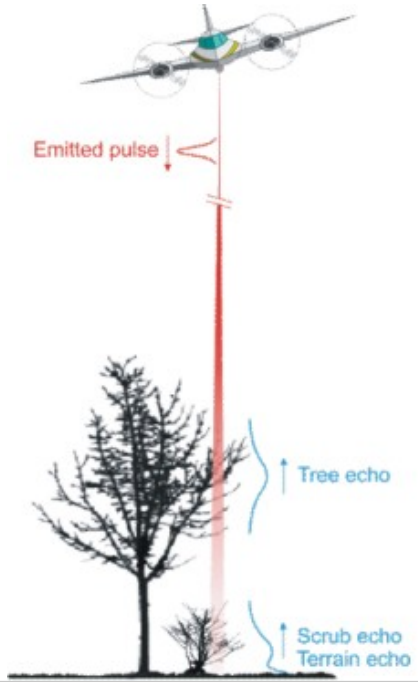
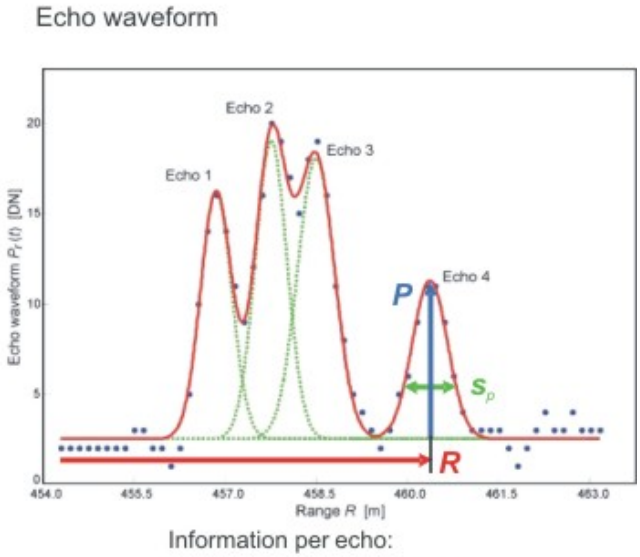
Full WaveForm (FWF) Lidar

- Concepts of FWF data
- Examples from Golm
- FWF signal decomposition
- FWF amplitude (intensity) and signal width

Full WaveForm (FWF) Lidar





Information per echo:

Amplitude (Intensity): P [DN]
Range: R [m]
Echo width: sp [ns]

Airborne lidar for profiling of surface topography

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Abstract. A lidar system is described that measures laser pulse time-of-flight and the distortion of the pulse waveform for reflection from Earth surface terrain features. This instrument system is mounted on a high-altitude aircraft platform and operated in a repetitively pulsed mode for measurements of surface elevation profiles. The laser transmitter makes use of recently developed short-pulse diode-pumped solid-state laser technology. Aircraft position in three dimensions is measured to submeter accuracy by use of differential Global Positioning System receivers. Instrument construction and performance are detailed.

Subject terms: lidar; laser altimetry; laser ranging; airborne lidar.

Optical Engineering 30(1), 72-78 (January 1991).

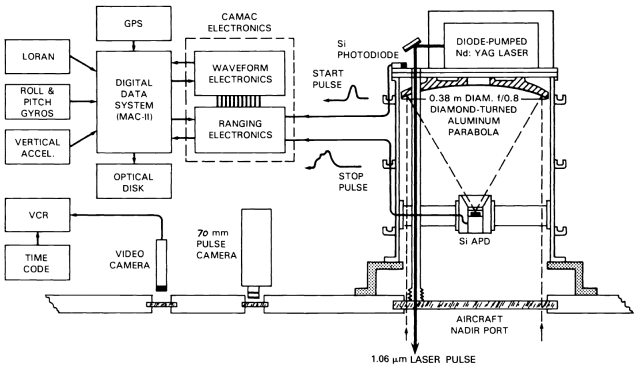

Fig. 1. The airborne lidar instrument developed at the Goddard Space Flight Center for profiling measurements of Earth surface topography with the NASA T-39 Sabreliner.

https://www.spiedigitallibrary.org/journals/Optical-Engineering/volume-30/issue-1/0000/Airborne-lidar-for-profiling-of-surface-topography/10.1117/12.55770.short?SSO=1

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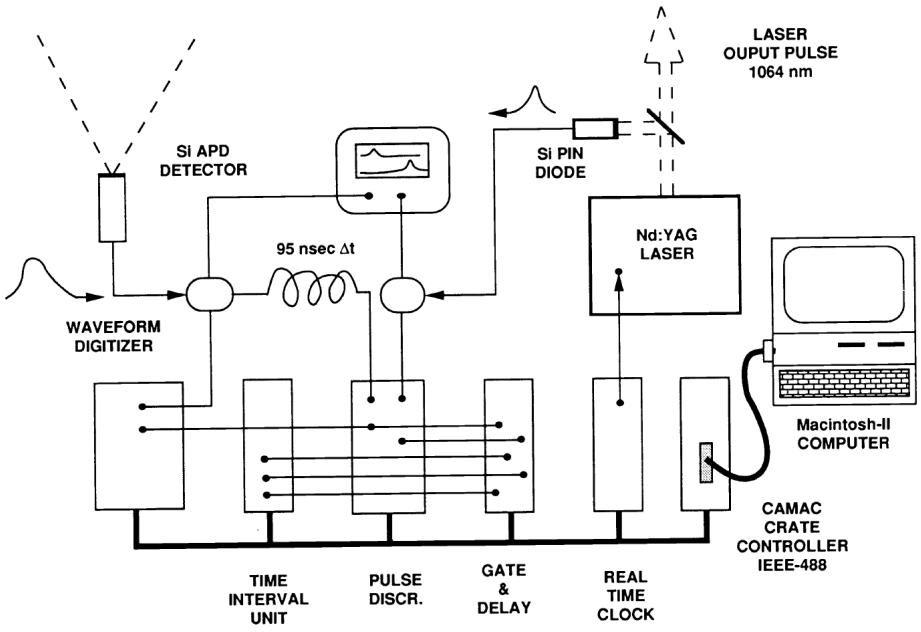


Fig. 4. Altimetry ranging and lidar electronics for Earth-surface topography measurements.

https://www.spiedigitallibrary.org/journals/Optical-Engineering/volume-30/issue-1/0000/Airborne-lidar-for-profiling-of-surface-topography/10.1117/12.55770.short?SSO=1

