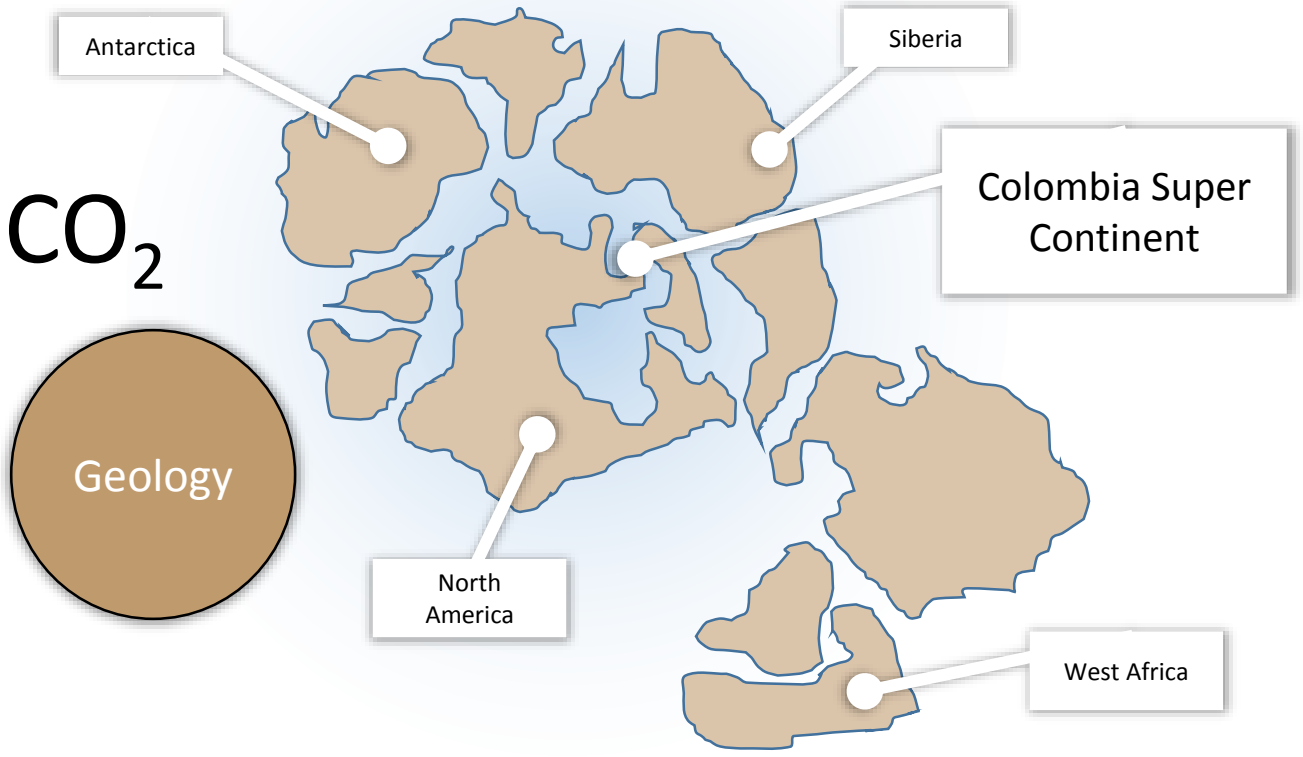
Topo-bathymetric lidar to support enhanced coastal mapping for shellfish Aquaculture & Eelgrass mapping

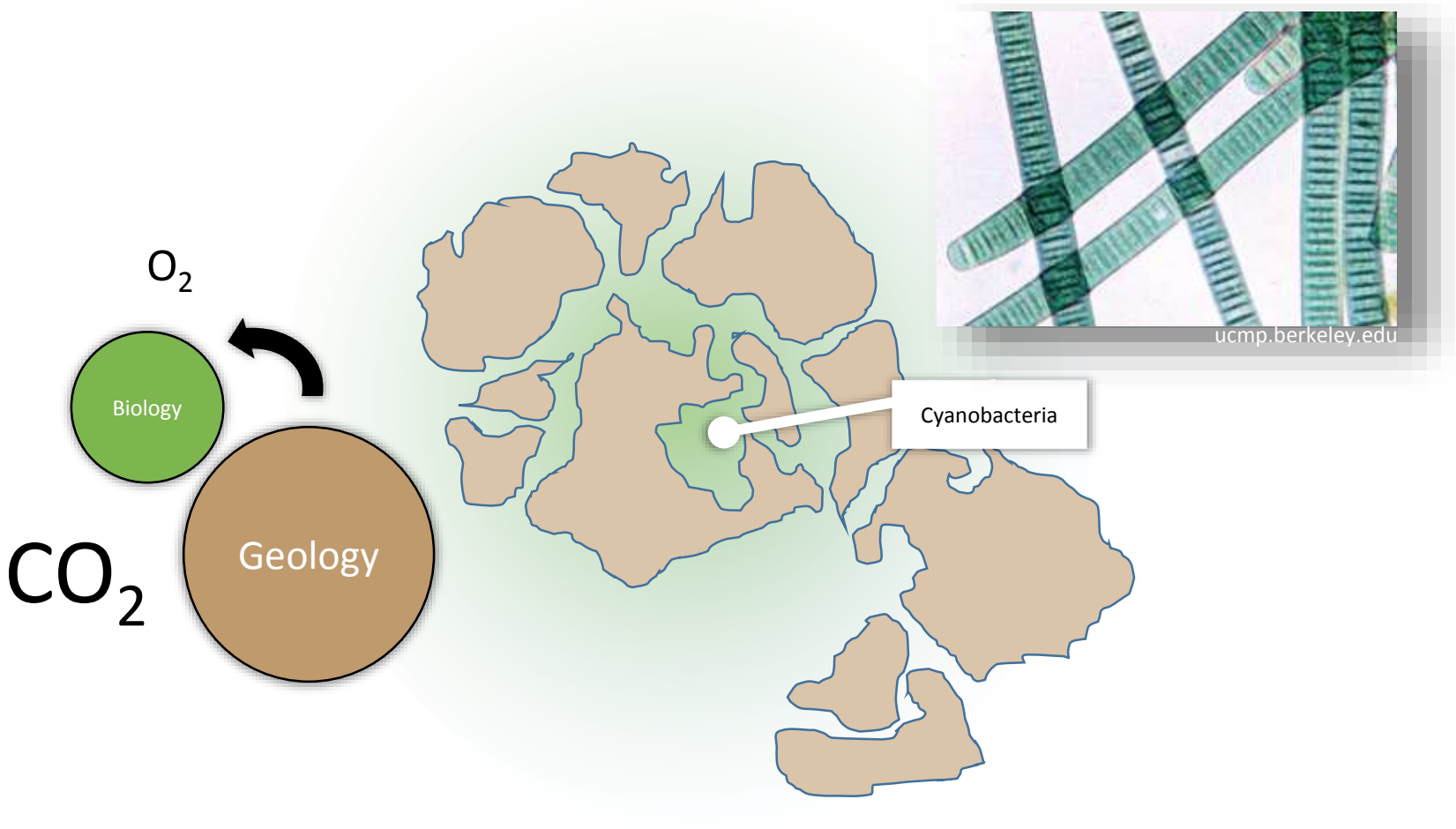
Department of Fisheries and Oceans Gulf Region –

Kevin McGuigan - Research Associate AGRG, NSCC

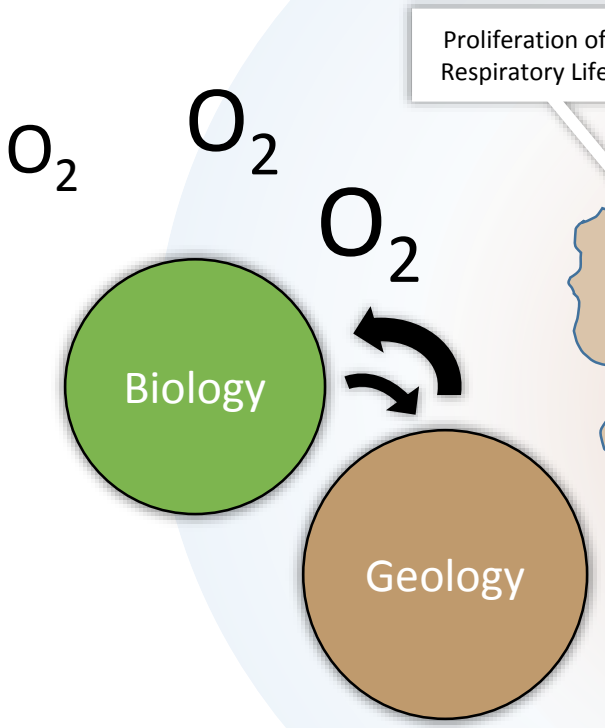
3 Billion years ago…

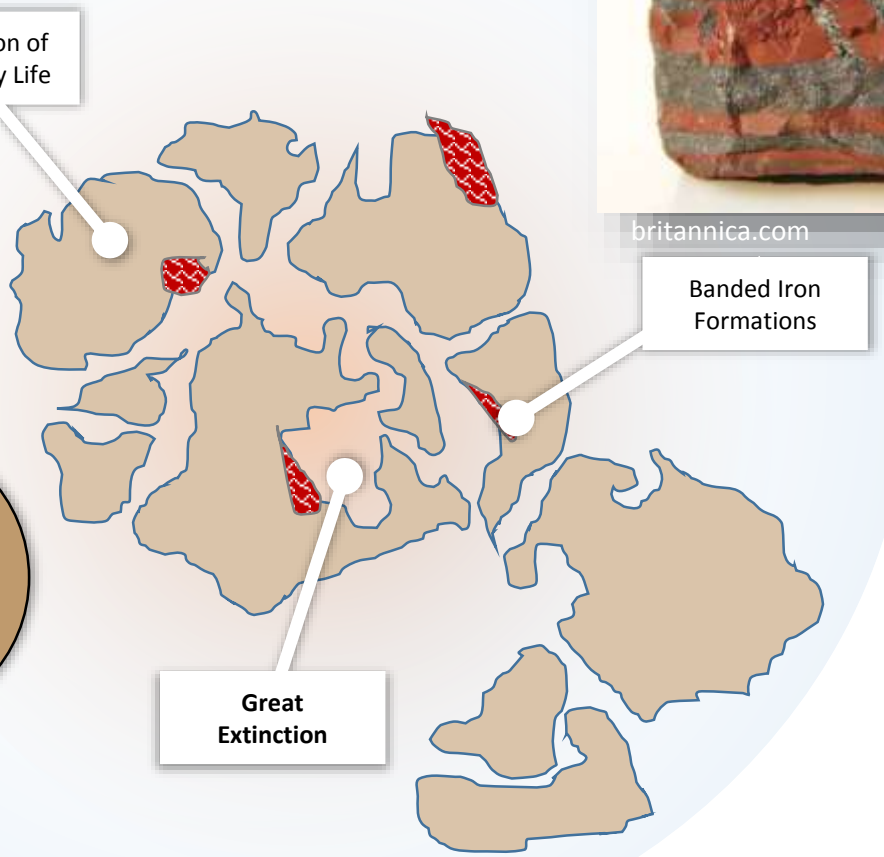


1.5 Billion years ago…

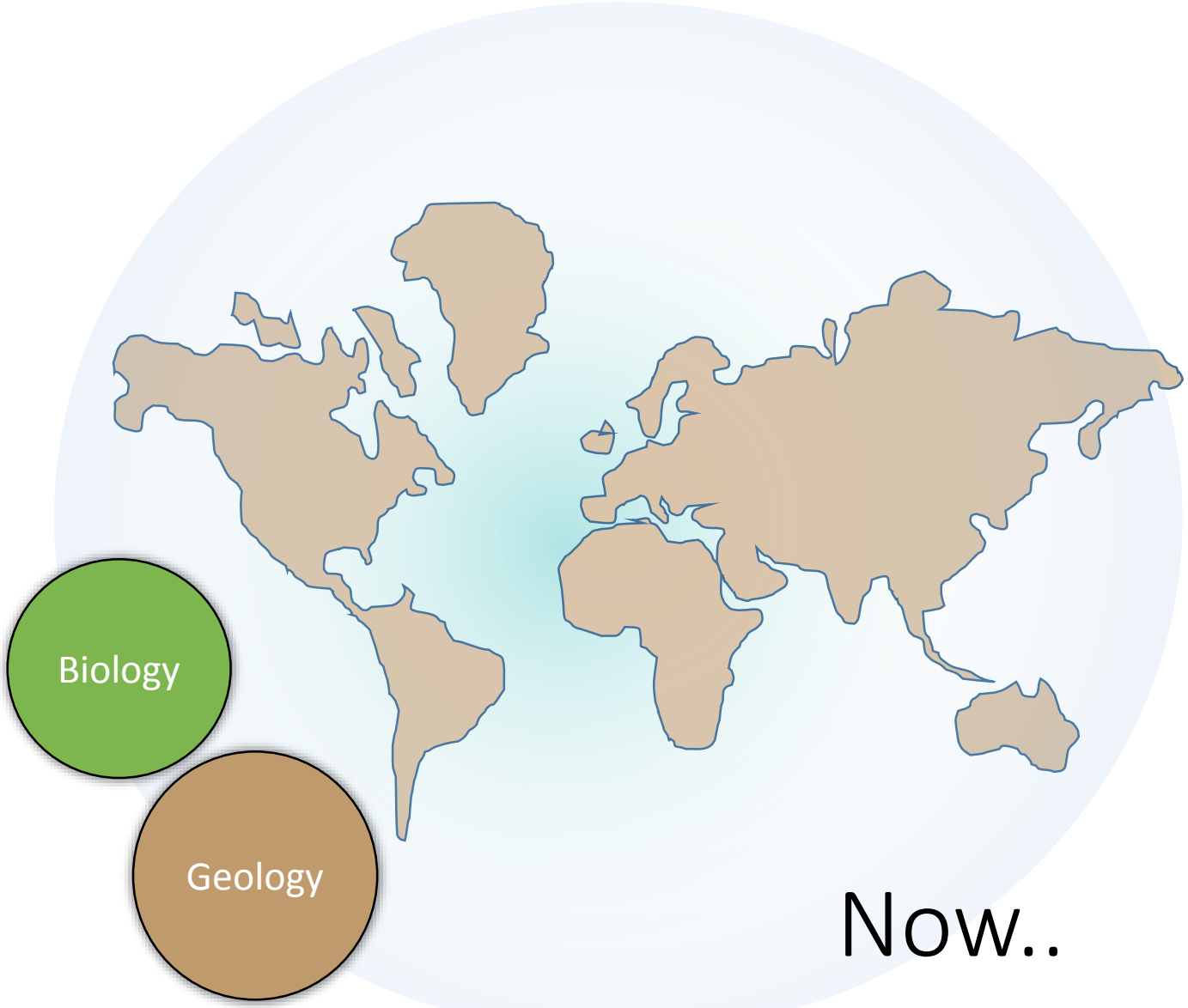


500 Million years ago…

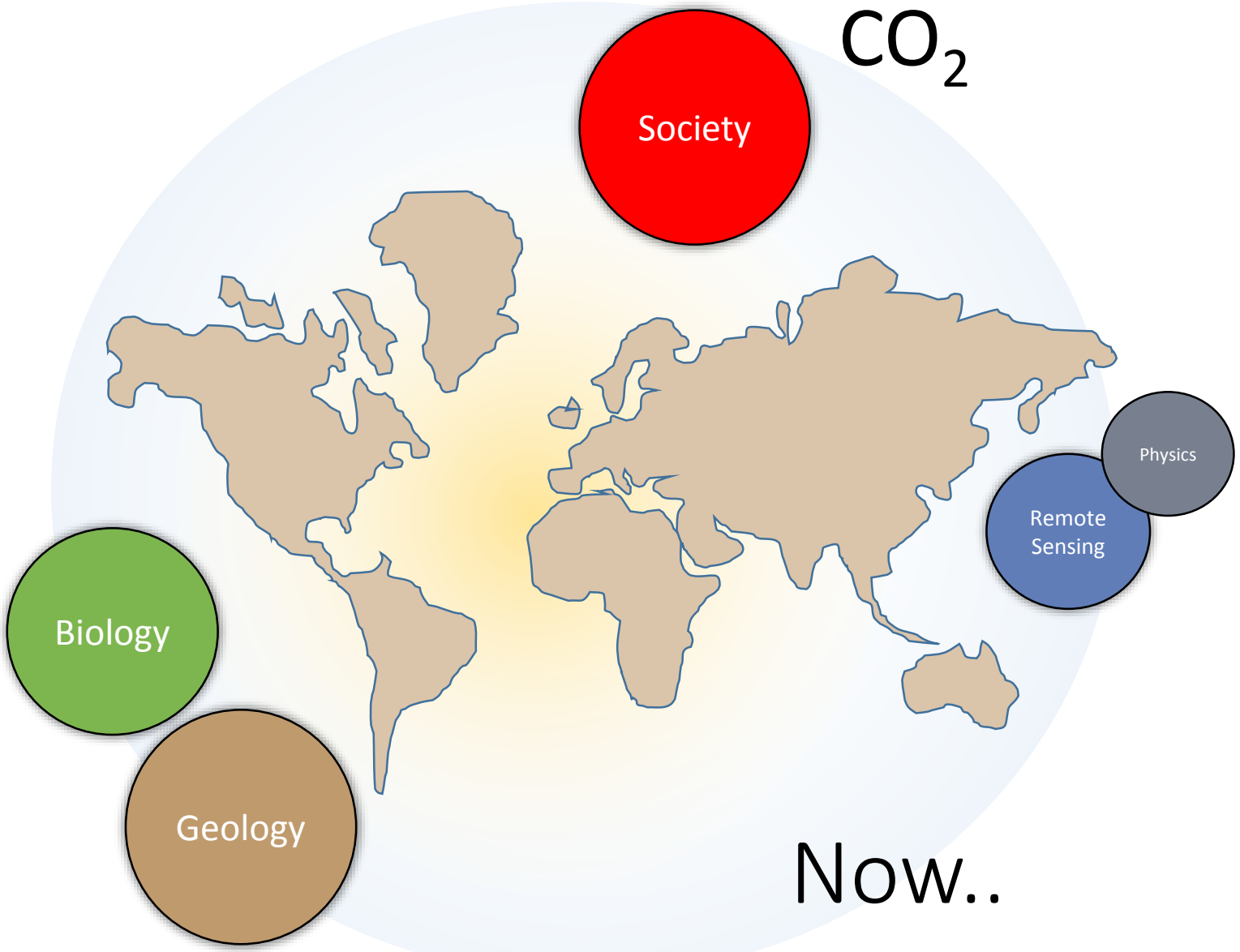




Fe_2O_3



Now..



Nova Scotia

NWATL, CHS, NRCAN, Boulder, NOAA, UNB, UNH, OPTECH, USGS, UofMaine

gov.pe.ca

AGRG

thechronicleherald.ca

thechronicleherald.ca

forsythesauctions.com

cbc.ca

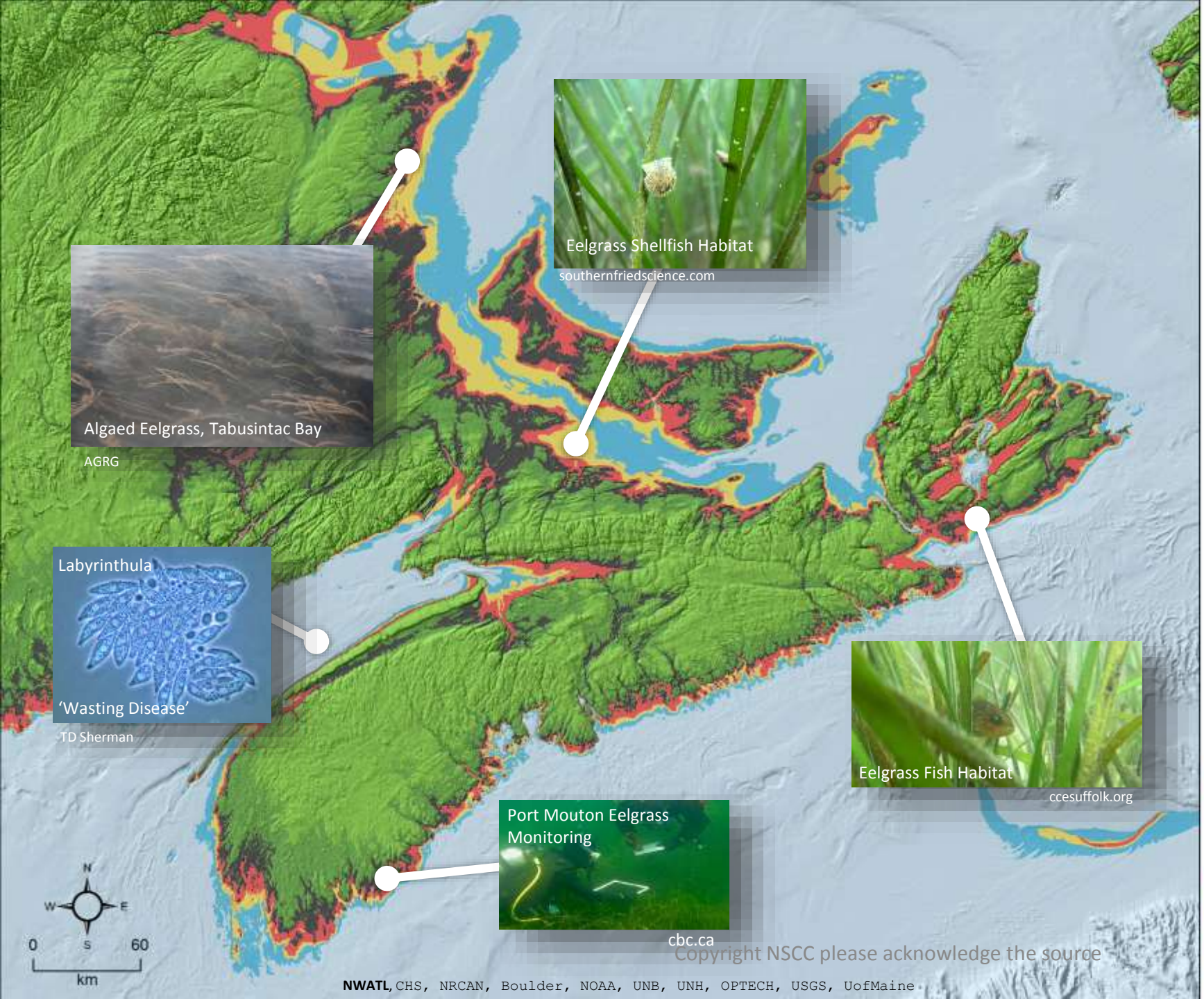
CLIM ATE CHANGE

N
W E
S
0 60
km

Society

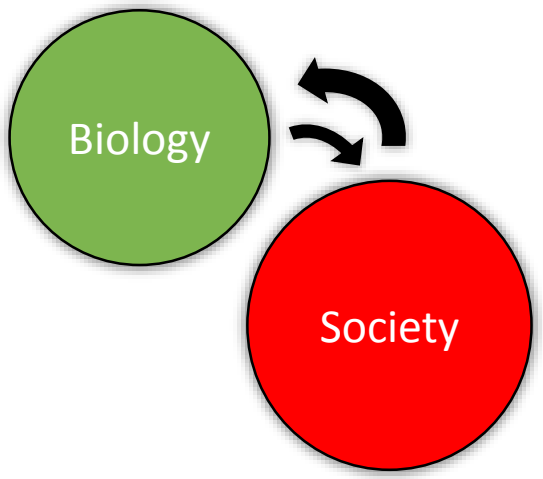
- **Coastal Stewards**
- **Challenges / Opportunities**

Height
Metres
0 - 30
30 - 80
80+
Water
Water



Biology

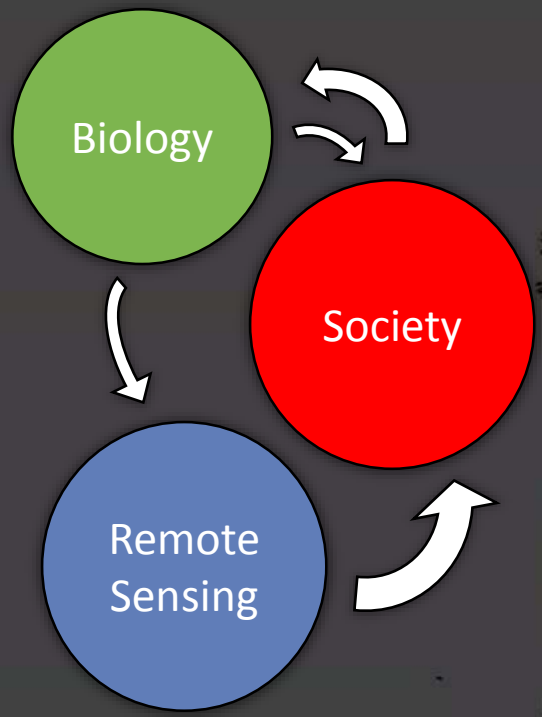
- **EELGRASS**
  - ***Zostera arina***
- **Coastal 'Canary in the coal mine'**



We need to *detect* and *communicate* changes in regional **eelgrass** *systematically*…

https://earthenginepartners.appspot.com/science-2013-global-forest

Global Forest Cover Change



Global Forest Change

Published by Hansen, Potapov, Moore, Hancher et al.

UNIVERSITY OF MARYLAND
DEPARTMENT OF GEOGRAPHICAL SCIENCES

Results from time-series analysis of Landsat images characterizing forest extent and change.

Trees are defined as vegetation taller than 5m in height and are expressed as a percentage per output grid cell as '2000 Percent Tree Cover'. 'Forest Cover Loss' is defined as a stand-replacement disturbance, or a change from a forest to non-forest state, during the period 2000–2014. 'Forest Cover Gain' is defined as the inverse of loss, or a non-forest to forest change entirely within the period 2000–2012. 'Forest Loss Year' is a disaggregation of total 'Forest Loss' to annual time scales.

Reference 2000 and 2014 imagery are median observations from a set of quality assessment-passed growing season observations.

Download the data.

Reset to default view

Data Products

Forest Loss Year (2014 Highlight)

2014
2013
:
2000
No loss
Water or no data

Other Data Layers

Tropical Hinterland Forests

Background Imagery

Year 2000 Bands 5/4/3

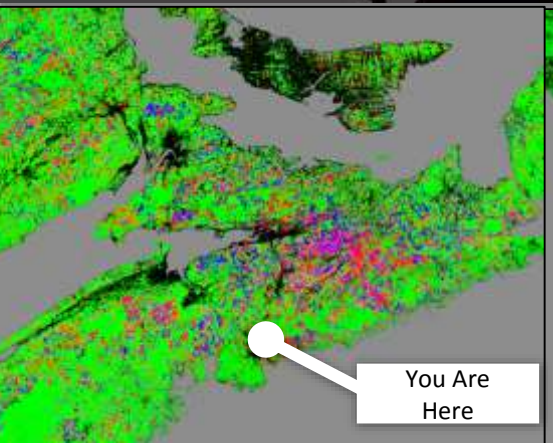
Example Locations

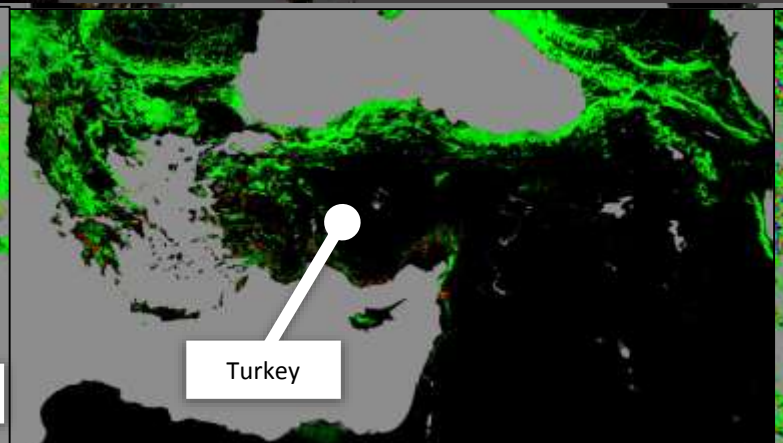
Forestry and Tornado in Alabama

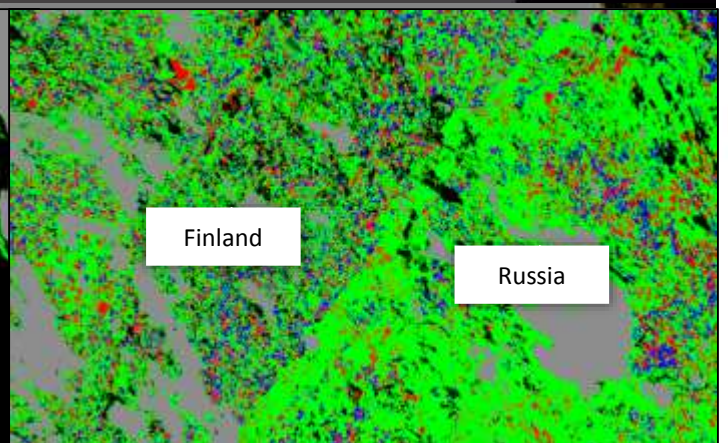
Zoom to area

The trail of destruction from the April 27 2011 Tuscaloosa-Birmingham tornado is clearly visible in location. This was one of 358 recorded tornadoes during the April 25-28, 2011 tornado outbreak, the m severe in US history.

Zoom out to spot tracks from other tornadoes nearb







How *do* we map eelgrass?

