sUAS for Biomass Monitoring using LiDAR and Multispectral Data

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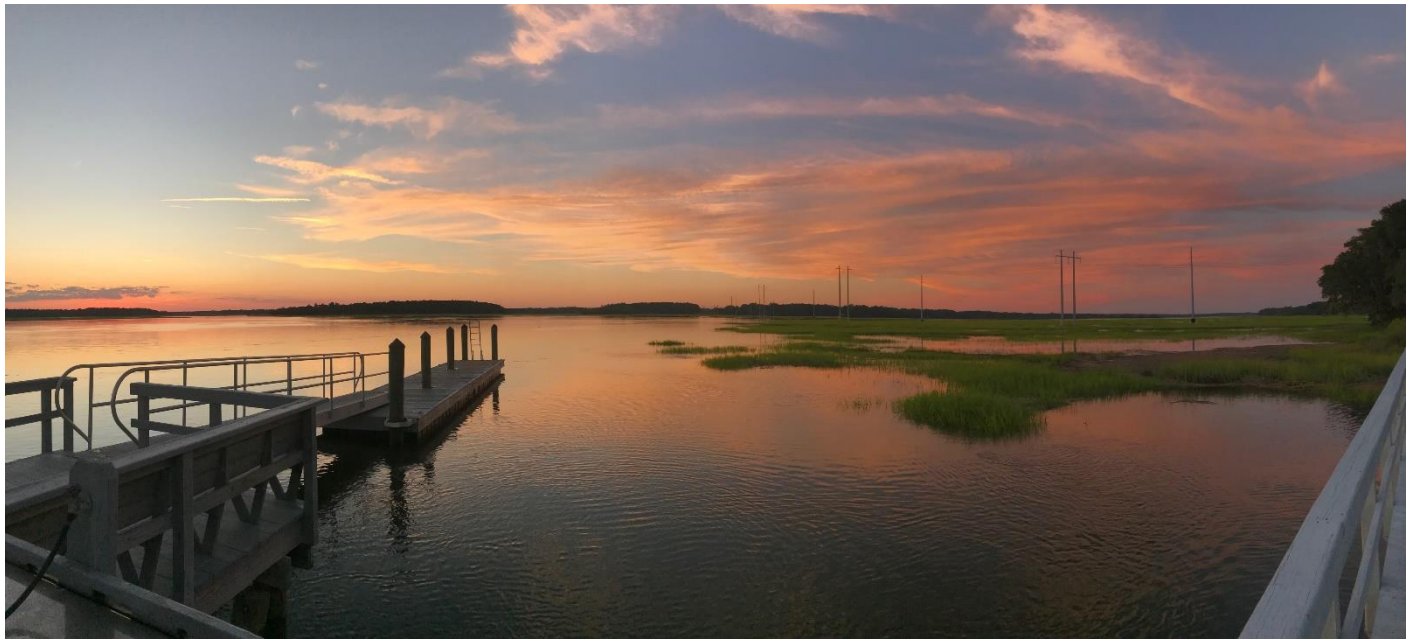
- **Tidal salt marsh** systems are incredibly important
  - **Protection**
  - **Essential habitat for wildlife**
  - **Economic**
  - **Carbon Sink**

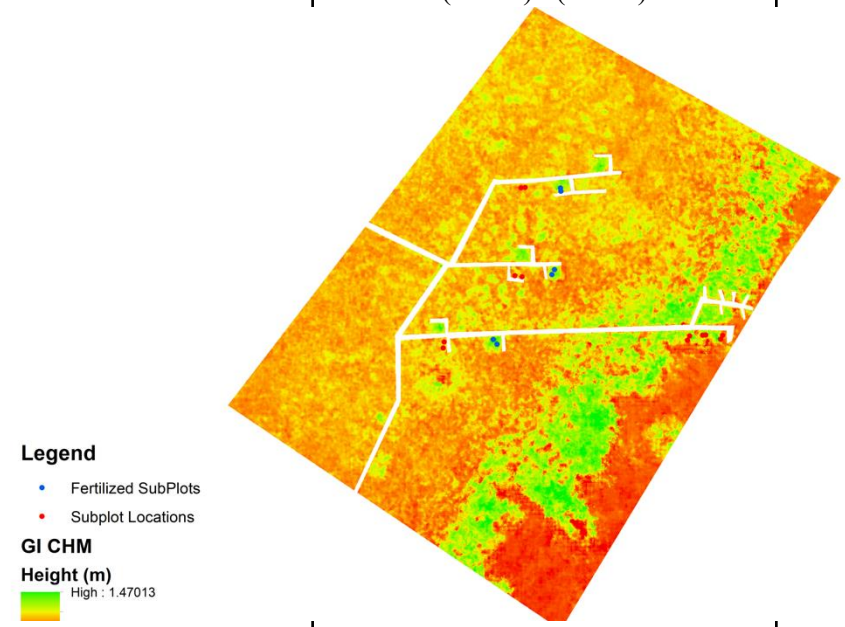
- High percentage of Atlantic coast wetlands are found in South Carolina, second to Georgia (Wiegert and Freeman 1990)



Experiences on drone ortho-imagery for marsh mapping

RGB Vegetation Indices

Index	Formula	Reference[1]
ExG	2 × G − R − B	Jing et al., 2017
GCC or Green Ratio	G / B + G + R	Yue et al., 2017
GRVI	(G − R) / (G + R)	Jing et al., 2017
VARI	(G – R) / (G + R – B)	Cen et al., 2019
VDVI or GLA	(2 * G – R – B) / (2 * G + R + B)	Cen et al., 2019

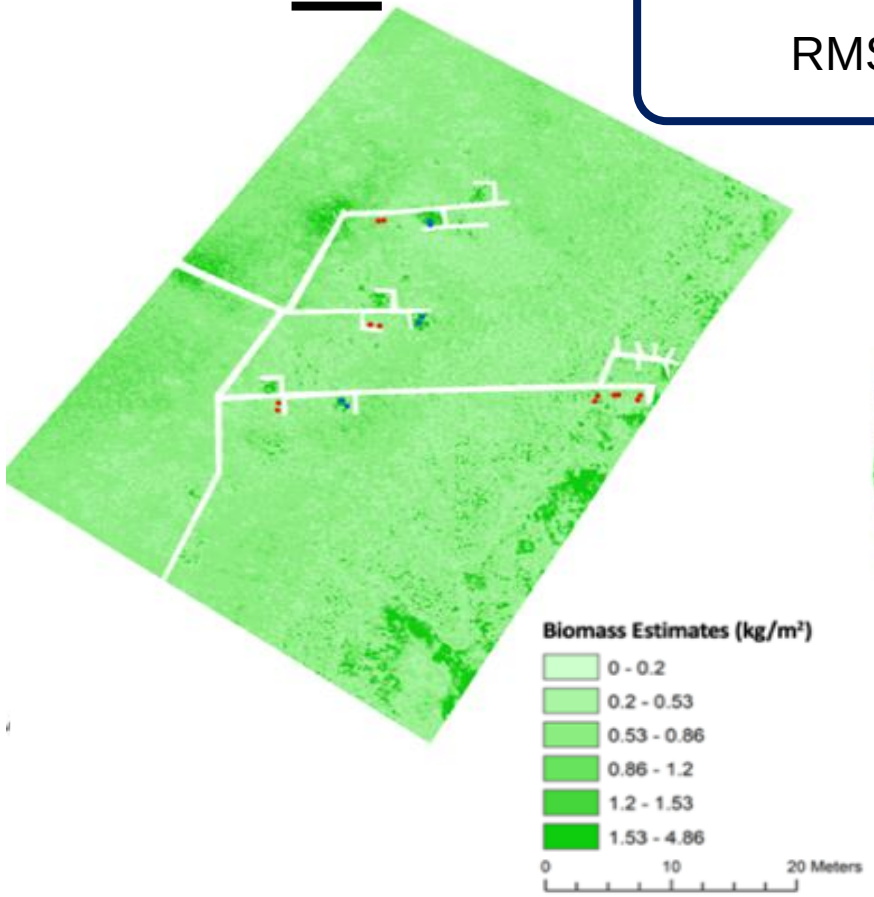


Experiences on drone ortho-imagery for marsh mapping

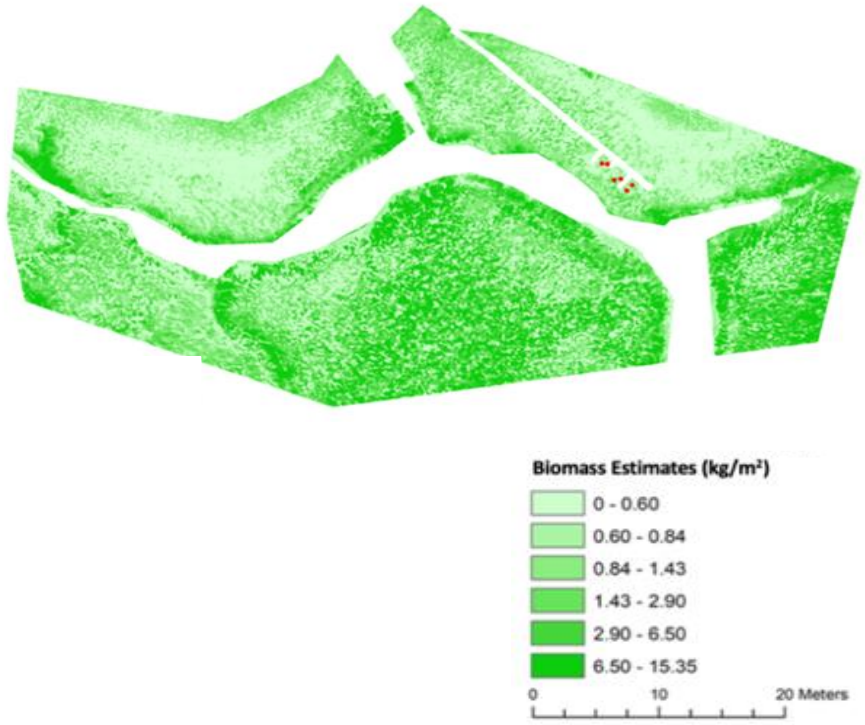
$$Biomass = 6943.5 * ExG^2 - 226.82 * ExG + 2.3477$$

