**Drones in the Coastal Zone (DITCZ)**
**Community of Practice (CoP)**

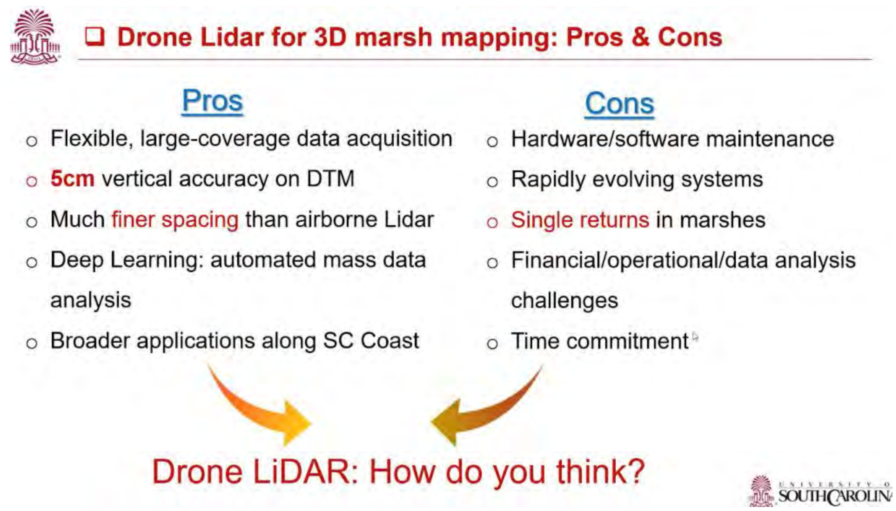
**Thursday, February 2, 2023 from 10:30am - 12:00pm**

**DITCZ Community of Practice Notes** – 63 people in attendance

- **Welcome and Introductions**
  - Stephanie and Whitney led an icebreaker: Are hot dogs a sandwich? After much debate, Steph settled it with the Merriam Webster definition: two or more slices of bread or a split roll having a filling in between 😊

- **Updates**
  - Student Competition
    - SECOORA will be sponsoring up to six candidates from the US Southeast and Caribbean region to attend three UAS executive education courses offered by the Nicholas School of the Environment at Duke University. Courses start October 2023. Below is a suggested timeline (subject to change).
      - Post RFP June 1, 2023
      - Submissions due June 30, 2023
      - Reviews July 5-30, 2023
      - Notify successful applicants by August 4, 2023
  - DITCZ Website
    - SECOORA is seeking volunteers to assist in drafting content for a DITCZ webpage. Please email abbey@secoora.org

- **Presentation:** Drone Lidar for Coastal Topography and 3D Marsh Mapping – Cuizhen (Susan) Wang, Department of Geography, University of South Carolina – **See Slides**
  - LiDAR measures height from laser beams and gathers individual points to produce 3D data. Airborne LiDAR is most common.
  - Challenges for coastal marshes using LiDAR: tidal effects, gentle topography, and short, sparse marsh plants. Produces profile data but it is too smooth.
  - Drone LiDAR flies at a lower height and is a cheaper system. Researching if it can be better for researching marsh fields. It is affordable, flexible, and mass points (denser point clouds).
  - Field experiment in August and September 2022 in North Inlet. Two LiDAR flights, four field plots, and 65 in field biomass samples. The Drone LiDAR collects more data.
  - Examples of high marsh and low marsh of Drone LiDAR vs USGS Lidar was showcased. Drone LiDAR was much denser and shows marsh field ecology.
  - PointCNN: deep learning for point cloud classification, Tested two classes: vegetation and ground. Training is time consuming (5+ hours). Once trained, takes half an hour to classify.
  - How good is drone LiDAR on extracting Bare Earth surface? Comparison showcased it is fairly accurate.
  - 3D Marsh modeling: overviewed how to derive average marsh canopy height (H = DSM - DTM)
  - Pros and Cons summary below:




- Q&A:
    - How high and fast? 5 meters per second and 300 ft (80 meters). Vendor assisted in comparing linear scan and XXX scan (??)
    - To derive DTM is that generated from the training set? Software (ArcGIS pro) picks up the ground points and removes all vegetation. PointCNN is on GitHub.
    - Susan stated do not need to train data for every application, can use the system that is already trained.

- **Presentation:** Integration of drone surveys as part of a SECOORA coastal flood monitoring network – Tiffany Troxler, Florida International University – **See Slides**
    - Approach to coastal flood observations is integration of citizen science collected samples, in situ water level measurements, drone surveys, and web camera monitoring to support flood adaptation decisions.
    - Location is primarily Miami-Dade County and kicked off with citizen science project. Proposal submitted to SECOORA included installing water level sensors and web cameras in different areas of coastal south Florida. Extend temporal and spatial resolution of observations at specific sites to improve flood products for that area.
    - Tiffany outlined issues related to urban planning and flood management.
    - Typical deliverables for drones in urban planning
        - 2D: orthomosaic, building footprints, seawall profile
        - 3D: digital surface models, digital terrain models, mesh
        - Features: building inventory improvement, infrastructure conditions, GIS databases
    - Digital models produced for flooding: photogrammy, 3D point clouds, etc.
    - Beach Monitoring with Photogrammetry and LiDAR: developing information for the target area of 400 acres. Six hours of flights and generated 15k photos to develop photogrammetry point clouds. Looking at change in beach elevation.
    - Monitoring flooded areas during king tides: Estimate flood extent using available LiDAR data along with arbitrary buffer areas. They delineated areas for drone surveys of flooded areas during king tides. They are determining and comparing estimated flood frequency and extent with outputs using improved temporal and spatial data resolution provided by high density LiDAR with drone surveys and webcam monitoring.

- Working to document and share the data via the SECOORA data portal.

- **Discussion items:**
  - Update on a basic look at the effect on rugosity of using Pix4D "Inverse Distance Weighting" vs. "Triangulation" for point cloud densification – Gary Sundin
    - Pix4D has a choice to create and interpolate spaces in a digital surface model using two different methods. Pix4D recommends Inverse Distance Weighting for building and triangulation for bare earth. Looking at oysters - flying drone at 100ft and 60 ft (typical height for mapping) and processed identically to create 3x3 meter plots to determine rugosity. Found 3D surface area using triangulation was greater 100% of the time. Triangulation appears to be the better Pix4D method of point cloud densification for showing surface detail of oyster reefs, especially for projects flown at low elevations.
  - Update on use of different types of ground control points (GCPs) – Brandon Puckett **See Slides**
    - Comparison of ground GCPs and raised GCPs that are both 1ftx1ft targets. Only raised GCPs can go in the water. DEM vertical model accuracy is good for both on land, but borderline useless in water (canopy overhangs decreased accuracy). Two approaches are analogous.
  - Does anyone have experience using the Google Earth engine for processing/analyzing drone imagery?
    - No one spoke up – If anyone comes across an expert with this technique, let Whitney Jenkins (whitney.jenkins@ncdenr.gov) know for a future meeting.

- **Next meeting topics:**
  - Rapid monitoring of Everglades buffer zones ecohydrological restoration – John Edward Sabin III, Doctoral Candidate, East Carolina University
  - Consultants or others outside our group to present to the CoP?
    - Stephanie: Coastal GeoTools conference coming up, will see if anyone attending would be appropriate for a future meeting
    - Erik Smith suggested Erik Harkin to give presentation on various applications of LiDAR
      - Eric Harkins, Founder & CEO, Back Forty Aerial Solutions
      - email: eric@backfortydrones.com
    - Melissa Cooke recommended Oceans Unmanned and has connections: https://oceansunmanned.org/
    - In a post meeting email, Clark Alexander suggested a presentation from CDM Smith on drone marsh mapping and biomass assessments at Fort Pulaski National Monument in Georgia:
      - Brendon Brown <BrownBV@cdmsmith.com>
      - Andrew C. Reicks reicksa@cdmsmith.com
  - Desire to hear about surface vehicles
  - Experiences and applications in use of underwater drones in coastal research and management. Email from Chris Taylor: our team has a growing arsenal of underwater drones/AUVs to support seafloor habitat mapping. We're still in the early stages in our work, but I can think more about candidates to speak to our CoP on this topic, if not someone from our habitat mapping team here in NCCOS.

