

Limulator2.0: A simulator for LiDAR Education

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LiDAR technology

- LiDAR technology is important due to its application in several problem solving
- Need to train students and professionals on LiDAR sensors, data, processes and applications
- LiDAR research needs a variety of LiDAR data with accurate ground truth

LiDAR education: Domain & Needs

- ❑ Theoretical background in LiDAR

- ❑ Understanding sensor functioning
 - ❑ Need a system which can show how different sensors work
 - ❑ Actual sensor availability is a problem due to cost

LiDAR education: Domain & Needs

- ❑ Understanding LiDAR data
 - ❑ Need lots of LiDAR data for different kinds of terrain and with different parameters
 - ❑ A few data are available but without ground truth
 - ❑ Data may not be available with desired parameter
 - ❑ Data are costly

LiDAR education: Domain & Needs

- ❑ Understanding errors in data
 - ❑ Need a system where errors can be introduced at will and their effect can be seen
 - ❑ Difficult as introducing error is not possible in sensors
 - ❑ The nature of error becomes known only after the flight
 - ❑ Experiments prove costly

LiDAR education: Domain & Needs

- Understanding the effect of flight/sensor parameters on data
 - Need LiDAR data with different sensor/flight parameters
 - Not feasible due to requirement of repeated flights thus cost
 - Some of the parameters may even not be attainable in available sensors

LiDAR education: Domain & Needs

- ❑ A comprehensive study requires full ground truth
 - ❑ Not possible for actual terrain
 - ❑ Involves cost in collecting ground truth

Conclusion from above

- Need for a system for proper LiDAR education which can provide the flexibility of sensor operation and LiDAR data as desired
- However, there is no such system or data available
- Cost

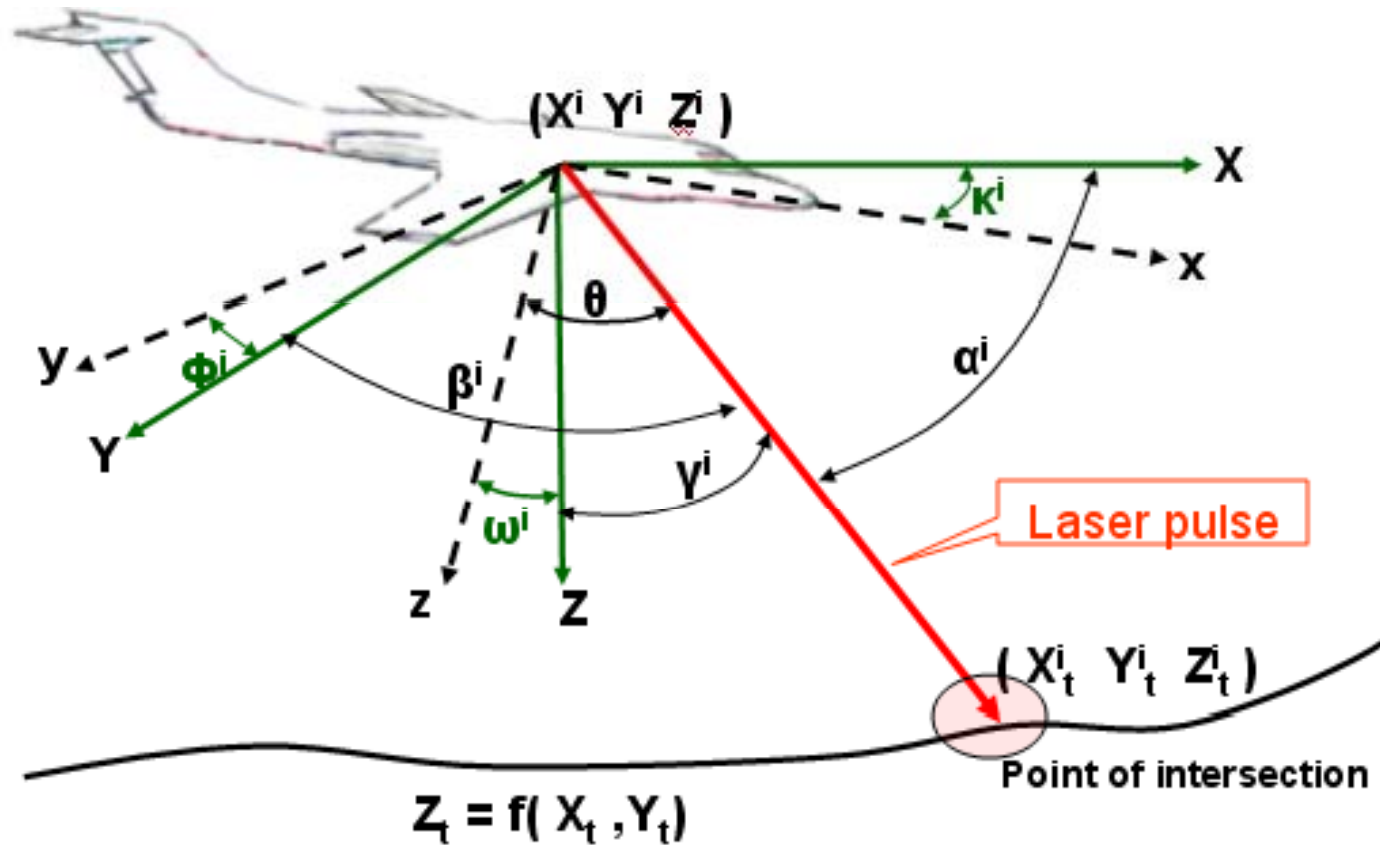
A solution !

Limulator2.0

Limulator 2.0

- Simulates LiDAR sensor
 - Generic
 - ALTM
 - ALS
- Uses mathematical models of ground, flight trajectory, sensor functioning
- Solves intersection of laser vector over a terrain to generate LiDAR data