RMSE = 0.598 kg/m^2; R^2 = 0 .376; P < 0.05

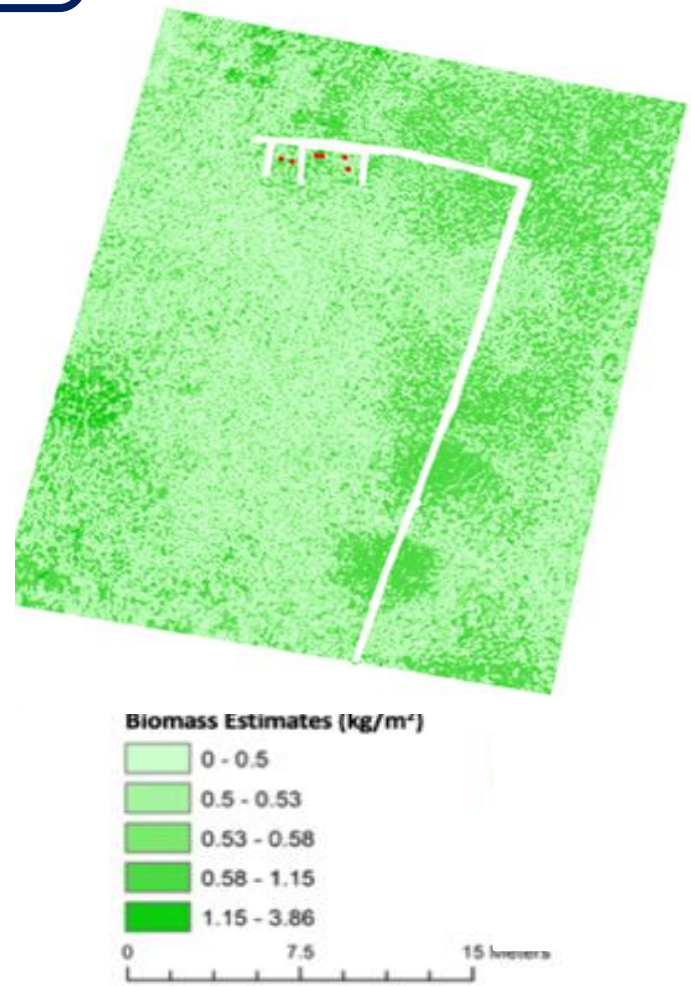
GI



OL-LM



OL-HM



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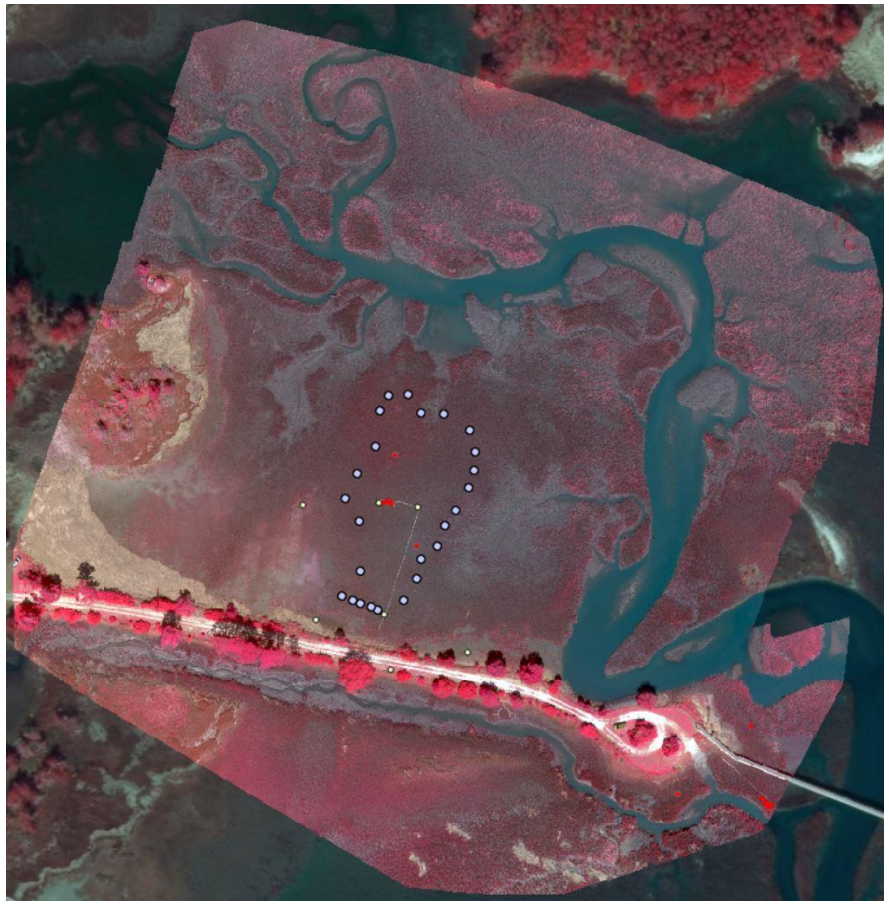
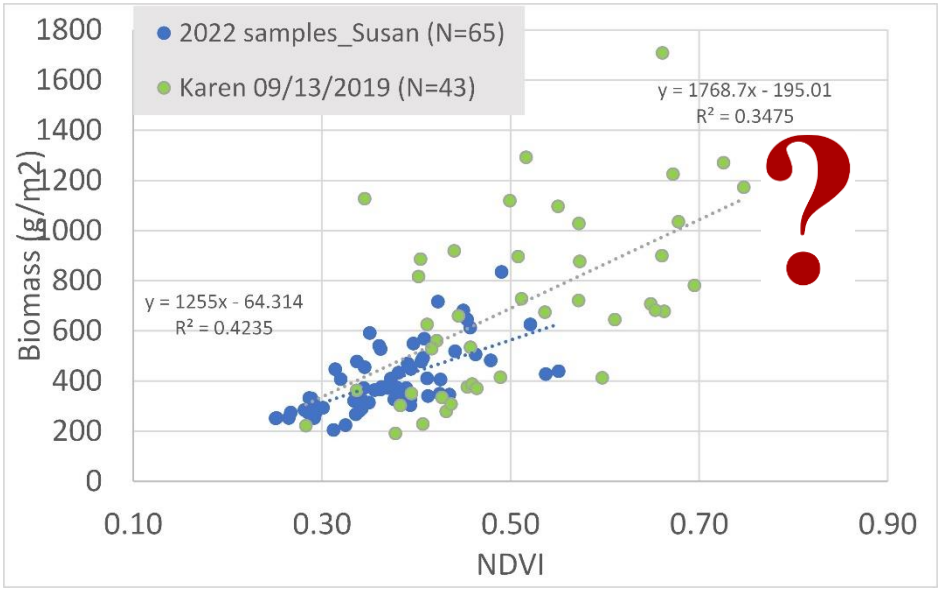
Experiences on drone ortho-imagery for marsh mapping

Matrice100/RedEdge-M, 09/22/2022
(Goat Island)



Drone-assisted marsh biomass experiments, North Inlet



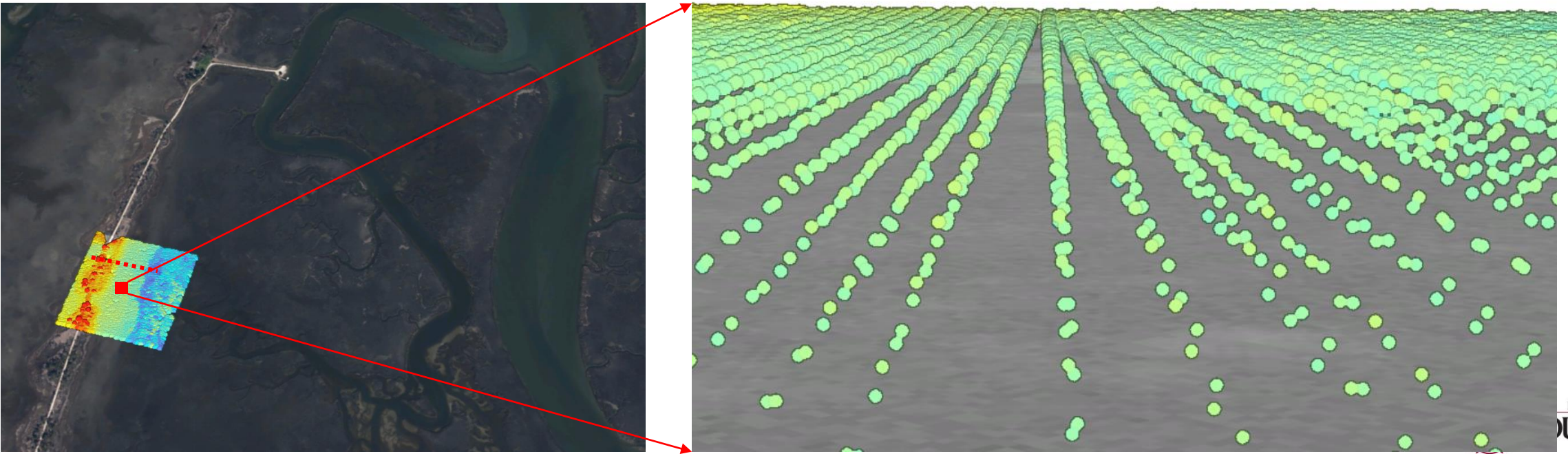
(Credits: Dr. James Morris and Karen Sundberg at BMFL, USC)

Airborne Lidar in coastal marshes: not as good as we had hoped...

