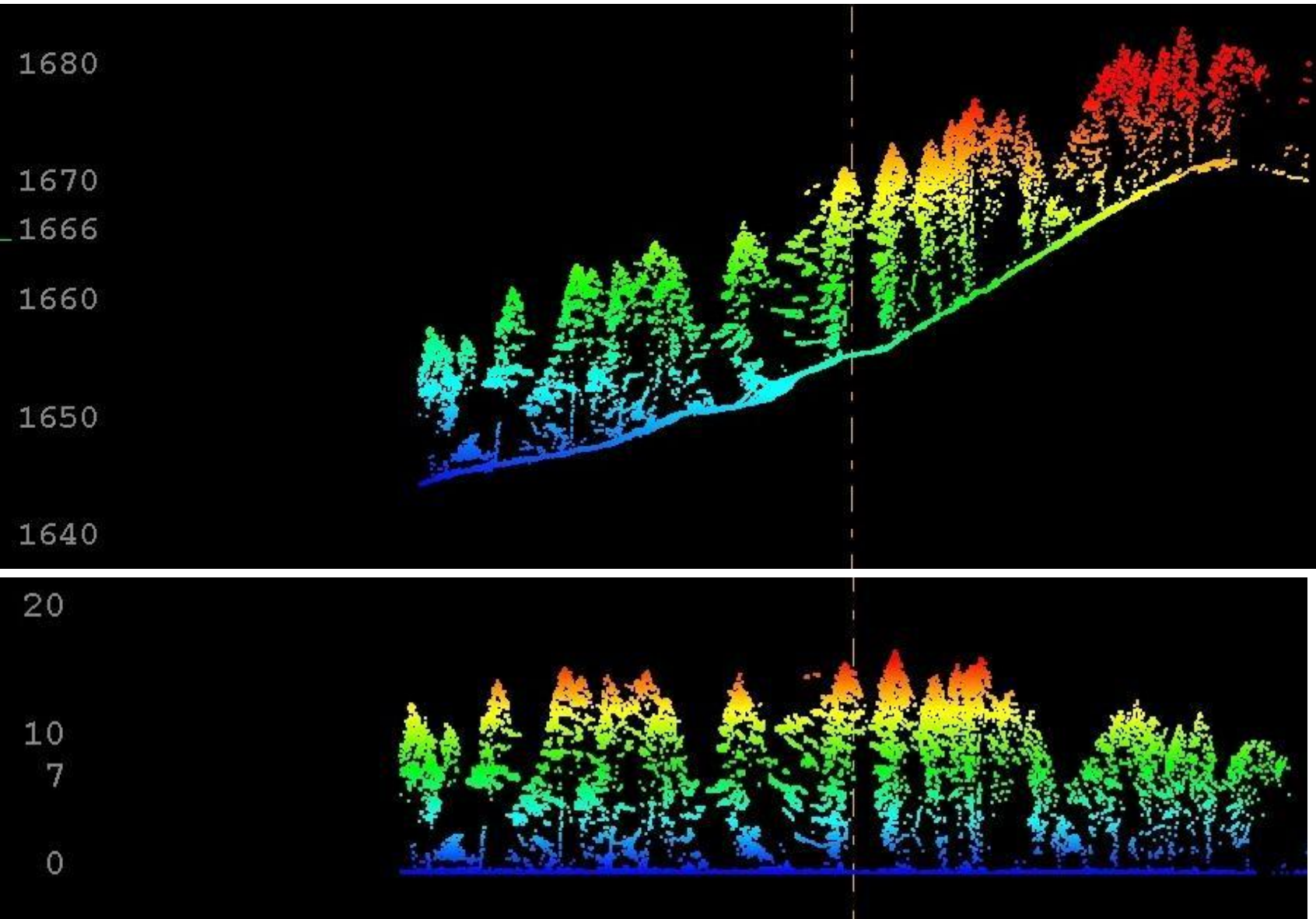
1. Laser scanner
2. Differential GPS
3. Inertial Measurement Unit (IMU)
4. On board computer to store data

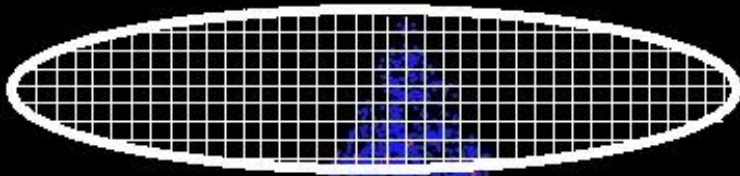




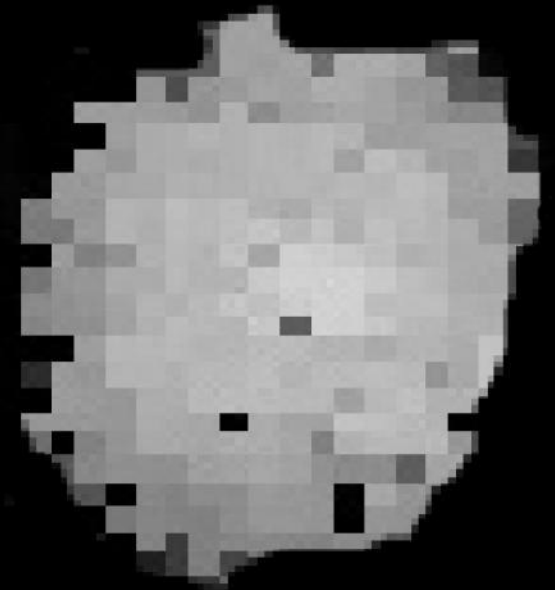
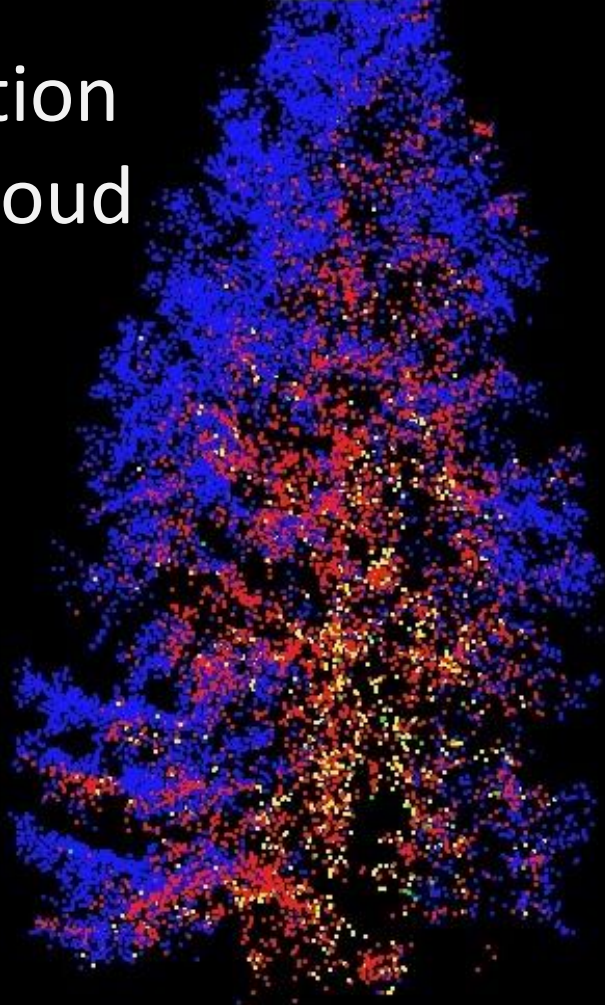
Trees in Point Cloud

Point cloud & normalised point cloud





Rasterization
of Point cloud

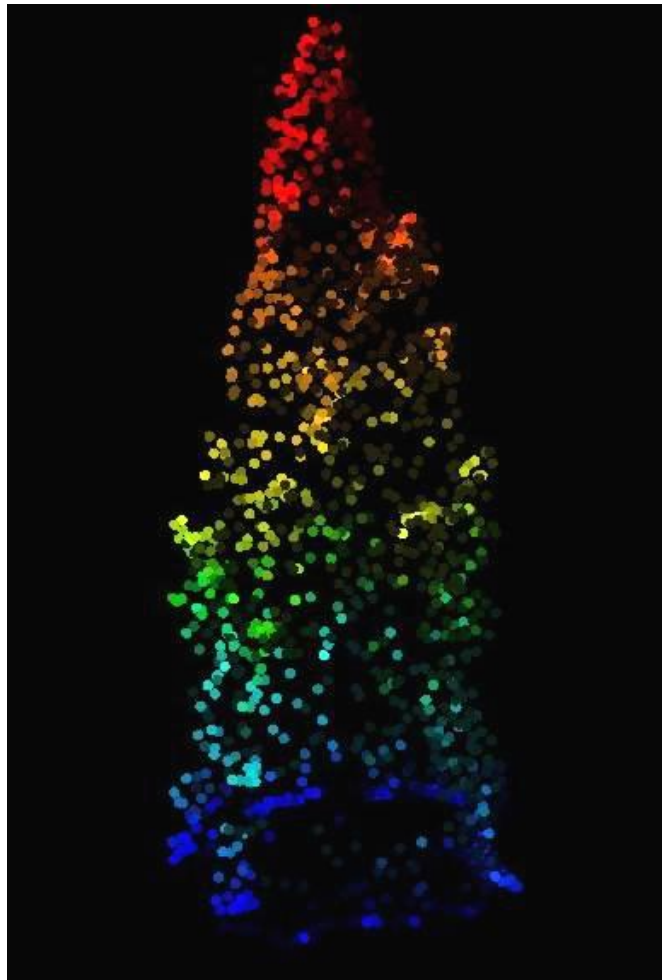


DSM

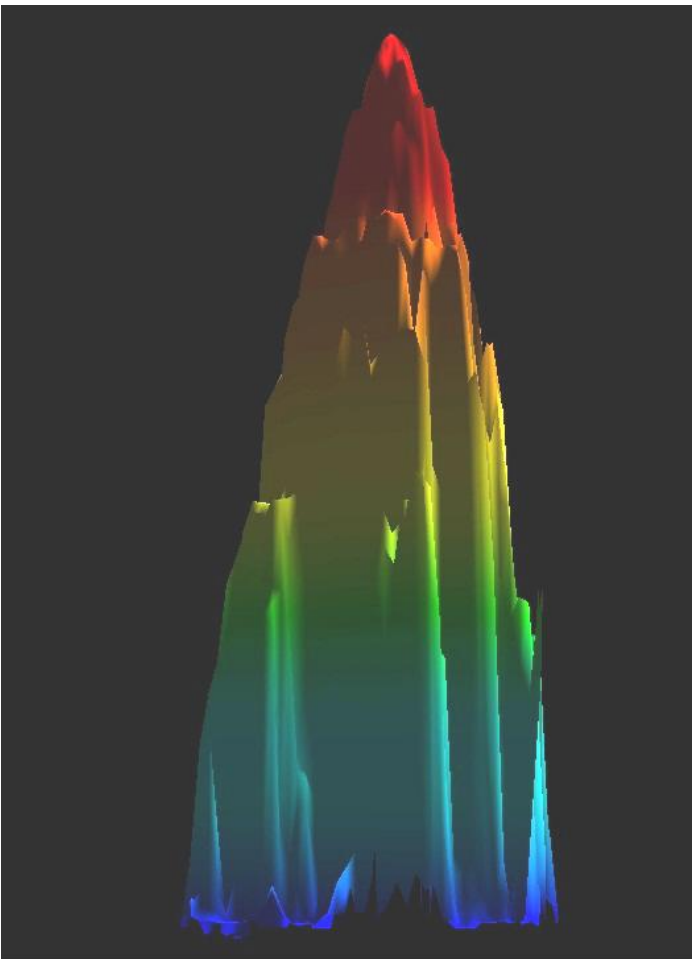
DSM generation = Gridding Point cloud (rasterization)