Full WaveForm (FWF) Lidar – additional resources

https://www.youtube.com/watch?v=A4MWxAkolO4

https://www.neonscience.org/lidar-basics

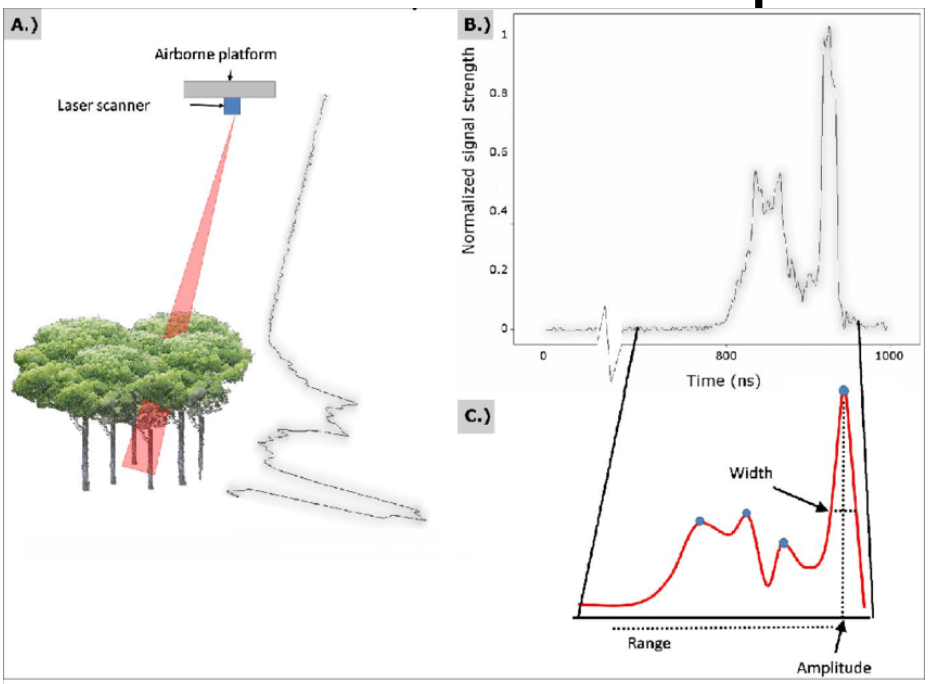
Full-waveform topographic lidar: State-of-the-art by C. Mallet
https://www.sciencedirect.com/science/article/pii/S0924271608000993

Analysis of full-waveform LiDAR data for classification of an orange orchard scene by K. Fieber
https://www.sciencedirect.com/science/article/pii/S0924271613001238

Full WaveForm (FWF) Lidar

- FWF signal travel velocity ~ speed of light in vacuum * atmospheric delay (@20C, standard atmosphere, light is n=1.0003 times slower: c=299,792,458 m/s to v = c/n = 299,702,547 m/s
- Signal width ~ 1ns (1e-9 s): Distance traveled in 1ns is 1e-9 s * v = 0.299m (~30cm)