Eelgrass Mapping Technologies

- Ground Sampling
- Underwater Photography
- Single Beam Echosounder
- Multibeam Sonar
- Bathymetric Lidar
- Aerial Photography
- Satellite Imagery

Eelgrass Mapping Technologies

- **Ground Sampling**
- Underwater Photography
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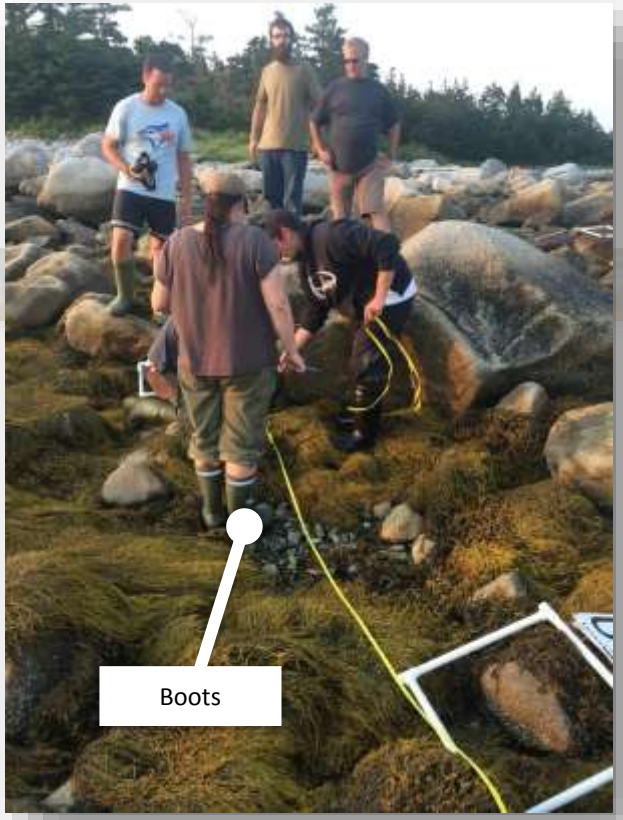
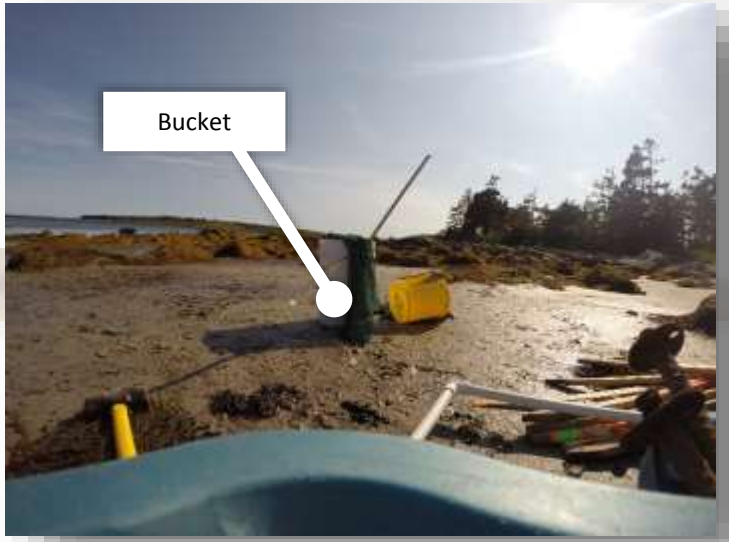


Shag Harbor, NS. AGRG



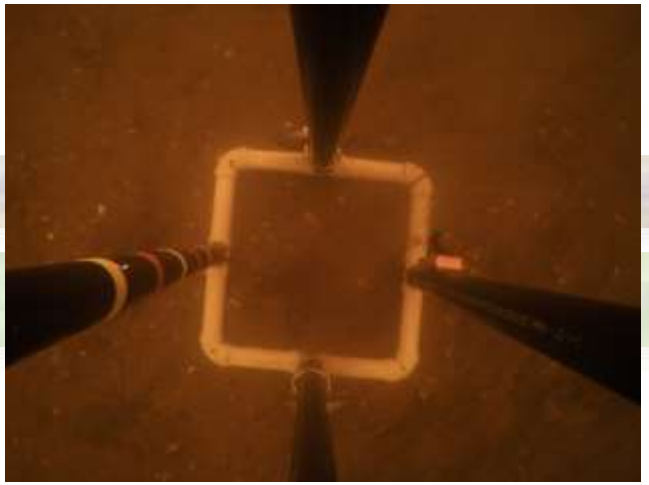
Shag Harbor, NS. AGRG

Cocagne River. AGRG

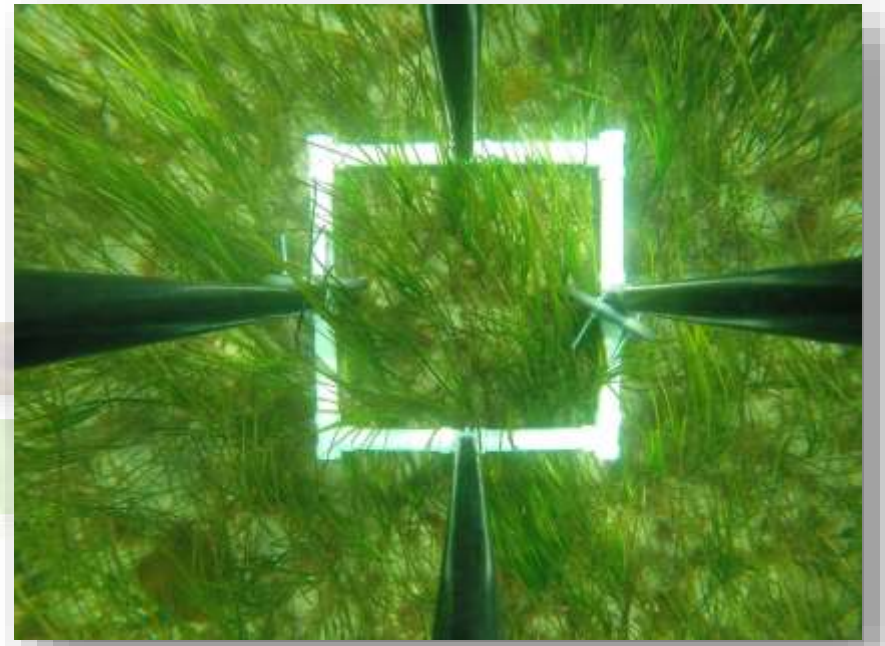
Cocagne River. AGRG

Eelgrass Mapping Technologies

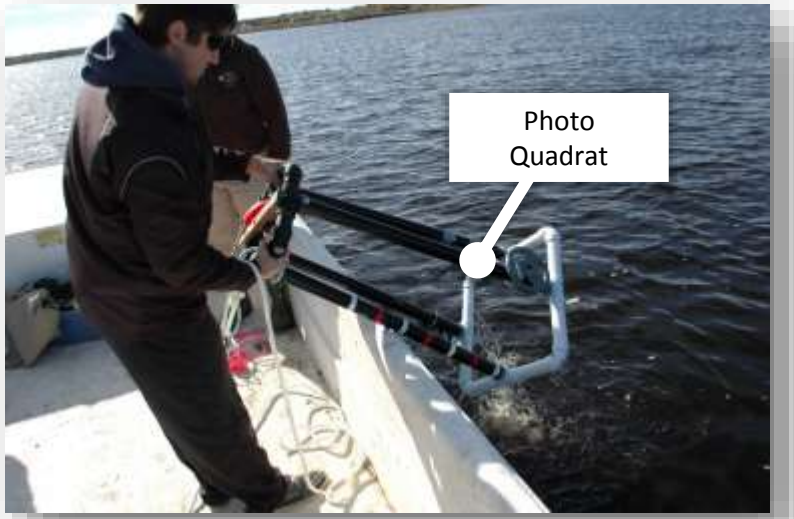
- Ground Sampling
- **Underwater Photography**
- Single Beam Echosounder
- Multibeam Sonar
- Bathymetric Lidar
- Aerial Photography
- Satellite Imagery



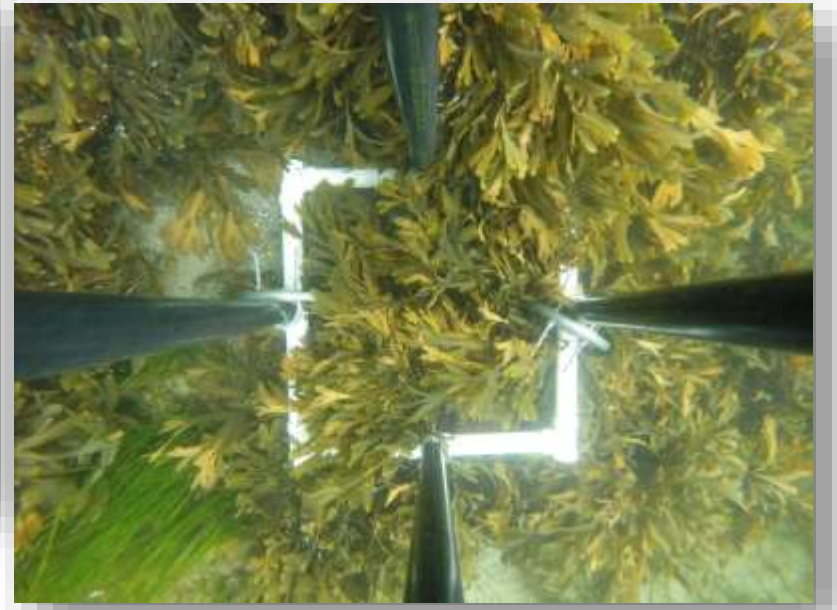
Cocagne River, October 18 2015. AGRG



Eelgrass, Shag Harbor, NS. AGRG



Cocagne River. AGRG

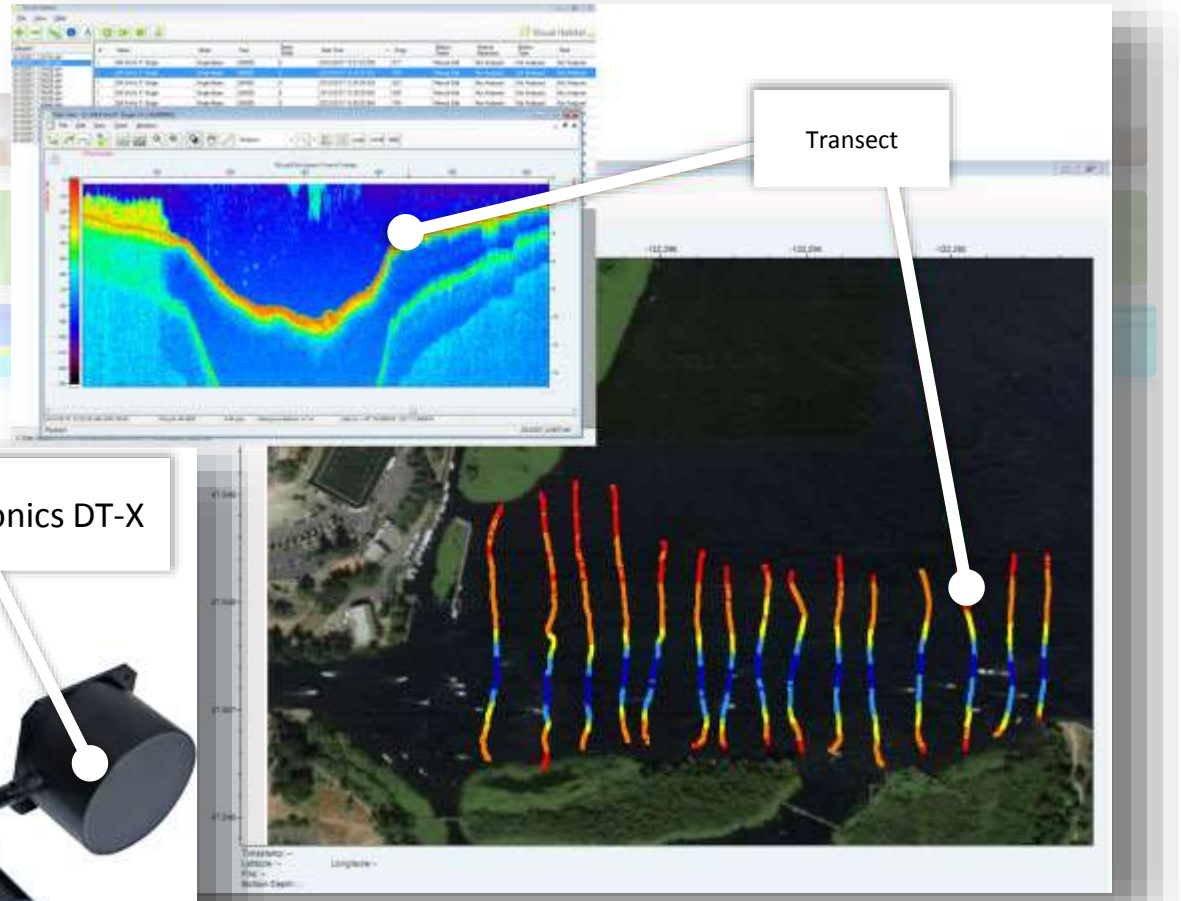


Kelp, Shag Harbor, NS. AGRG

Eelgrass Mapping Technologies

- Ground Sampling
- Underwater Photography
- **Single Beam Echosounder**
- Multibeam Sonar
- Bathymetric Lidar
- Aerial Photography
- Satellite Imagery

biosonicsinc.com



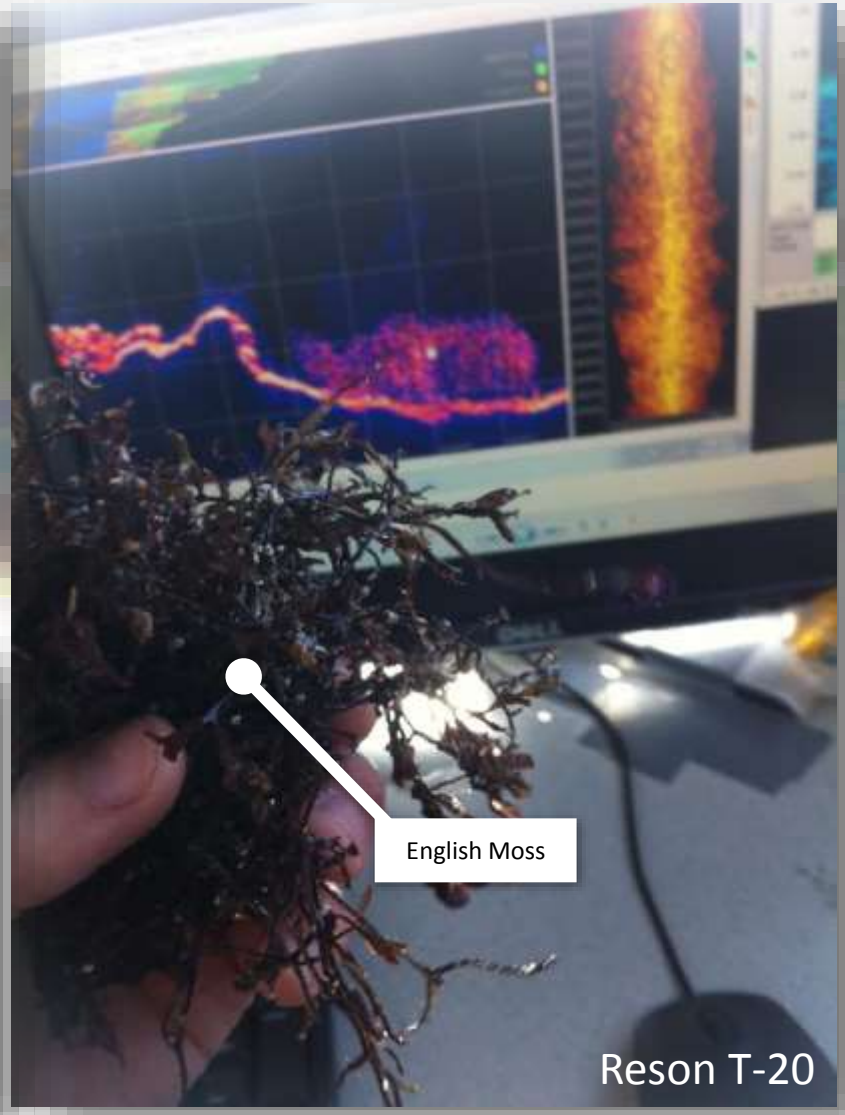
biosonicsinc.com

Eelgrass Mapping Technologies

- Ground Sampling
- Underwater Photography
- Single Beam Echosounder
- **Multibeam Sonar**
- Bathymetric Lidar
- Aerial Photography
- Satellite Imagery

teledyne-reson.com

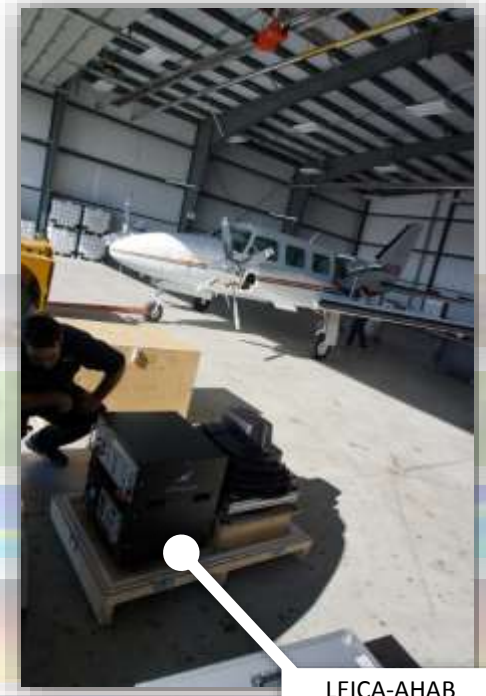
Multibeam Deployment, 2014. AGRG

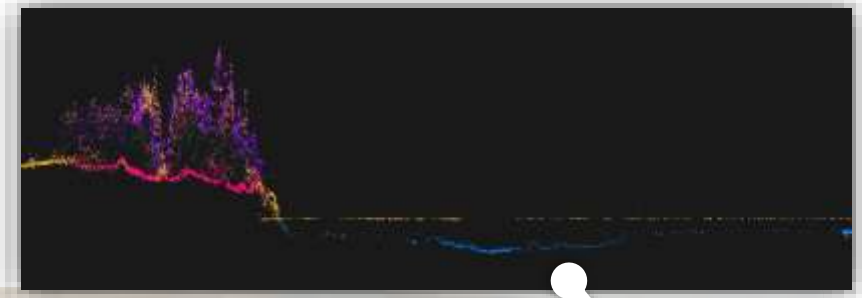


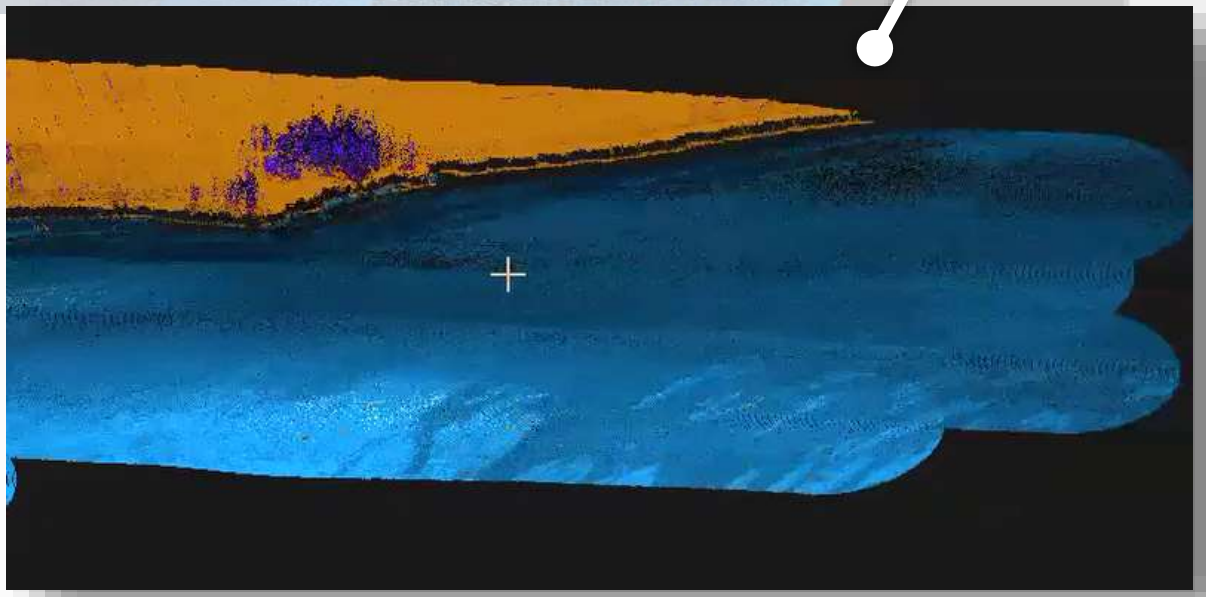
Cape John, NS. AGRG

Eelgrass Mapping Technologies

- Ground Sampling
- Underwater Photography
- Single Beam Echosounder
- Multibeam Sonar
- **Bathymetric Lidar**
- Aerial Photography
- Satellite Imagery



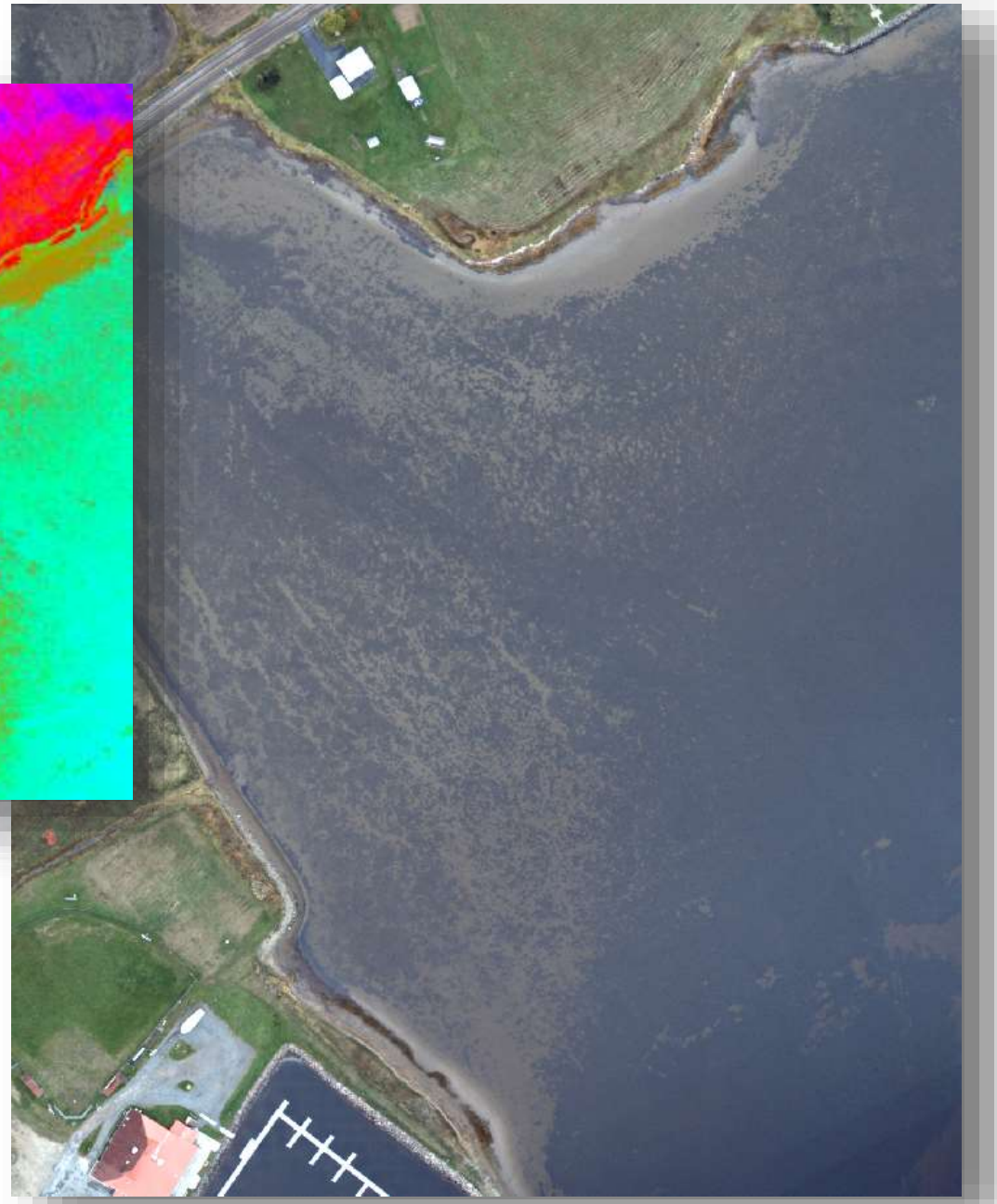




Eelgrass Mapping Technologies

- Ground Sampling
- Underwater Photography
- Single Beam Echosounder
- Multibeam Sonar
- Bathymetric Lidar
- **Aerial Photography**
- Satellite Imagery

NDPI



Cocagne River NB, 2015. AGRG

Eelgrass Mapping Technologies

- Ground Sampling
- Underwater Photography
- Single Beam Echosounder
- Multibeam Sonar
- Bathymetric Lidar
- Aerial Photography
- **Satellite Imagery**

Abasolo, J (2015); DOI: 10.1109/TGRS.2014.2377300

Eelgrass Mapping Technologies

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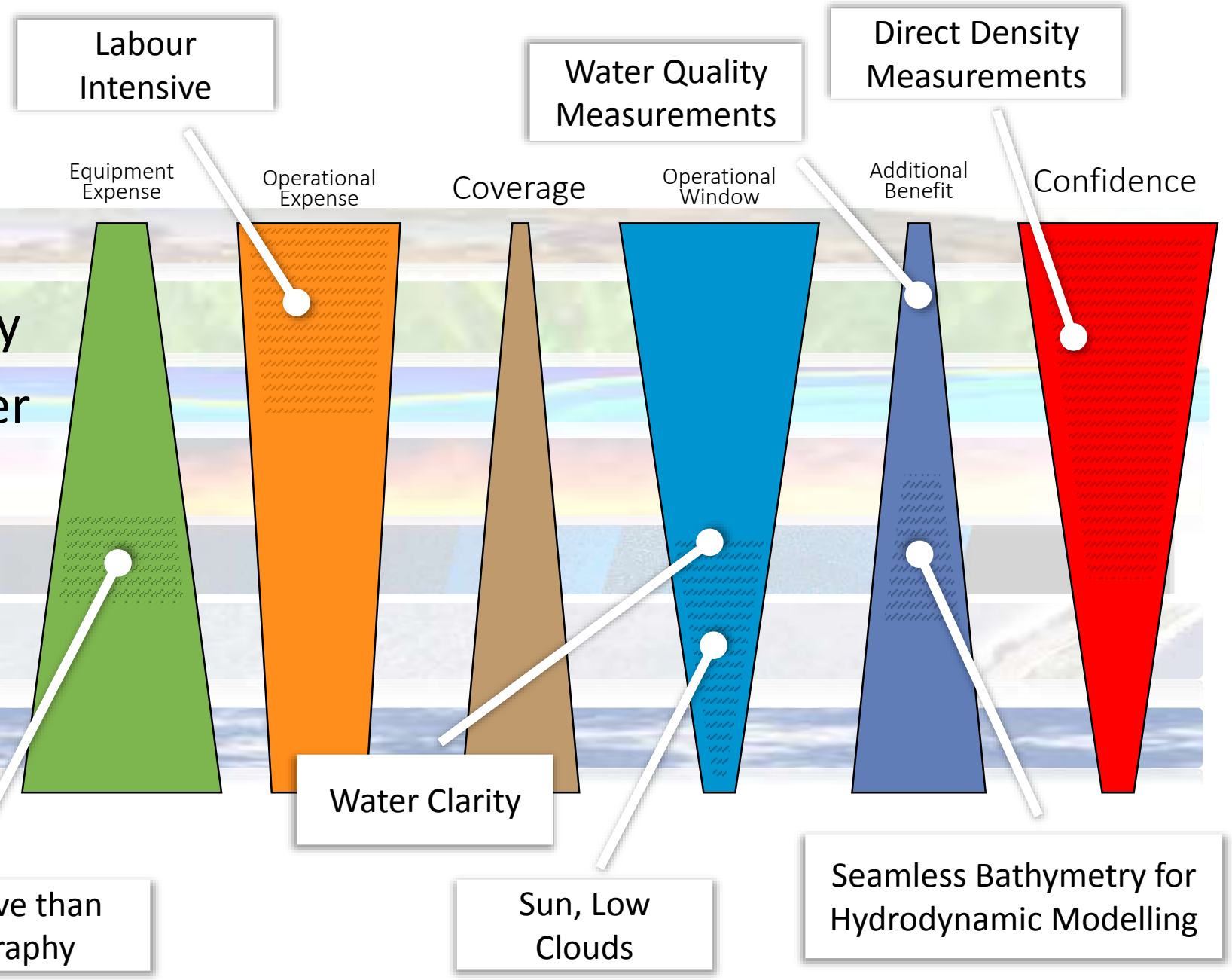