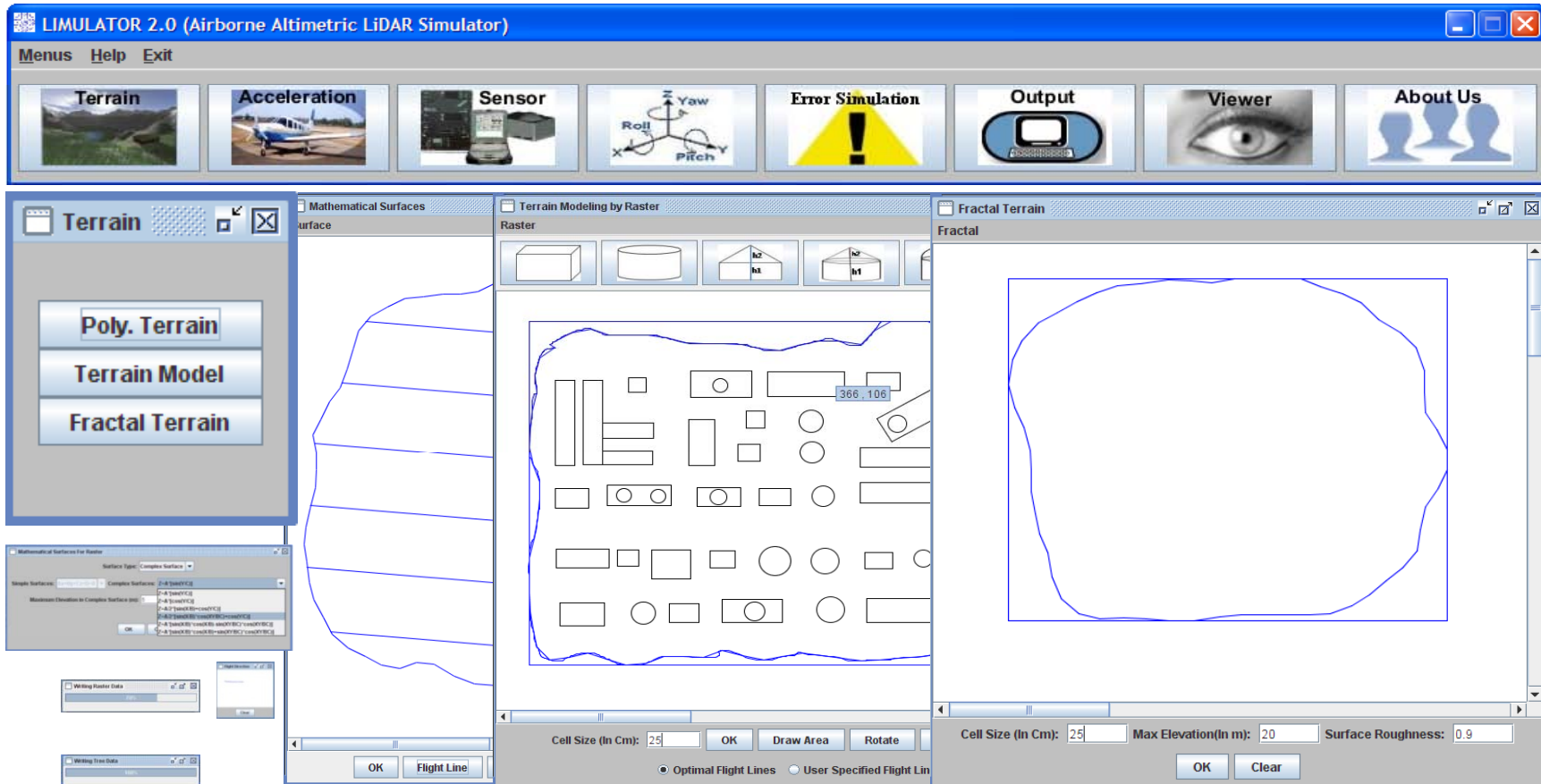
Laser vector and ground intersection



$$\frac{X - X^i}{a^i} = \frac{Y - Y^i}{b^i} = \frac{Z - Z^i}{c^i}$$

Glimpses of the GUI of Limulator2.0

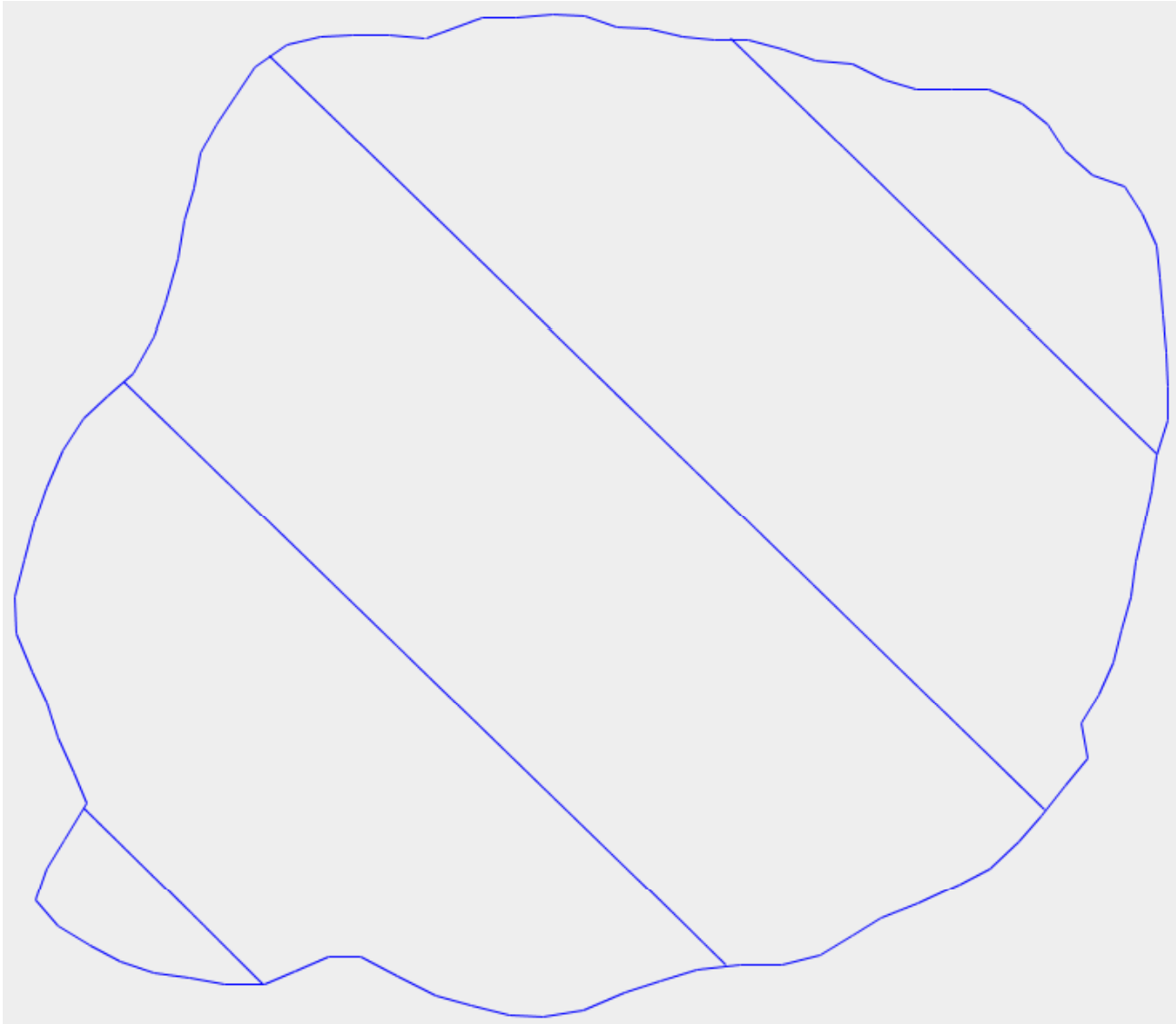
Terrain generation



System defined optimal flight lines



User chosen flight lines



Acceleration and Attitude

LIMULATOR 2.0 (Airborne Altimetric LiDAR Simulator)

Menus Help Exit

Terrain Acceleration Sensor Error Simulation Output Viewer About Us

Acceleration Choice

Select Acceleration Type

Simulated Acceleration Without Acc

OK Cancel

Acceleration Parameters

Enter values of acceleration parameters

A, B, C & D values for accelerations:

	A	B	C	D
ax:	1.05	2.38	0.51	2.77
	0.25	4.45	0.27	3.88
	0.3	80	0.2	100
ay:	0.05	3.38	0.51	3.77
	1.25	2.45	1.07	2.88
	0.3	85	0.2	95
az:	0.85	1.38	1.51	4.77
	0.25	4.45	1.07	0.88
	0.2	80	0.3	100
m:	0.0			

Roll, Pitch and Yaw

Select Roll, Pitch, and Yaw O

Simulated RPY RPY from Fi

OK Cancel

Roll, Pitch and Yaw Parameters

Enter values of RPY parameters

A, B, C & D values for RPY:

	A	B	C	D
Roll:	0.05	1.38	0.51	1.77
	0.25	0.8	0.27	0.88
Pitch:	0.7	0.5	0.51	1.4
	0.25	0.7	0.57	0.7
Yaw:	0.85	0.4	0.51	1.3
	0.8	0.8	0.7	0.7
m:	0.0			



Sensors: Generic, ALTM and ALS



Parameters for Generic Sensor

Flight Plan

Altitude (m AGL) :

Overlap (%) :

Velocity (m/s) :

LiDAR Settings

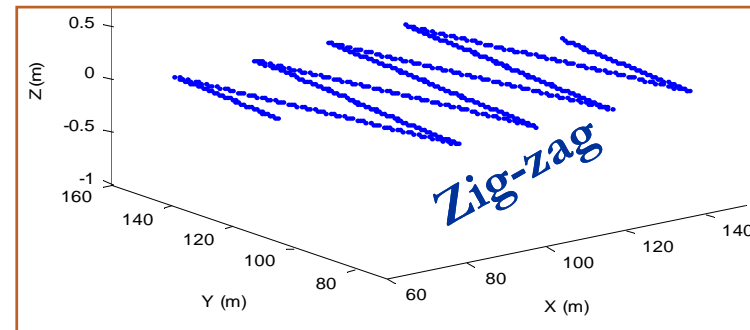
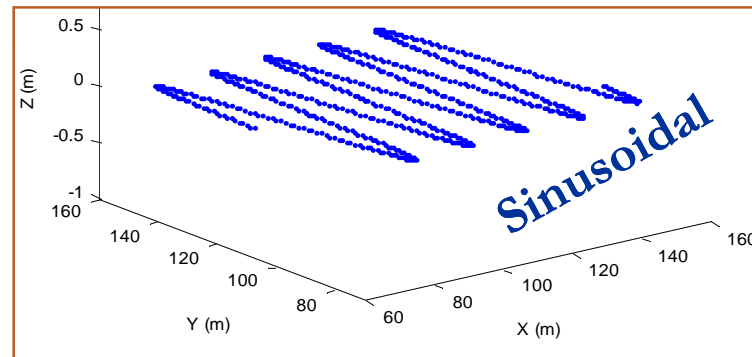
Scan Pattern :

Firing Frequency (kHz) :

Scan Frequency (Hz) :

Scan Angle (deg) : +/-

Scan pattern



Error introduction

The screenshot displays the LIMULATOR 2.0 (Airborne Altimetric LiDAR Simulator) interface. The main window has a menu bar (Menus Help Exit) and a toolbar with icons for Terrain, Acceleration, Sensor, a 3D coordinate system (Roll, Pitch, Yaw), Error Simulation (highlighted with a yellow warning sign), Output, Viewer, and About Us.

The **Error Simulation** dialog box is open, showing options for error introduction. It is divided into two main sections: **Error Indroction in:** and **Trajectory (Cm):**.

Error Indroction in:

	Systematic Error	Random Error
<input type="checkbox"/> Range(Cm):	0	2
<input type="checkbox"/> Scan Angle(Deg):	0	0.01
<input type="checkbox"/> Attitude(Deg):		
Roll:	0	0.005
Pitch:	0	0.005
Yaw:	0	0.005

Trajectory (Cm):

<input type="checkbox"/> Trajectory (Cm):			
X:	0	0.05	
Y:	0	0.05	
Z:	0	0.05	
<input type="checkbox"/> Overall Error in Data			
Standard Deviation in (Cm):			
X:	30	Y: 30	Z: 15