FWF – multiple echos



F. Pirotti

Full WaveForm (FWF) Lidar

- Concepts of FWF data
- **Examples from Golm**
- FWF signal decomposition
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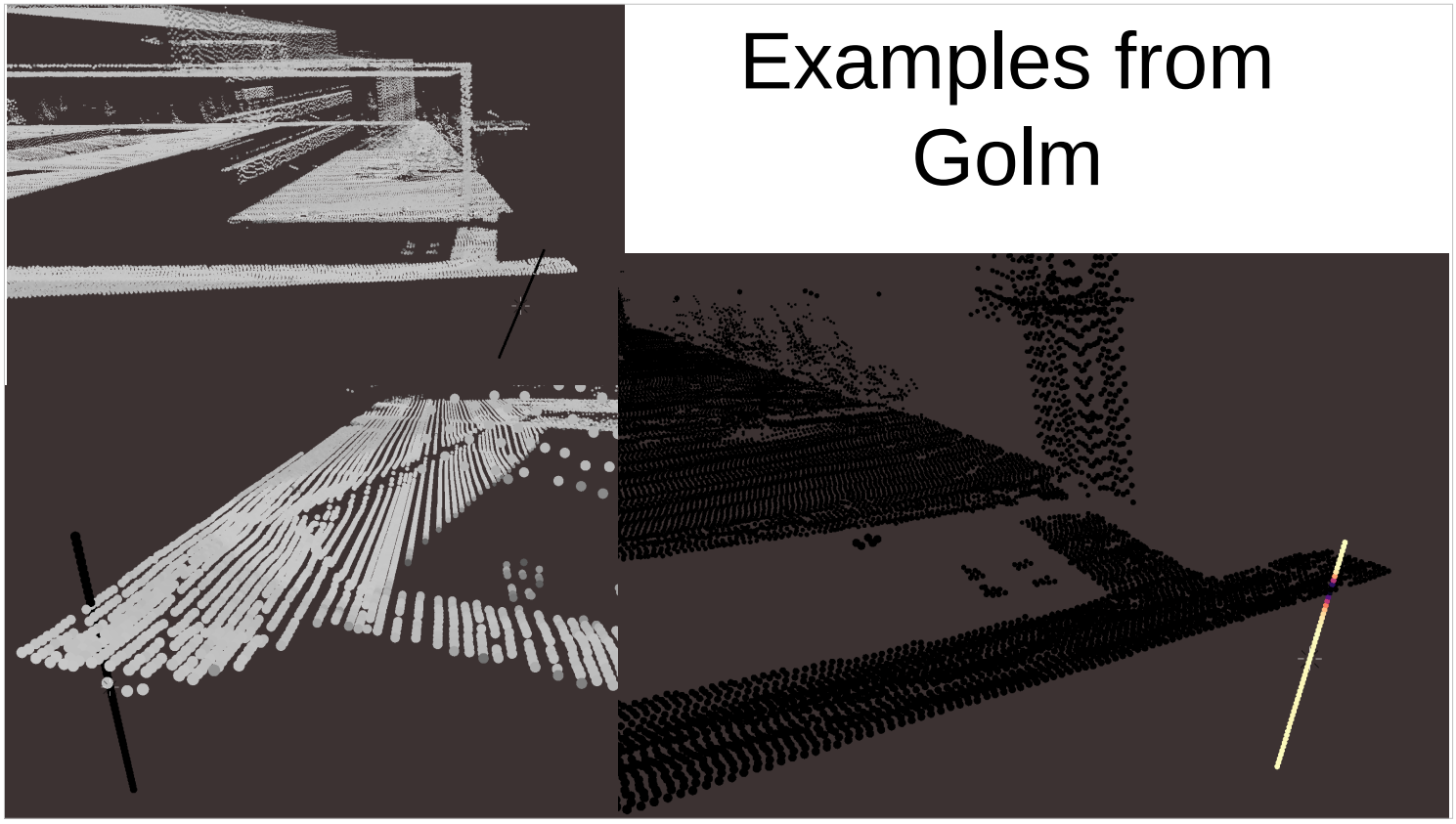
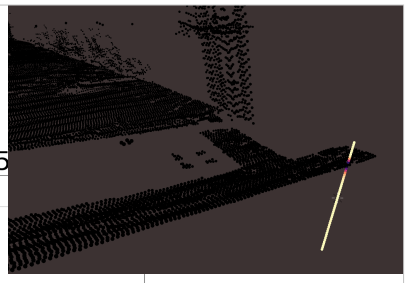
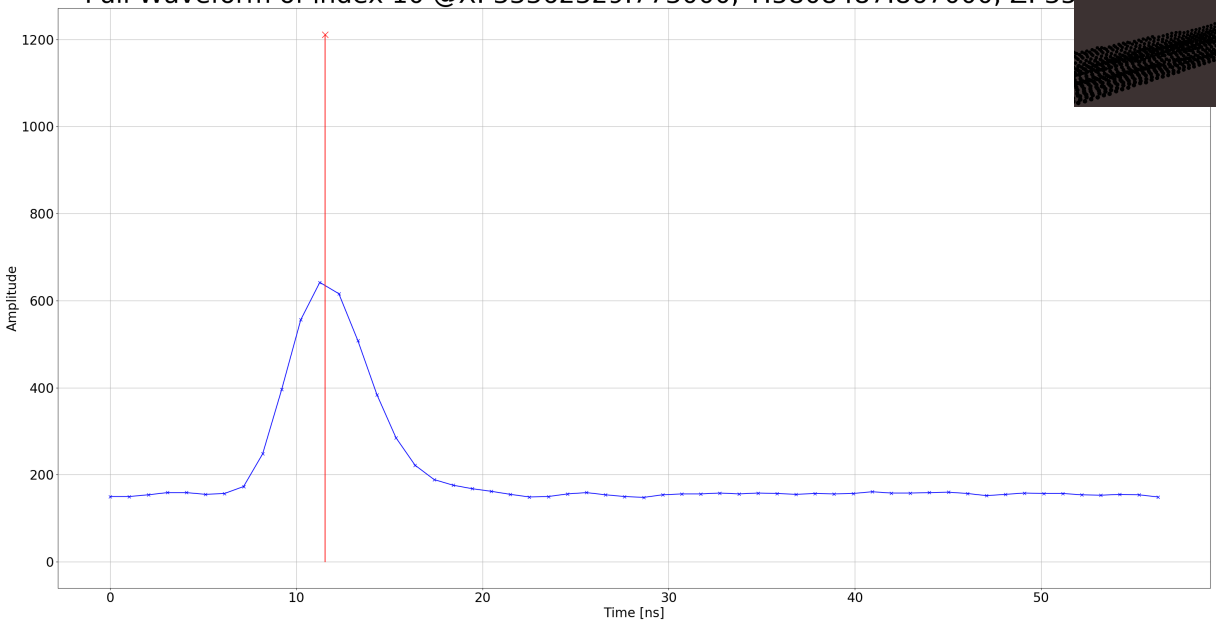
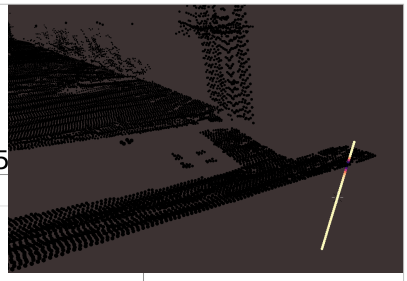
Examples from Golm