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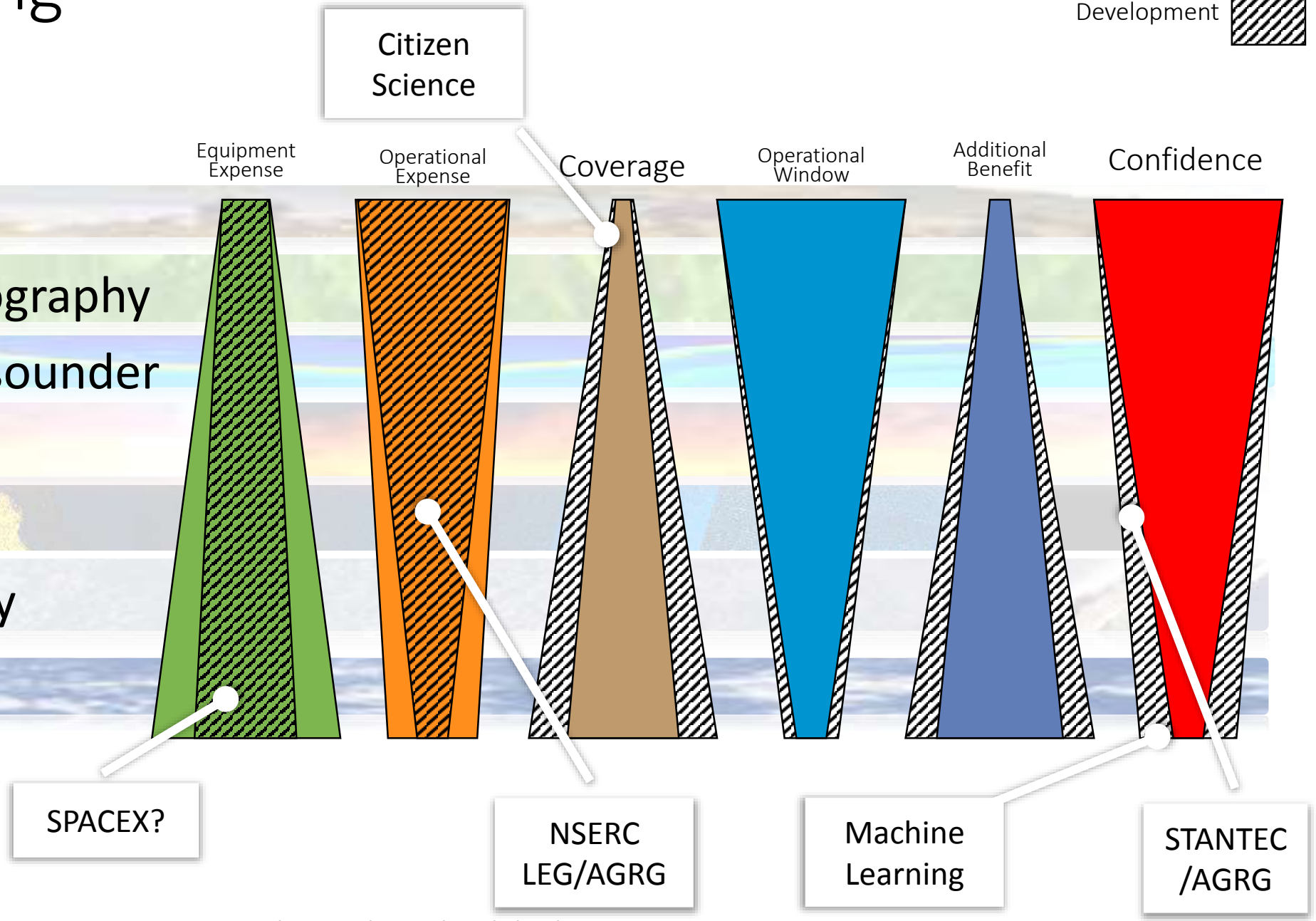
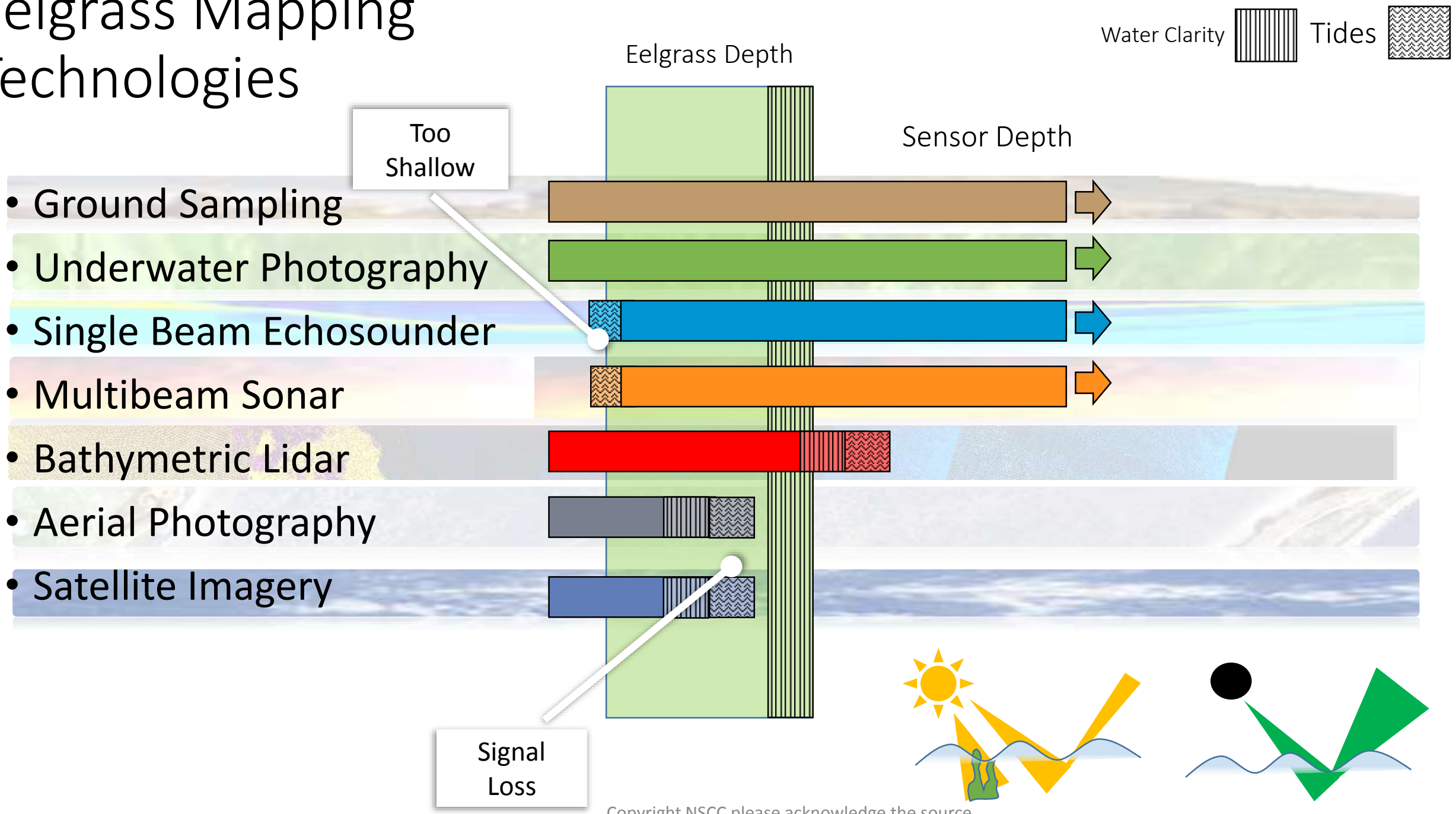
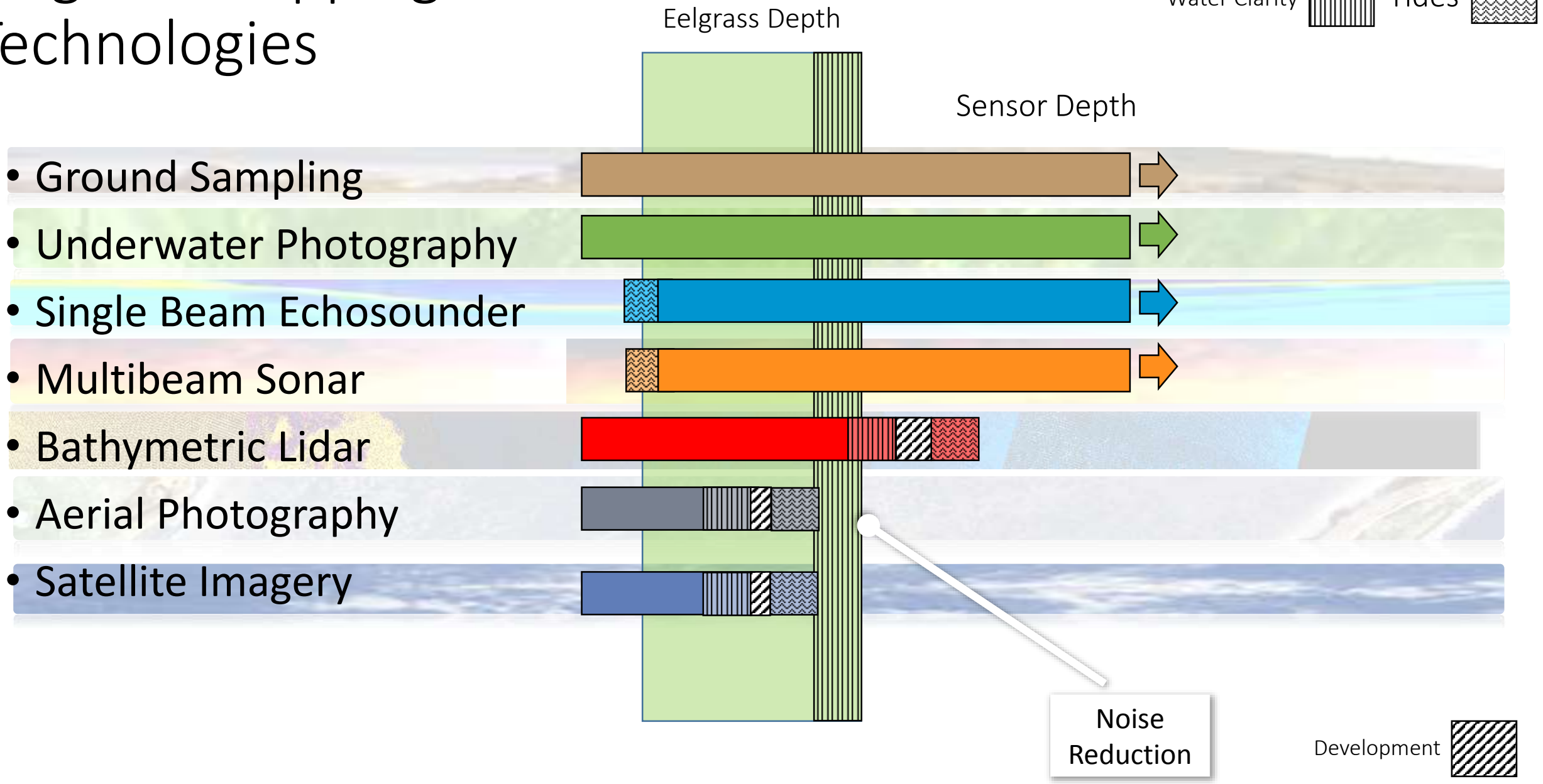


Eelgrass Mapping Technologies

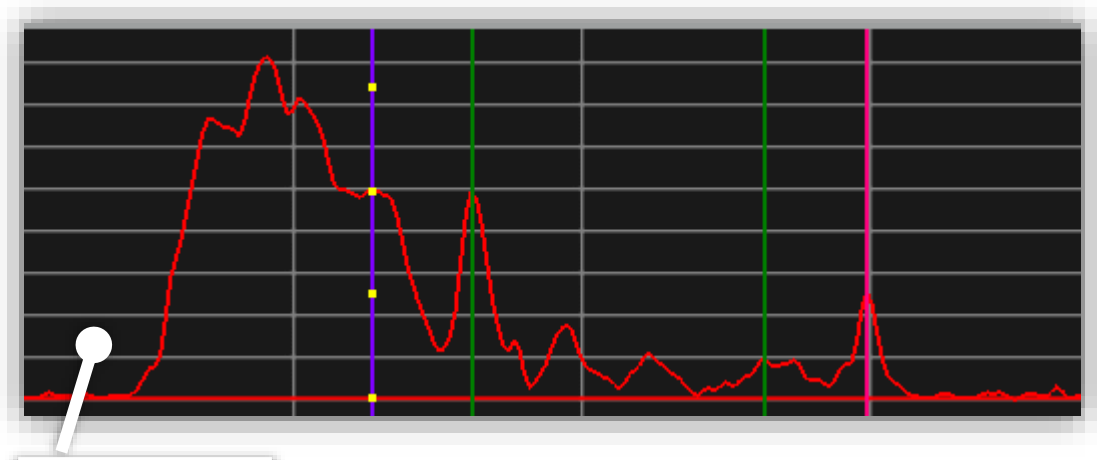


Eelgrass Mapping Technologies

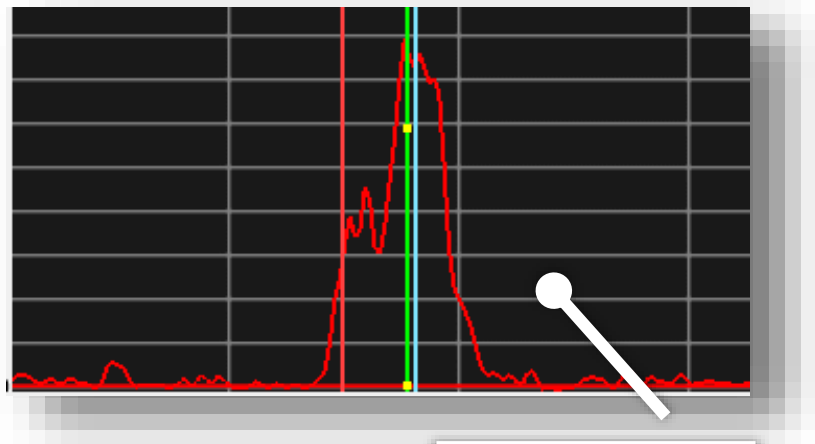


With **lidar**.

… (and *other* technologies)