highest point of first return in each pixel are selected

Single tree in point cloud & in CHM

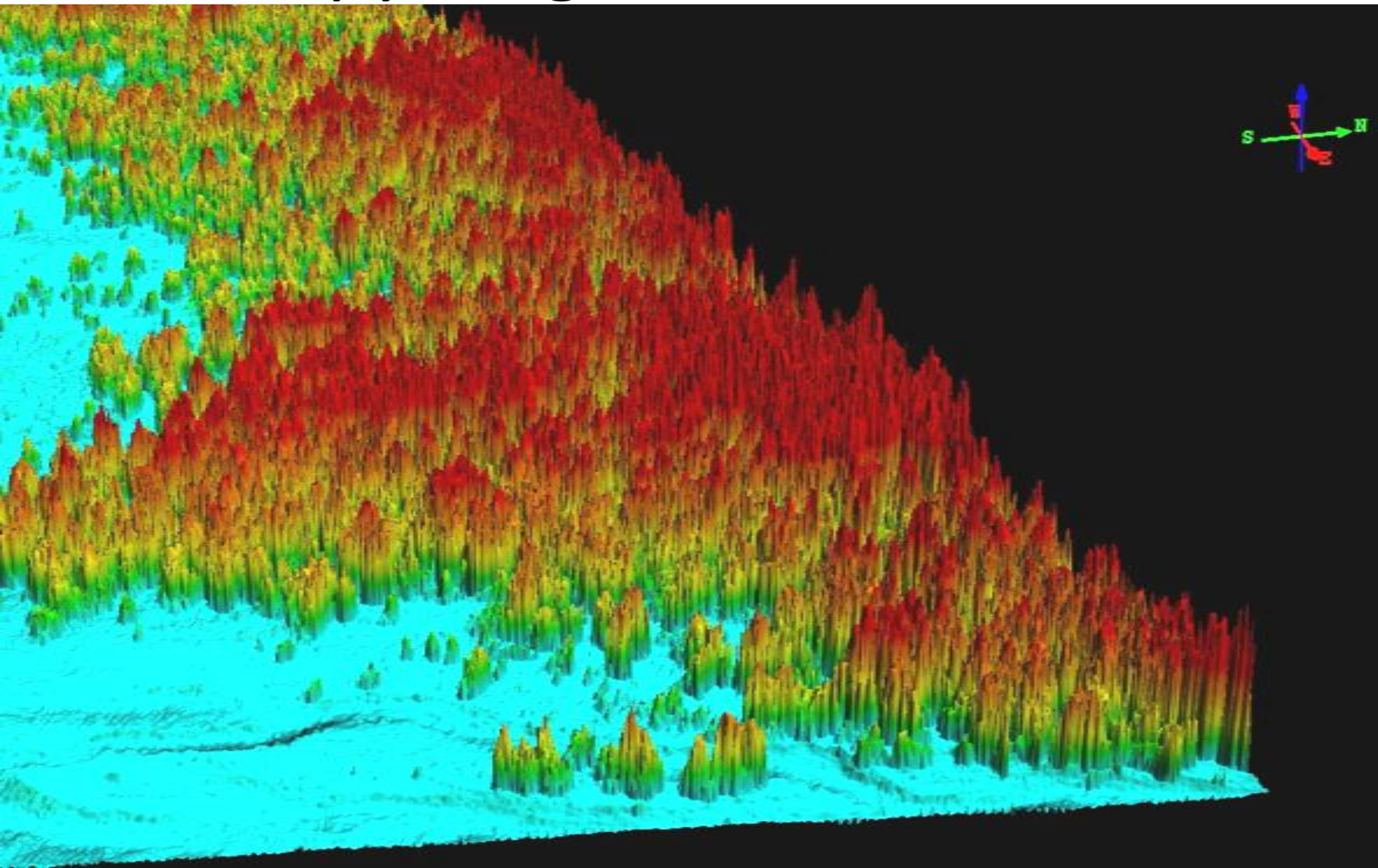


Single tree in normalized point cloud



Single tree in CHM

Canopy Height Model in 3D

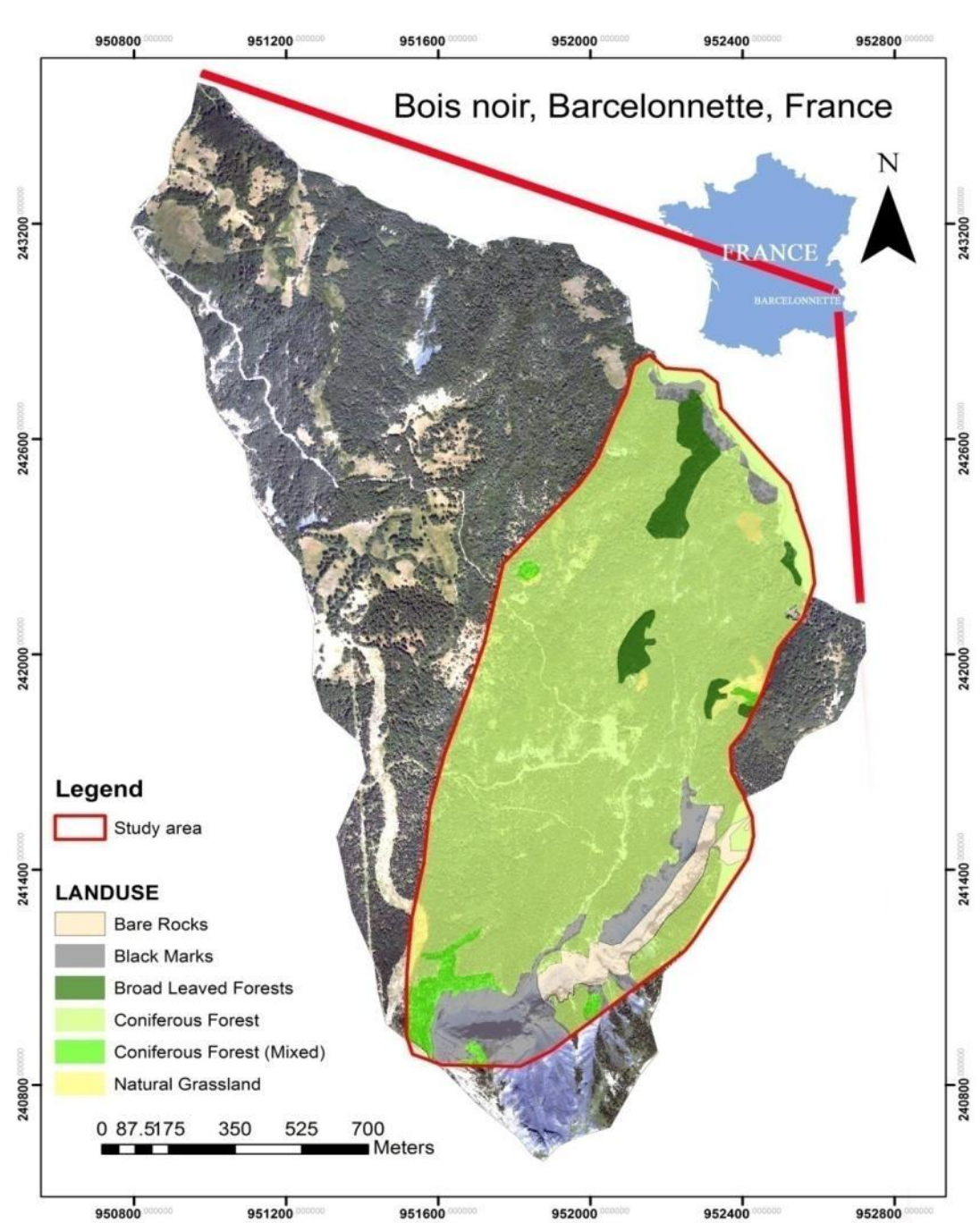


Tree parameters for 3D modelling

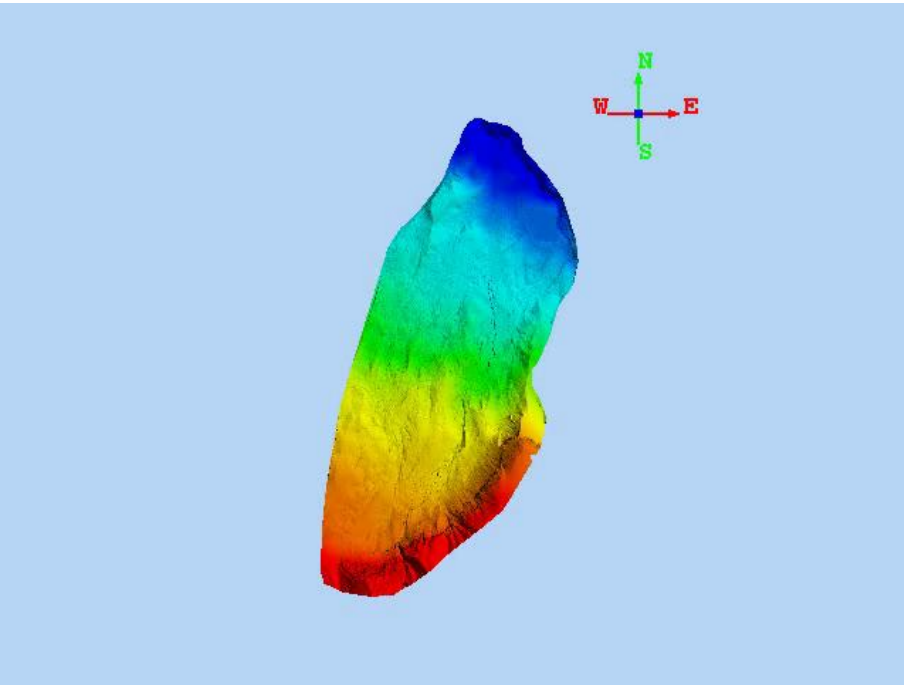
1. Tree peak identification and crown delineation
2. Extraction of tree inclination and orientation
3. Species classification

Study Area

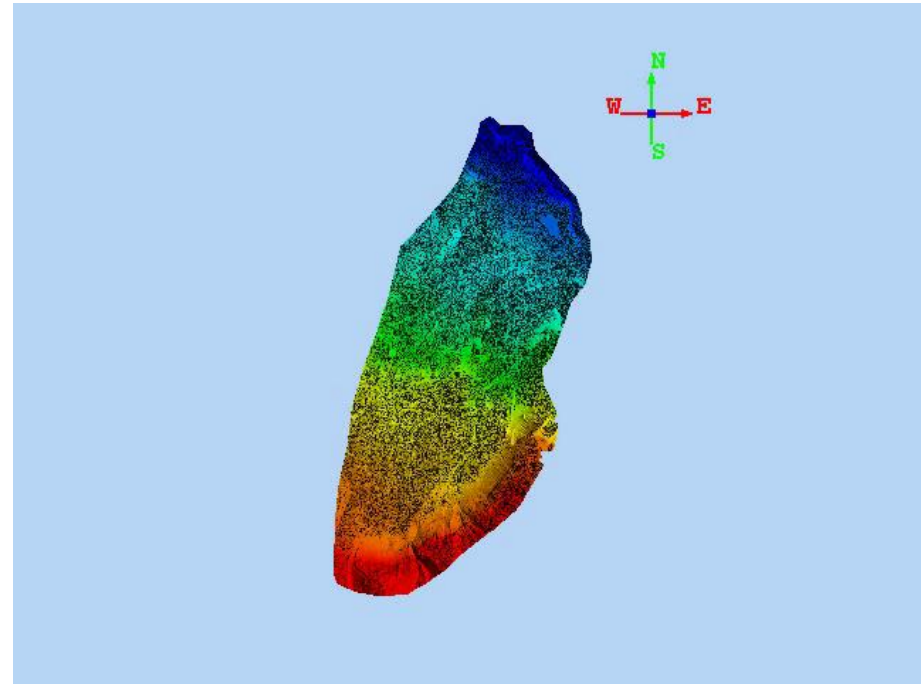
- Area = 1.5 KM², ortho A=1.3 KM²
- 92 % forest
- Mainly coniferous forest
Pinus uncinata
- Slope 10° to 35° avg slope=14.5°
- Undulating terrain
- Frequent landslides