# Drone Lidar for Coastal Topography and 3D Marsh Mapping

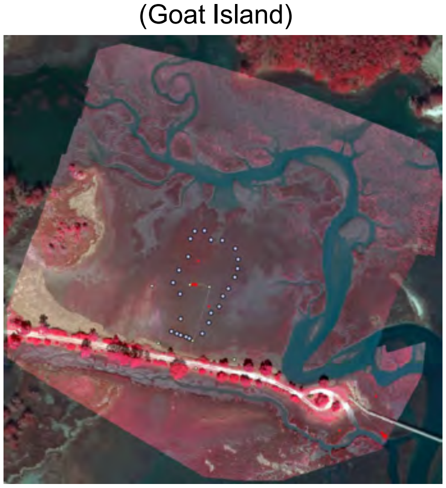
***Cuizhen (Susan) Wang***
*Professor, Department of Geography*
*University of South Carolina, Columbia, SC*

Q1 Meeting, Drones in the Coastal Zone Community of Practice (DITCA CoP), February 2, 2023

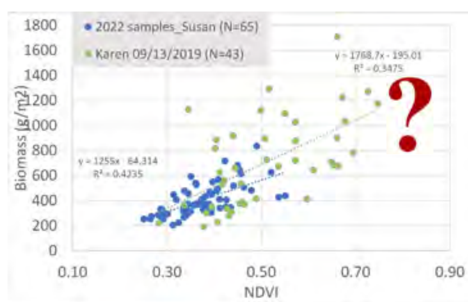
1

## 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)

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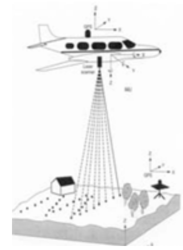
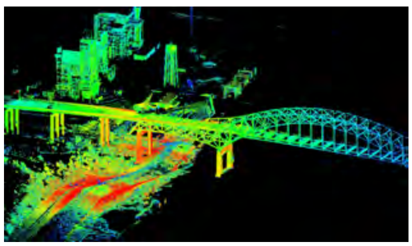
2

## LiDAR: a "non-imaging" technology to measure distance with multiple returns of laser beams.

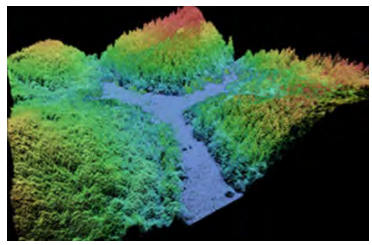
3D point cloud



*Successful stories in many fields…*



(GIS LOUNGE)



USGS Lidar Point Cloud (National Map 3DEP)

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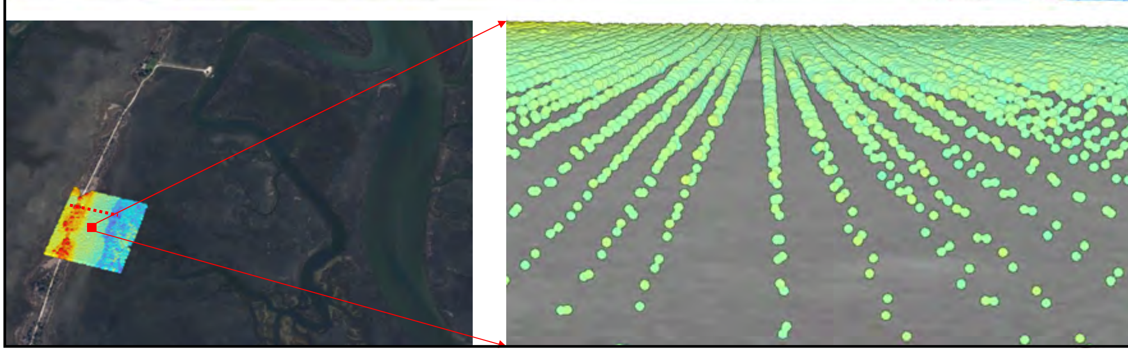
3

## Airborne Lidar in coastal marshes: not so fortunate...

*Challenges on Lidar classification:*

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

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



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4

## **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

+573/333#srlqw2v,

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

5

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

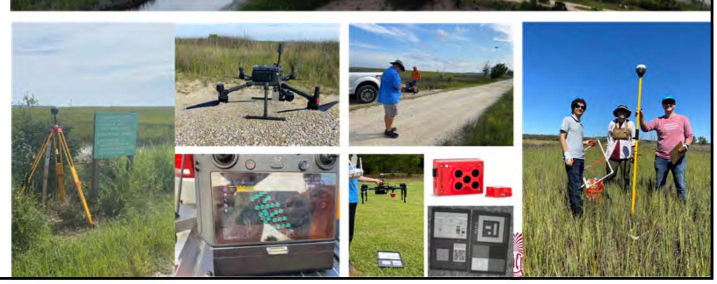
*(Baruch Marine Field Laboratory, USC)*

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

Vendor: Back Forty Aerial Solutions, Columbia, SC (*Eric Harkins*)

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

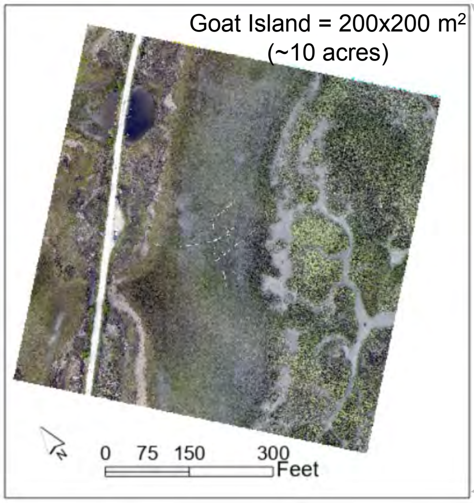
NASA EPSCOR Project team:
*Susan Wang,*
*Jim Morris,*
*Grayson Morgan,*
*Alex Fullham,*
*Naser Lessani*