Challenges on Lidar classification:

- ✓ *Tidal effects*
- ✓ *Gentle topography*
- ✓ *Short, sparce marsh plants*

USGS Lidar Point Cloud (LPC):
Spacing = 2-3 ft



Question: Could Drone Lidar play a better role in marshes?

- ✓ *Affordable: significantly reduced prices*
- ✓ *Flexible: flight parameters*
- ✓ *Mass points: much denser point clouds*

Low-cost drone Lidar systems, ready-to-go package (<20k):

DJI Zenmuse L1
(Lidar +RGB)
$13,000

ROCK Robotic R2A
(Livox Avia + RGB)
$19,000

(240,000 points/s)

❑ **Field experiment**: August – September 2022, North Inlet

(Baruch Marine Field Laboratory, USC)

✓ **Drone Lidar missions**: 08/31 – 09/01

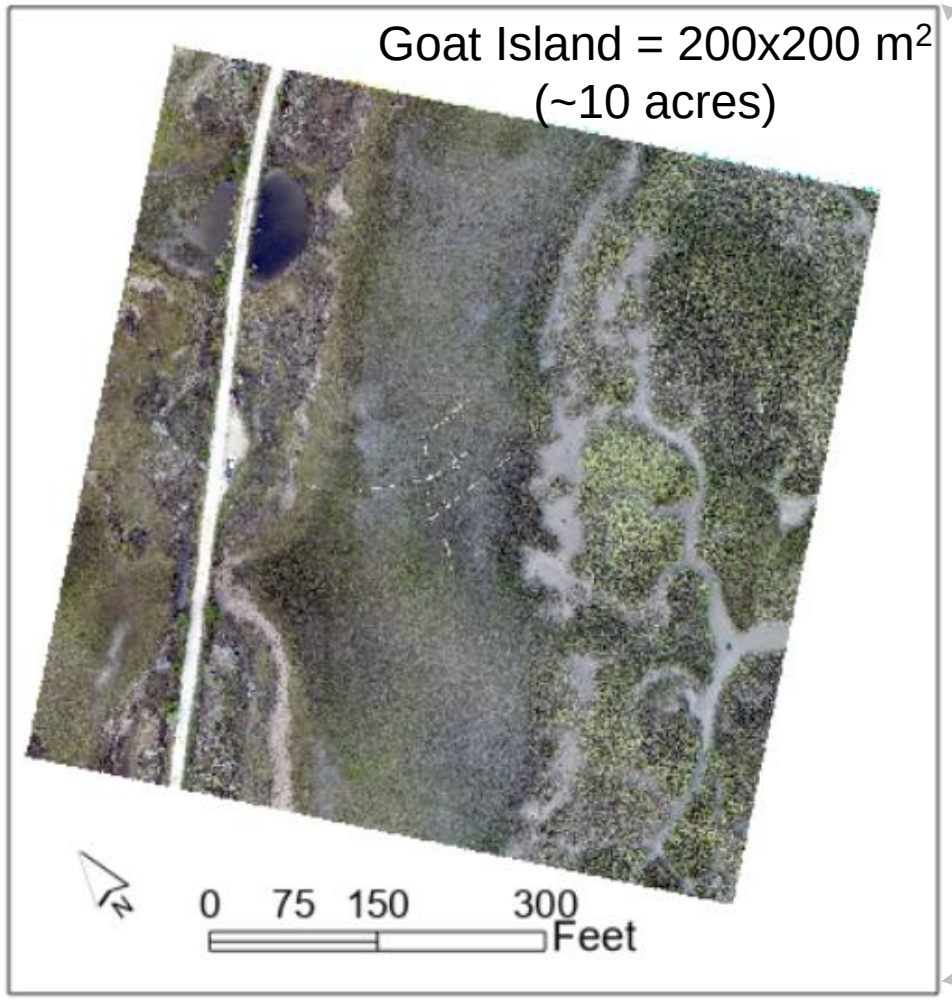
Vendor: Back Forty Aerial Solutions, Columbia, SC

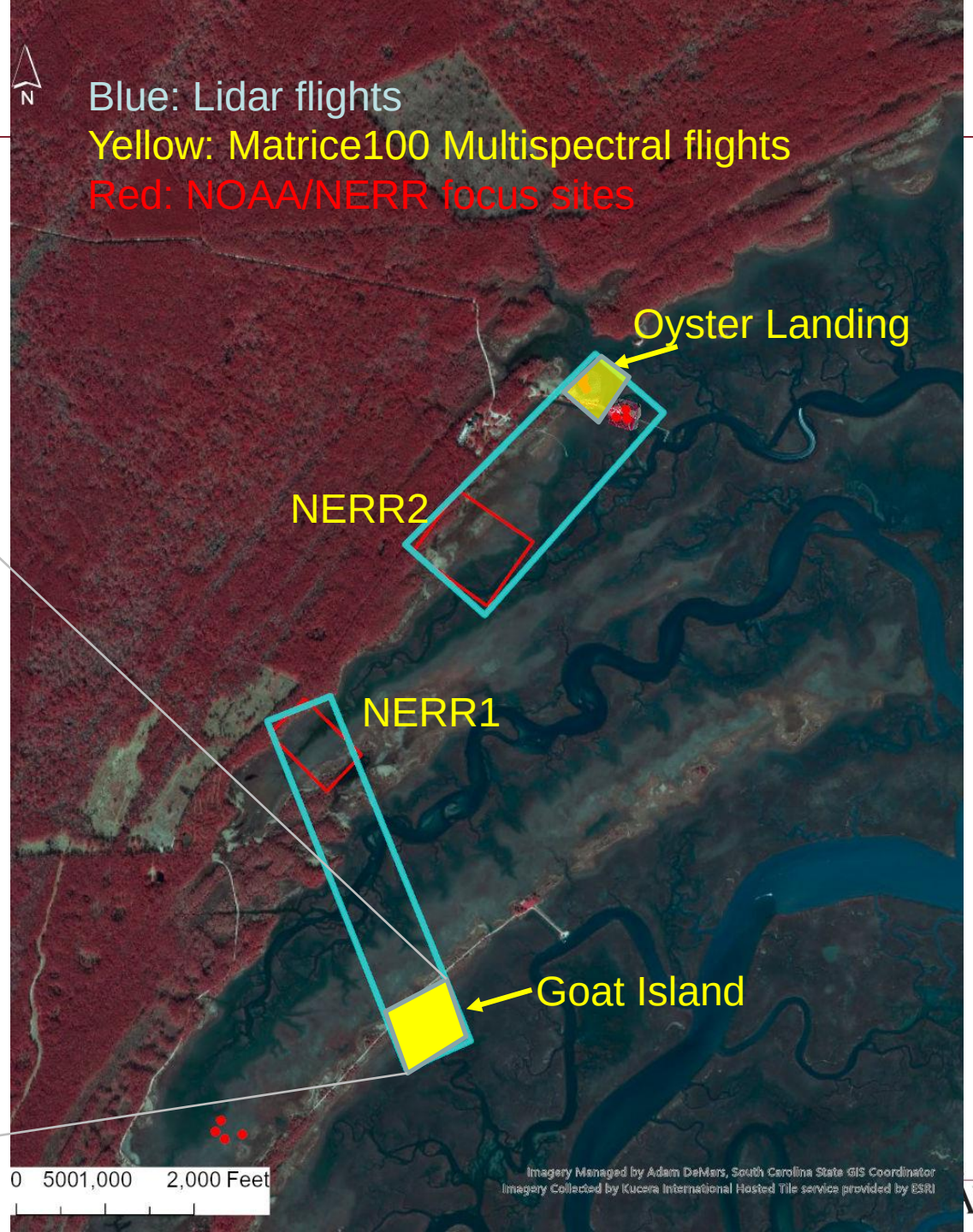
✓ **Multispectral drone missions and field survey**: 09/20 – 09/24

NASA EPSCOR Project team:
Susan Wang,
Jim Morris,
Grayson Morgan,
Alex Fullham,
Naser Lessani