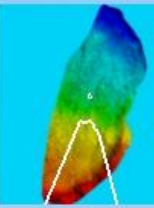
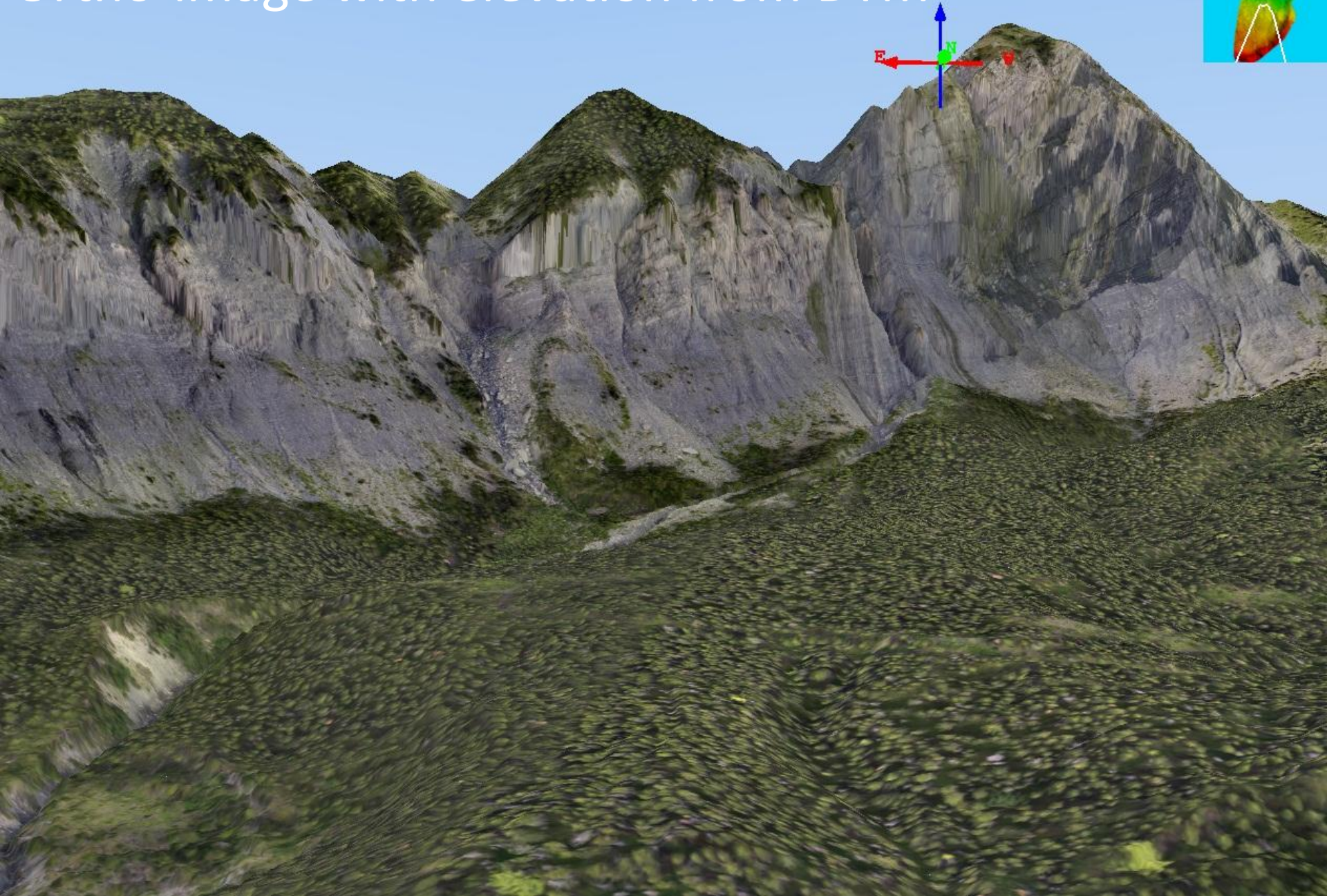
DTM