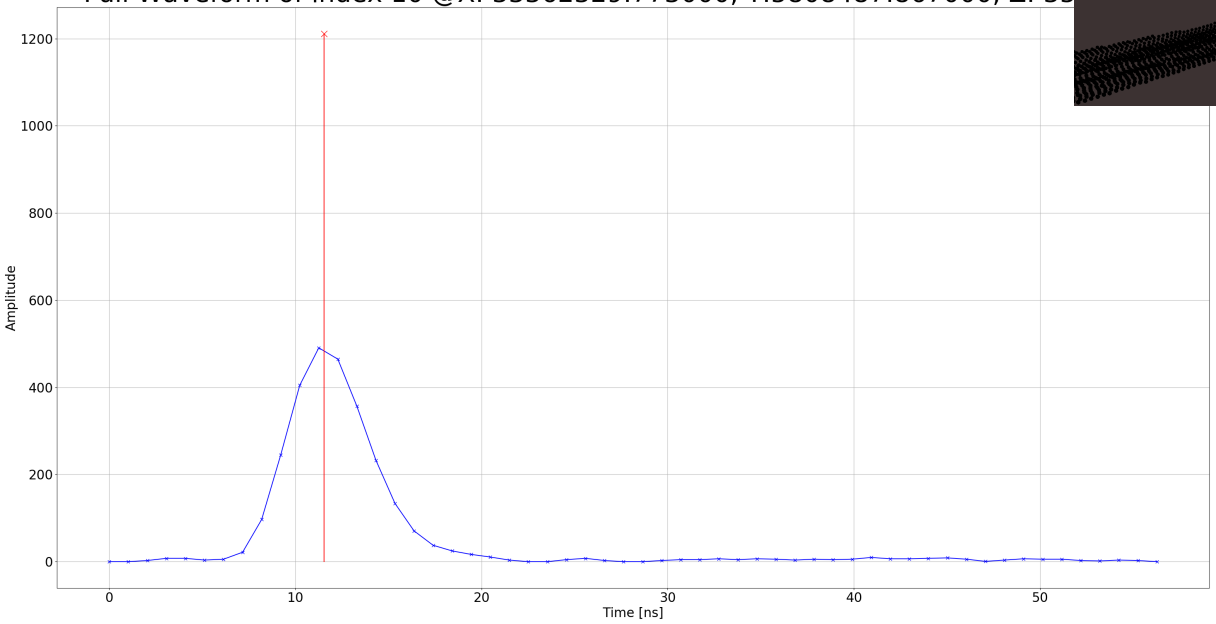


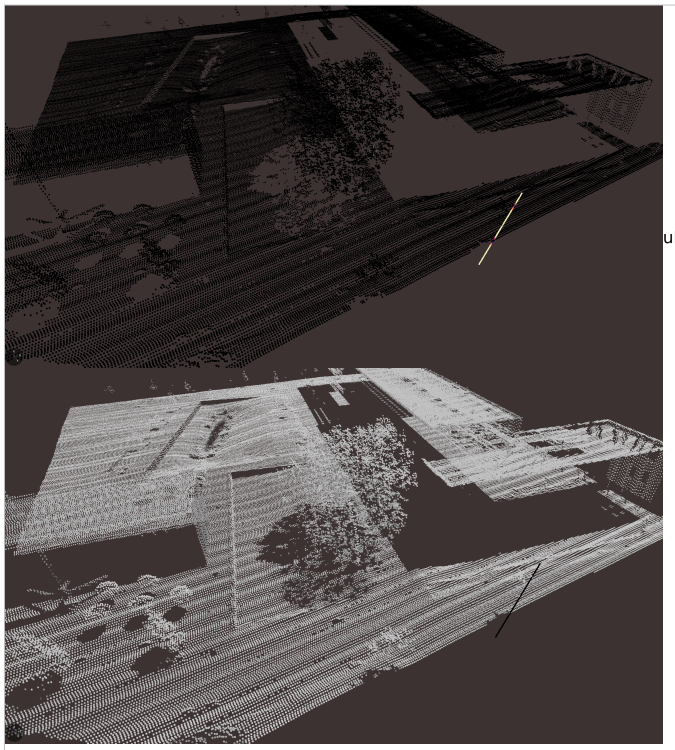




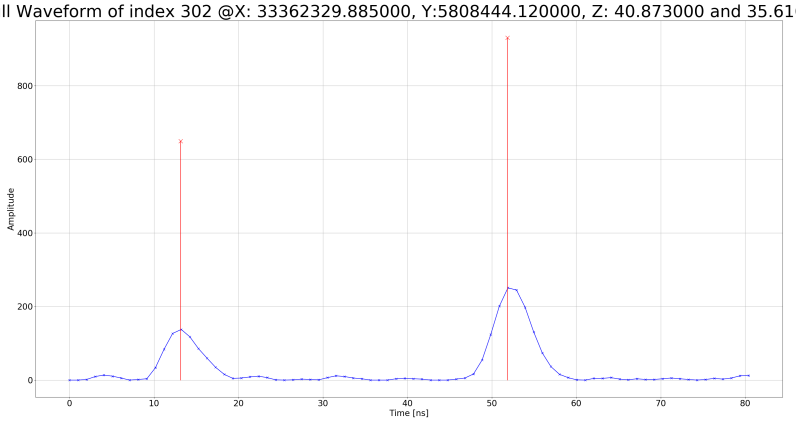


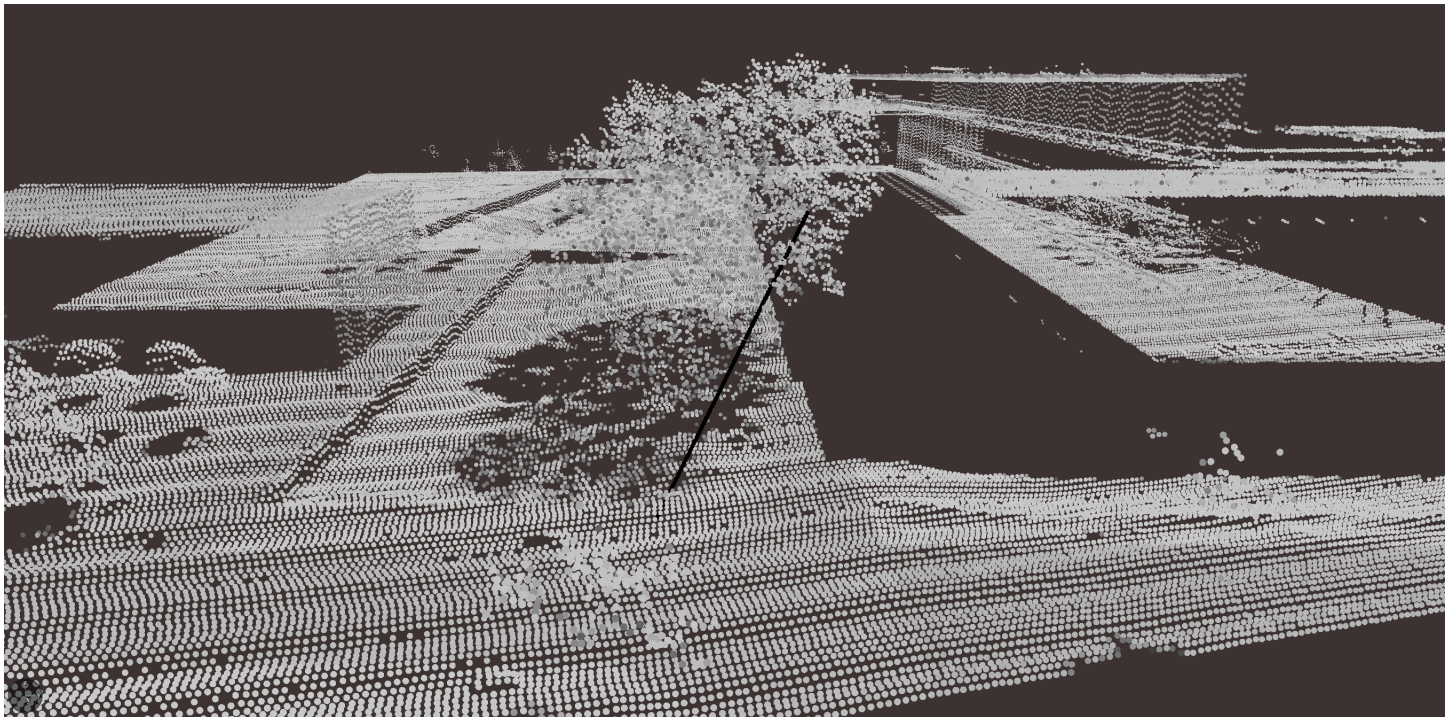
Full Waveform of index 10 @X: 33362329.773000, Y:5808487.867000, Z: 35