Buttons: Ok, Cancel

Output and LiDAR data Viewer

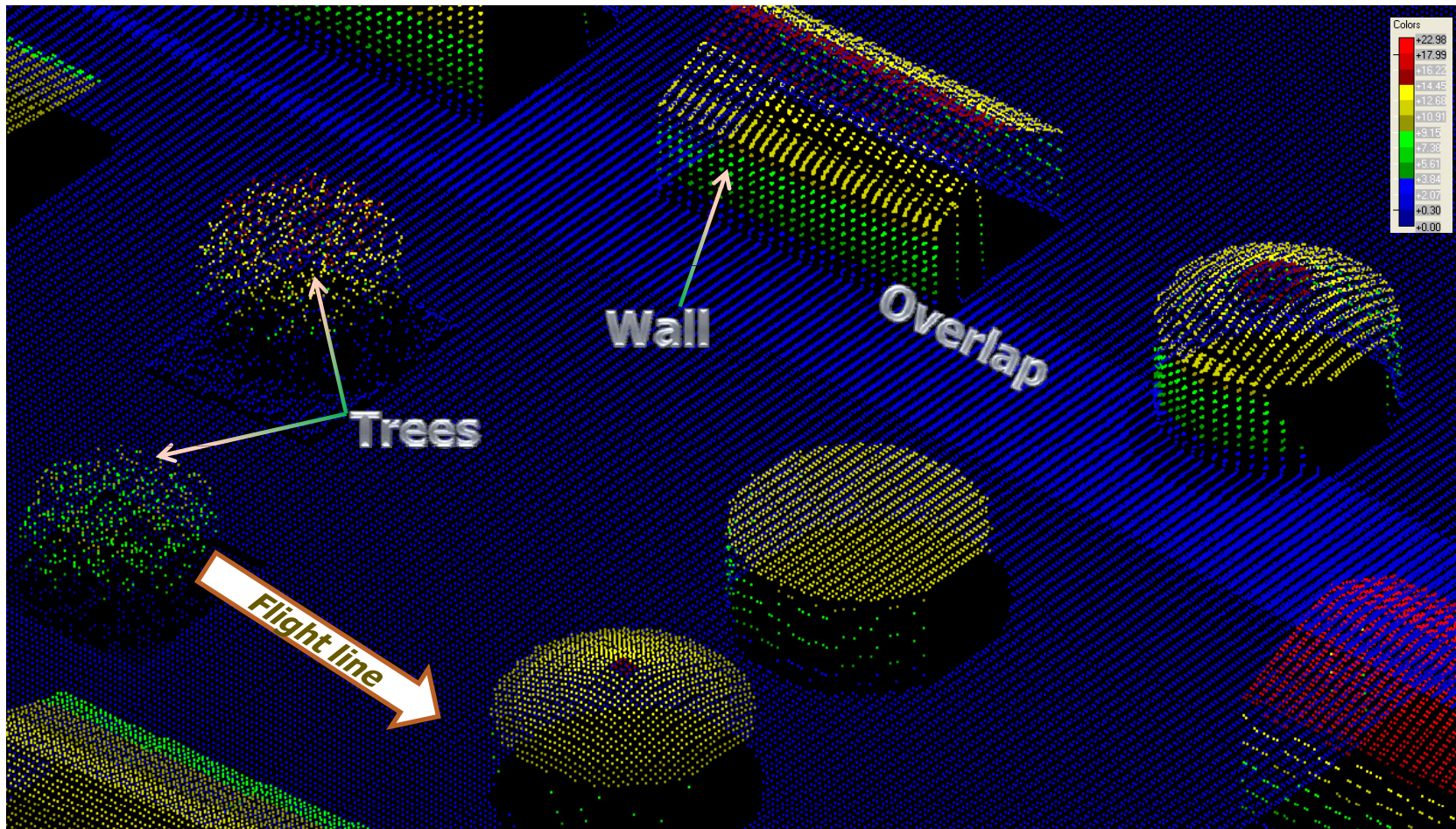
The screenshot displays the LIMULATOR 2.0 (Airborne Altimetric LiDAR Simulator) interface. The main window has a menu bar (Menus Help Exit) and a toolbar with icons for Terrain, Acceleration, Sensor, Roll/Yaw/Pitch, Error Simulation, Output, Viewer, and About Us. The 'Output of the Processes' window is open, showing a 'Select Output:' section with the following options:

- X, Y, Z, Values.
- LAS binary (Version 1.0).
- LAS binary (Version 1.1).
- Time, Attitude.
- Time, Accelerations.
- Time, X, Y, Z, Attitude, Accelerations.
- Error in Various Processes.
- Report.

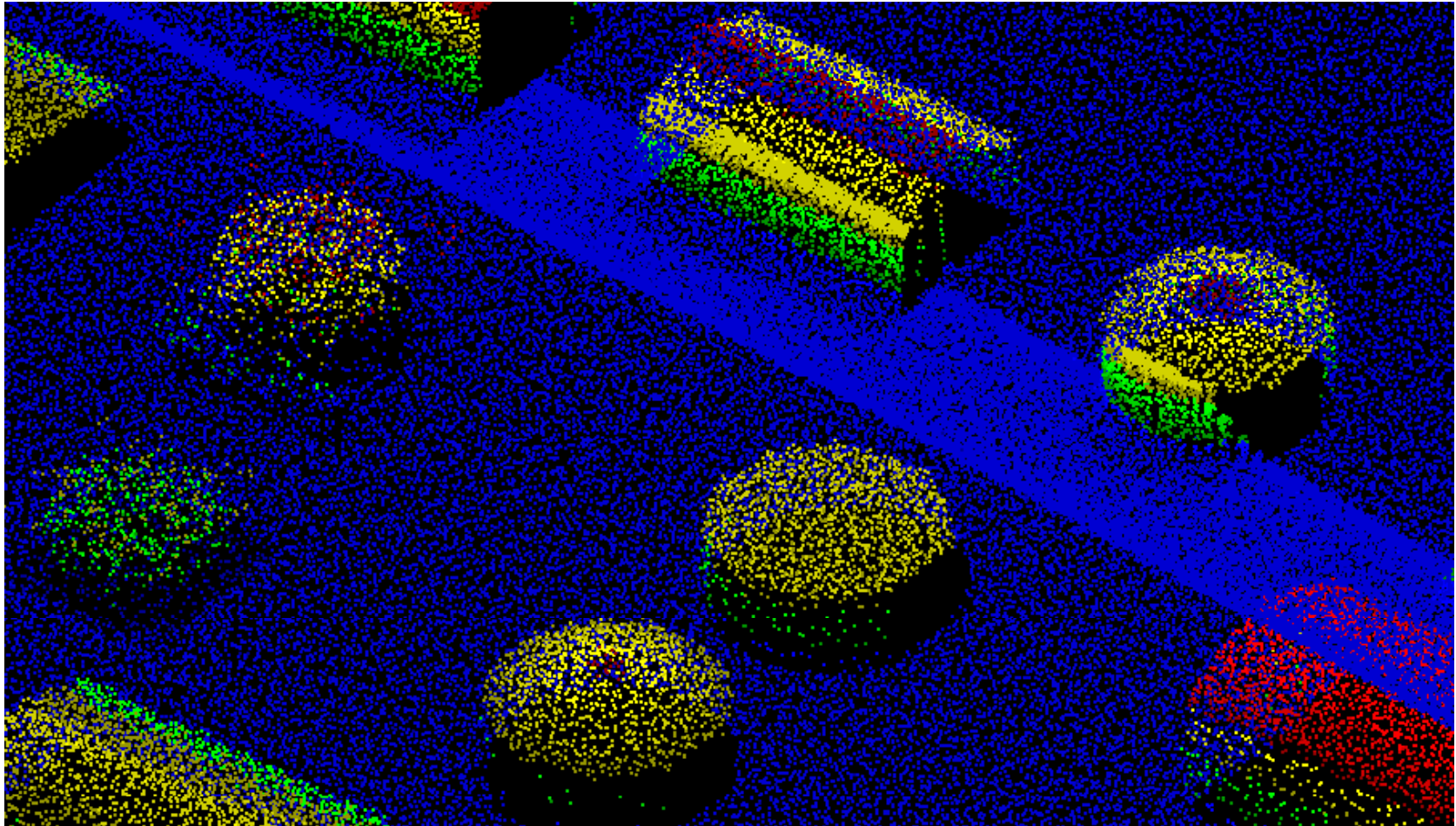
The 'Point Cloud Display' window is also open, showing a 3D visualization of a point cloud with a green ground plane and various colored objects (red, purple, black) representing buildings and structures. A 'File' menu is open in the Point Cloud Display window, showing options: Open LAS File, Open Text File, and Close.