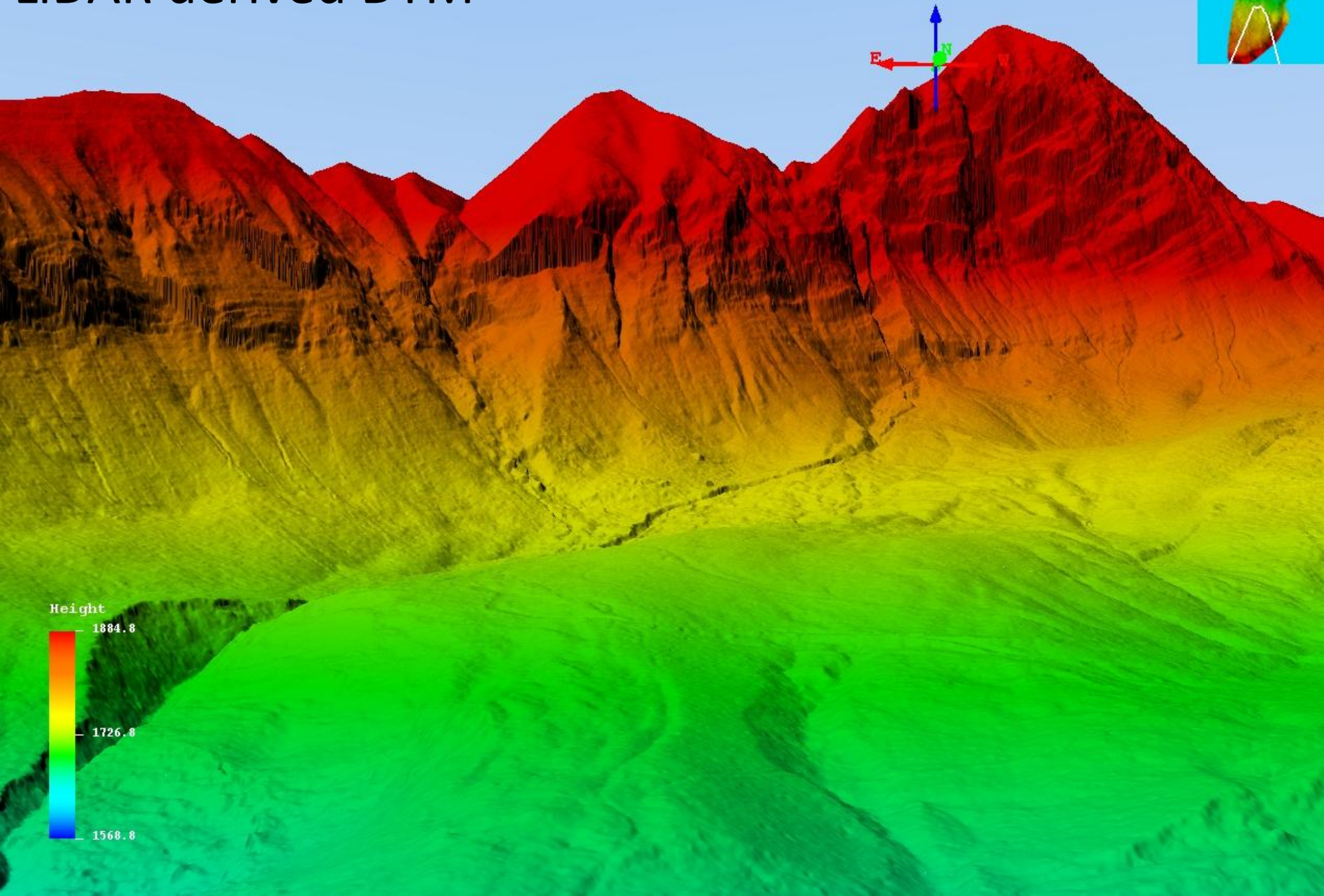
DSM



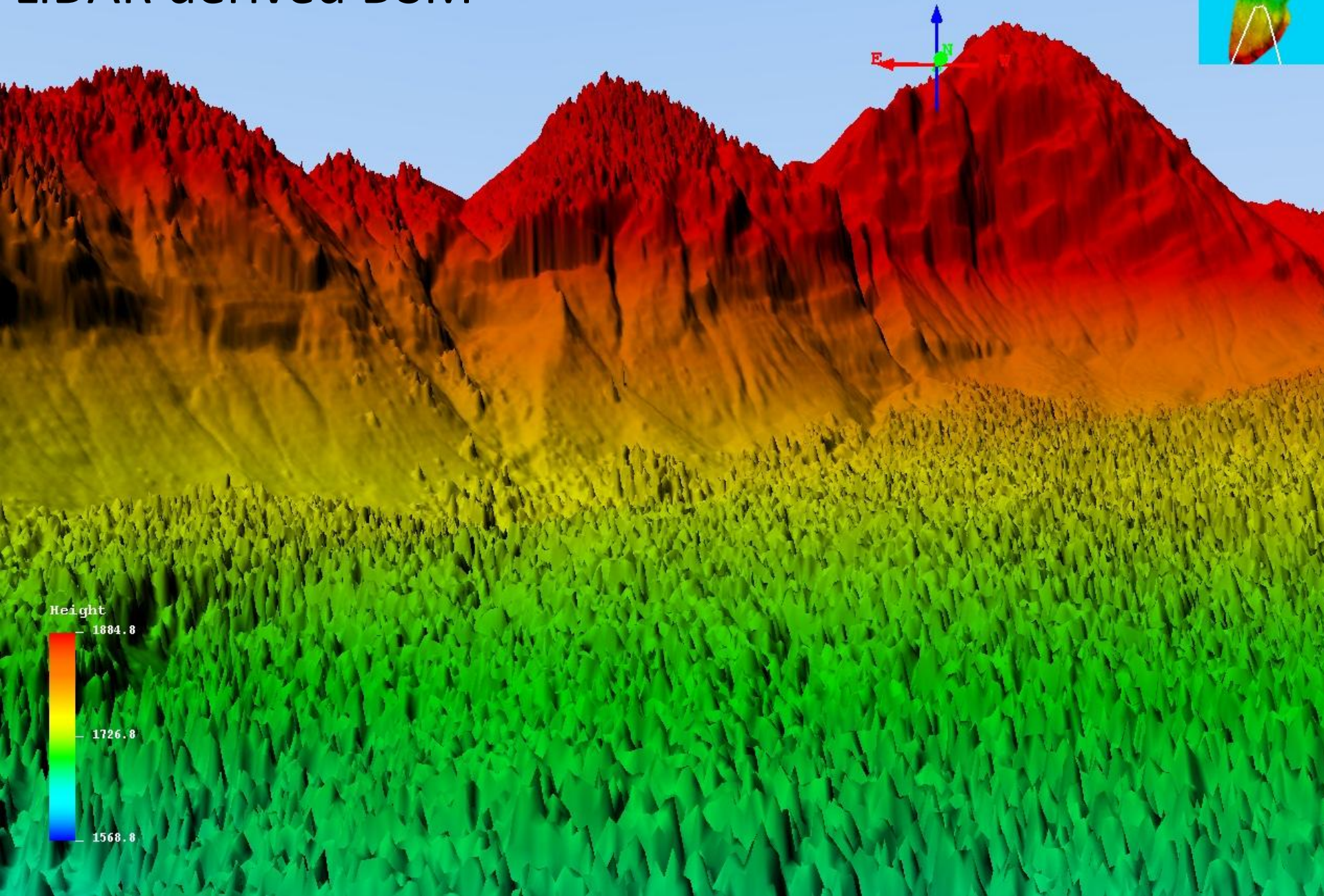
Ortho-image with elevation from DTM



LiDAR derived DTM

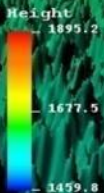
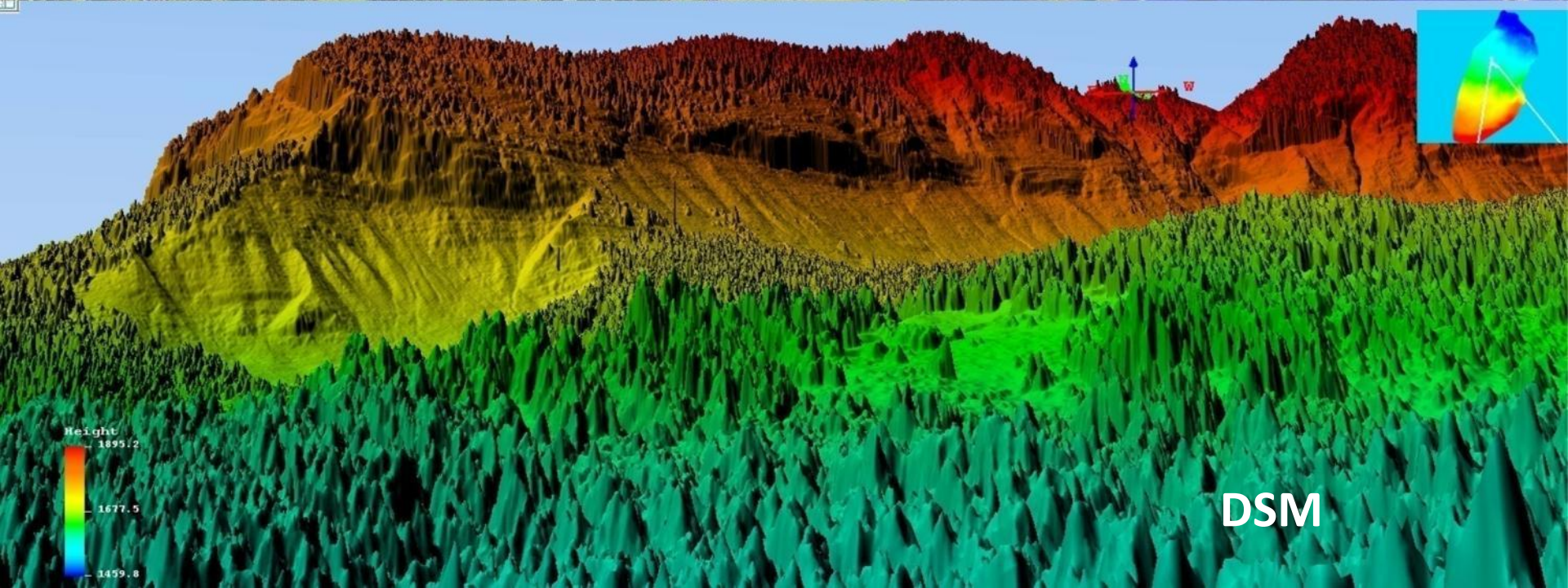


LiDAR derived DSM



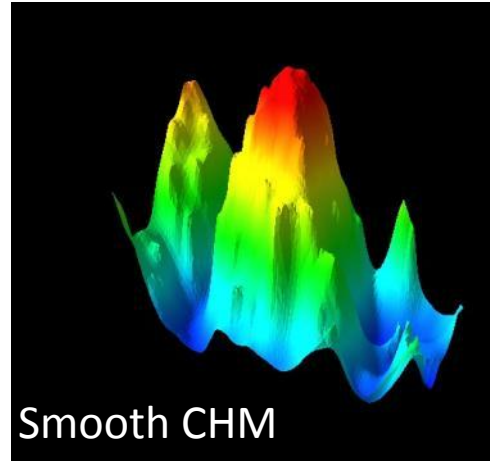
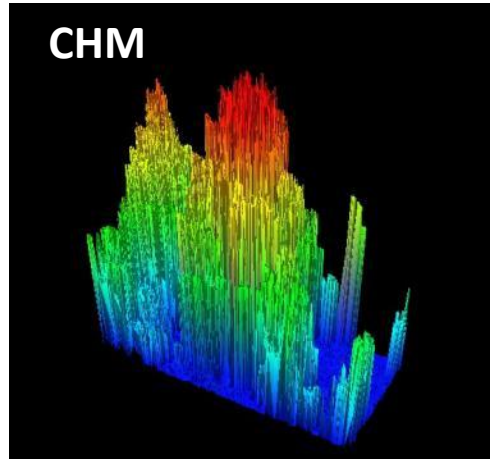
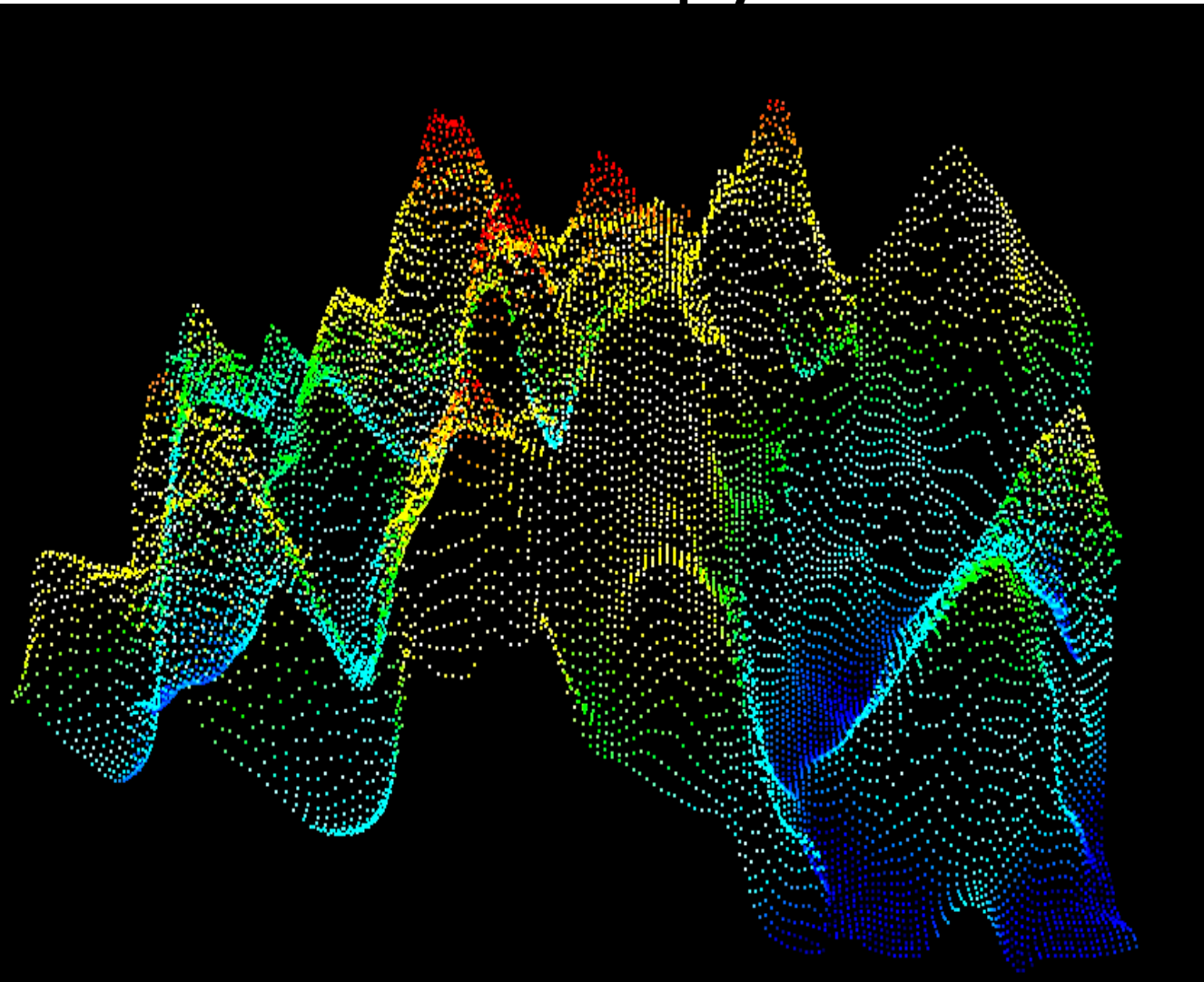