Drone Lidar data footprint

R2A/RGB ortho image

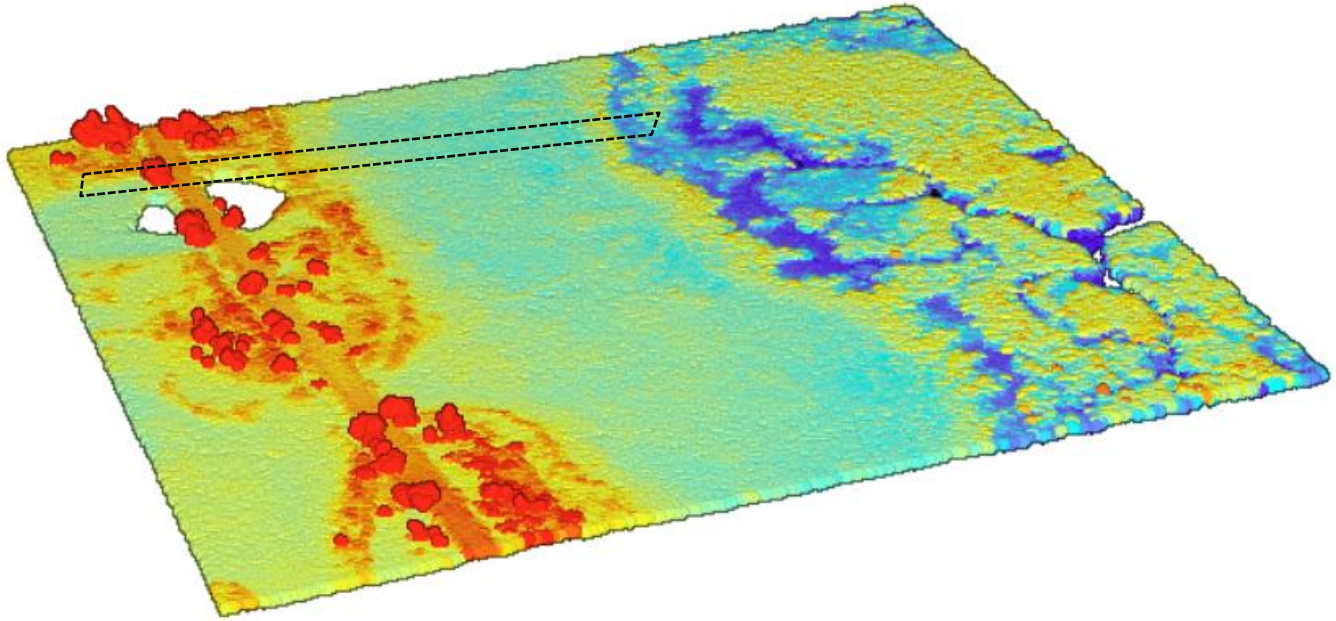




R2A/Lidar point cloud

Goat Island subset	Drone Lidar	USGS Lidar
Point count	29,561,422	95,269
Spacing	0.036 m	0.639 m
Point density (#/m^2)	771	2.43

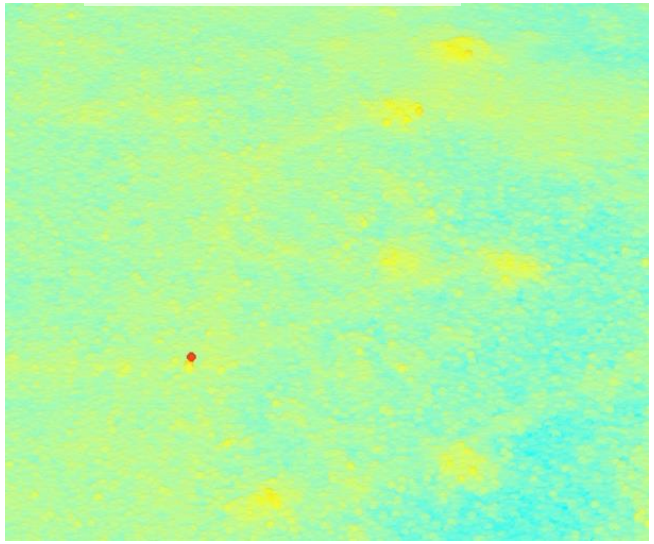
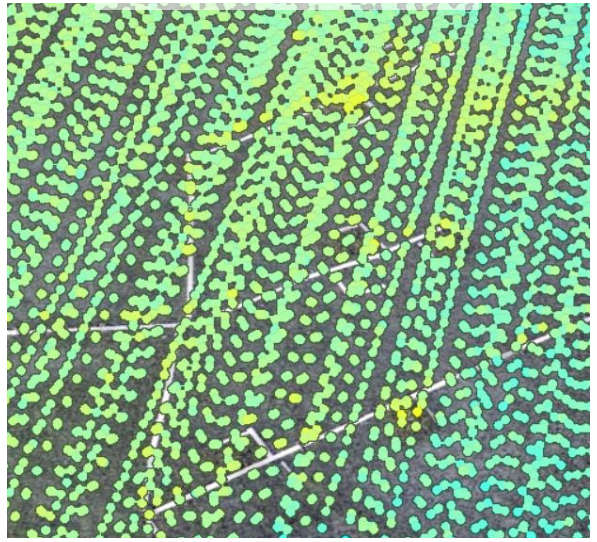
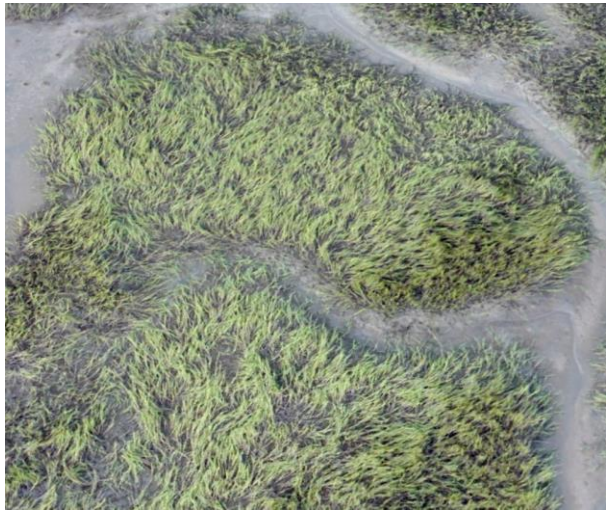
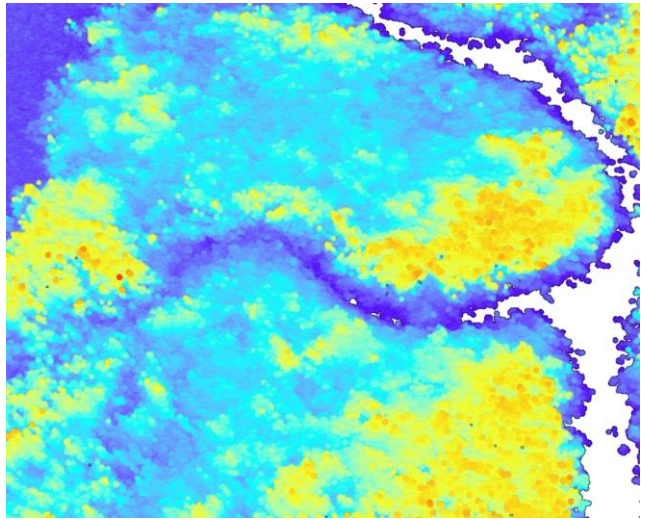
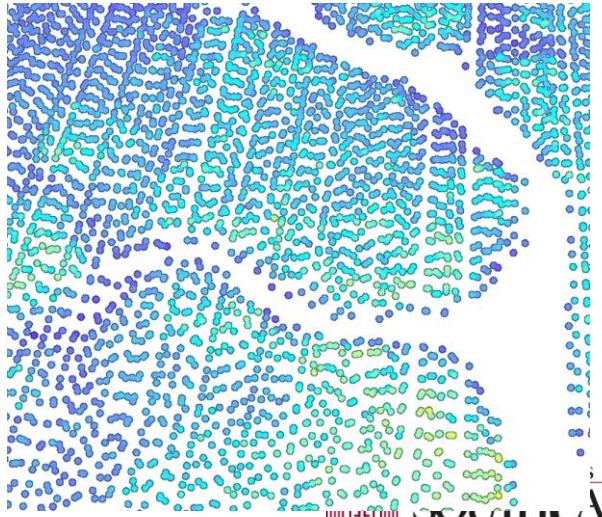
Caution: R2A Lidar points only have one return in marsh fields!



R2A Drone Lidar profile:

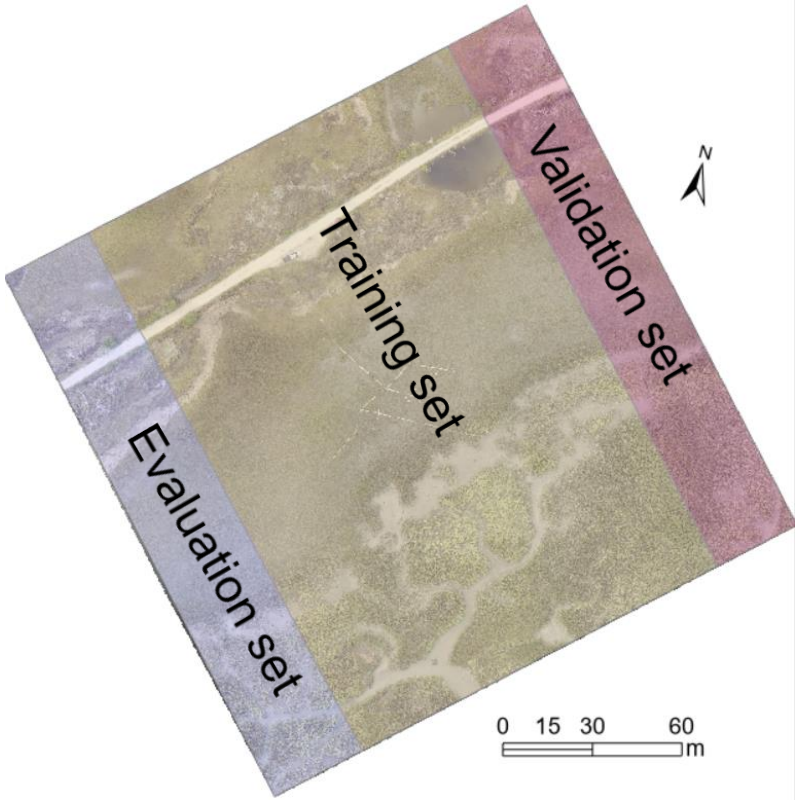
USGS Lidar profile:

Visual comparison: Drone Lidar vs. USGS Lidar

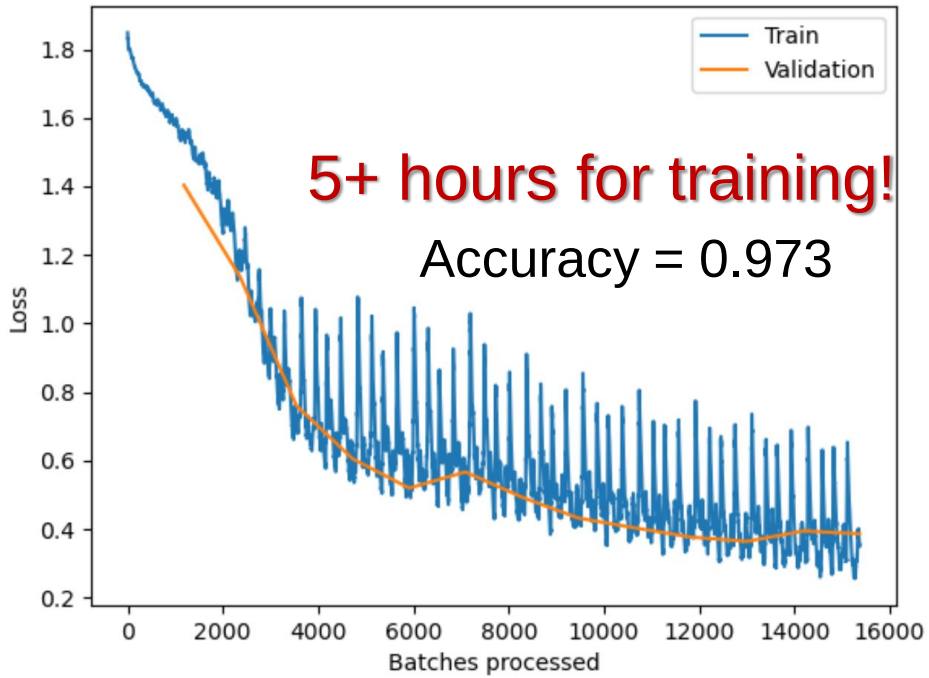
	Ortho-image	Drone Lidar	USGS Lidar
High marsh			
Low marsh			

❑ PointCNN: Deep learning for point cloud classification

We only tested two classes:
Vegetation and **Ground**.



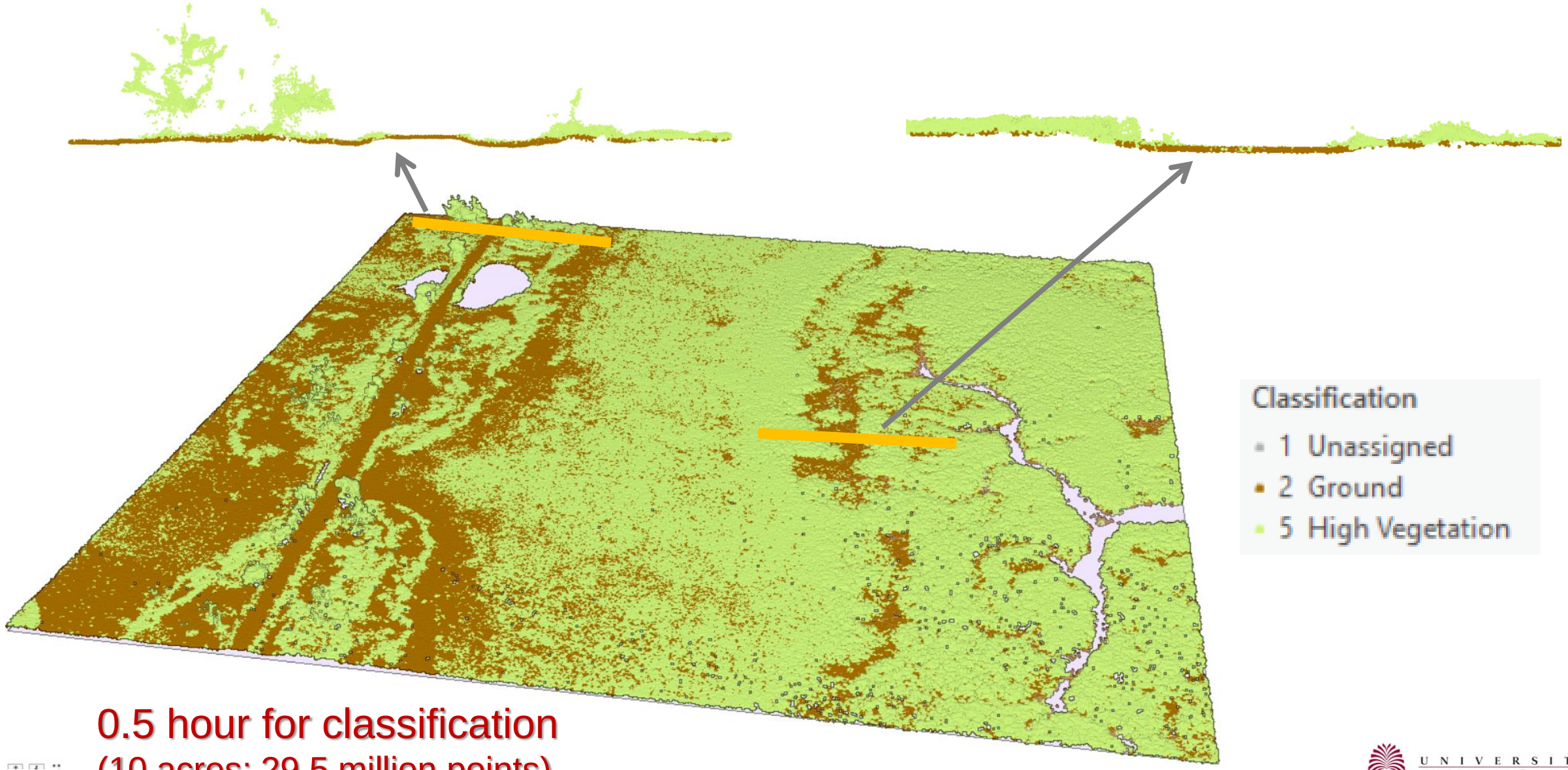
Training/validation loss curves



Evaluation matric

CLASS_CODE	CLASS_NAME	PRECISION	RECALL	F1_SCORE
1	background	0.002441	0.032227	0.004538
2	Ground	0.969974	0.957472	0.963683
5	High Vegetation	0.992208	0.982159	0.987158

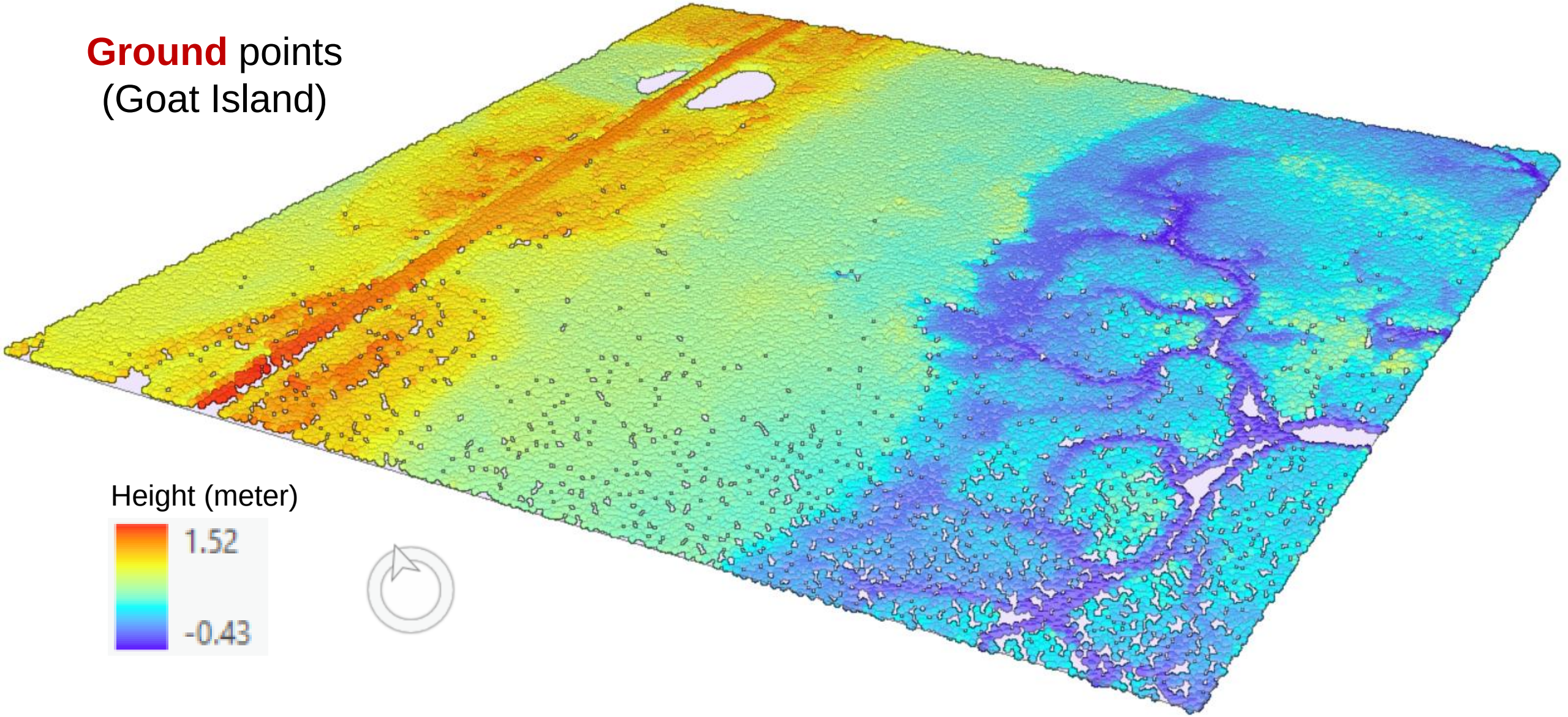
Point classification results at Goat Island