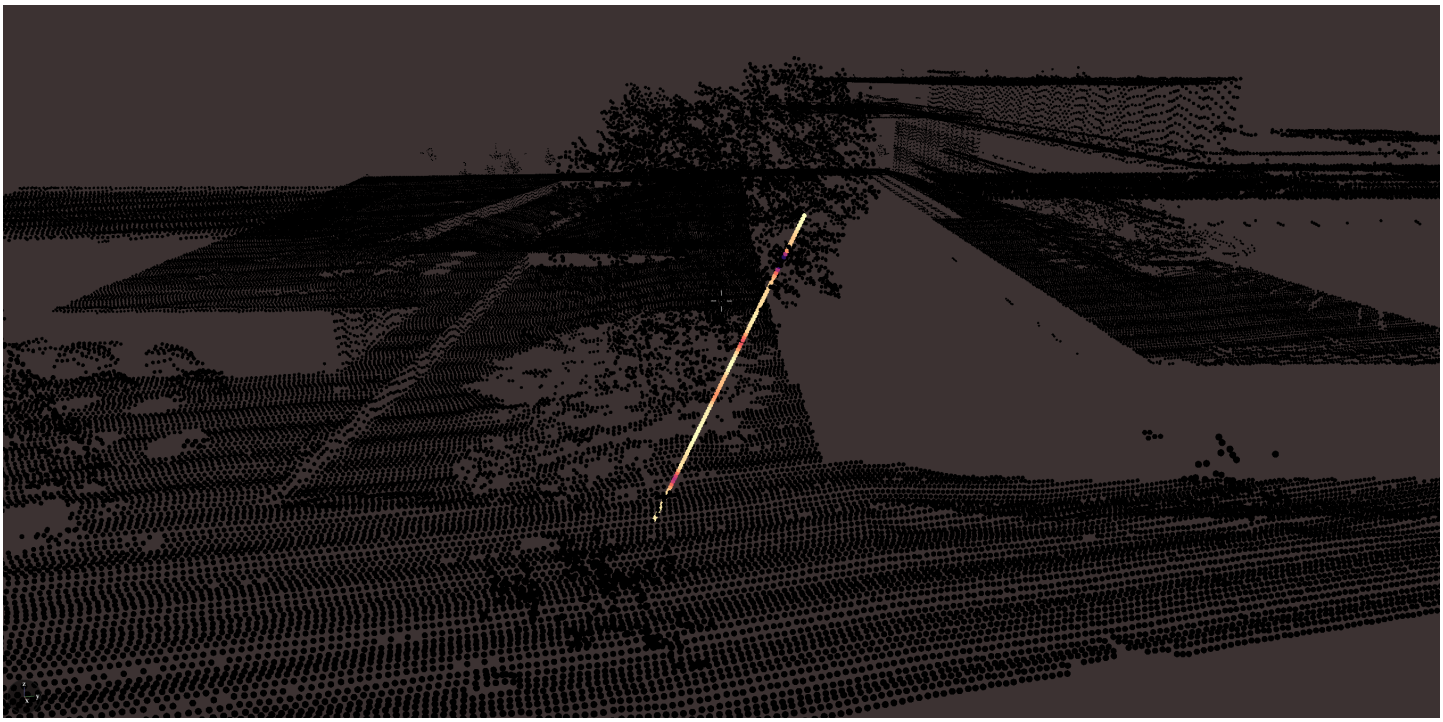


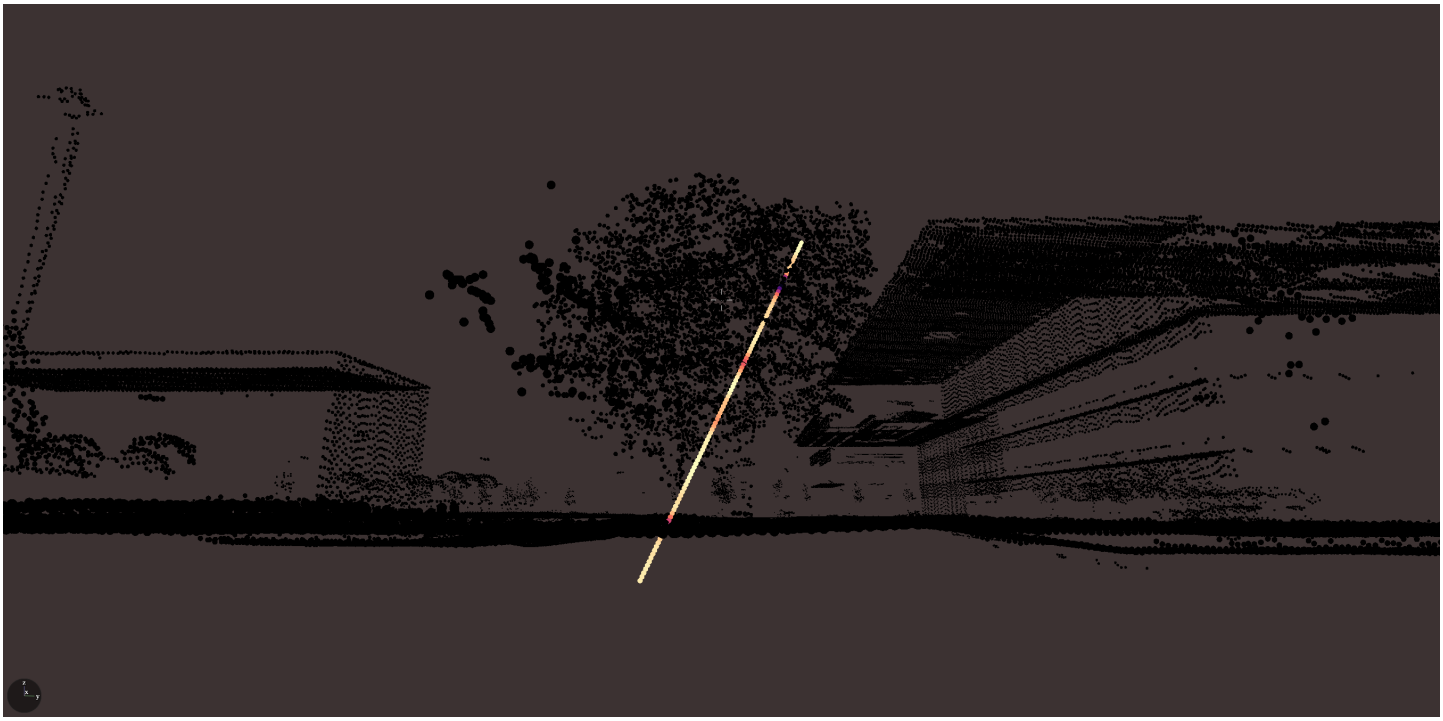


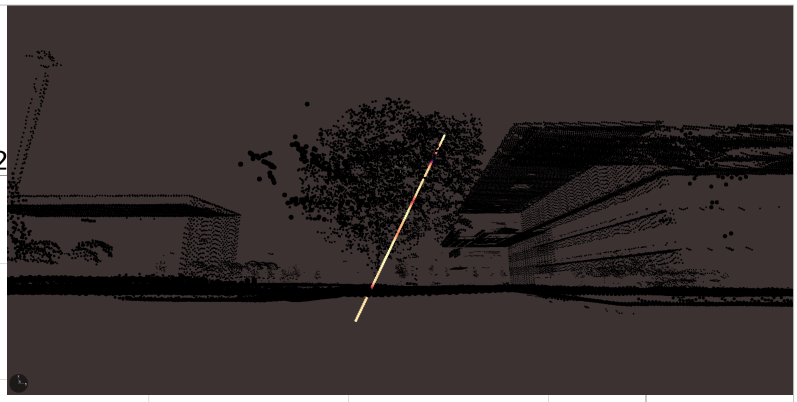
ull Waveform of index 302 @X: 33362329.885000, Y:5808444.120000, Z: 40.873000 and 35.6160