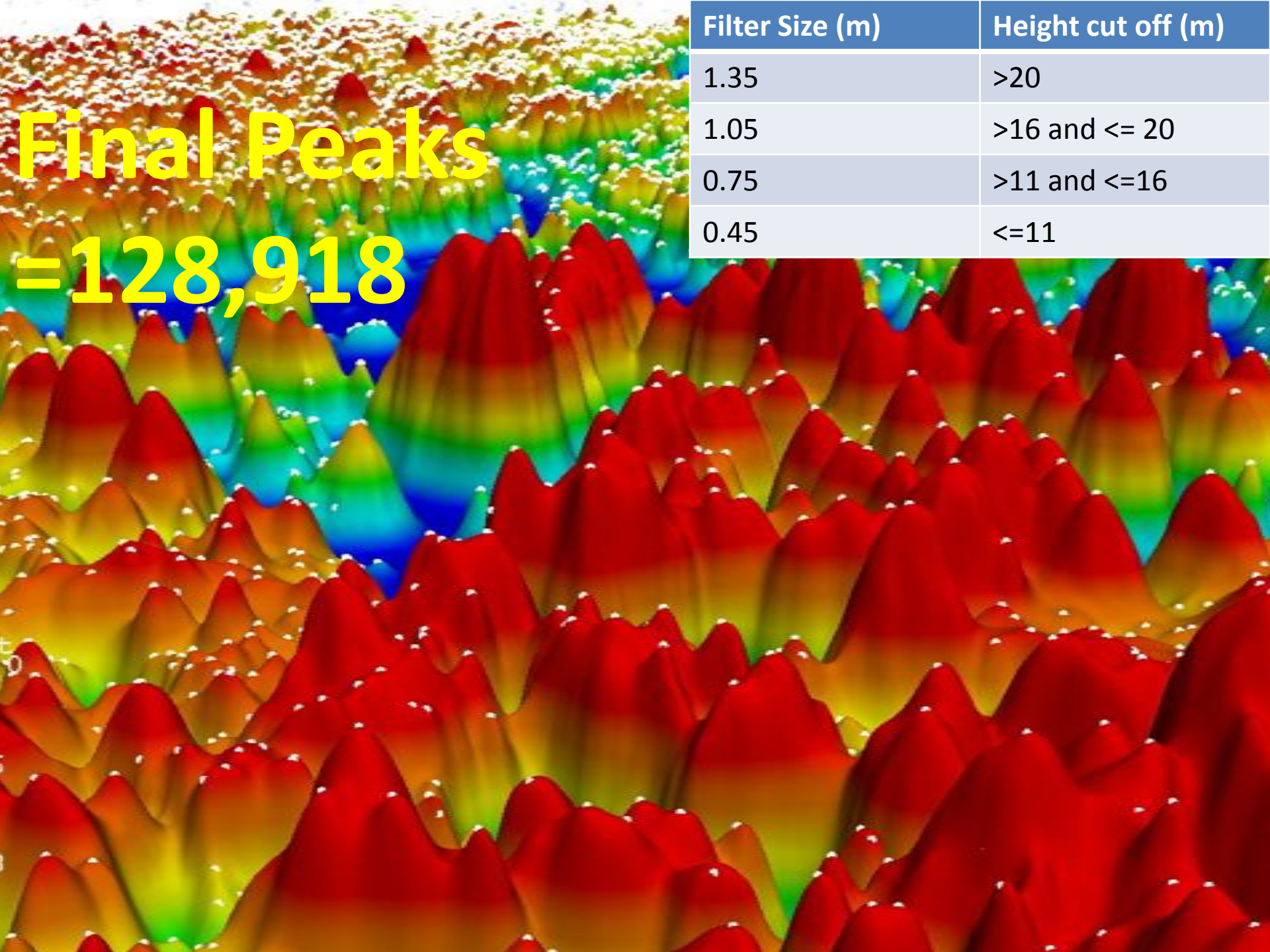
Actual Picture



DSM

Tree Peak detection in enveloping canopy surface



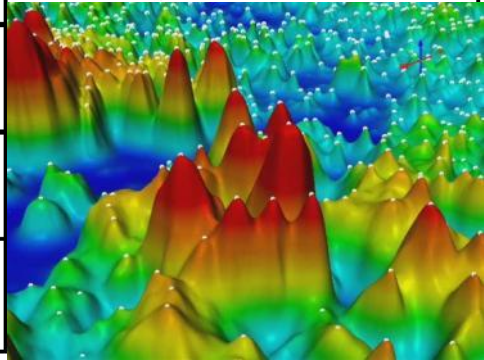


**Final Peaks
=128,918**

Filter Size (m)	Height cut off (m)
1.35	>20
1.05	>16 and <= 20
0.75	>11 and <=16
0.45	<=11

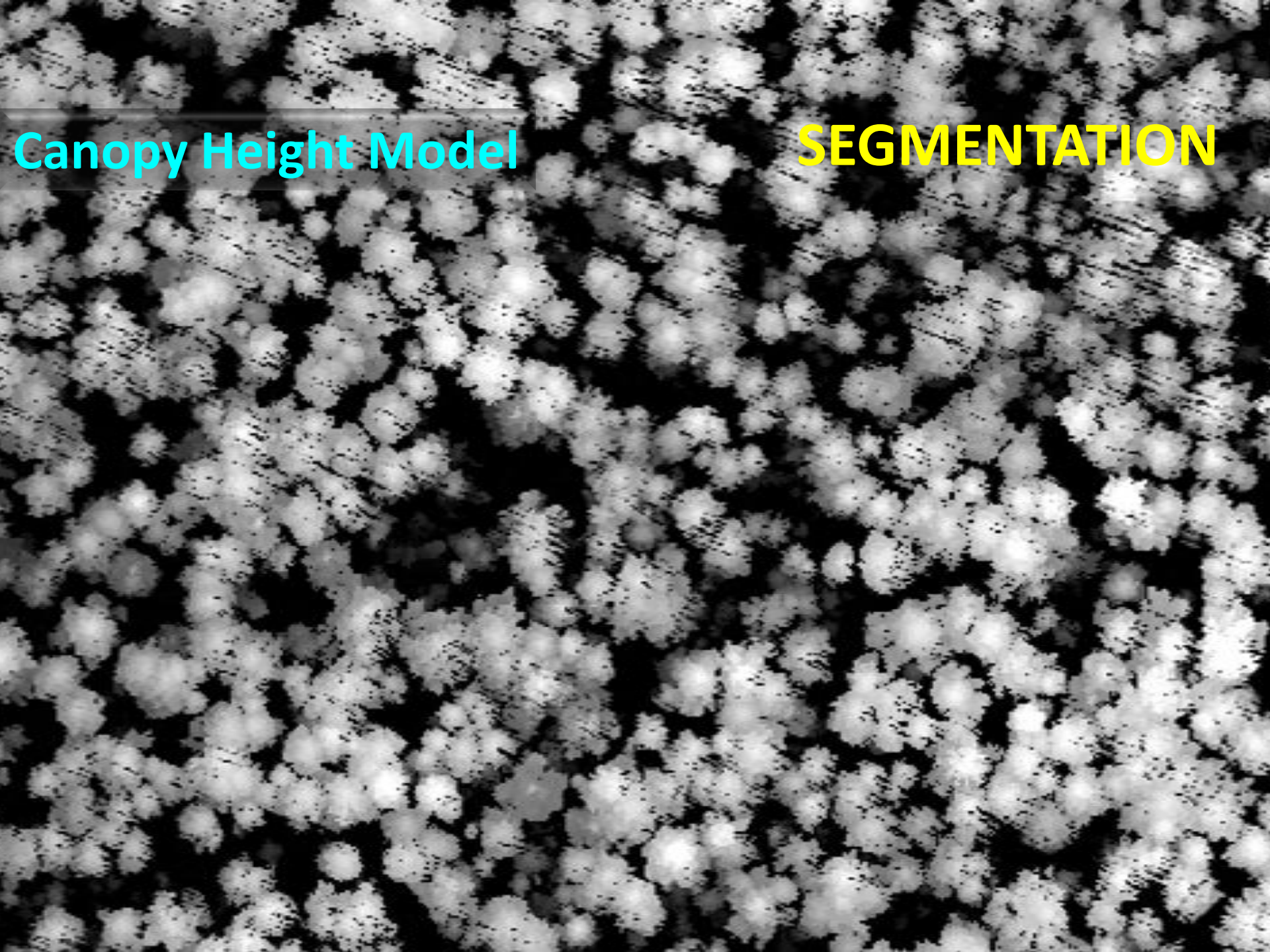
Tree peak identification in point cloud

No. of sample trees	No. tree peaks identified	Accuracy %
275	264	96

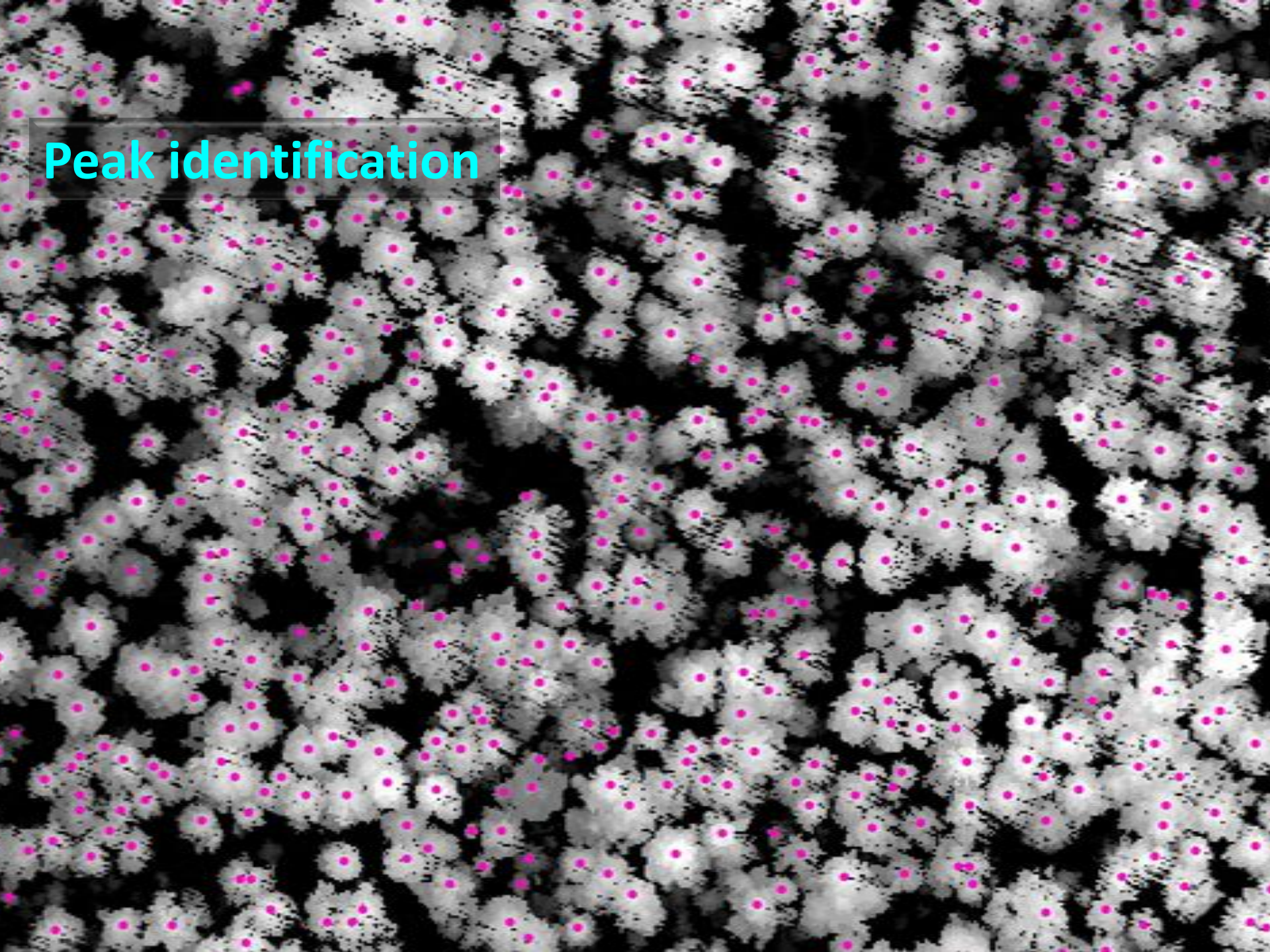
Smooth CHM	Tree peaks detected	Final Peaks
sCHM3 Filter size- 0.45 m	164,787	128,918
sCHM5 Filter size- 0.75 m	92,867	
sCHM7 Filter size- 1.05 m	72,609	
sCHM9 Filter size- 1.35 m	54,194	