Results produced from Limulator 2.0

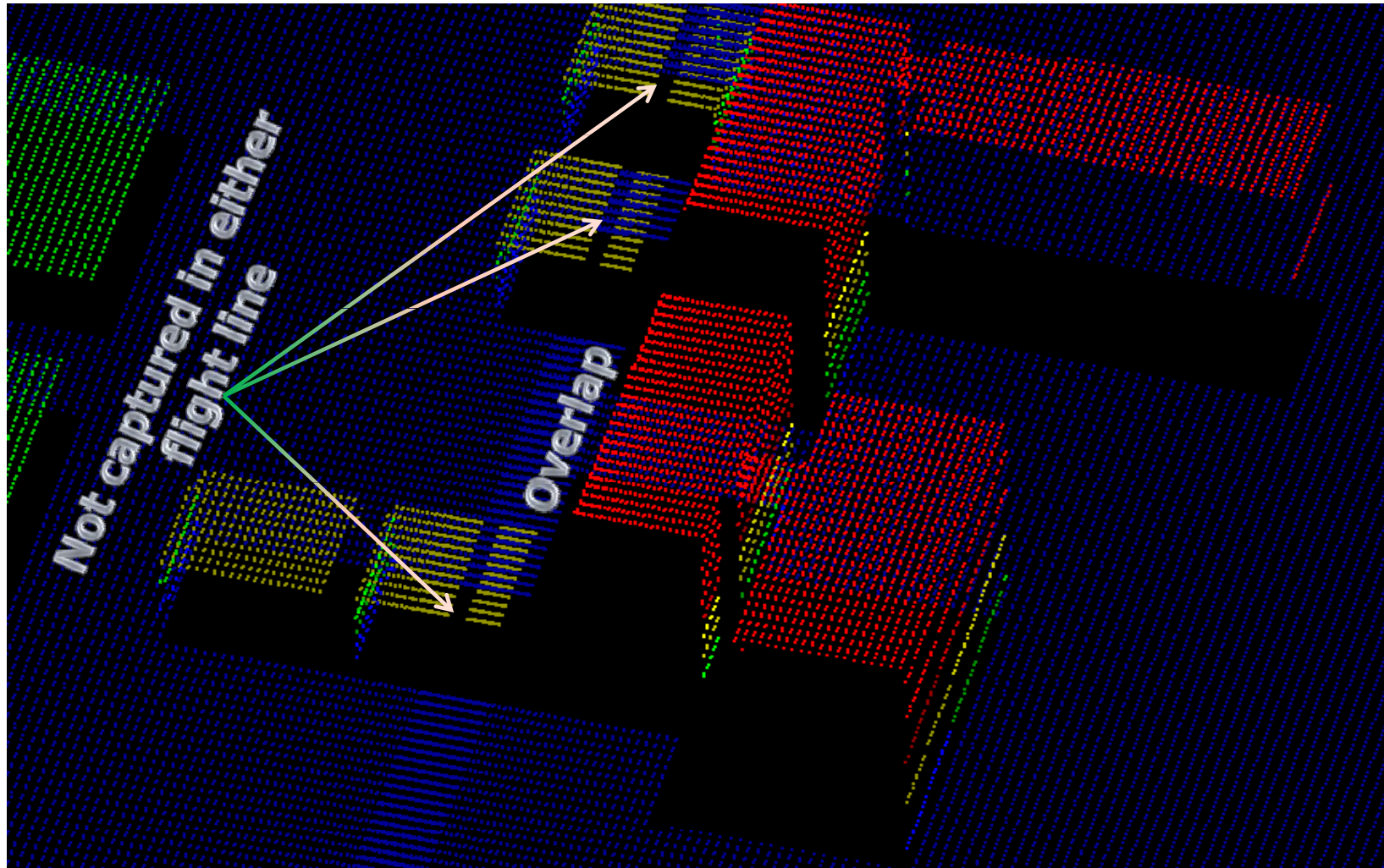
LiDAR Data with no error



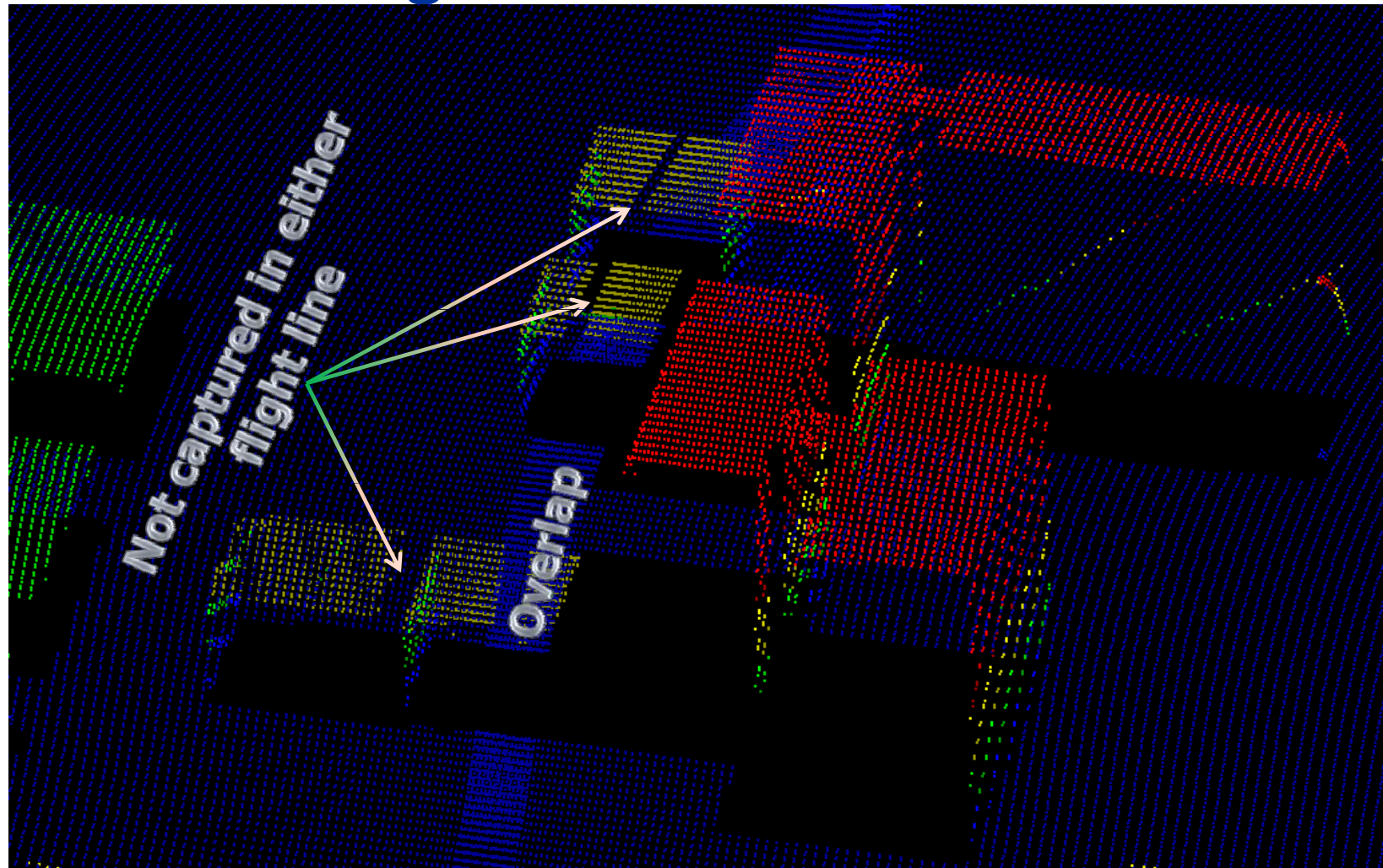
LiDAR Data with error



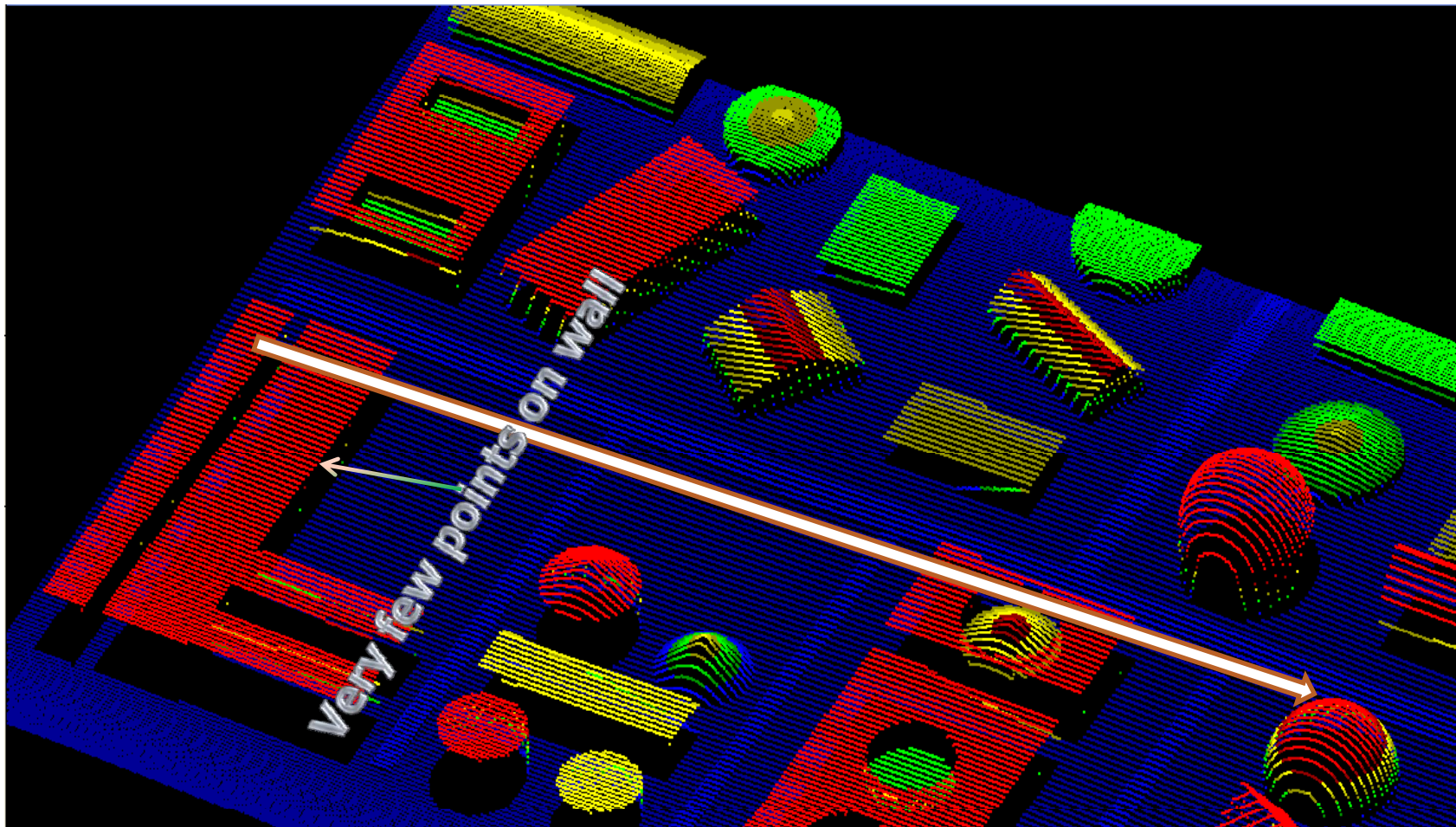
Data with no attitude variation

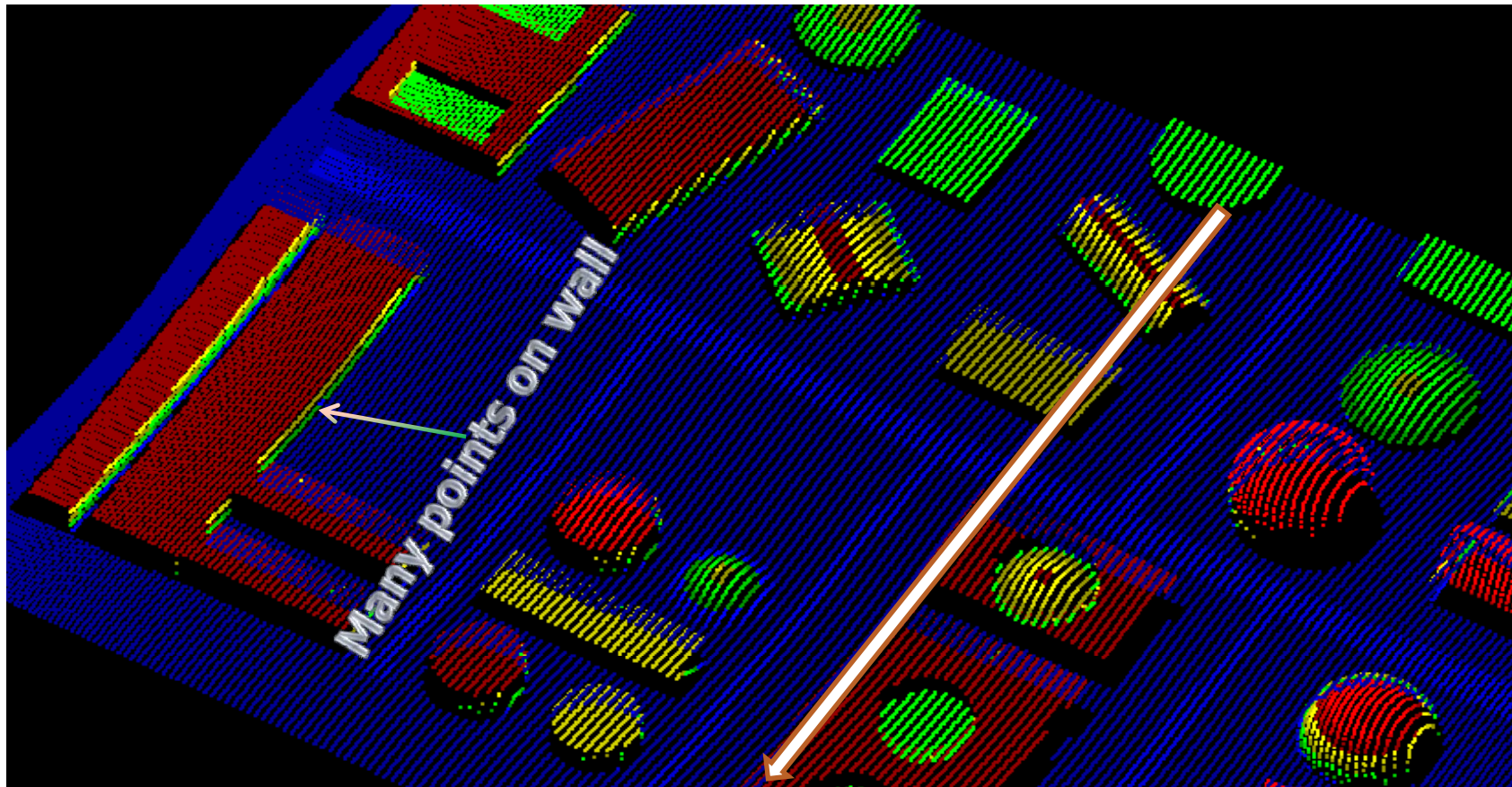