0.5 hour for classification
(10 acres; 29.5 million points)

Bare Earth Surfaces

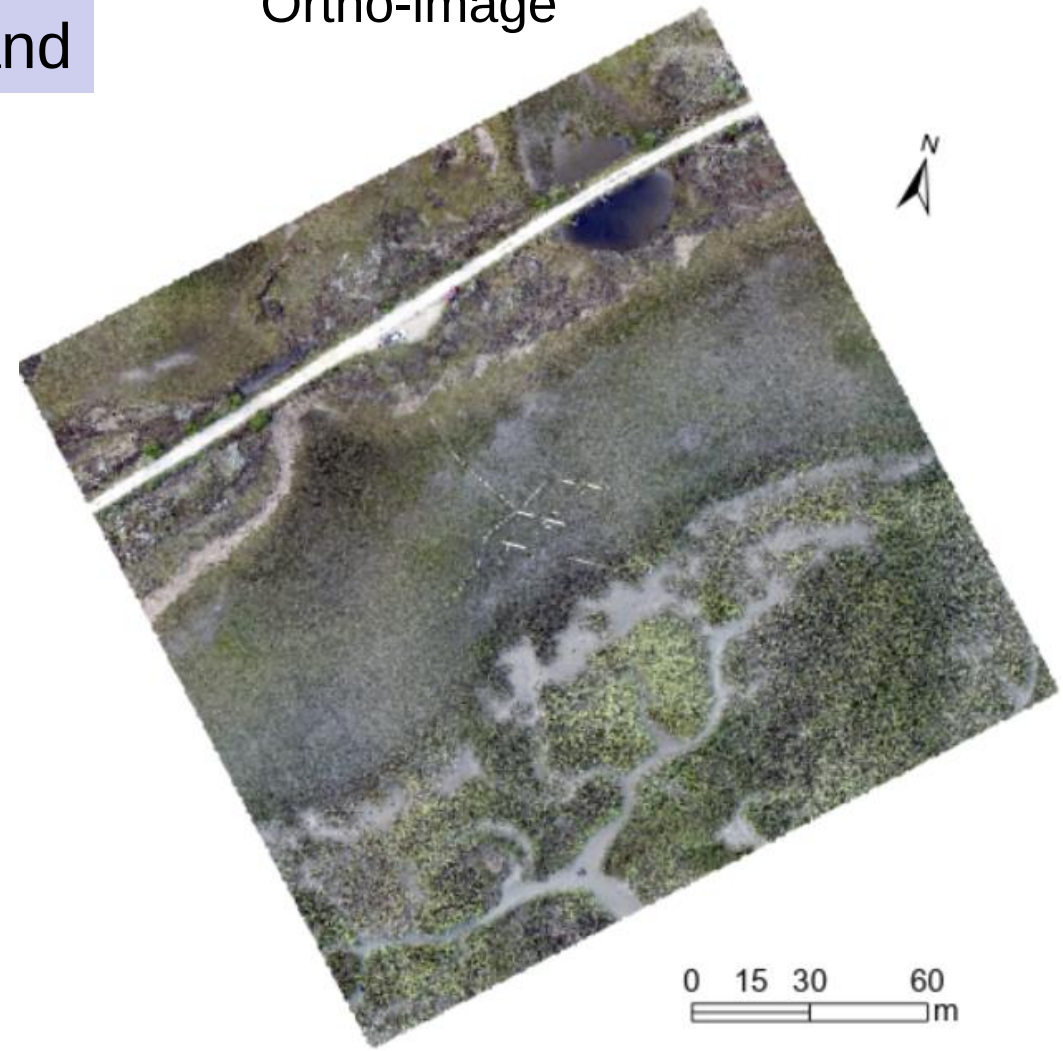
Ground points
(Goat Island)



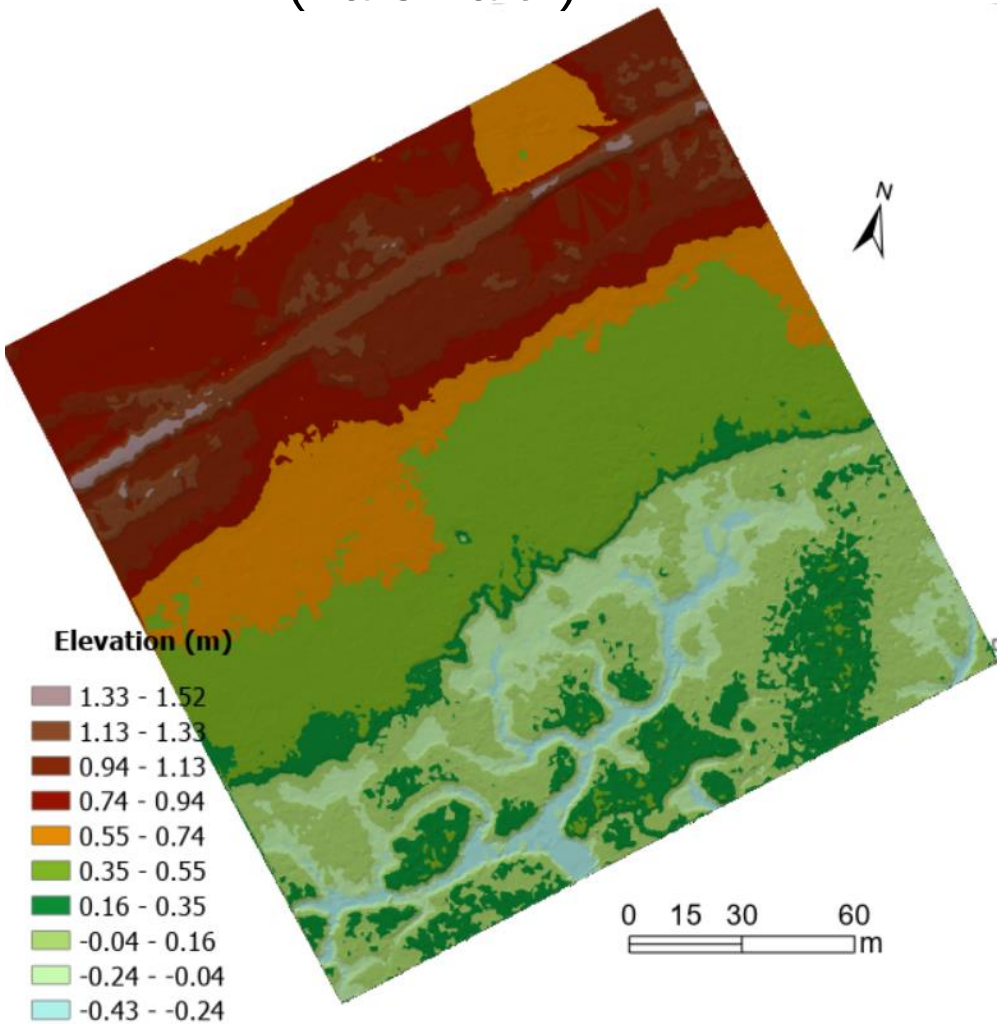
❑ Topography in marshes: bare Earth surfaces