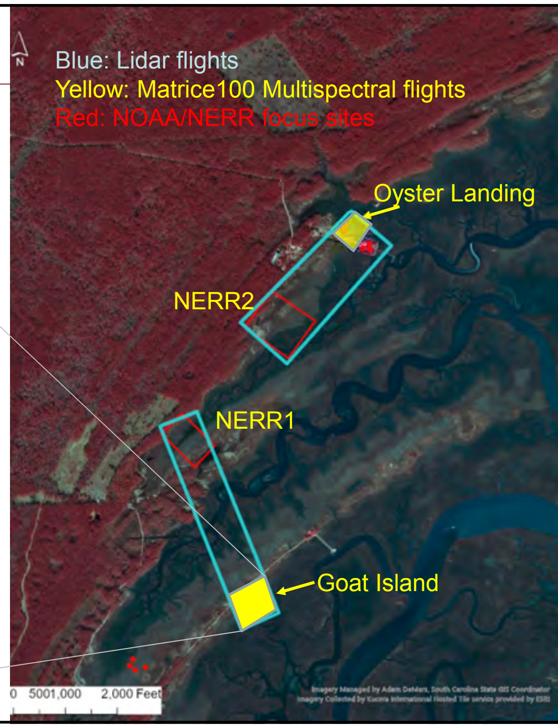


6

# Drone Lidar data footprint

## R2A/RGB ortho image



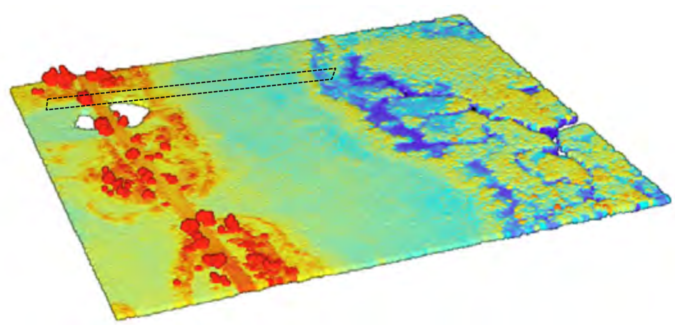



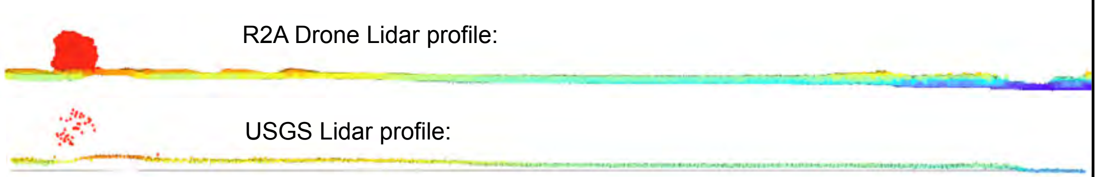

7

# 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 returns in marsh fields!





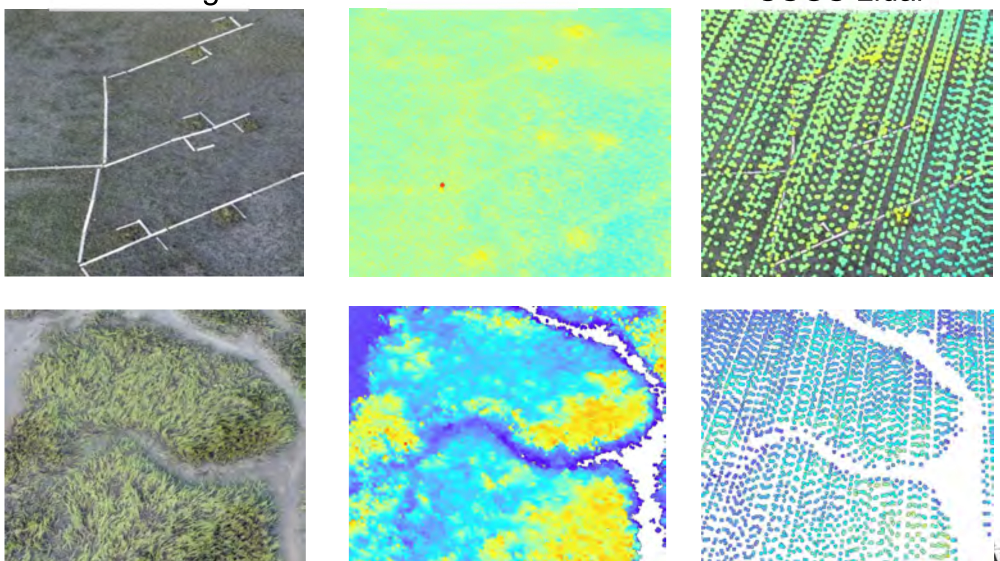

8

## Visual comparison: Drone Lidar vs. USGS Lidar

Ortho-image | Drone Lidar | USGS Lidar

High marsh

Low marsh

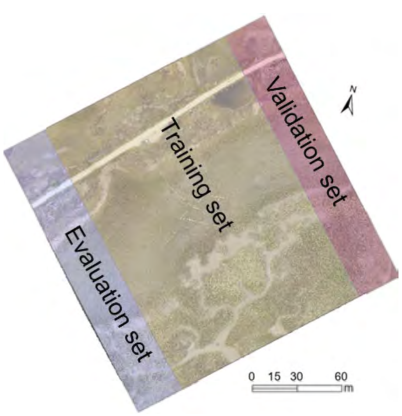




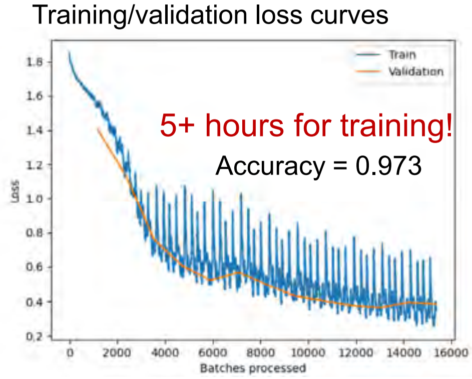
## ❑ PointCNN: Deep learning for point cloud classification

ArcGIS® Pro

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




Training/validation loss curves



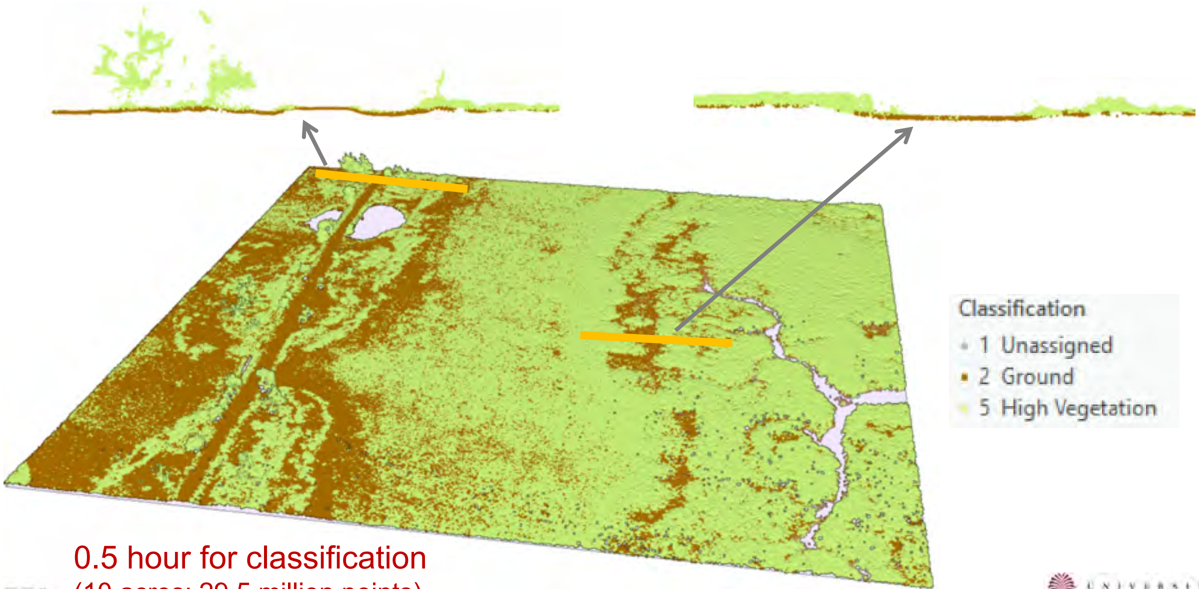

5+ hours for training!