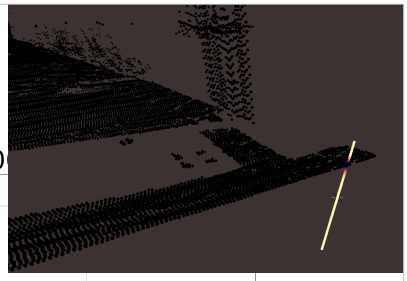


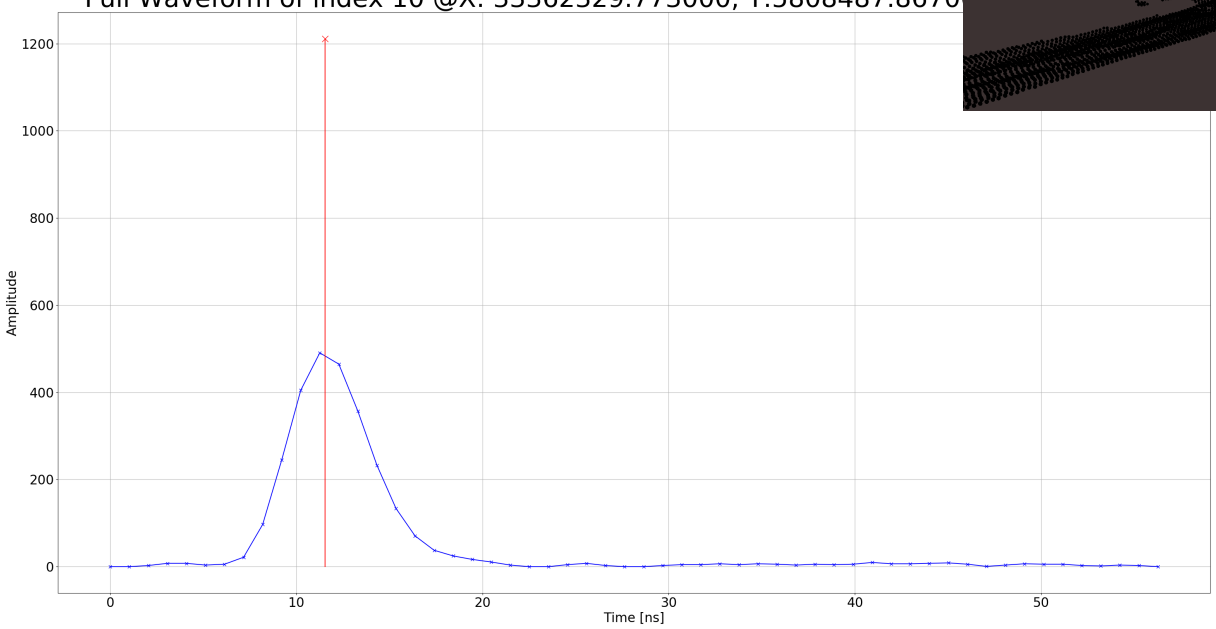


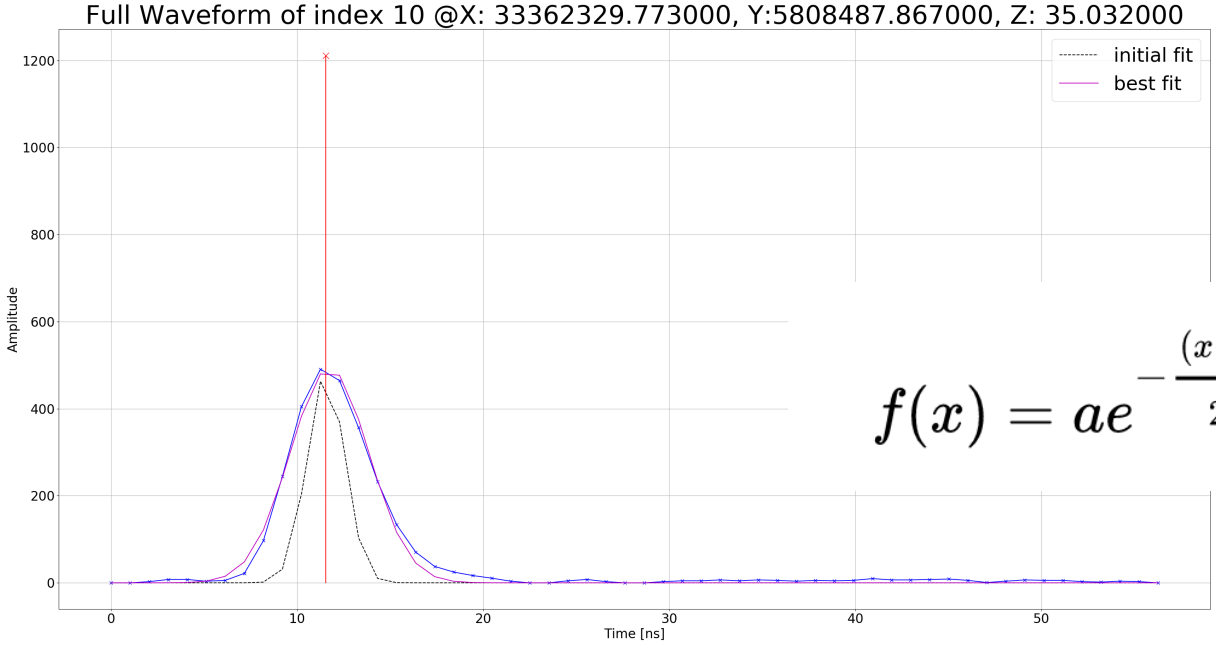




Full Waveform of index 15859 @X: 33362316.2
Amplitude
Time [ns]
0
200
400
600
800
0
20
40
60
80
100

