Flood Modelling and Mapping
The Cornerstone of Flood Safety and Management in Ontario

Introduction to Bathymetric Lidar

Dushan Arumugam

Education

BSc Geomatics Engineering

University of Calgary (1996)

ASCM Certified Hydrographer

Work Experience

Geomatics Data Solutions Inc.

GDS, Canada (April 2009 - Present)

Project Manager Bathymetric Lidar (HawkEye II)

Blom Aerofilms Ltd, Cheddar, UK (May 2008 - April 2009)

Lead Hydrographer / Party Chief Lidar (SHOALS-1000T)

Fugro Pelagos, Inc., San Diego, California (2004 - 2008)

Lead Hydrographer NOAA Projects

Fugro Pelagos, Inc., San Diego, California (1999 - 2004)

Offshore Surveyor,

Racal Survey USA, Houston, TX (1996 - 1999)

- Small, specialized company of highly trained and technical staff
  - Airborne lidar (bathymetric and topographic)
  - Vessel based sonar (multibeam, singlebeam, sidescan and scanning)
  - Supporting survey requirements (GNSS control, tidal datum determination)
- Offices in Calgary, Alberta and Hillsboro, Oregon
- Projects worldwide
  - Canadian Hydrographic Service: Haida Gwaii, Lake Superior, Newfoundland/Labrador
  - Halifax Regional Municipality: Coastal and inland Nova Scotia
  - Tonga: Nautical charting program teamed with iXblue for LINZ
  - US Public Sector: NOAA, USGS, NGA, Bureau of Reclamation
  - Klamath River, Oregon/California: Dam removal reservoir and river surveys
  - Snake River, Idaho: Snake River and high-resolution scanning for Idaho Power

Bathymetric Lidar History

1st Generation (early 70's)

- US: PLADS
- Australia: WRELADS I
- USSR, Sweden, Canada: Ship-borne lidar

2nd-3rd Generation (mid 70's – late 80's)

- US: AOL, HALS, ALARMS
- Australia: WRELADS II, RAN LADS
- USSR: GOI, Chaika, Markel-II
- Sweden: OWL, FLASH-1
- Canada: CCRS, LARSEN-500, China: BLOL

Operational systems (early 90's – today)

- US/Canada: SHOALS, EAARL
- Australia: LADS
- Sweden: HawkEye

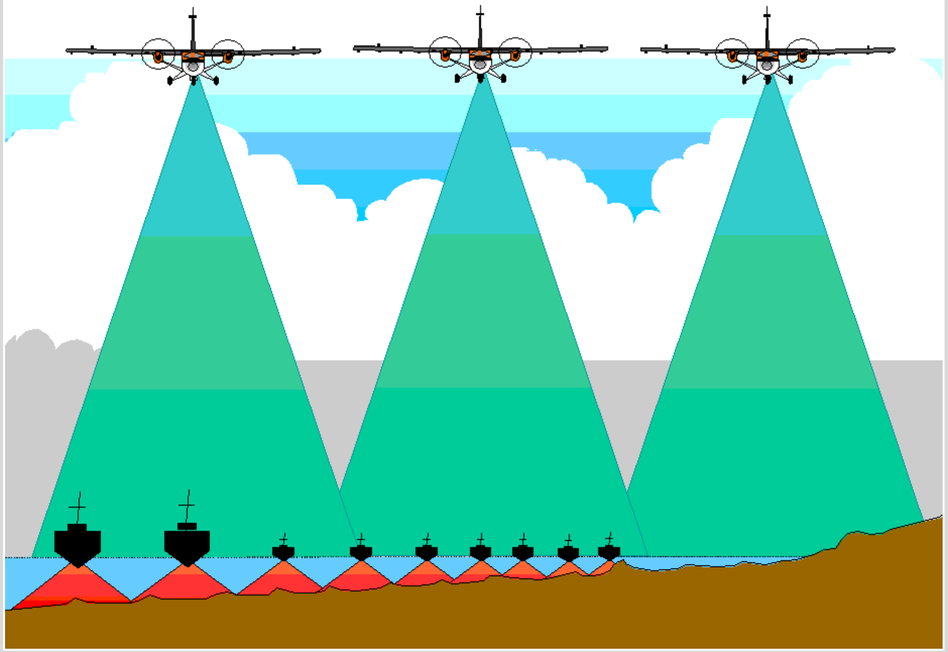
Current Sensors

- Optech: CZMIL, Titan
- Leica: HawkEye 4x, Chiroptera 4x
- Fugro LADS: LADS Mk III, RAMMS
- Riegl: VQ820-G, VQ880-G

Increased Capabilities
(higher PRF, additional Sensors, ...)

Decreased Size & Weight

- Consistent swath widths
- More efficient coverage in very shallow water (<5 – 15m)
- Eliminates safety concerns of boat operations in shallow uncharted water
- Can be combined with multibeam for optimal survey results, efficiency & safety



Sample Project >200km^2

- Very Shallow Depths (3m on average)
- Understand limitations

Technology	Time to Survey
Full Coverage Multibeam	1 year
100% Sidescan Sonar (*with singlebeam or skunk striped bathy*)	60 days
Bathy Lidar	**2 days**

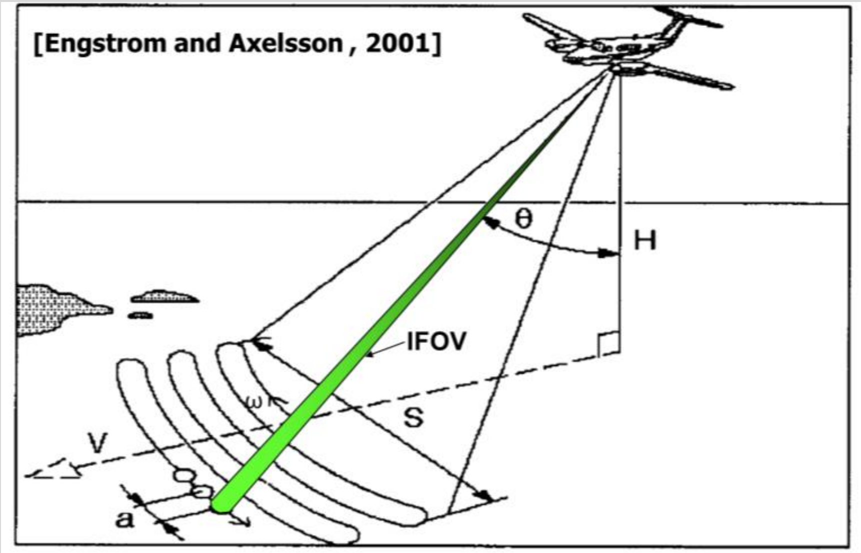
- Traditional / High-Power
  (Deep Channel Systems)
  - Optech CZMIL
  - Fugro LADS Mk III
  - Fugro RAMMS
  - Leica HawkEye 4x

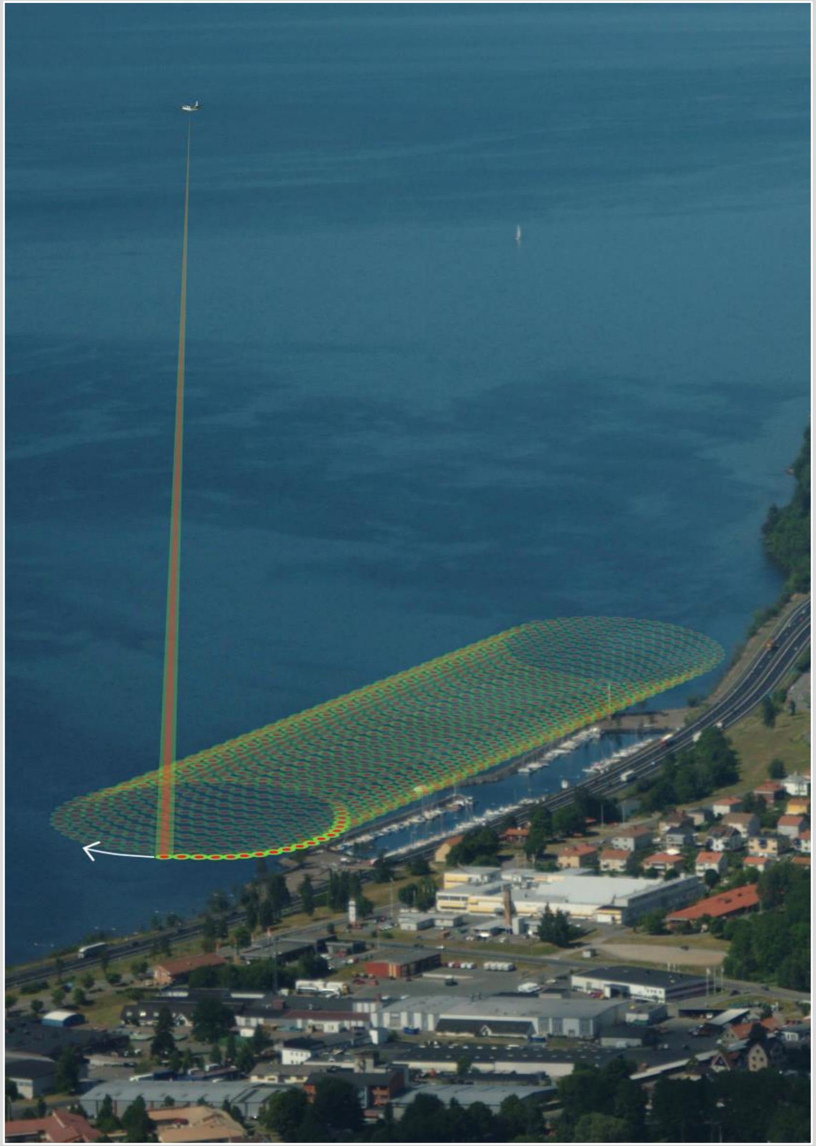
- Low-Power
  (Topo-Bathy or Shallow Channel Systems)
  - EAARL-B
  - Optech Titan?
  - Leica Chiroptera 4x
  - Riegl VQ820-G / VQ880-G

Deep v Shallow Sensors

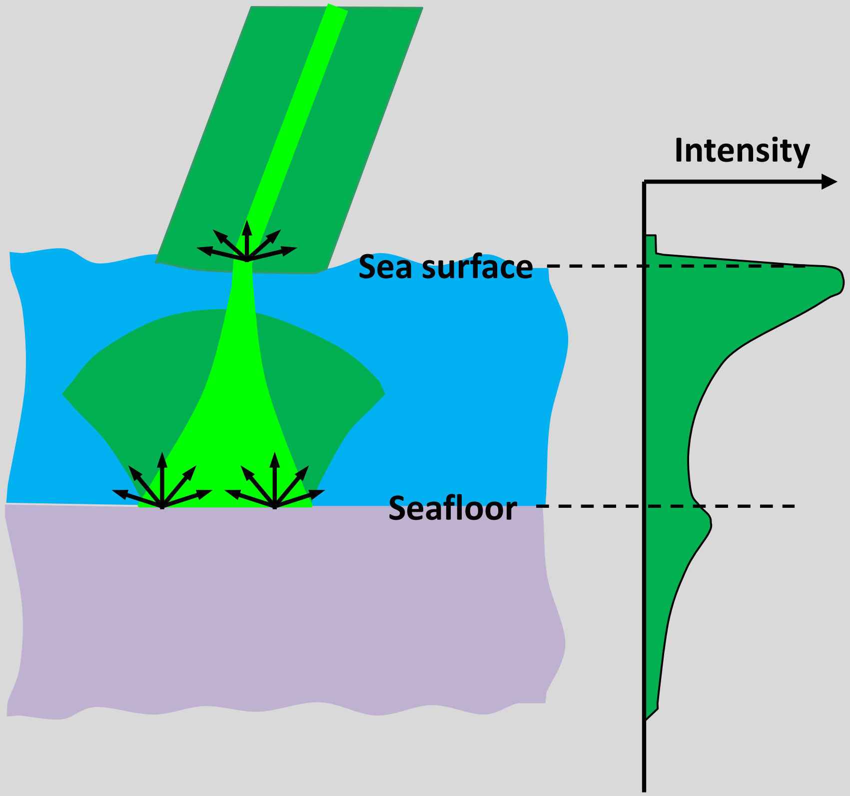
	Deep Channel Sensor	Shallow Channel Sensor
Flying Speed (knots)	120-180	120-180
Flight Altitude (m)	200 - 600	200 - 600m
Swath Width (m)	60 - 585	~ 290m
Sounding Density (m)	0.4 to 0.05 pts /m^2	1.5 to >10 pts /m^2
PRF	1 – 10 kHz (70kHz shallow for CZMIL)	Up to 550 kHz
Min Depth (m)	0 / 0.2m / 1.5m	0m
Max Depth (m) *	~ 50 – 80m 2 – 3.5 x Secchi Depth	~ 15m 1.5 x Secchi Depth
Depth Accuracy	IHO Order 1 or Better	IHO Order 1 or Better
Horizontal Accuracy	IHO Order 1 or Better	IHO Order 1 or Better
Power	50A – 100A @ 28 VDC	~30A @ 18-32 VDC
Weight	190 – 500 kg	< 100kg
Nominal Footprint Size	2 – 3m	~ 40cm

- Frequency Doubled ND:YAG Class IV Laser output **or** Independent Lasers:
  - **Infrared (1064nm)**
  - **Visible Green (532nm)**
- Laser fires against a scanning mirror or circular palmer scanner to create a swath of points.

