Topo-Bathymetric Lidar: From Charting to mapping Benthic Habitat

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nscc Applied Research

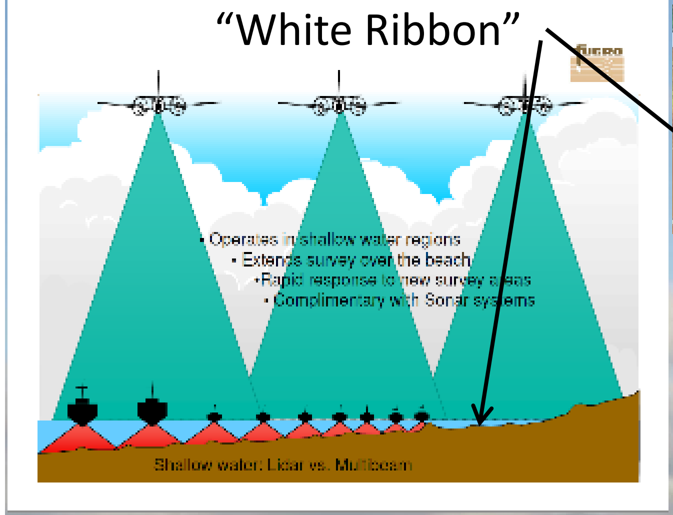
NSERC CRSNG

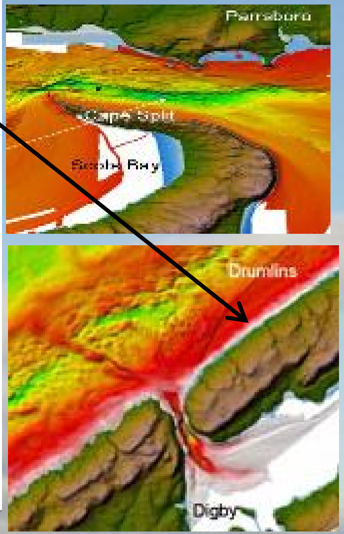
AGRG Applied Geomatics Research Group

INNOVATION.CA CANADA FOUNDATION FOR INNOVATION | FONDATION CANADIENNE POUR L'INNOVATION

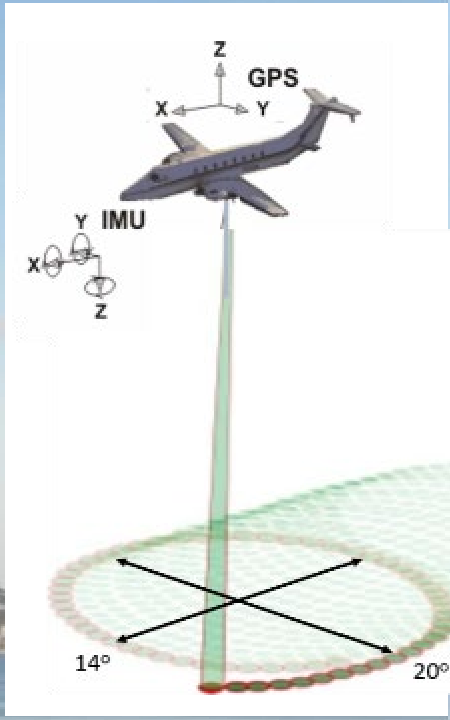
NSRIT Nova Scotia Research and Innovation Trust

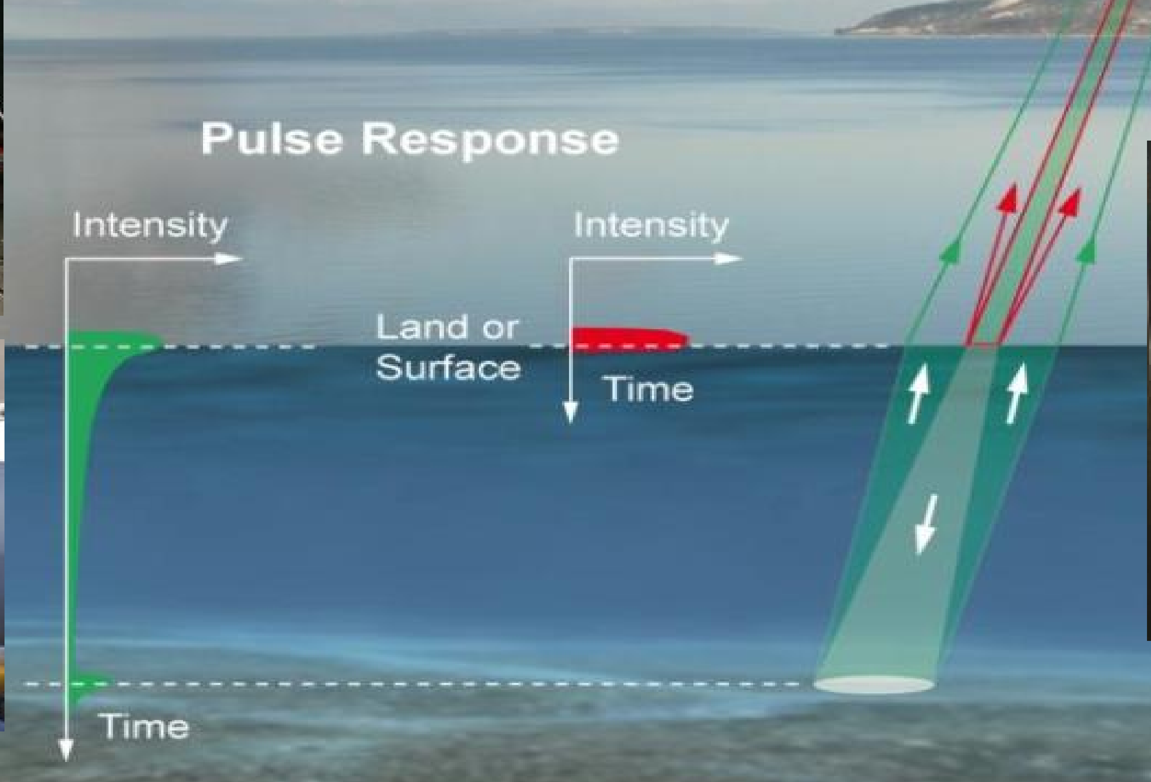
Chiroptera$_{II}$ – Lidar principles

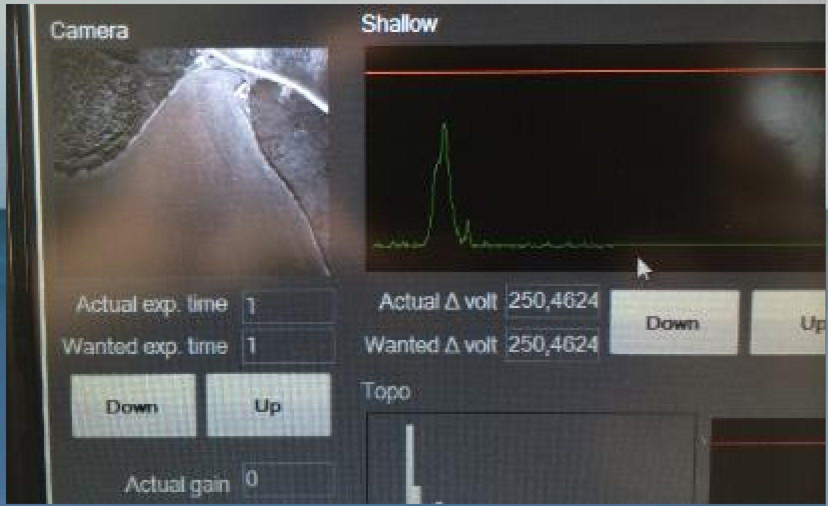




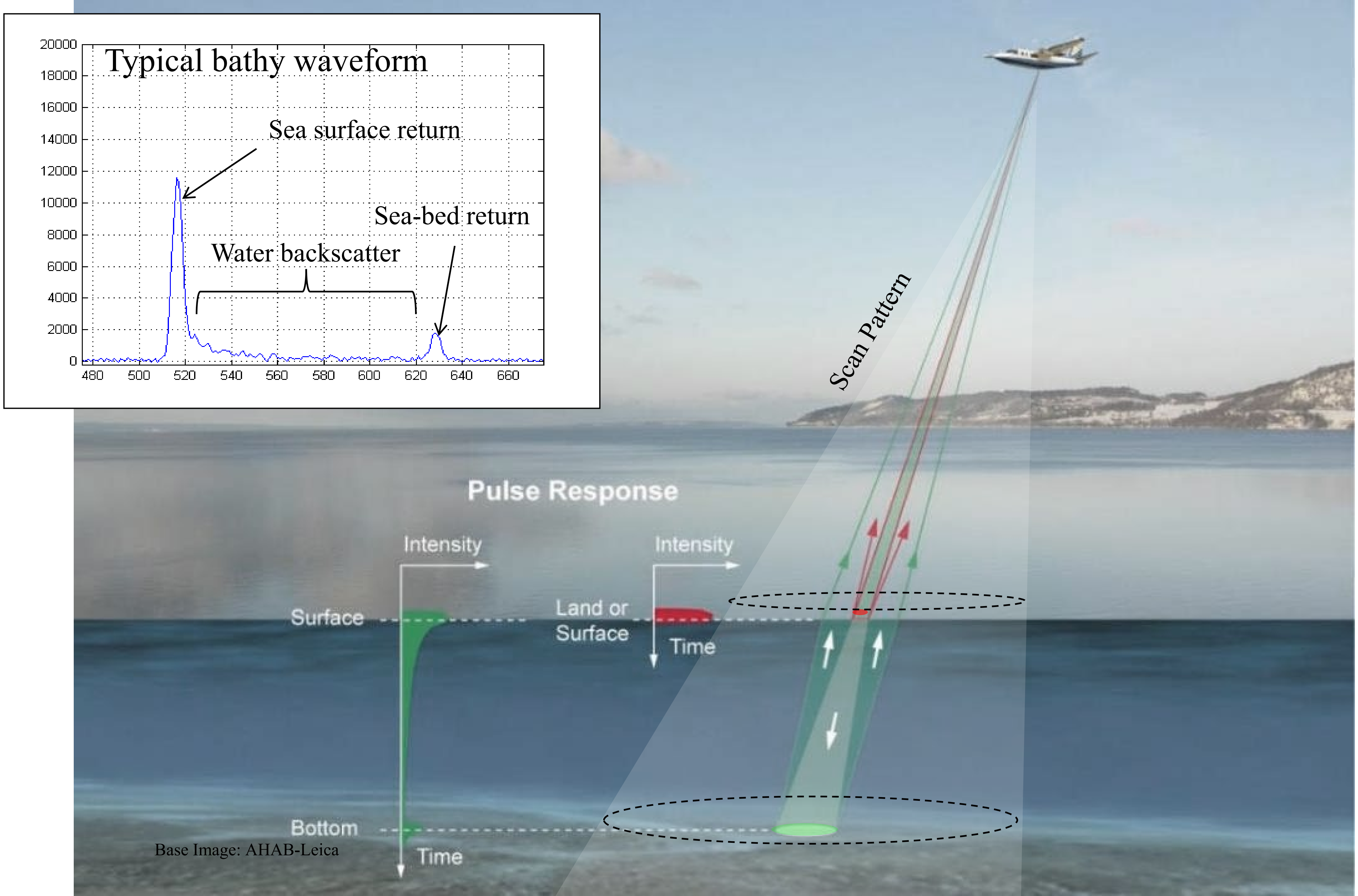
4 sensors
NIR laser 500kHz
Green laser 35 kHz
RCD30 60 MP RGB, NIR
5 MP QA camera

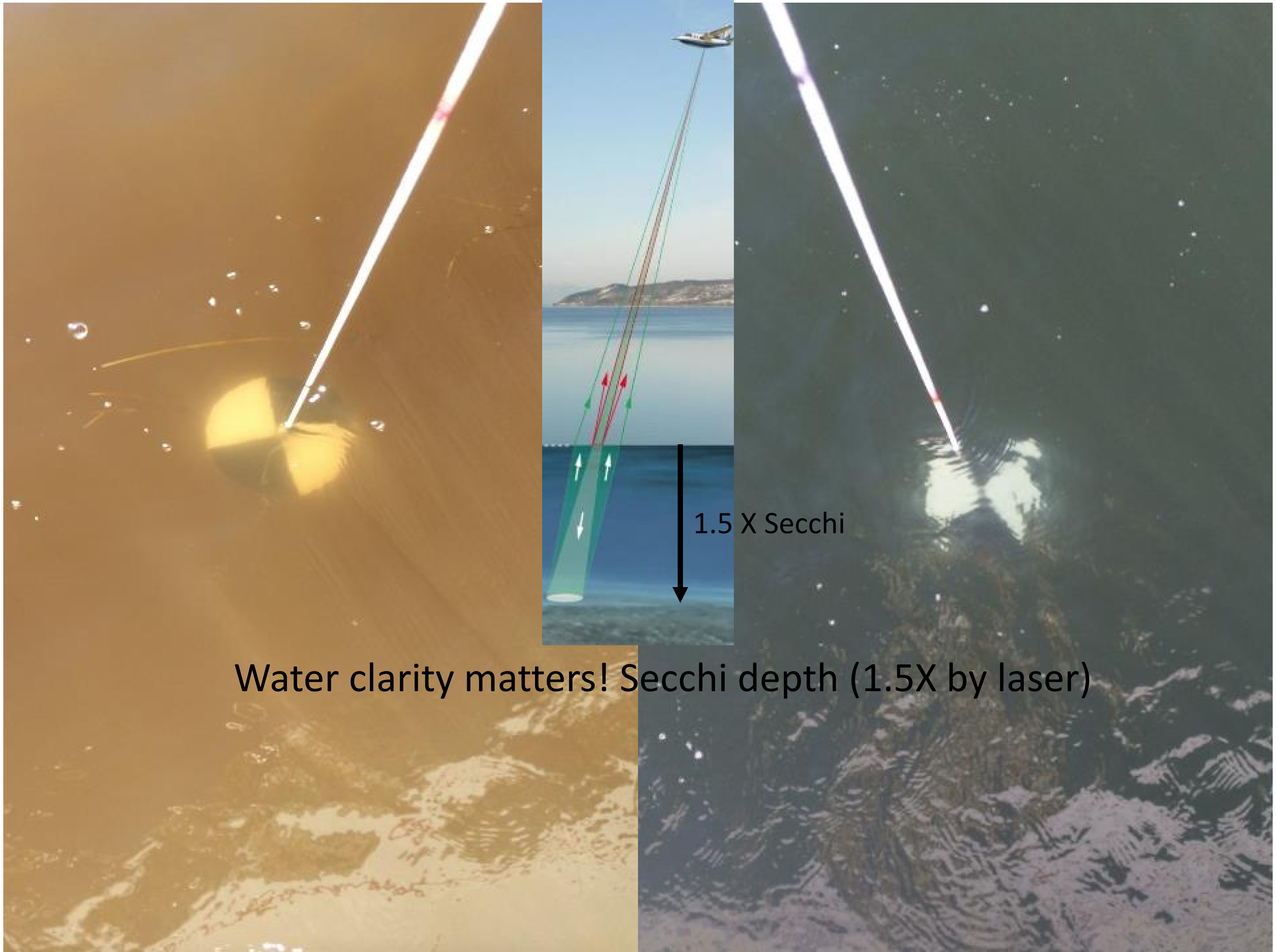




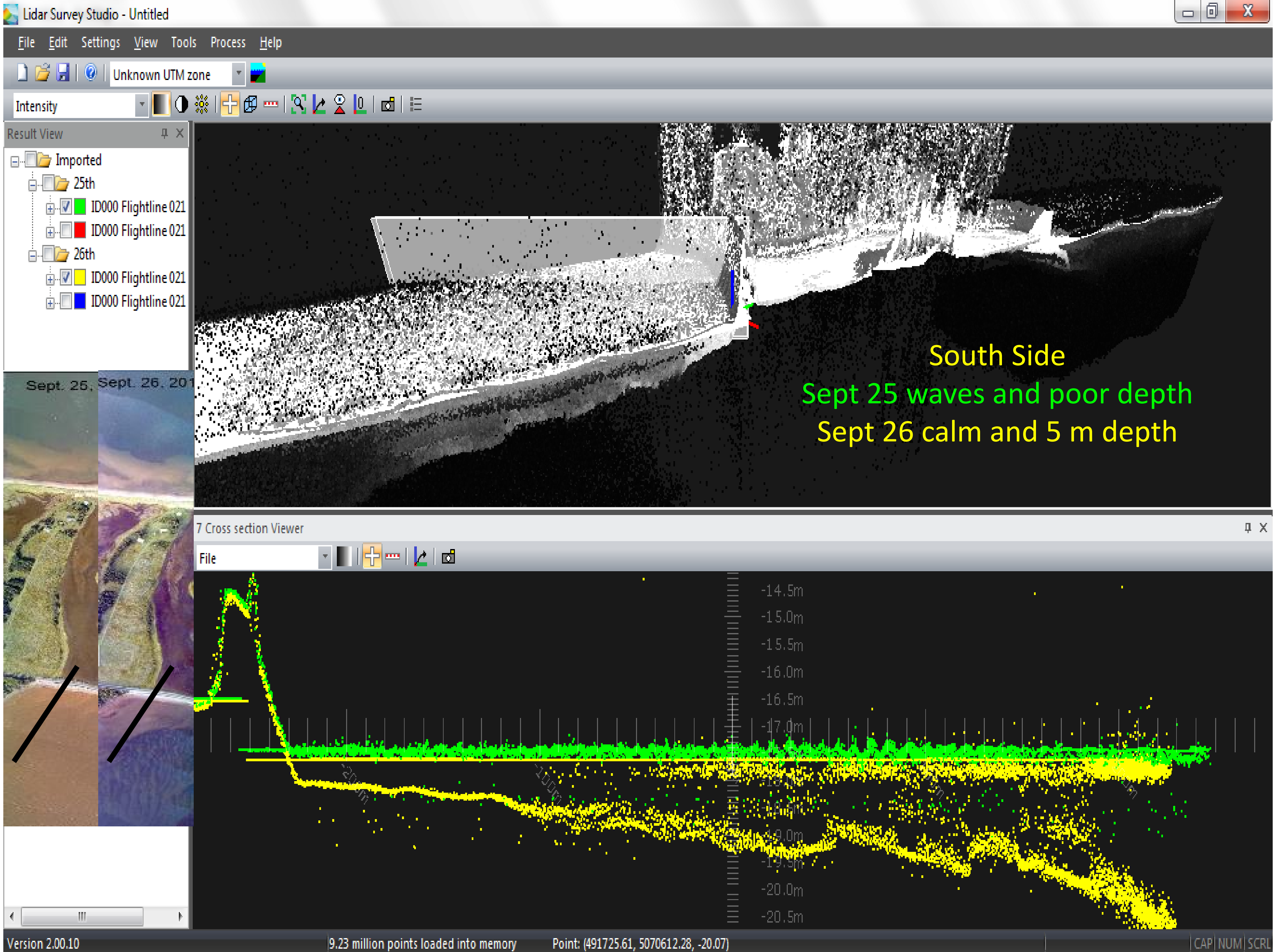


Source: Leica Geosystems


Typical bathy waveform
Sea surface return
Sea-bed return
Water backscatter
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
480
500
520
540
560
580
600
620
640
660
Scan Pattern
Pulse Response
Intensity
Intensity
Surface
Land or Surface
Time
Bottom
Time
Base Image: AHAB-Leica

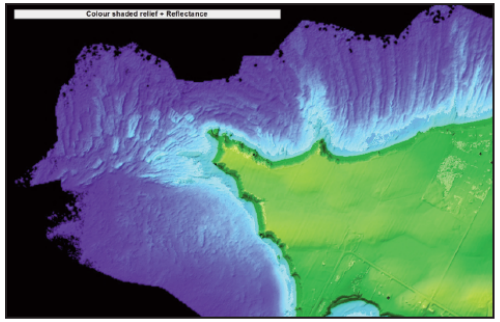


Water clarity matters! Secchi depth (1.5X by laser)


Lidar Survey Studio - Untitled
File Edit Settings View Tools Process Help
Unknown UTM zone
Intensity
Result View
Imported
25th
ID000 Flightline 021
ID000 Flightline 021
26th
ID000 Flightline 021
ID000 Flightline 021
Sept. 25,
Sept. 26, 201
South Side
Sept 25 waves and poor depth
Sept 26 calm and 5 m depth
7 Cross section Viewer
File
-14.5m
-15.0m
-15.5m
-16.0m
-16.5m
-17.0m
-20.0m
-20.5m
Version 2.00.10
9.23 million points loaded into memory
Point: (491725.61, 5070612.28, -20.07)
CAP NUM SCRL

The use of Topo-bathymetric lidar to enhance Geological Structural Mapping in Maritime Canada. GeoScience Canada.Vol. 43;

SERIES



Remote Predictive Mapping 7. The Use of Topographic–Bathymetric Lidar to Enhance Geological Structural Mapping in Maritime Canada

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SUMMARY
An airborne topo-bathymetric lidar survey was conducted at Cape John, on the north shore of Nova Scotia, Canada, using the shallow water Leica AHAB Chiroptera II sensor. The survey revealed new bedrock features that were not discovered using previous mapping methods. A thick blanket of glacial till covers the bedrock on land, and outcrops are exposed only along the coastal cliffs and offshore reefs. The seamless land-seabed digital elevation model produced from the lidar survey revealed significant bedrock outcrop offshore where ocean currents have removed the glacial till, a significant finding that was hitherto hidden under the sea surface. Several reefs were identified offshore as well as a major fold structure where block faulting occurs along the limbs of the fold. The extension of the Malagash Mine Fault located ~10 km west of Cape John is proposed to explain the local folding and faulting visible in the submerged outcrops. The extension of this fault is partially visible on land, where it is obscured by glacial till, and its presence is supported by the orientation of submerged bedding and lineaments on both the south and north sides of Cape John. This paper demonstrates how near-shore high-resolution topography from bathymetric lidar can be used to enhance and refine geological mapping.