Canopy Height Model

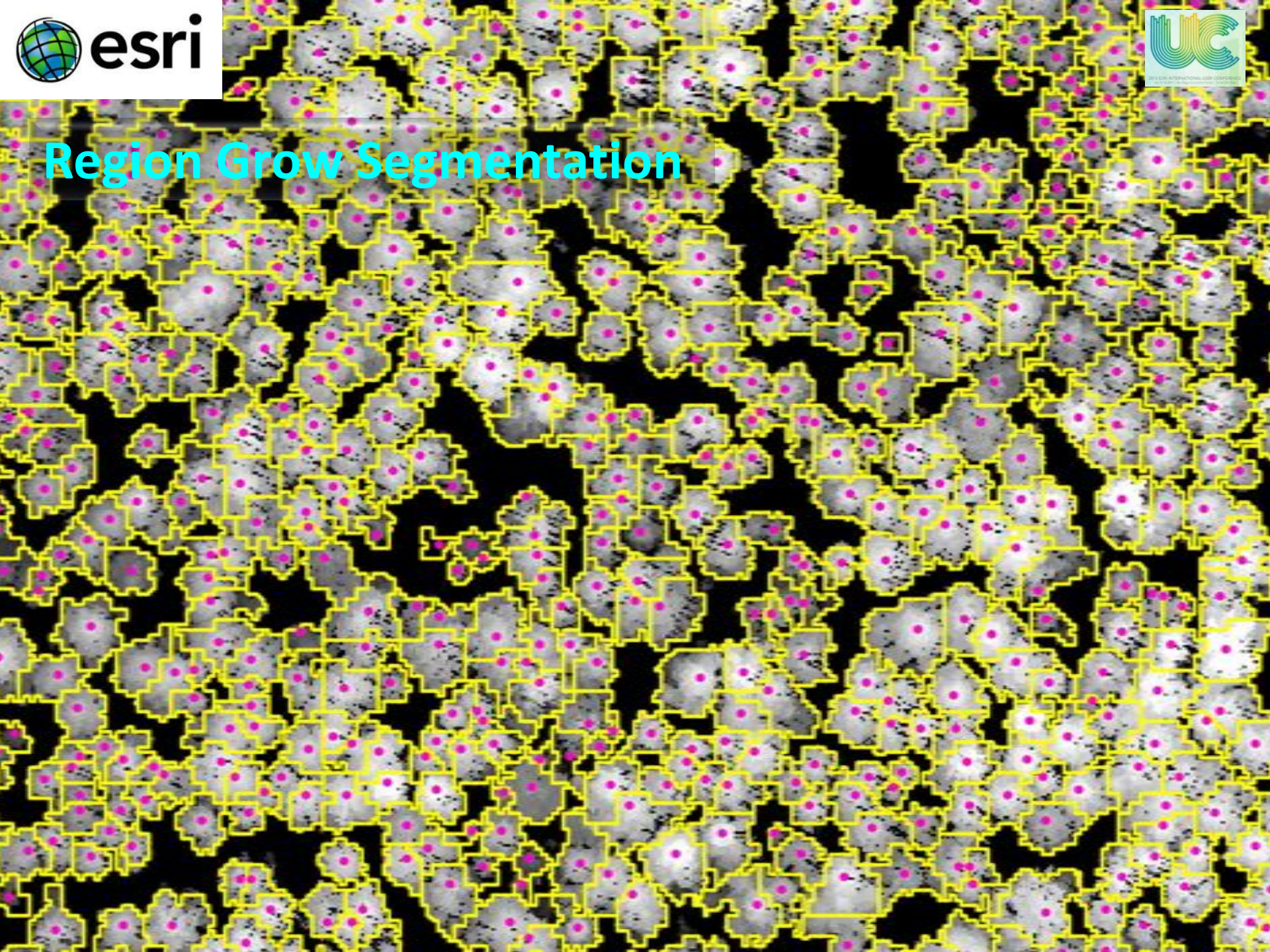
SEGMENTATION



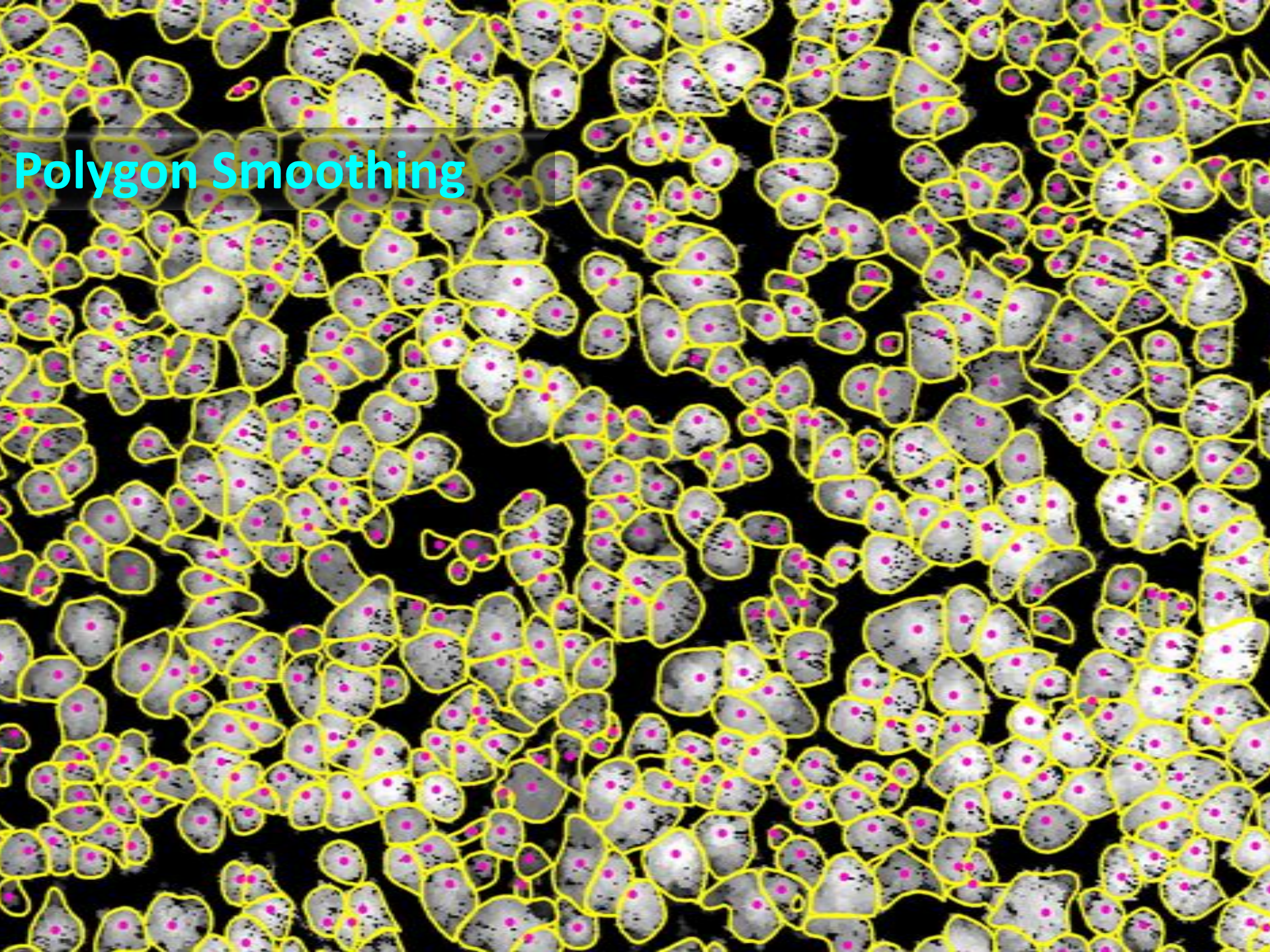
Peak identification



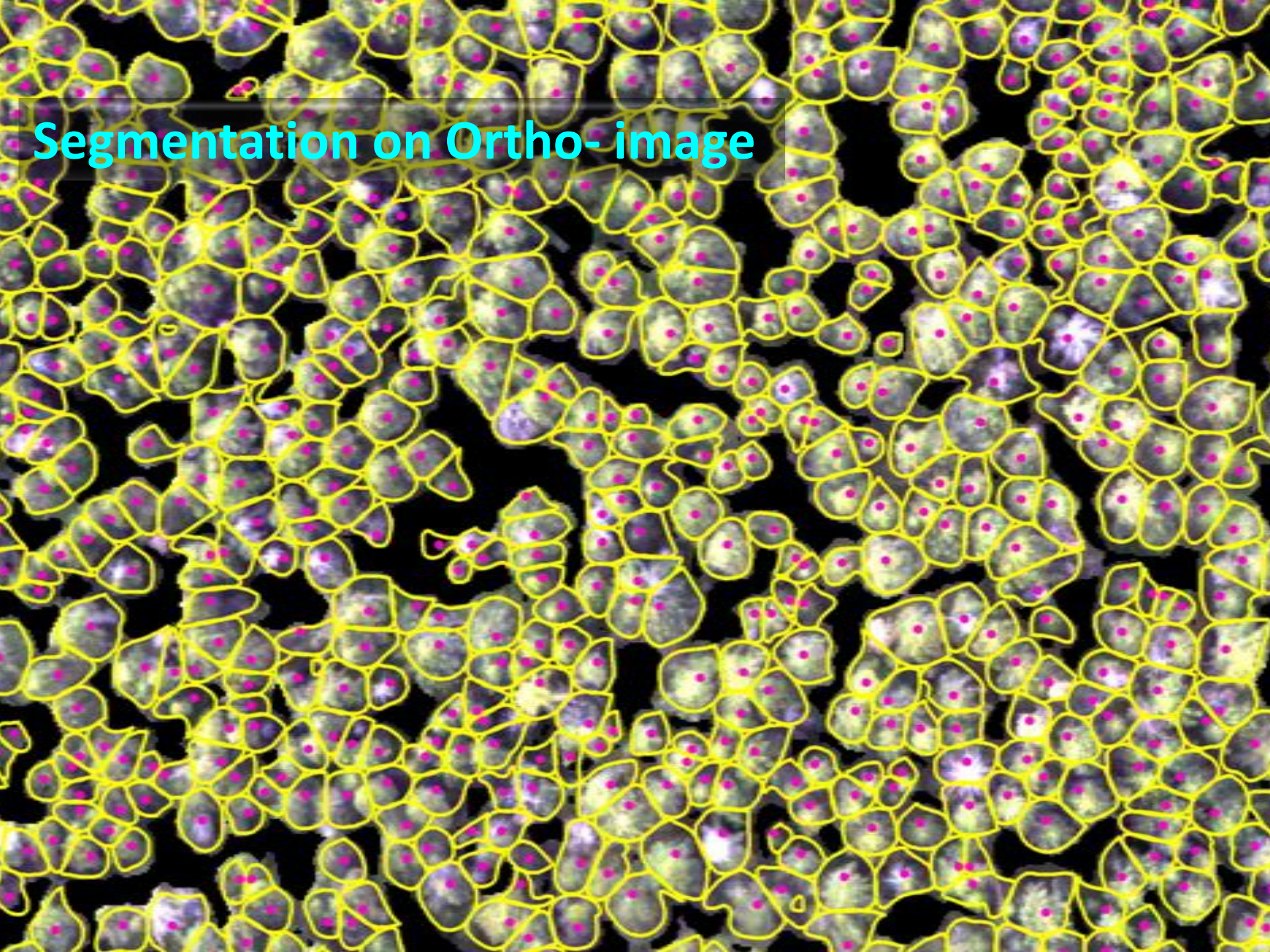
Region Grow Segmentation



Polygon Smoothing



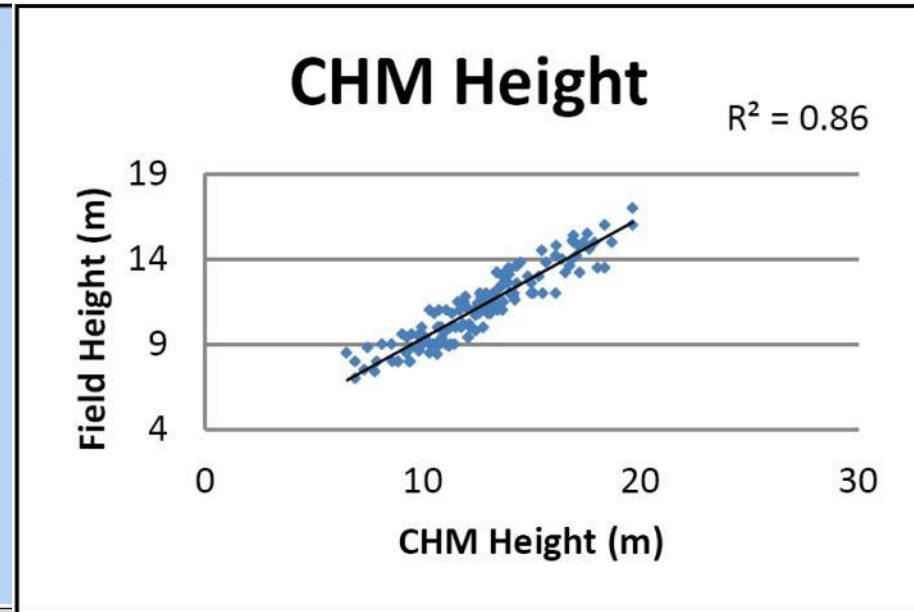
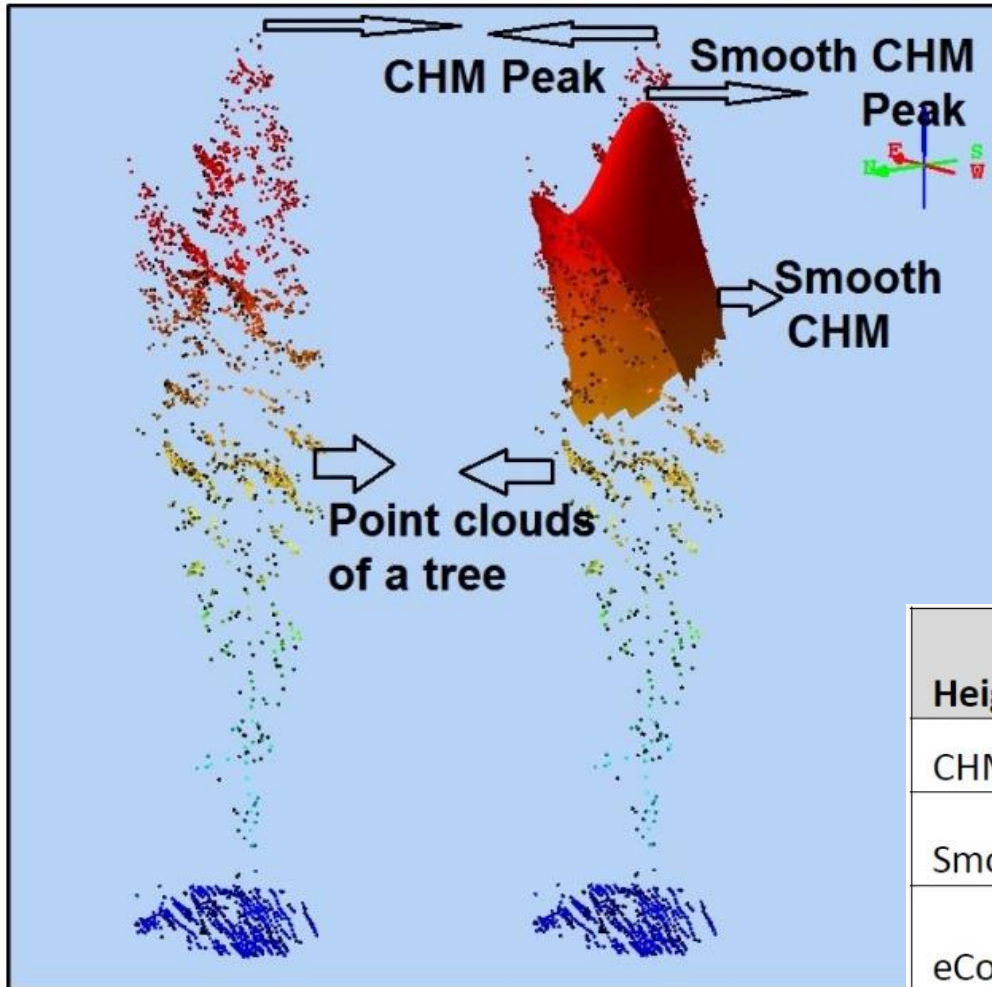
Segmentation on Ortho- image



1:1 correspondence

Tree species	reference	1:1 correspondence		accuracy %	
		Region growing	Thiessen polygons	Region growing	Thiessen polygons
<i>Pinus uncinata</i>	200	187	188	93.5	94.0