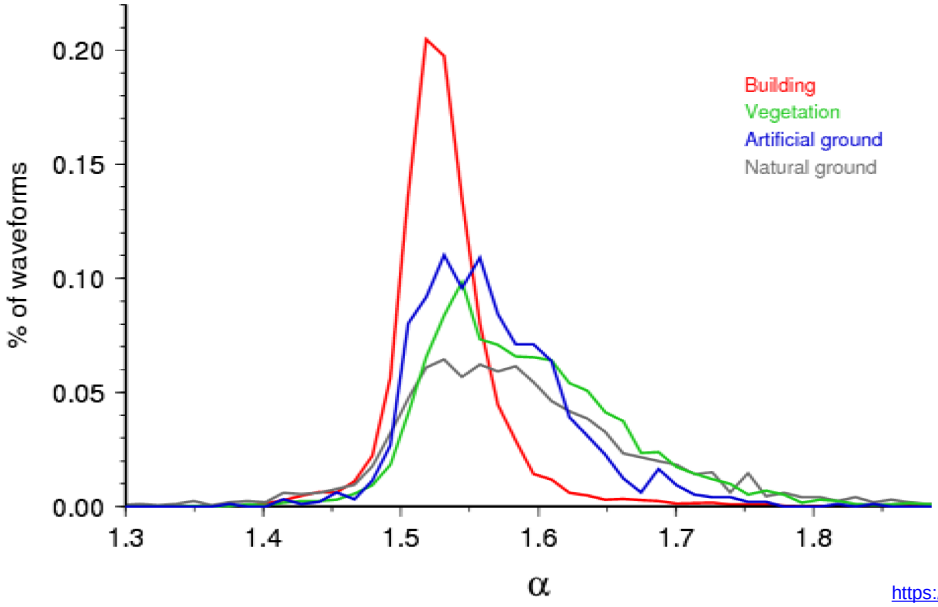






$$f(x) = ae^{-\frac{(x-b)^2}{2c^2}}$$

Fitting FWF data



Generalized Gaussian (GG) Model

$$f_{GG} = A \cdot \exp\left(-\frac{|x-\mu|^{\alpha^2}}{2\sigma^2} \right)$$

https://www.isprs.org/proceedings/XXXVII/congress/3_pdf/13.pdf

Fitting multiple signals to FWF data

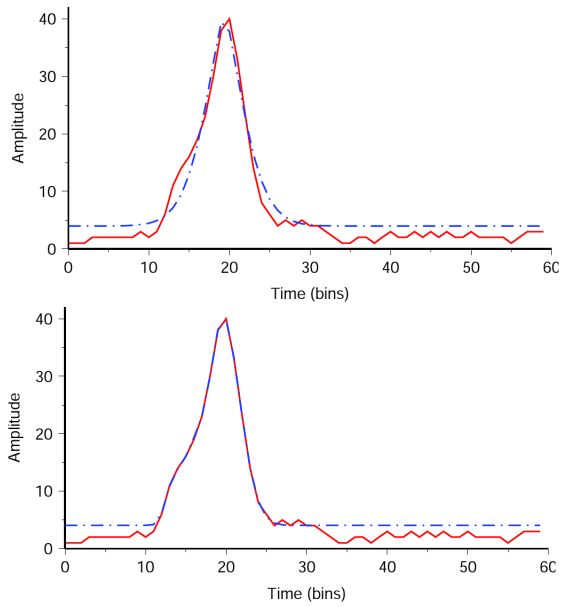


Figure 3: Example of complex waveform. The RIEGL system data is in red colour (continuous line) and the fitted result in blue (dashed line). Data is first thresholded to the value of 4 before pulse detection. **Top:** Fit with only a coarse pulse detection. **Bottom:** Fit with a fine detection. Two echoes are now found.

PROCESSING FULL-WAVEFORM LIDAR DATA: MODELLING RAW SIGNALS by Adrien Chauve, Clement Mallet, Frederic Bretar, Sylvie Durrieu, Marc Pierrot Deseilligny and William Puech