Data with high attitude variation



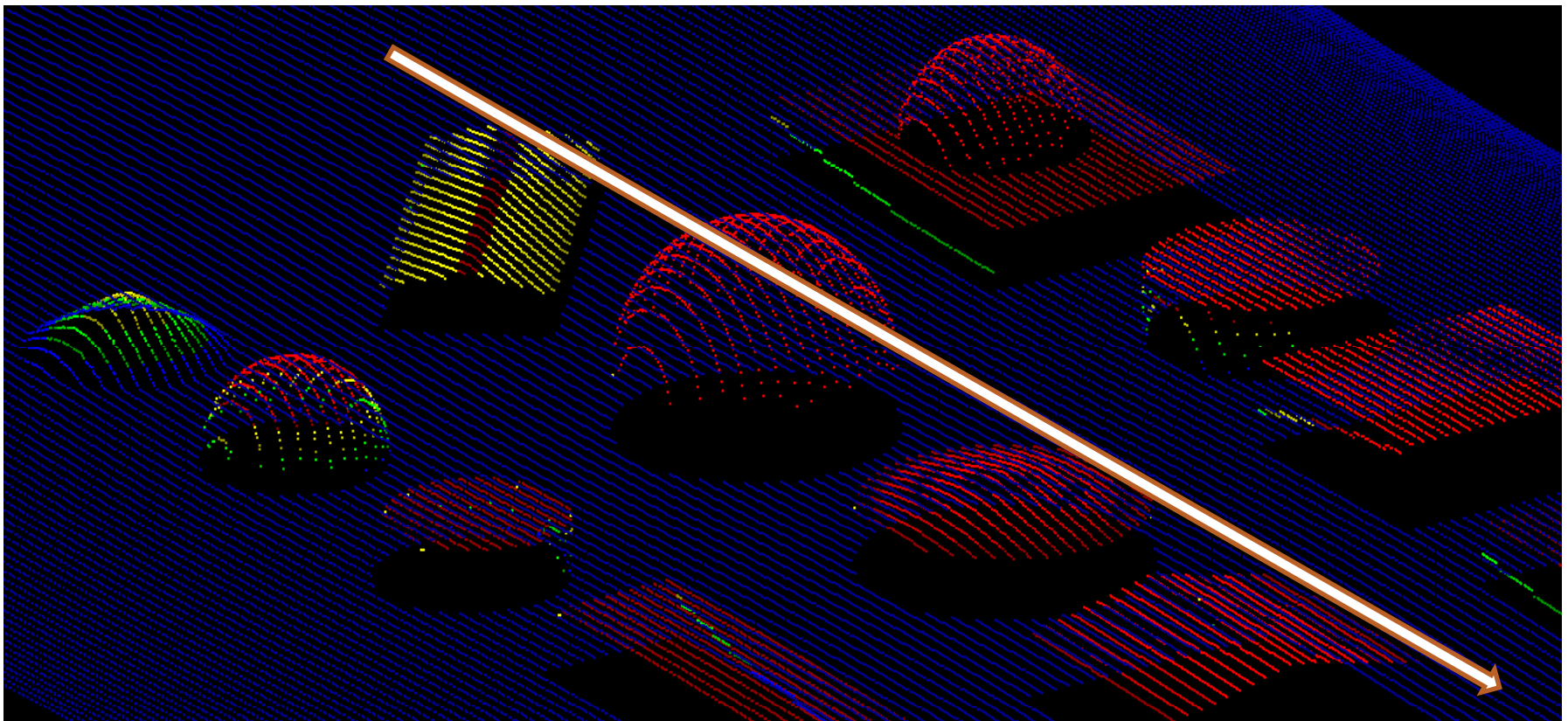
Effect of different flight direction



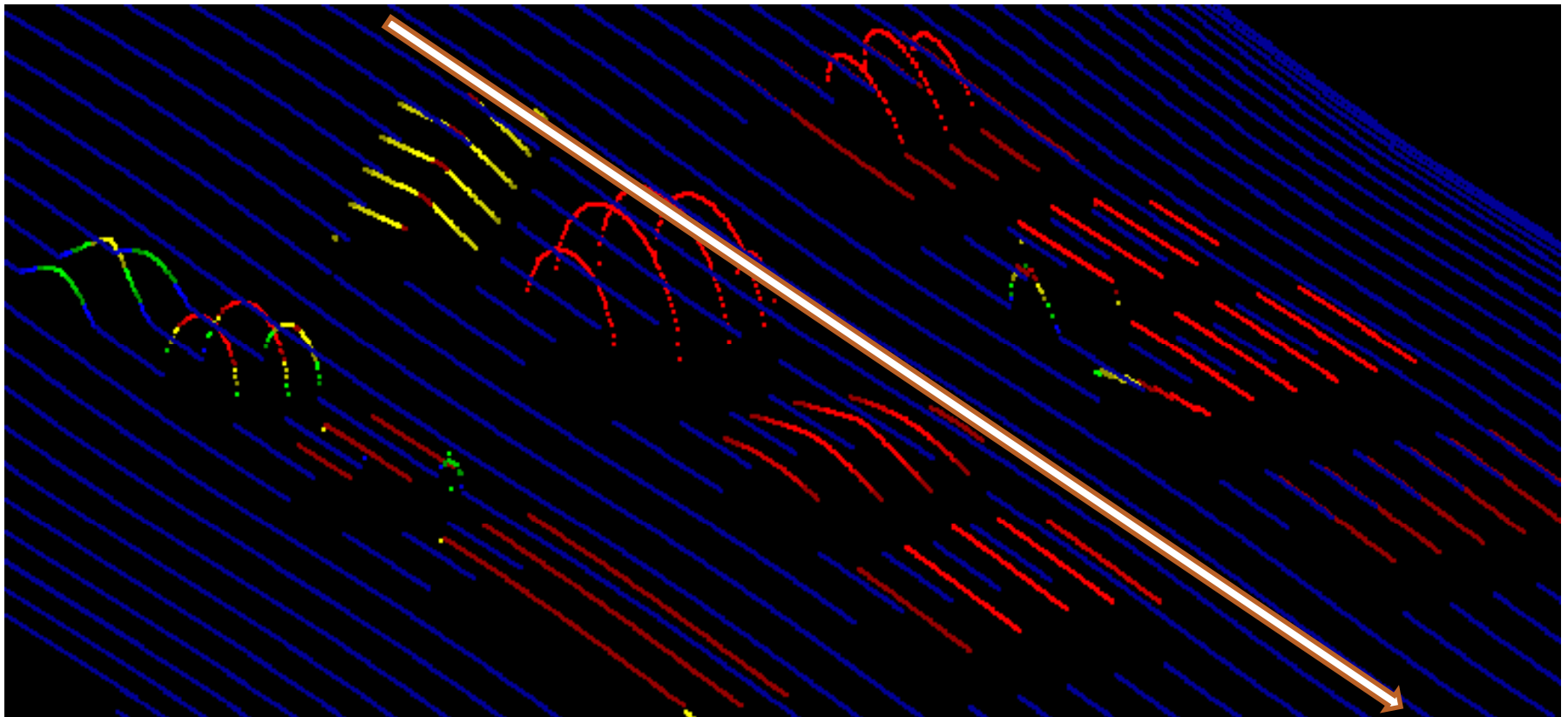


Effect of data density

Altitude=400m
Overlap=2%
Velocity=60m/s
Sensor-ALS-50
Firing frequency=20KHz
Scan frequency=48Hz
Scan angle=50°