Goat Island

Ortho-image

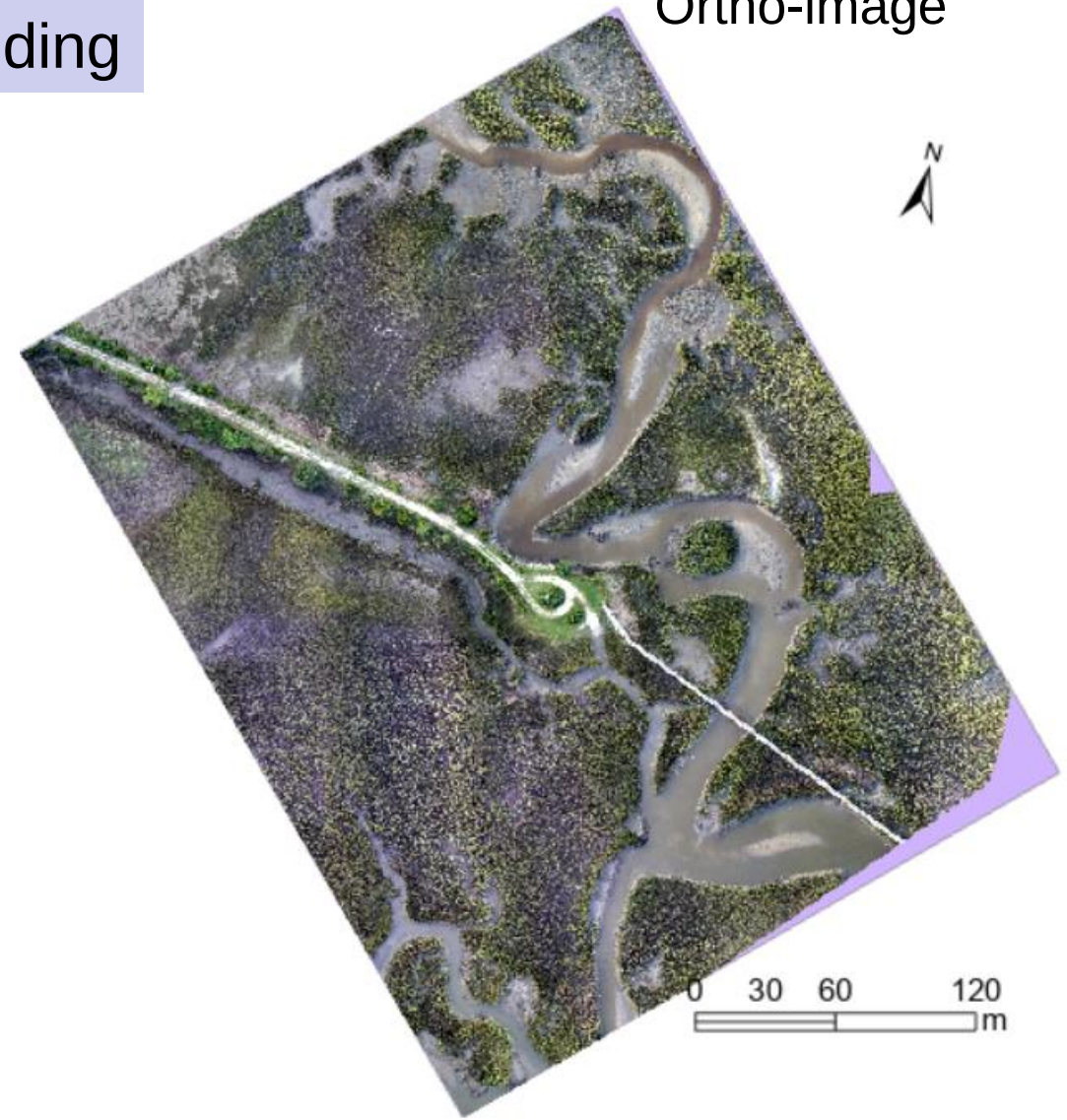


TIN (Bare Earth)

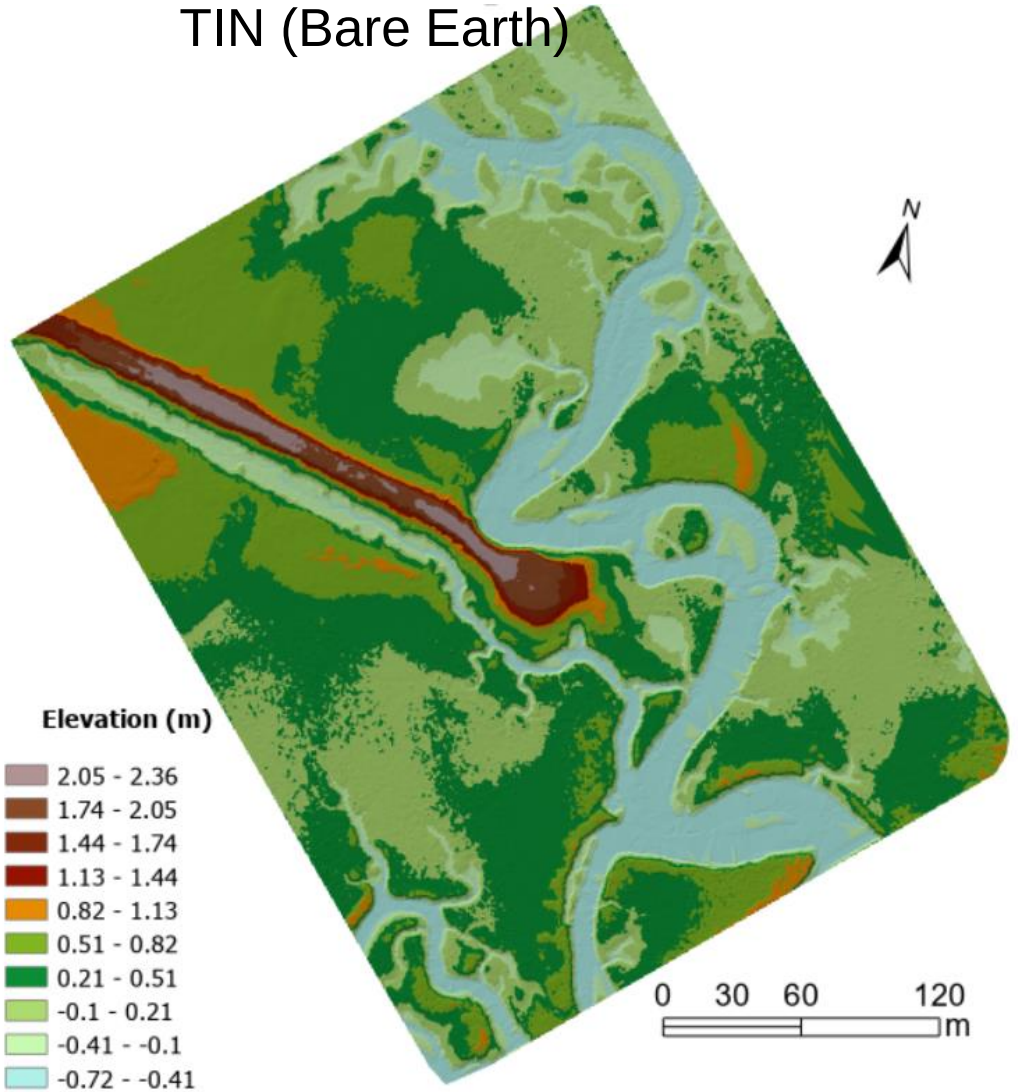


Oyster Landing

Ortho-image



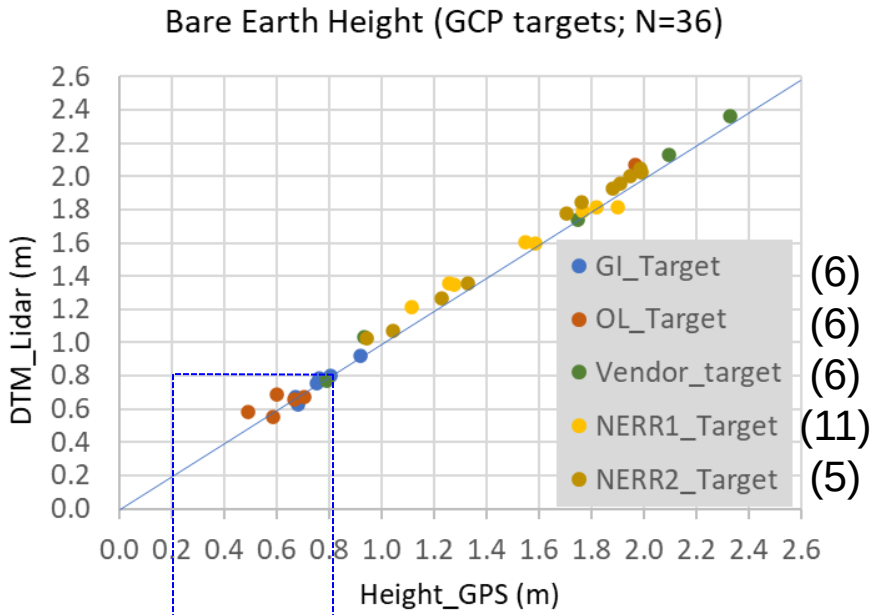
TIN (Bare Earth)

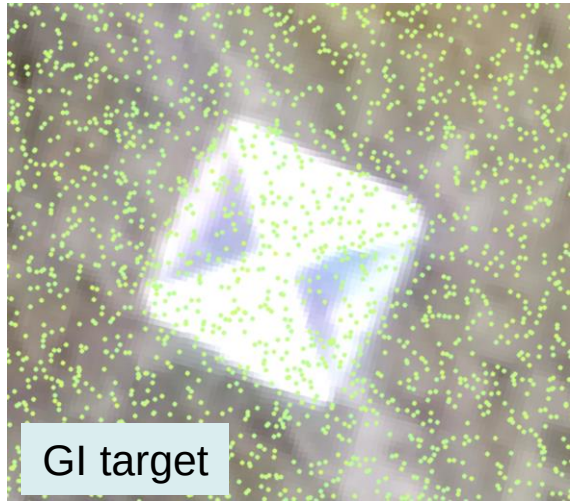


How good is drone Lidar on extracting Bare Earth surface (DTM)?