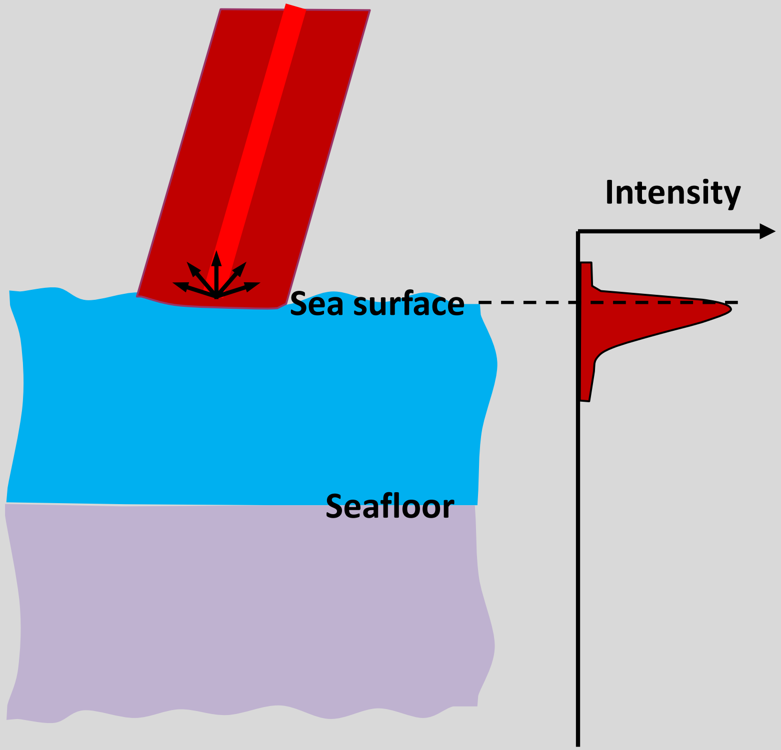




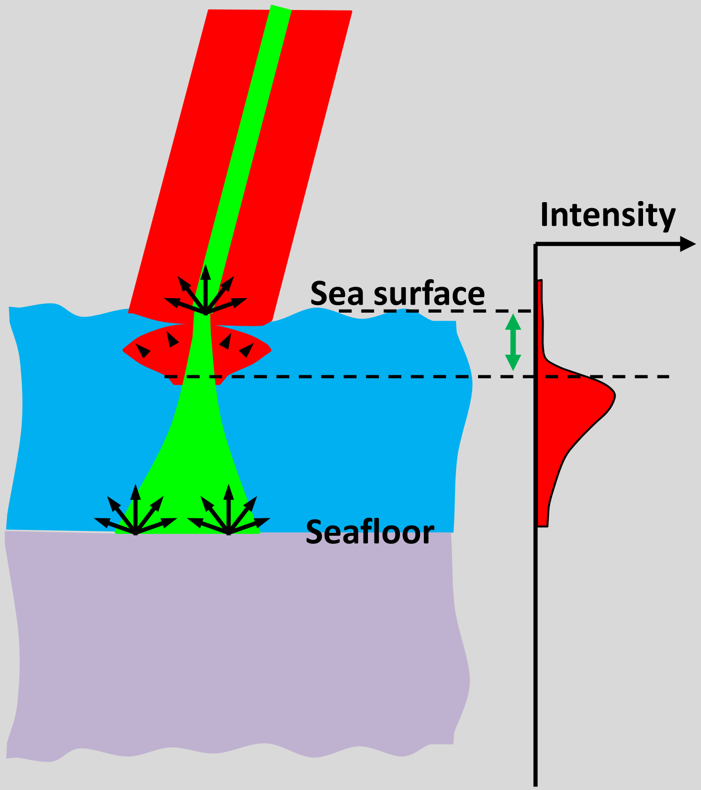
Green (532nm)
sea surface, water column & seafloor