Accuracy = 0.973

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)

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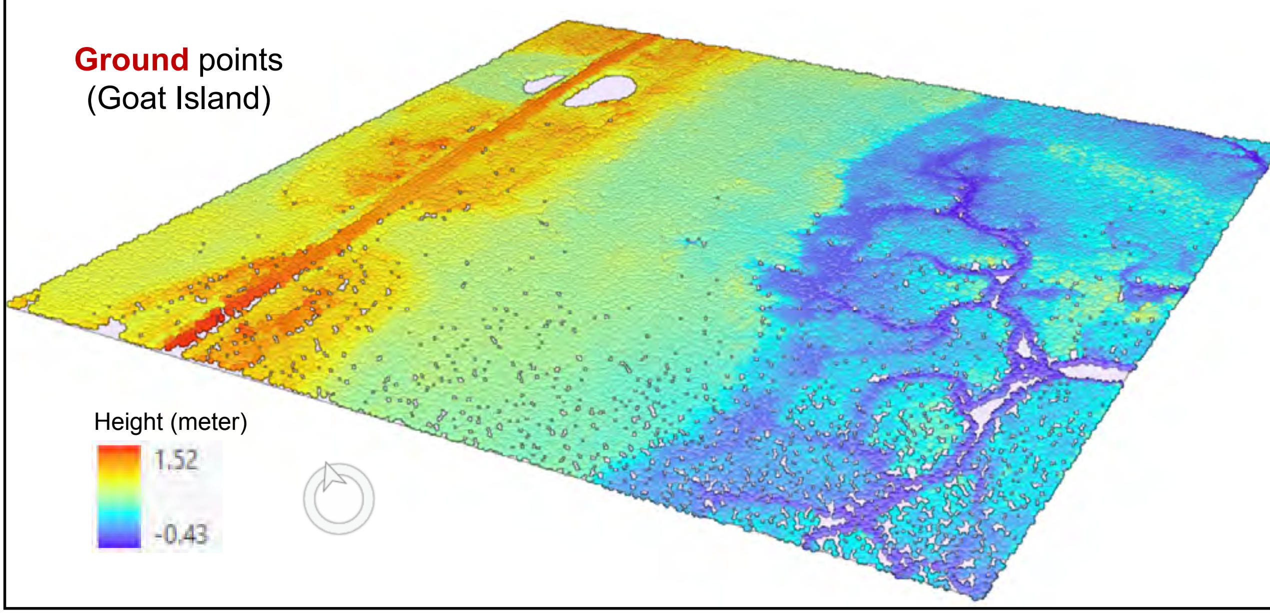
11

## Bare Earth Surfaces

**Ground** points
(Goat Island)



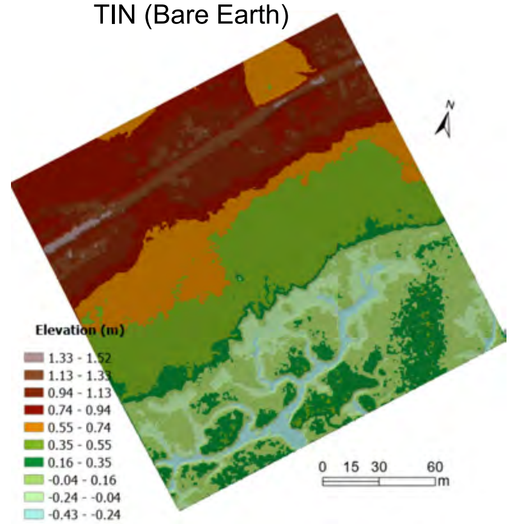

12

## ❑ Topography in marshes: bare Earth surfaces

Goat Island

Ortho-image


TIN (Bare Earth)

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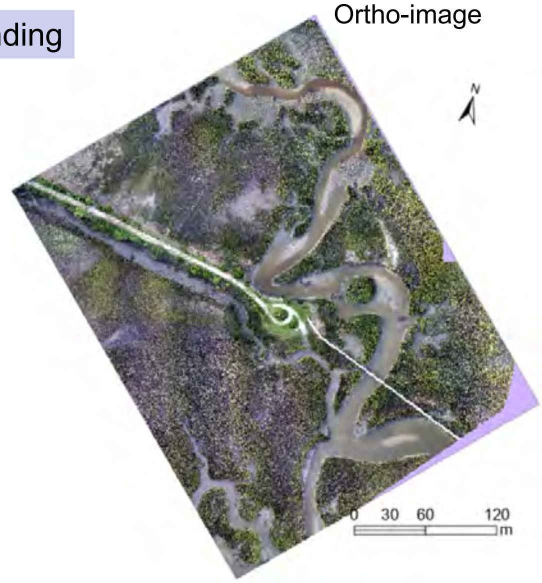
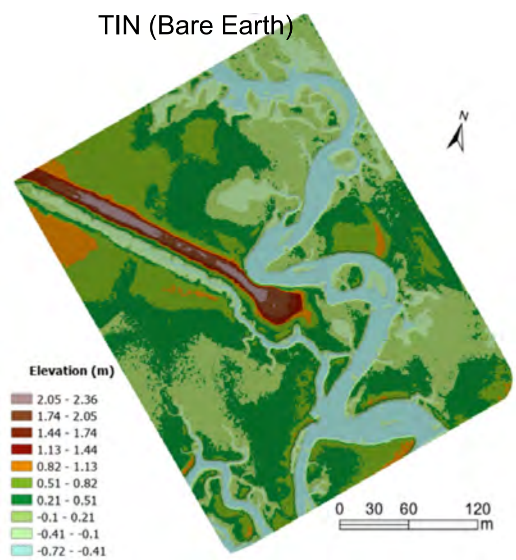
13

Oyster Landing

Ortho-image




TIN (Bare Earth)

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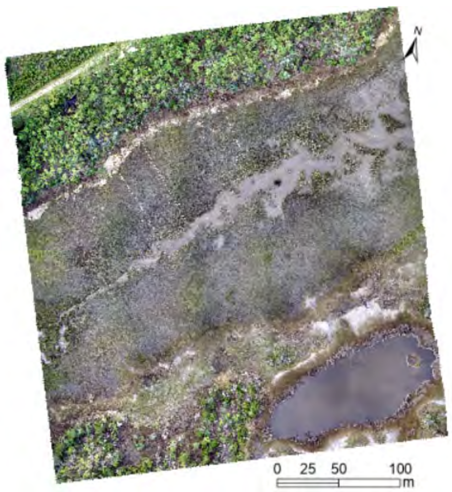
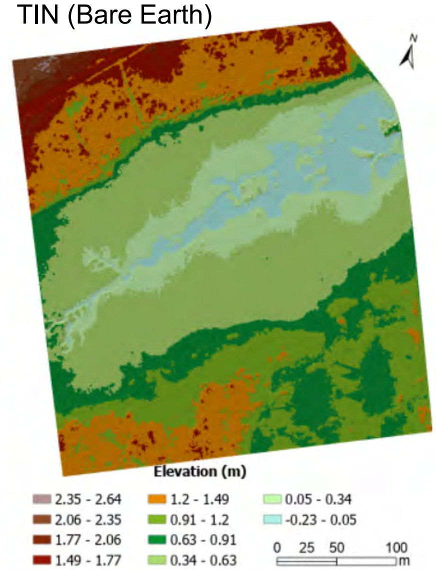
14

## NERR1

Ortho-image



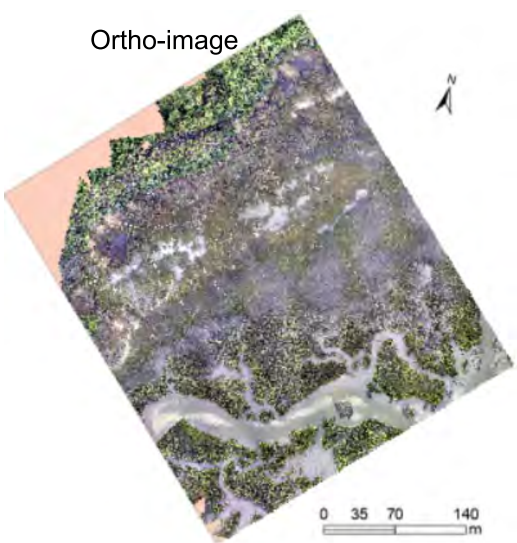

TIN (Bare Earth)



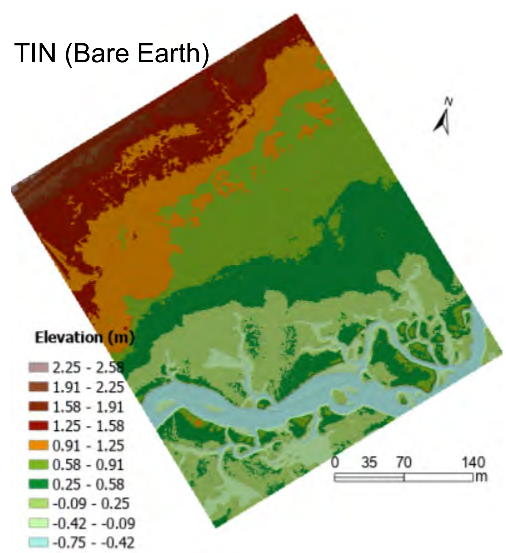

15

## NERR2

Ortho-image




TIN (Bare Earth)