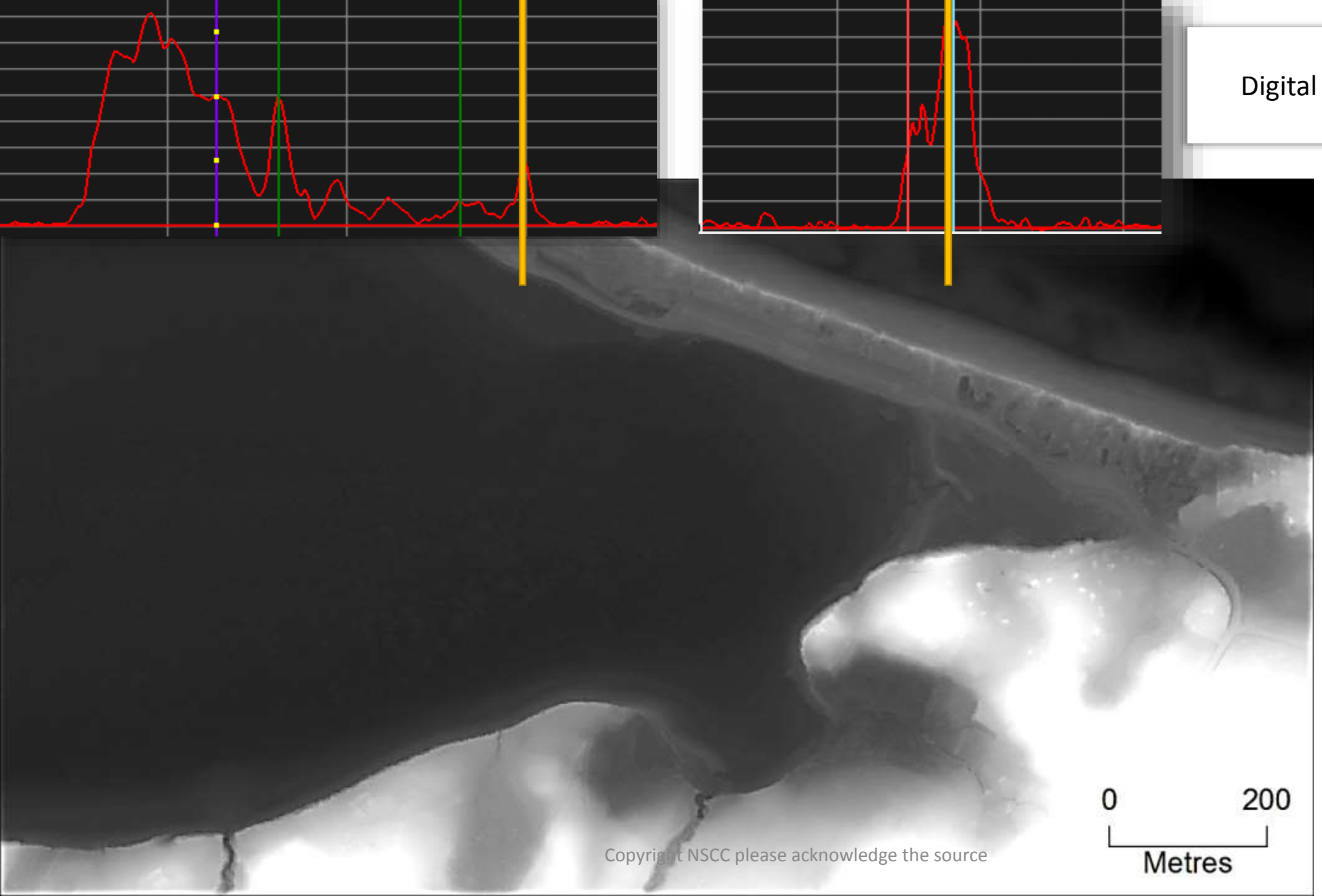


Lidar Land Waveform

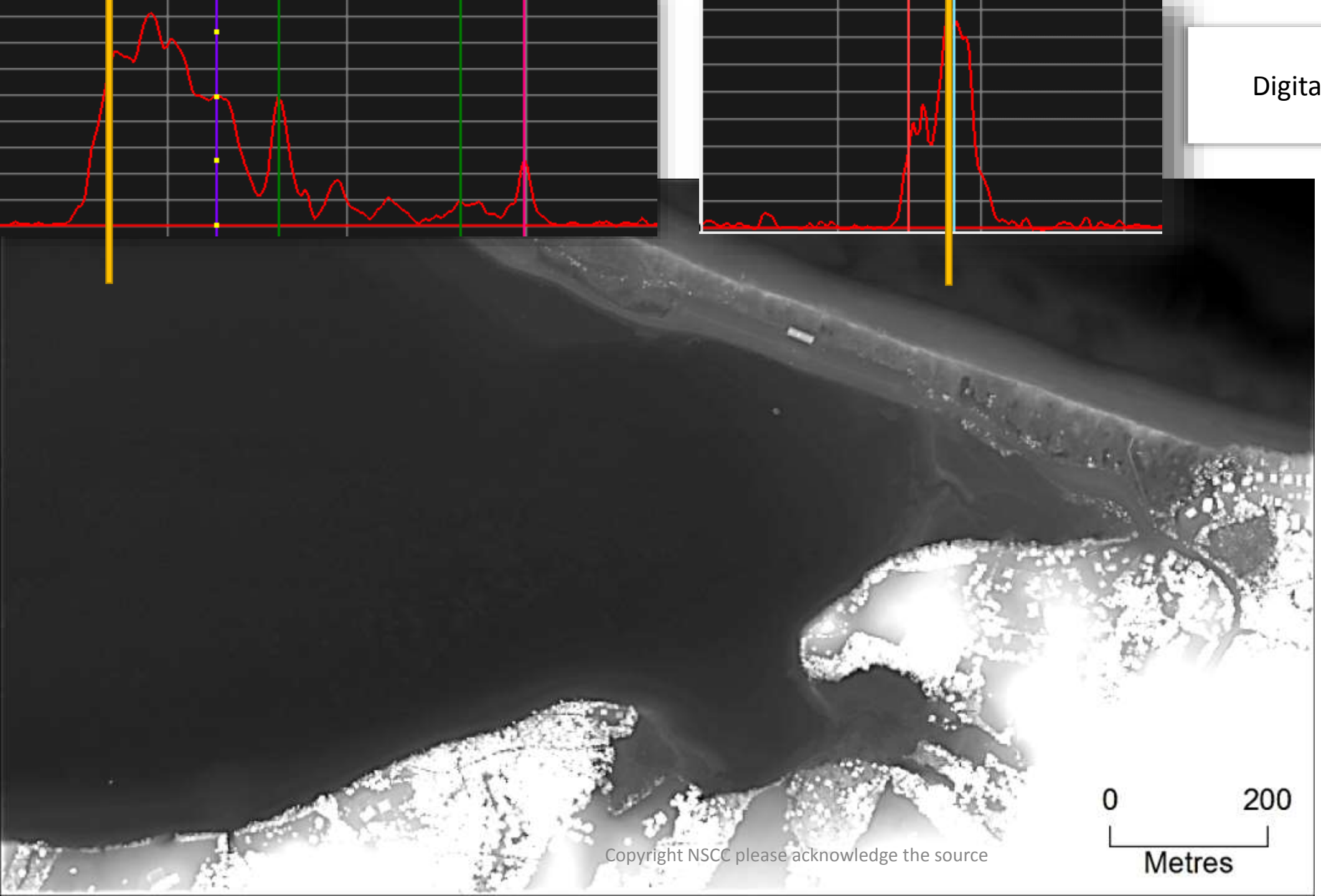


Lidar Water Waveform

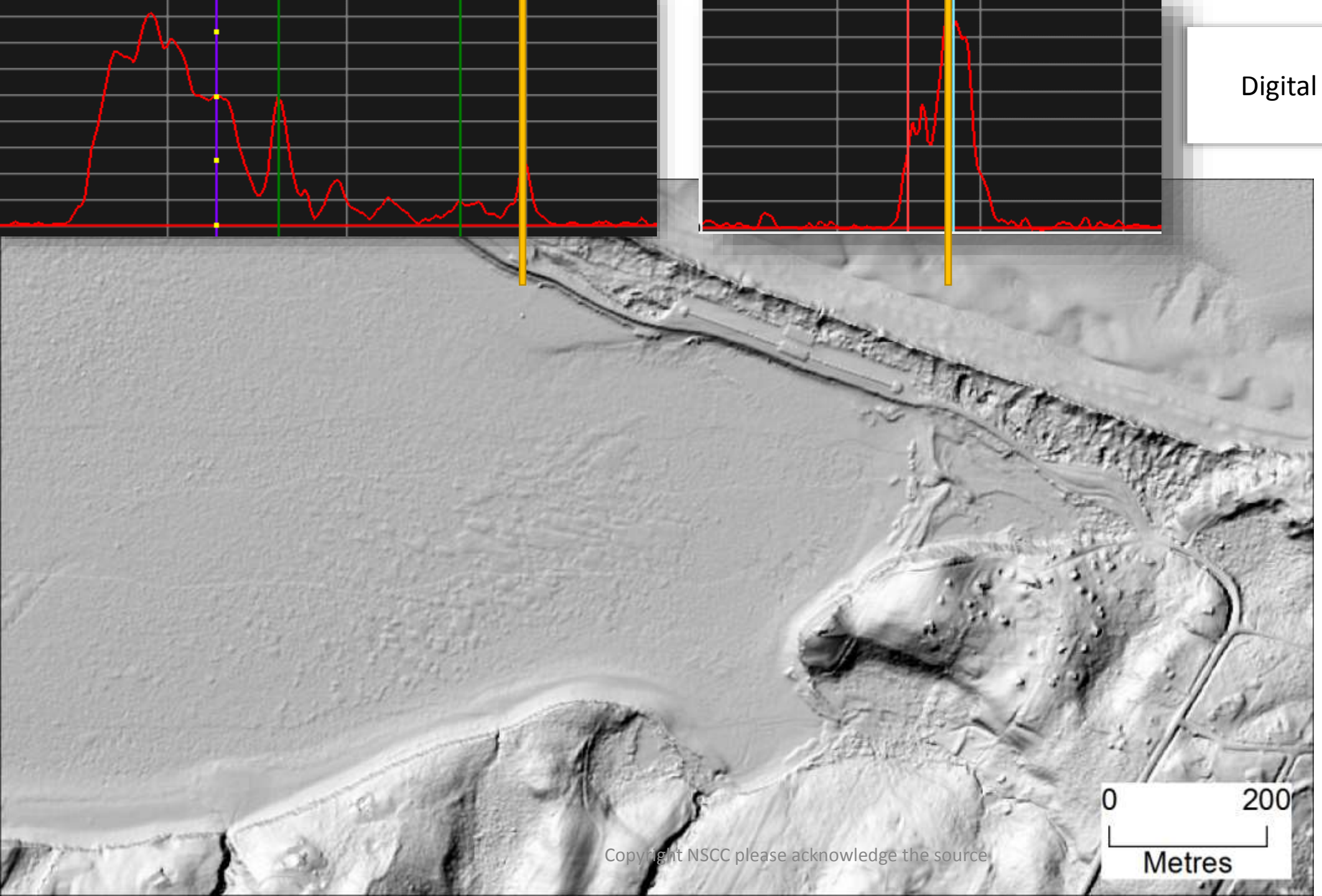
Digital Elevation Model



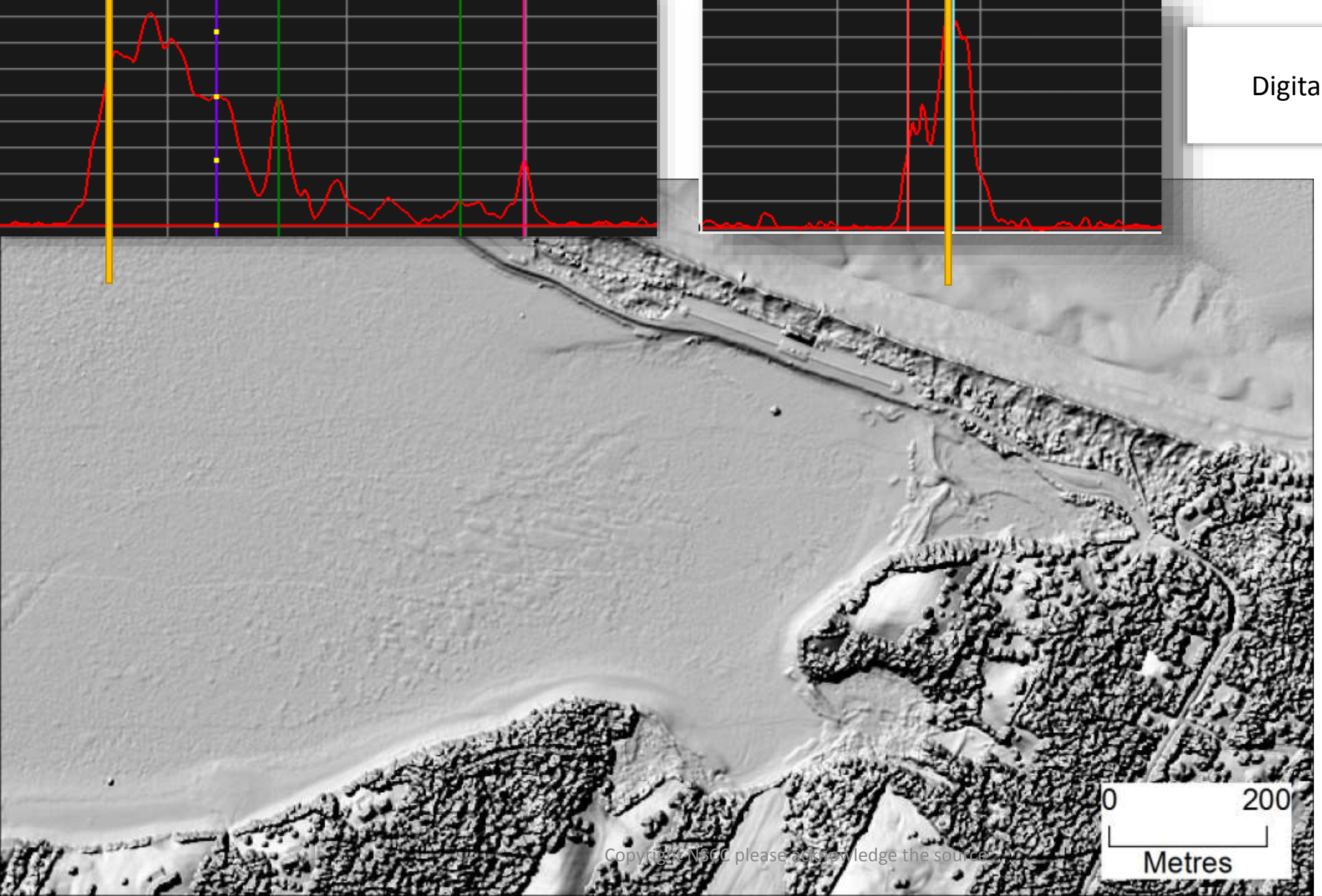
Digital Surface Model



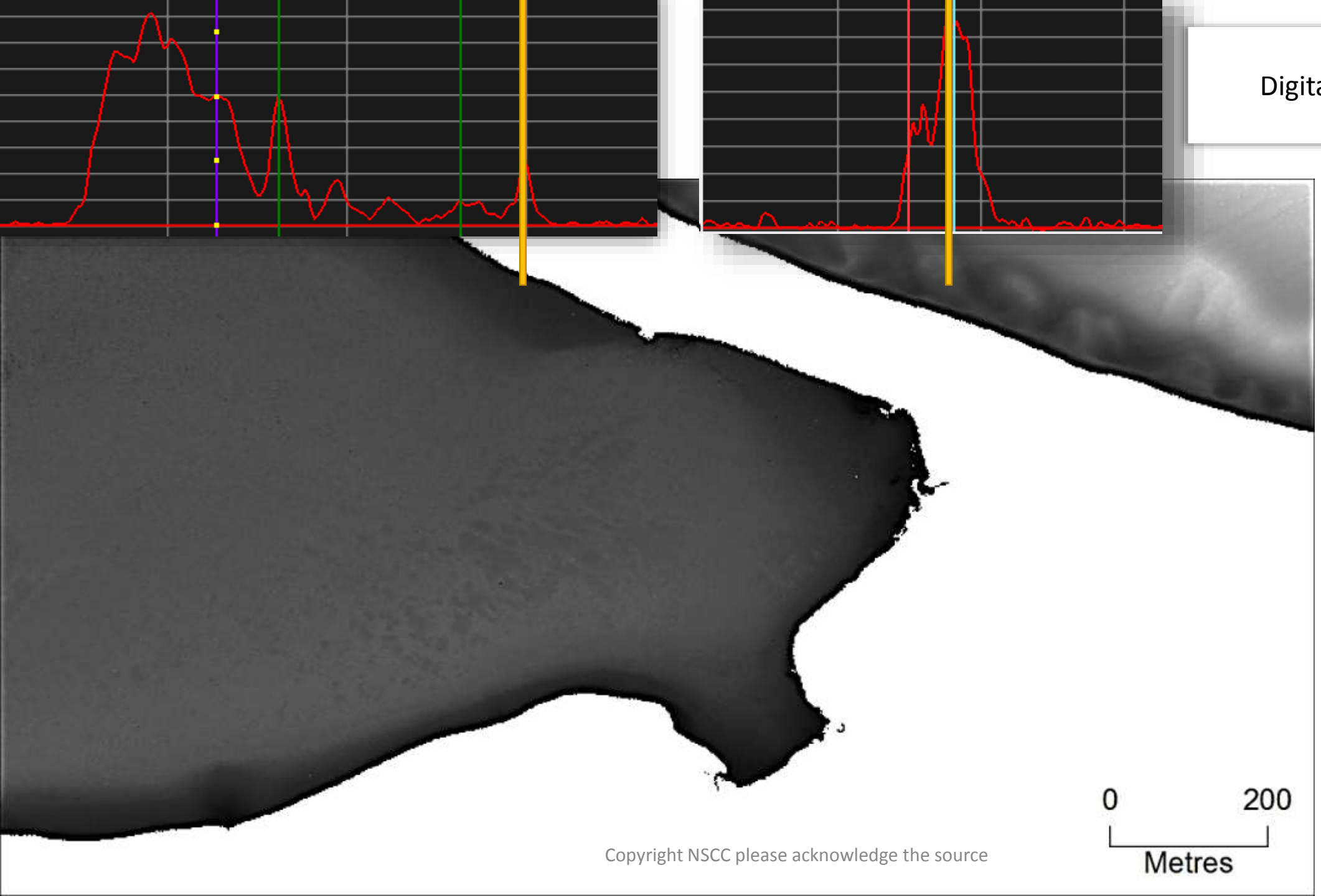
Digital Elevation Model



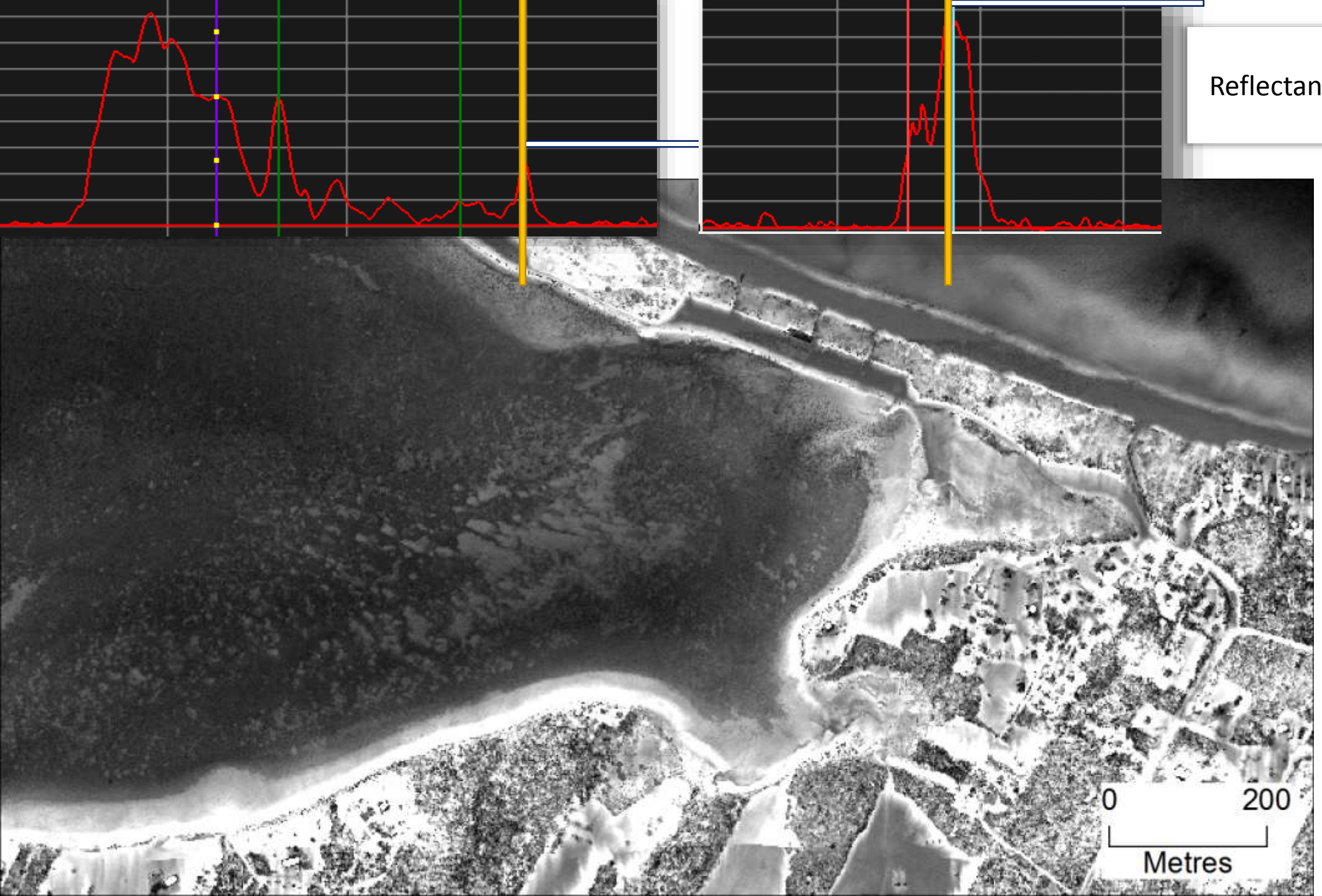
Digital Surface Model

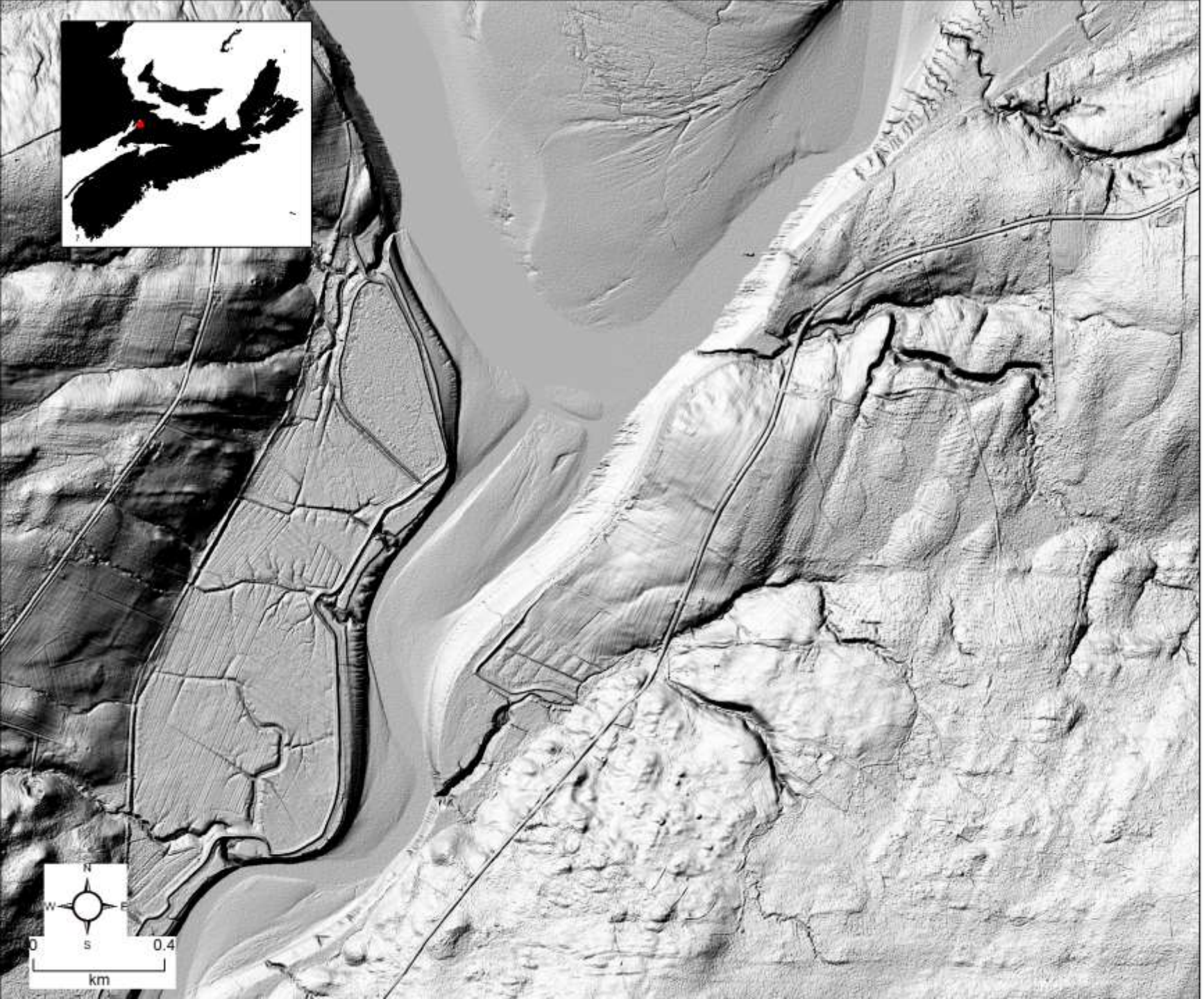


Digital Depth Model



Reflectance/Intensity Model





Digital Elevation Model

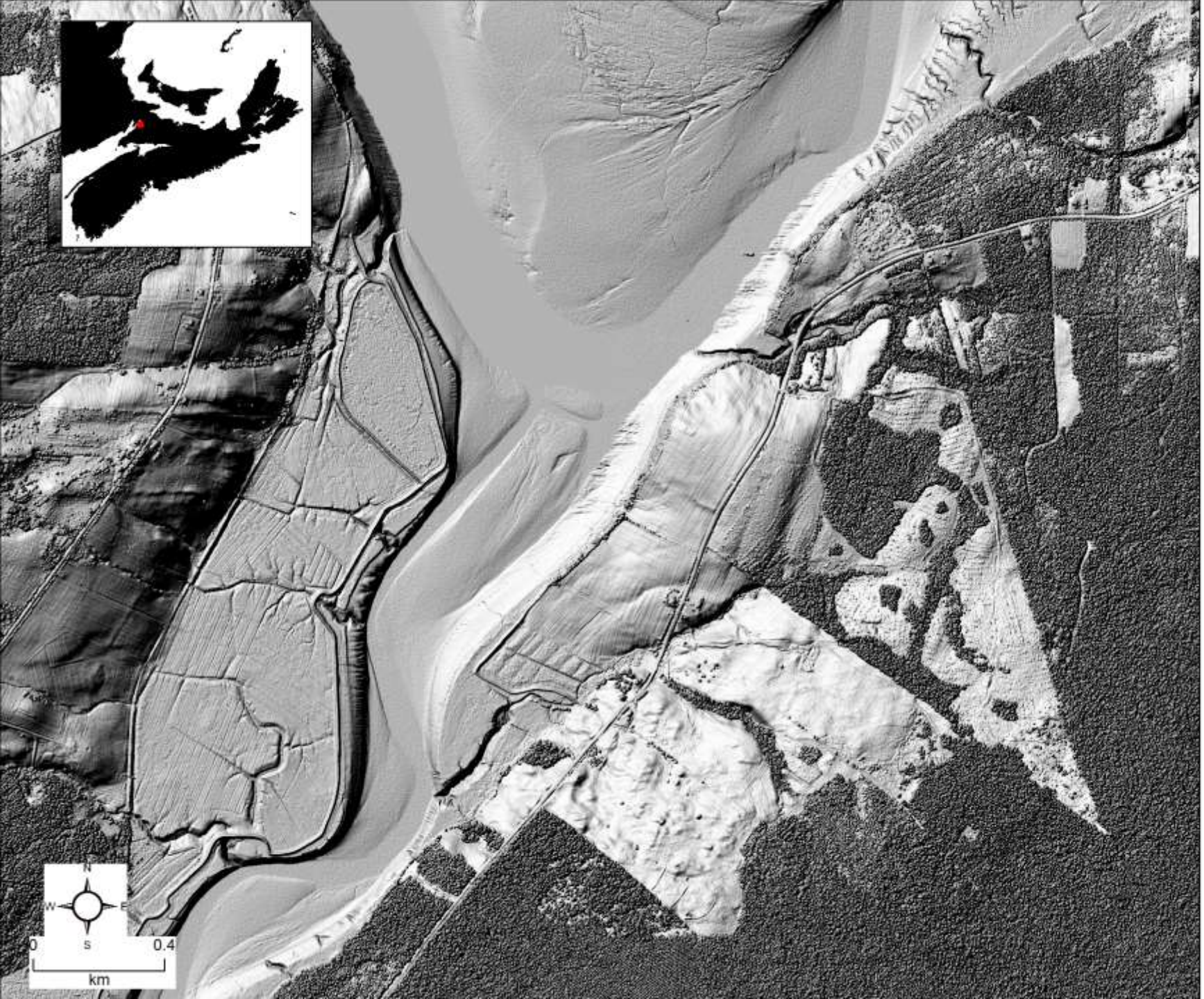
Lidar Surveys

AMH DEM 2009

Shade

High : 255

Low : 0



Digital Surface Model

Lidar Surveys

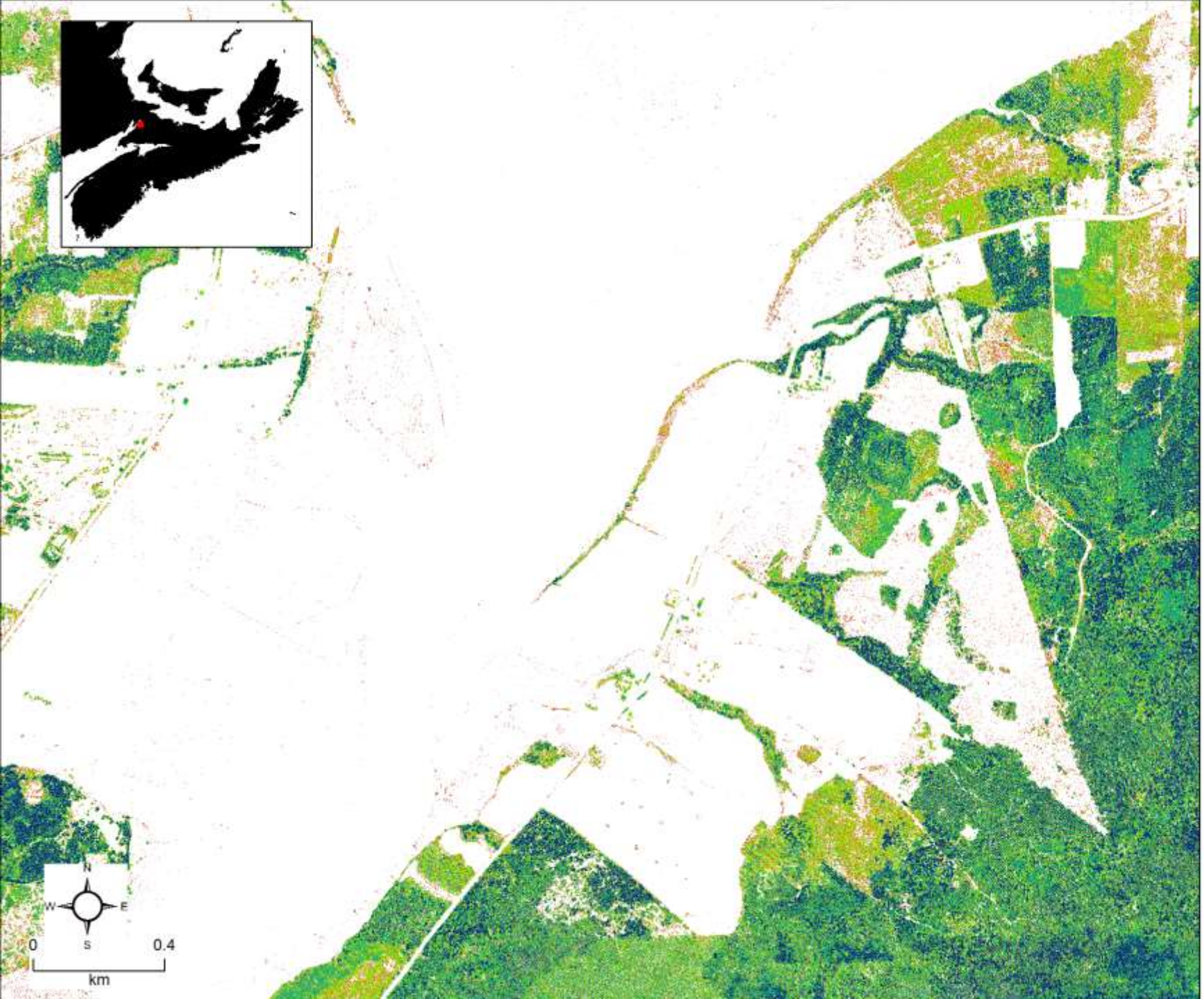
AMH DSM 2009

Shade

High : 255

Low : 0

Vegetation Height Model

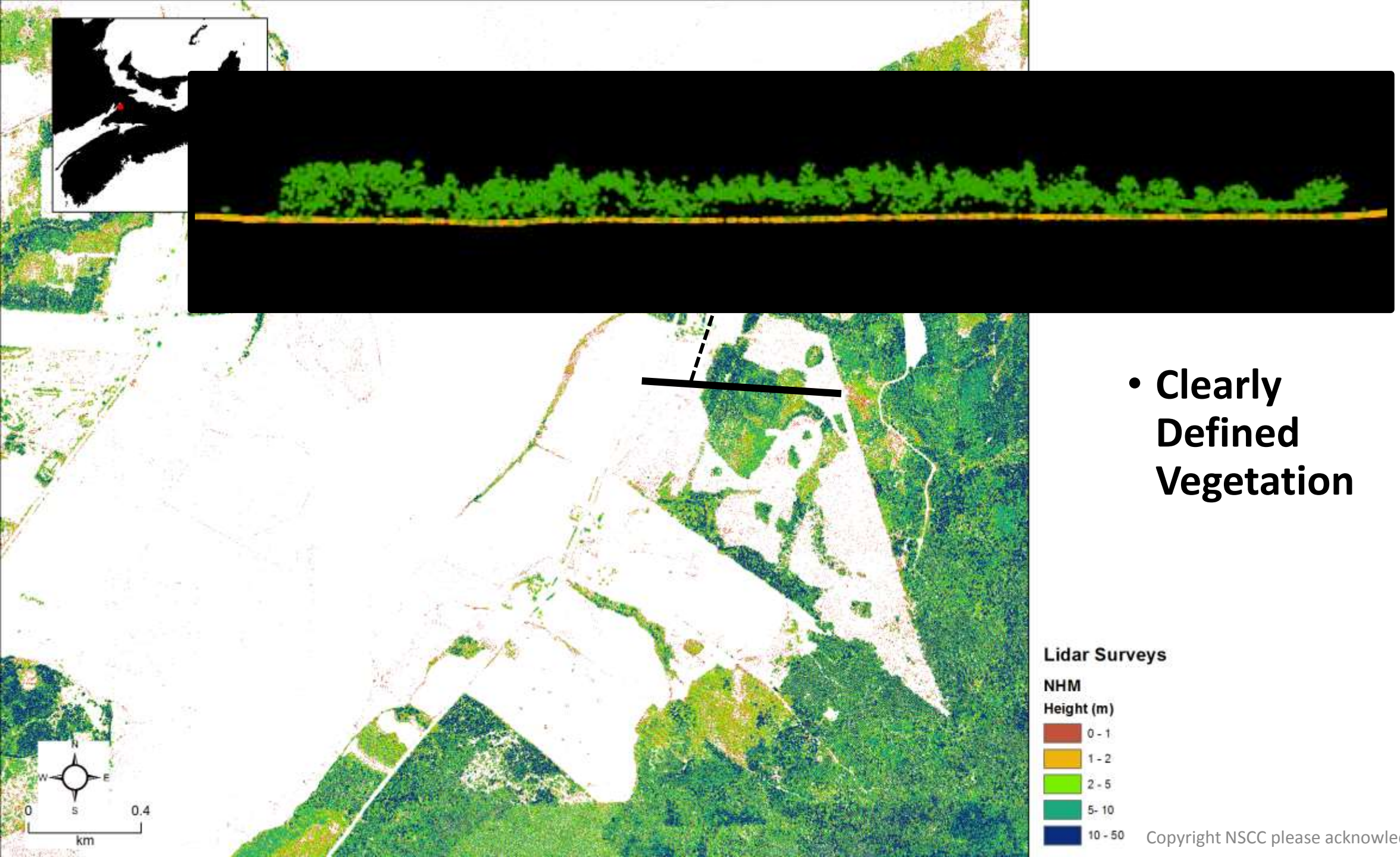


Lidar Surveys

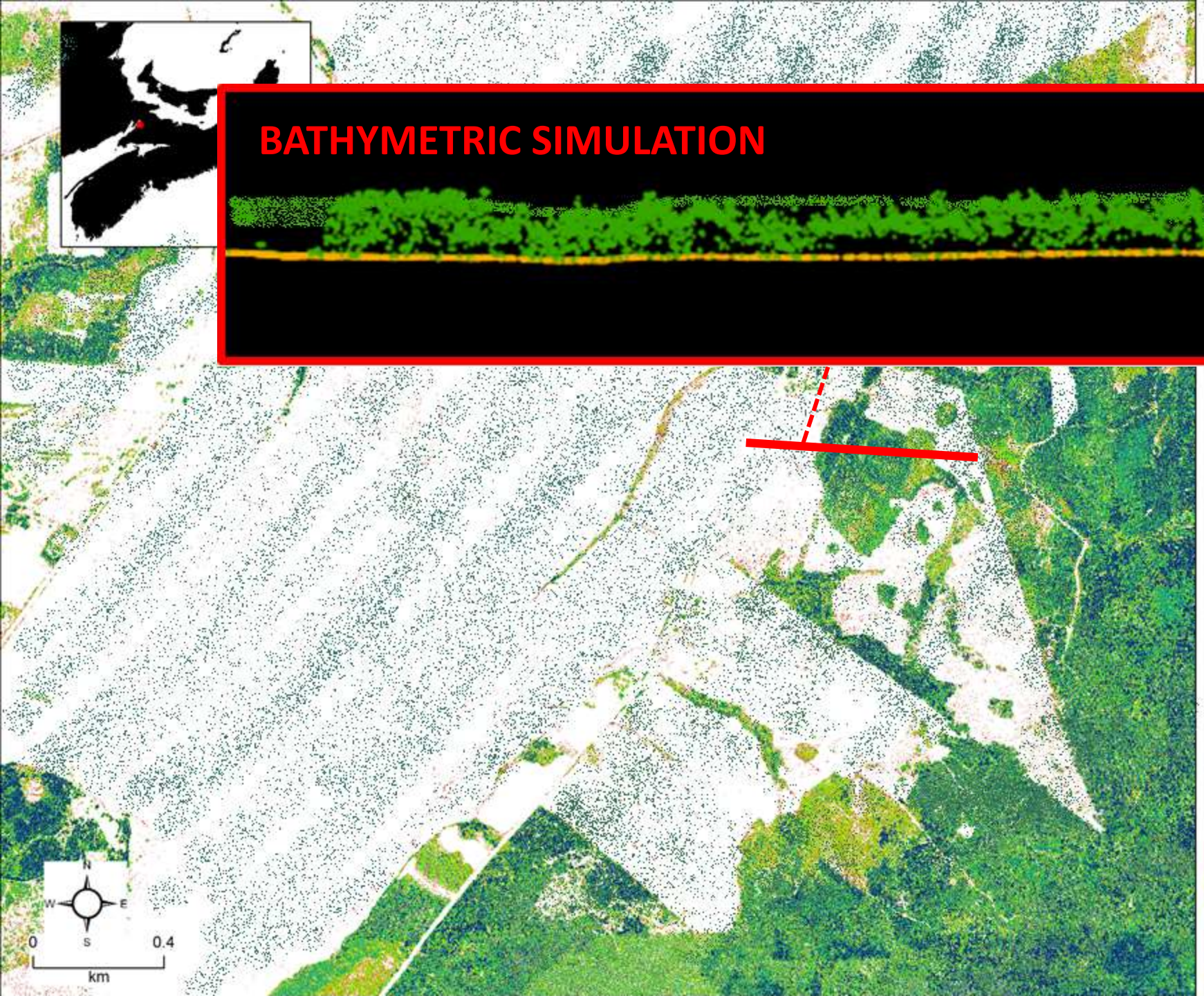
NHM

Height (m)

- 0 - 1
- 1 - 2
- 2 - 5
- 5- 10
- 10 - 50

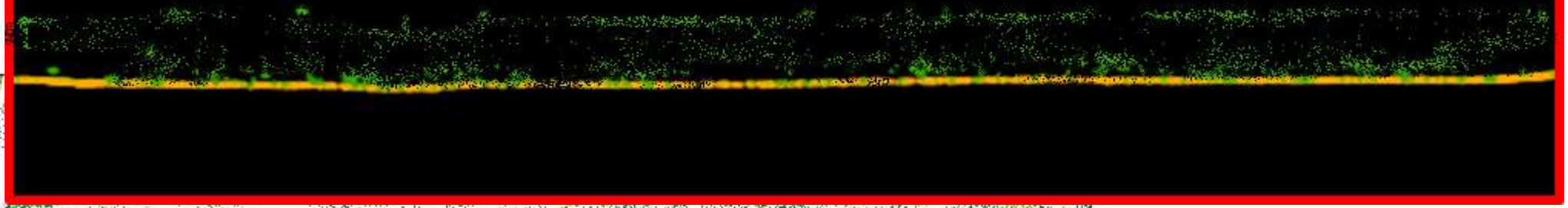


- **Clearly Defined Vegetation**



- What if there were a water surface?
- Unequal Water Column Noise?