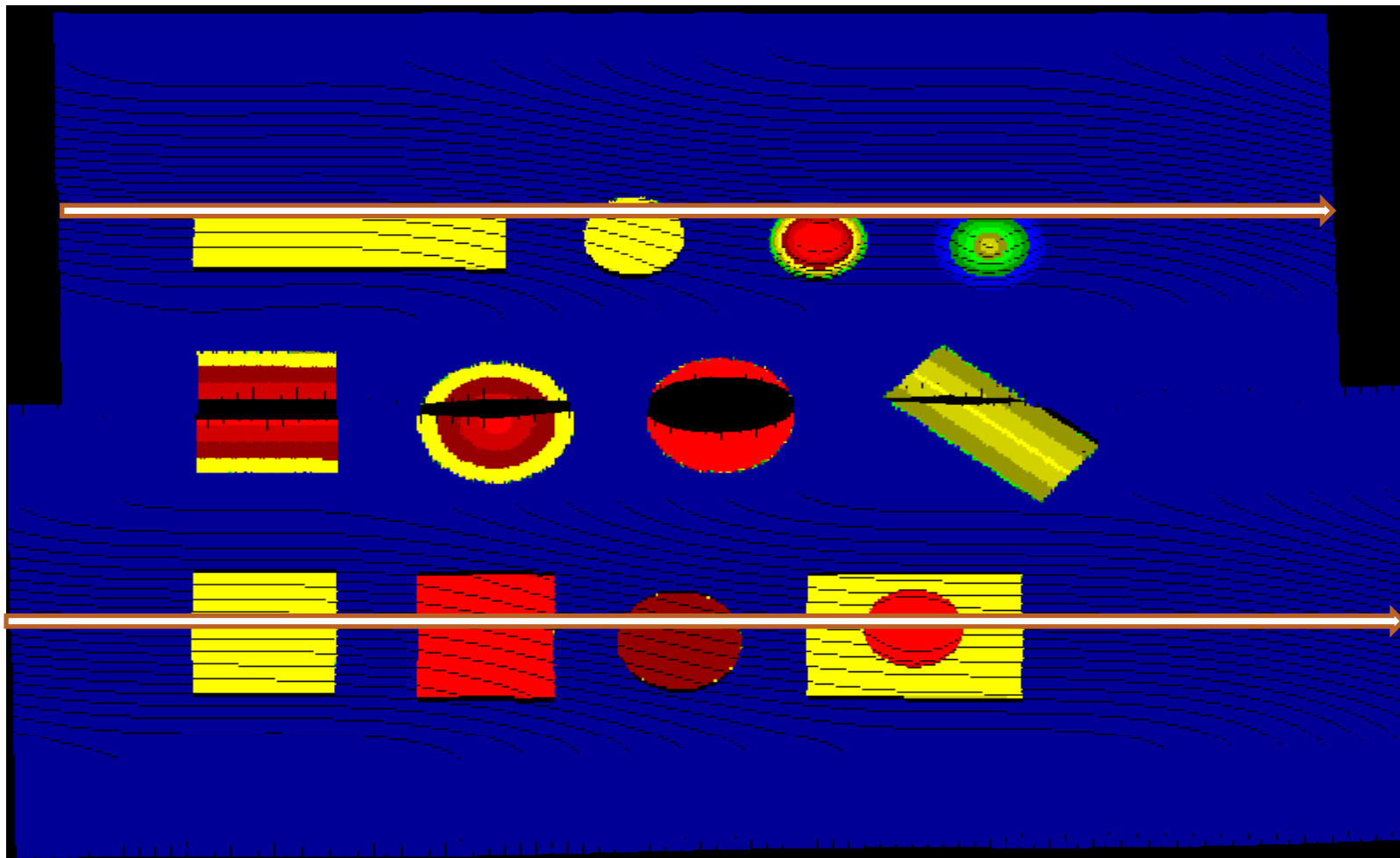


Altitude=400m
Overlap=2%
Velocity=60m/s
Sensor-ALS-50
Firing frequency=5 KHz
Scan frequency=48Hz
Scan angle=50°

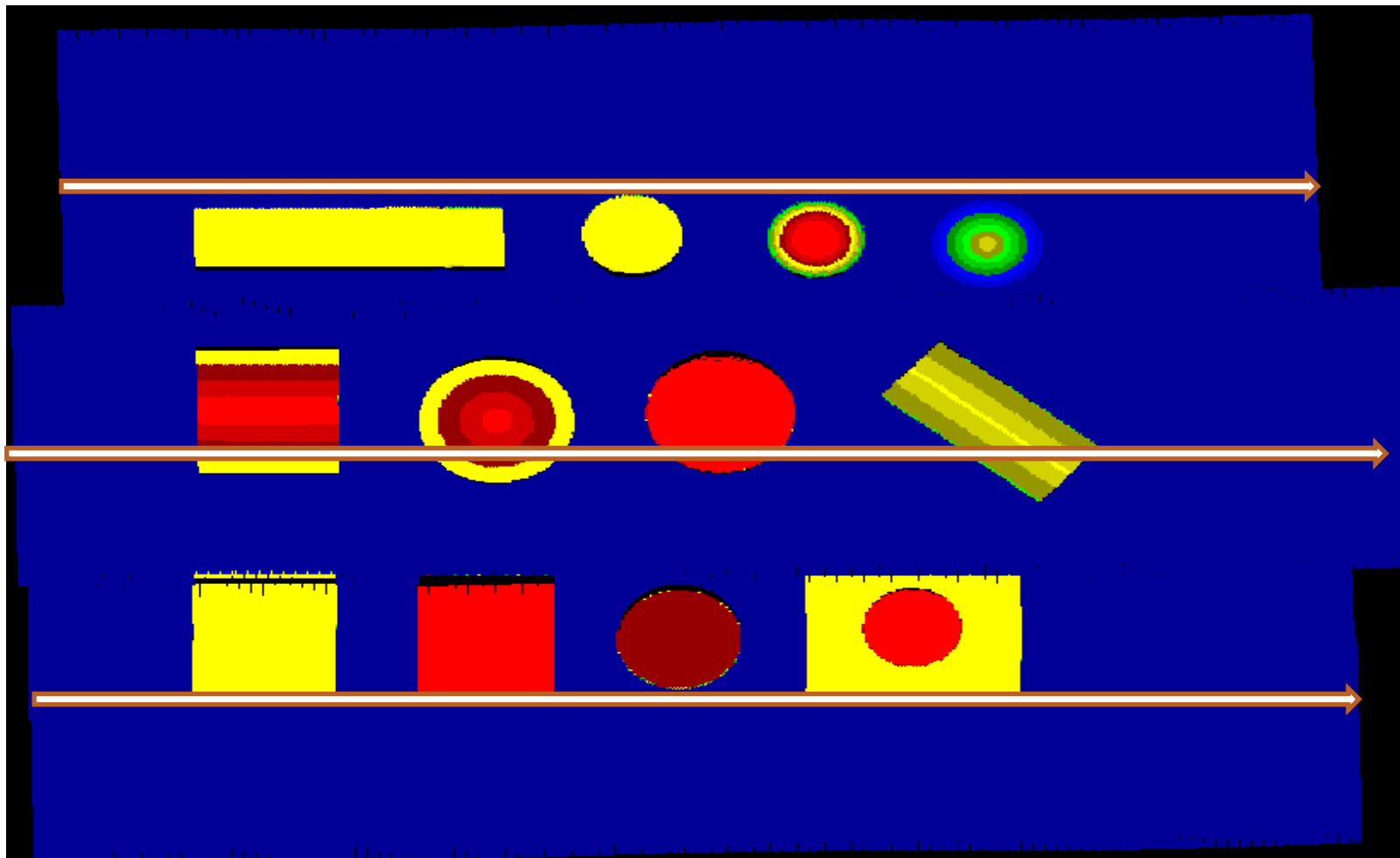


Effect of different scan angle

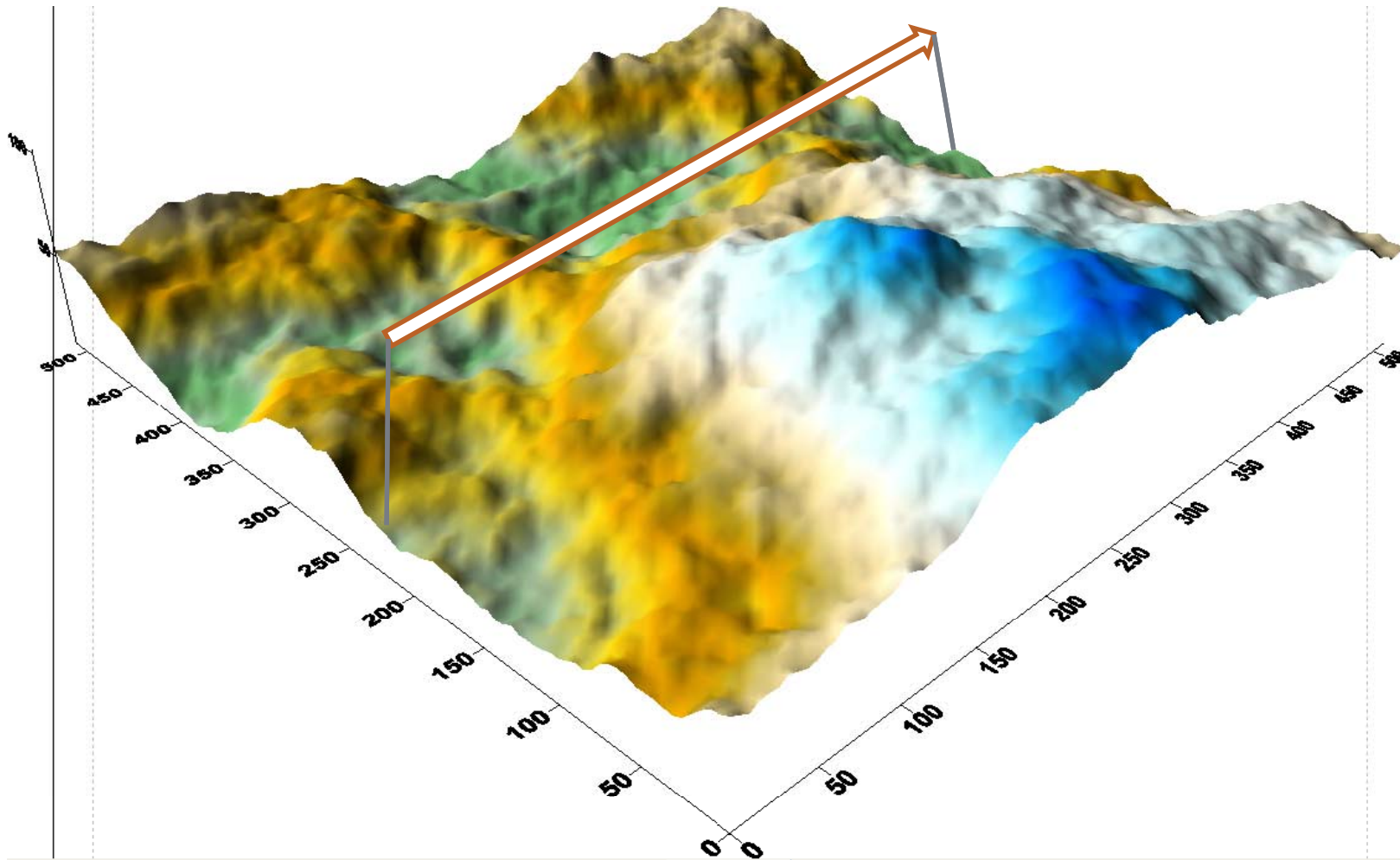
Altitude=200m
Overlap=2%
Velocity=60m/s
Sensor-ALS-50
Firing frequency=5 KHz
Scan frequency=48Hz
Scan angle=50°