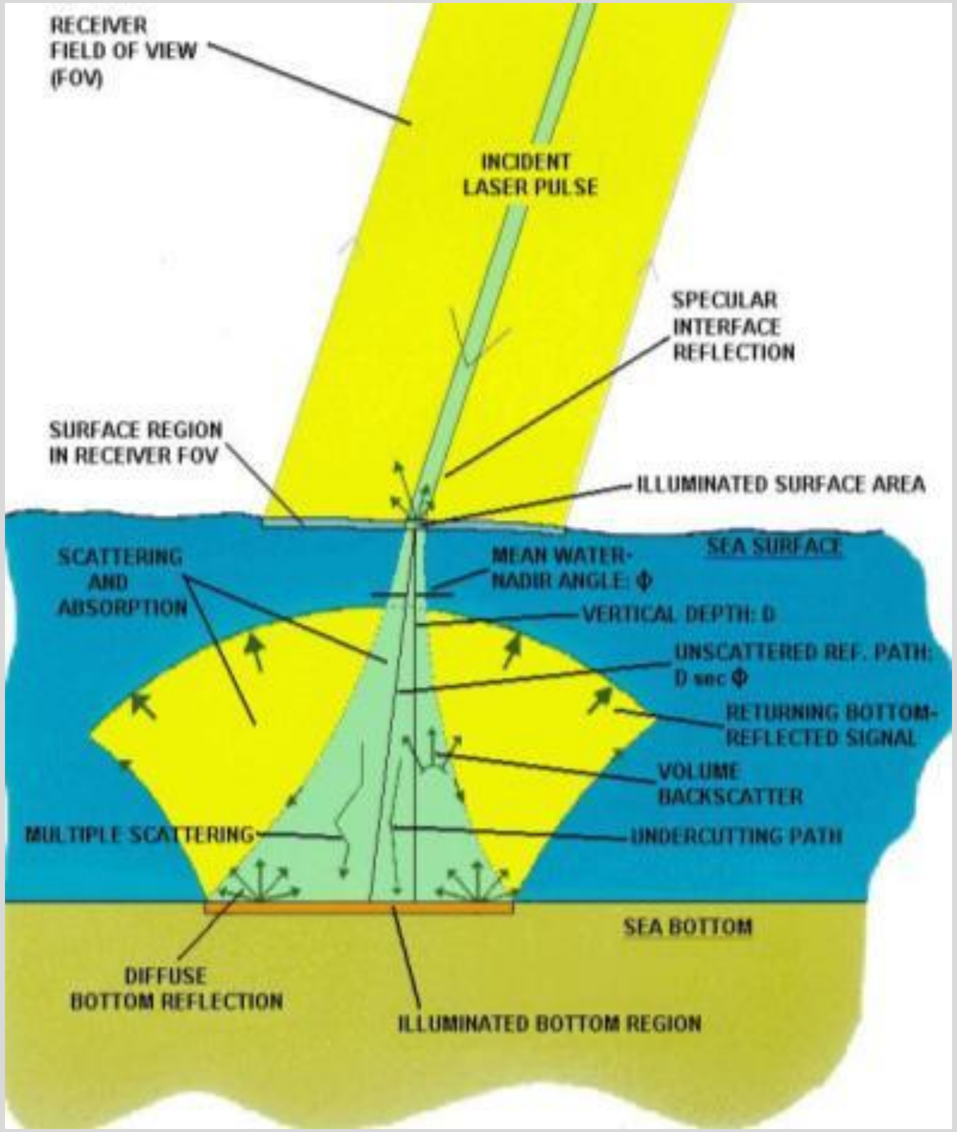
IR (1064nm)
sea surface

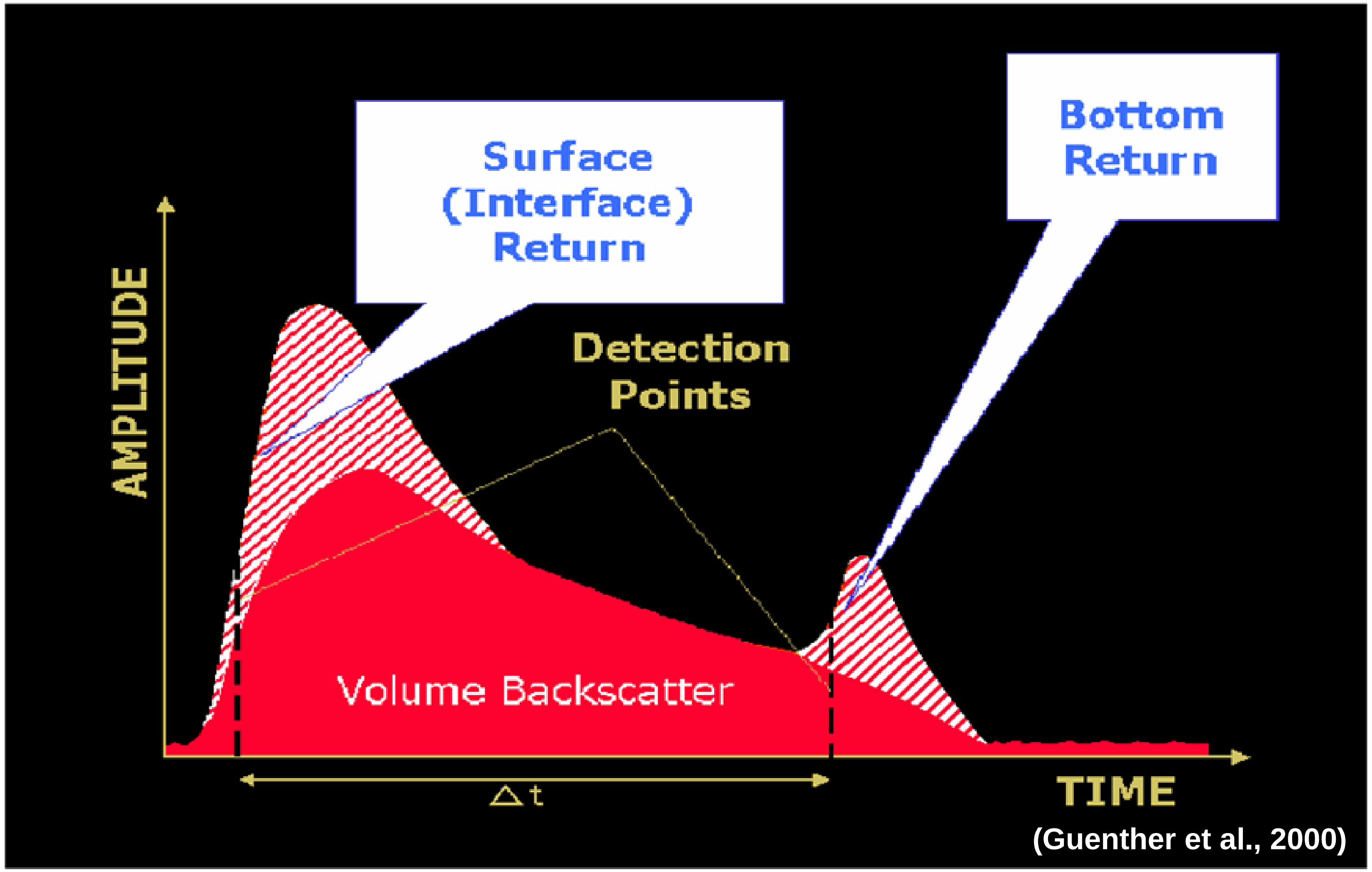


Raman Return (Red 640 to 670nm)
sea surface, upper water column



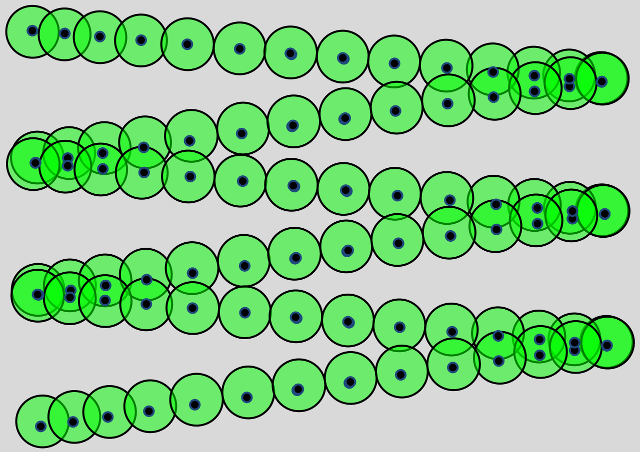
Conceptual Green Waveform





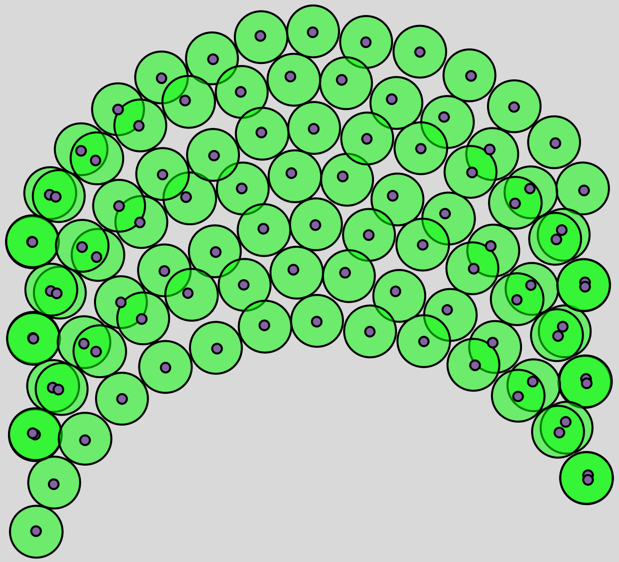
Line Scanning

e.g. LADS Mk III



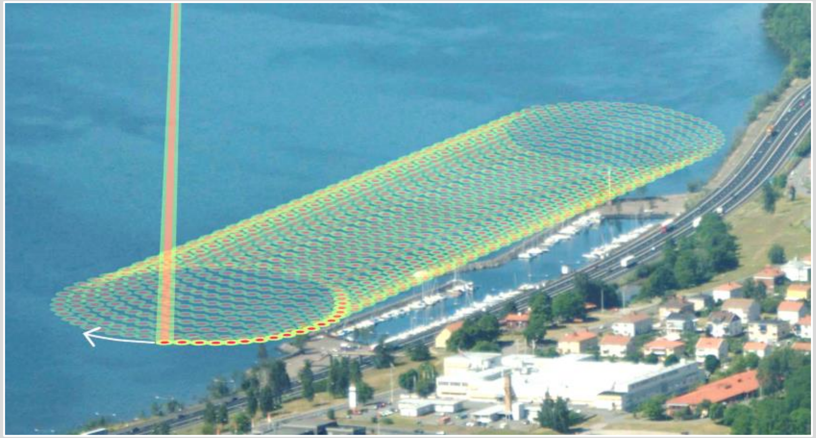
Arc Scanning

e.g. SHOALS, Riegl VQ-820-G

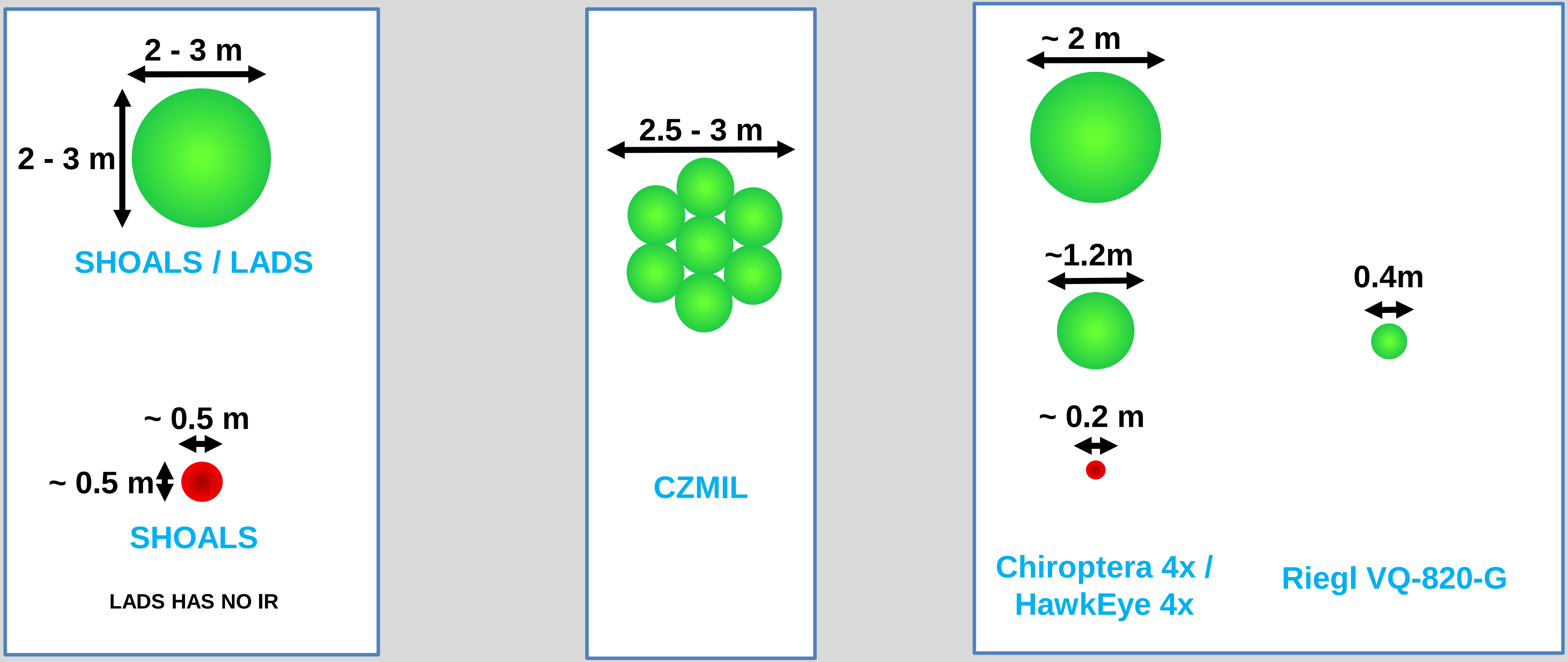


Elliptical Scanning

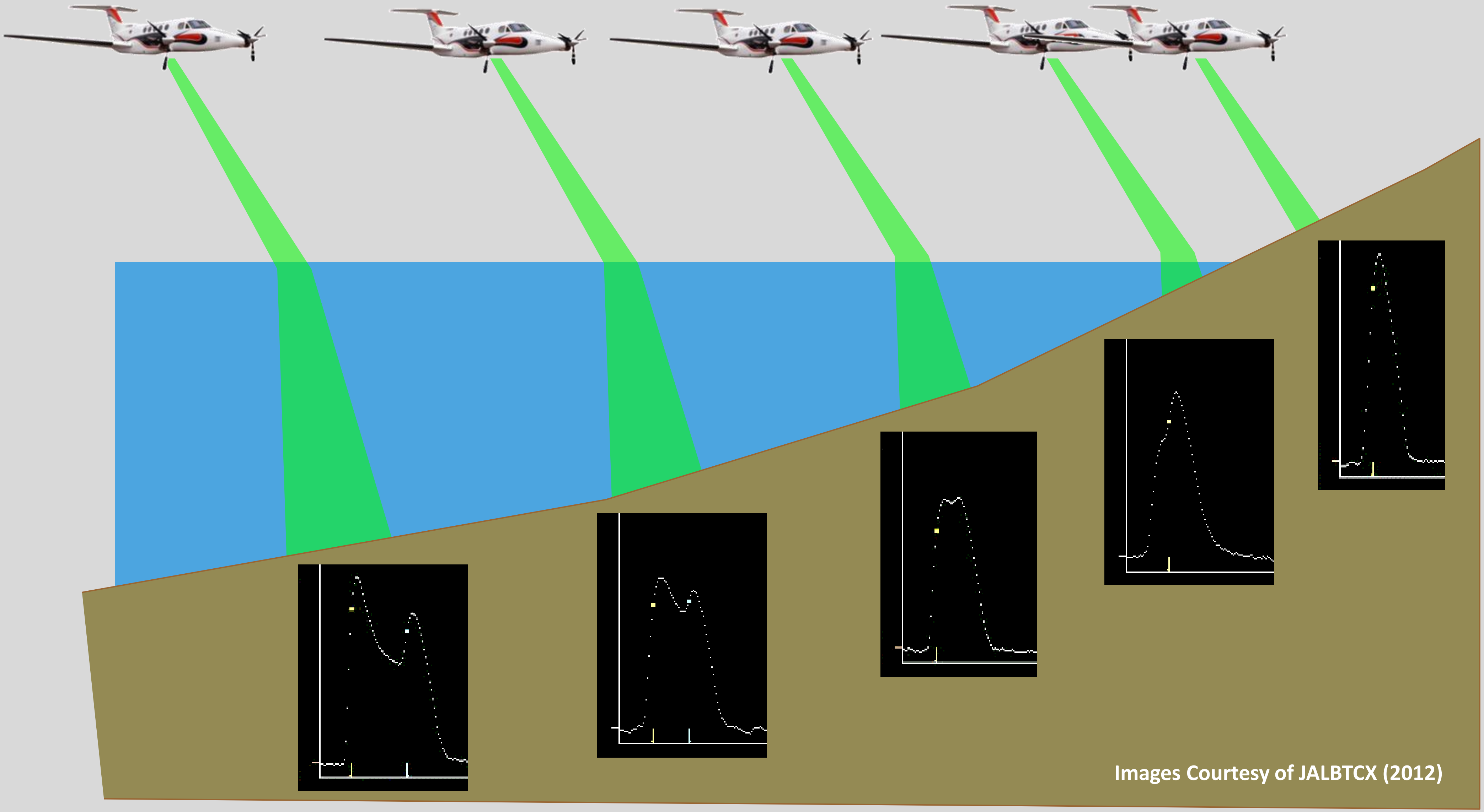
e.g. CZMIL, HawkEye,Chiroptera, Riegl VQ-880-G



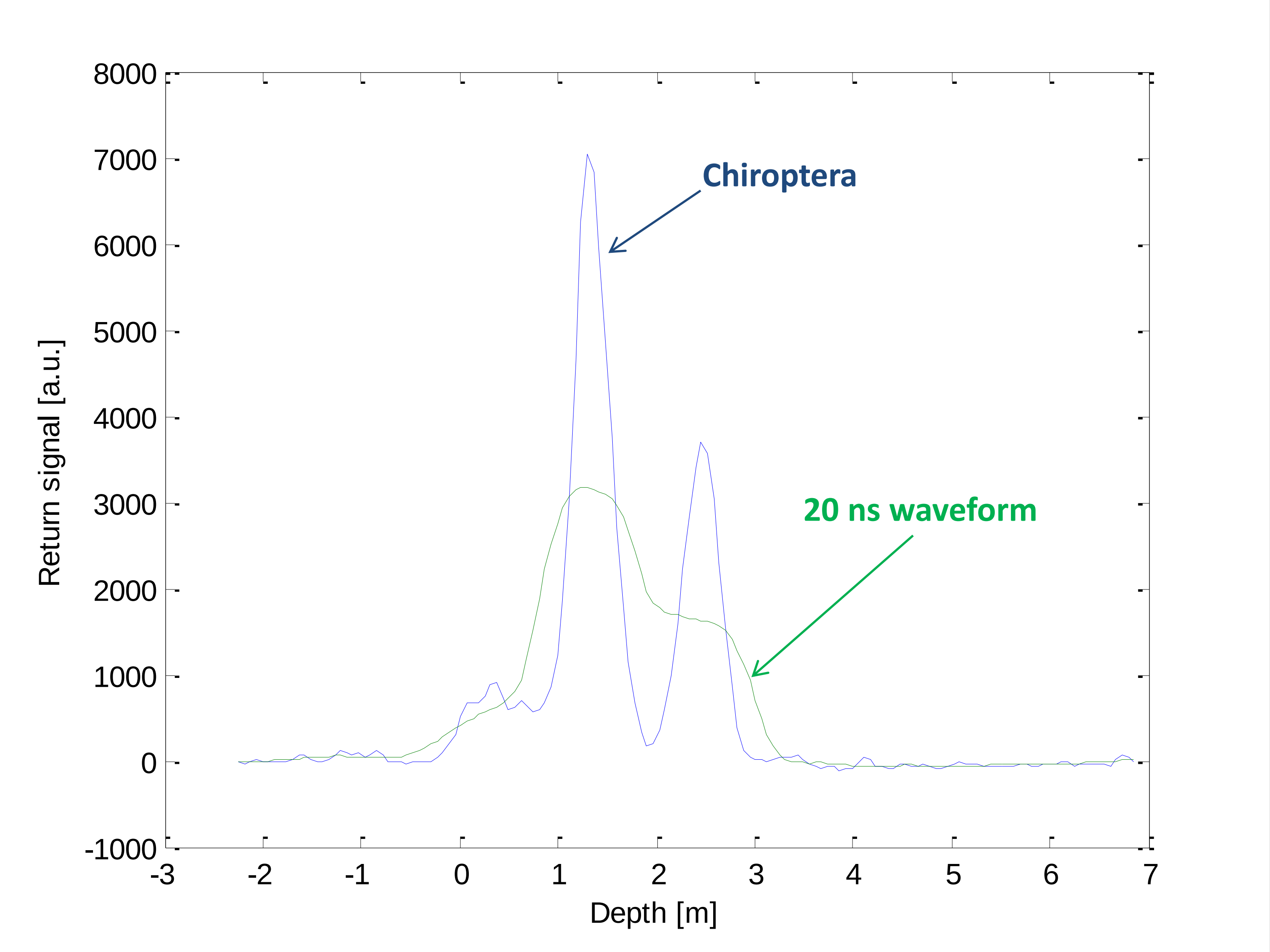
Changes in Footprint Concept: Segmented Detection