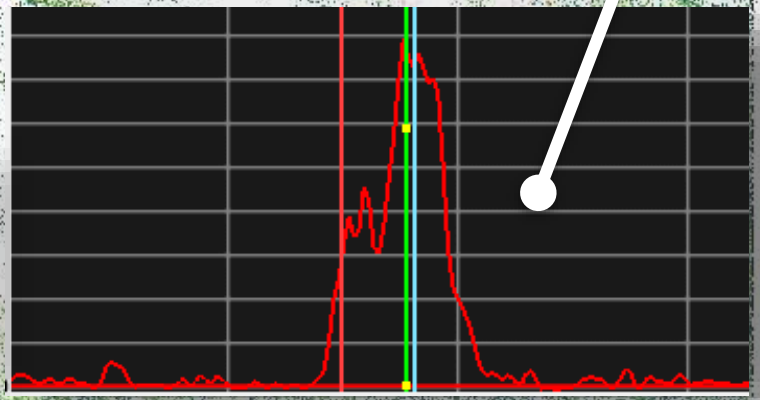
BATHYMETRIC SIMULATION

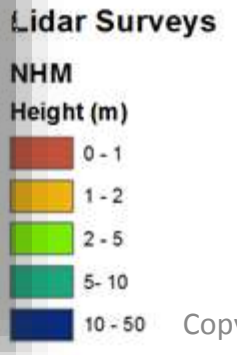


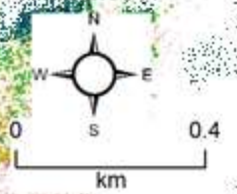
- **What if noise reduction removed many valid vegetation returns?**

Lidar Land Waveform

Lidar Water Waveform

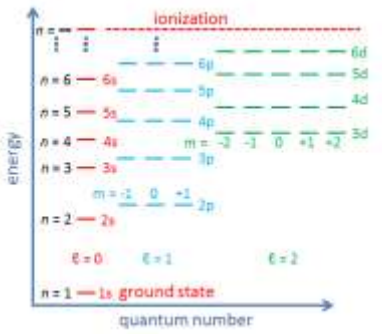




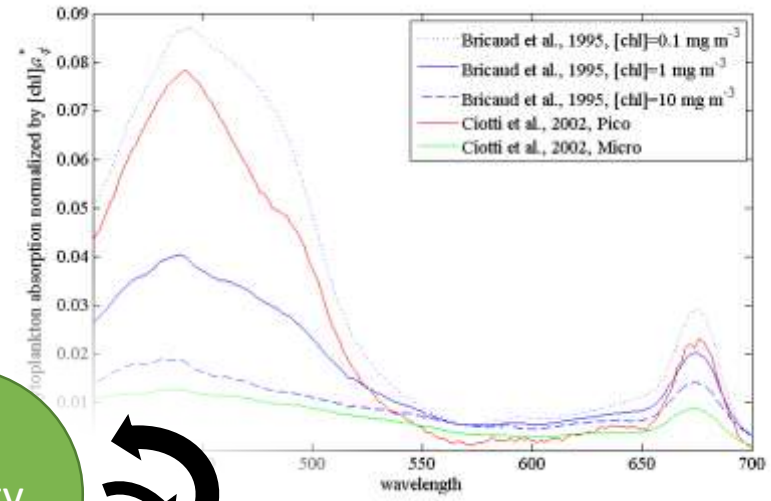


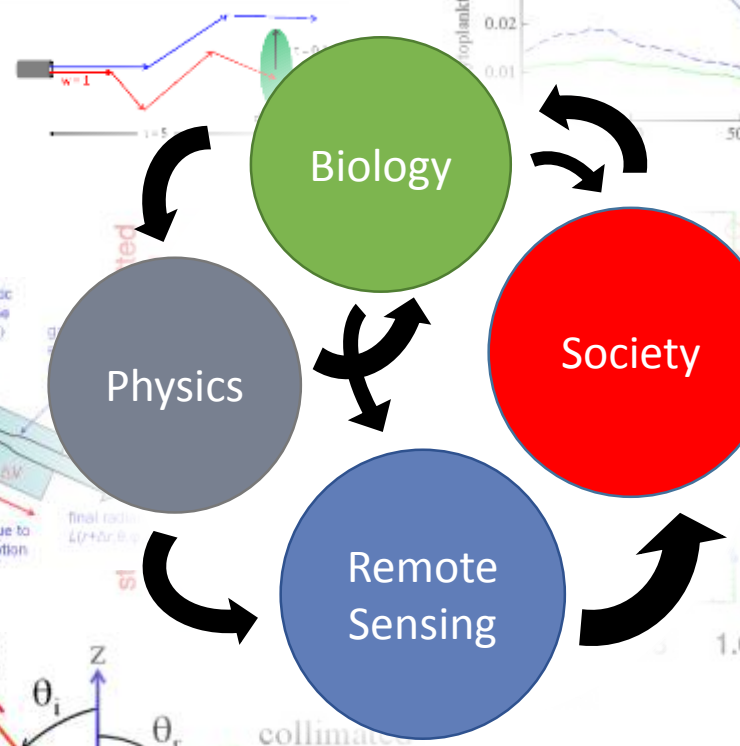
Optical Physics of Bathymetric Lidar

- Photosynthesis
- Radiometric Absorption
- Diffuse attenuation coefficient
- Substrate dependence
- Carrying capacity
- Ecosystem health
- Sustainable aquaculture
- **Height, density, presence**

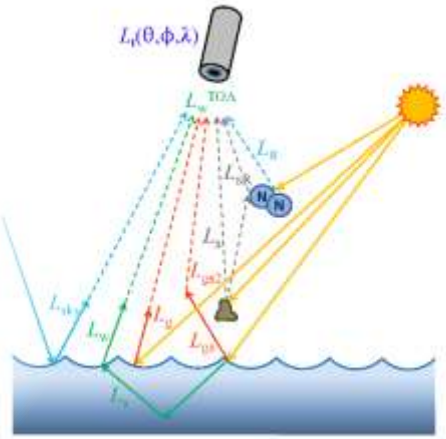


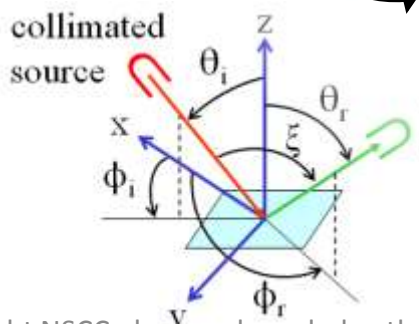
$$F = PAR[chla]a^*_{pyto}\phi_f$$





$$L_t = L_{atm} + L^{TOA}_{surf} + L^{TOA}_{w}$$

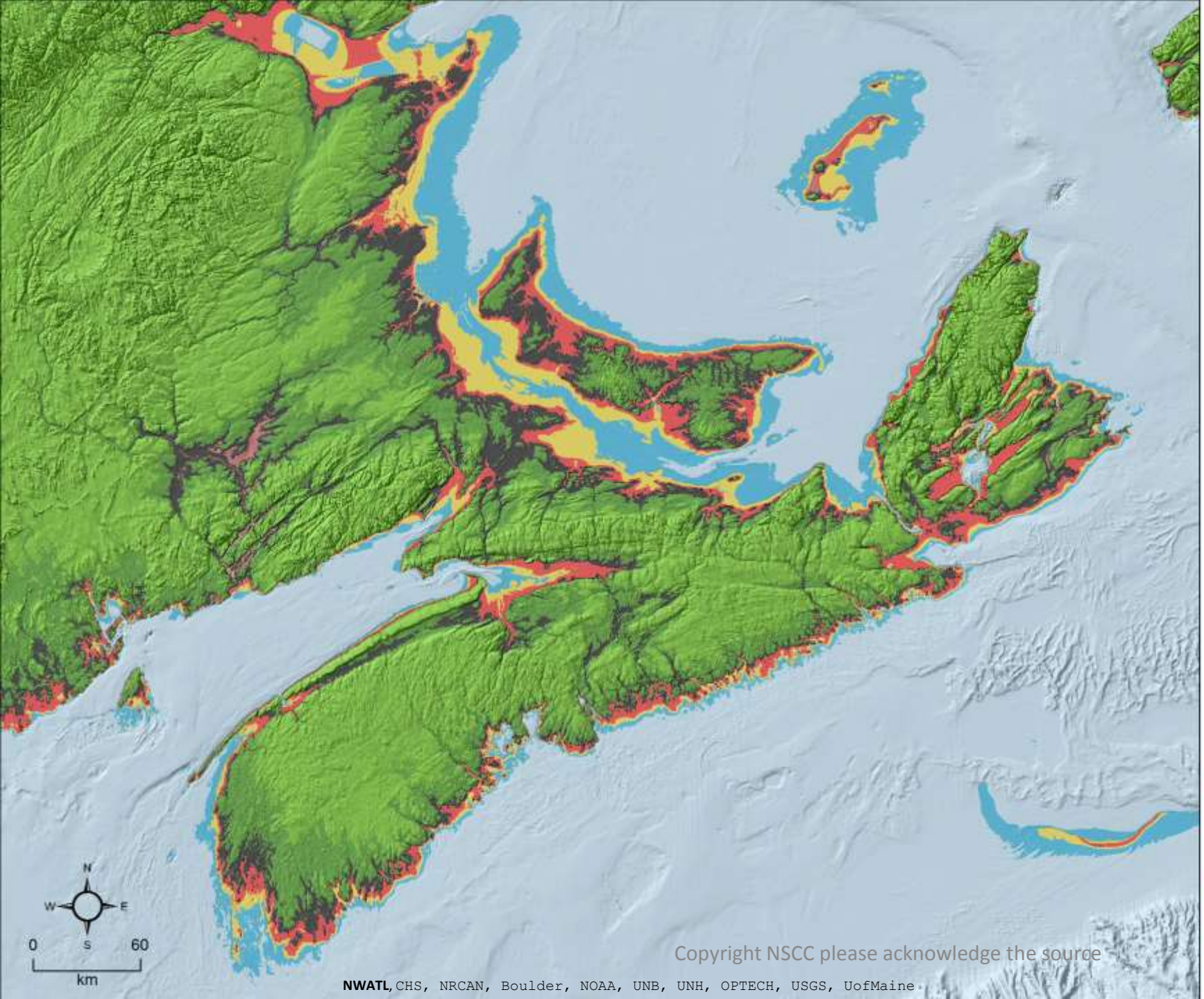




$$\frac{dL(r,\theta,\phi,\lambda)}{dr} = -a(r,\lambda)L(r,\theta,\phi,\lambda) + S(r,\theta,\phi,\lambda)\ .$$

$$\int_0^{2\pi}\int_0^{\pi} L(z,\theta',\phi')\,\beta(\theta',\phi' \rightarrow \theta,\phi)\,\sin\theta'\,d\theta'\,d\phi'\ ,$$

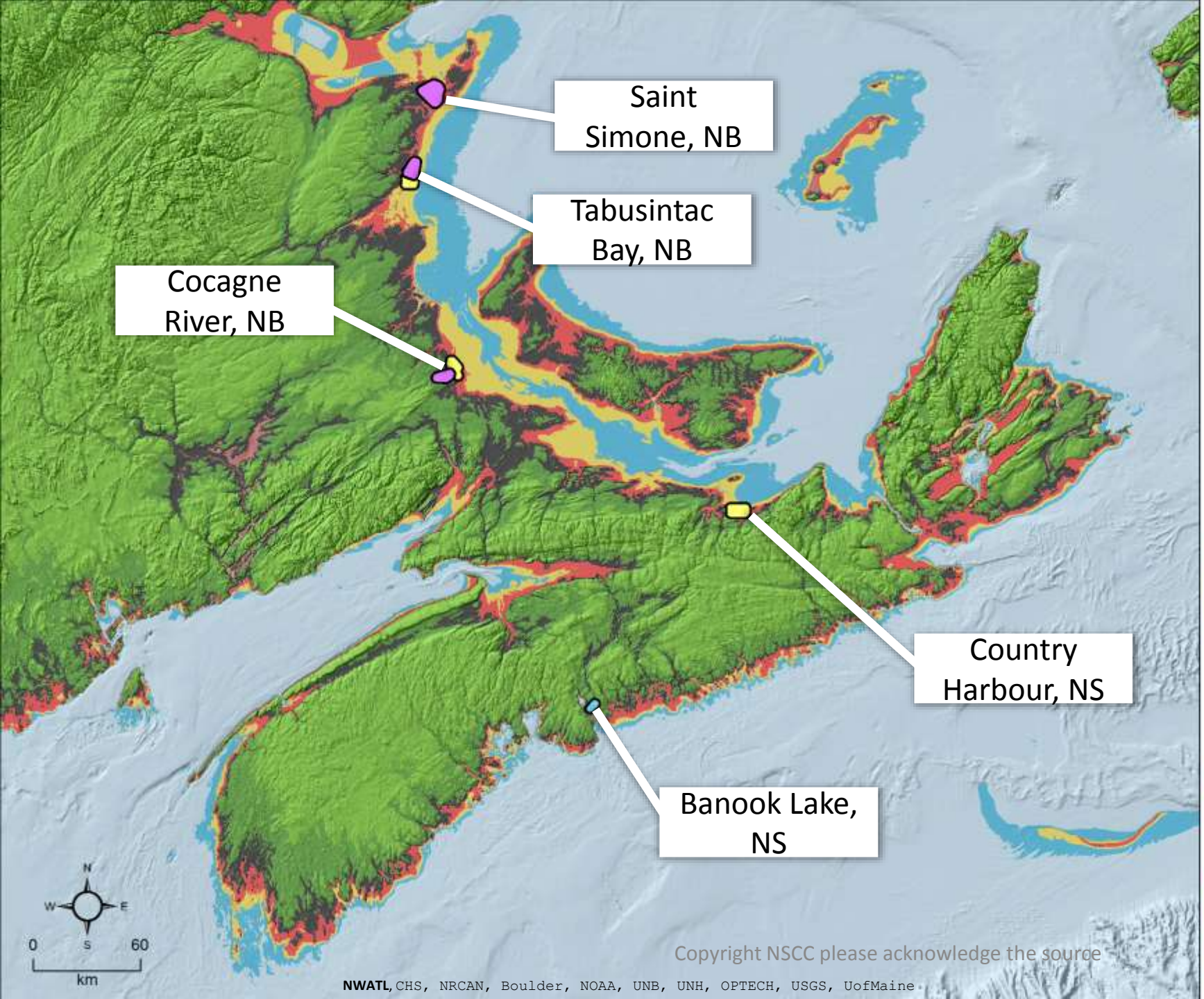
http://www.oceanopticsbook.info/



Height
Metres
null
1 - 30
30 - 80
80+

Depth
Metres
<5
5 - 15
15 - 30
30+

NWATL, CHS, NRCAN, Boulder, NOAA, UNB, UNH, OPTECH, USGS, UofMaine



Lidar Surveys

- Sept. 2014 (Lake)
- Oct. 2015
- Sept. 2014

Height

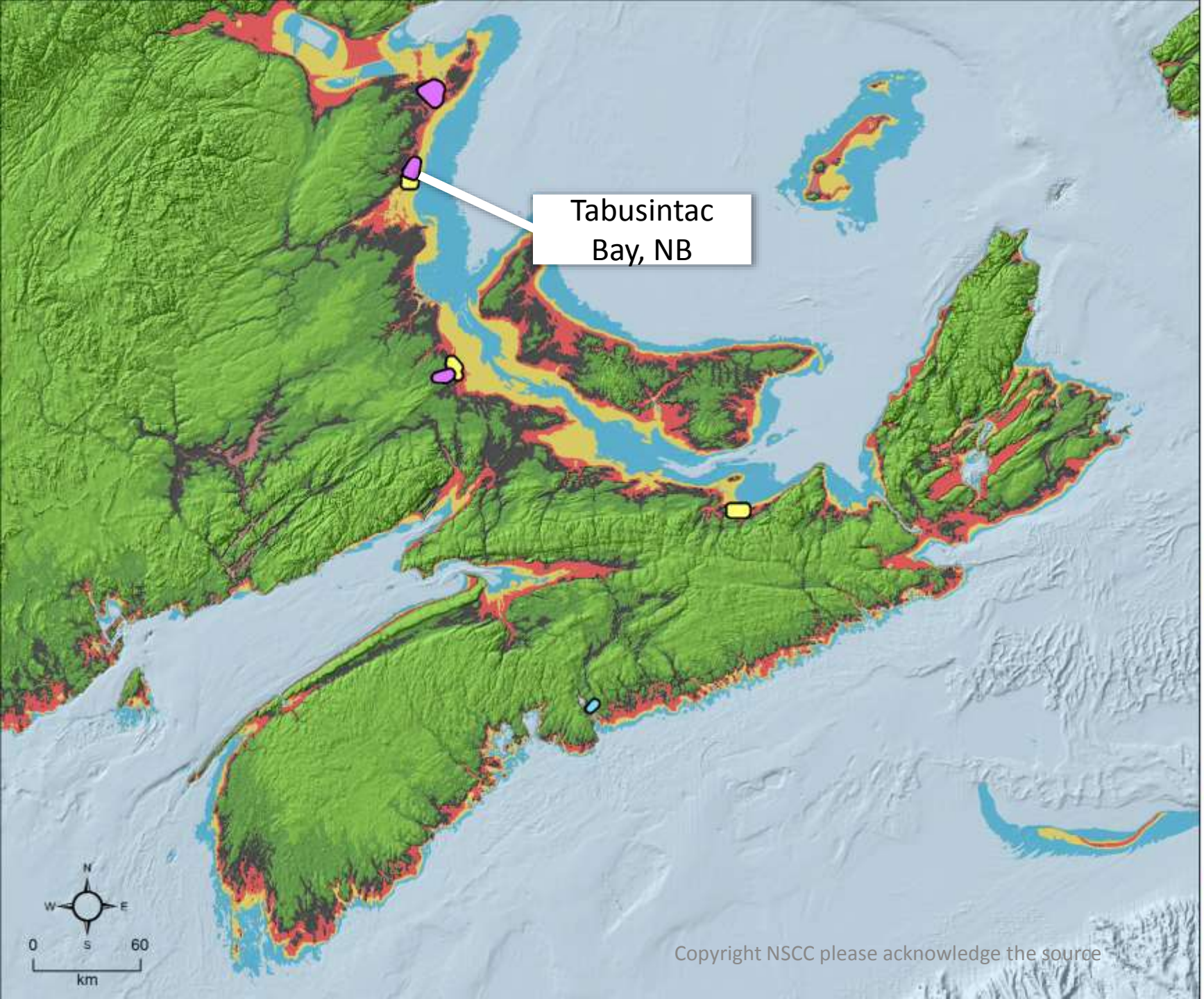
Metres

- null
- 1 - 30
- 30 - 80
- 80+

Depth

Metres

- <5
- 5 - 15
- 15 - 30
- 30+



Lidar Surveys

- Sept. 2014 (Lake)
- Oct. 2015
- Sept. 2014

Height

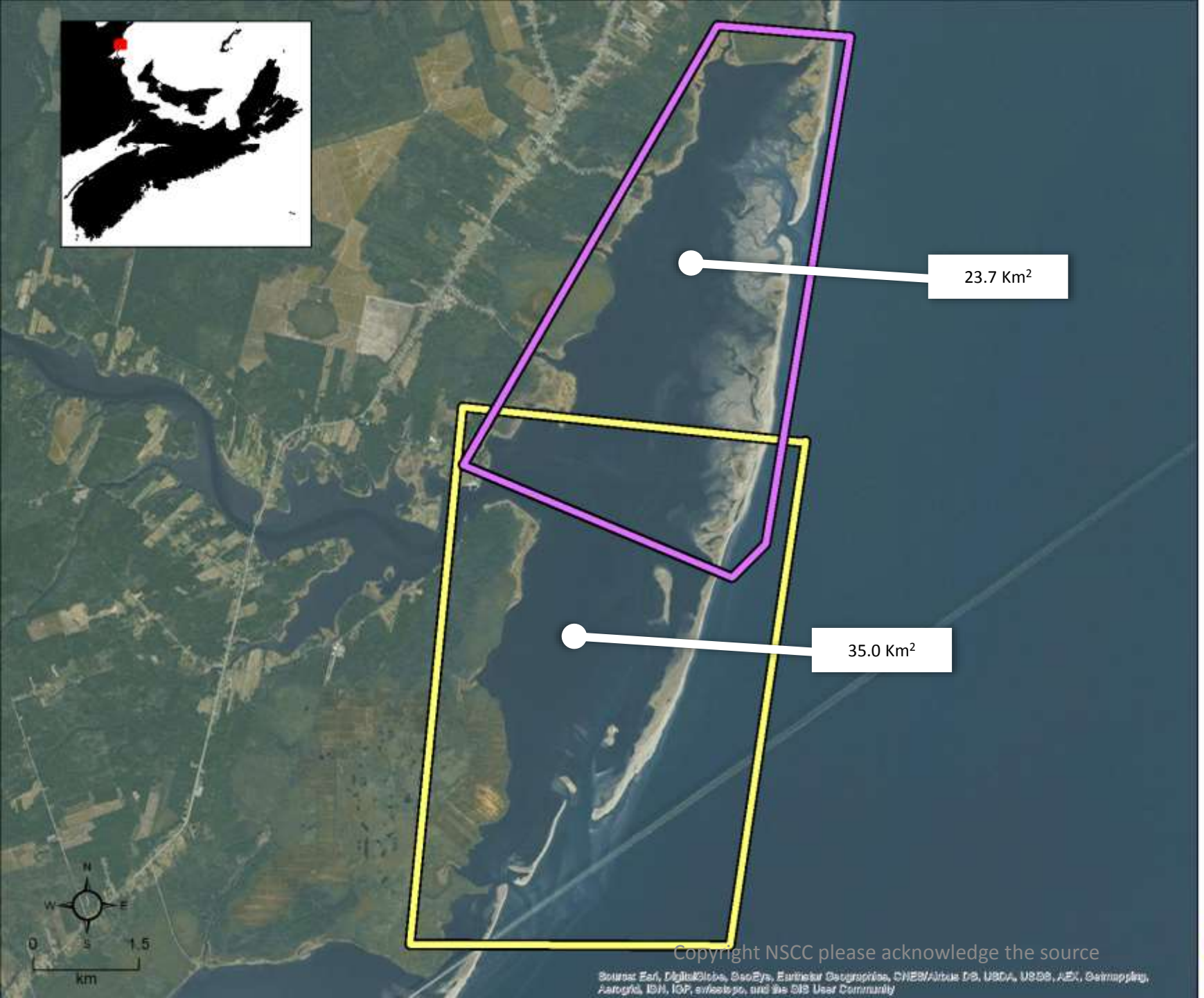
Metres

- null
- 1 - 30
- 30 - 80
- 80+

Depth

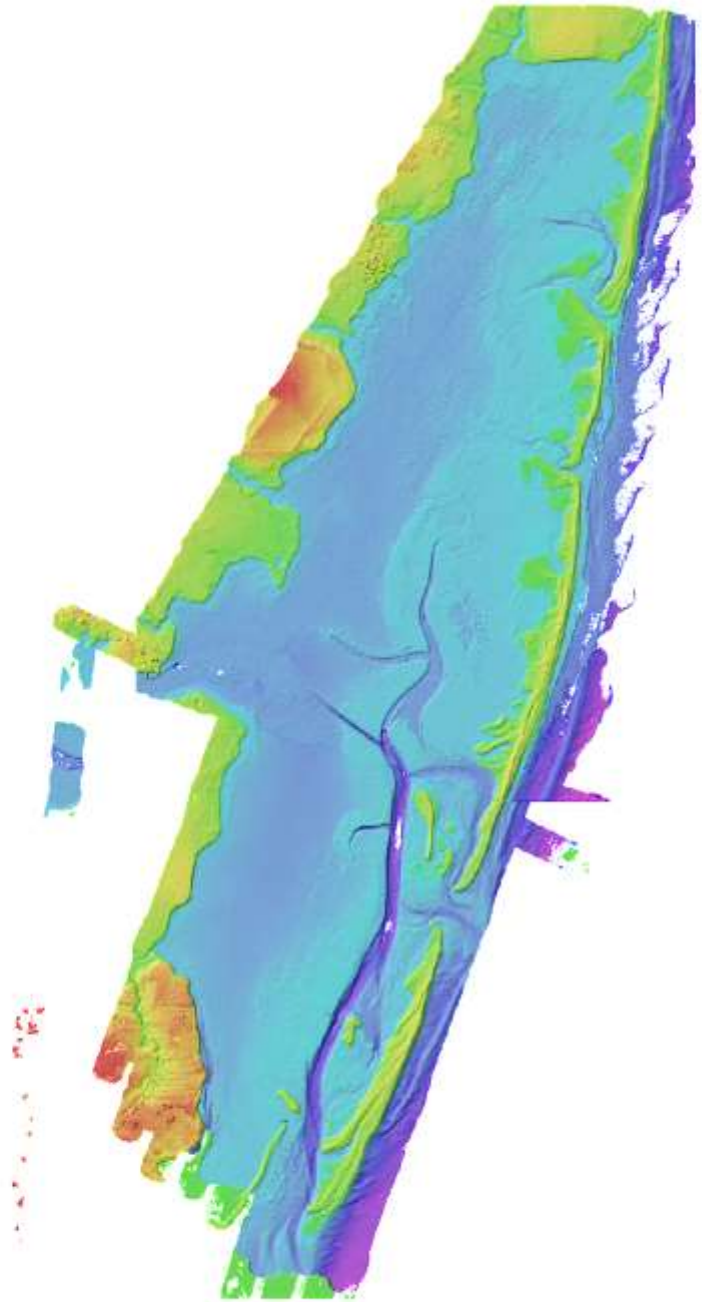
Metres

- <5
- 5 - 15
- 15 - 30
- 30+



Lidar Surveys

- Tabusintac 2015
- Tabusintac 2014



N
W E
S
0 2
km

Lidar Surveys

TAB 2014/2015

Value

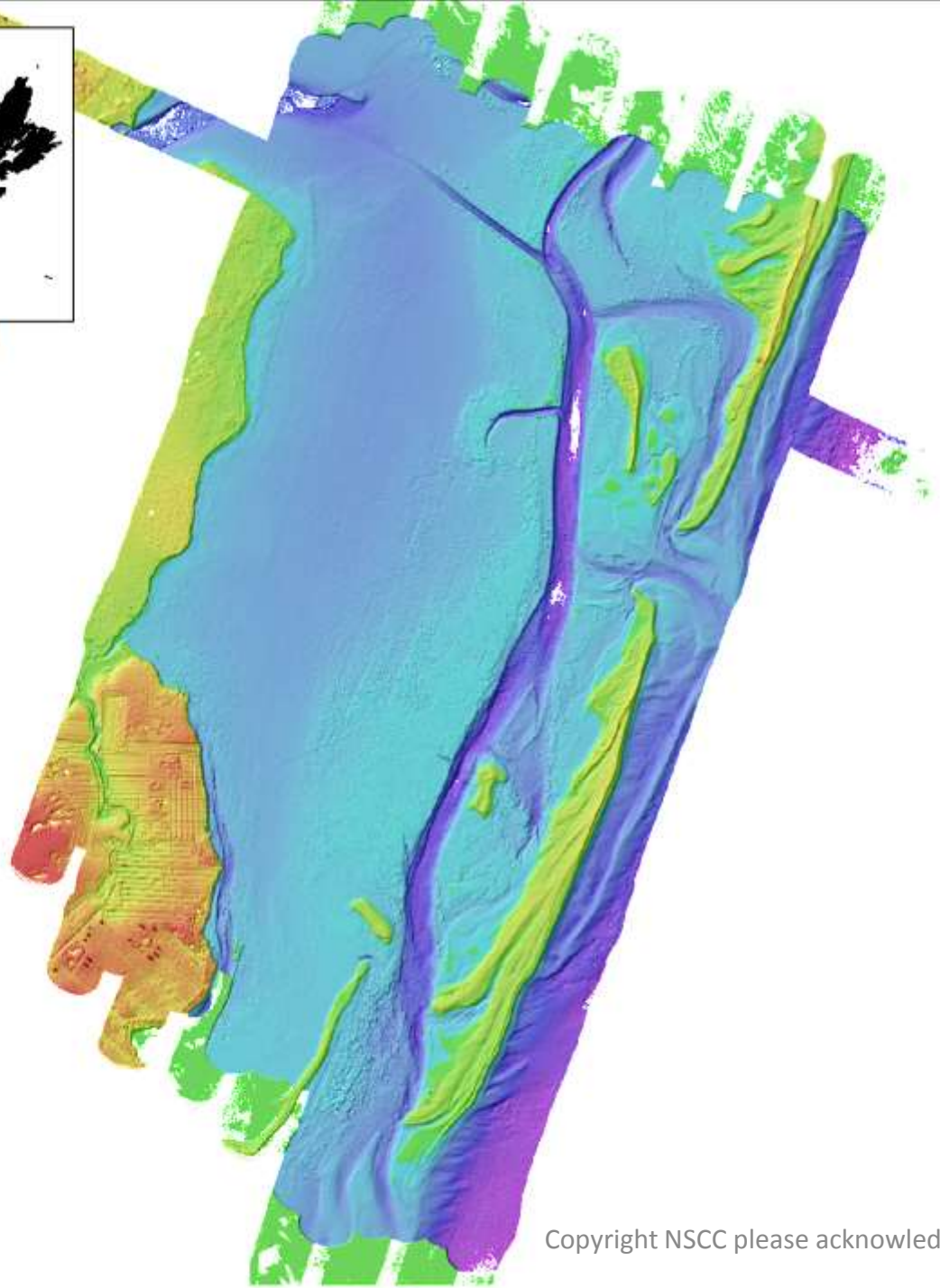
High : 0

Low : -7.5

Value

High : 5

Low : 0



N
W E
S
0 1
km

Lidar Surveys

TAB 2014

Ell. Ht. (m)

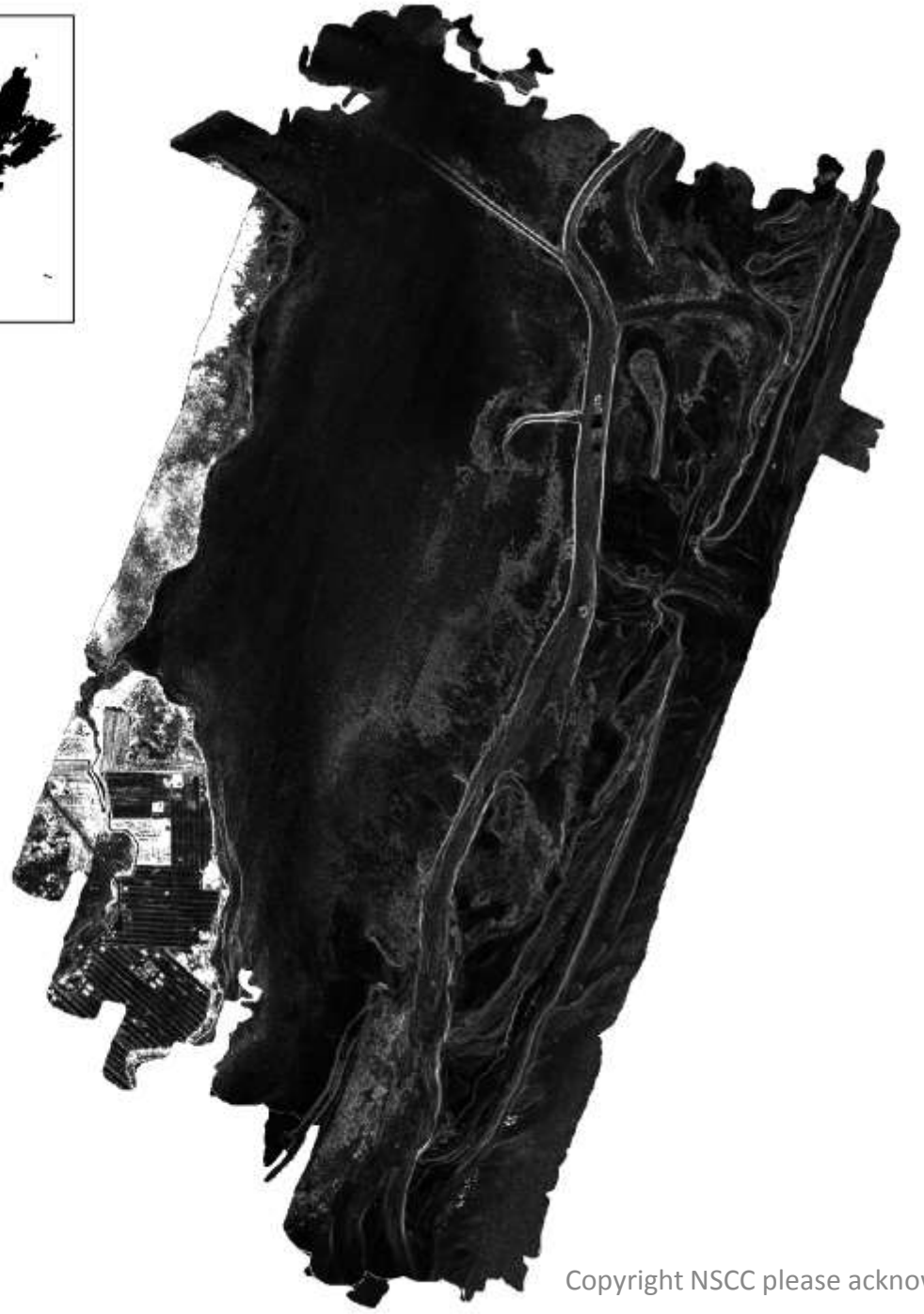
High : 0

Low : -7.5

Ell. Ht. (m)