DTM
at Ground Control Targets (36)

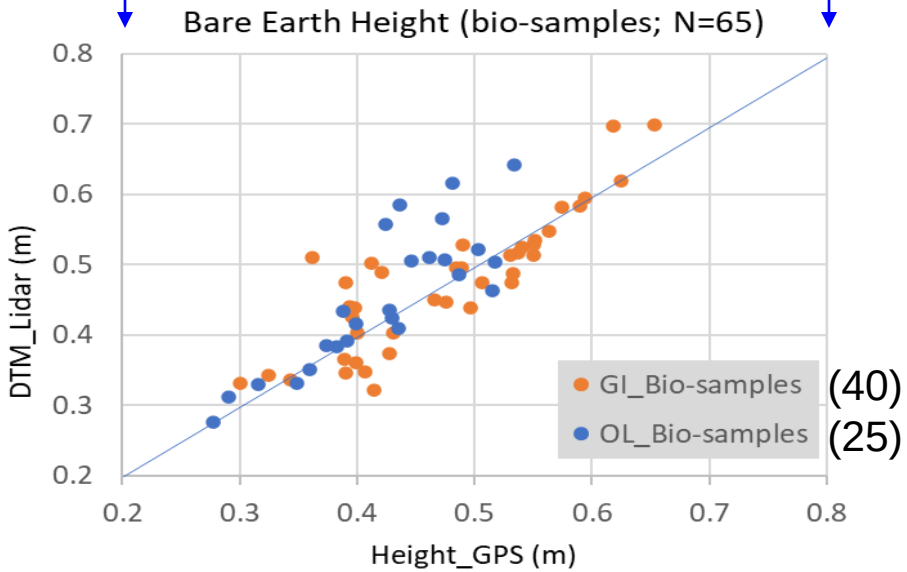
RMSE = 5.55 cm

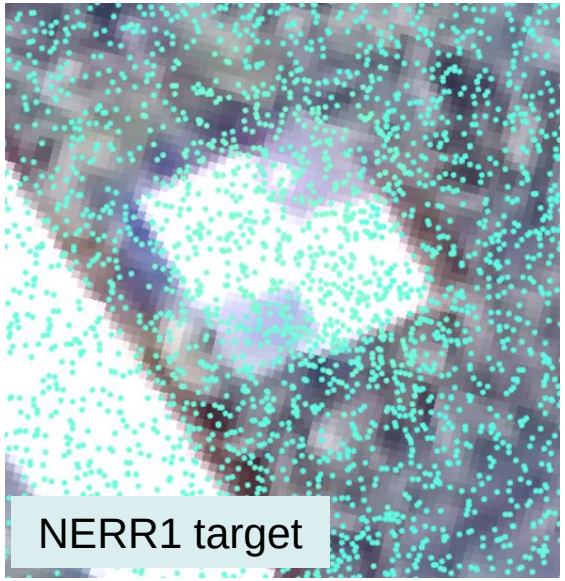




DTM
at Biomass samples (65)

RMSE = 5.33 cm





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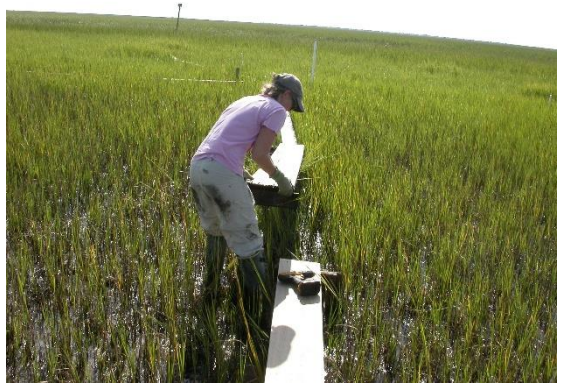
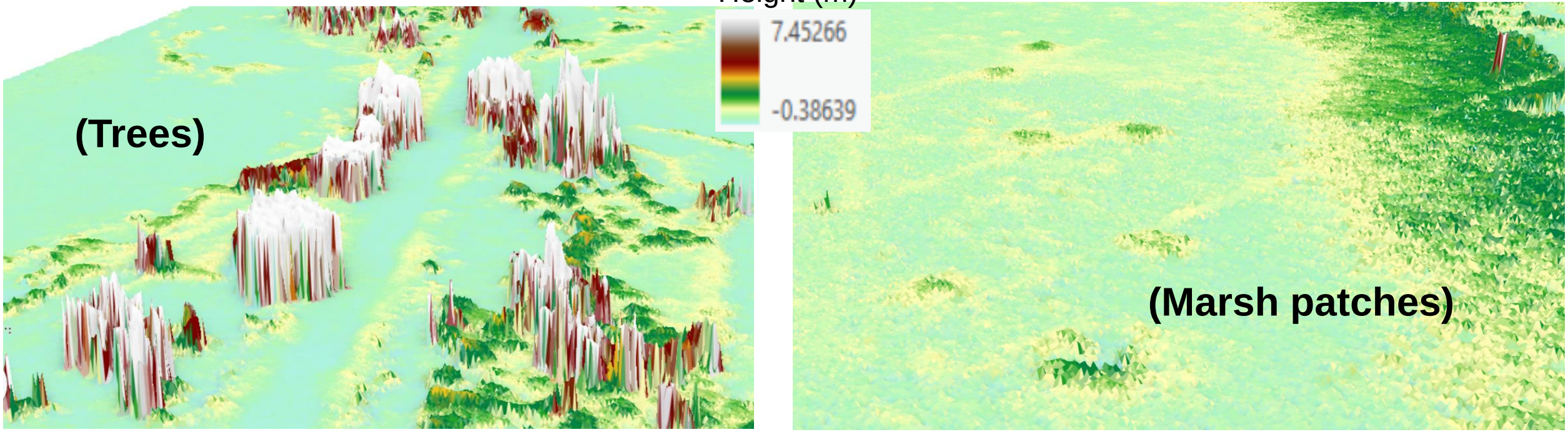
❑ 3D marsh modeling

Marsh canopy height:

H = DSM-DTM





(Goat island)

Marsh biomass model (preliminary)

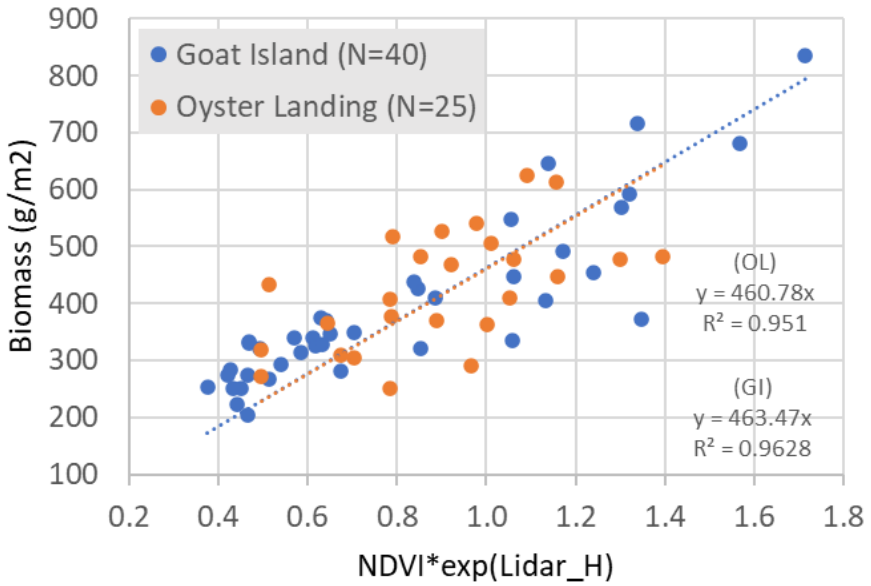
Model calibration (Goat Island, N=40):

$$\textbf{Marsh Biomass } (g/m^2) = 463.47 \times NDVI \times e^{H}$$

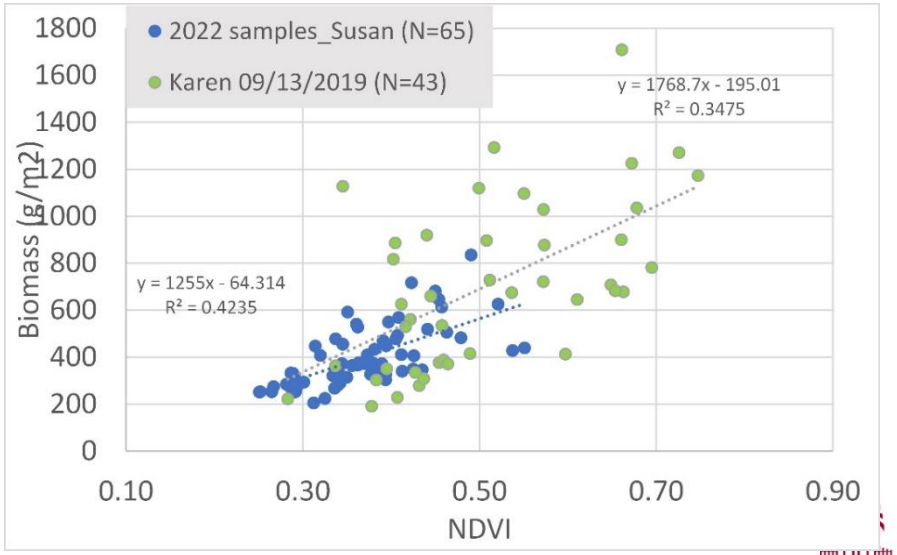
Model validation (Oyster Landing, N=25):

$$\textbf{RMSE} = 96.81\ g/m^2$$

Marsh biomass model with Lidar + multispectral camera



Recall what we got without Height information:



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❑ Drone Lidar for 3D marsh mapping: Pros & Cons

Pros

- Flexible, large-coverage data acquisition
- **5cm** vertical accuracy on DTM
- Much finer spacing than airborne Lidar
- Deep Learning: automated mass data analysis
- Broader applications along SC Coast

Cons

- Hardware/software maintenance
- Rapidly evolving systems
- Single returns in marshes
- Financial/operational/data analysis challenges
- Time commitment

Questions?

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