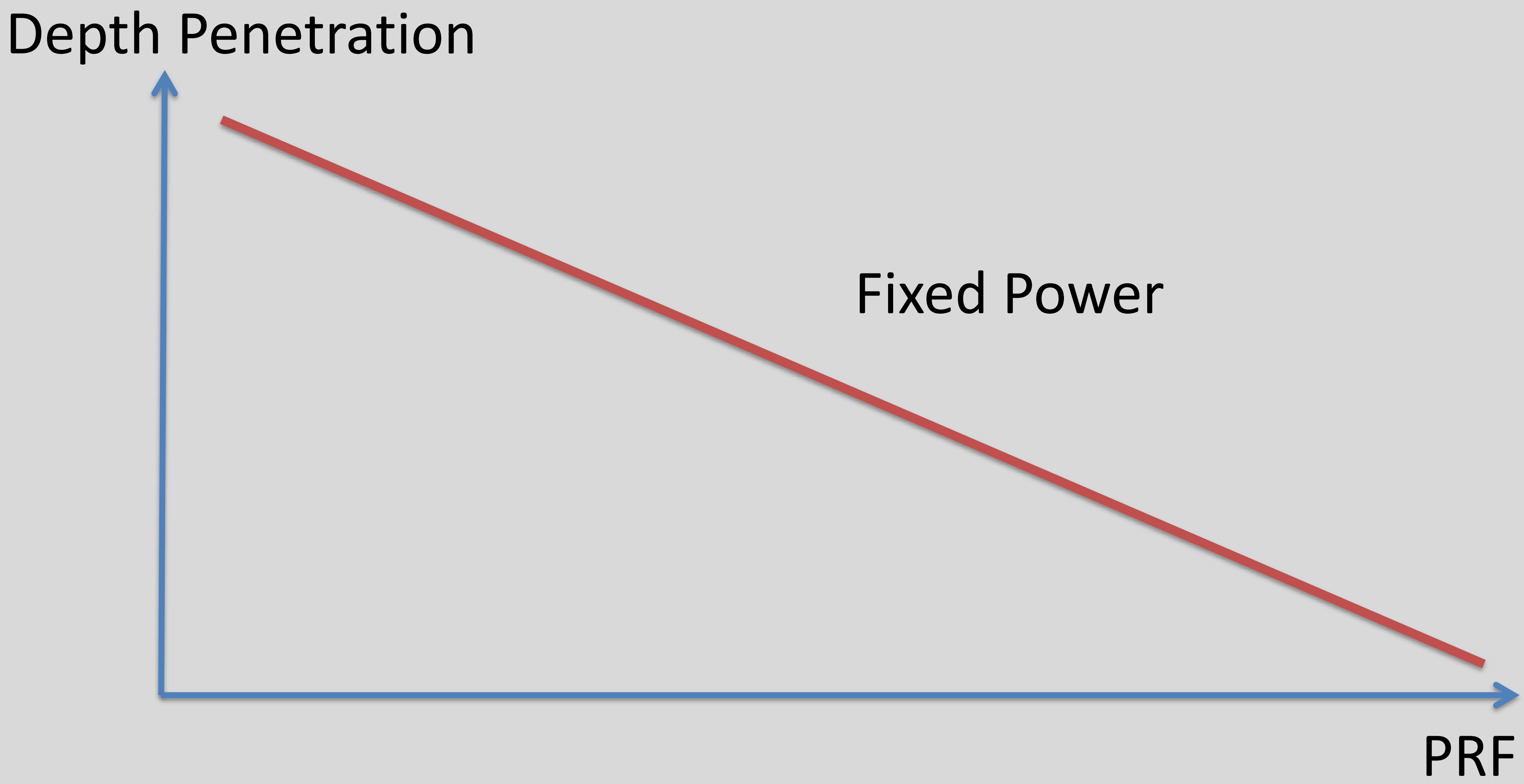


Shallow Water Discrimination



Actual Chiroptera waveform at 1.2 meters depth (blue) versus simulated waveform with a 20 ns response time (green)




Depth Penetration
Fixed Power
PRF

Real World Accuracy Statistics

Comparing Lidar and Acoustic Bathymetry Using TPU and the CUBE Algorithm, ILMF (2008) , C. Lockhart, D. Lockhart, J. Martinez

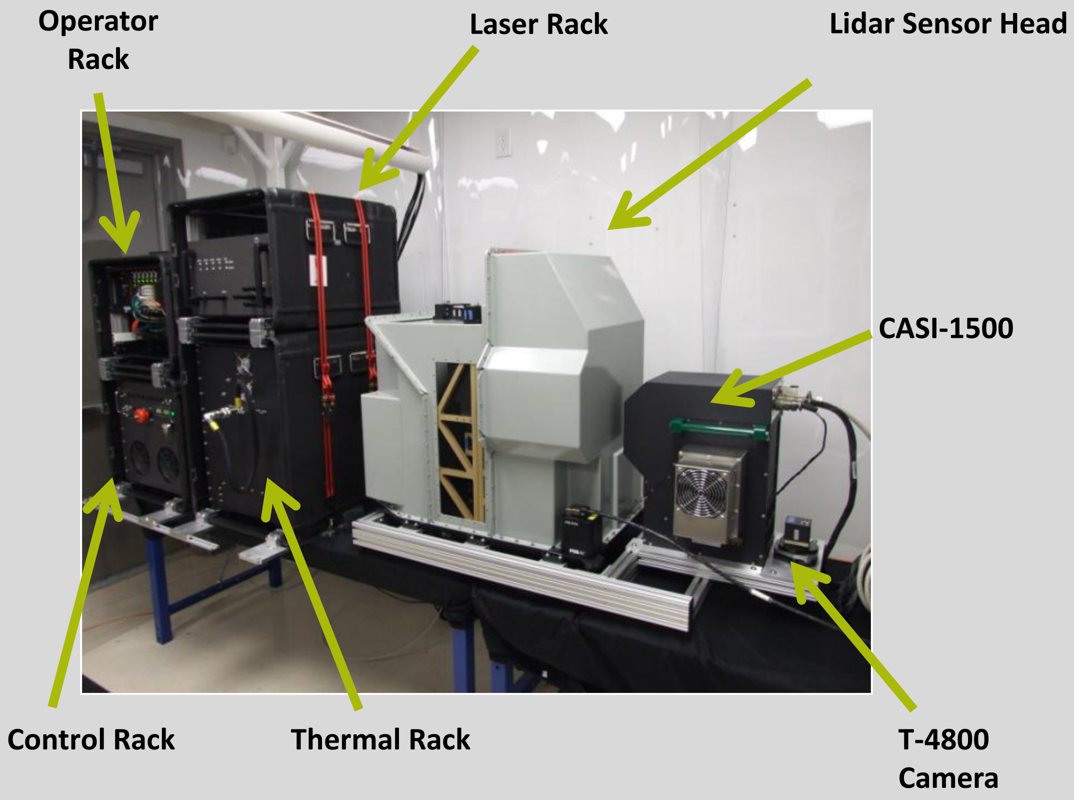
Riegl VQ880-G

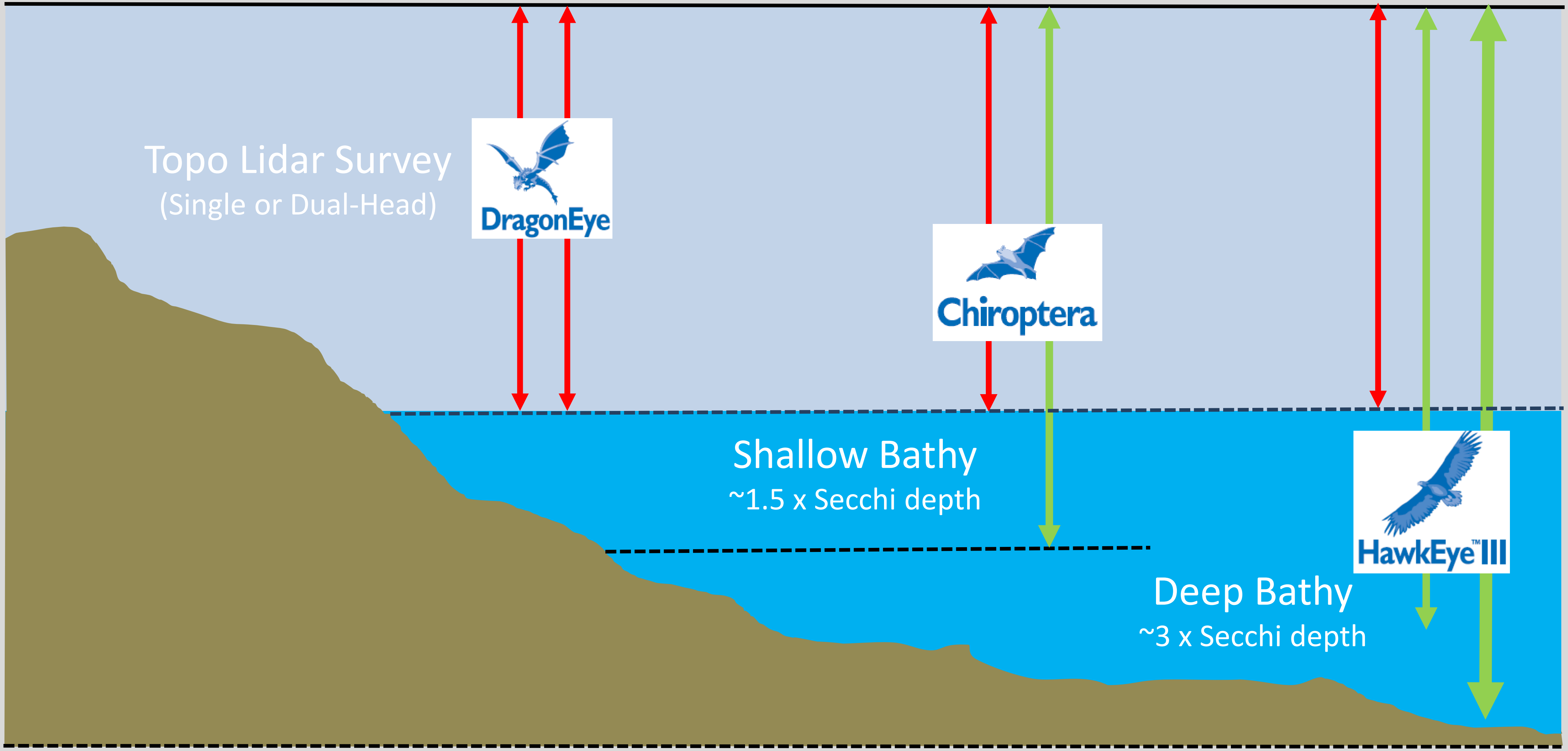
RIEGL VQ-880-G installed on GSM-3000 stabilized platform to be used in a helicopter or fixed-wing aircraft

Riegl VQ820-G

Image provided courtesy of QSI

Optech CZMIL




Topo Lidar Survey
(Single or Dual-Head)
DragonEye
Chiroptera
Shallow Bathy
~1.5 x Secchi depth
HawkEye™ III
Deep Bathy
~3 x Secchi depth

CHIROPTERA II / HAWKEYE III SENSOR HEADS

DUAL HEAD DRAGONEYE / CHIROPTERA II INSTALLATION

HawkEye III Installation

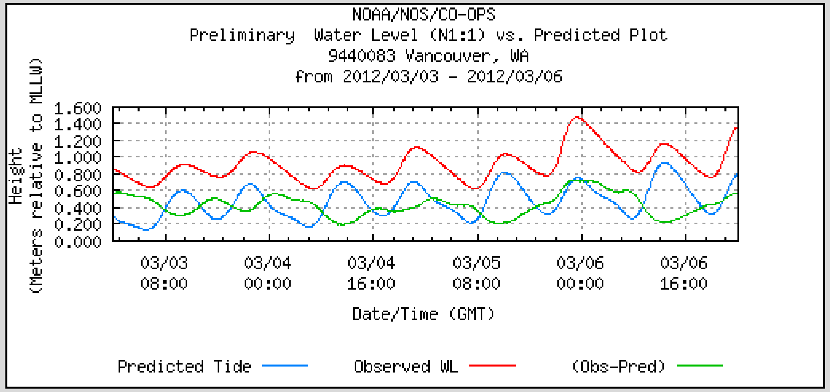
Operational Considerations: Is Lidar a Suitable Tool?