High : 5

Low : 0



N
W E
S
0 1
km

- **Bottom Slope**

Small Sample

Med Sample

Coarse Sample

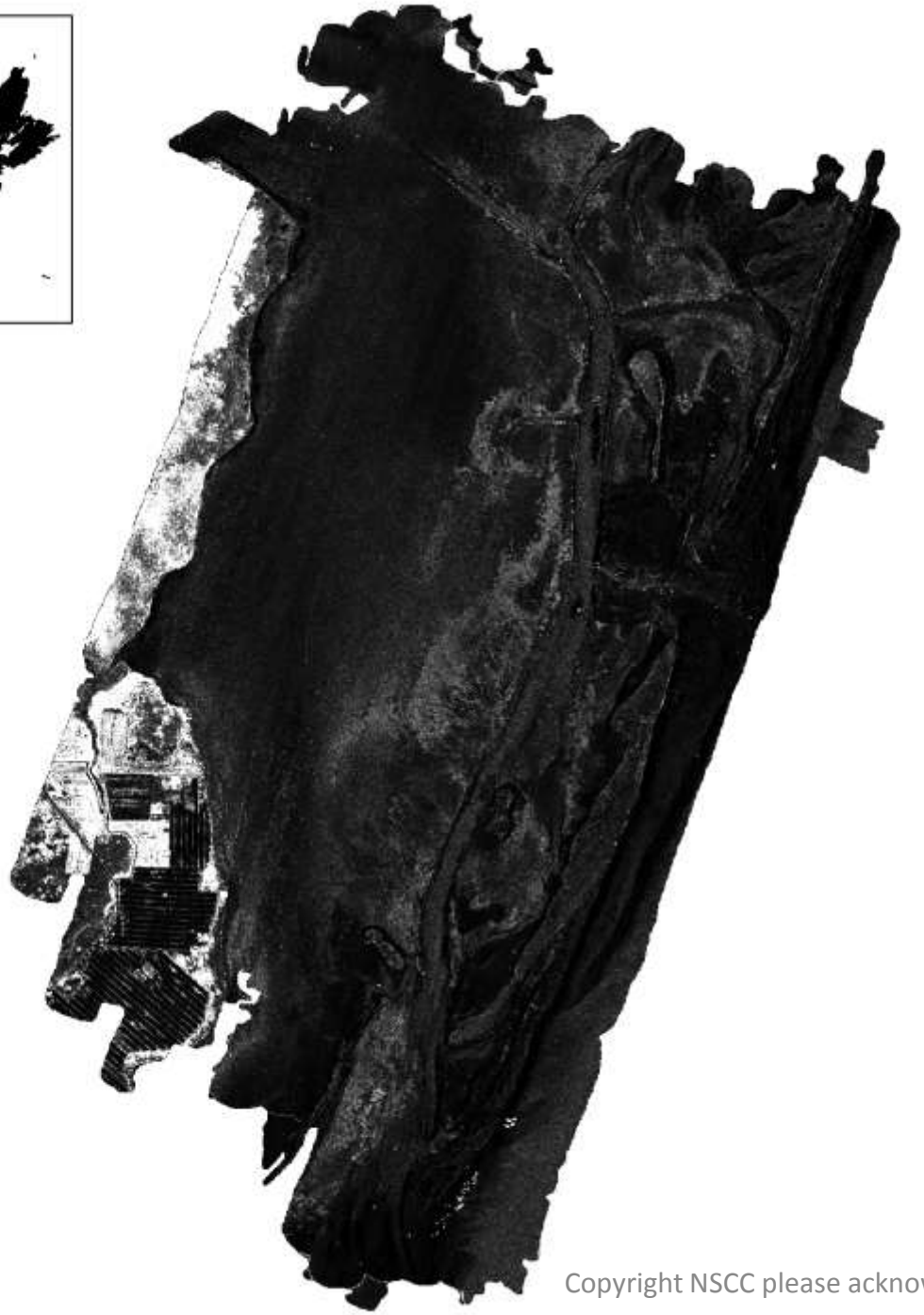
Eelgrass Proc.

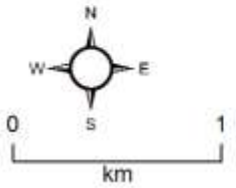
TAB 2014

Slope

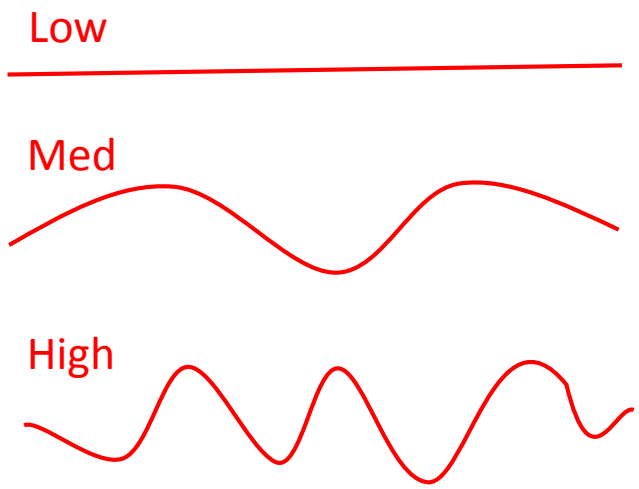
High

Low





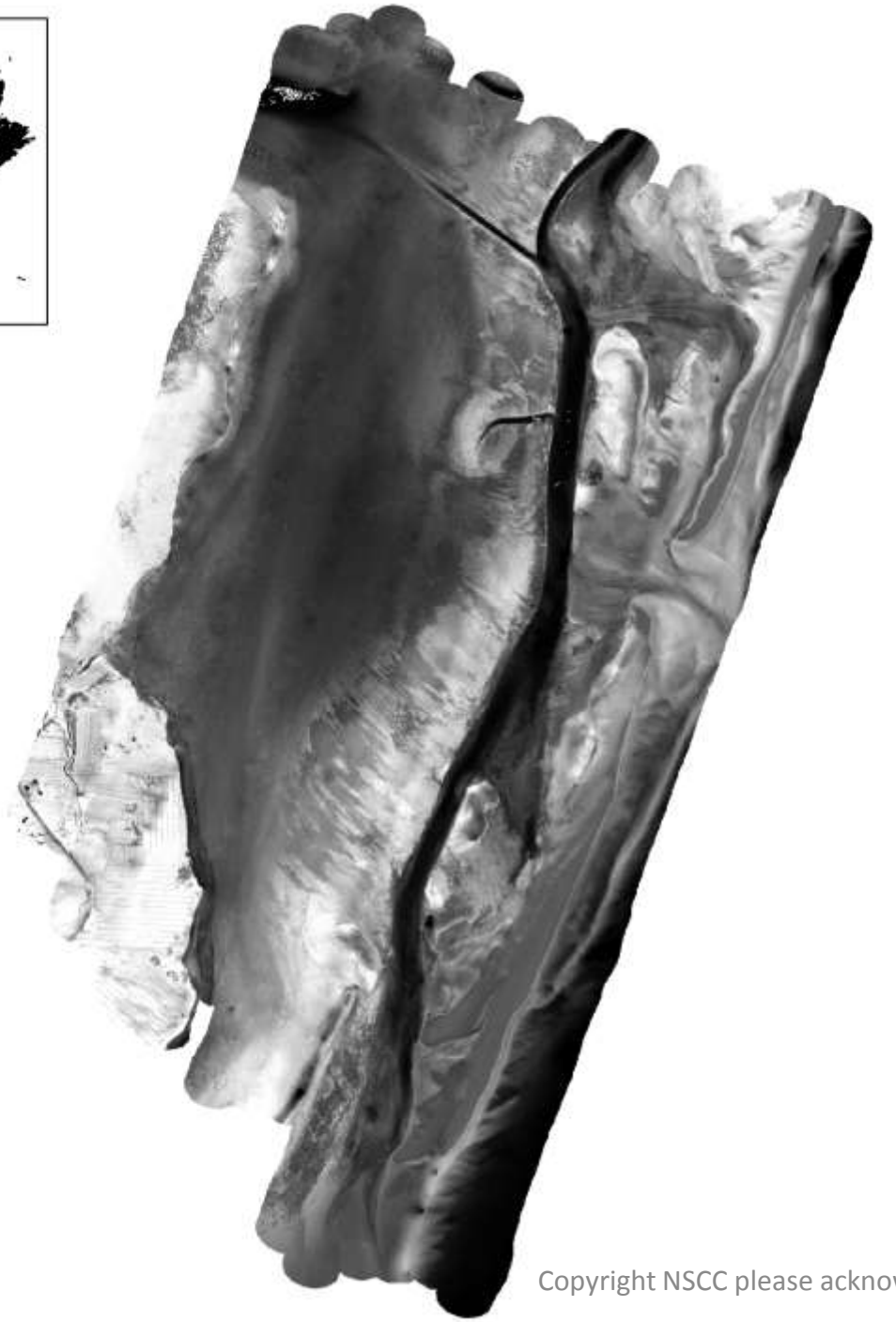
- **Bottom Roughness or "Rugosity"**



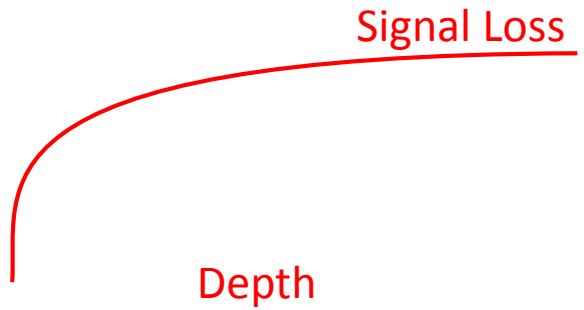
Eelgrass Proc.

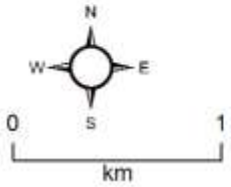
TAB 2014

Slope x STD Aspect



- **Lidar Reflectance Intensity**





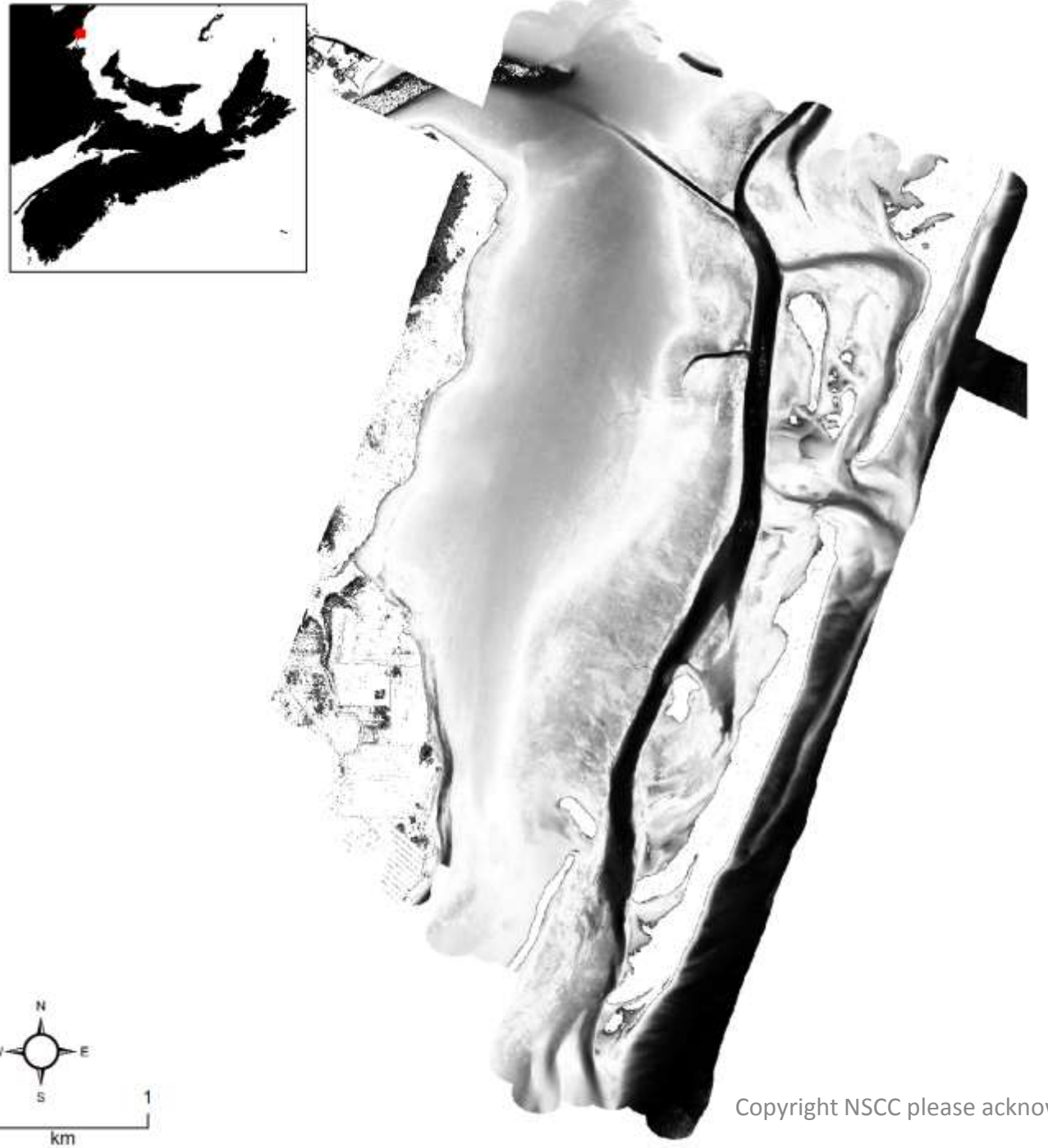
Eelgrass Proc.

TAB 2014

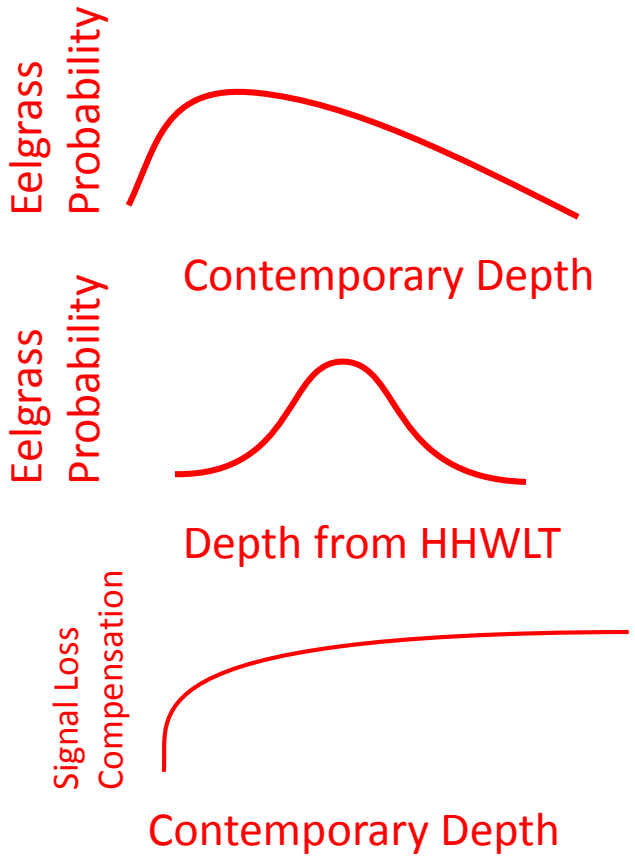
Reflectance

High

Low



- **Eelgrass Depth Curve**



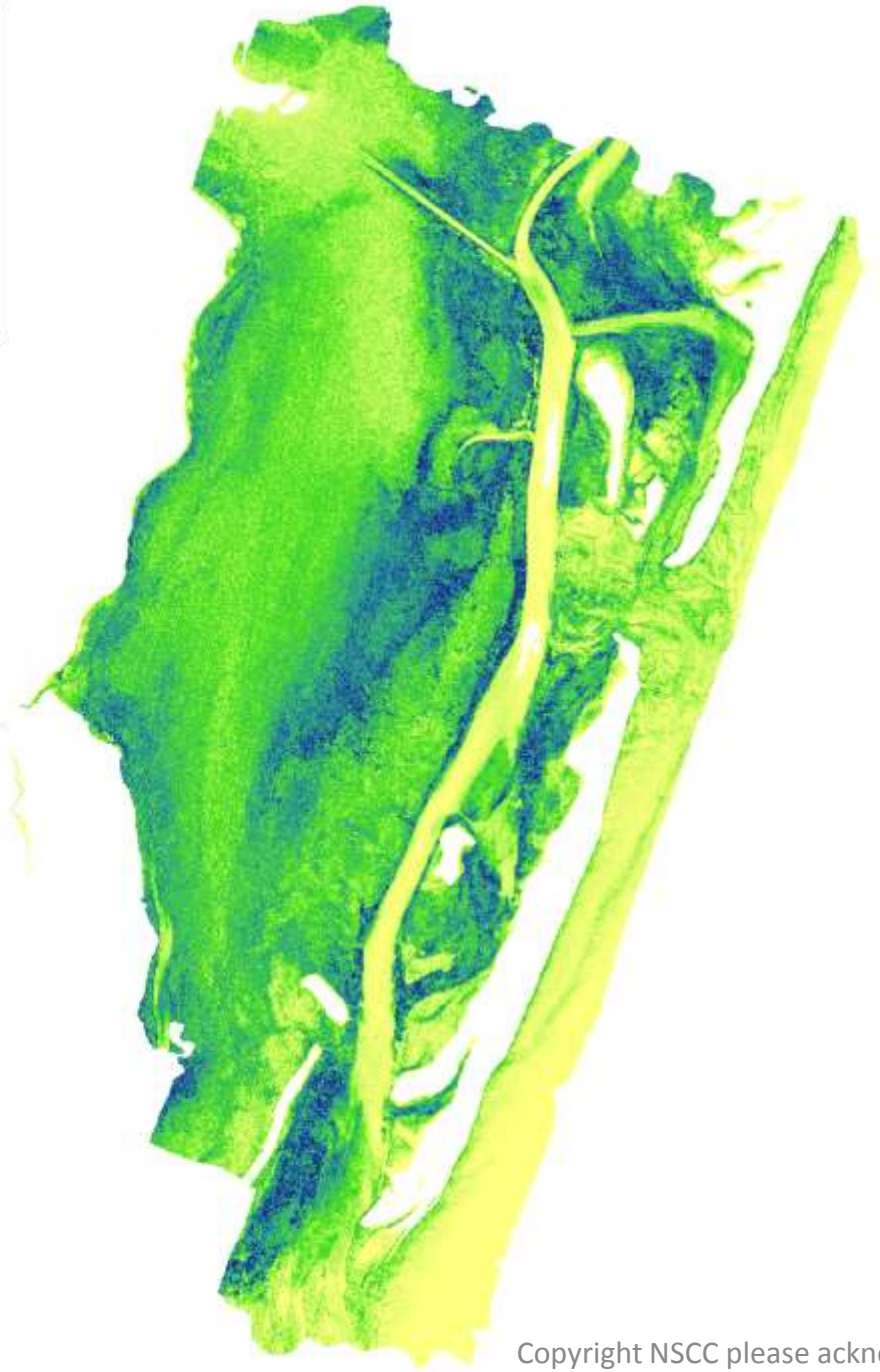
Eelgrass Proc.

TAB 2014

Value

High

Low



N
W E
S
0 1
km

- **Eelgrass Height Index Map**

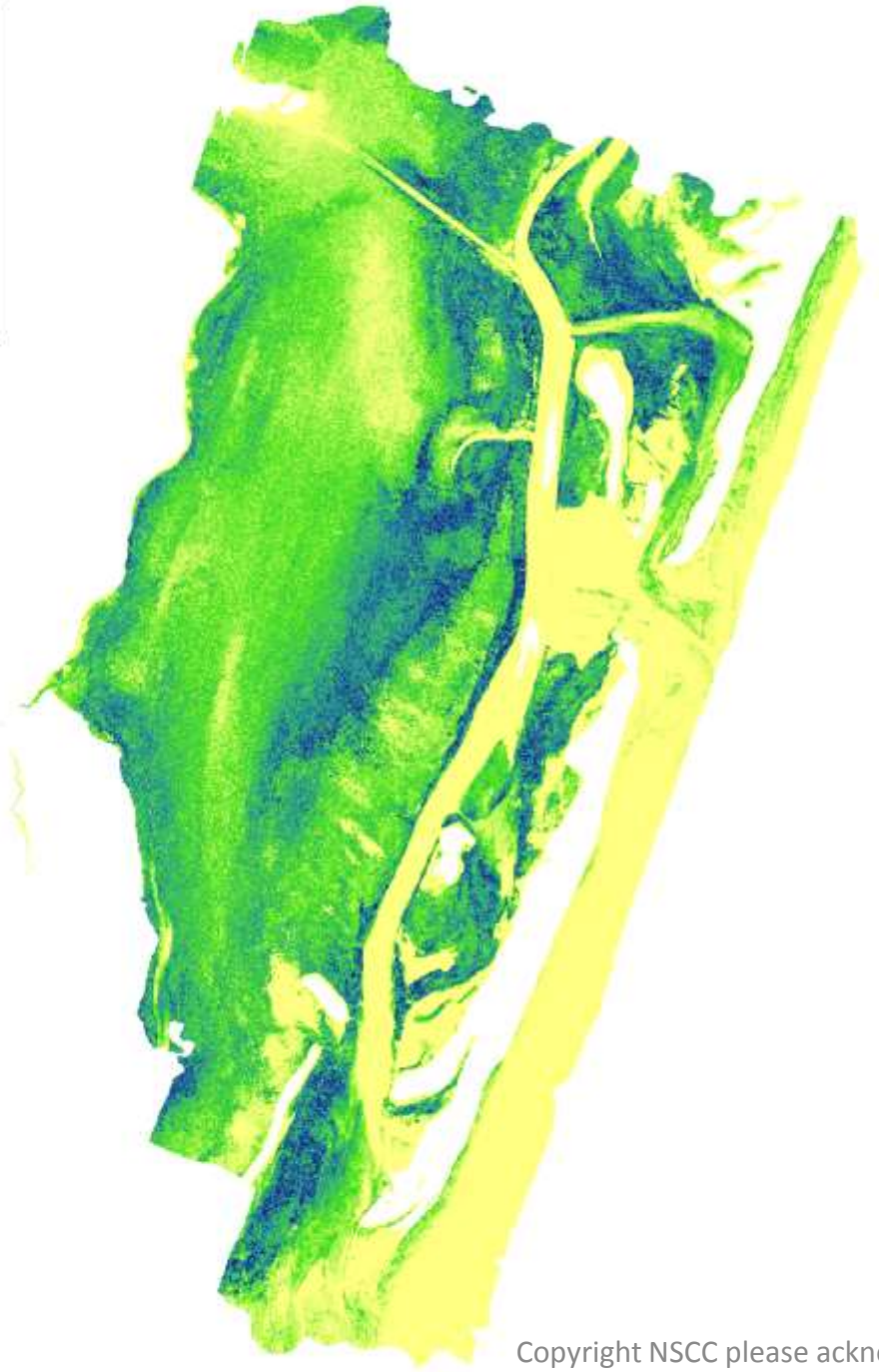
Eelgrass

TAB 2014

VHI

High : 3.58438

Low : 0



N
W E
S
0 1
km

- **Eelgrass Height Index Map – Photo Adjusted**

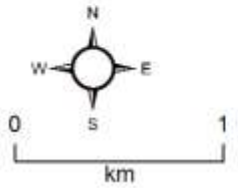
Eelgrass

TAB 2014

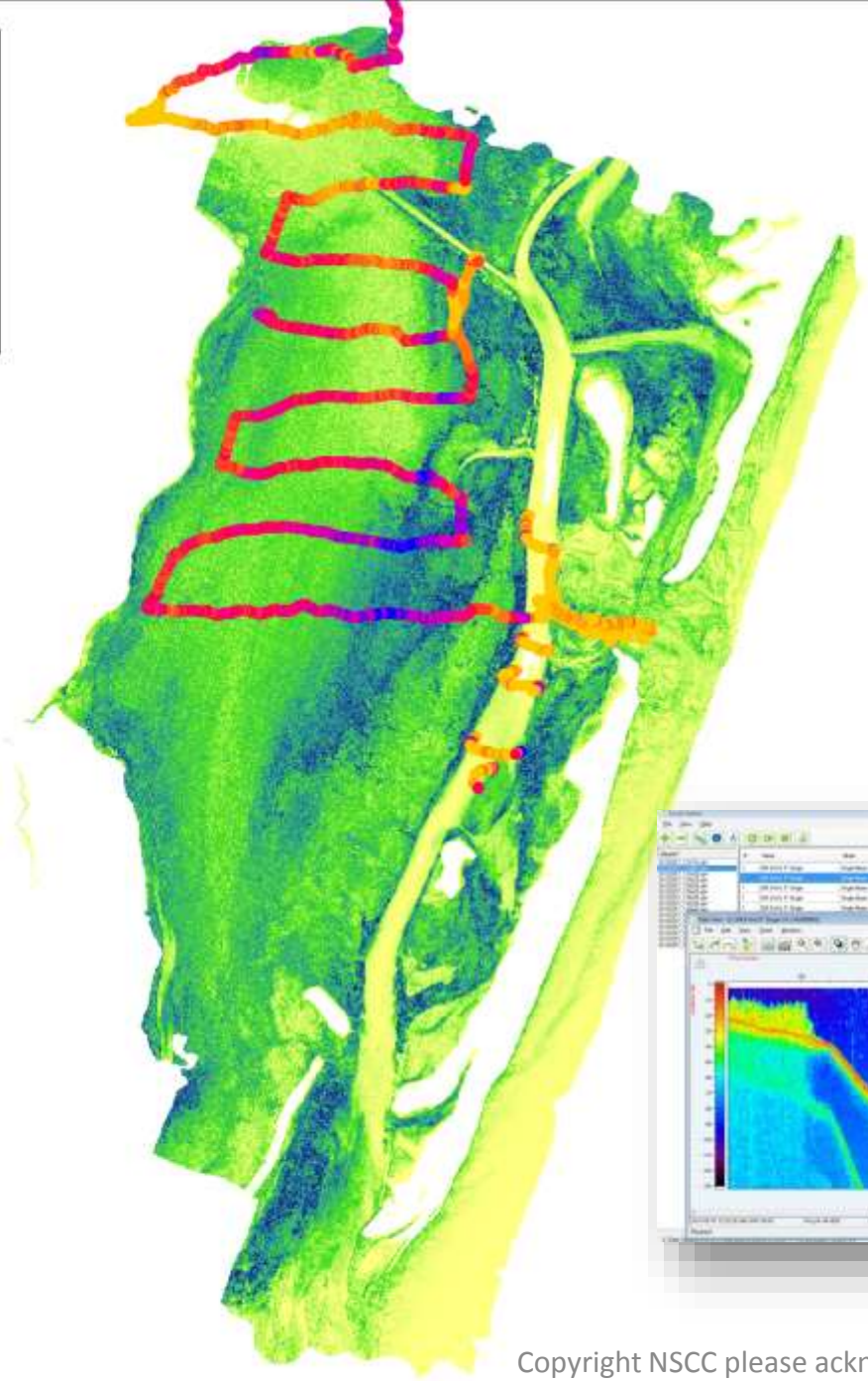
VHIP

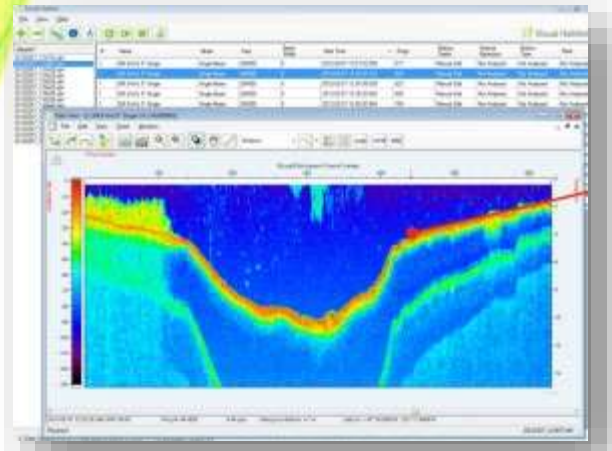
High : 3.58438

Low : 0



- **Eelgrass Presence / Absence product**





- Eelgrass Height Index
- Biosonics Validation Provided by Stantec

Eelgrass

Biosonics

PlantHeigh

- 0.00
- 0.01 - 0.20
- 0.21 - 0.24
- 0.25 - 0.28
- 0.29 - 0.32
- 0.33 - 0.36
- 0.37 - 0.41
- 0.42 - 0.48
- 0.49 - 0.57
- 0.58 - 0.86