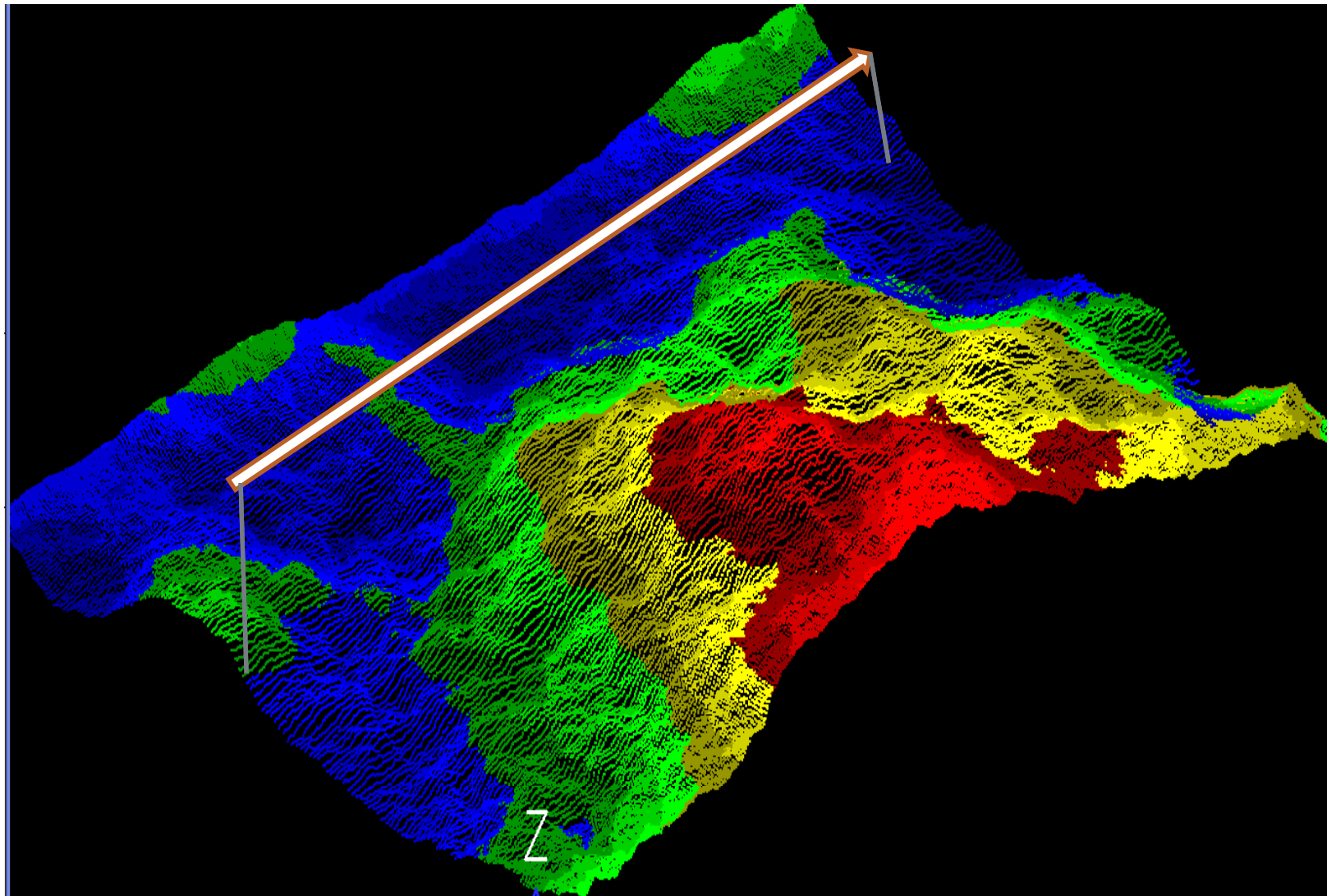
Altitude=200m
Overlap=2%
Velocity=60m/s
Sensor-ALS-50
Firing frequency=5 KHz
Scan frequency=48Hz
Scan angle=32°