- Water Clarity / Turbidity
  - Seasonal
  - Daily (tides / currents)
- Seabed Reflectivity
  - Bed type, Vegetation
- Weather
  - Temperature
  - Rain
  - Wind
  - Cloud Ceiling
  - Sea State
- Expected Terrain & Expected Depths

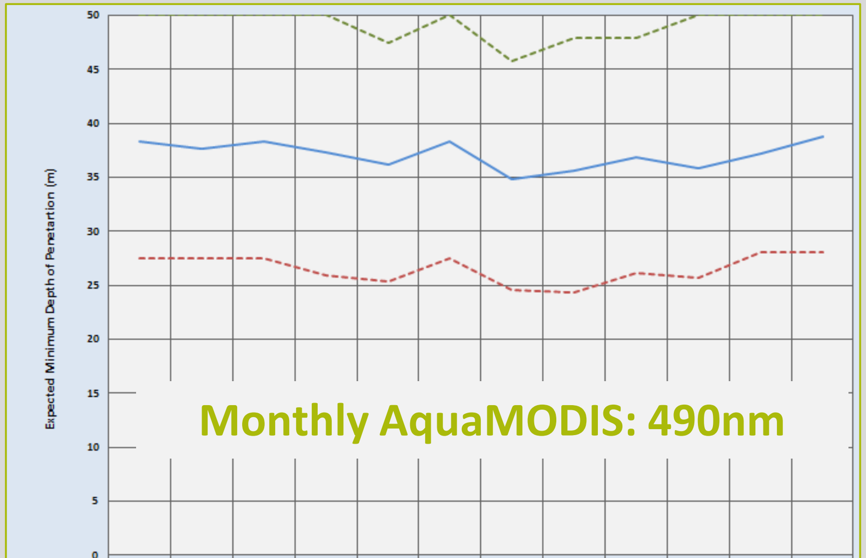
- Depth penetration depends on:
  - Turbidity
  - Seafloor reflectance

High Power = 2 to 3 x Secchi Depth **Low Power = 1 x Secchi Depth**

- Tides/Currents



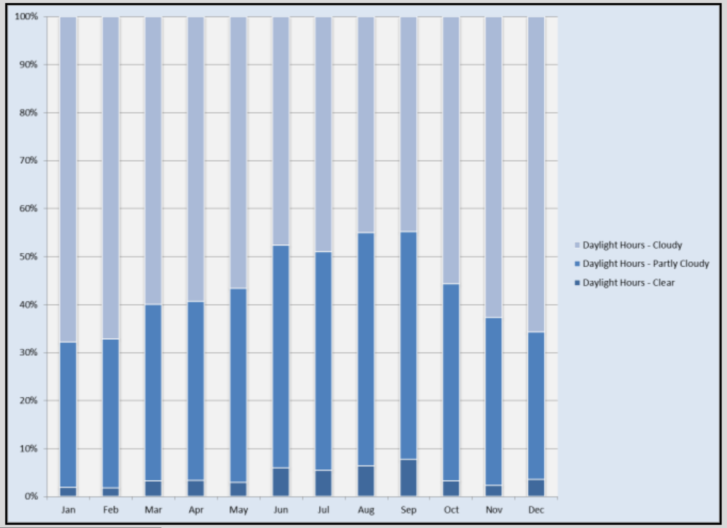
- Seasonal Assessment

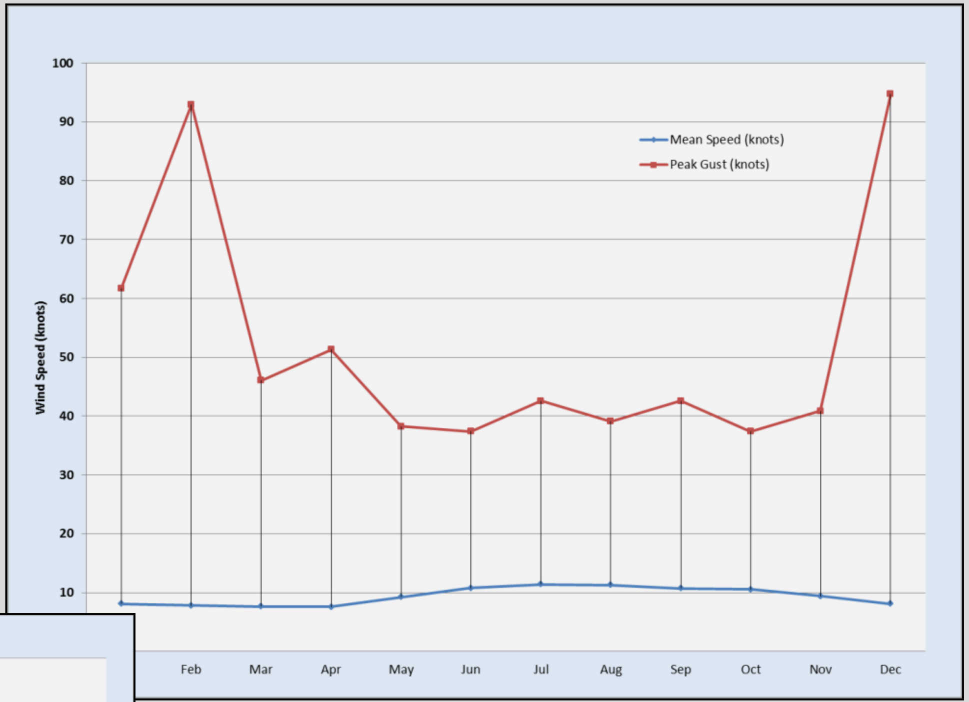


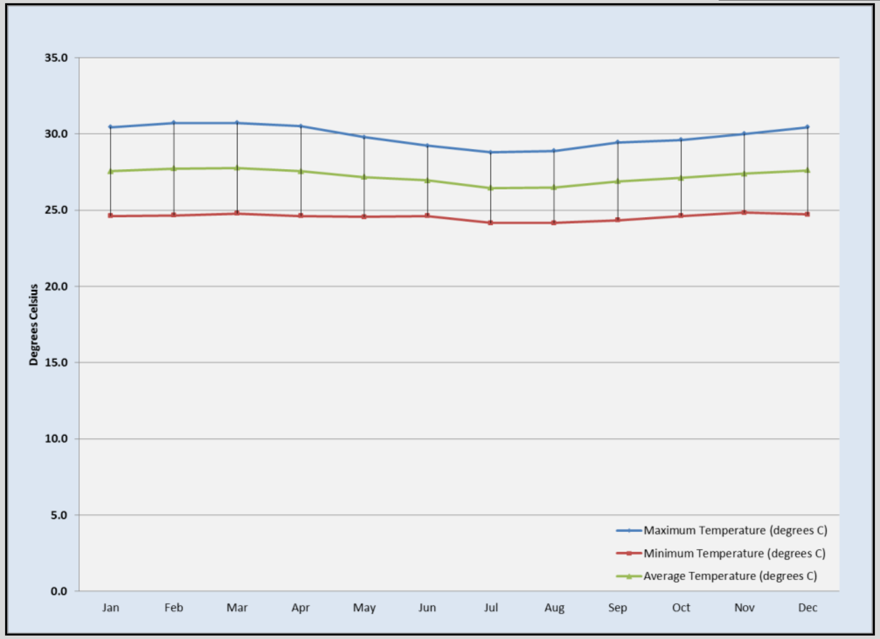
	January	February	March	April	May	June	July	August	September	October	November	December
Minimum	27	27	27	26	25	27	25	24	26	26	28	28
Mean	38	38	38	37	36	38	35	36	37	36	37	39
Maximum	50	50	50	50	47	50	46	48	48	50	50	50

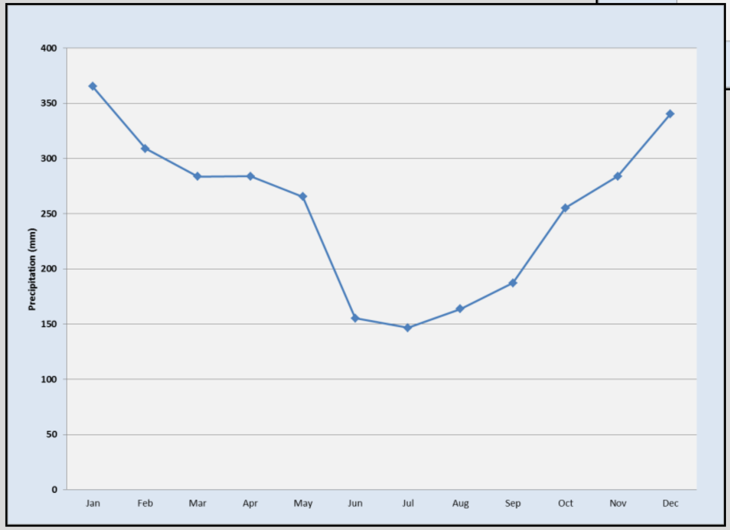
Weather

- Temperature
- Wind
- Rain
- Cloud Ceiling
- Sea State









Operational Considerations

Additional Operational Considerations

- Flight Planning Considerations Include:
  - Tide range, high/low tide times
  - Water quality / weather & time of year to survey

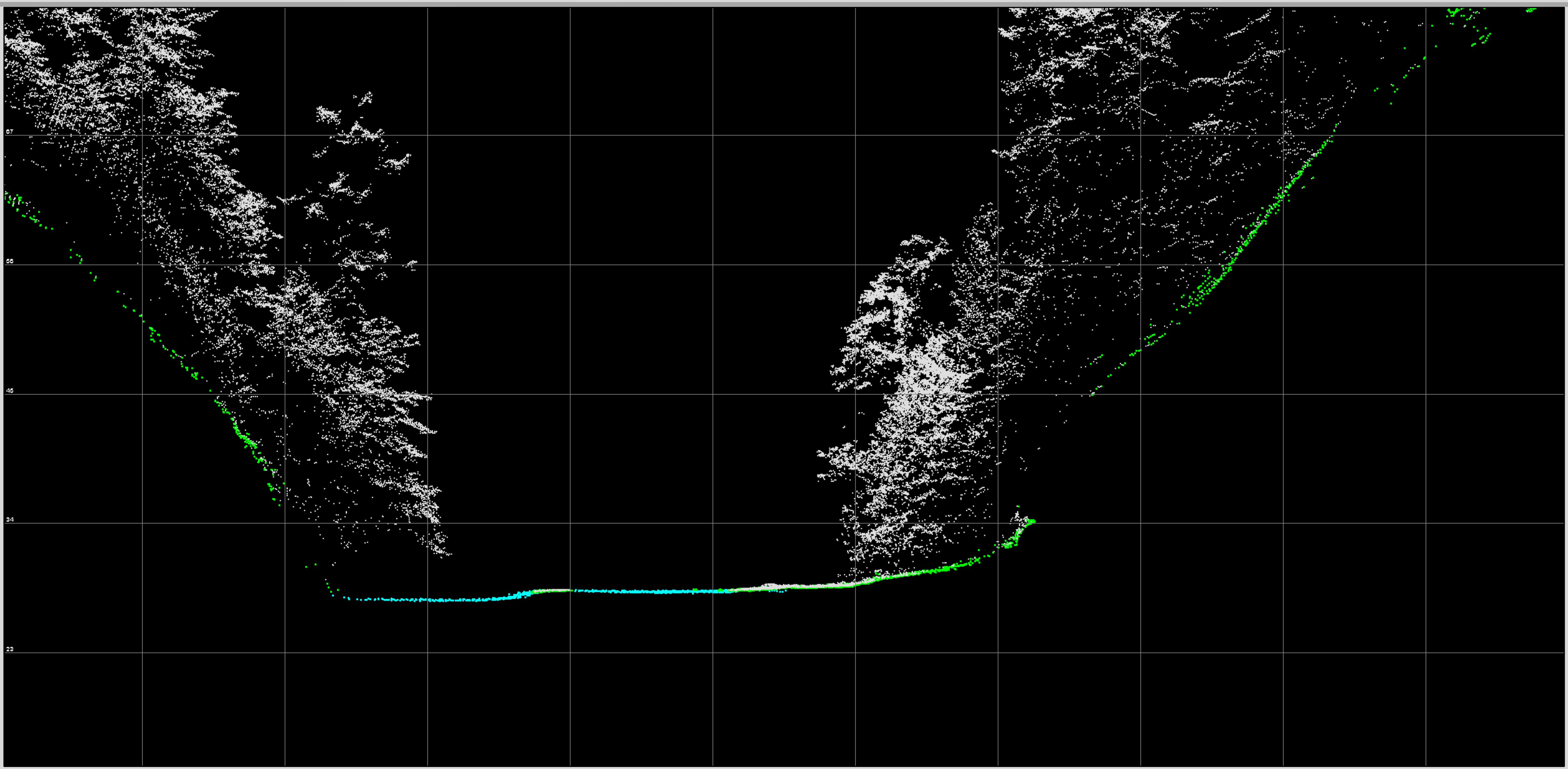
  - Shape of survey area (Coastal strip or Large polygon)
  - Size of survey area (maximum line lengths)
  - Flying height and local terrain (Aircraft Type; Deep / Shallow Power System)
  - Expected Depths (Deep / Shallow Power System)
  - GPS stations and tide gauges (Single / Multi-base, SmartBASE, PPP, Tide Plan)
  - Air traffic in the survey area
  - Restricted airspace / special flight permits
  - Operations base airport and logistics