TAB 2014

VHI

High : 3.58438

Low : 0

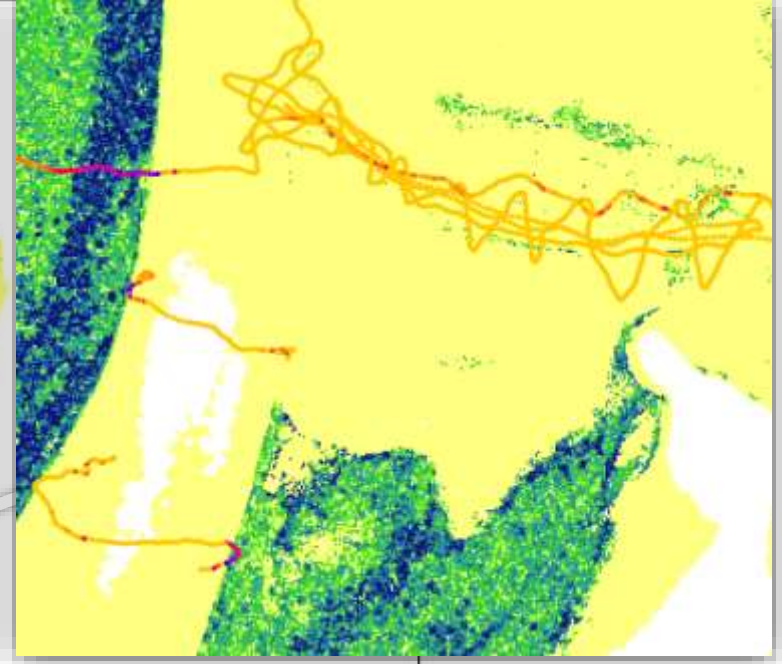
N

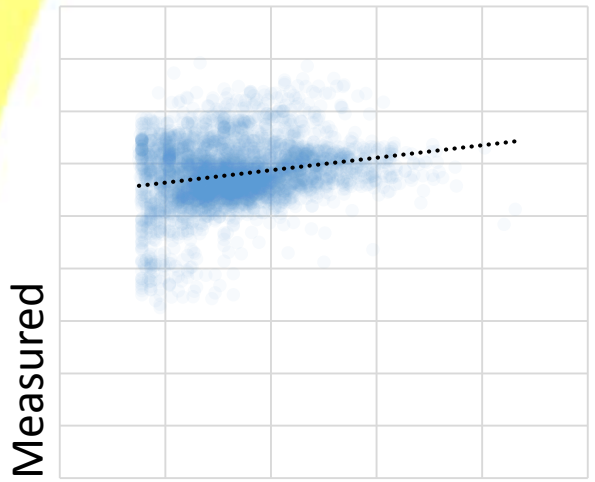
W E

S

0 1

km





Eelgrass

Biosonics

PlantHeigh

- 0.00
- 0.01 - 0.20
- 0.21 - 0.24
- 0.25 - 0.28
- 0.29 - 0.32
- 0.33 - 0.36
- 0.37 - 0.41
- 0.42 - 0.48
- 0.49 - 0.57
- 0.58 - 0.86

TAB 2014

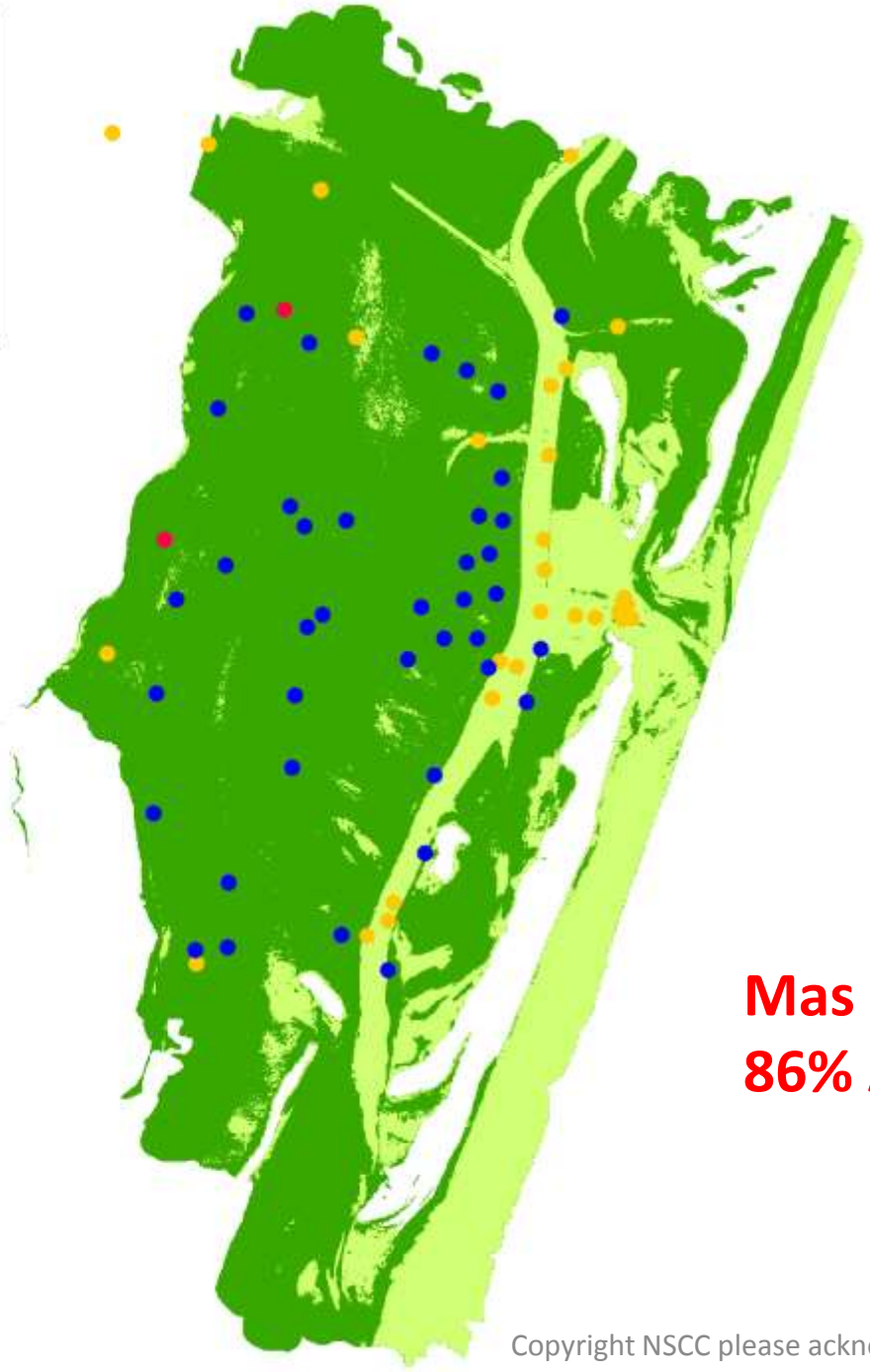
VHIP

High : 3.58438

Low : 0

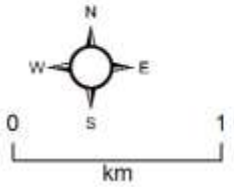
N
W E
S

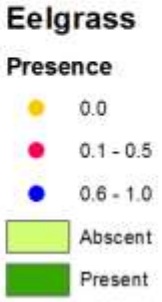
0 1
km



- Eelgrass Presence / Absence product
- Eelgrass Presence Validation Provided by AGRG/DFO

Mas Much As 86% Agreement?





- Eelgrass Presence / Absence product
- Biosonics % cover Provided by Stantec

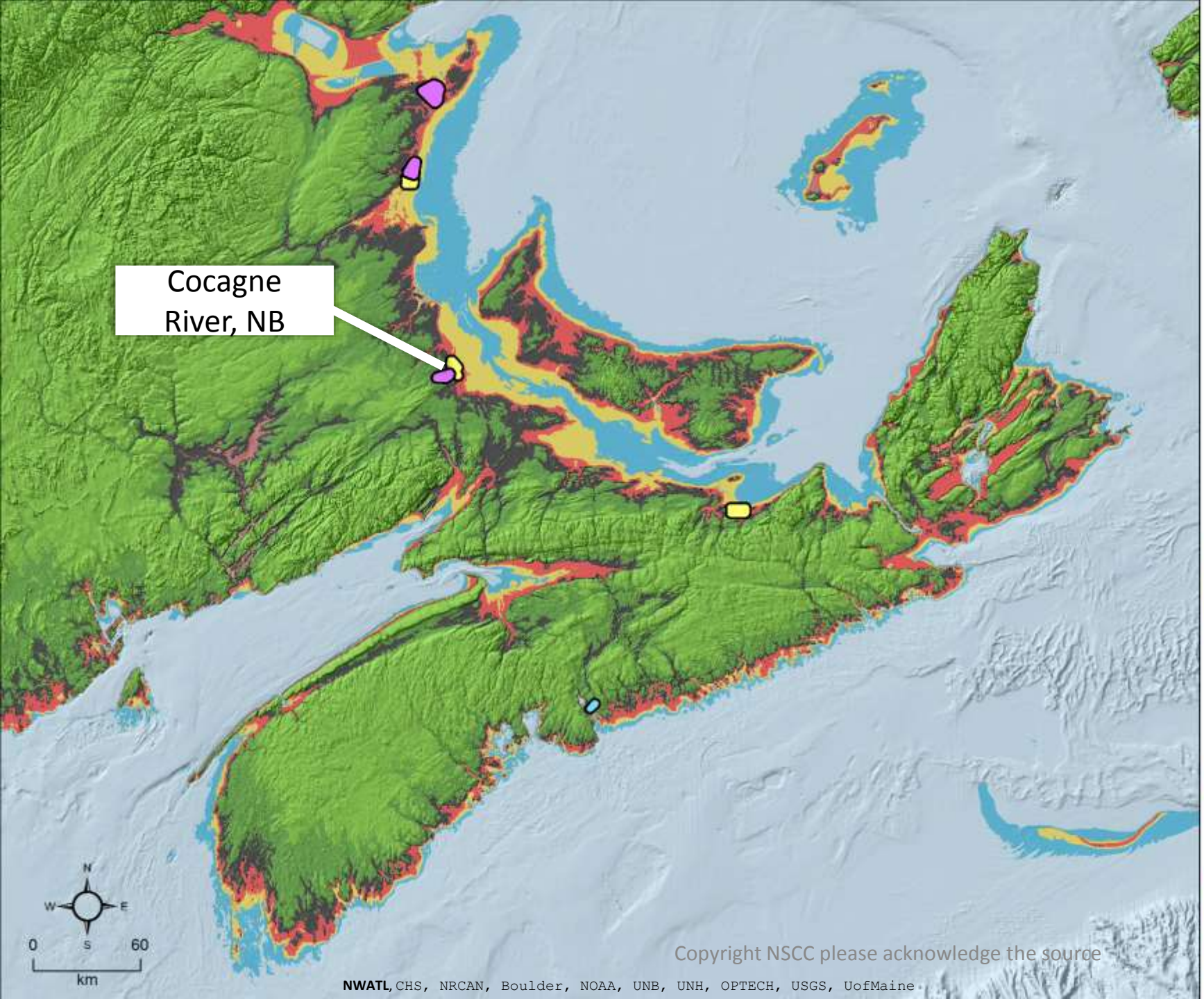
Mas Much As 92% Agreement?

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

N
W E
S
0 1
km

With **lidar**.

… (and *some air photos, and some ground truth, and some singlebeam*)



Lidar Surveys

- Sept. 2014 (Lake)
- Oct. 2015
- Sept. 2014

Height

Metres

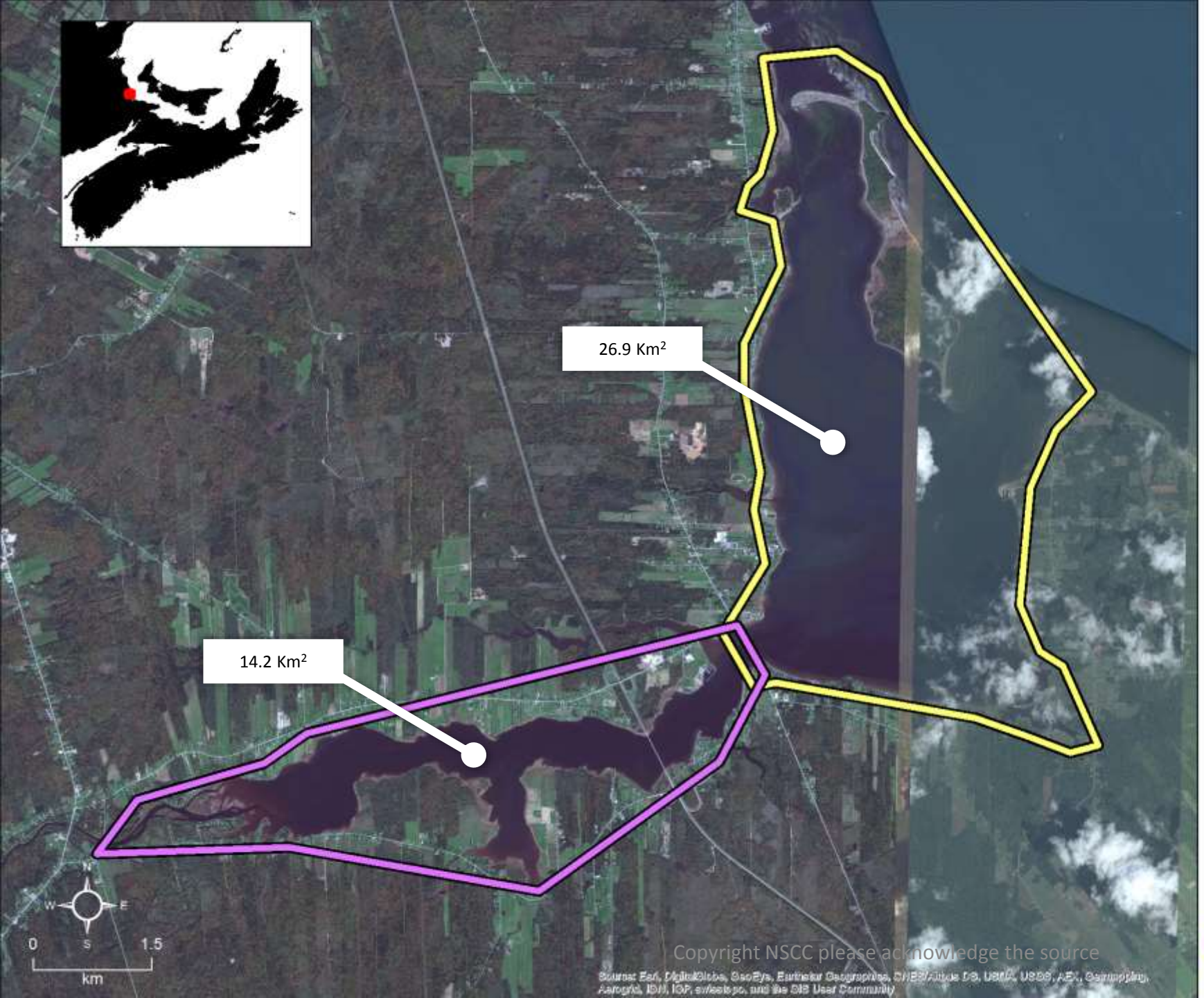
- null
- 1 - 30
- 30 - 80
- 80+

Depth

Metres

- <5
- 5 - 15
- 15 - 30
- 30+

NWATL, CHS, NRCAN, Boulder, NOAA, UNB, UNH, OPTECH, USGS, UofMaine



Lidar Surveys

COC 2014/2015

Ell. Ht. (m)

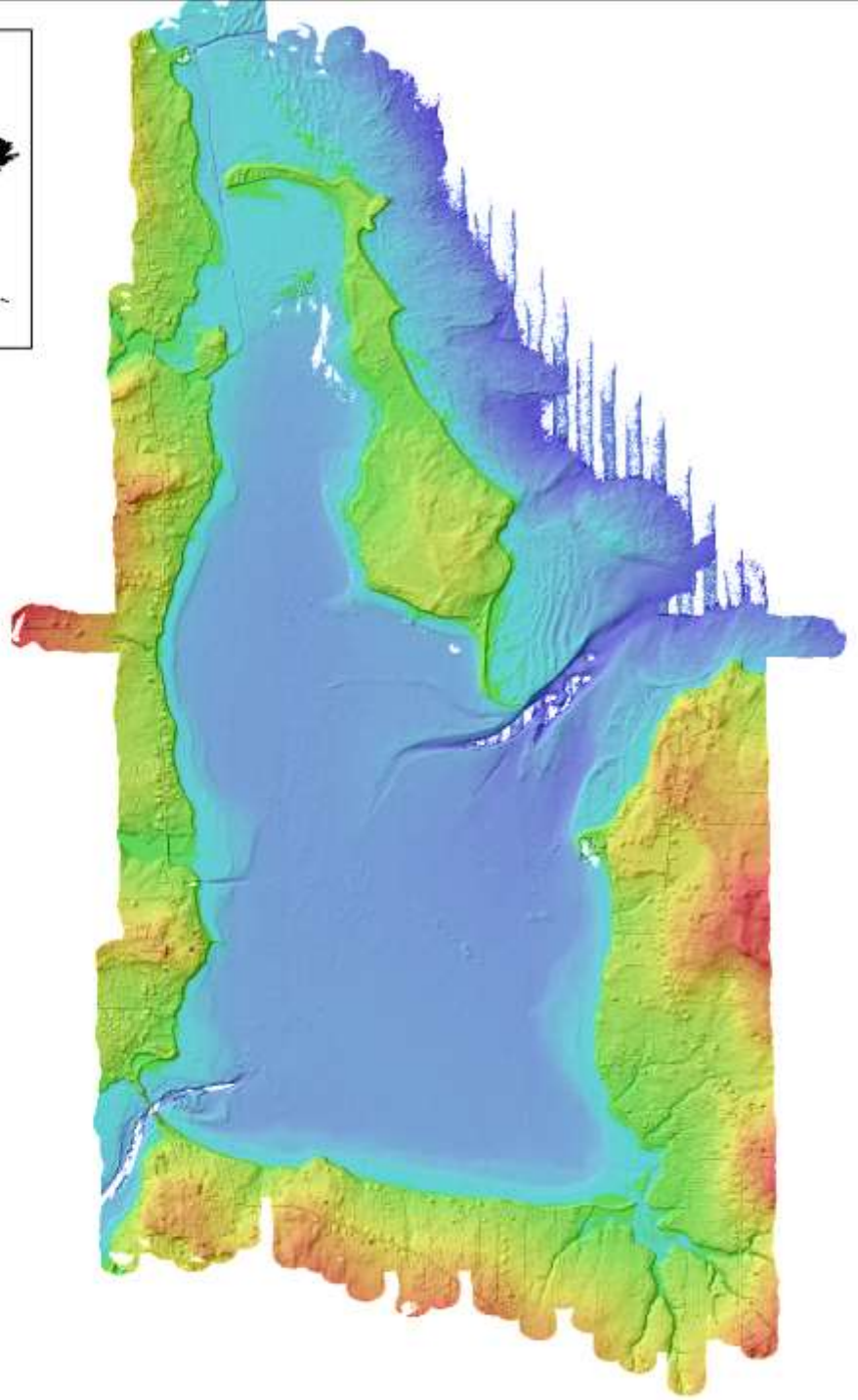
High : 0

Low : -11

Ell. Ht. (m)

High : 20

Low : 0



N
W E
S
0 1
km

Lidar Surverys

COC 2014

Value

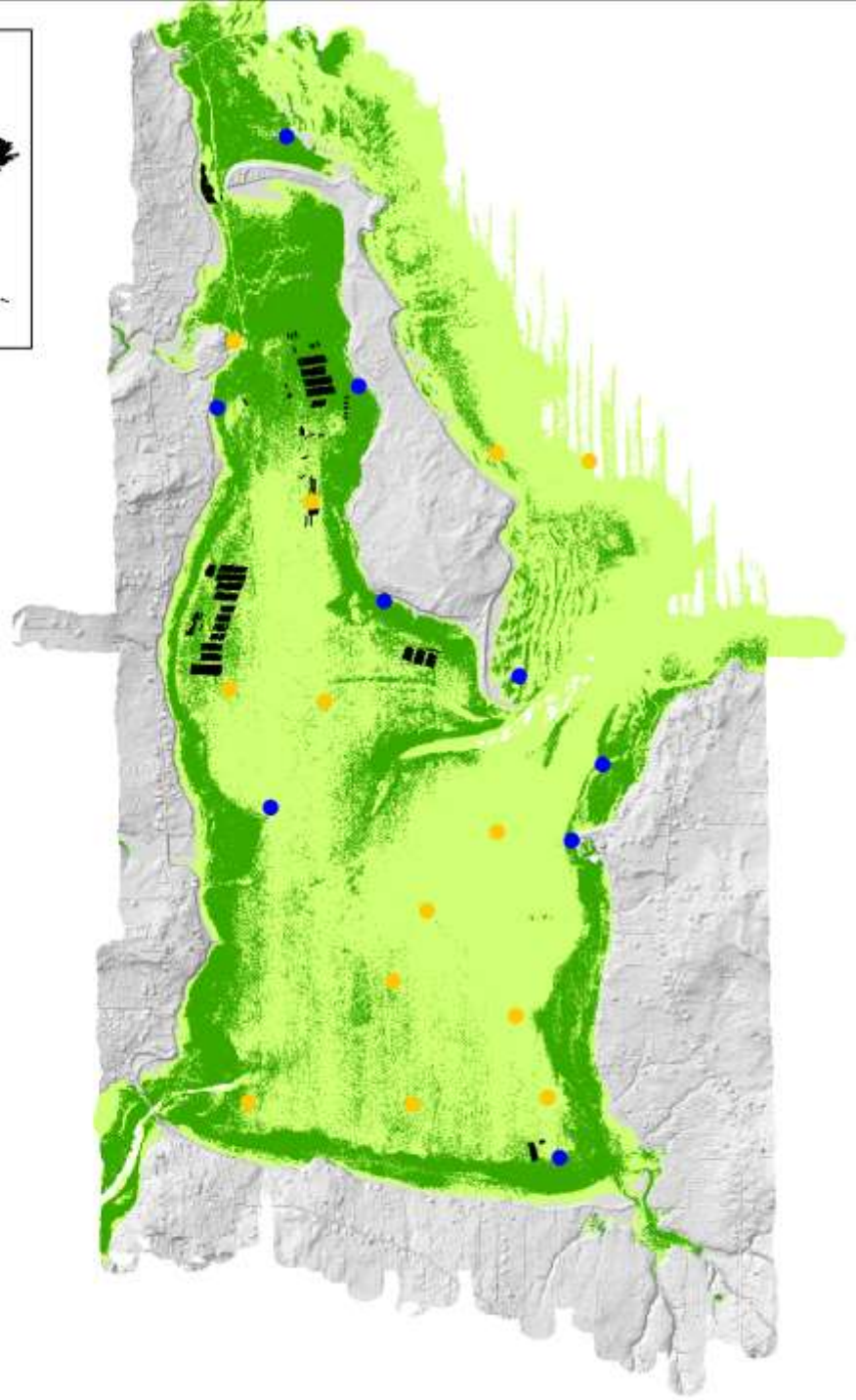
High : 0

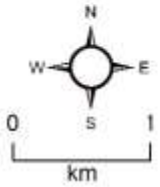
Low : -11

Value

High : 20

Low : 0





Eelgrass

- 0
- 1
- Aquaculture
- Abscent
- Present

See, Aquaculture!