RÉSUMÉ
Un levé lidar topo-bathymétrique été réalisé à Cape John, sur la rive nord de la Nouvelle-Écosse, Canada, en utilisant un capteur Leci AHAB Chiroptera II. Ce levé a permis de repérer des affleurements que les méthodes de cartographie plus anciennes n'avaient pu détecter. Une épaisse couche de till glaciaire recouvre la roche en place sur le continent, et la roche affleure seulement le long des falaises côtières et des récifs côtiers. Le modèle numérique de dénivelé en continu terres et fonds marins obtenu par le levé lidar a révélé l'existence d'affleurement rocheux considérables au large des côtes, là où les courants océaniques ont emporté le till glaciaire, une découverte importante demeurée cachée sous la surface de la mer jusqu'alors. Plusieurs récifs ont été identifiés au large des côtes, ainsi qu'une structure de pli majeure, à l'endroit où se produit un morcellement en blocs le long des flancs du pli. Une extension de la faille de la mine Malagash situé ~ 10 km à l'ouest de Cape John est proposé pour expliquer les plis et les failles locaux visibles dans les affleurements submergés. L'extension de cette faille est partiellement visible sur la terre, voilée par le till, et sa présence est étayée par l'orientation de la stratification et des linéaments submergés tant du côté sud que nord de Cape John. Cet article montre comment la topographie haute résolution du lidar bathymétrique peut être utilisée pour améliorer et affiner la cartographie géologique.

Traduit par le Traducteur

INTRODUCTION
In this paper we present the results of offshore coastal mapping using airborne topo-bathymetric lidar at Cape John, Nova Scotia along the Northumberland Strait in the Gulf of St. Lawrence (Fig. 1). Traditional remote sensing mapping methods such as aerial photography and boat-based echo sounding used in the mapping of geological structures on the seabed can be difficult, time-consuming and expensive to locate. It is generally assumed that terrestrial outcrops extend underwater; Cape John is known to have outcrops along the coast but there

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Optimization of Data Collection and Refinement of Post-processing Techniques for Maritime Canada's First Shallow Water Topographic-bathymetric Lidar Survey

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ABSTRACT

Webster, T.; McGuigan, K.; Crowell, N.; Collins, K., and MacDonald, C., 2016. Optimization of data collection and refinement of post-processing techniques for Maritime Canada's first shallow water topographic-bathymetric lidar survey. *In*: Brock, J.C.; Gesch, D.B.; Parrish, C.E.; Rogers, J.N., and Wright, C.W. (eds.), *Advances in Topobathymetric Mapping, Models, and Applications. Journal of Coastal Research*, Special Issue, No. 76, pp. 31–43. Coconut Creek (Florida), ISSN 0749-0208.

An airborne topographic-bathymetric lidar survey was conducted for five coastal study sites in Maritime Canada in fall 2014 using the shallow water Leica AHAB Chiroptera II sensor. The sensor utilizes near-infrared (NIR) and green lasers to map topography, water surface, and bathymetry, and is equipped with a 60 MPIX camera, which results in 5-cm resolution color and NIR orthophotos. Depth penetration of the lidar sensor is limited by water clarity, and because the coastal zone is vulnerable to reduced water clarity/increased turbidity due to fine-grained sediment suspended by wind-induced waves, several techniques were employed to obtain maximum depth penetration of the sensor. These included monitoring wind speed, direction, and water clarity at study locations, surveying a narrow pass of the study area to assess depth penetration, and quickly adapting to changing weather conditions by altering course to an area where water clarity was less affected by wind-induced turbidity. These techniques enabled 90% depth penetration at all five of the shallow embayments surveyed and up to 6 m depth penetration in the exposed coastal region. Synchronous ground truth surveys were conducted to measure water depth and clarity and seabed cover during the surveys. GPS checkpoints on land indicated that the topographic lidar had an accuracy of better than 10 cm RMSE in the vertical. The amplitude of the green laser bathymetric returns provides information on bottom type and can be useful for generating maps of vegetation distribution. However, these data are not automatically compensated for water depth attenuation and signal loss in post-processing, which results in difficulties in interpreting the amplitude imagery derived from the green laser. An empirical approach to generating a depth-normalized amplitude image which is merged with elevation derivatives to produce a 2-m resolution map product that is easily interpreted by end users is presented. An eelgrass distribution model was derived from the bathymetric elevation parameters with 80% producer's accuracy.

ADDITIONAL INDEX WORDS: *Eelgrass, lidar seabed reflectance, depth normalization, seabed classification.*

INTRODUCTION
The coastal zone of Maritime Canada is estimated to be >11,000 km (Sebert and Monroe, 1972, 1:250,000 scale). The coast plays a significant role in the economy of Maritime Canada through tourism, recreation, fishing, aquaculture, and industry (Fisheries and Oceans Canada, 2008) and has the potential to support more economic development (Tedsen *et al.*, 2014). As the global climate changes, Maritime Canada's coast is at risk from rising sea level and increased erosion (Forbes *et al.*, 2009; Peltier, 2004; Rahmstorf *et al.*, 2007; Shaw *et al.*, 1998; Stocker *et al.*, 2013), and ecosystems are threatened by declining eelgrass and fish habitat (AMEC Earth & Environmental, 2007; Fisheries and Oceans Canada, 2009; Hanson, 2004). The requirement for accurate and detailed mapping of shorelines, nearshore bathymetry, and coastal ecosystems is imperative in order to protect existing infrastructure and vulnerable habitat from erosion and flooding, plan for future sustainable development, and make sound decisions with regard to controversial activities that support economic growth, such as aquaculture and energy infrastructure.

Mapping the coastal zone using traditional aerial photography or boat-based echo sounder methods can be expensive, time consuming, and challenging in shallow water (Elhassan, 2015; Waddington and Hart, 2003). Airborne topographic-bathymetric (topobathy) lidar overcomes these challenges by utilizing a near-infrared (NIR) laser for topographic data collection and a green laser for bathymetric data collection to generate high-resolution, continuous land-sea digital elevation models (DEMs) and aerial orthophoto mosaics. Although shallow water topobathymetric lidar (TBL) sensors are relatively new, the deeper water airborne laser bathymetry (ALB) sensors have been used to demonstrate a variety of coastal research applications ranging from bottom classification and fine-detail bathymetry mapping to coastal management; many of these uses of ALB are summarized in Brock and Purkis (2009). ALB has been demonstrated in

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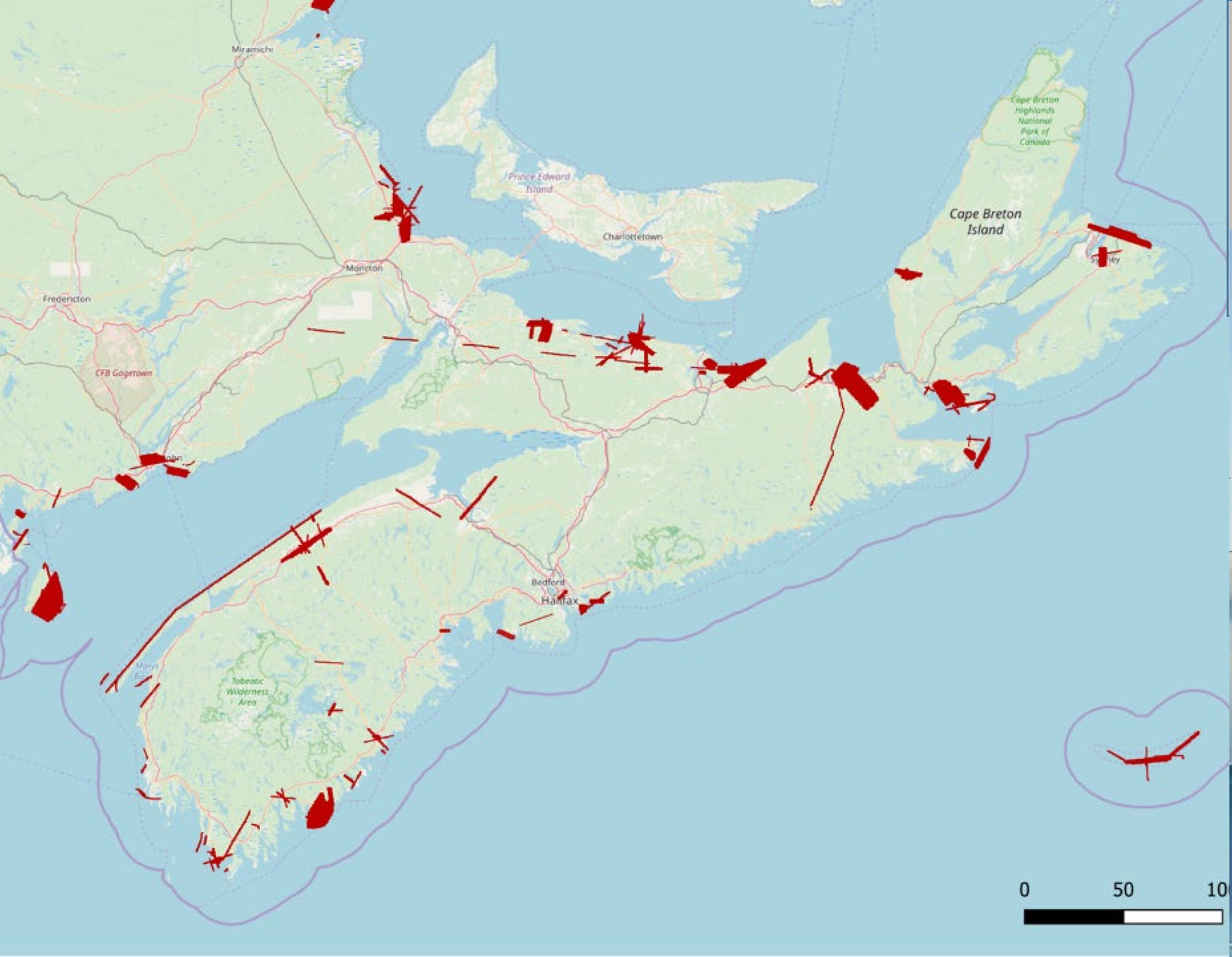
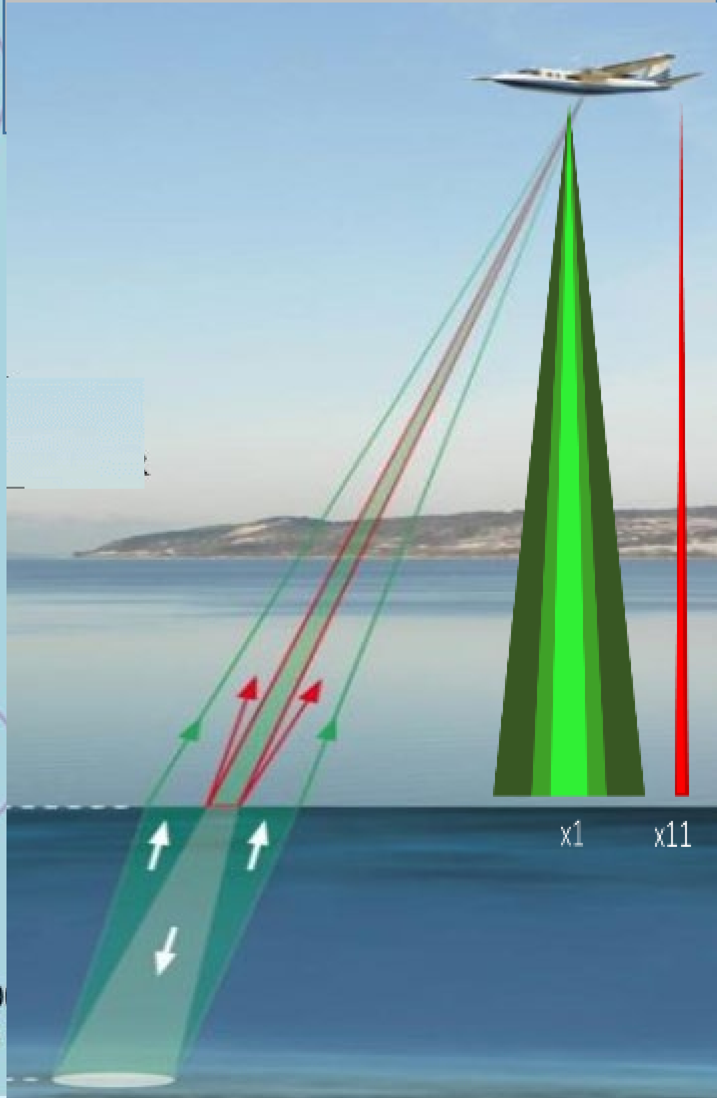
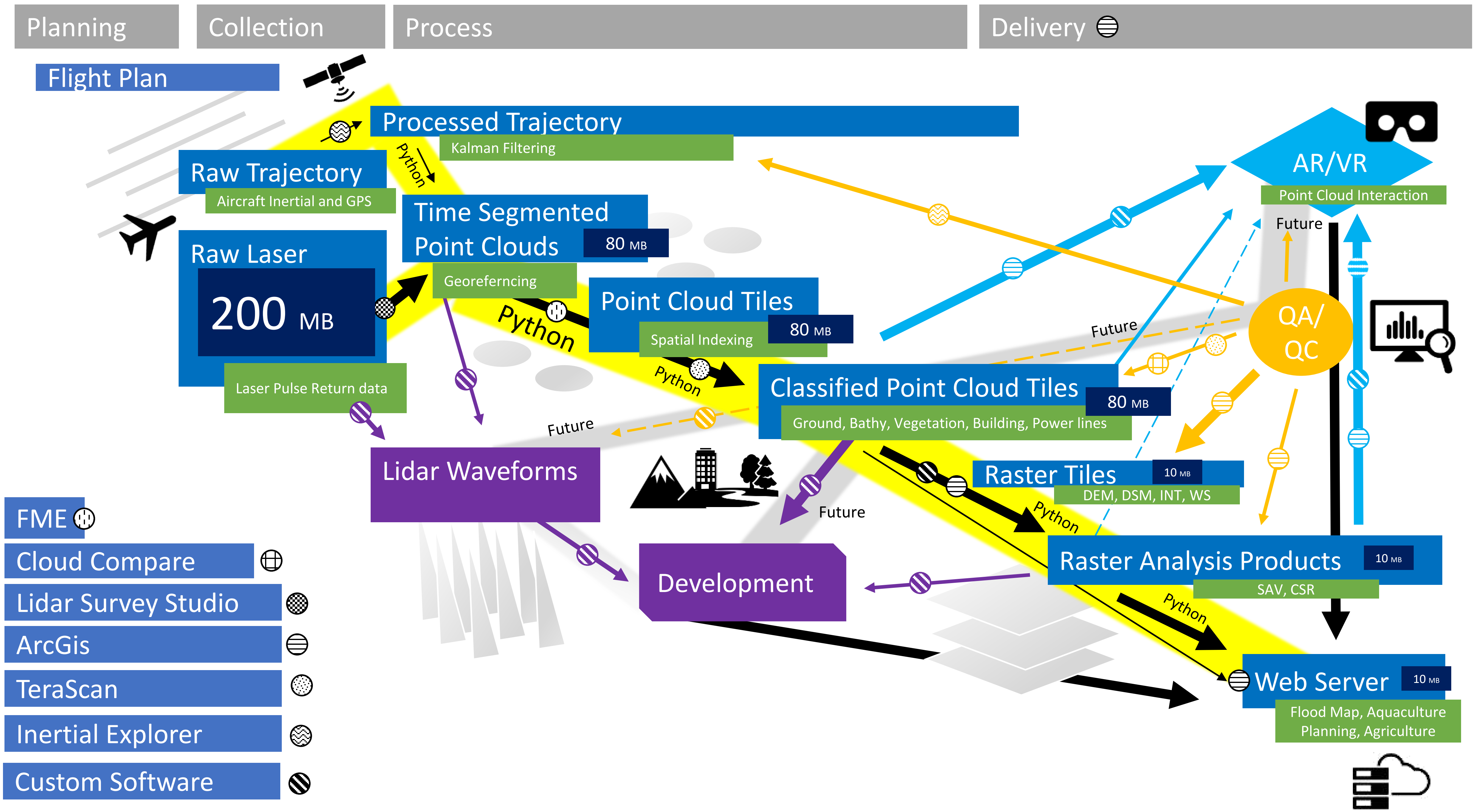


Operation since 2014
>81 collection flights
>127.3 hours on flight
>16.4 tb
>4303 sq. km.

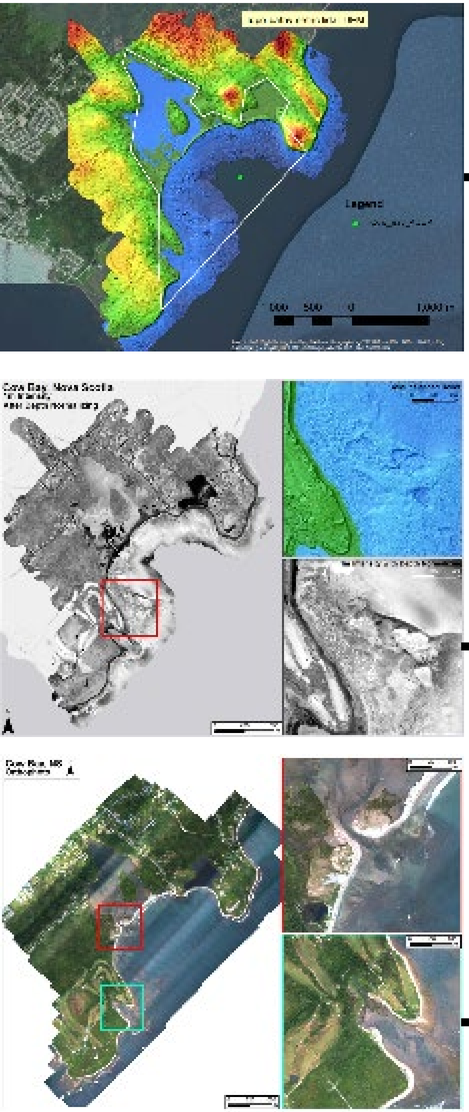




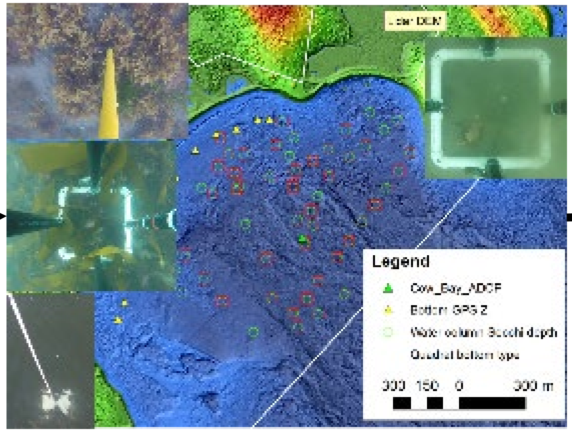
Planning
Collection
Process
Delivery
Flight Plan
Processed Trajectory
Kalman Filtering
Python
Raw Trajectory
Aircraft Inertial and GPS
Time Segmented Point Clouds
80 MB
Raw Laser
200 MB
Georeferncing
Python
Point Cloud Tiles
80 MB
Spatial Indexing
Python
Laser Pulse Return data
Classified Point Cloud Tiles
80 MB
Ground, Bathy, Vegetation, Building, Power lines
Future
Lidar Waveforms
Future
Raster Tiles
10 MB
DEM, DSM, INT, WS
Python
AR/VR
Point Cloud Interaction
Future
Future
QA/ QC
Development
Raster Analysis Products
10 MB
SAV, CSR
Python
Web Server
10 MB
Flood Map, Aquaculture Planning, Agriculture
FME
Cloud Compare
Lidar Survey Studio
ArcGis
TeraScan
Inertial Explorer
Custom Software