16

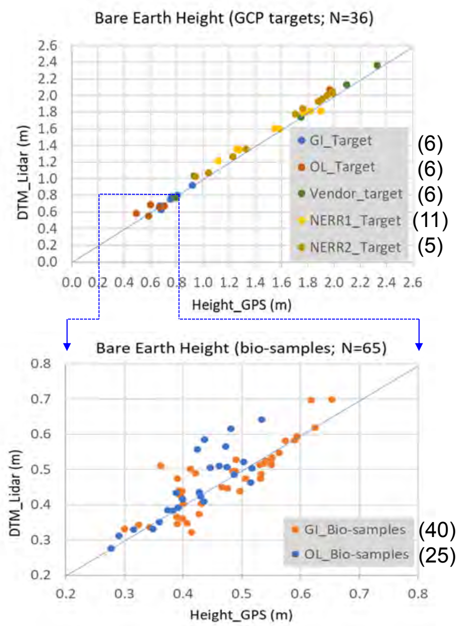
## How good is drone Lidar on extracting Bare Earth surface (DTM)?

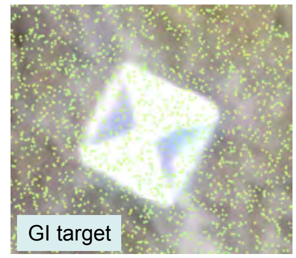
DTM
at Ground Control Targets (36)

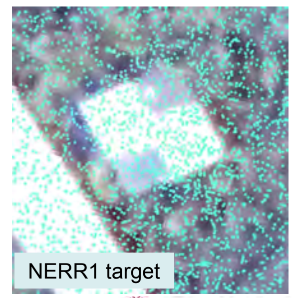
**RMSE = 5.55 cm**

DTM
at Biomass samples (65)

**RMSE = 5.33 cm**

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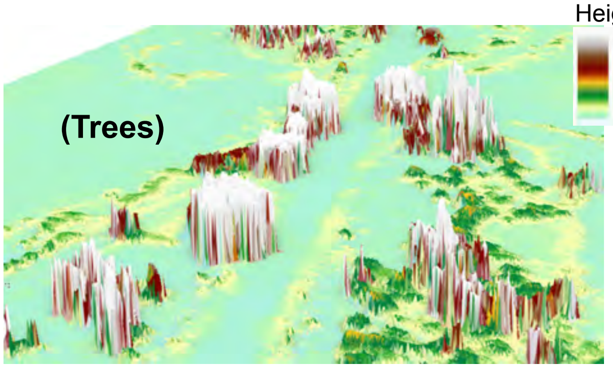
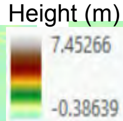
17

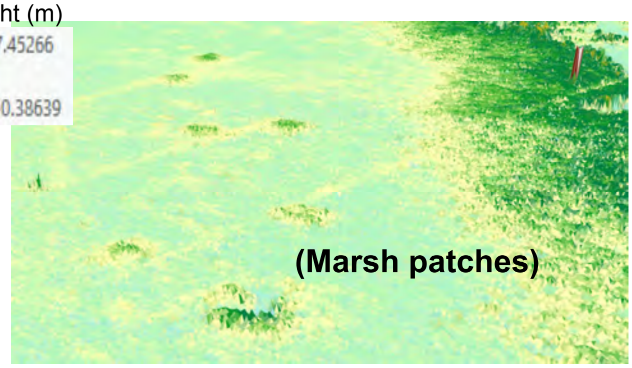
## ❑ 3D marsh modeling

Marsh canopy height:

**H = DSM-DTM**




(Goat island)

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18

## Marsh biomass model (preliminary)

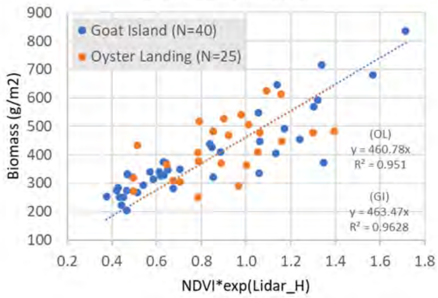
Model calibration (Goat Island, N=40):

**Marsh Biomass $(g/m^2)$=463.47×$NDVI$×$e^H$**

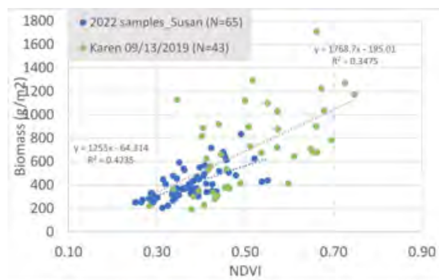
Model validation (Oyster Landing, N=25):

**RMSE = 96.81 $g/m^2$**

Marsh biomass model with Lidar + multispectral camera




Recall what we got without Height information:

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19

## ❑ 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

Drone LiDAR: How do you think?

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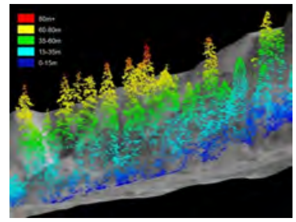
20

*Dreams not coming true beautifully… But something is there for sure.*

# Thanks!



Acknowledgement: This research is supported by **South Carolina NASA EPSCoR Program,** 2022-2023. The team appreciate the contribution of Dr. Grayson Morgan and two graduate students at UofSC, and technical/facility support of **Karen Sundberg** and the **Baruch Marine Field Laboratory** during the field experiments. The work could not be done without the generous support from **Eric Harkins** at **Back Forties Aerial Solutions**.

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21

# INTEGRATION OF DRONE SURVEYS AS PART OF A SECOORA COASTAL FLOOD MONITORING NETWORK

Tiffany G. Troxler, PhD, CFM, Florida International University /
Alexander Nunez, Digital E. Consulting

February 2, 2023 | Drones in the Coastal Zone Community of Practice Meeting

1

## Integrated coastal flood observation network for citizen engagement, enhanced data and flood adaptation decision support

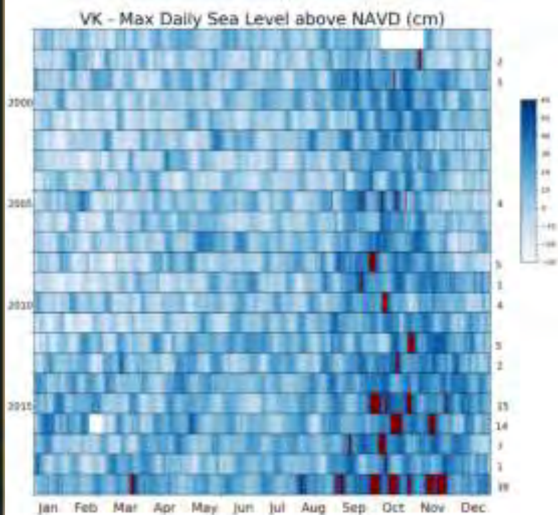
PROJECT TEAM: PI – Tiffany Troxler, Florida International University (FIU); Co-Is - Jayantha Obeysekera & Mike Sukop, FIU; Greg Dusek, NOAA; Amy Clement, University of Miami; Other collaborators – Carlos Genatios, Miami-Dade College; Alexander Nunez, Digital E Consulting

© Jürgen Freund

2

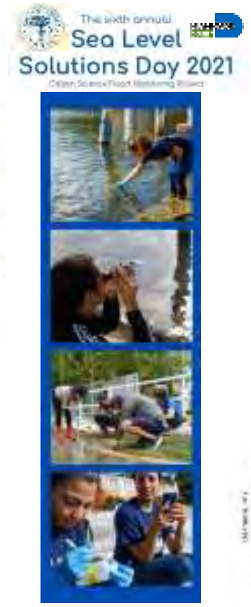
## Heightened awareness of sea level rise in Southeast Florida