Eelgrass

0

1

Aquaculture

Eelgrass

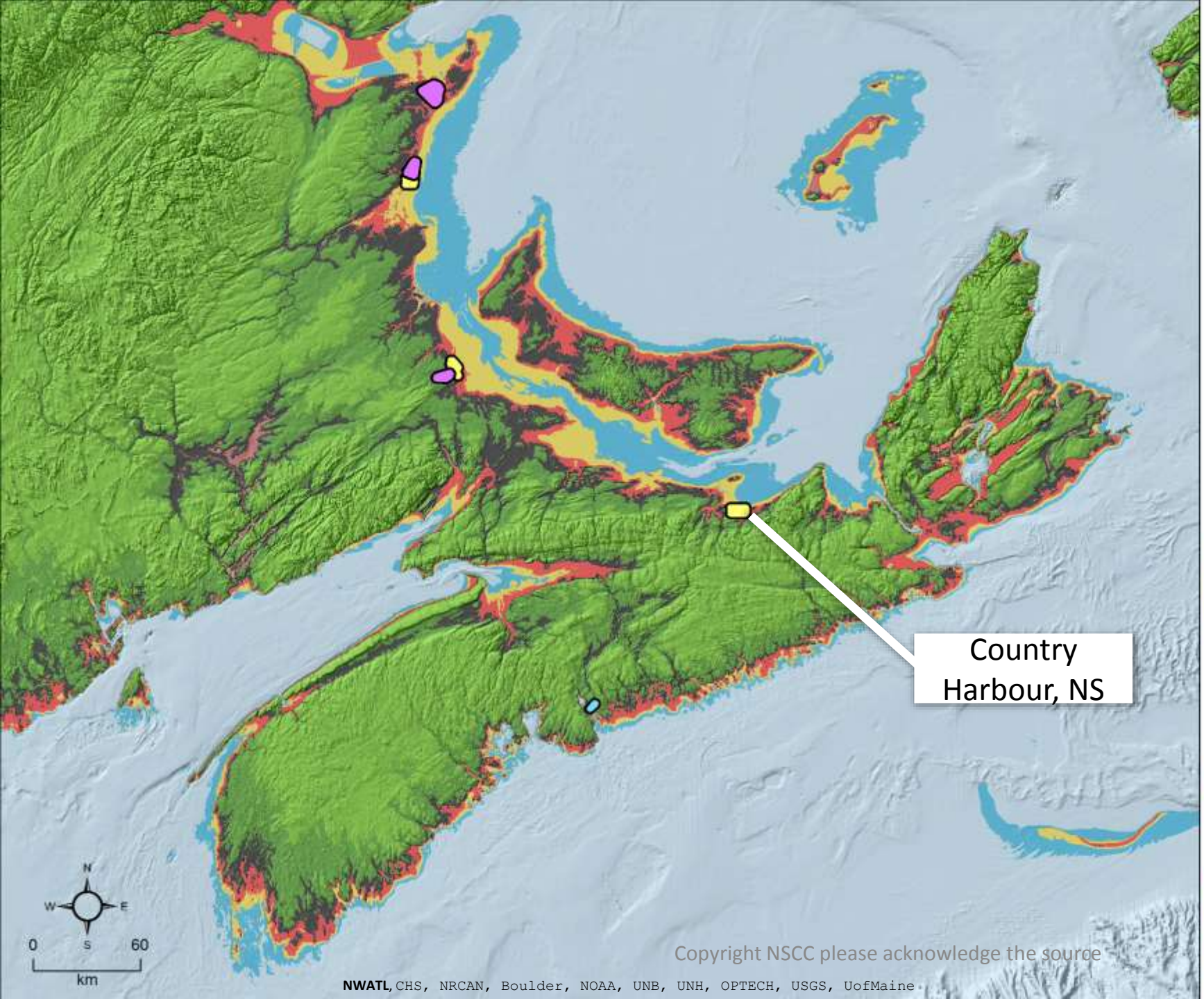
- 0
- 1
- Aquaculture
- Present

Eelgrass

- 0
- 1

Eelgrass

- 0
- 1
- Present



Lidar Surveys

- Sept. 2014 (Lake)
- Oct. 2015
- Sept. 2014

Height

Metres

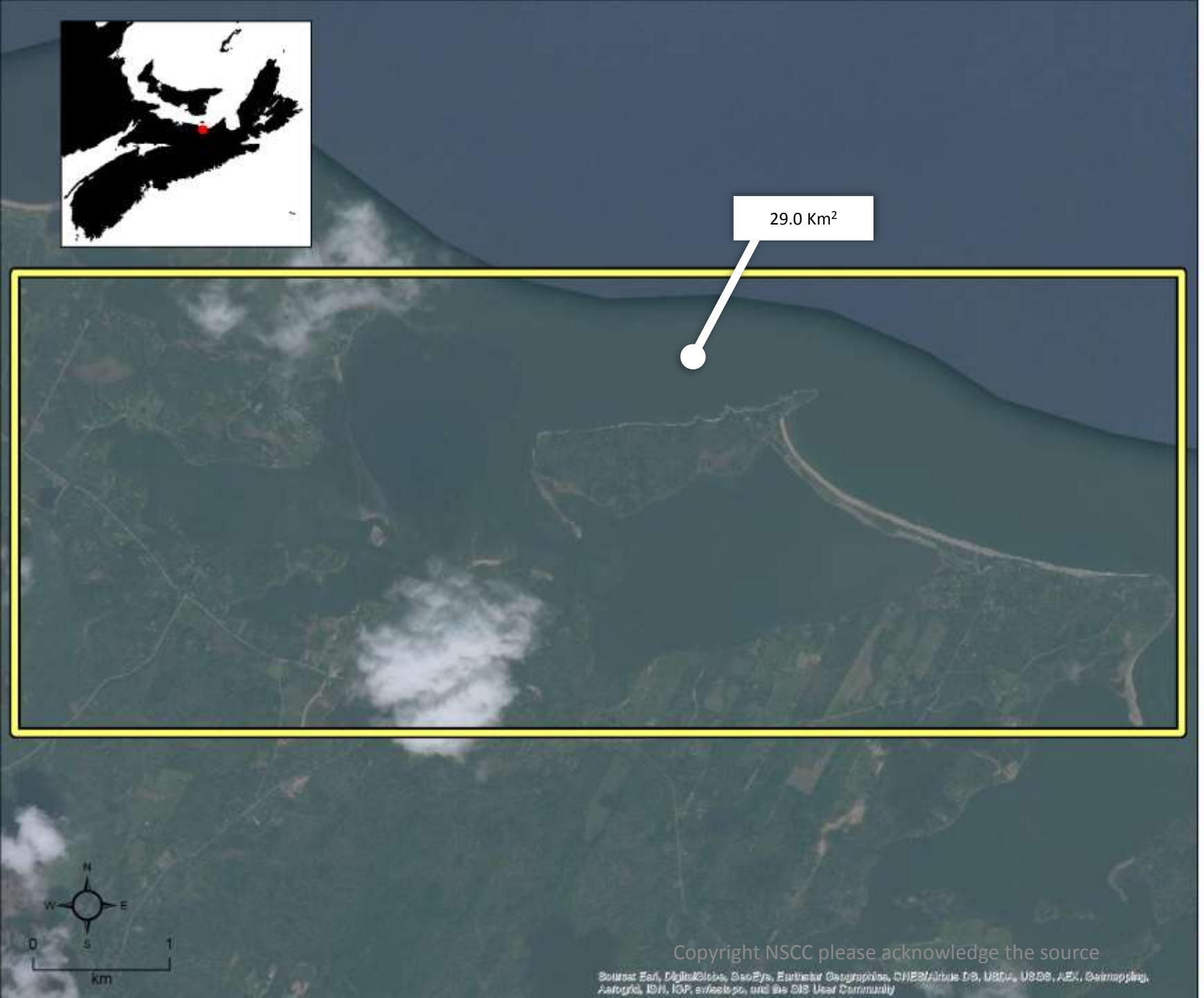
- null
- 1 - 30
- 30 - 80
- 80+

Depth

Metres

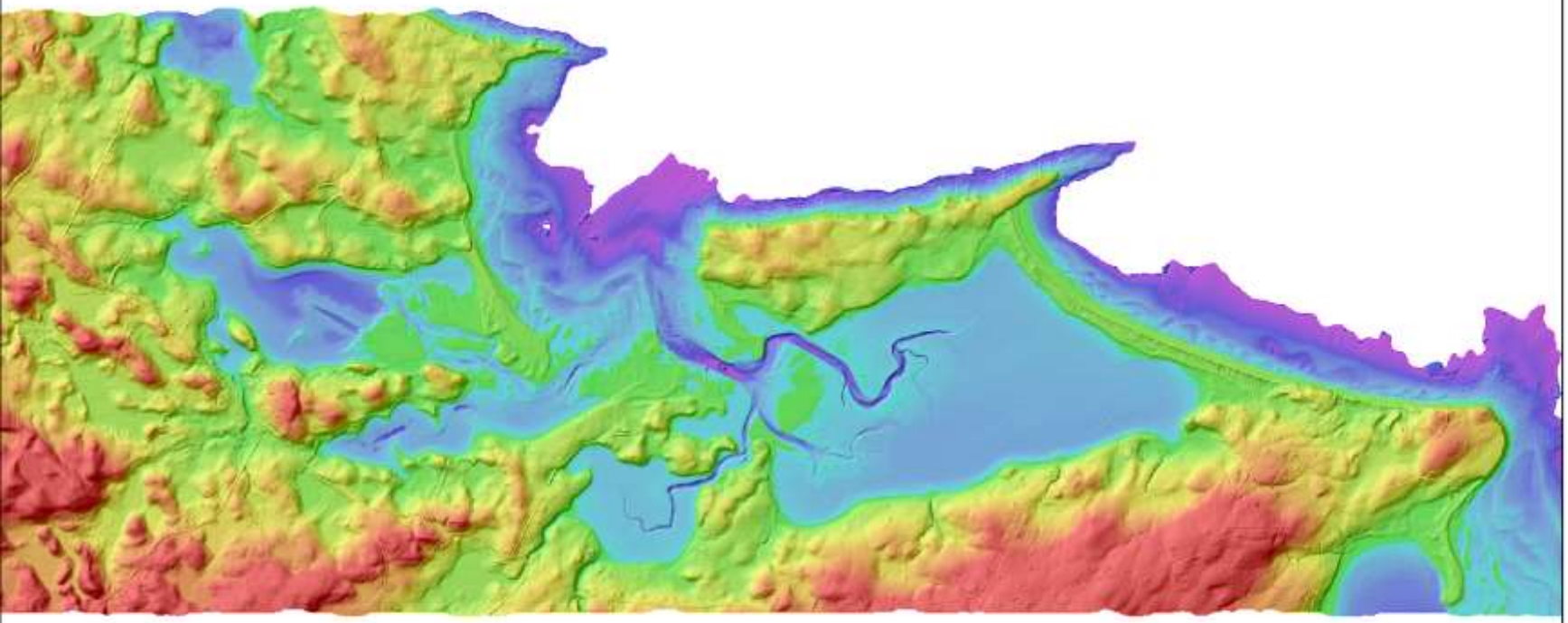
- <5
- 5 - 15
- 15 - 30
- 30+

NWATL, CHS, NRCAN, Boulder, NOAA, UNB, UNH, OPTECH, USGS, UofMaine



Lidar Surveys

Country Har. 2014



N
W E
S
0 1
km

Lidar Surveys

LH 2014

Ell. Ht. (m)

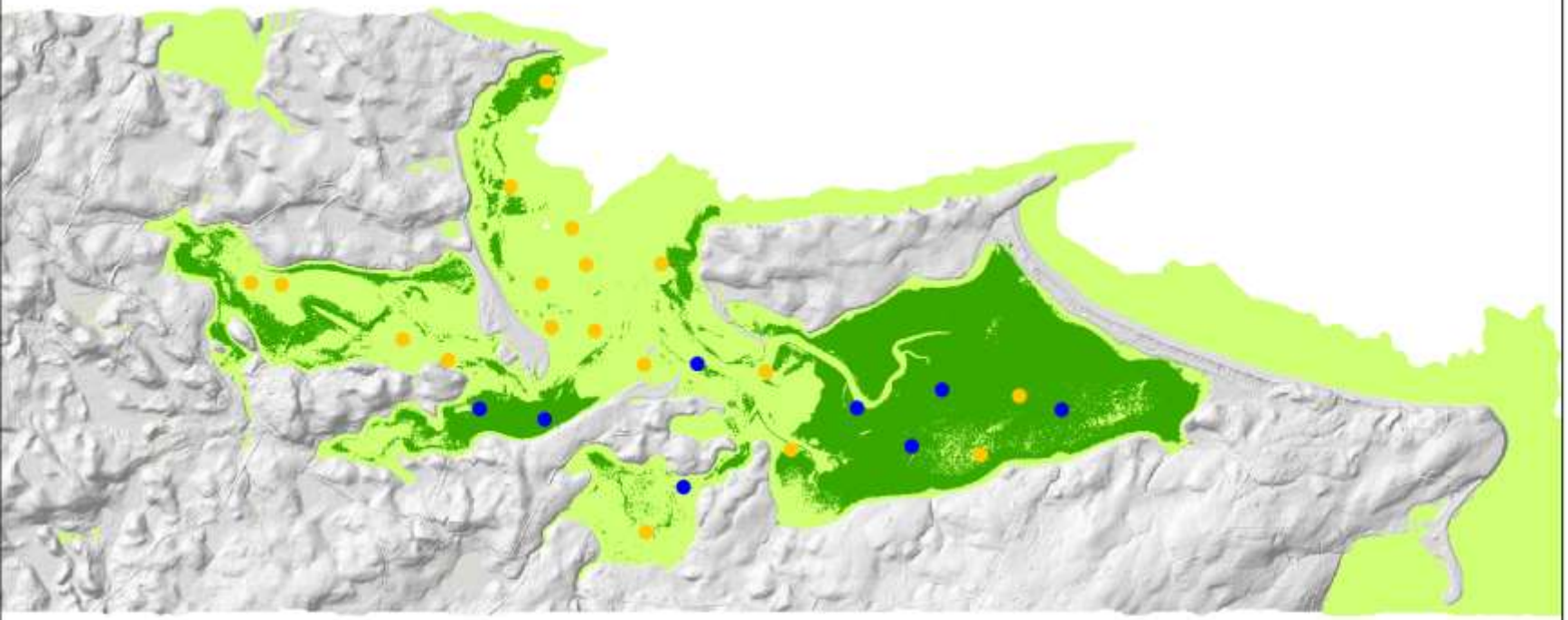
High : 0

Low : -6

Ell. Ht. (m)

High : 25

Low : 0



N
W E
S
0 1
km

Eelgrass

Presence

0

1

Abscent

Present

Eelgrass

Presence

- 0
- 1

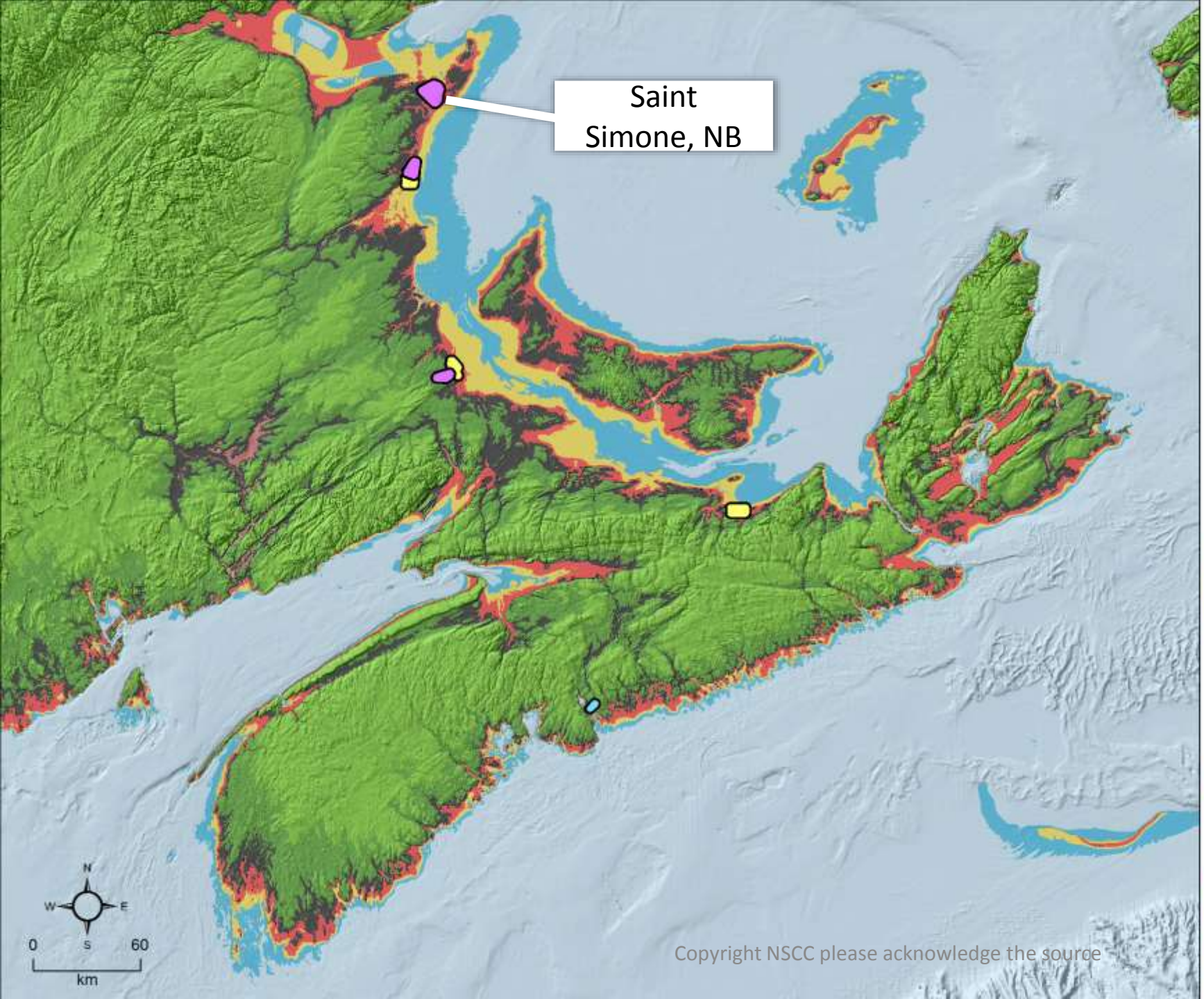
Eelgrass

Presence

0

1

Present



Lidar Surveys

- Sept. 2014 (Lake)
- Oct. 2015
- Sept. 2014

Height

Metres

- null
- 1 - 30
- 30 - 80
- 80+

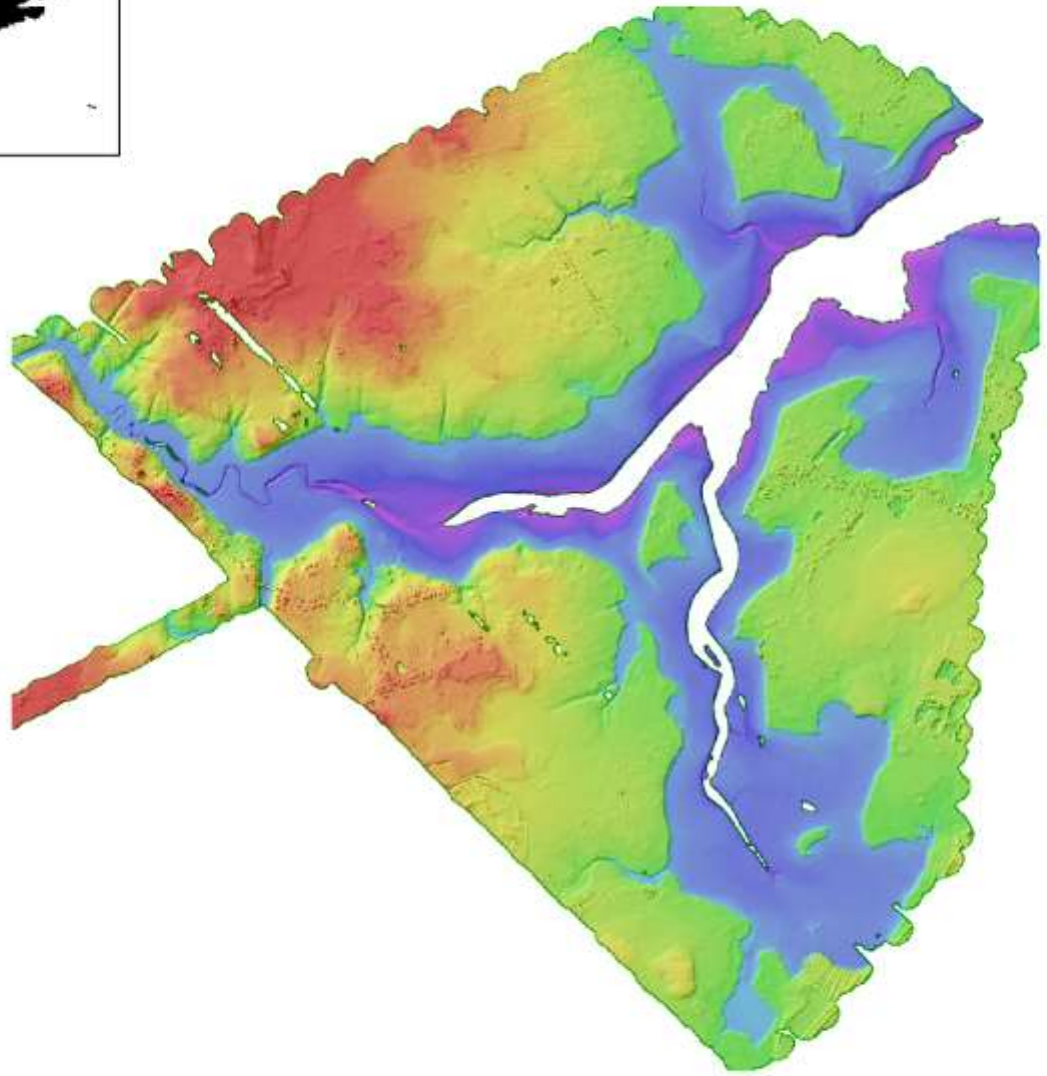
Depth

Metres

- <5
- 5 - 15
- 15 - 30
- 30+

Lidar Surveys

Saint-Simone2015



N
W E
S
0 2
km

Lidar Surveys

SS 2015

Ell. Ht. (m)

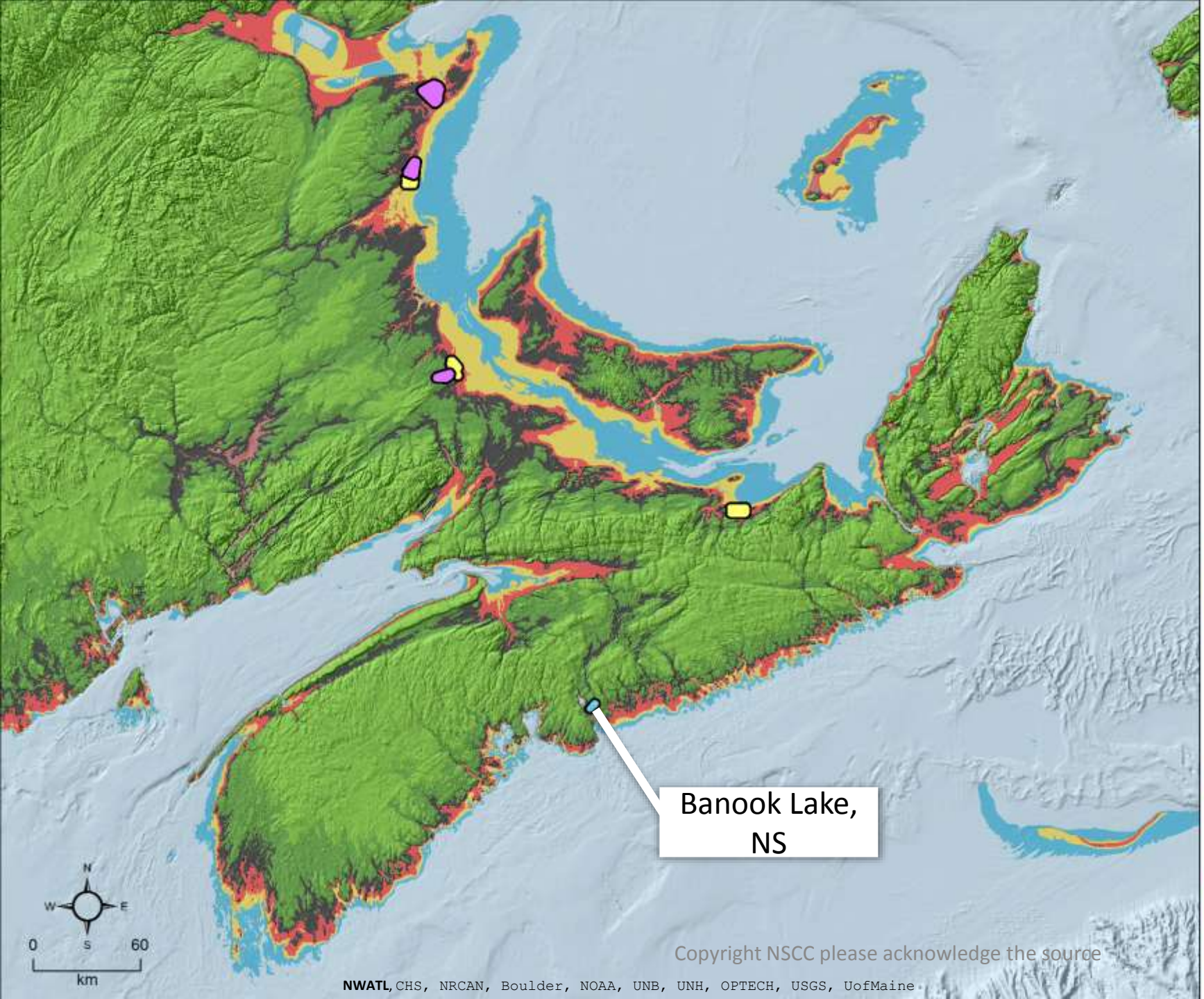
High : 0

Low : -5.2

Ell. Ht. (m)

High : 10

Low : 0



Lidar Surveys

- Sept. 2014 (Lake)
- Oct. 2015
- Sept. 2014

Height

Metres

- null
- 1 - 30
- 30 - 80
- 80+

Depth

Metres

- <5
- 5 - 15
- 15 - 30
- 30+

NWATL, CHS, NRCAN, Boulder, NOAA, UNB, UNH, OPTECH, USGS, UofMaine

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Lidar Surveys

Sept. 2014 (Lake)

N
W E
S
0 0.2
km

Lidar Surverys

LB 2014

Depth (m)

High : 5.8

Low : 0

Ell. Ht. (m)

High : 75

Low : 12

N
W E
S
0 0.2
km

Sub. Aq. Veg.

0
1
Abscent
Present

N
W E
S
0 0.2
km

Sub. Aq. Veg.

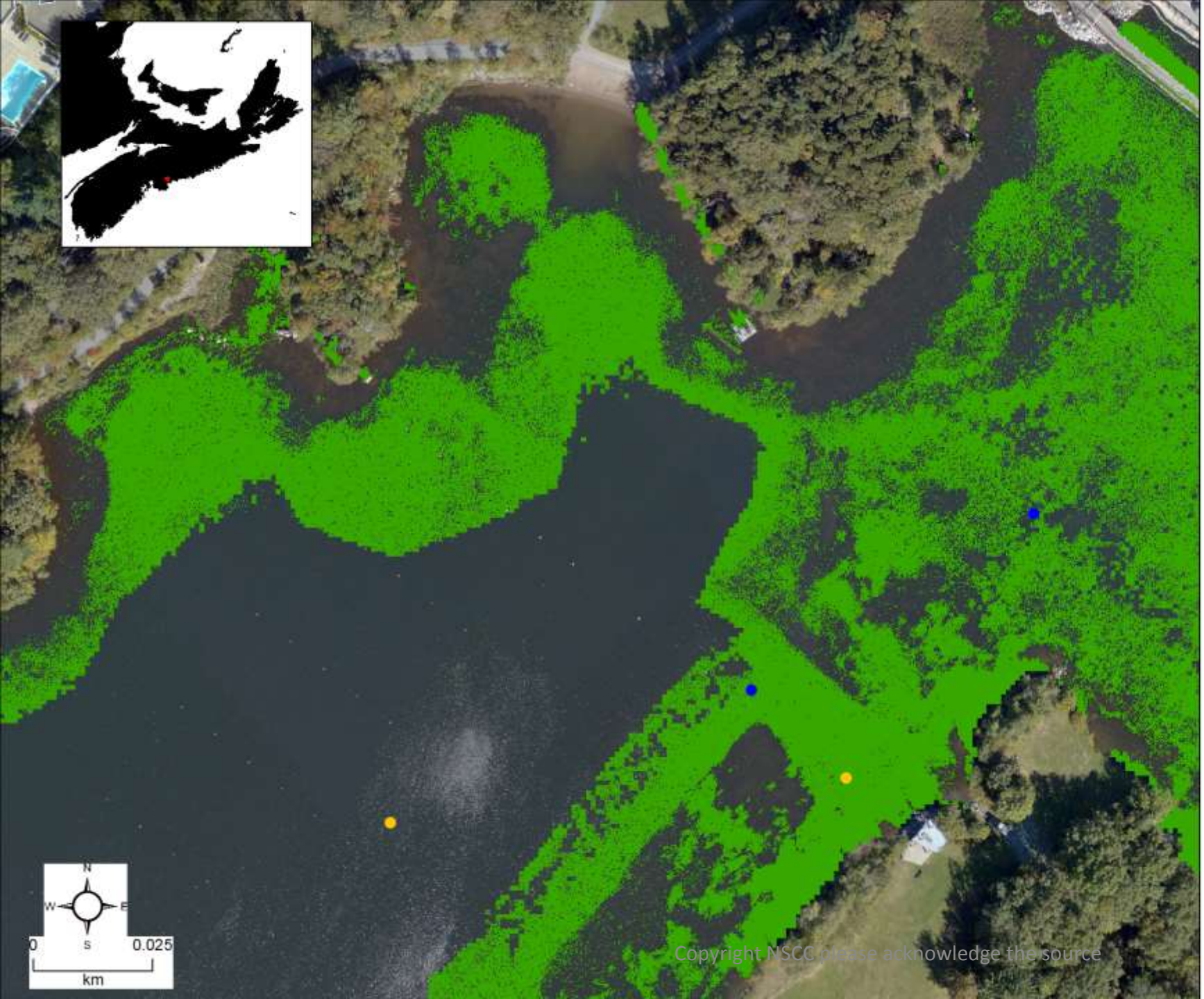
SAV Ht. (m)

High : 0.3

Low : 0

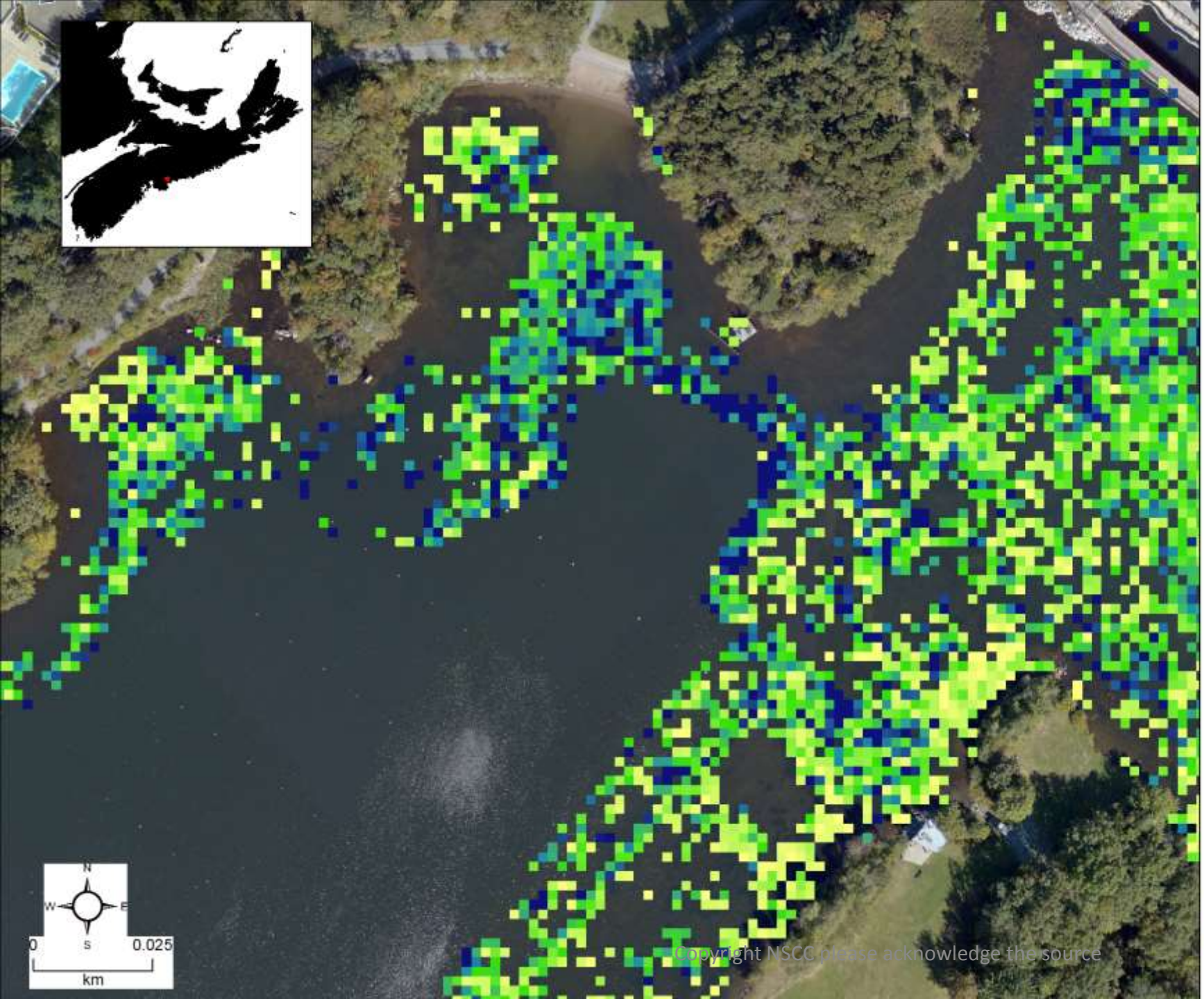
Sub. Aq. Veg.

- 0
- 1



Sub. Aq. Veg.

- 0
- 1
- Present



Sub. Aq. Veg.

SAV Ht. (m)

High : 0.3

Low : 0

Things to work on
MAKE IT WORK MORE CONSISTENTLY

- Noise Reduction in water column
- Depth Attenuation Compensation
- Airphoto Air/Water Correction
- Glint/Sun Angle Removal
- Wave Form Metric Extraction
- Extracting Additional points from lidar
- Many more …

Thanks too..

Mark Skinner, Stantec
Marc Ouellette, DFO
Monique Niles, DFO
Anders Ekelund, Leica AHAB

Equipment Support provided by CFI, NSRIT

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