<i>Pinus Sylvestris</i>	51	48	49	94.1	96.1
<i>Larix decidua</i>	23	21	21	91.3	91.3
<i>Picea abies</i>	1	1	1	100	100.0
Total	275	257	259	93.5	94.2

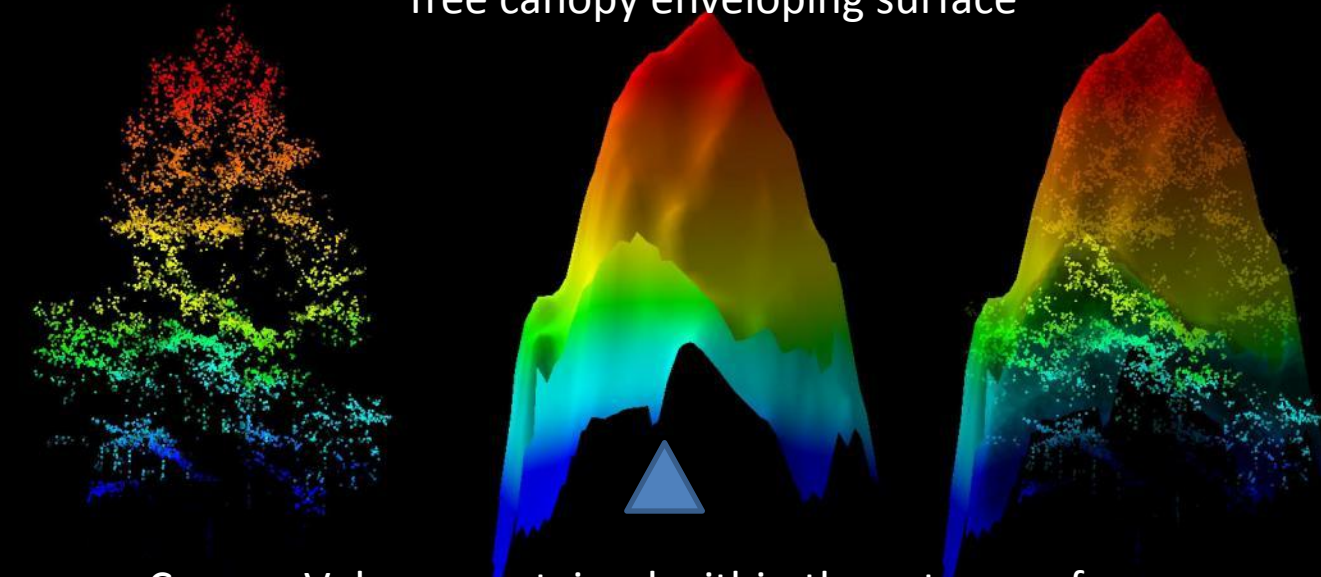
Tree Height



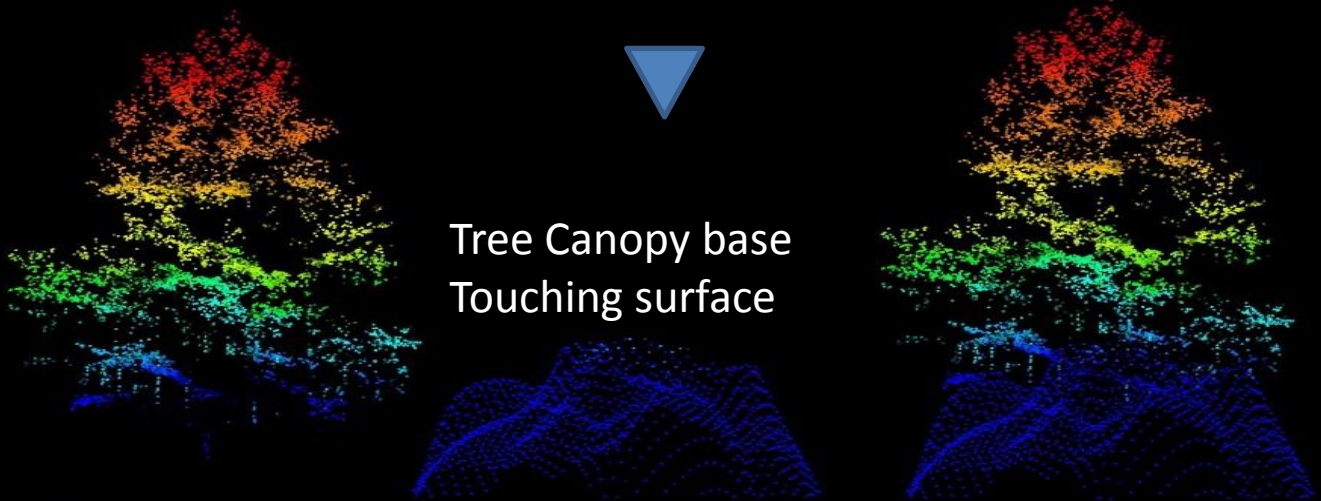
Height	R^2	RMSE (m)
CHM Height	0.86	0.80
Smooth CHM Height	0.85	0.83
eCognition CHM Height	0.81	0.93
eCognition smooth CHM Height	0.81	0.93

Canopy Volume

Tree canopy enveloping surface



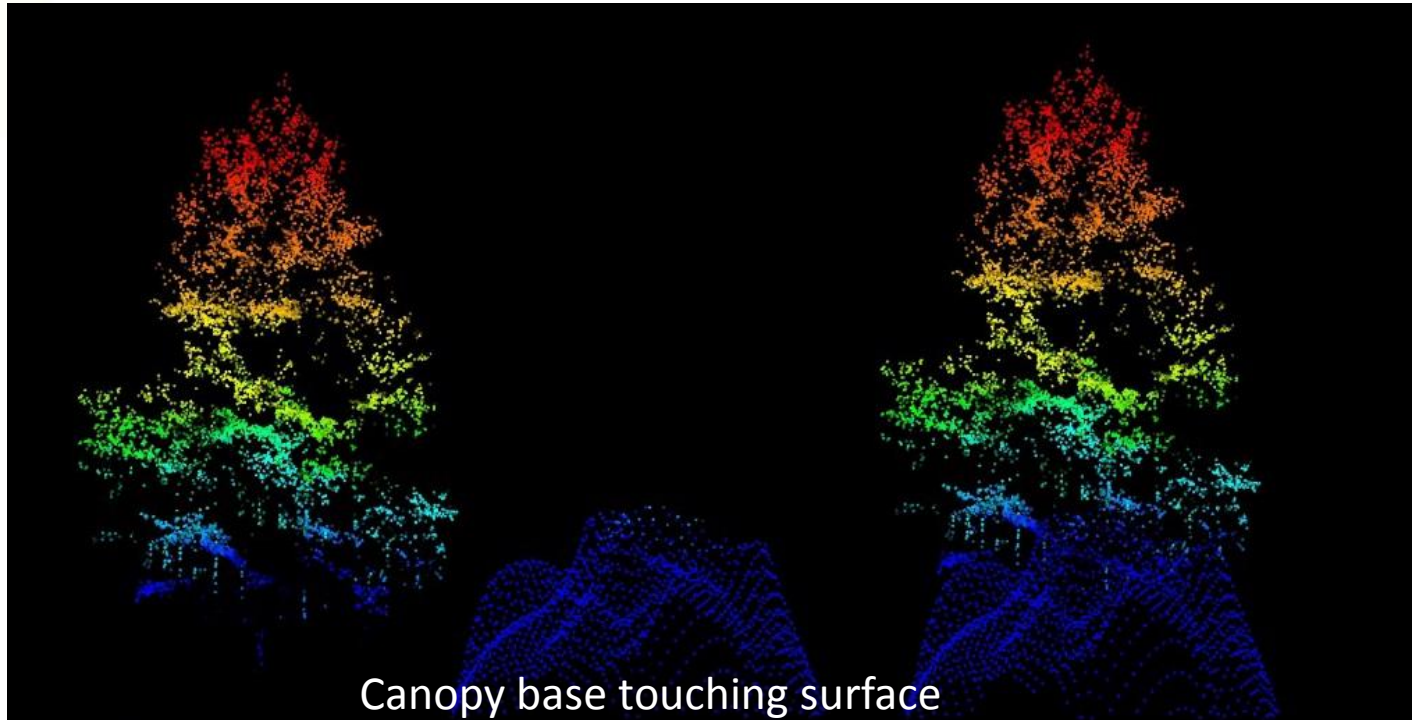
Canopy Volume contained within these two surfaces