FIU
Institute of Environment

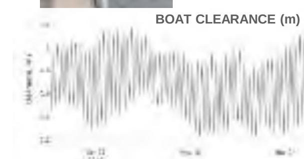



Frequency of tidal flooding in Miami Beach, based on Virginia Key NOAA tide gauge. Higher than normal tides shown as red bars. Number of events in a given year listed in the right margin (Wdowinski, 2019, *In Unified Sea Level Rise Projection Southeast Florida, 2019 Update)*

## New university-local government collaborations








3

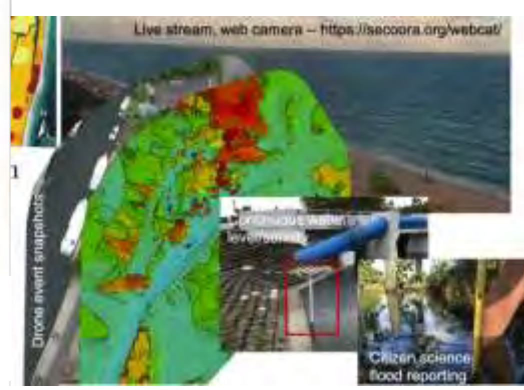
## Develop a multi-sensor network of integrated coastal flood observation sites

SECOORA


High tide flooding (in red, DigitalCoast, NOAA) and coastal flood observation sites (yellow stars)

Combines approaches of:

1) crowd-sourced, citizen flood measurements
2) in-situ measurements of depth, temperature and salinity
3) webcam video surveillance and
4) drone surveys




4

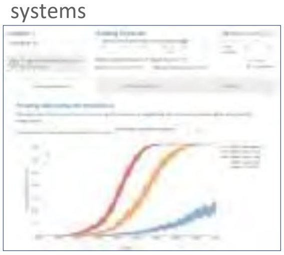
| **Table 1.** Parameters, collection methods, units of measurement and scales of observing assets | | | | | |
|---|---|---|---|---|---|
| **Observing Asset** | **Parameter/s** | **Collection Method/s** | **Unit** | **Spatial Scale** | **Temporal Scale** |
| *Crowd-sourced, citizen science* | Surface flood inundation depth | Meter stick and photos | Depth (cm); photo (image file) | $1m^2$ – $1km^2$ | Seasonal (high tide flood events) |
| | Surface flood water quality (salinity, total & dissolved nutrients and carbon, and fecal indicator bacteria (FIB) | Refractometer, photos, grab sample of water for TN, TP, NH4, N+N, SRP, DOC, and relative concentration E. coli/Enterococci) | Salinity (ppt); photo (image file); nutrients, carbon (mg/L); FIB (MPN) | $1m^2$ – $1km^2$ | Seasonal (high tide flood events) |
| *Drone* | Multispectral and point cloud data | UAV | Inundation extent (km2) and volume (acre-ft); NDVI (unitless, index value) | $1\text{-}5km^2$ | Seasonal (high tide flood events – flood and non-flood condition) |
| *Water Level/salinity gauge* | Surface flood level, subsurface depth, and subsurface salinity | Vented pressure transducer coupled with conductivity sensor | Pressure (psi); conductivity (uS) | $1\text{-}10m^2$ | Continuous, 15-min |
| *Web cam* | Surface flood extent | Mounted video camera | Video (video file) | $1\text{-}2km^2$ | Continuous, instantaneous |

5

## Promoting the translation of science and interdisciplinary knowledge for effective sea level rise adaptation

- Enhancing citizen engagement, awareness and agency

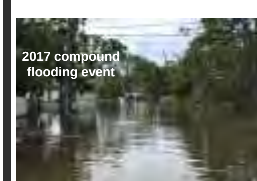

- Verifying and improving localized flood thresholds and recurrent flood metrics
- Supporting early warning systems



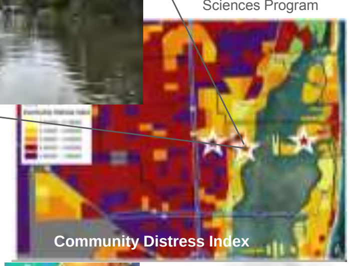
- Improving information about where, when and to what extent king tide flooding occurs, what the quality of the water is, and how it changes over time

- Strengthening and expanding local interdisciplinary and inter-institutional collaboration

- Supporting implementation of Greater Miami & Beaches Resilient305 Strategy
- Co-producing a Resilience Learning System to promote more effective, transparent, and inclusive community resilience outcomes




NOAA Adaptation Sciences Program




6

# 01.
# CHALLENGES FOR URBAN PLANNING AND FLOOD MANAGEMENT

### Urban planning
- Require multiple forms of high-quality data
- Flood risk are necessary to incorporate
- Certain types of publicly available datasets can be incomplete or outdated

### Flood management
- Require detailed understanding of flood risk
- Flood model simulations may incorporate low resolution, inadequate data – depending on form and access to sites – urban infrastructure really complicates flood modeling
- High quality data necessary for flood risk mapping and setting insurance rates

7

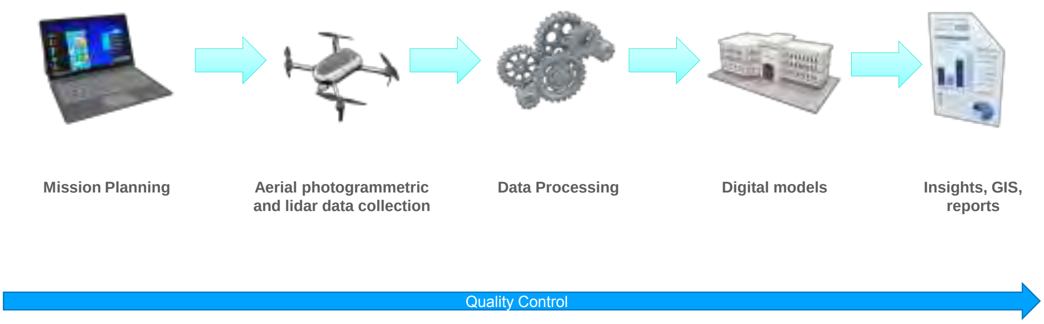
# 02.
# DRONES IN URBAN PLANNING AND FLOOD SIMULATIONS

### Typical deliverables

| 2D | 3D | Features |
|---|---|---|
| • Orthomosaic<br>• Building footprints<br>• Seawall profile | • Digital Surface Models<br>• Digital Terrain Models<br>• Mesh | • Building inventory improvement<br>• Infrastructure's conditions<br>• GIS databases |

8

## 02.1
## DRONES IN URBAN PLANNING AND FLOOD SIMULATIONS




9

## 03.
## DIGITAL MODELS

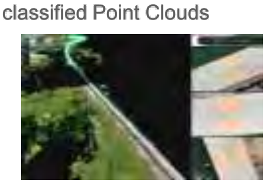

Photogrammetry Point Clouds


Digital Surface Models

Lidar classified Point Clouds


2D high-res georeferenced maps


Building footprints


Seawall profiles

10

# 04.

# CASE STUDY - BEACH MONITORING WITH PHOTOGRAMMETRY AND LIDAR

### North Beach – Miami Beach

Small Unmanned Aircraft Systems (sUAS) were used to collect visual and geographic data for topographic reconstruction using photogrammetric techniques and Lidar, flying under FAA rule 14 CFR part 107. Ground Control Points (GCP) were laid in the target area and their GPS coordinates were recorded. Finally, the data was processed, and GIS deliverables were prepared.

In red, photogrammetry area. In yellow, Lidar area.

Target area was 410 acres.

Census Tracts: 12086003909, 12086003911, 12086003913

11

# 04.1

# CASE STUDY - BEACH MONITORING WITH PHOTOGRAMMETRY

### Operational Plan

- Maximum sUAV flight altitude was 380 ft AGL (RTH) .
- sUAV flight path always remained within the delimited area.
- The flights took place in solely Visual Flight Rules (VFR) conditions and conducted in Visual Meteorological Conditions (VMC).