Cost Consideration

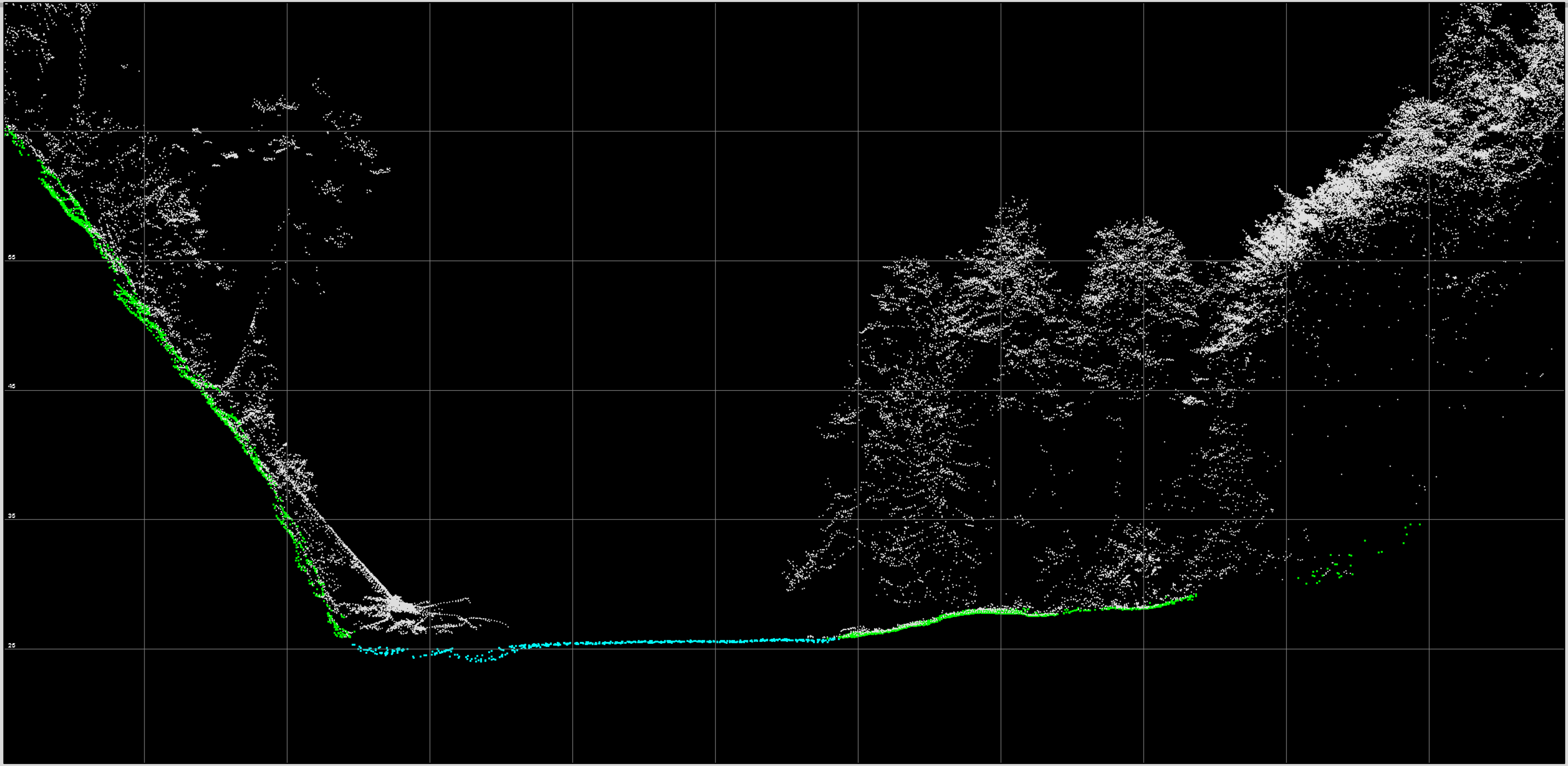
+ Mobilization
+ Shape of Rivers
+ Project size

Steep Slopes Well Defined; Seamless Topo-Bathy

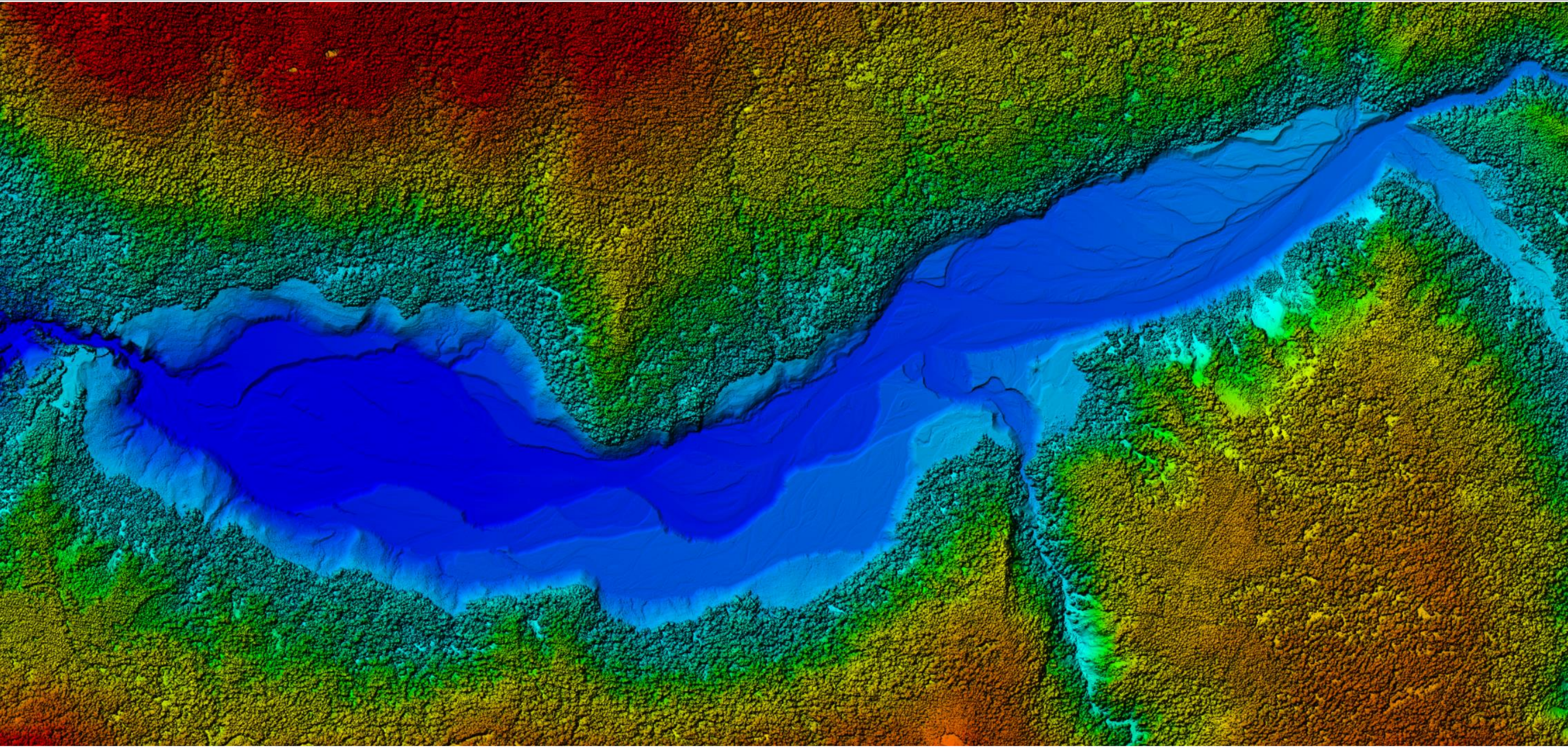
Elliptical Scan / Multiple Returns Allow Bathy Returns Under Vegetation



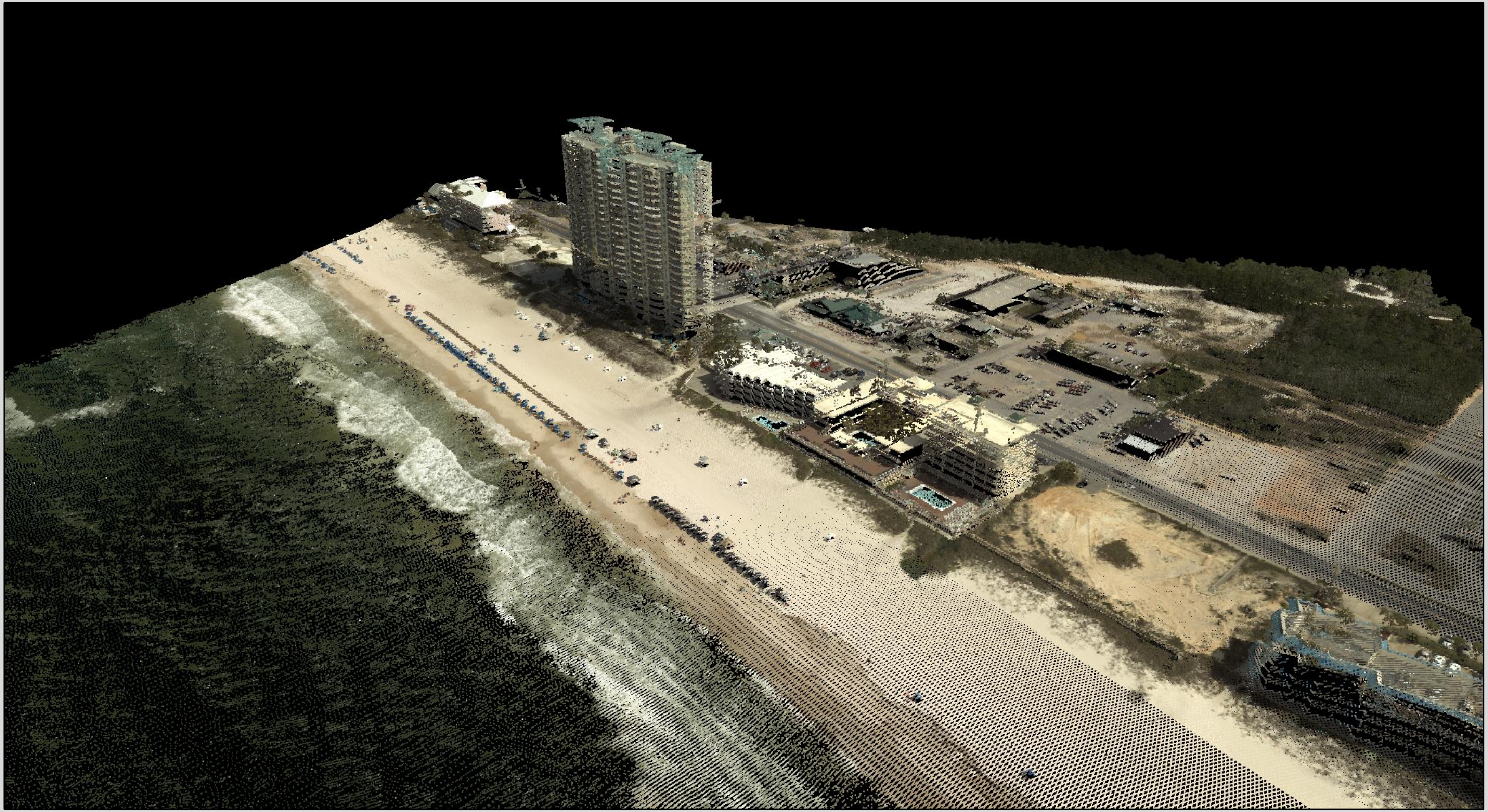
Elliptical Scan / Multiple Returns Allow Bathy Returns Under Vegetation