Tree Canopy base
Touching surface

Canopy Base Height

calculated as average height of canopy base touching surface



Parameters extracted for inventory database

From the point cloud	Derived from 1st column	Other data layers
1 Height	15 Crown diameter	24 Landuse
2 Canopy Projection Area (CPA)	16 Perimeter CPA	25 Landslide zone
3 Canopy Volume	17 Major & minor axis CPA	
4 Canopy base height	18 Local tree density	
5 Canopy tilt	19 Local canopy gap %	
6 Canopy orientation	20 Canopy Shape	
7 Canopy density	21 Tree species	
8 Elevation	22 Biomass	
9 Slope	23 Carbon	
10 Aspect		
11 Location of Peak (cloud)		
12 Location of Peak (DSM)		
13 Location of centroid (CPA)		
14 Average CPA height		

- INVENTORY DATA

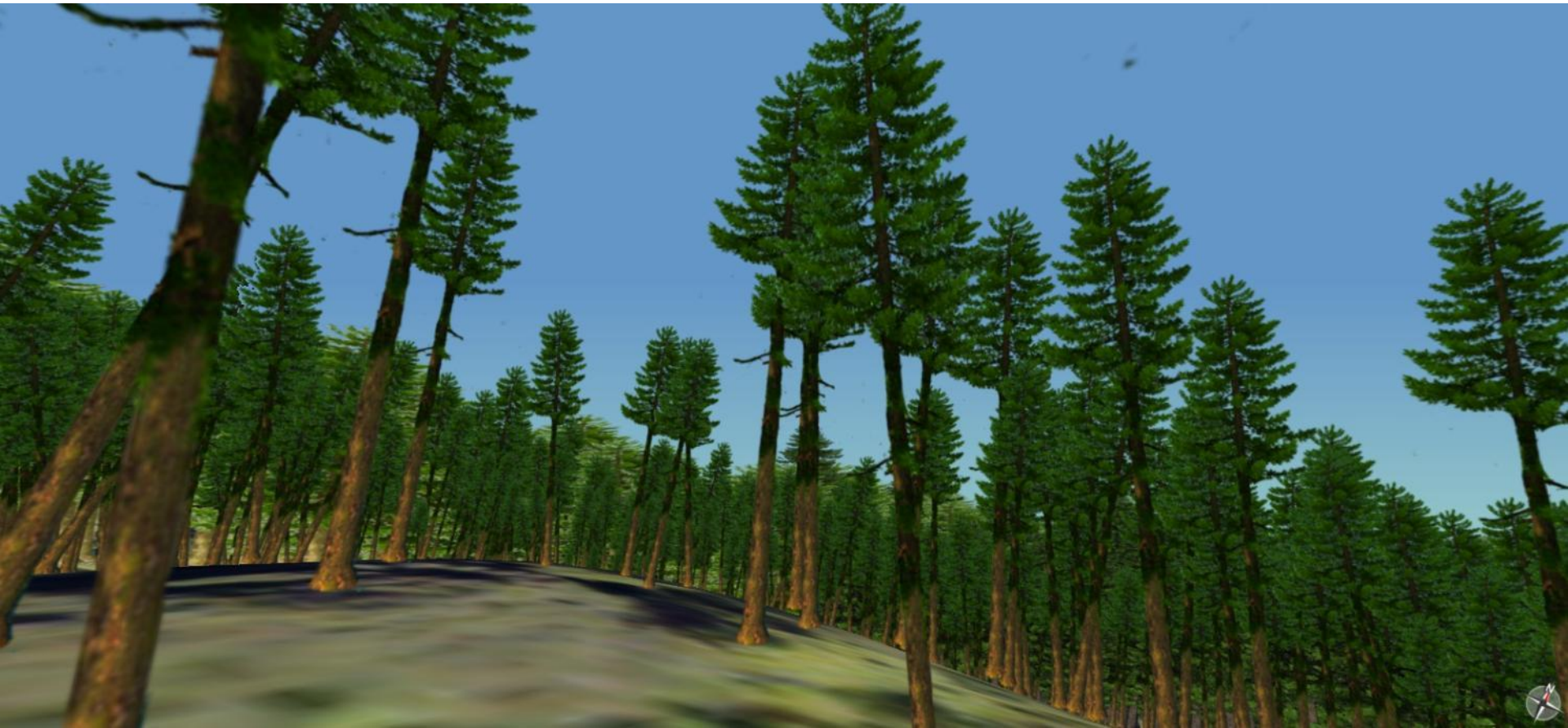


Accuracy of extracted parameters

Parameter	R ²	RMSE
CPA (Region growing smooth)	0.87	3.67 m ²
CPA (Thiessen smooth)	0.90	3.16 m ²
Canopy base height (CBH)	0.73	0.86 m
Canopy tilt	0.57	3.26 degree

3D forest modeling from inventory data

- **Tree:** Location, Species, Height, Inclination, Orientatioion.





Actual Photo



Model Photo

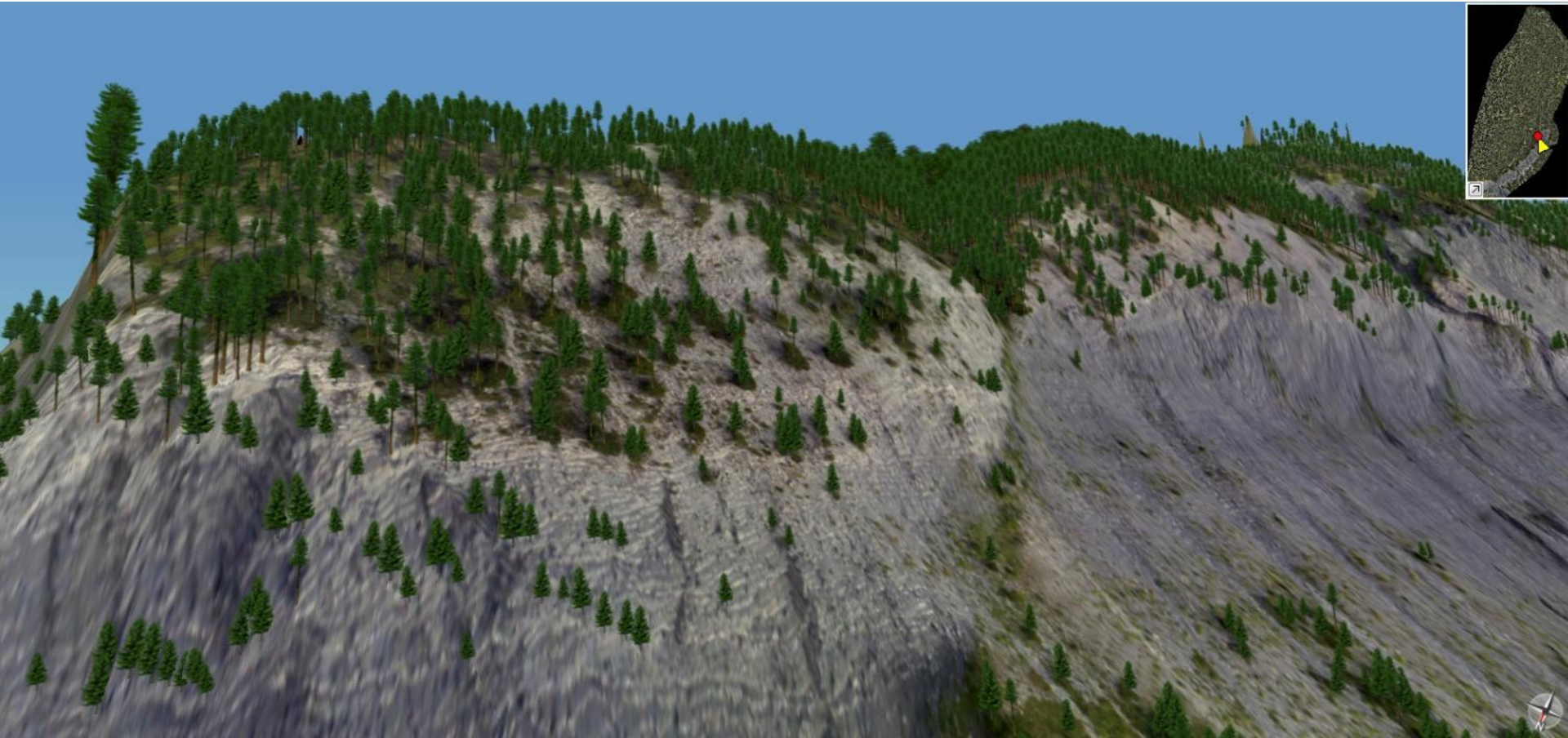
Visualizing open forests



Visualizing forest path

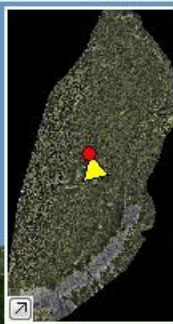


Visualizing inaccessible areas



Visualizing landslide areas



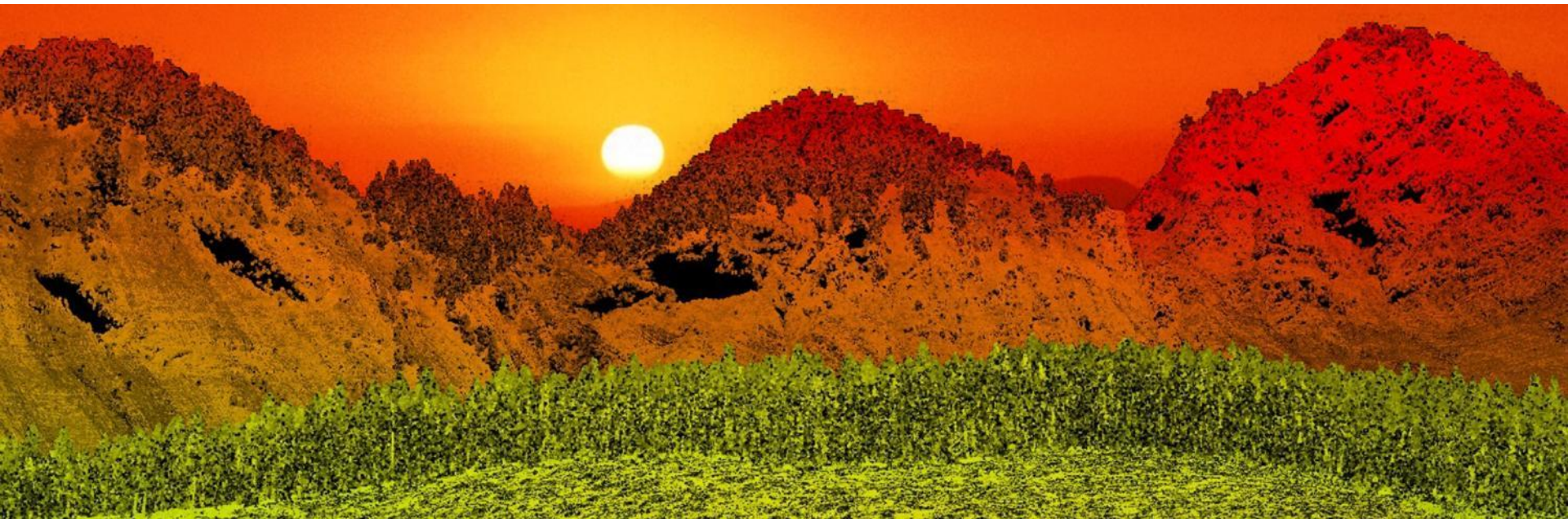




3D Fly Through Model of a real Forest

<https://www.youtube.com/watch?v=dkfolP-e6Uo>

Thanks



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