Research & Development of additional map products

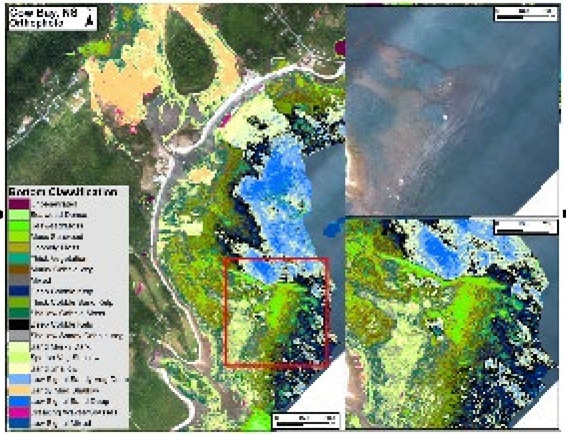
Raster Products



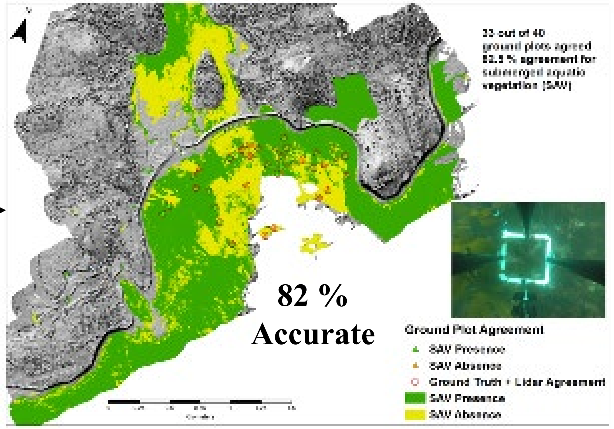
Ground Truth Support



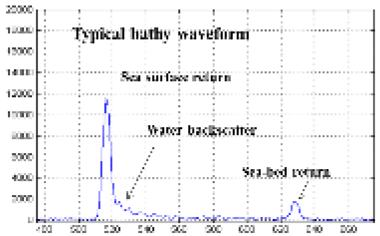
Bottom "benthic habitat" Map

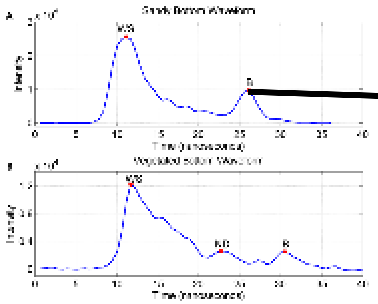


Submerged Aquatic Vegetation Map



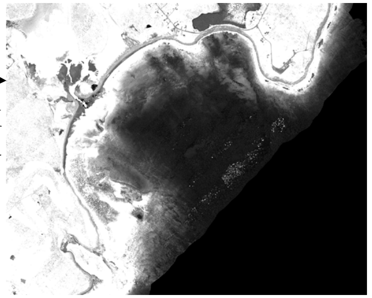
Development





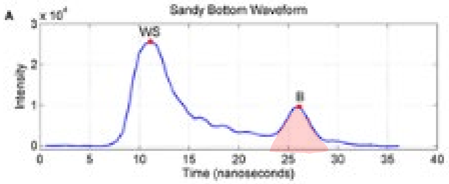
Photo

Peak Intensity

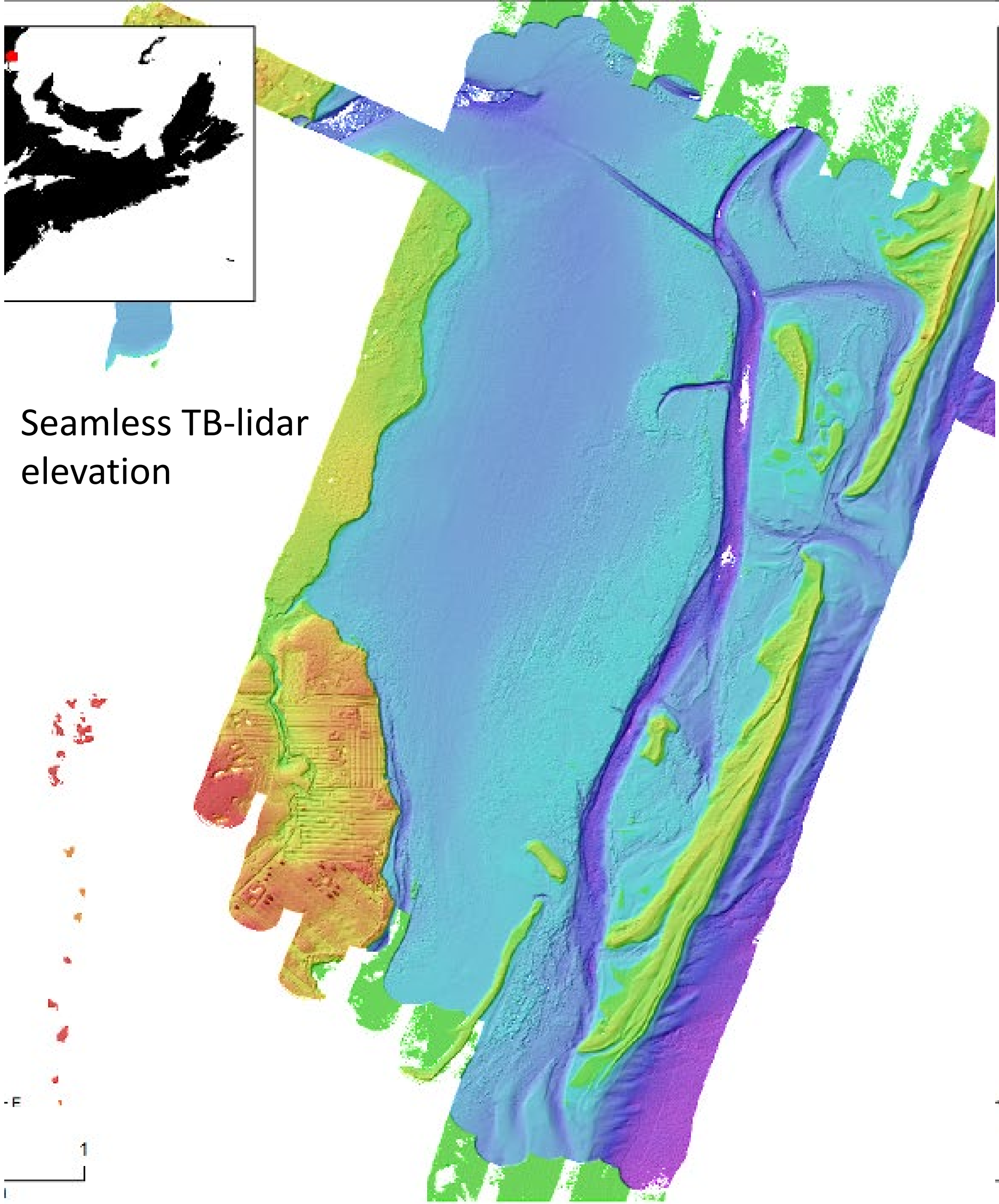


Area Under the Curve

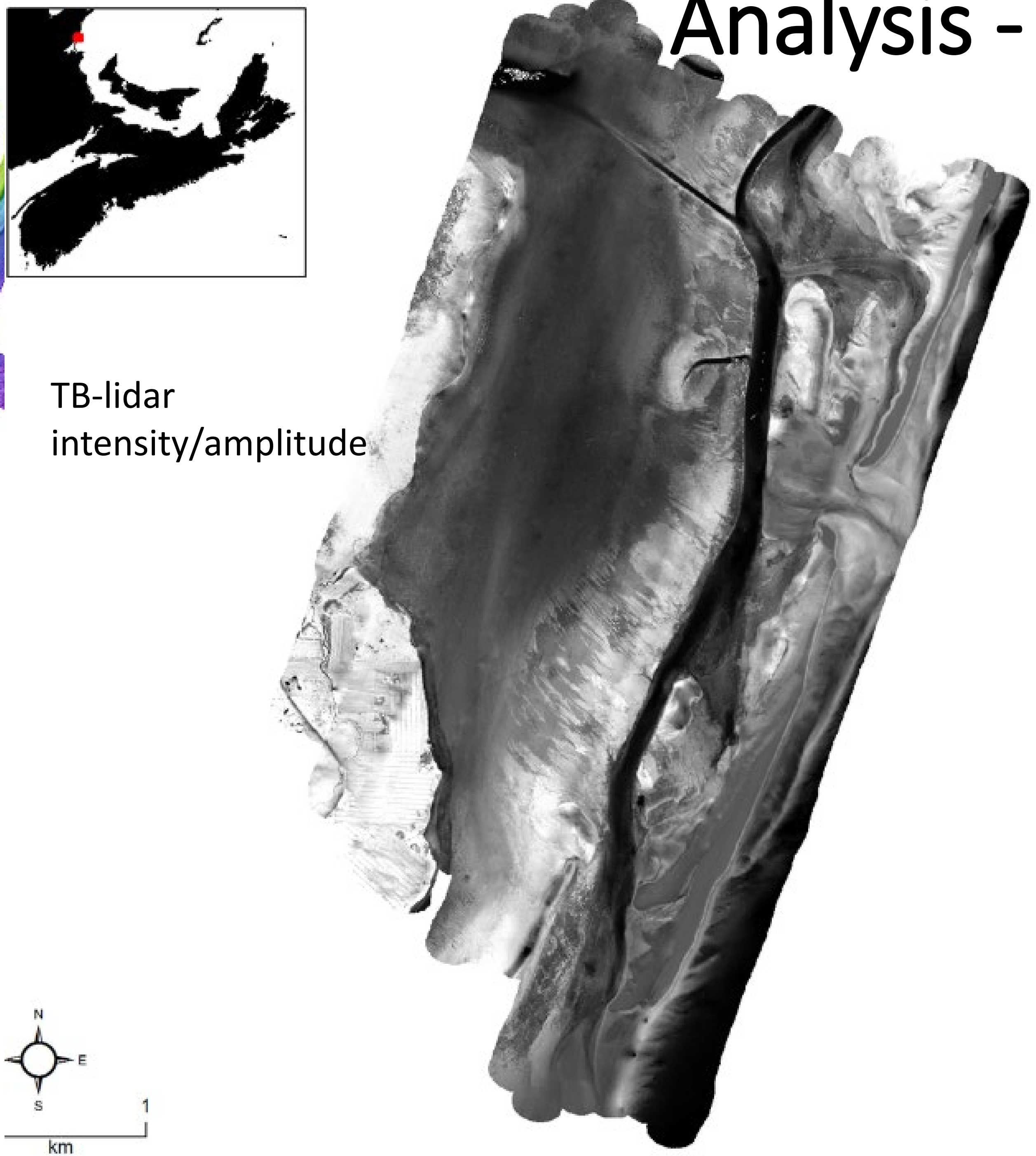
Area Under the Curve Normalized by Depth