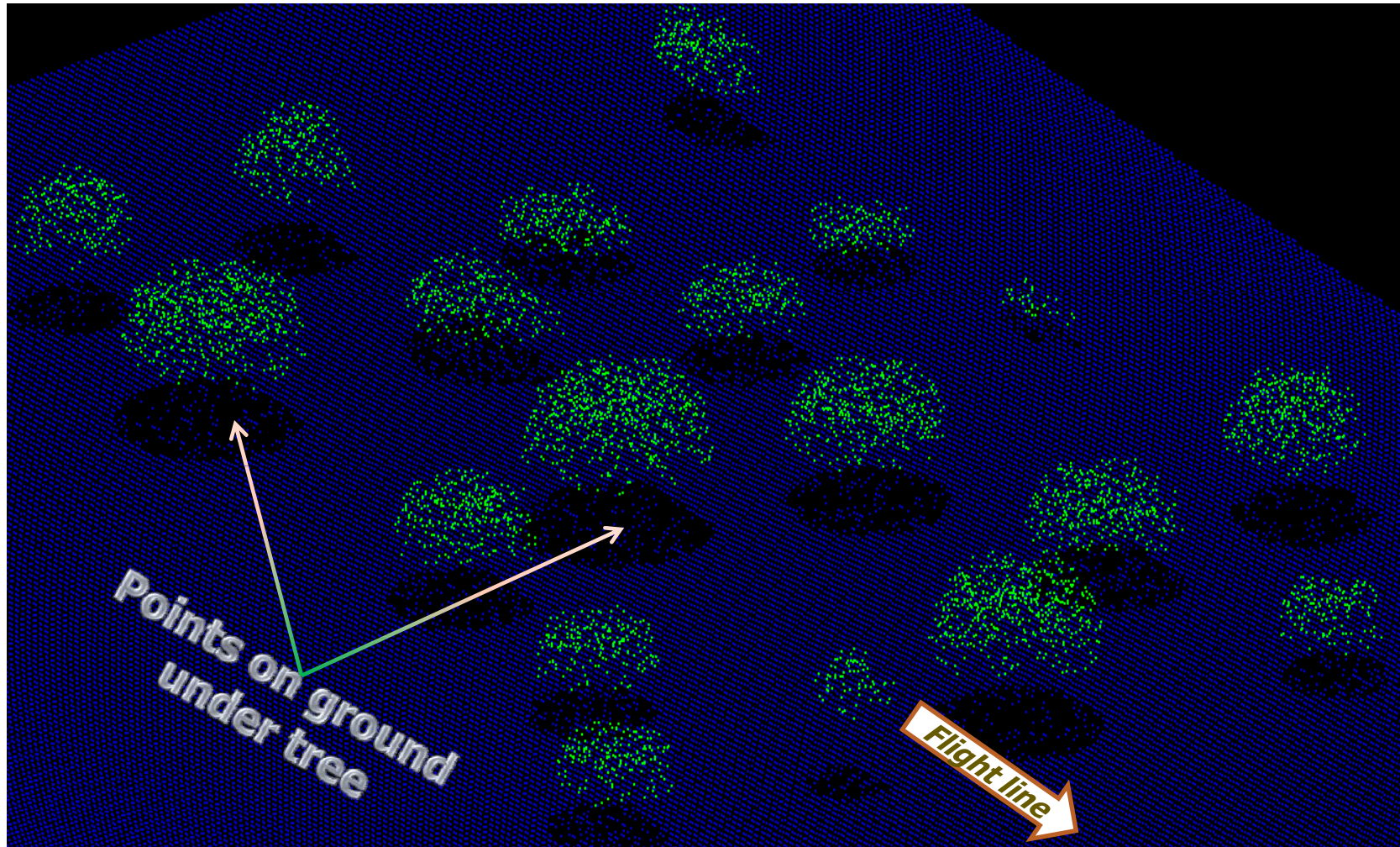
Fractal data displayed in Surfer



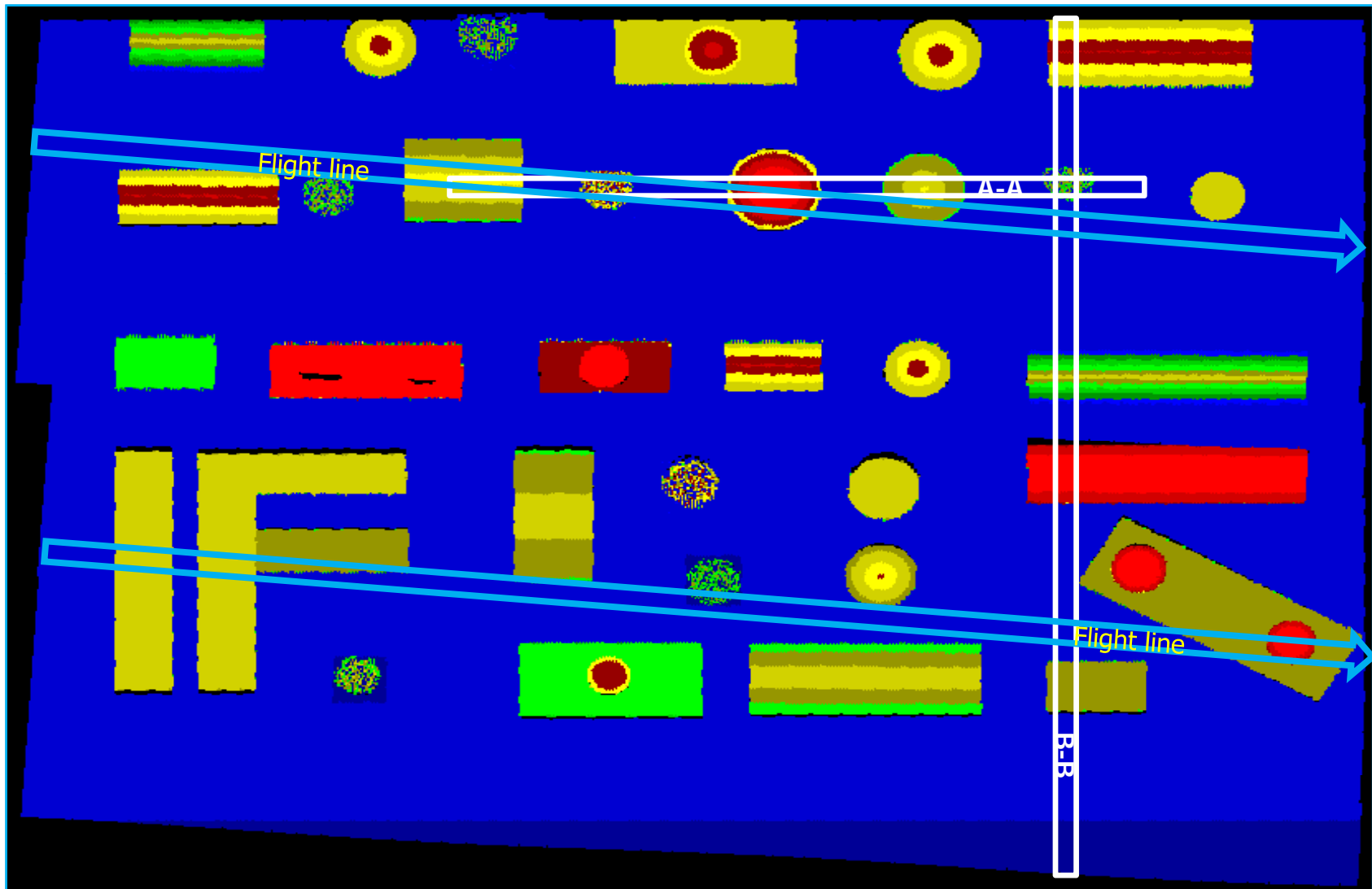
LiDAR data for fractal surface



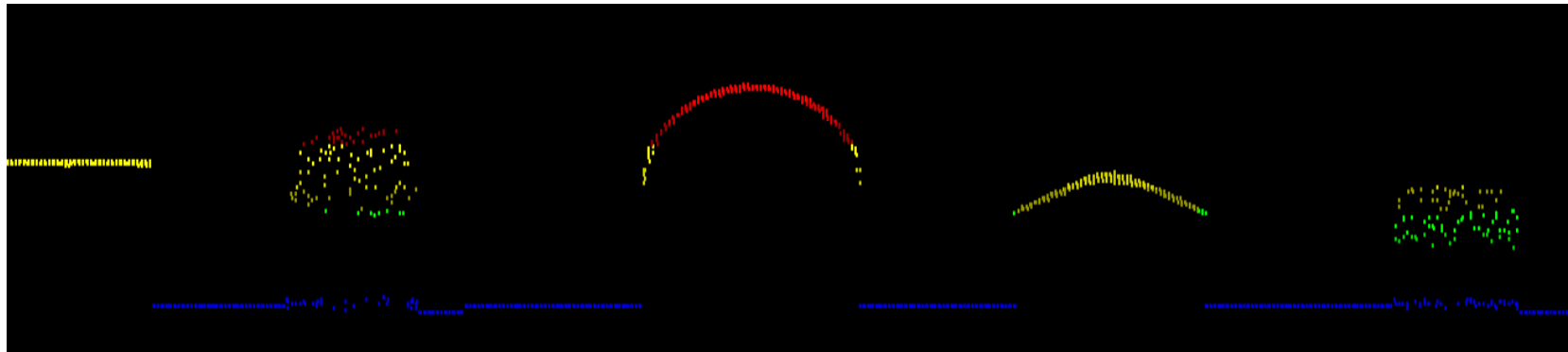
LiDAR data for trees



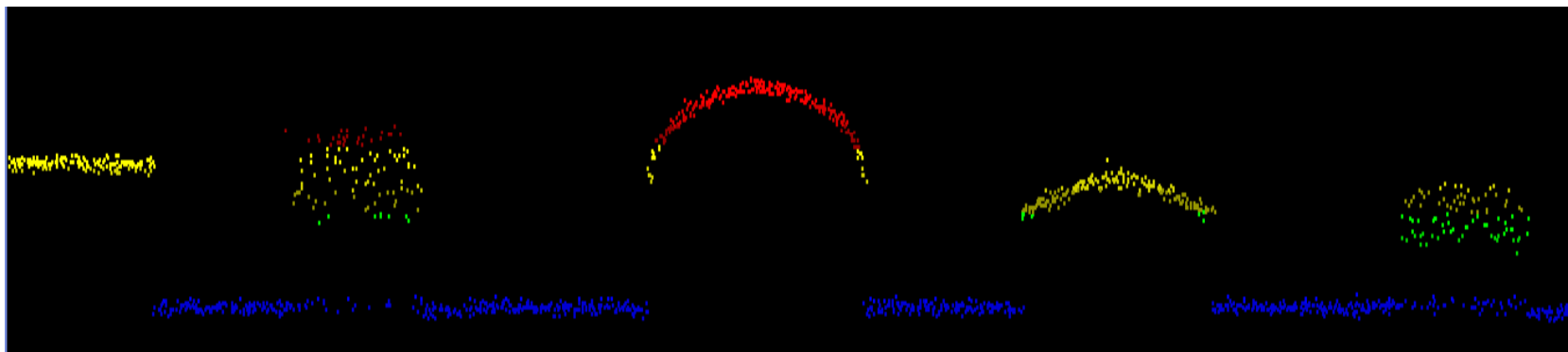
LiDAR data plot in plan



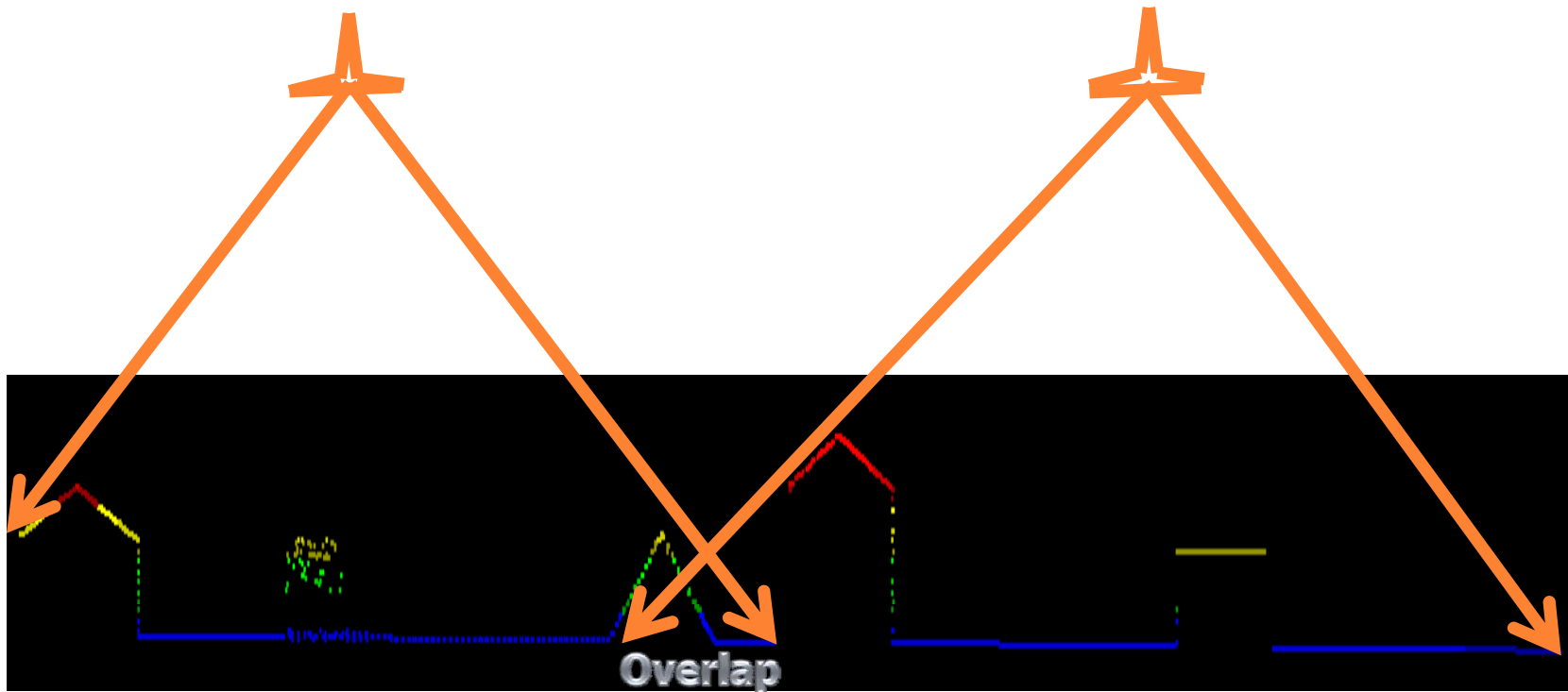
Profile A-A with no error



Profile B-B with error



Profile B-B w. r. t. flight lines



Thank You !!