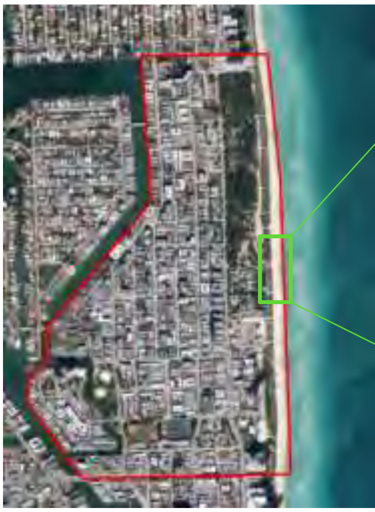
Photogrammetry (DJI P1)

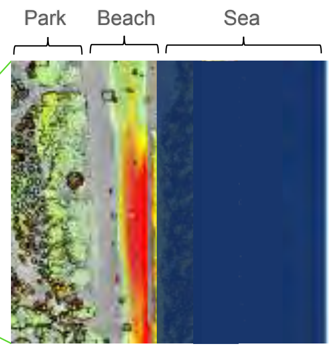
| ID | Time (min) | NADIR and oblique Photos |
|---|---|---|
| A | 72 | 3435 |
| B | 60 | 2375 |
| C | 47 | 1938 |
| D | 42 | 1789 |
| E | 72 | 3121 |
| F | 54 | 2481 |
| **Total** | **6h** | **15139** |


12

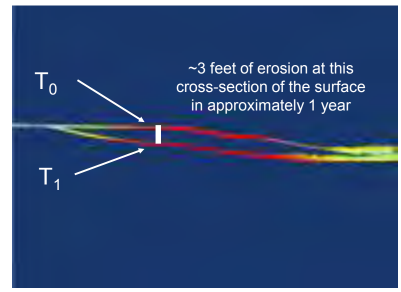
# 04.2

## CASE STUDY - BEACH MONITORING WITH LIDAR (RECURRING FLIGHTS)






Change detection in volume




Cross-section of the surfaces

13

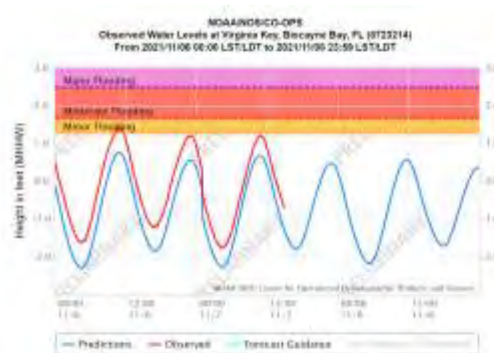
# 05.

## CASE STUDY – MONITORING FLOODED AREAS DURING KING TIDES

**Objectives**

In areas experiencing periodic high tide flooding,

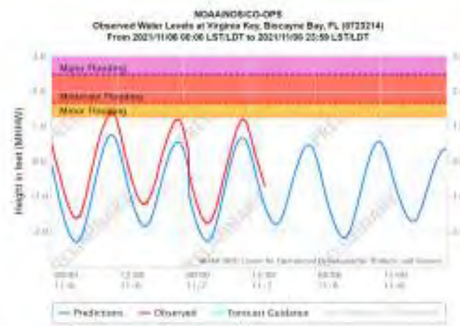
- Establish continuous flood monitoring stations
- Continue citizen science flood observations during king tides
- Estimate flood extent using available LiDAR data along with arbitrary buffer areas
- Delineate areas for drone surveys of flooded areas during king tides
- Establish web cam monitoring at a subset of sites
- Determine and compare estimated flood frequency and extent with outputs using improved temporal and spatial data resolution provided by high density LiDAR with drone surveys and webcam monitoring
- Identify where adaptation actions have been implemented
- Verify impacts of interventions




14

# 05.1

## CASE STUDY – MONITORING FLOODED AREAS DURING KING TIDES



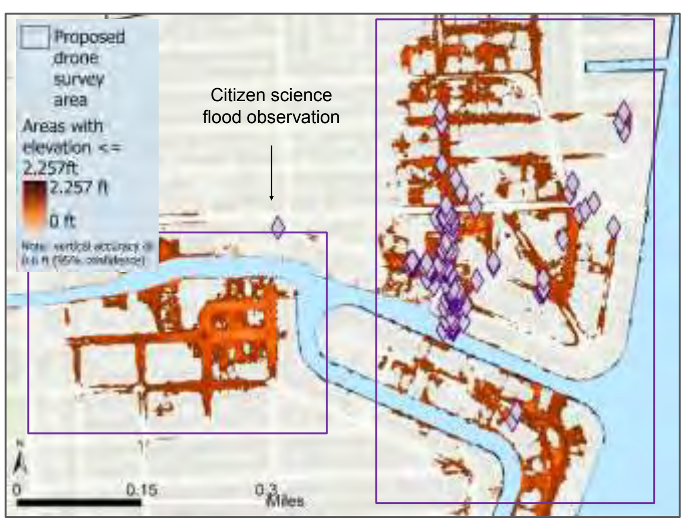


Aerial surveys

15

# 05.2

## CASE STUDY - MONITORING FLOODED AREAS DURING KING TIDES

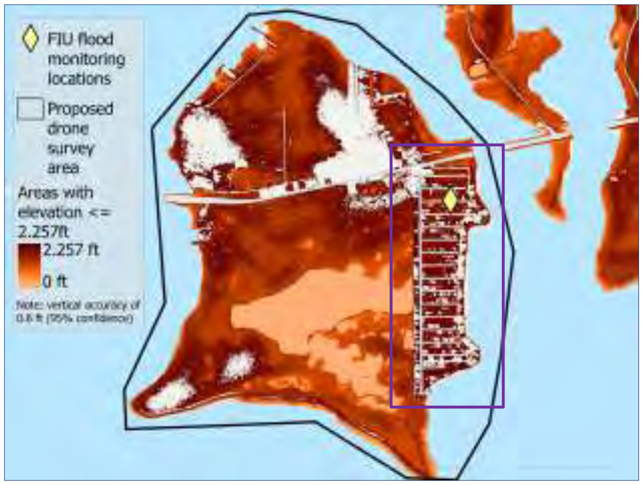



Little River East

16

05.2

## CASE STUDY - MONITORING FLOODED AREAS DURING KING TIDES




**Ramrod Key**

17

06.

## SOME NEXT STEPS FOR DRONE MONITORING

- Begin surveys this Spring at a subset of sites
- Develop some initial estimates to assess preliminary results
- Work with team to document and share data
- Refine locations and boundaries for next set of surveys

18

Thank you!