Analysis - Ee

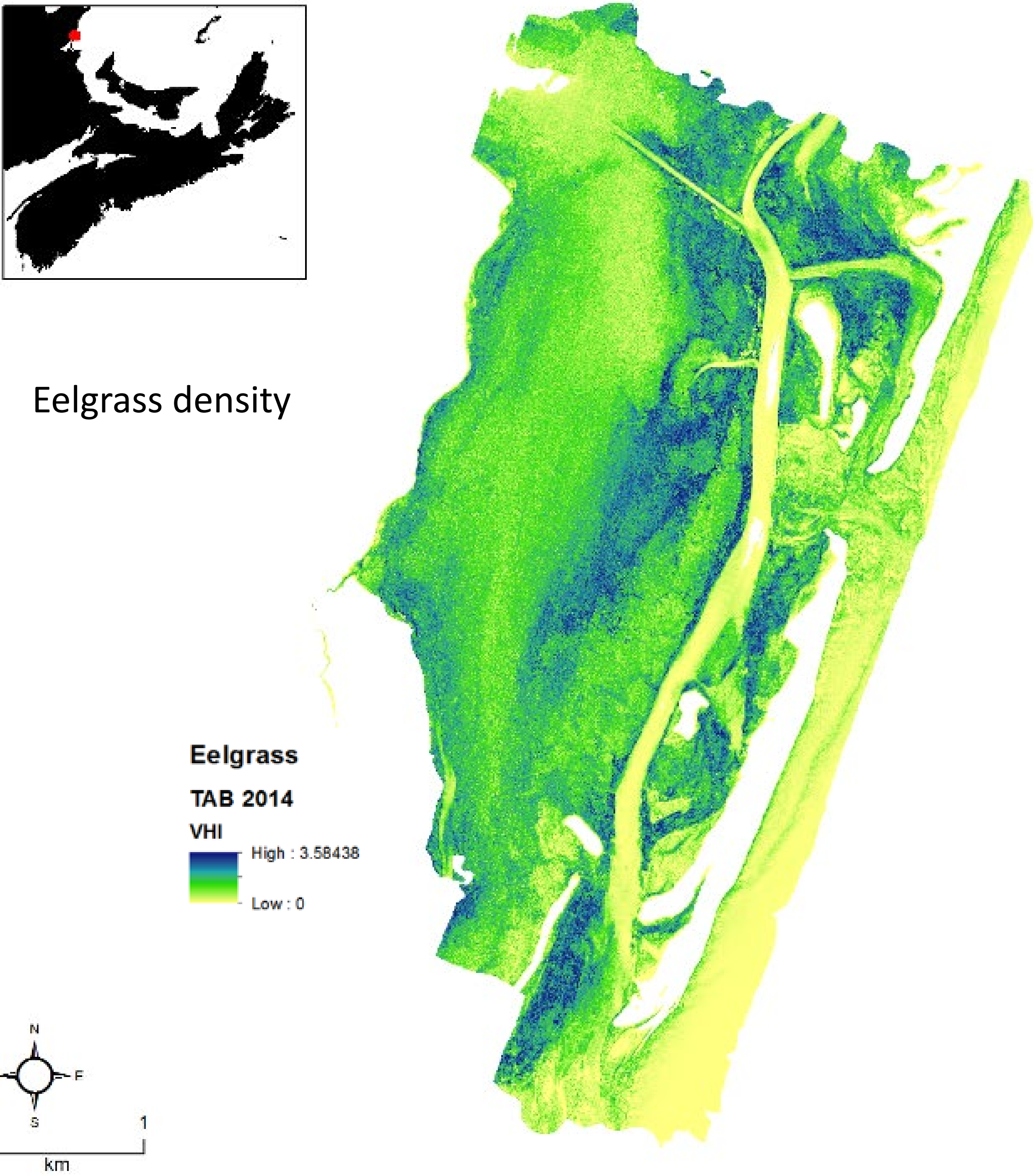


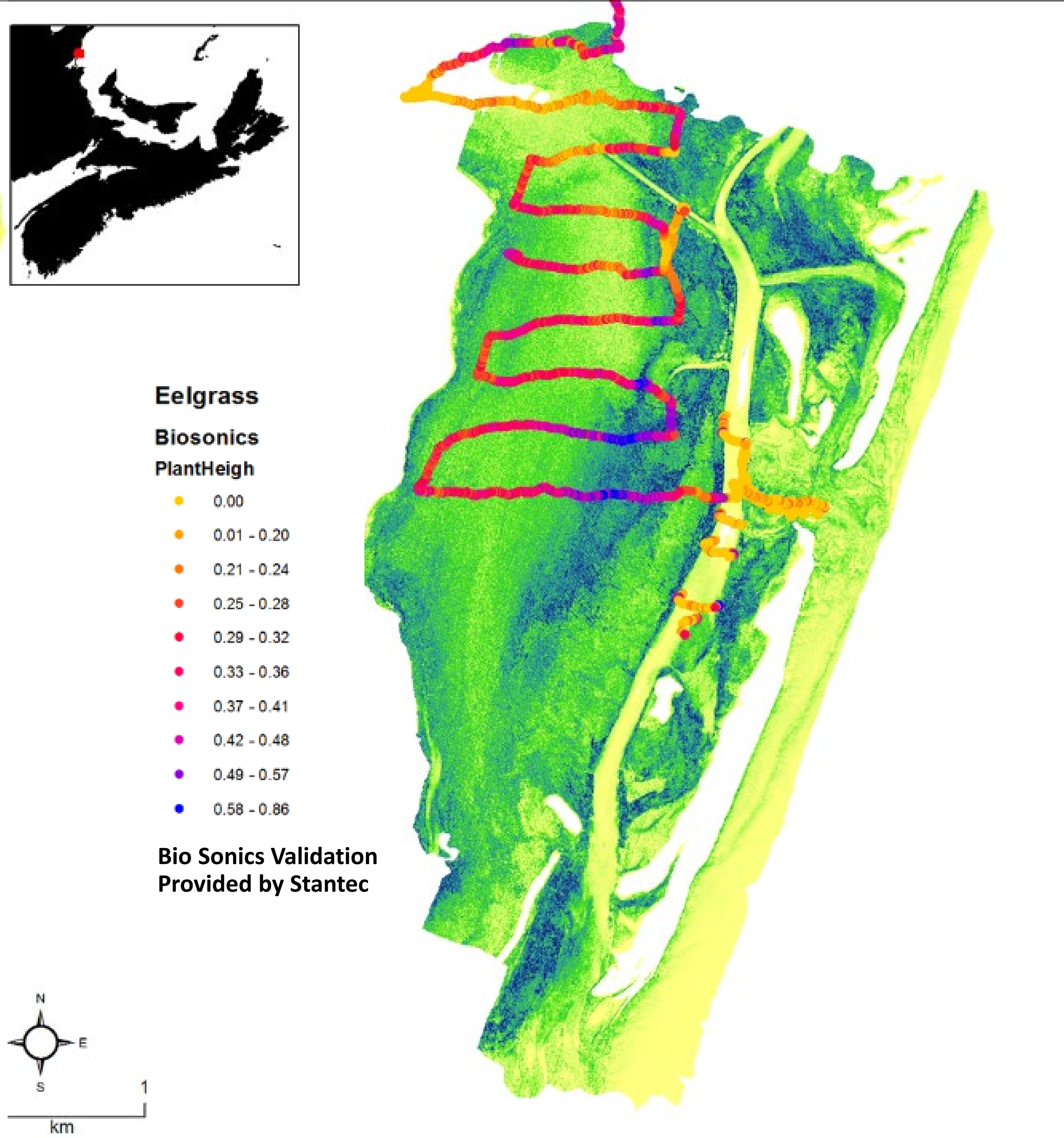
Seamless TB-lidar elevation

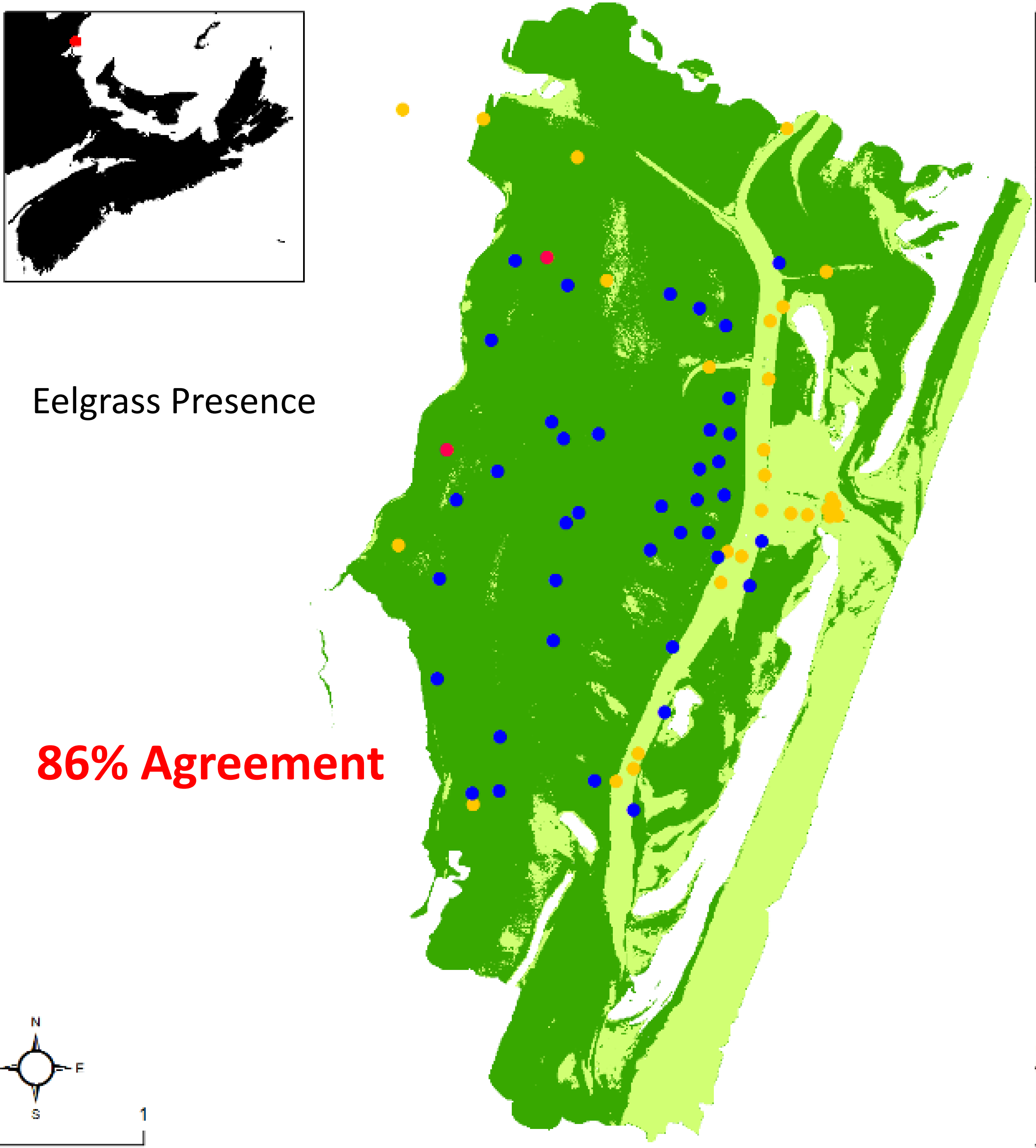


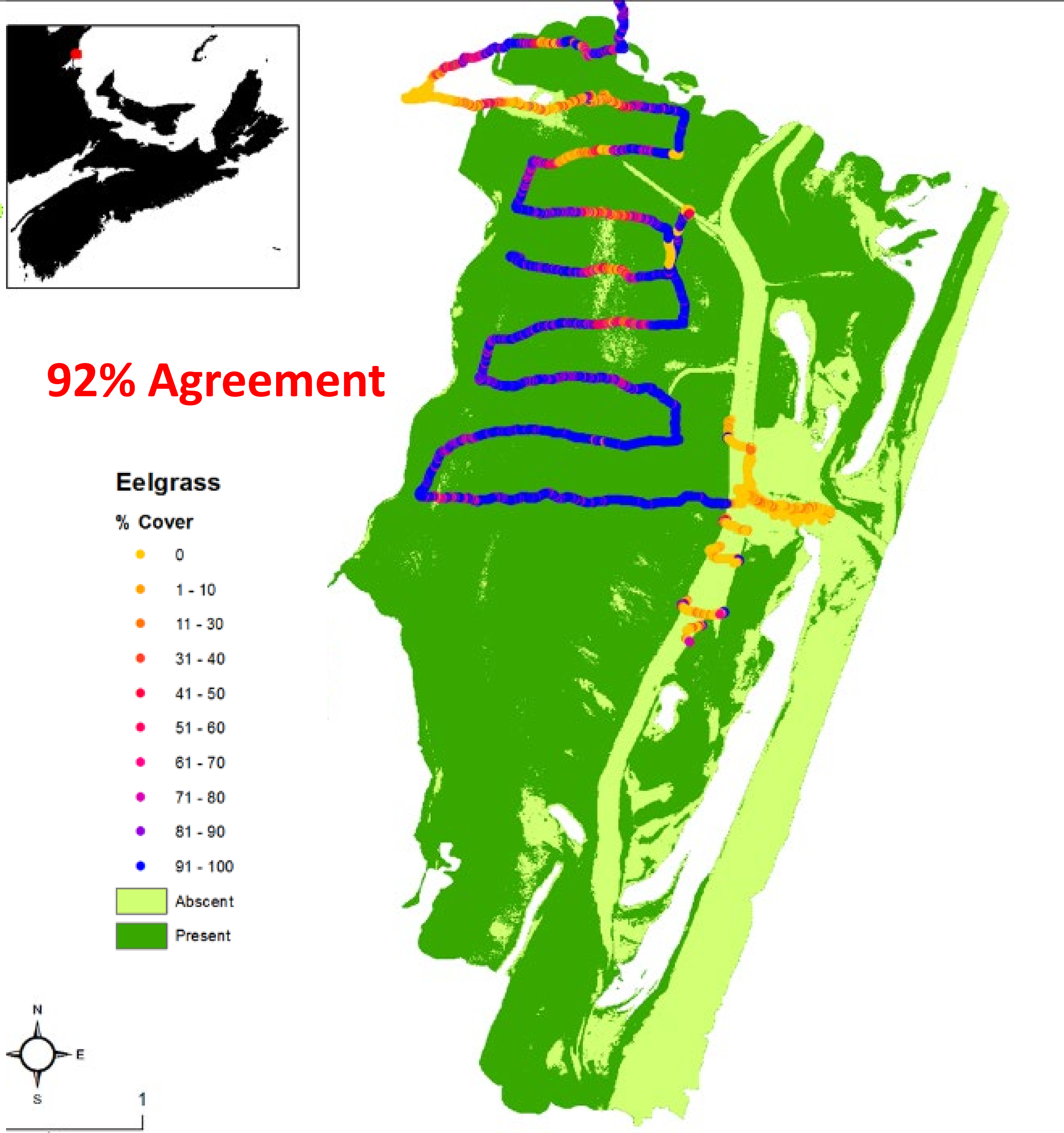
TB-lidar intensity/amplitude

Eelgrass density

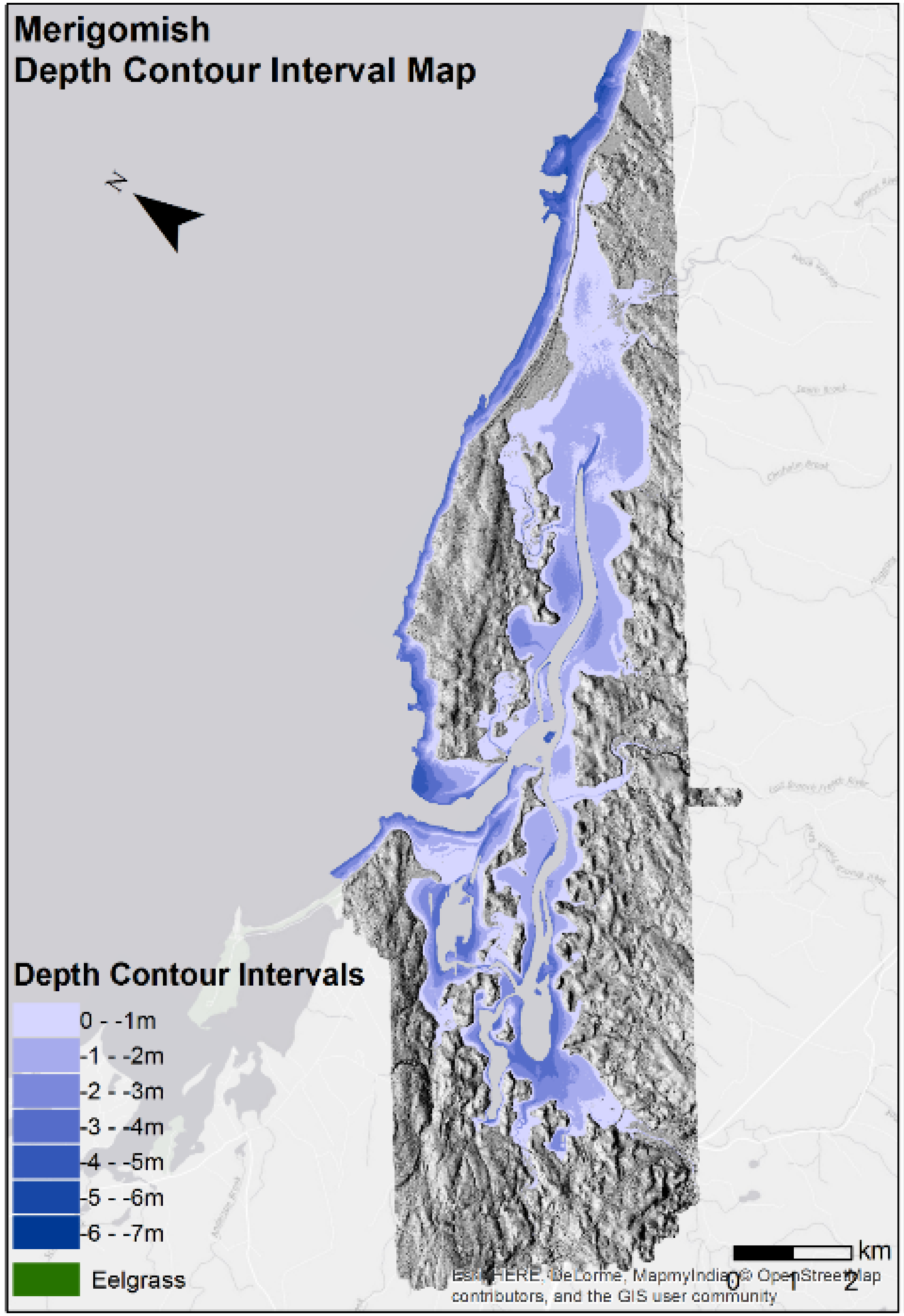


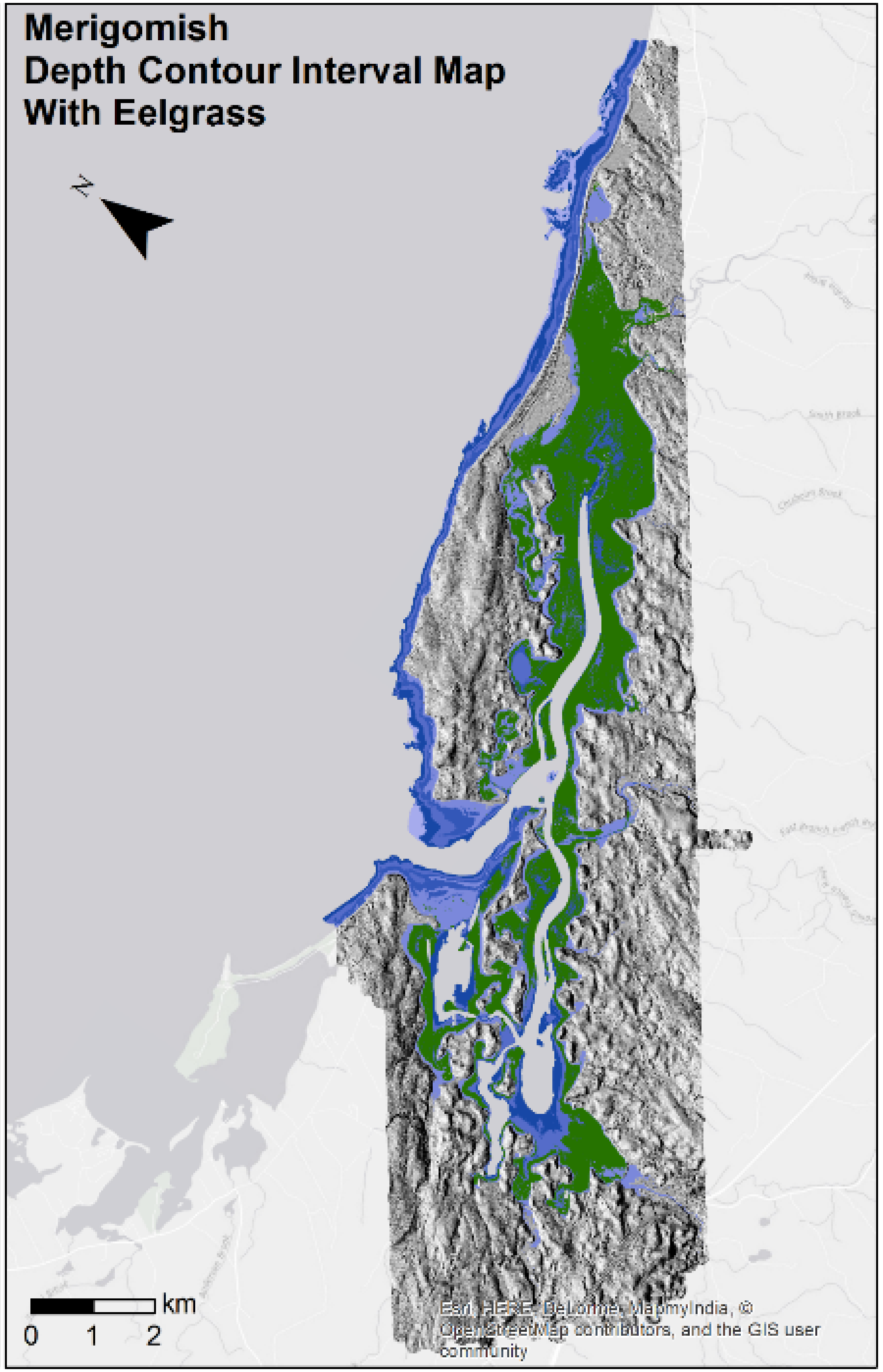


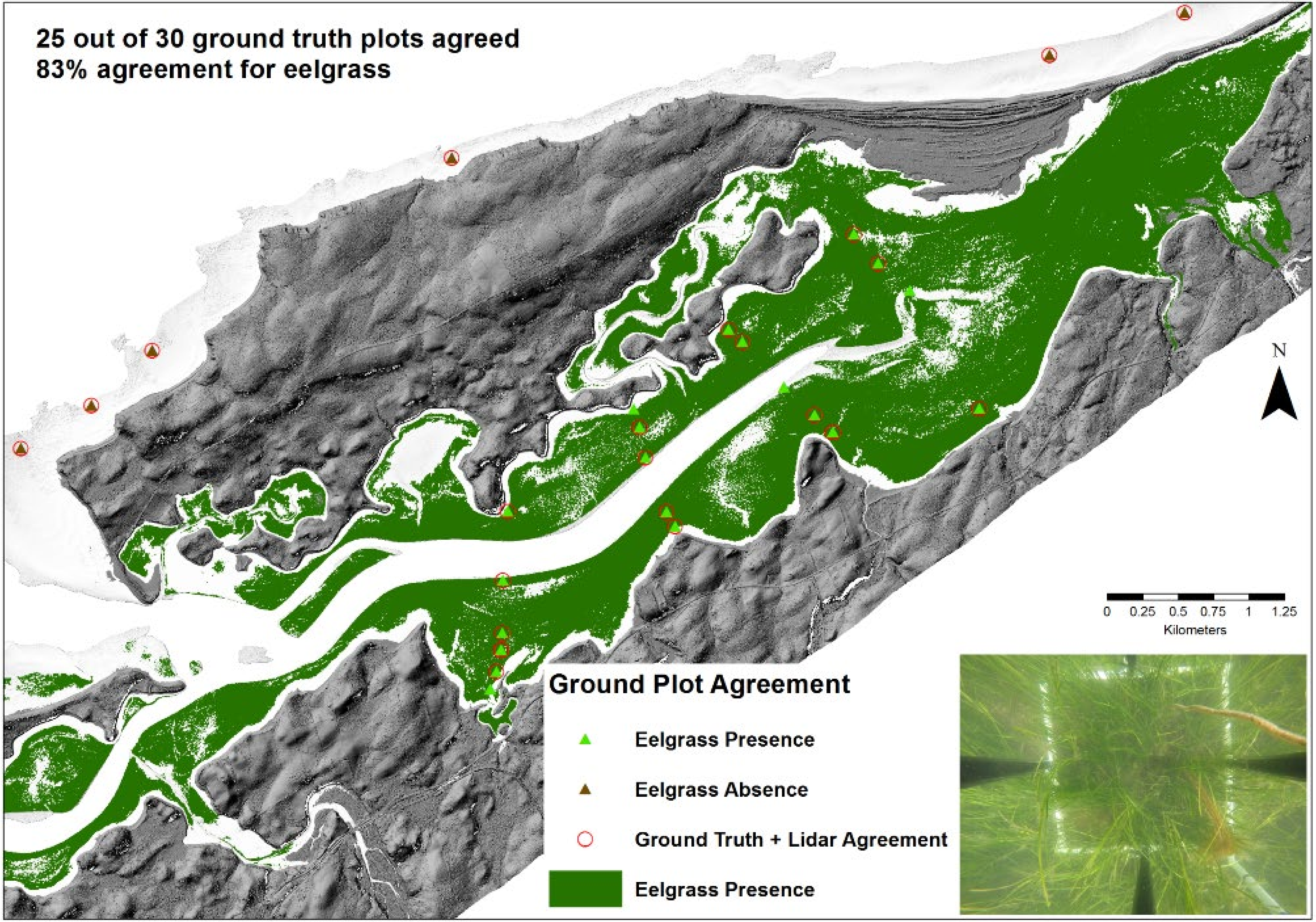

Eelgrass Presence
86% Agreement
N
E
S
1
km


92% Agreement
Eelgrass
% Cover
0
1 - 10
11 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
Abscent
Present
N
E
S
1
km

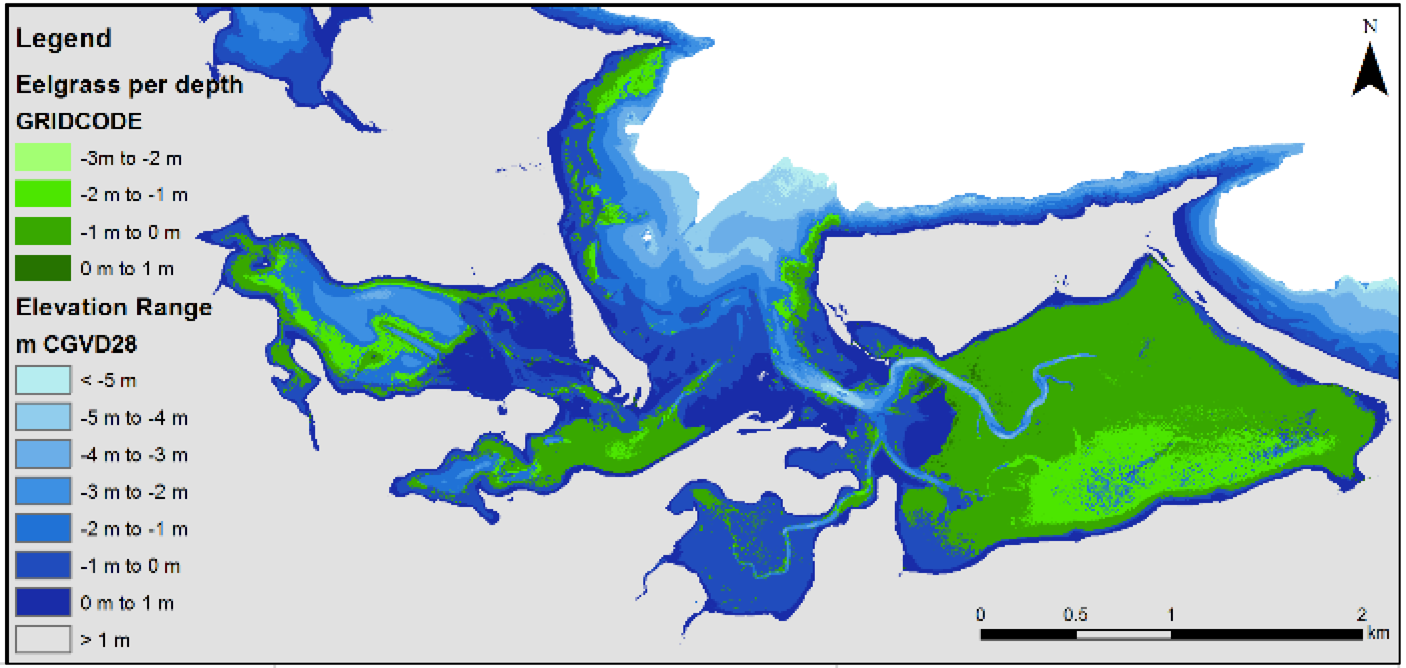
Eelgrass continued





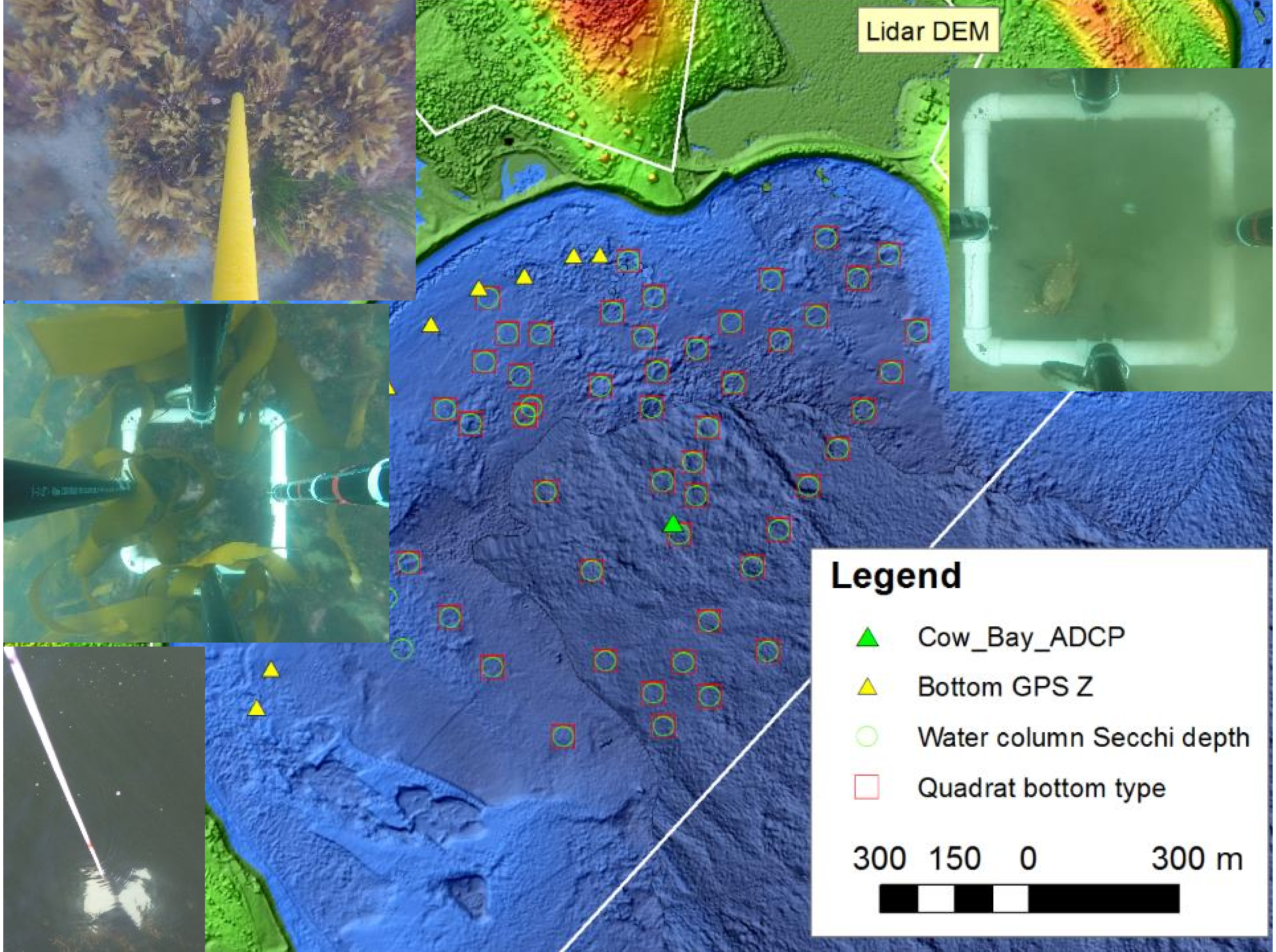

25 out of 30 ground truth plots agreed
83% agreement for eelgrass
N
0 0.25 0.5 0.75 1 1.25
Kilometers
Ground Plot Agreement
Eelgrass Presence
Eelgrass Absence
Ground Truth + Lidar Agreement
Eelgrass Presence

Lidar 'value add'