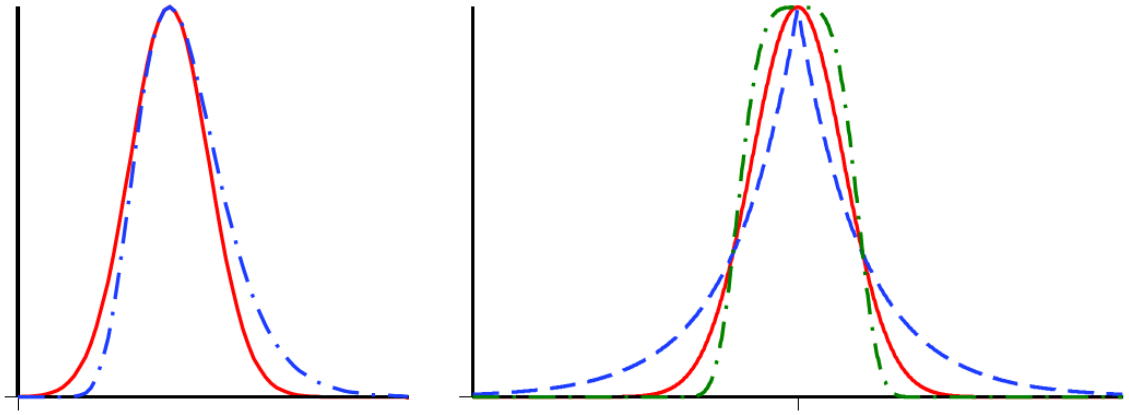
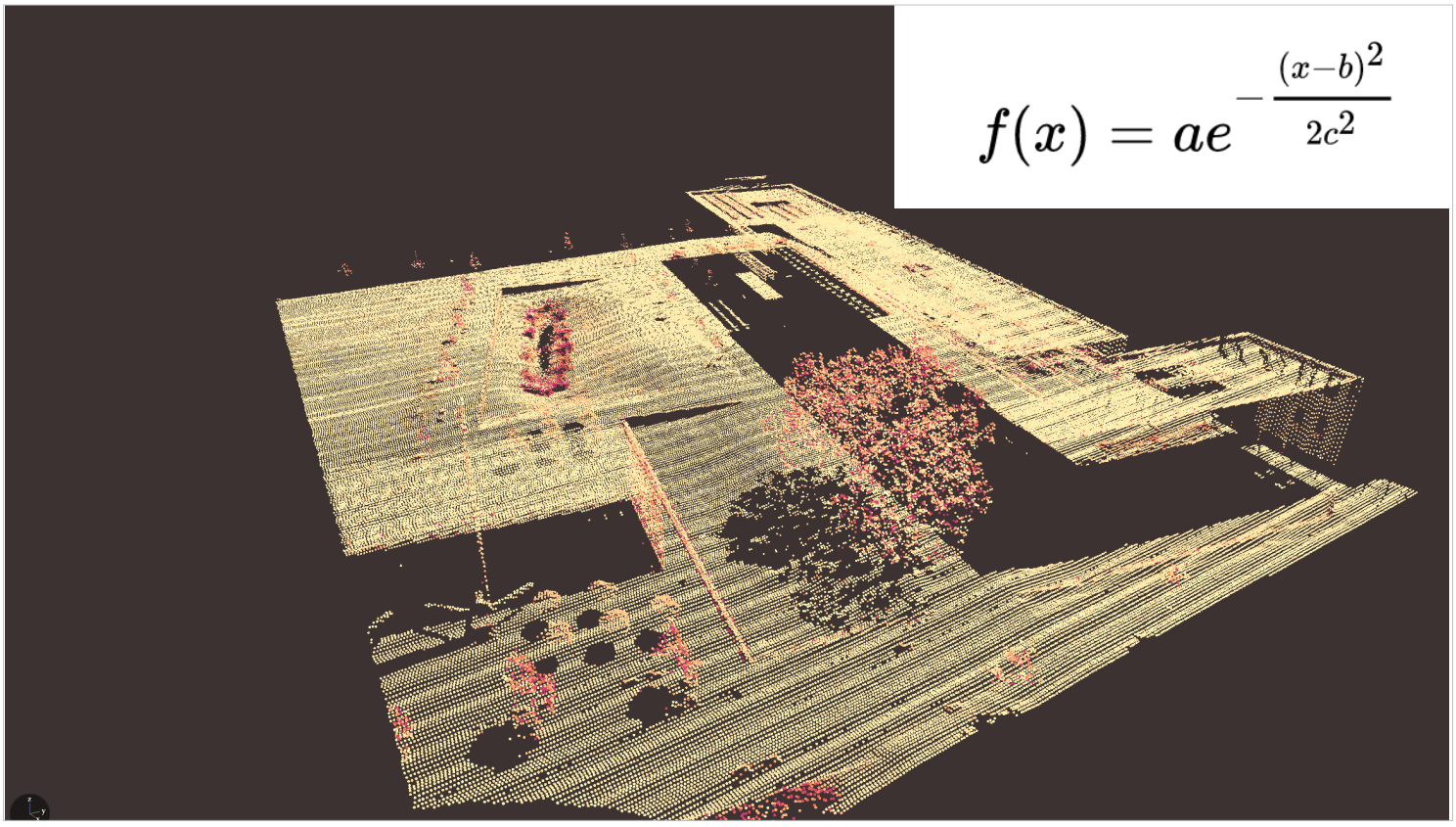


Figure 4: **Left:** Comparison between Gaussian (continuous line) and Lognormal (dotted line) functions. **Right:** The generalized Gaussian function: α=1 = Laplace function (dashed line), α=$\sqrt{2}$ = Gaussian function (continuous line) and α=2 (dotted line).



File Format

VLR (stored in LAS header):

Reserved:	43707
User ID:	LASF_Spec
Record ID:	100
Record Length after Header:	26
Description: "Wave Packet Descriptor 1"	
Bits per sample:	8
Waveform compression type	0
Number of samples	88
Temporal Sample Spacing	1000
Digitizer Gain	0.0086453
Digitizer Offset	-0.1326341

Sample Returns (of one pulse)

Return 1 of 3:

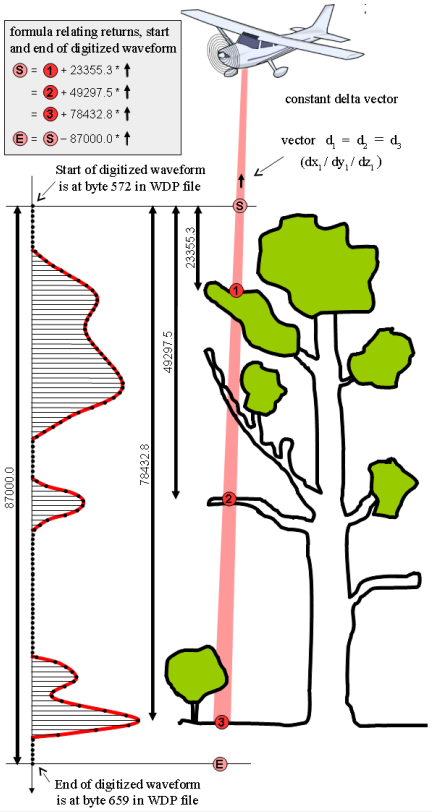
GPS time:	129850.124053
x:	235374.66
y:	5800928.34
z:	276.50
Wave Packet Descriptor Index	1
Byte offset to waveform data	572
Waveform packet size in bytes	88
Return Point Location L_1	23355.3
dx_1	4.9922e-005
dy_1	5.89773e-006
dz_1	0.000141175

Return 2 of 3:

GPS time:	129850.124053
x:	235375.96
y:	5800928.19
z:	272.84
Wave Packet Descriptor Index	1
Byte offset to waveform data	572
Waveform packet size in bytes	88
Return Point Location L_2	49297.5
dx_2	4.9922e-005
dy_2	5.89773e-006
dz_2	0.000141175

Return 3 of 3:

GPS time:	129850.124053
x:	235377.41
y:	5800928.02
z:	268.72
Wave Packet Descriptor Index	1
Byte offset to waveform data	572
Waveform packet size in bytes	88
Return Point Location L_3	78432.8
dx_3	4.9922e-005
dy_3	5.89773e-006
dz_3	0.000141175



https://github.com/ASPRSorg/LAS/wiki/Waveform-Data-Packet-Descriptors-Explained