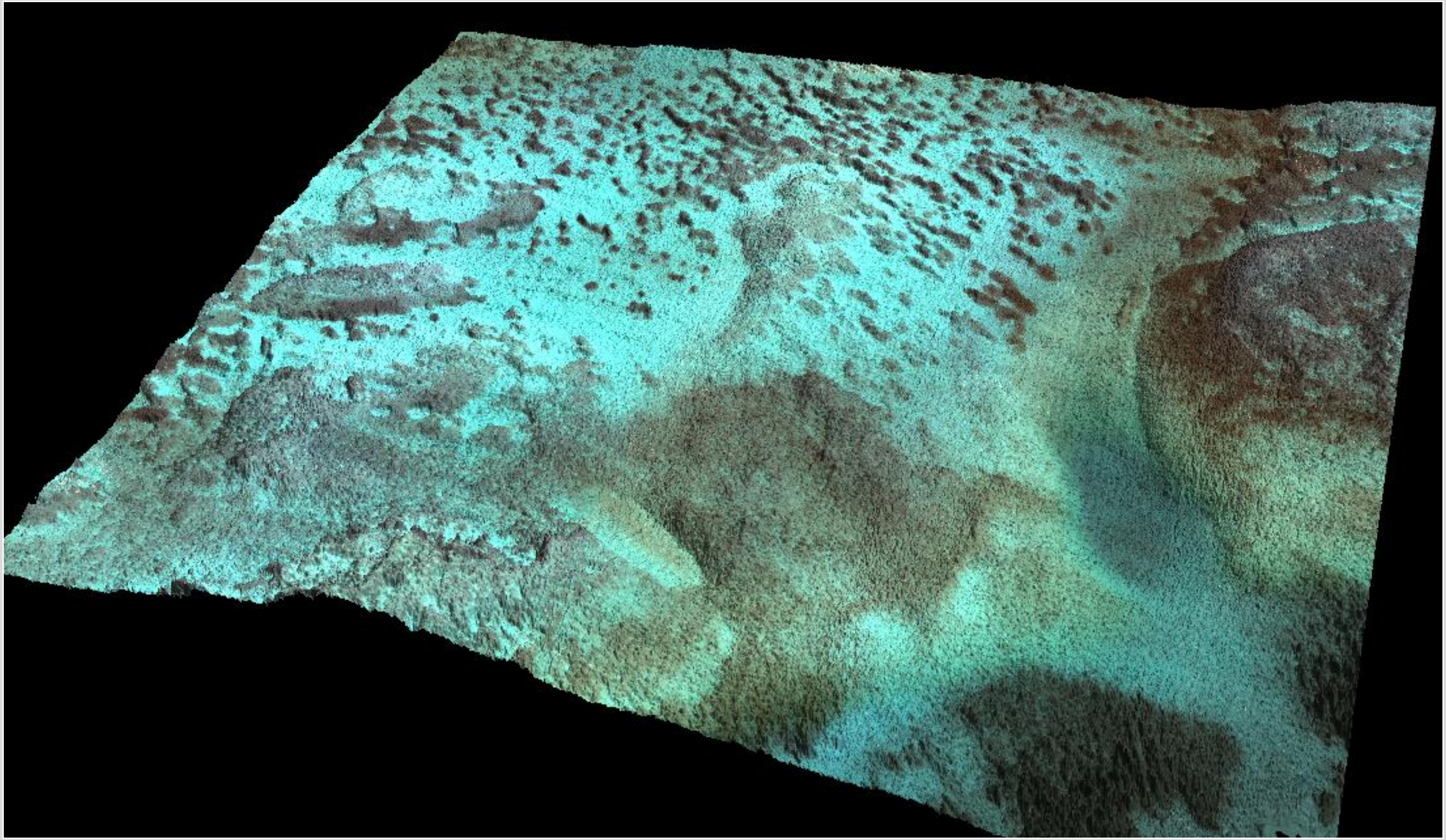
Seamless Model



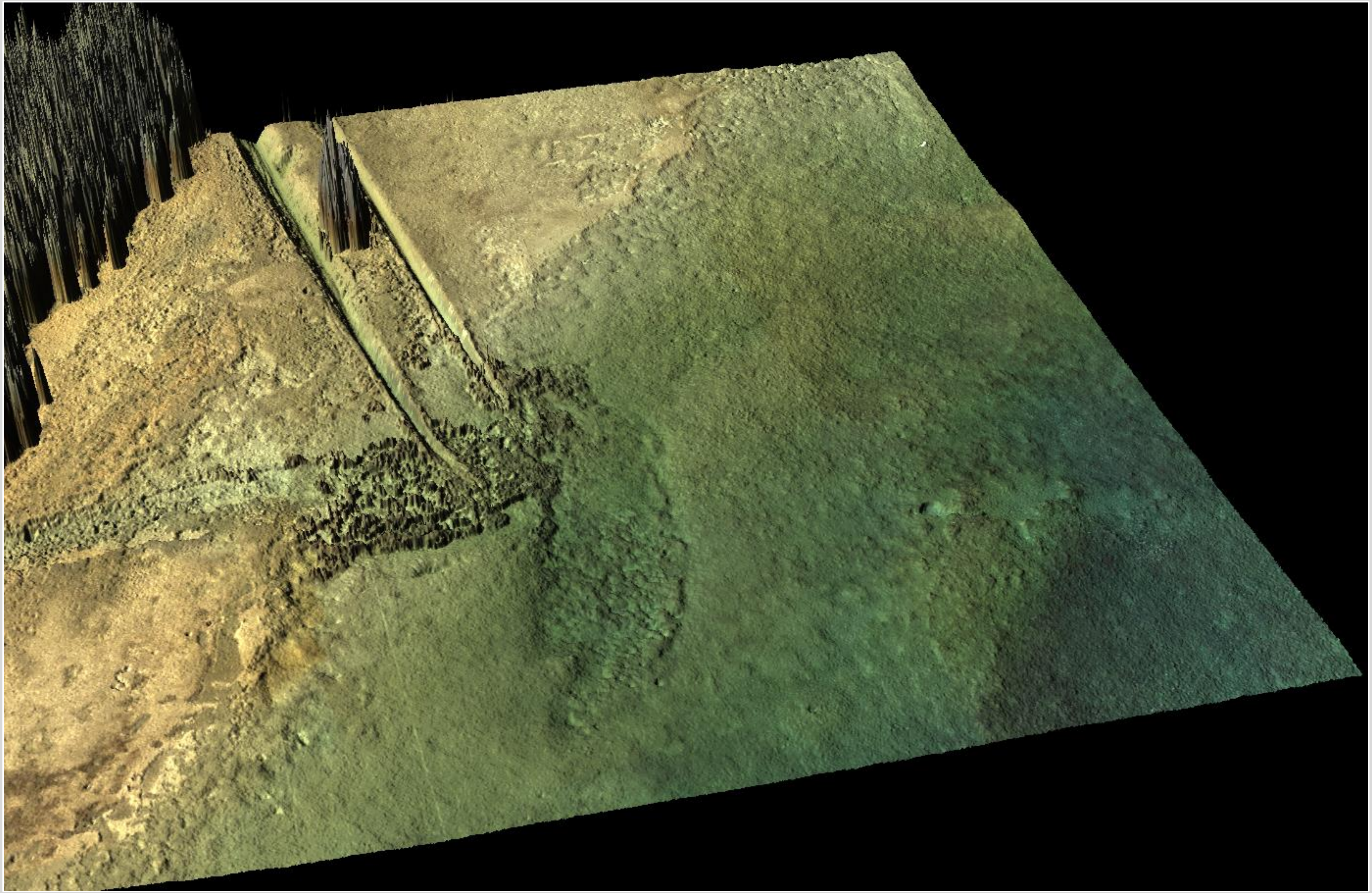
Elliptical Scan and Wave Action / Seamless Topo-Bathy