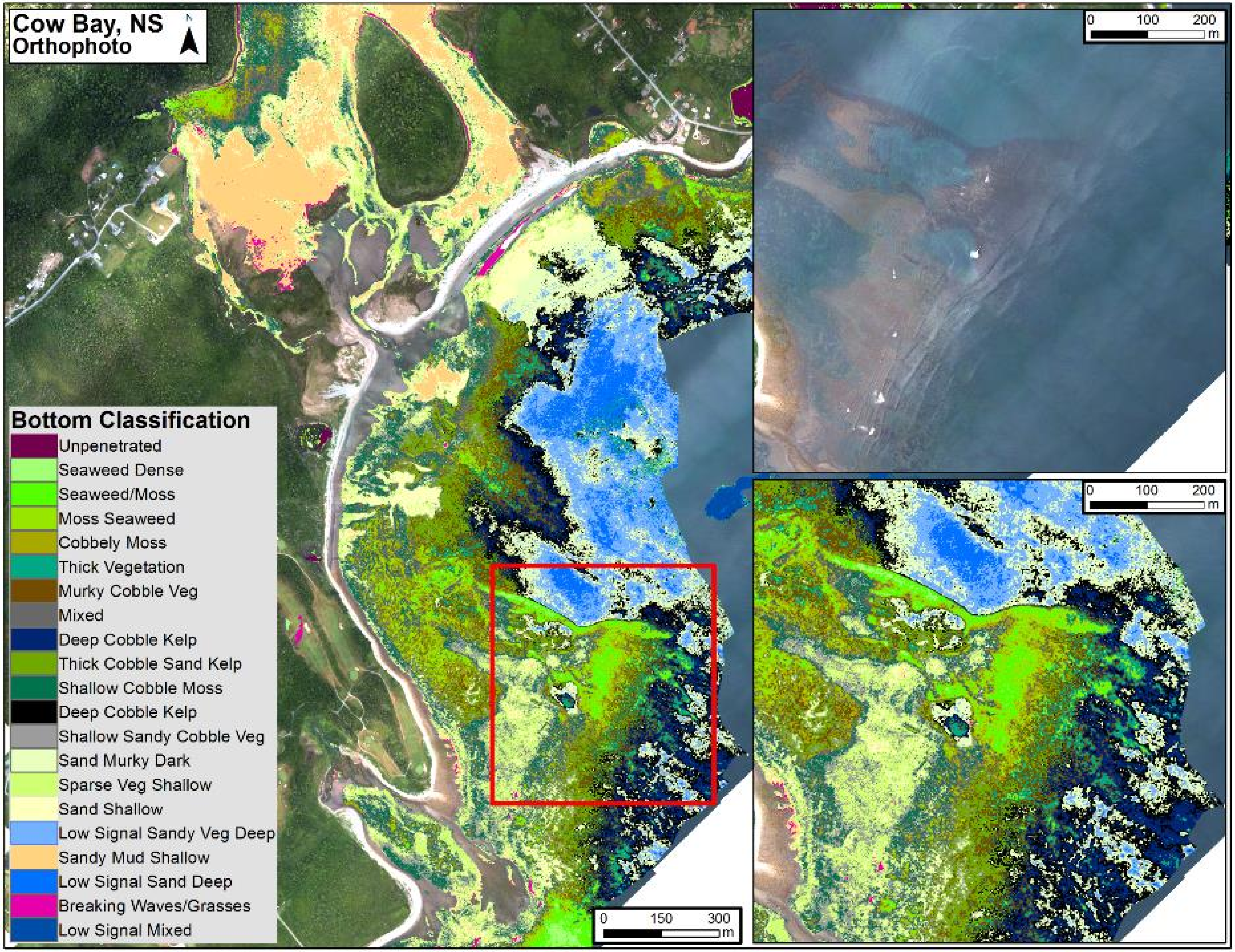


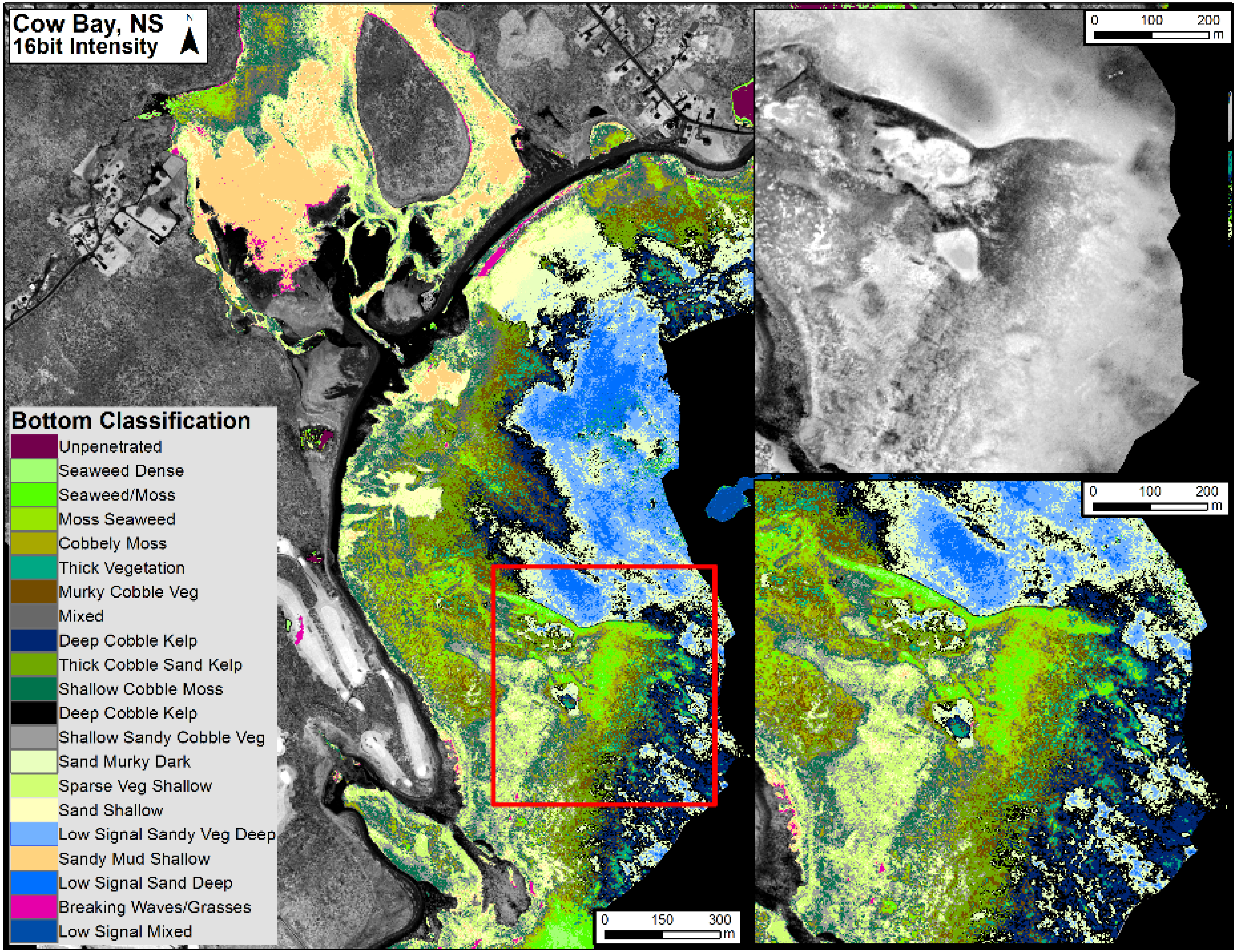
Contour Interval	Total Area (m^2)	Eelgrass Area (m^2)	% Eelgrass
0 - -1m	10,238,676	5,008,766	48.9
-1 - -2m	8,660,126	6,285,895	72.6
-2 - -3m	3,545,780	910,242	25.7
-3 - -4m	2,591,283	19,501	0.75
-4 - -5m	785,226	27.5	0
-5 - -6m	65,577	0	0
-6 - -7m	1,053	0	0
Total Bay Area (HHWLT – to lidar depth extent)	24,647,666	12,224,432	49.6

Cow Bay
Outside
Halifax, NS

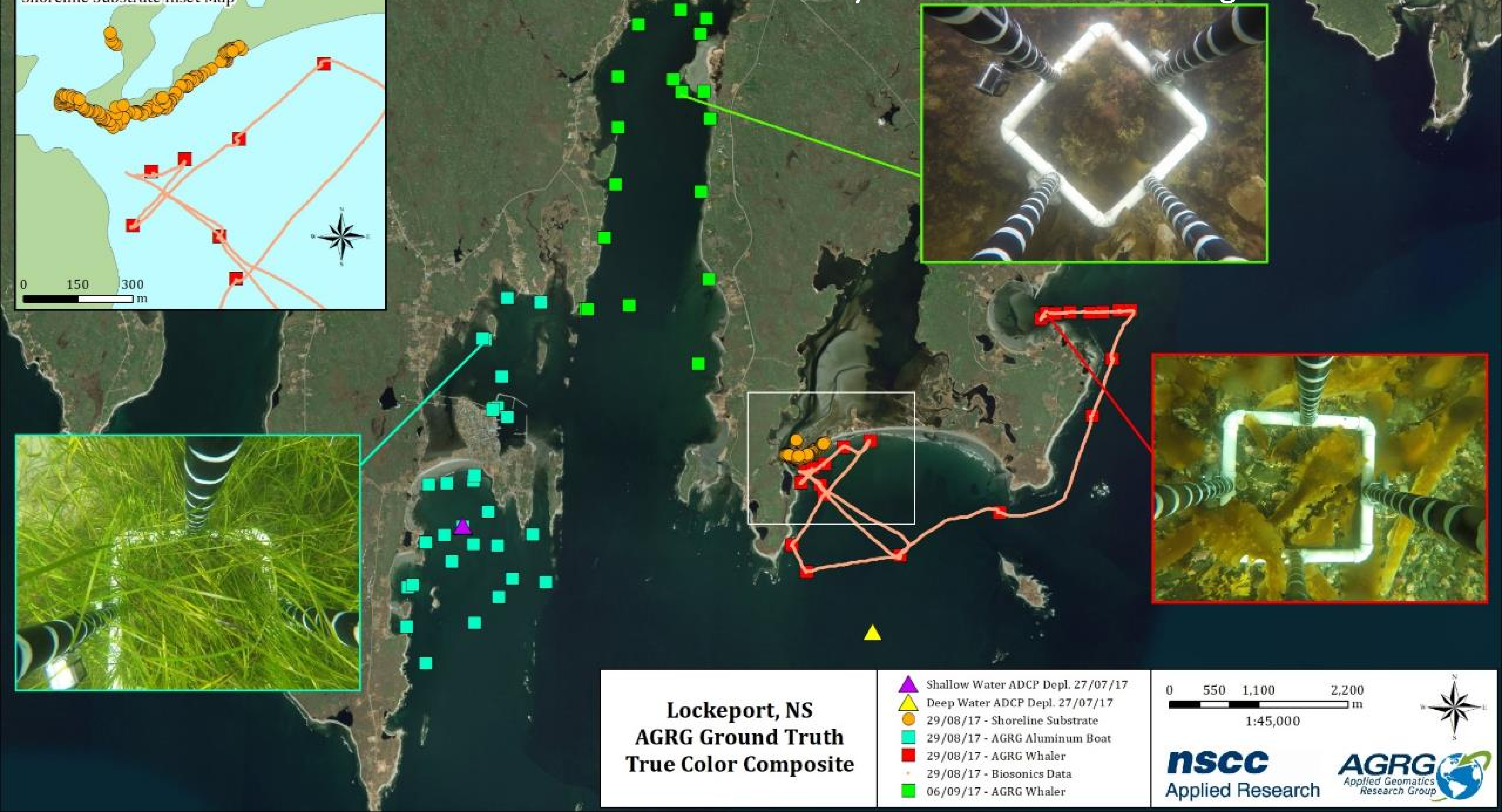


Cow Bay Expanding Benthic habitat classes

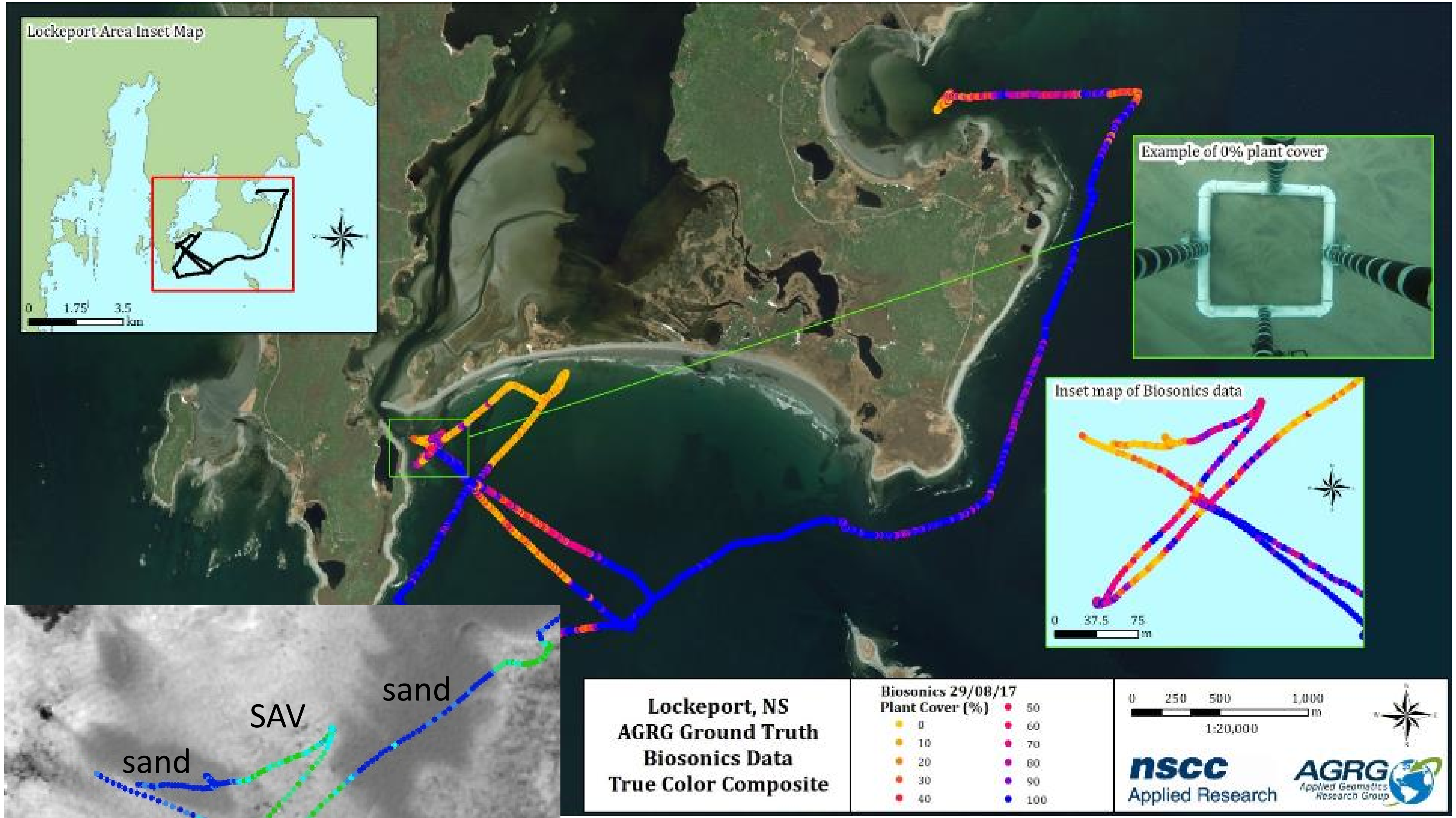


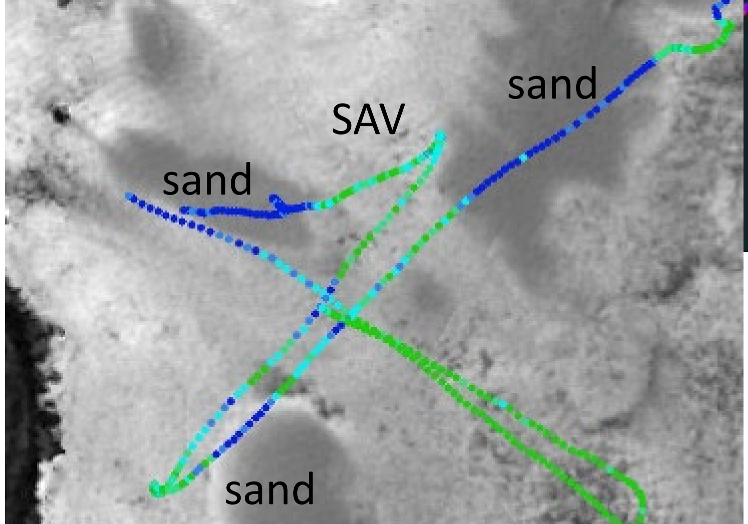

Cow Bay, NS
16bit Intensity
N
Bottom Classification
Unpenetrated
Seaweed Dense
Seaweed/Moss
Moss Seaweed
Cobbely Moss
Thick Vegetation
Murky Cobble Veg
Mixed
Deep Cobble Kelp
Thick Cobble Sand Kelp
Shallow Cobble Moss
Deep Cobble Kelp
Shallow Sandy Cobble Veg
Sand Murky Dark
Sparse Veg Shallow
Sand Shallow
Low Signal Sandy Veg Deep
Sandy Mud Shallow
Low Signal Sand Deep
Breaking Waves/Grasses
Low Signal Mixed
0 150 300 m
0 100 200 m
0 100 200 m

Ground truth data collection synchronous with lidar flight

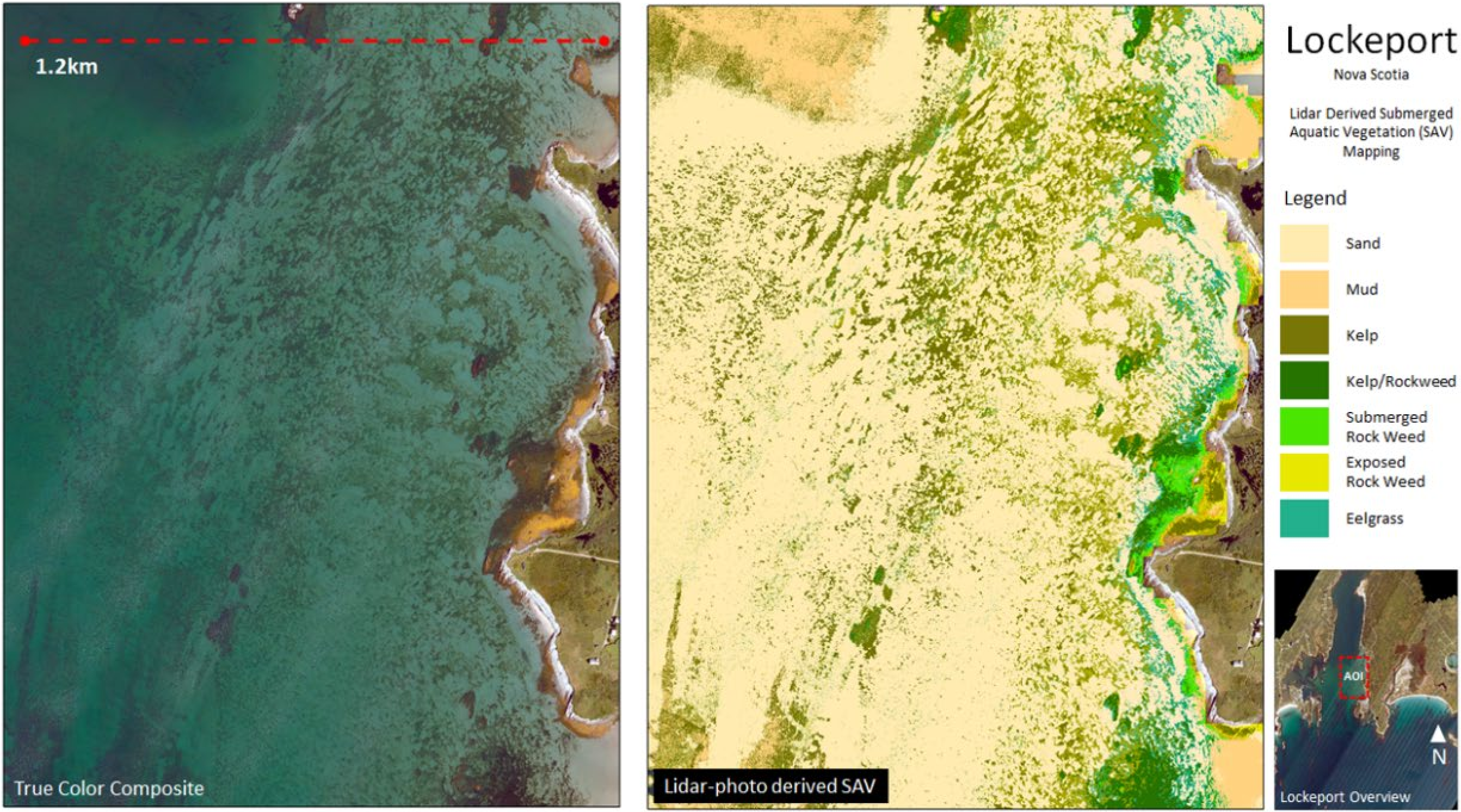


Biosonics echo sounder for submerged vegetation mapping





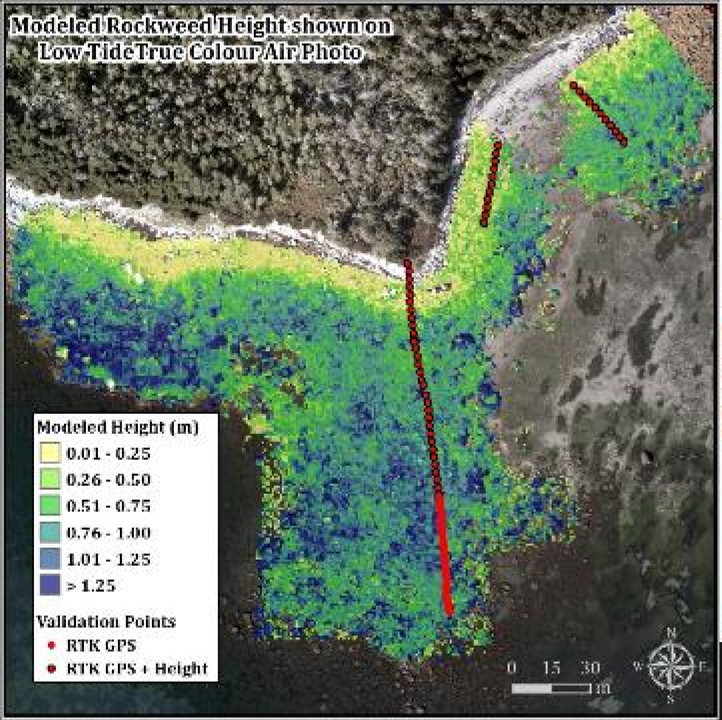
Lidar green laser bottom reflectance
With Biosonics points SAV (green-cyan) vs sand (blue)

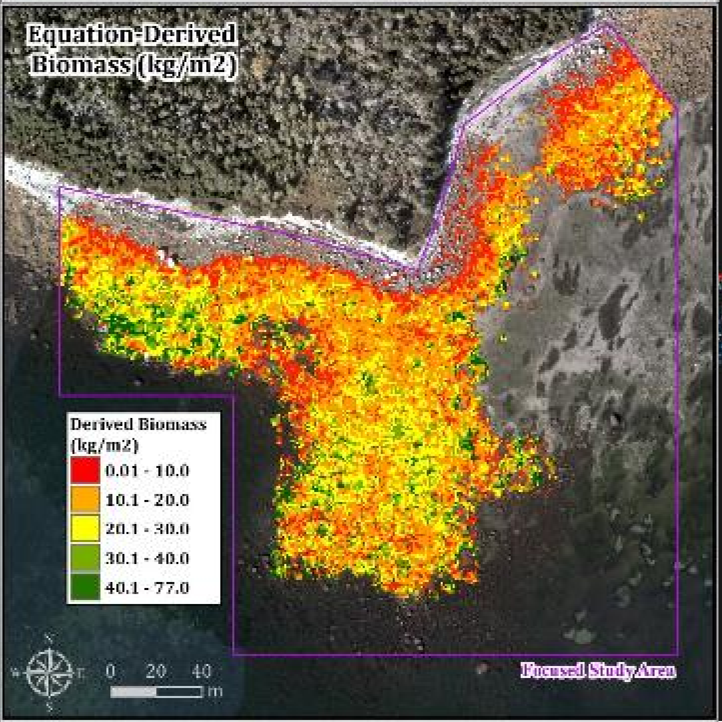

1.2km
True Color Composite
Lidar-photo derived SAV
Lockeport
Nova Scotia
Lidar Derived Submerged Aquatic Vegetation (SAV) Mapping
Legend
Sand
Mud
Kelp
Kelp/Rockweed
Submerged Rock Weed
Exposed Rock Weed
Eelgrass
AOI
N
Lockeport Overview

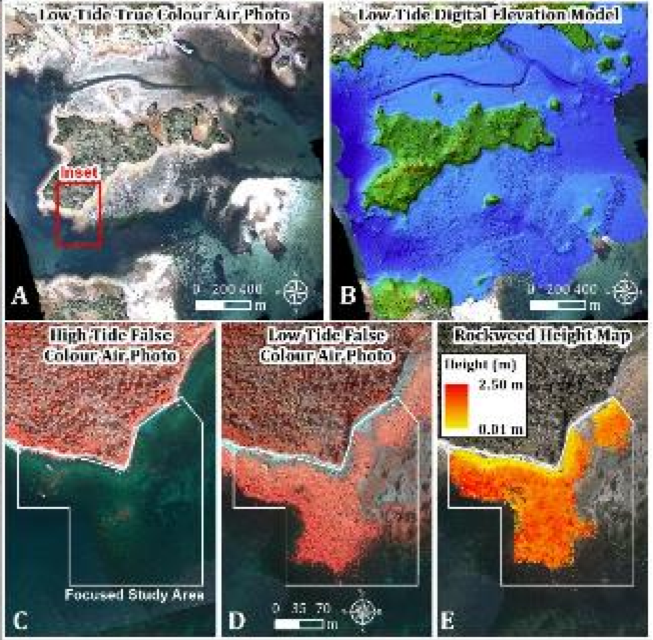
Analysis - Rockweed Metrics

- Acadian Seaplants Ltd.