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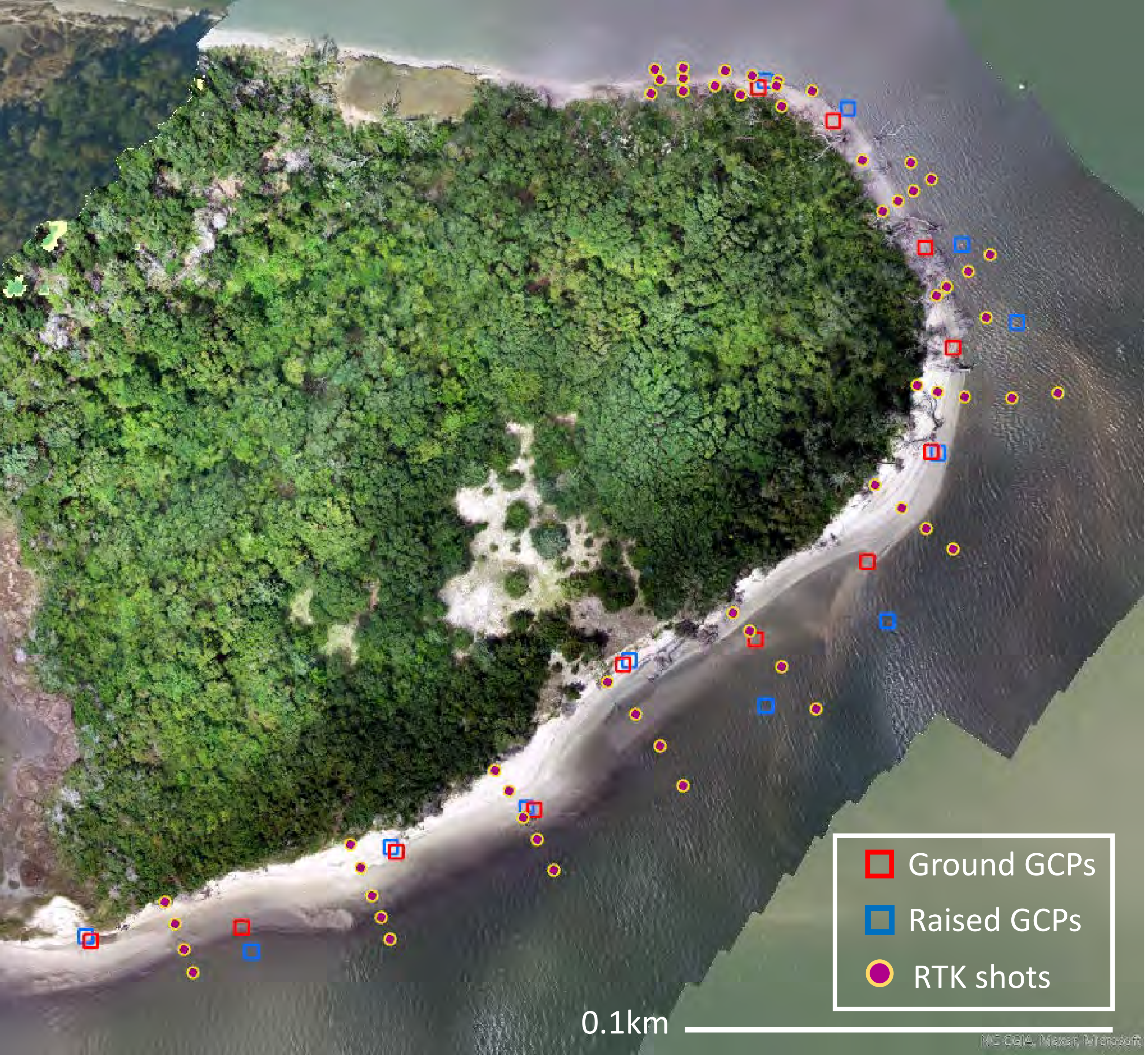
19

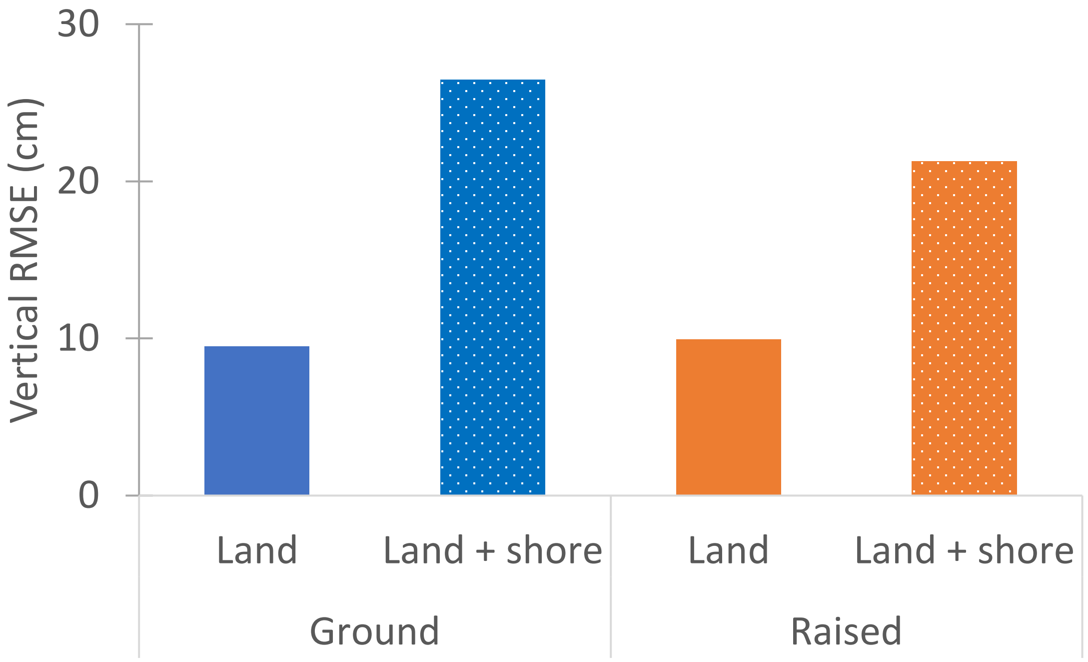
# Comparing model accuracy using ground vs raised GCPs

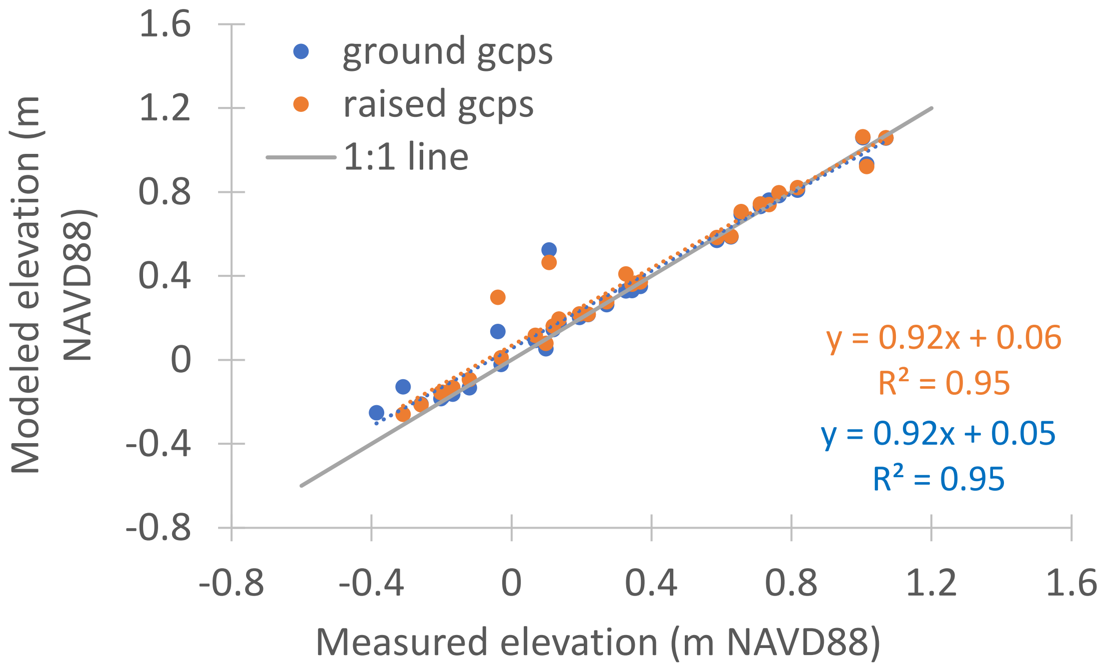
Brandon Puckett and Ryan Giannelli
NOAA National Centers for Coastal Ocean Science




- Location: Coastal NC, Rachel Carson NERR
- DJI Phantom 4 Pro
- 50m altitude (GSD = 1.29cm/px)
- 12 ground GCPs (1’ x 1’ targets)
- 12 raised GCPs (1’ x 1’ targets)
- 56 RTK ground points

# DEM vertical model accuracy



# DEM vertical model accuracy