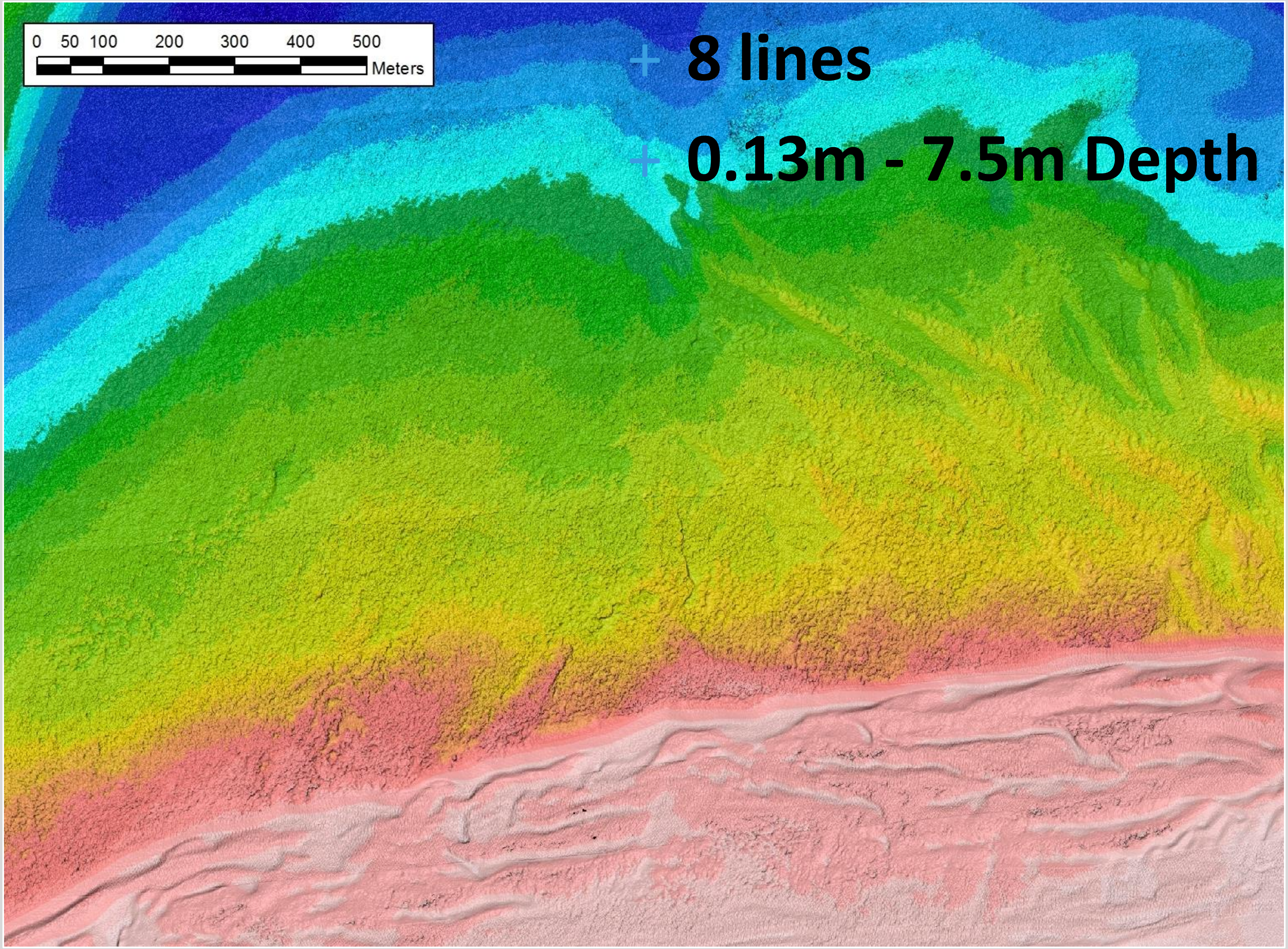
Sample Shallow Bathymetry Detail



SAMPLE SHALLOW BATHYMETRY DETAIL



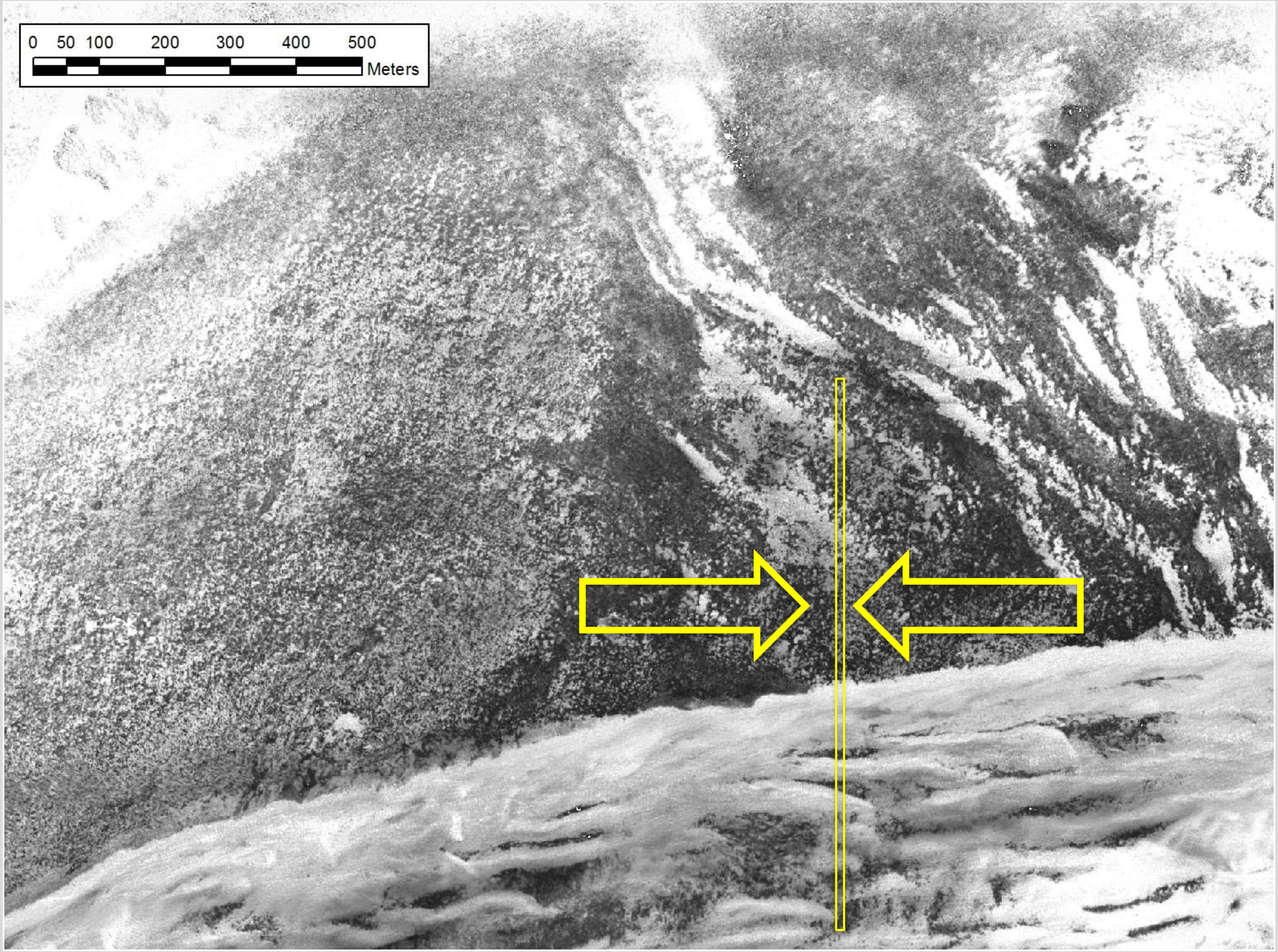
Elevation - Poel, Baltic Sea



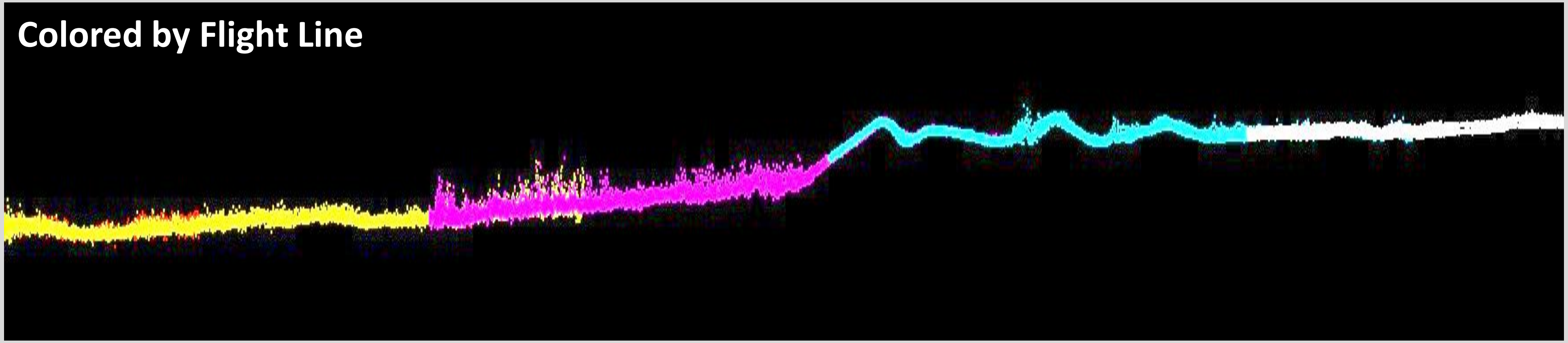
- 8 lines
- 0.13m - 7.5m Depth

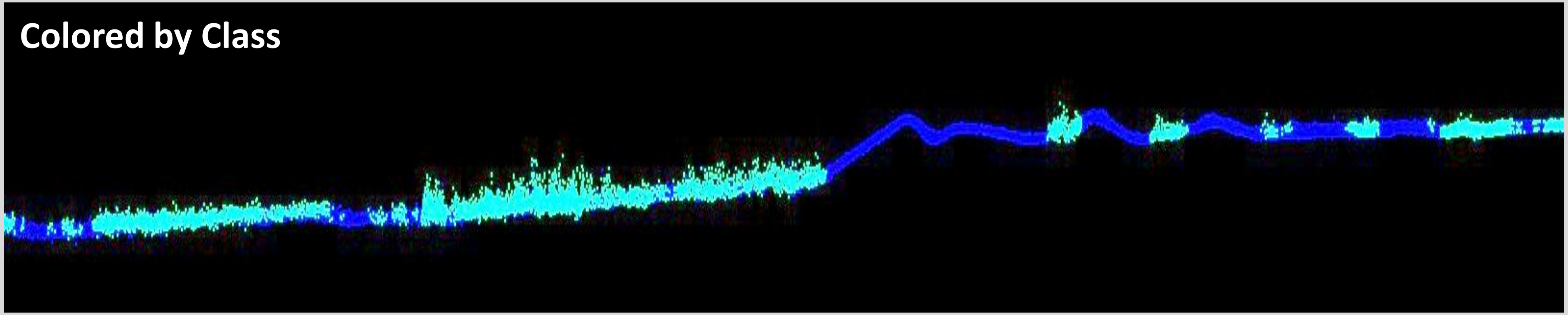

Raw Intensity
Corrected Intensity
Classified Image
Raster to Vector
Classify LAS

Intensity - Poel, Baltic Sea



- 20x Vertical Exaggeration
- Seagrass is approximately 25cm high



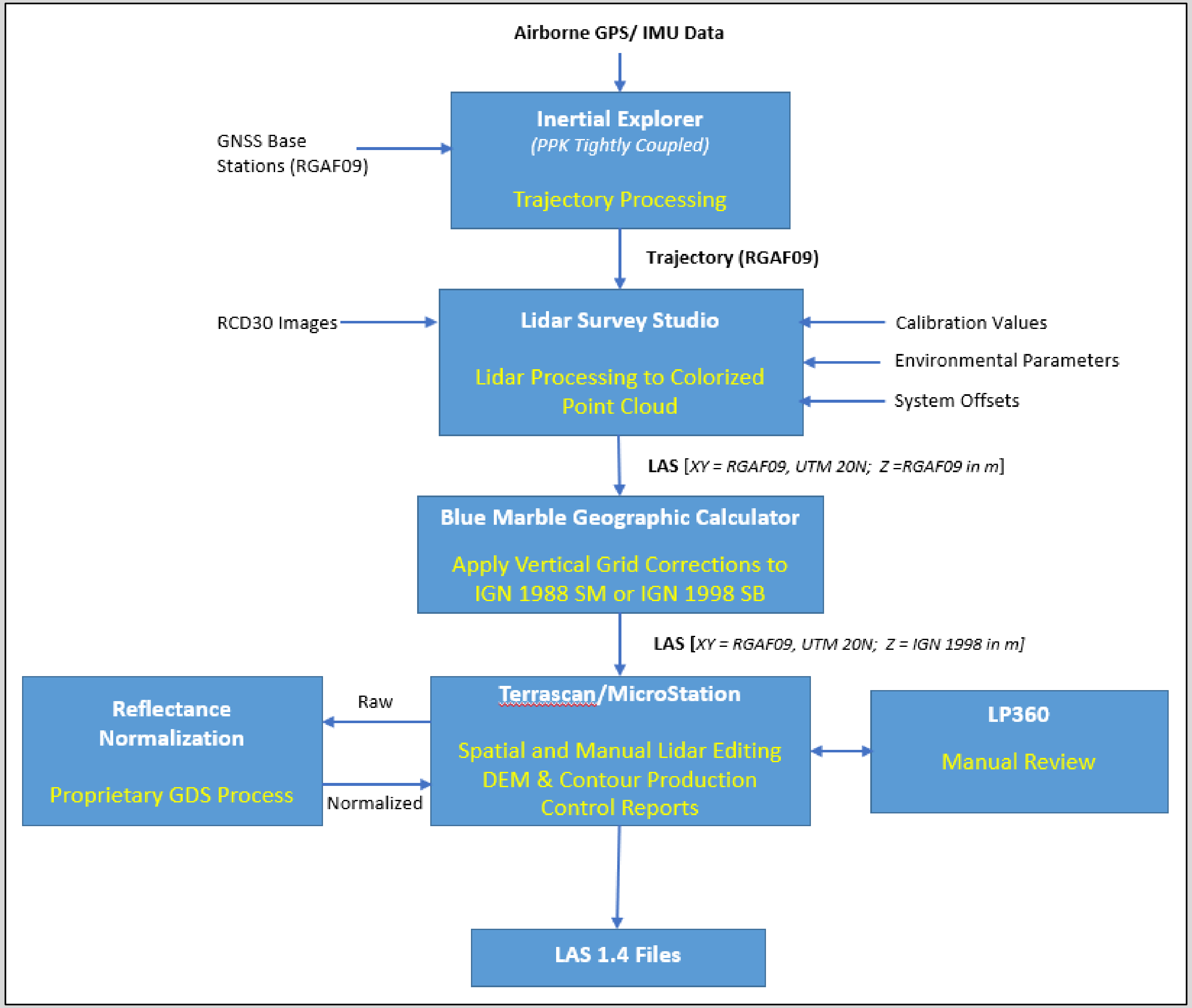


- GSD dependent on altitude: 3cm (0.1ft) to 18cm (0.6ft)

RGBN

Color Infrared

NDVI (Normalized Difference Vegetation Index)



Airborne GPS/ IMU Data
Inertial Explorer
(PPK Tightly Coupled)
Trajectory Processing
GNSS Base Stations (RGAF09)
Trajectory (RGAF09)
Lidar Survey Studio
Lidar Processing to Colorized Point Cloud
RCD30 Images
Calibration Values
Environmental Parameters
System Offsets
LAS [XY = RGAF09, UTM 20N; Z =RGAF09 in m]
Blue Marble Geographic Calculator
Apply Vertical Grid Corrections to IGN 1988 SM or IGN 1998 SB
LAS [XY = RGAF09, UTM 20N; Z = IGN 1998 in m]
Reflectance Normalization
Proprietary GDS Process
Raw
Normalized
Terrascan/MicroStation
Spatial and Manual Lidar Editing
DEM & Contour Production
Control Reports
LP360
Manual Review
LAS 1.4 Files

Thank You

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