Flew TB-lidar to Low Tide and High Tide to map rockweed height & estimate biomass

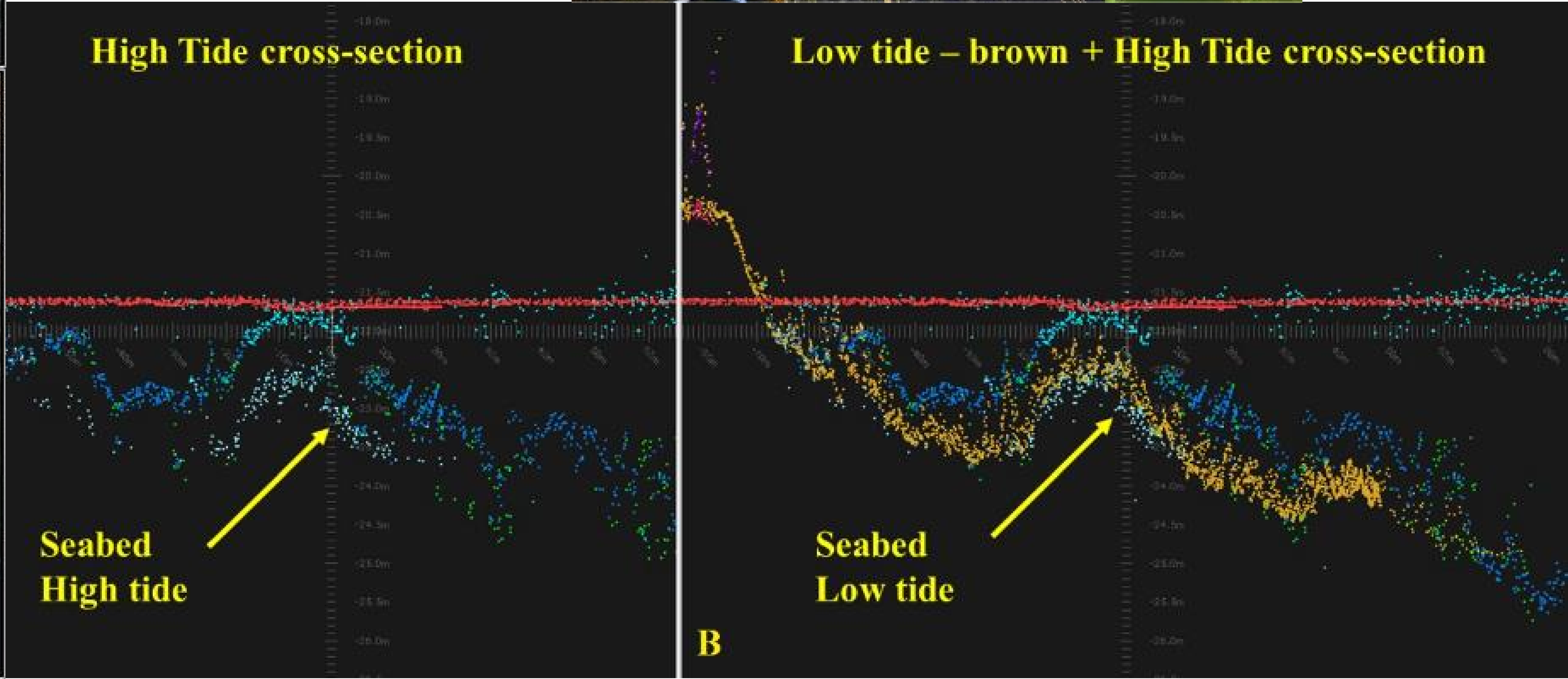

Modeled Rockweed Height shown on
Low Tide True Colour Air Photo
Modeled Height (m)
0.01 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.25
> 1.25
Validation Points
RTK GPS
RTK GPS + Height
0 15 30
m


Equation-Derived
Biomass (kg/m2)
Derived Biomass
(kg/m2)
0.01 - 10.0
10.1 - 20.0
20.1 - 30.0
30.1 - 40.0
40.1 - 77.0
0 20 40
m
Focused Study Area


Low Tide True Colour Air Photo
Inset
A
Low Tide Digital Elevation Model
B
High Tide False
Colour Air Photo
Focused Study Area
C
Low Tide False
Colour Air Photo
D
0 35 70
m
Rockweed Height Map
Height (m)
2.50 m
0.01 m
E


A
B
C
D
E
F


Source: ESRI
Gulf of
Saint Lawrence
48°N
46°N
44°N
Fredericton
Sydney
Nova Scotia
Halifax
64°W
60°W


High Tide cross-section
Low tide – brown + High Tide cross-section
Seabed
High tide
Seabed
Low tide
B

Botanica Marina, 2019


DE GRUYTER

Botanica Marina 2019; aop

Tim Webster*, Candace MacDonald, Kevin McGuigan, Nathan Crowell,
Jean-Sebastien Lauzon-Guay and Kate Collins

Calculating macroalgal height and biomass using bathymetric LiDAR and a comparison with surface area derived from satellite data in Nova Scotia, Canada

https://doi.org/10.1515/bot-2018-0080
Received 22 August, 2018; accepted 1 October, 2019

Abstract: The ability to map and monitor the macroalgal coastal resource is important to both the industry and the regulator. This study evaluates topo-bathymetric lidar (light detection and ranging) as a tool for estimating the surface area, height and biomass of *Ascophyllum nodosum*, an anchored and vertically suspended (floating) macroalga, and compares the surface area derived from lidar and WorldView-2 satellite imagery. Pixel-based Maximum Likelihood classification of low tide satellite data produced 2-dimensional maps of intertidal macroalgae with overall accuracy greater than 80%. Low tide and high tide topo-bathymetric lidar surveys were completed in southwestern Nova Scotia, Canada. Comparison of lidar-derived seabed elevations with ground-truth data collected using a survey grade global navigation satellite system (GNSS) indicated the low tide survey data have a positive bias of 15 cm, likely resulting from the seaweed being draped over the surface. The high tide survey data did not exhibit this bias, although the suspended canopy floating on the water surface reduced the seabed lidar point density. Validation of lidar-derived seaweed heights indicated a mean difference of 30 cm with a root mean square error of 62 cm. The modelled surface area of seaweed was 28% greater in the lidar model than the satellite model. The average lidar-derived biomass estimate was within one standard deviation of the mean biomass measured in the field. The lidar method tends to overestimate the biomass compared to field measurements that were spatially biased to the mid-intertidal level. This study demonstrates an innovative and cost-effective approach that uses a single high tide bathymetric lidar survey to map the height and biomass of dense macroalgae.

Keywords: bathymetric lidar; classification; macroalgae; mapping; satellite imagery.

Introduction

Algae serve many ecological functions in the coastal zone and the ability to map and monitor this resource is important to both the industry and the regulator. *Ascophyllum nodosum* [(L.) Le Jolis] (rockweed) is a brown seaweed that grows within the intertidal to the shallow subtidal zone in the North Atlantic. Rockweed is replaced by or mixed with other related species (*Fucus* spp.) in the most exposed or ice-scoured areas (Sharp 1986). Rockweed has become the most important commercial seaweed in Canada as it is the dominant perennial seaweed in the intertidal zone along the Atlantic coastline of the Maritime Provinces where it forms extensive beds (Ugarte and Sharp 2001, 2012). The ability to establish baseline measurements of macroalgal distribution is important to assess future stock conditions that may be influenced by climate change. In Canada, the harvesting of rockweed is done from boats during high tide using specially designed rakes with blades. Since 1986, Acadian Seaplants Limited (ASL) has maintained a long-term research and monitoring program to study the population dynamics of the rockweed resource in Atlantic Canada (Ugarte and Sharp 2001). ASL has traditionally utilised provincially available aerial photography to map where the rockweed occurs and conducted detailed plot-based sampling to calculate biomass. The provincial aerial photography was flown for the purpose of supporting the forest inventory and thus capturing the images at low tide was not a criterion during the flights. Consequently, not all the coastal zone has been surveyed at low tide, therefore making it challenging to map the distribution of rockweed using this method. The annual biomass harvest of the resource in southwest Nova Scotia has been estimated to vary between 3.5 and 5.5 kg of wet material per square meter, or 35–55% of the total biomass. This information is consistent with previous harvest studies

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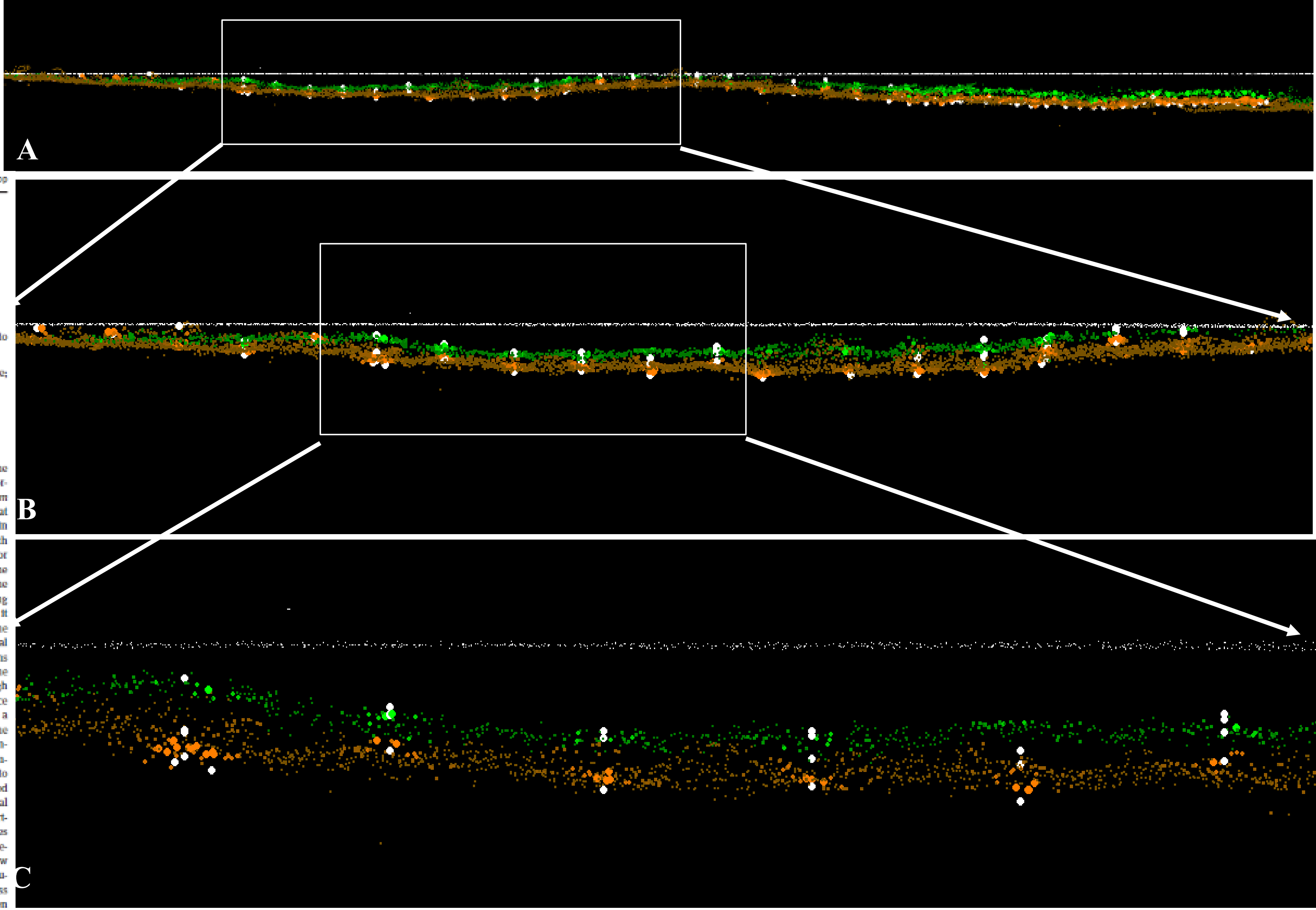
Candace MacDonald, Kevin McGuigan, Nathan Crowell and Kate Collins: Applied Geomatics Research Group, Nova Scotia Community College, 295 Commercial Street, Middleton, NS, B0S 1P0, Canada
Jean-Sebastien Lauzon-Guay: Acadian Seaplants Limited, 30 Brown Avenue, Dartmouth, NS, B3B 1X8, Canada



Ground truth points WHITE, ground + up to 3 plant heights.
Lidar seabed BROWN, rockweed GREEN, sea surface BLUE.
Cross-section 3 m thick.

Mail - Timothy.Webster@nscc.ca | Leica Chiroptera 4X Bathymetric

https://leica-geosystems.com/products/airborne-systems/bathymetric-lidar-sensors/leica-chiroptera

Apps | glcf.umd.edu/esdi2-h | Webmail

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News Release

EXPLORE BATHYMETRIC LIDAR SENSORS

Bathymetric point density increase 4 Times

Leica Chiroptera 4X Bathymetric & Topographic LiDAR

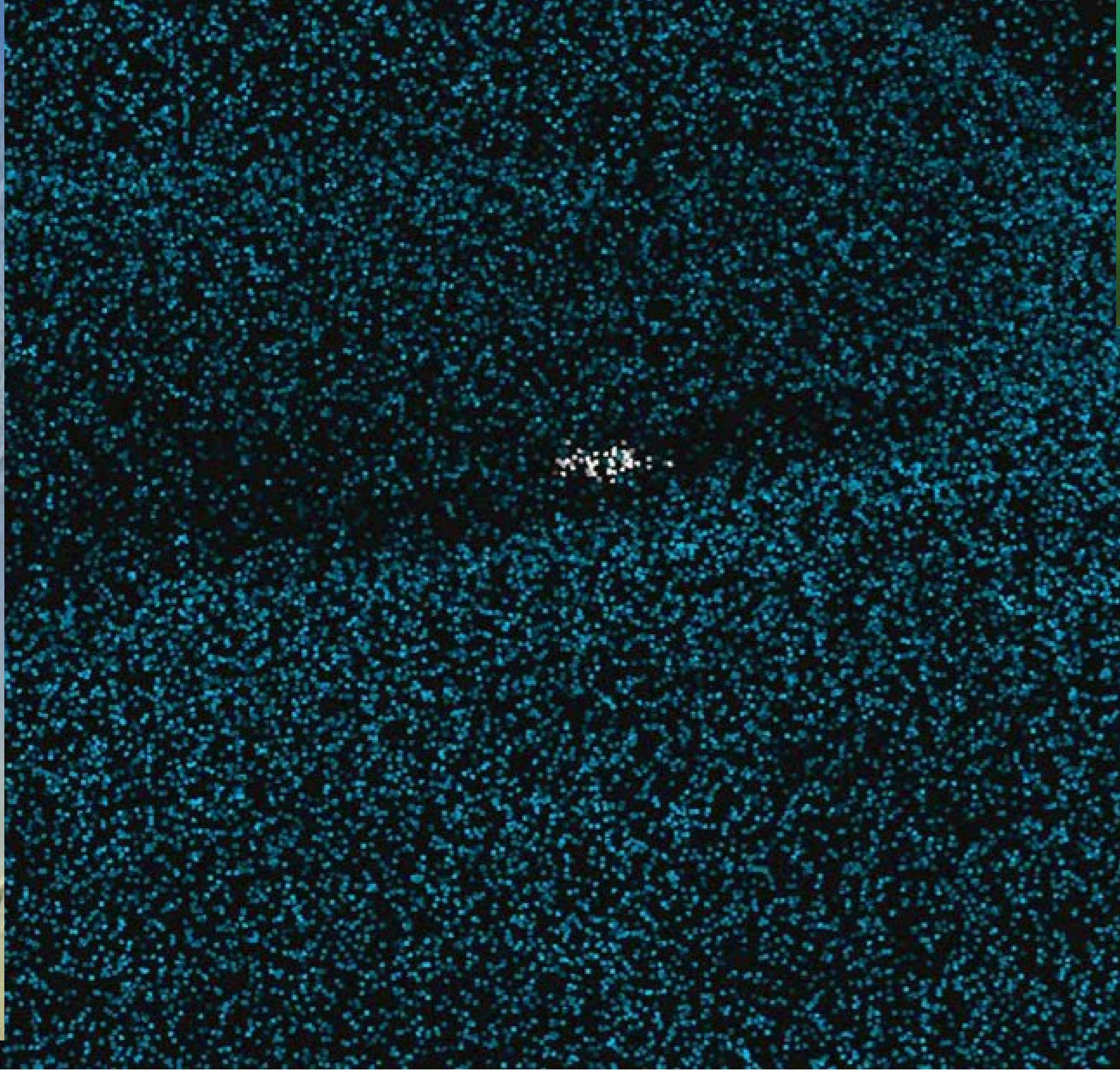
Efficient coastal survey LiDAR sensor producing seamless data from land to water at 4X the point density

GA2018 Schedule.pdf | Show all

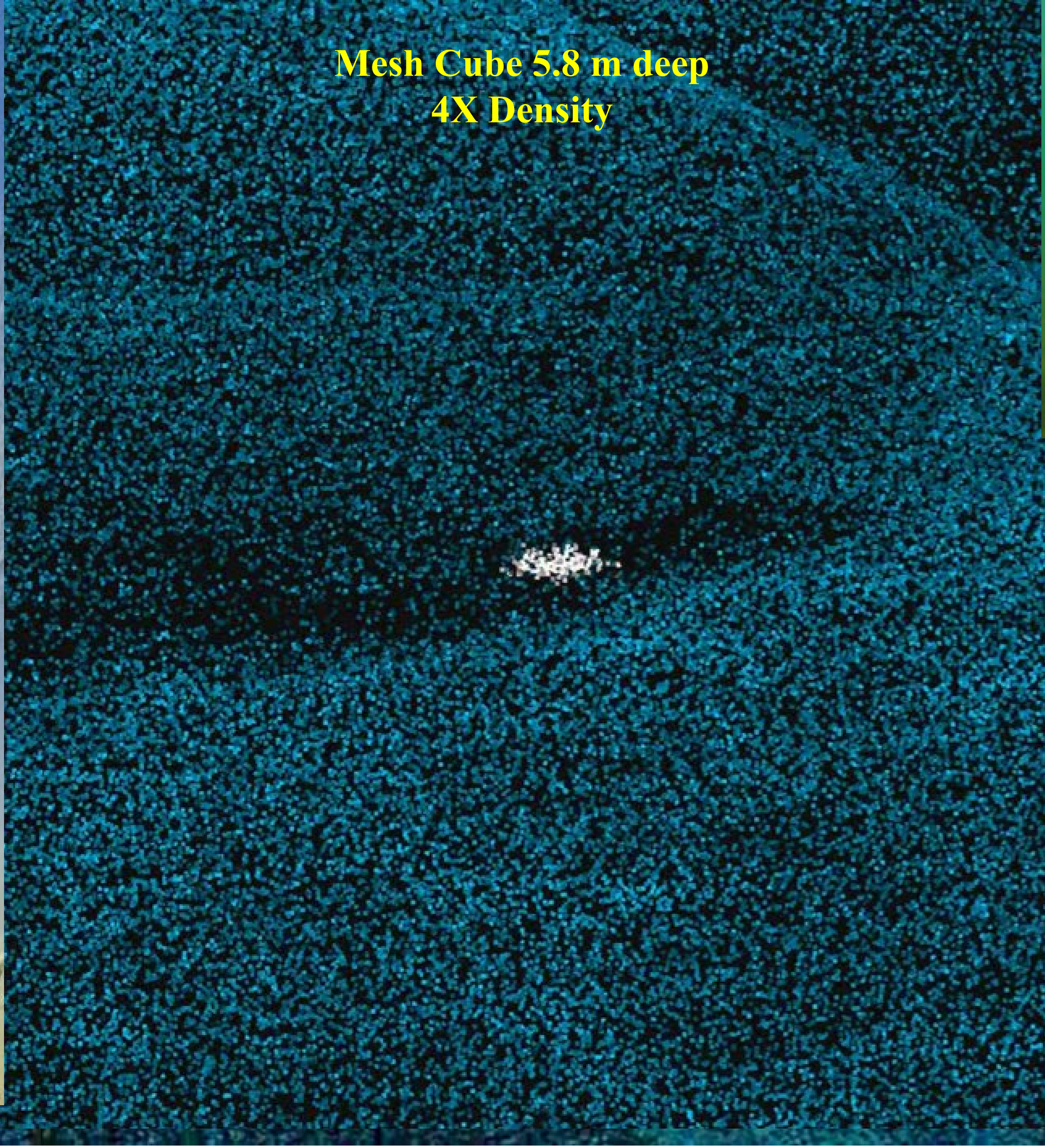
8:24 PM
11/12/2018

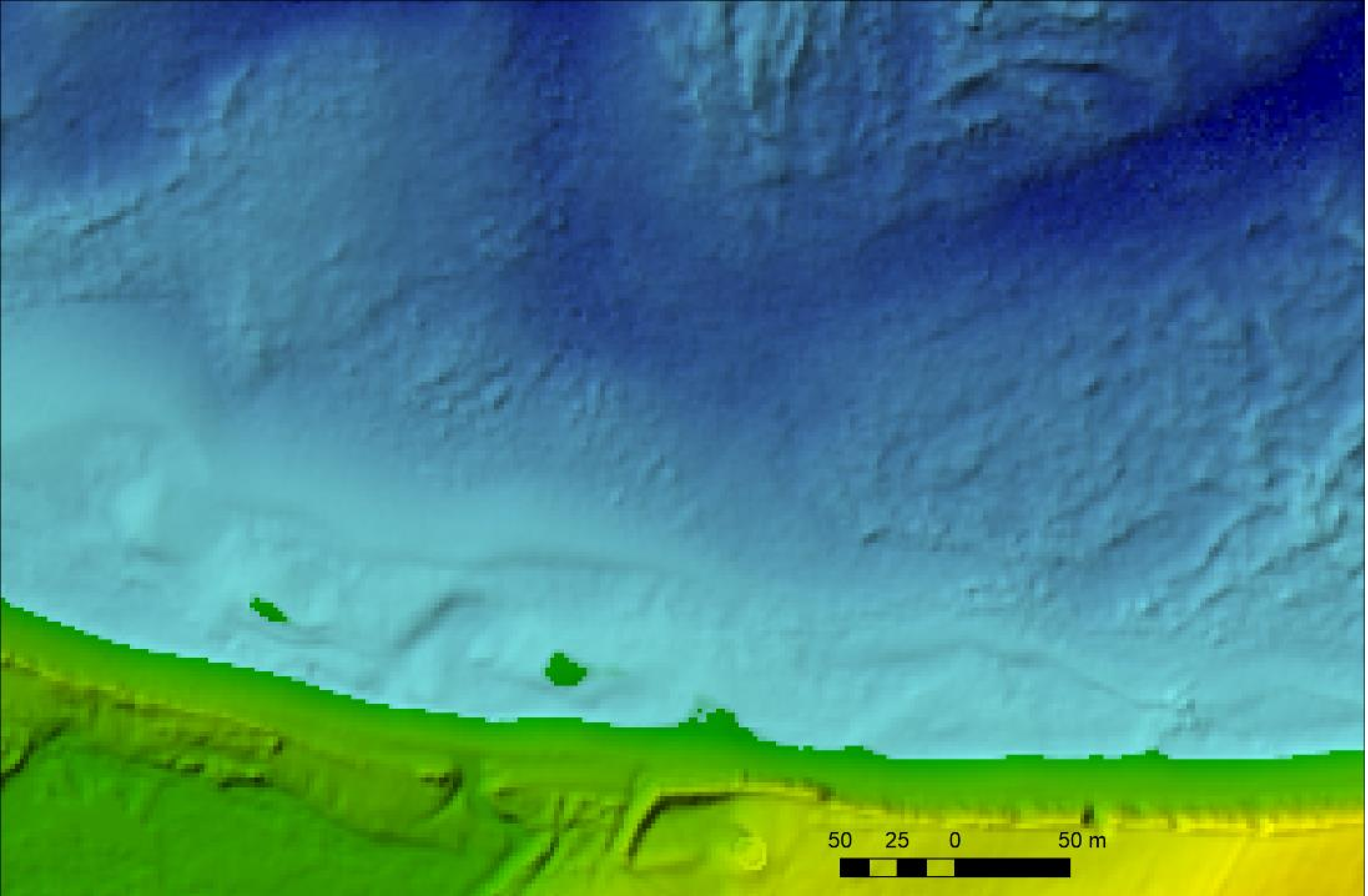

The experiment
Deploying Targets
4 - 1 m X 1 m cubes
2 mesh
1 solid white
1 solid green
Light sensors
Pressure sensors
Light
Turbidity
Pressure
Temp, DO, Ph, Conductivity
Flat photo targets

Mesh Cube 5.8 m deep
Standard Point Density

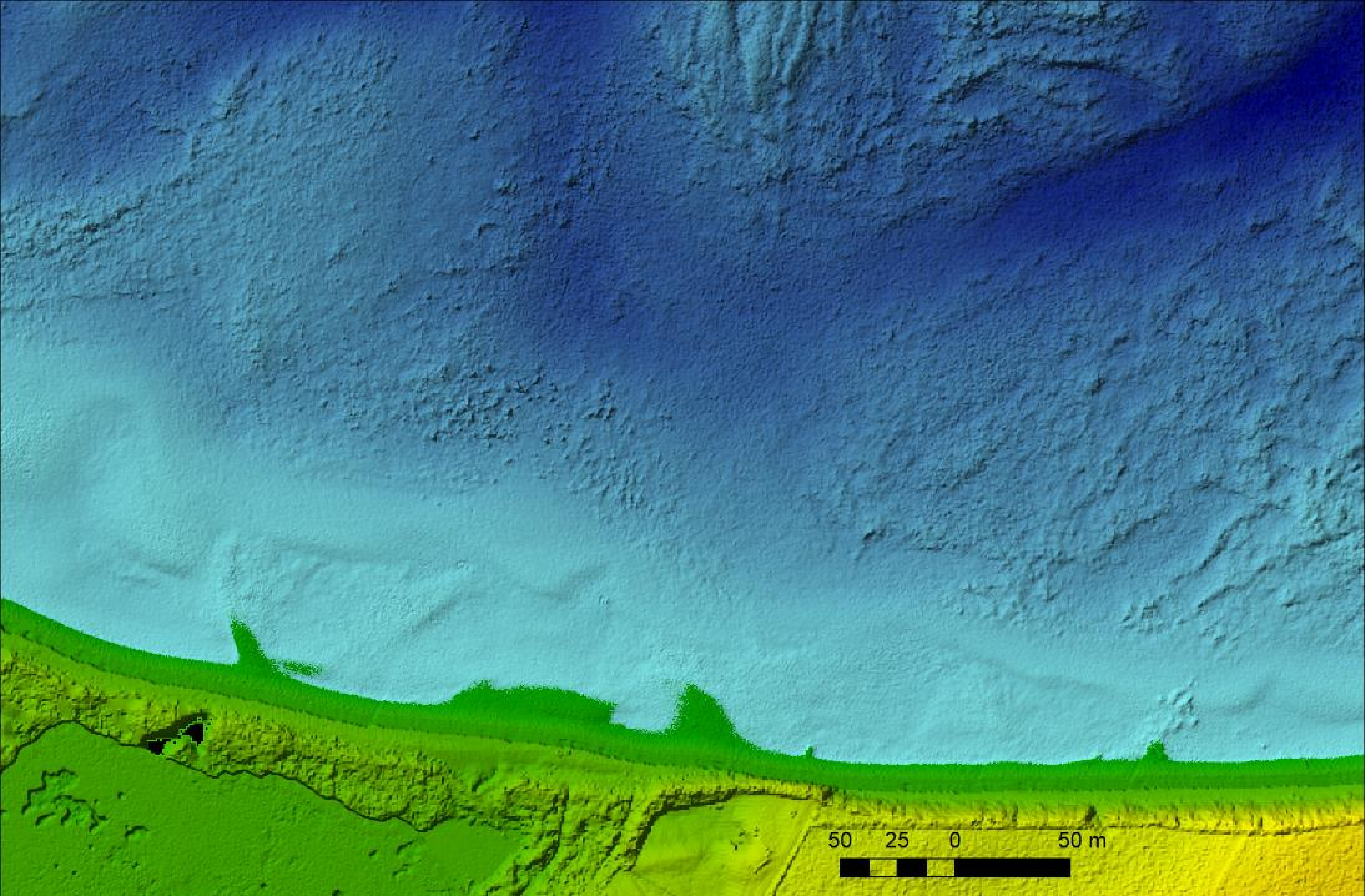



CB50 - 8m
D4 - 8m
8m
8m
6m
D3 - 6m
4m
D2 - 4m
D3
D4
D1
D2
D1 - 2m
50
0
50
100
150

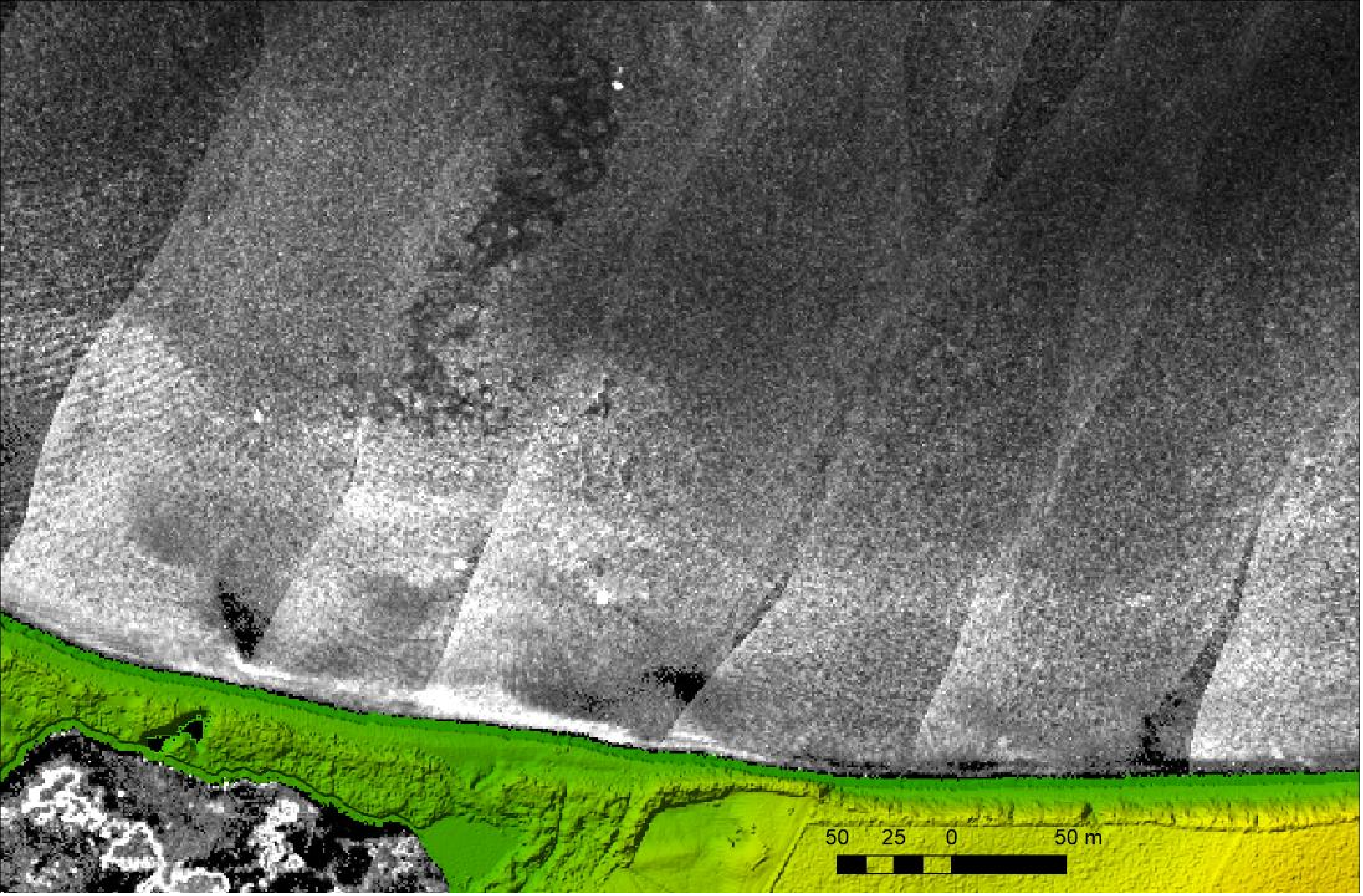

Mesh Cube 5.8 m deep
4X Density



2014,
400 m AGL

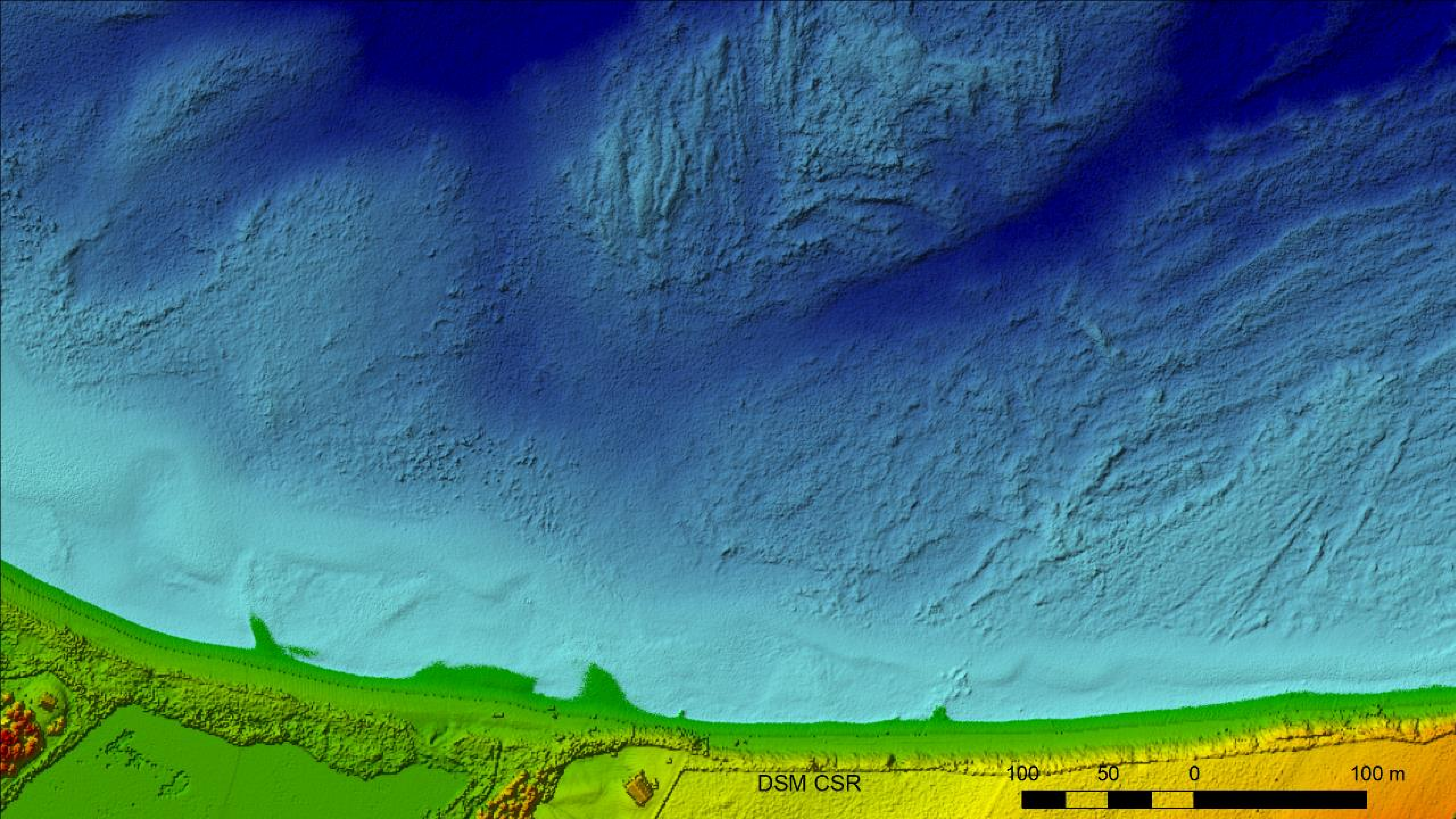


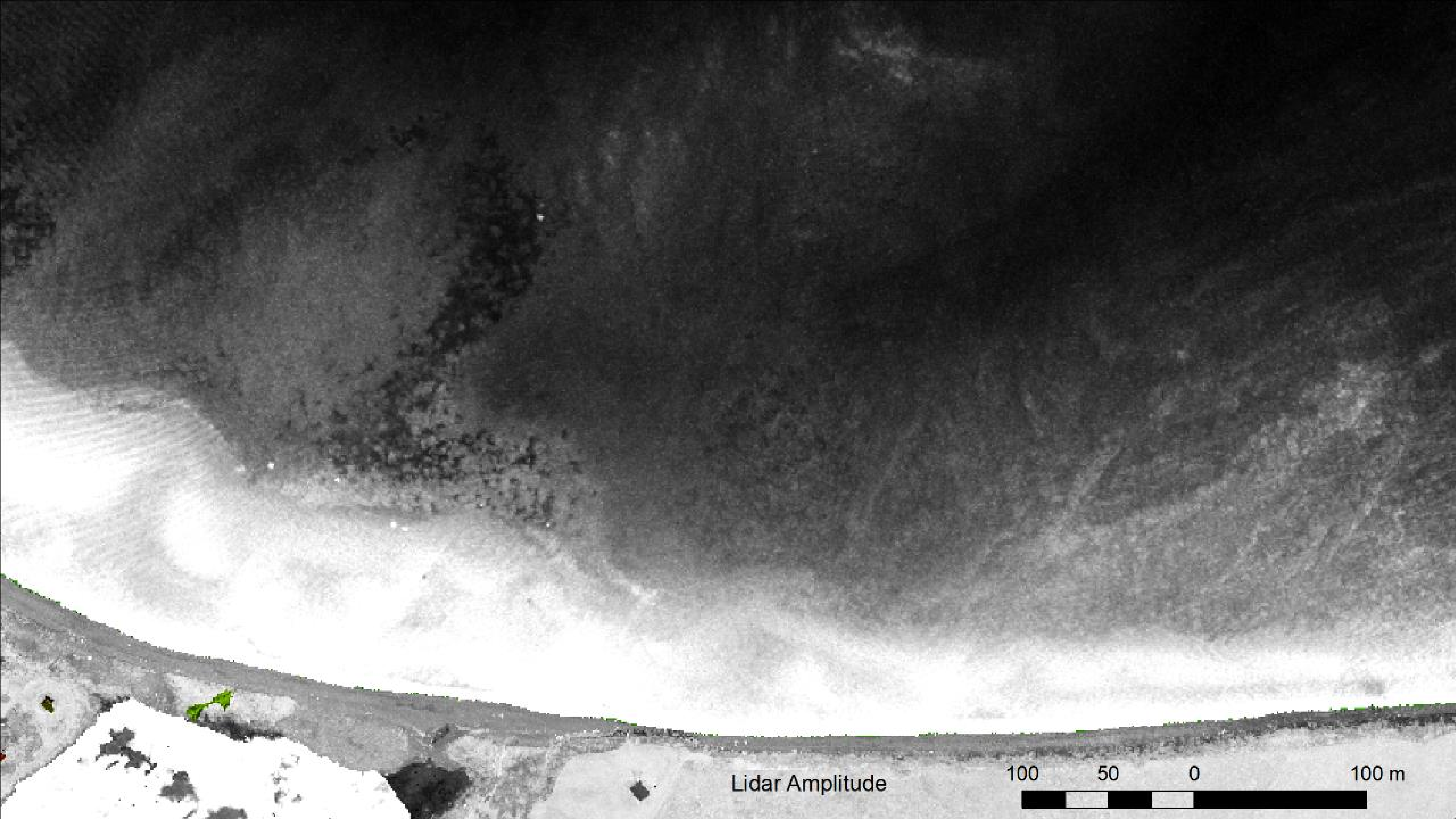
2018 4X,
400 m AGL

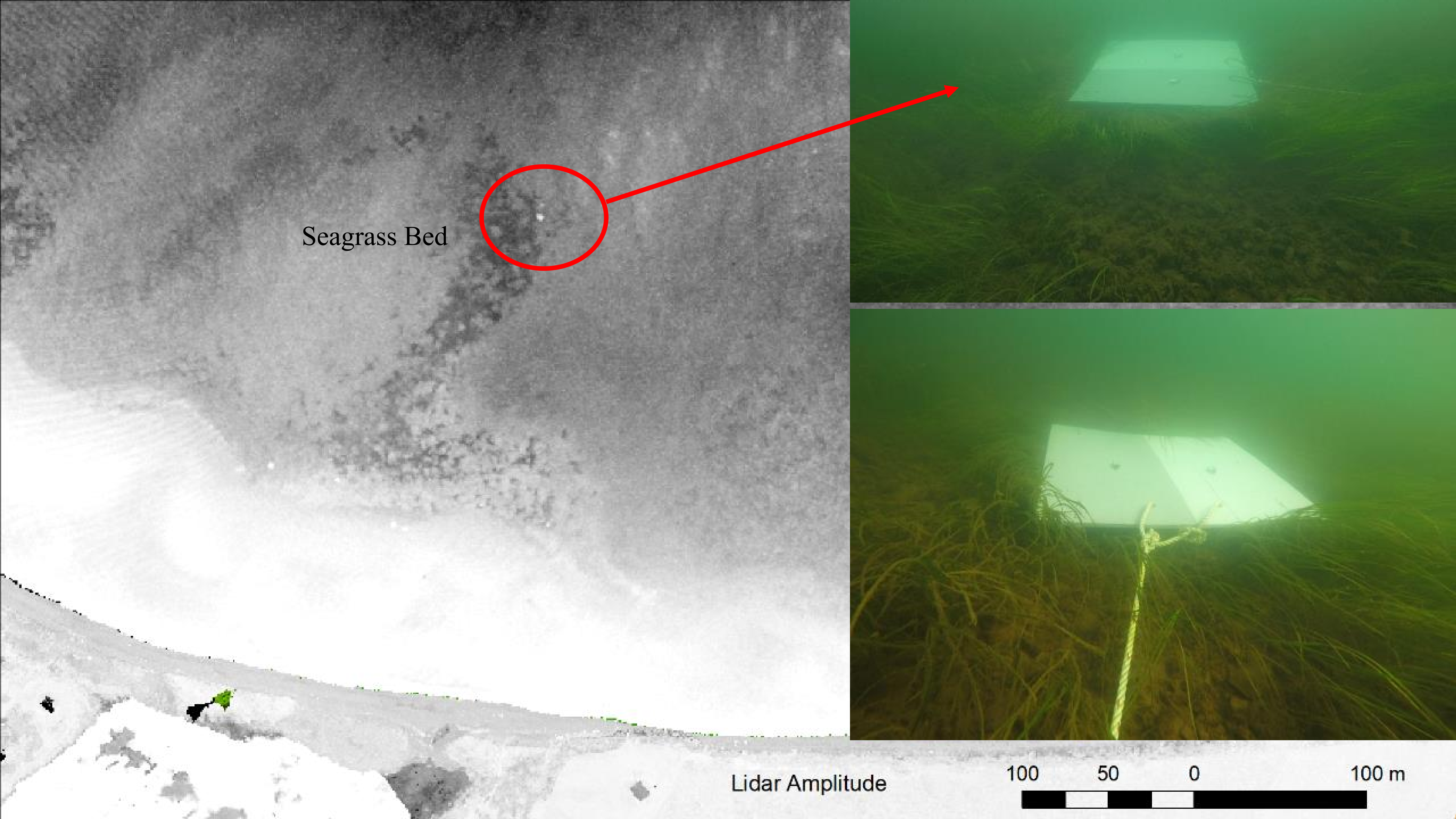


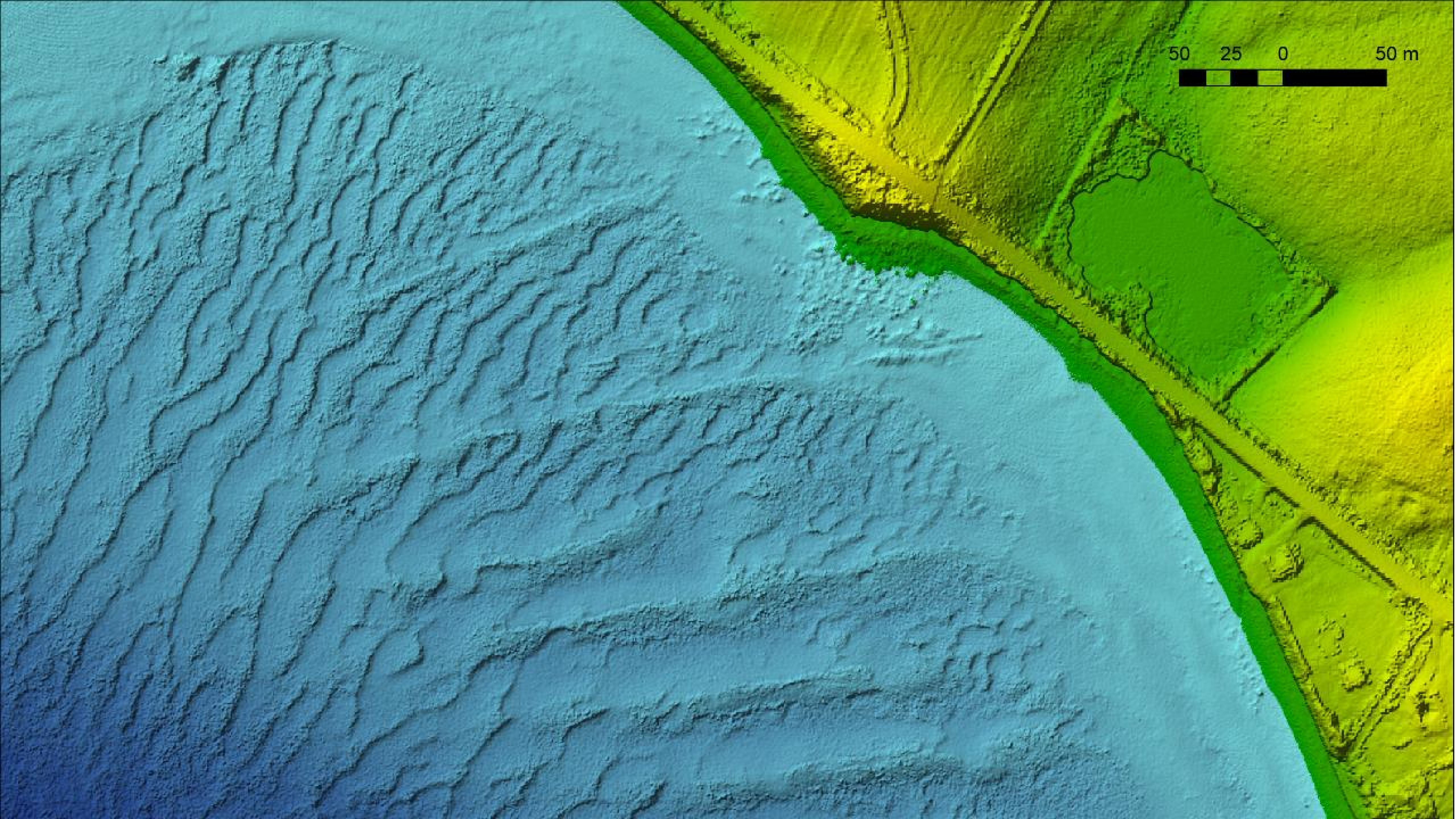
2018 4X,
400 m AGL
Intensity


Orthophoto
100
50
0
100 m

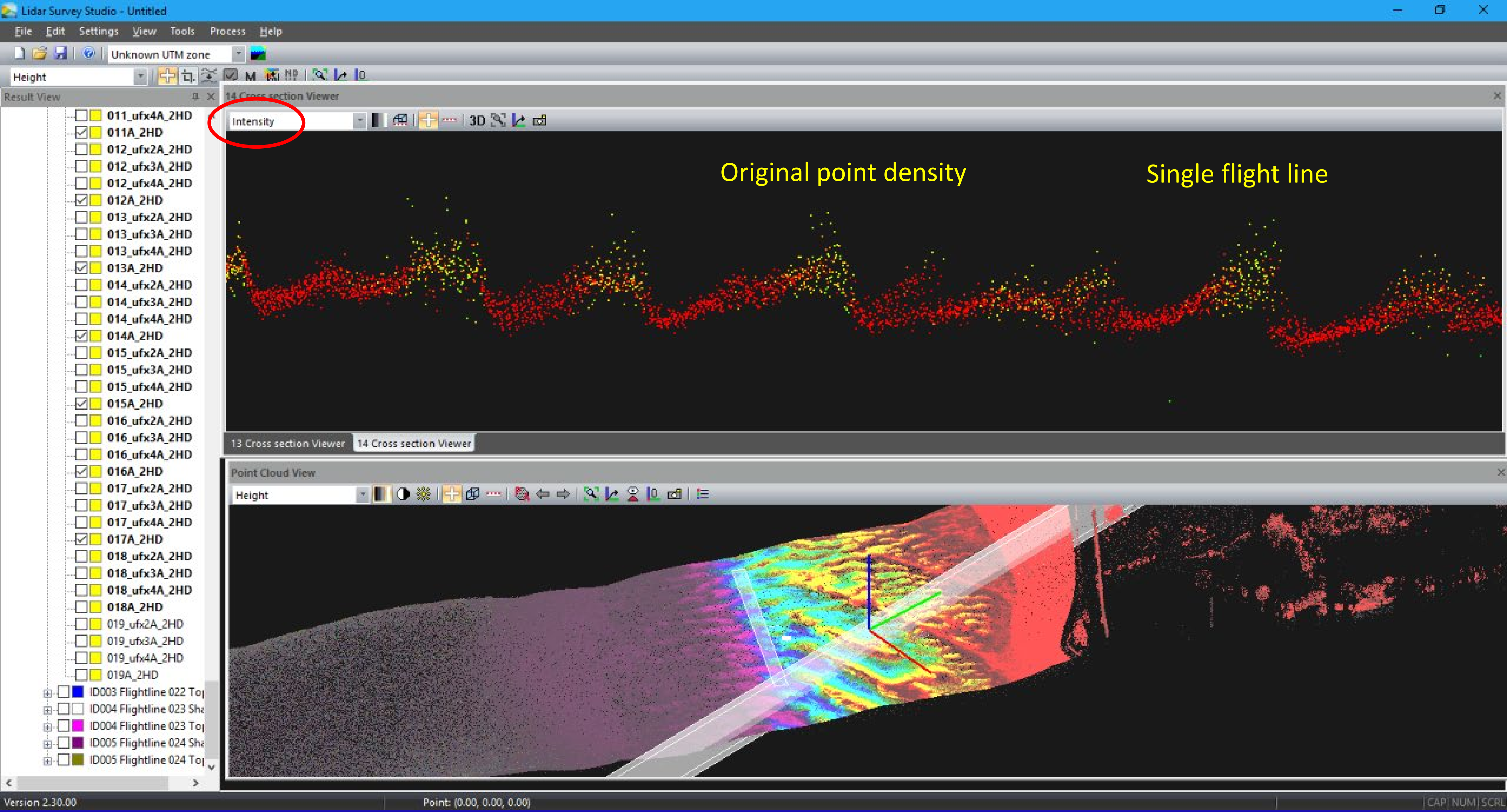

DSM CSR
100
50
0
100 m


Lidar Amplitude
100
50
0
100 m


Seagrass Bed
Lidar Amplitude
100
50
0
100 m


50 25 0 50 m


50 25 0 50 m



Lidar Survey Studio - Untitled
File Edit Settings View Tools Process Help
Unknown UTM zone
Height
Result View
011_ufx4A_2HD
011A_2HD
012_ufx2A_2HD
012_ufx3A_2HD
012_ufx4A_2HD
012A_2HD
013_ufx2A_2HD
013_ufx3A_2HD
013_ufx4A_2HD
013A_2HD
014_ufx2A_2HD
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014A_2HD
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015_ufx3A_2HD
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015A_2HD
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016_ufx3A_2HD
016_ufx4A_2HD
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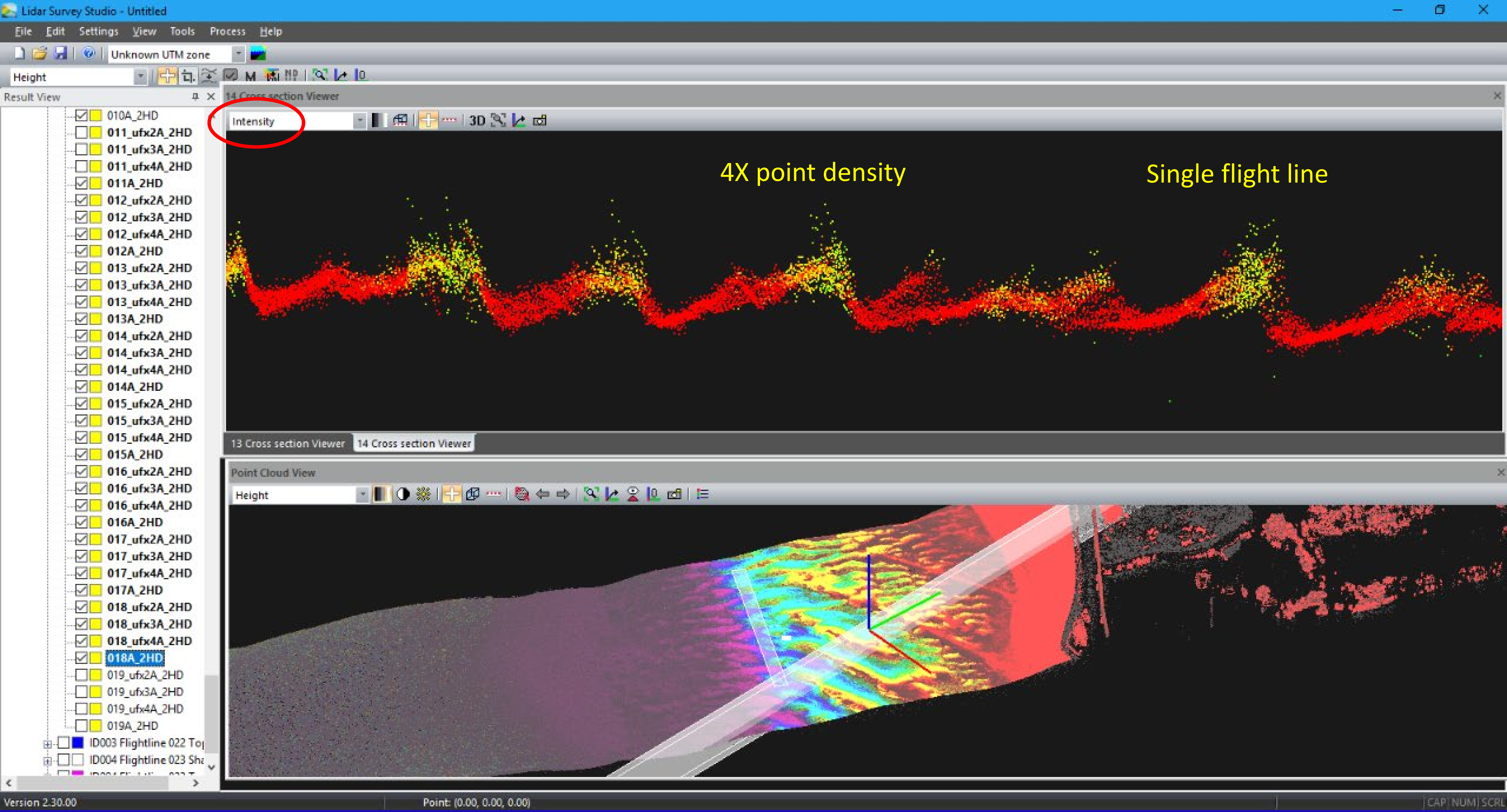
017_ufx3A_2HD
017_ufx4A_2HD
017A_2HD
018_ufx2A_2HD
018_ufx3A_2HD
018_ufx4A_2HD
018A_2HD
019_ufx2A_2HD
019_ufx3A_2HD
019_ufx4A_2HD
019A_2HD
ID003 Flightline 022 To
ID004 Flightline 023 Sha
ID004 Flightline 023 To
ID005 Flightline 024 Sha
ID005 Flightline 024 To
14 Cross section Viewer
Intensity
3D
Original point density
Single flight line
13 Cross section Viewer
14 Cross section Viewer
Point Cloud View
Height
Version 2.30.00
Point: (0.00, 0.00, 0.00)
CAP NUM SCRL


Lidar Survey Studio - Untitled
File
Edit
Settings
View
Tools
Process
Help
Unknown UTM zone
Height
Result View
010A_2HD
011_ufx2A_2HD
011_ufx3A_2HD
011_ufx4A_2HD
011A_2HD
012_ufx2A_2HD
012_ufx3A_2HD
012_ufx4A_2HD
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013_ufx3A_2HD
013_ufx4A_2HD
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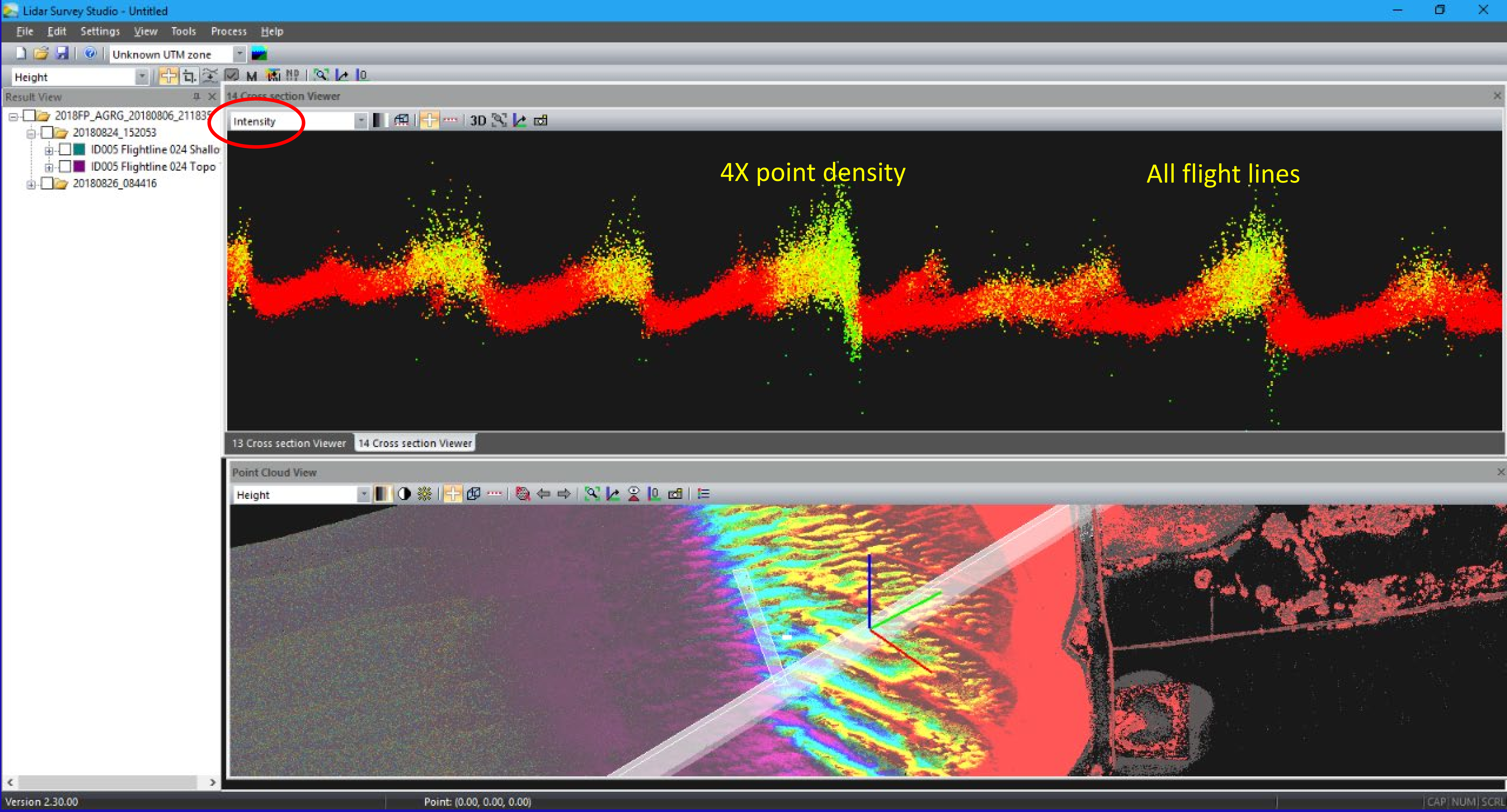
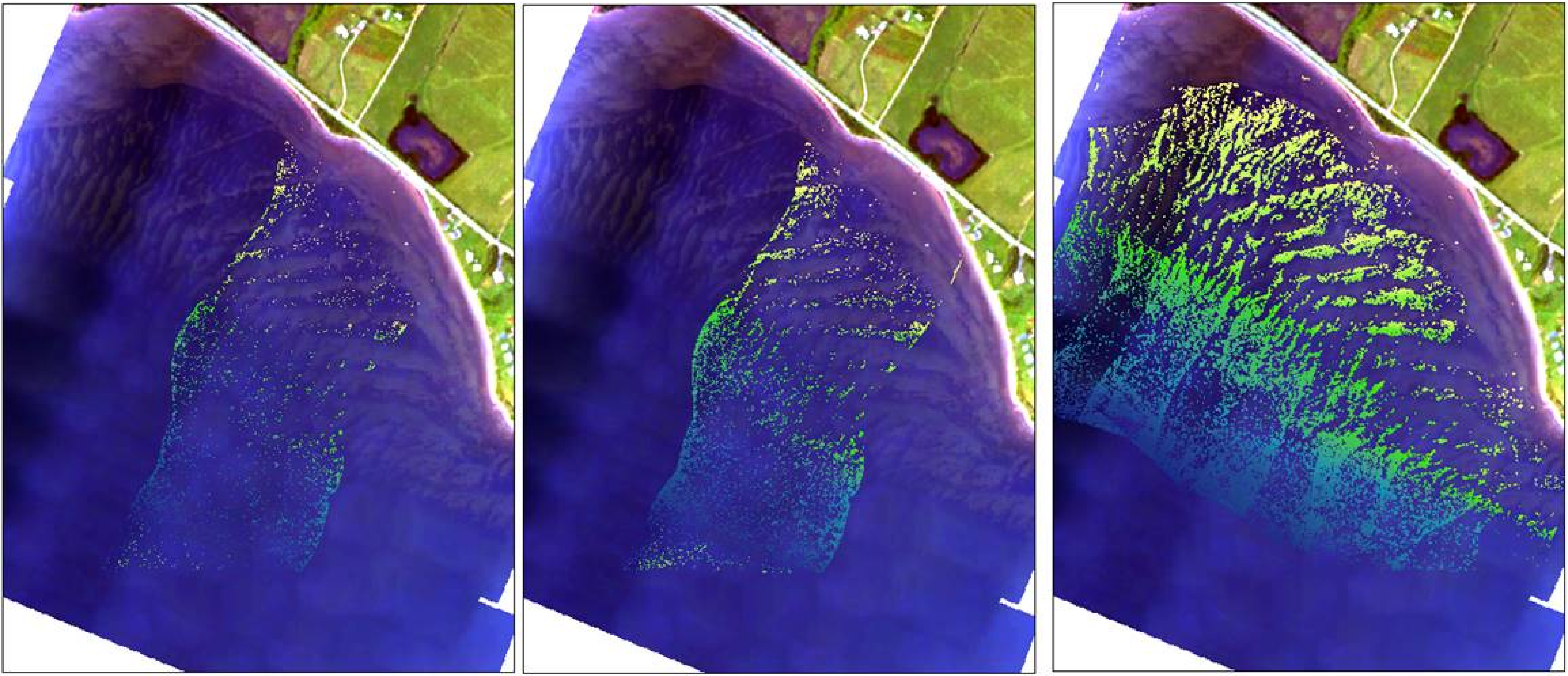
018_ufx4A_2HD
018A_2HD
019_ufx2A_2HD
019_ufx3A_2HD
019_ufx4A_2HD
019A_2HD
ID003 Flightline 022 To
ID004 Flightline 023 Sh
14 Cross section Viewer
Intensity
3D
4X point density
Single flight line
13 Cross section Viewer
14 Cross section Viewer
Point Cloud View
Height
Version 2.30.00
Point: (0.00, 0.00, 0.00)
CAP NUM SCRL


Lidar Survey Studio - Untitled
File Edit Settings View Tools Process Help
Unknown UTM zone
Height
Result View
2018FP_AGRG_20180806_211835
20180824_152053
ID005 Flightline 024 Shallo
ID005 Flightline 024 Topo
20180826_084416
14 Cross section Viewer
Intensity
3D
4X point density
All flight lines
13 Cross section Viewer
14 Cross section Viewer
Point Cloud View
Height
Version 2.30.00
Point: (0.00, 0.00, 0.00)
CAP NUM SCRL

Lidar Derived Automate Submerged Aquatic Vegetation Mapping

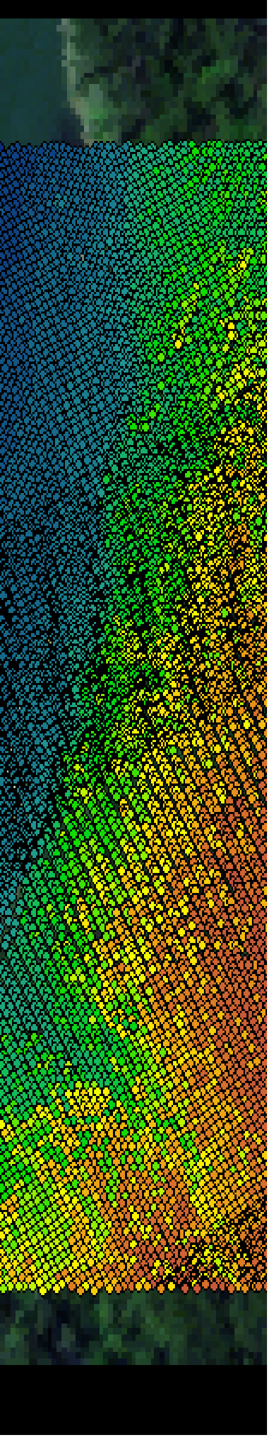
In Development



Single Flightline, Typical HD

Single Flightline, U4X

Multi Flightline, U4X



Conclusions

- Topo-bathymetric lidar – seamless elevation across the salt or fresh water–land boundary to depths of 15 m + depending on water clarity
- Multiple applications of the surveys beyond charting – benthic habitat, marine spatial planning, hydrodynamic models, storm surge, waves, research into waveform metrics and improved point discretization
- 4X results of Leica Chiroptera II significant increase in point density, improved target detail & detection limits, potential for more direct benthic point classification
- 1 x 1 m cubes detectable with lidar, deeper = wider
- Colour effects target reflectivity ~ detectability, green cube darker and fewer points than white cube
- Mixed and Virtual Reality system enhance our understanding of the data and thus the geography through better interaction & visualization
- YouTube Channel (Google AGRG Geomatics)

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