LONE STAR UAS
CENTER OF EXCELLENCE & INNOVATION

Bringing UAS to America's Skies

Activities at Lone Star UAS Test Site and TAMUCC

An update
Scientific Committee for Oceanographic Aircraft Research
October 4, 2022

Presenter:
Michael J. Starek
Associate Professor
Texas A&M University-Corpus Christi (TAMUCC)

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MANTIS

TEXAS A&M ENGINEERING

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FAA Test Site: >4,400 flights and 250+ customers (to date)

Update information provided by Tye Payne

Assistant Director of Operations, Test, & Evaluation

LSUASC

DJI Phantom w/ Modifications

- Flights have been conducted to support an NSF grant to a Marine Life Sciences Professor at TAMUCC
- Flights were to monitor bottlenose dolphin populations in and around the Corpus Christi, Aransas Pass, and Port Aransas
- DJI Phantom was modified to include a laser altimeter to assist with measurements of animals
  – Based off a research paper, the logger was built in-house at LSUASC

*Due to national permit restrictions, no pictures from the actual flights are allowed.

Large UAS BVLOS Testing

- In 2022, LSUASC completed a 2.5 year project focused on large UAS flying BVLOS
- Flight campaigns in 2021 & 2022
  - Large UAS flew over 45 flights and had over 17 hours of flight time in conjunction with an optionally-piloted aircraft (OPA) over the Texas Inter-Coastal Waterway

Photos courtesy TAMUCC MARCOM

sUAS Disaster Response

- LSUASC received funding from the State of Texas to develop prototype disaster response packages
- Conducted multiple exercises both internally and in conjunction with local first response agencies in August & September 2022
- LSUASC is continuing to build our disaster response capabilities through 2023

Moving Forward in 2023

- Flight campaigns and research have increased steadily since 2020-2021
- Moving into 2023, research focus remains high in the following areas:
  - BVLOS Operations
  - Large UAS Operations
  - Mission/Control Dispatch Centers
  - Traffic Management
  - Disaster Operations

UAS Activities at TAMUCC

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Project: Simulation and Field Validation of UAS-SfM Accuracy Based on Different GNSS Solutions for Shoreline Mapping

Research Team (NOAA OCS): LCDR Damian Manda, John Doroba

Research Team (TAMUCC): Michael Starek, Jose Congo, Jacob Berryhill

Research Team (OSU): Christopher Parrish, Chase Simpson, Richard Slocum

Coast Survey

Collaboration Goals

Why UAS-SfM?

- Improve safety & efficiency, especially in hazardous or remote areas
- Satisfy feature positioning requirements (< 0.5 m vertical uncertainty at 95%)

Eliminate GCPs and "boots on the ground" for UAS-SfM surveys of shorelines

Investigate GNSS positioning correction methods and vertical uncertainty
field experiments and simulation

esri

Develop processing workflows compatible with software available to NOAA

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Research Objective: evaluate GNSS solutions and SfM software workflows

Oregon State University

Research Objective: test and simulate GNSS uncertainty on SfM accuracy

NOAA

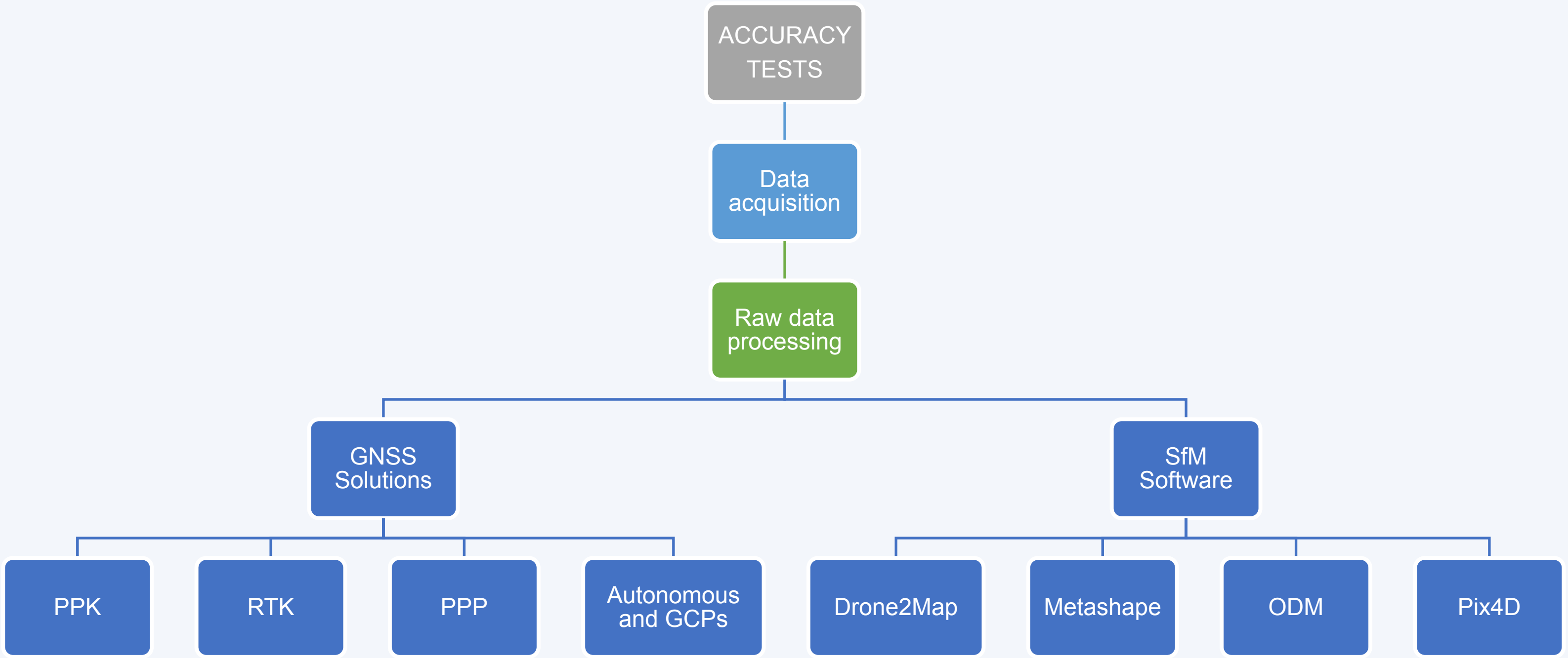
TAMUCC Contributions

Evaluation of GNSS Solutions

- Post-Processed Kinematic (PPK)
  - Baseline distance, sampling rate
- Real-Time Kinematic (RTK)
- Precise Point Positioning (PPP)
- Quantitative comparison (TS/RTK/TLS)

Evaluation of SfM Processing

- Pix4D, Metashape, ESRI Drone2Map, Web OpenDroneMap (ODM)
- Assess vertical accuracy
- Assess quality of derivative products
- Processing report accuracy vs LAStools



General workflow used for this study

- ArcGIS Pro (v2.9.0)
- CSRS-PPP (v3.0)
- Docker (v4.3.0)
- Drone2Map (v2.3.2)
- GIT (v2.9.0)
- Inertial Explorer (v8.80)
- LAStools
- Metashape (v1.7.2)
- Pix4Dmapper (v4.6.4)
- Python (v3.8)
- REDtoolbox (v2.82)
- WebODM (1.9.11)
- WingtraHub (v2.2.0)

GNSS | **Both** | **SfM Software**

Study Sites

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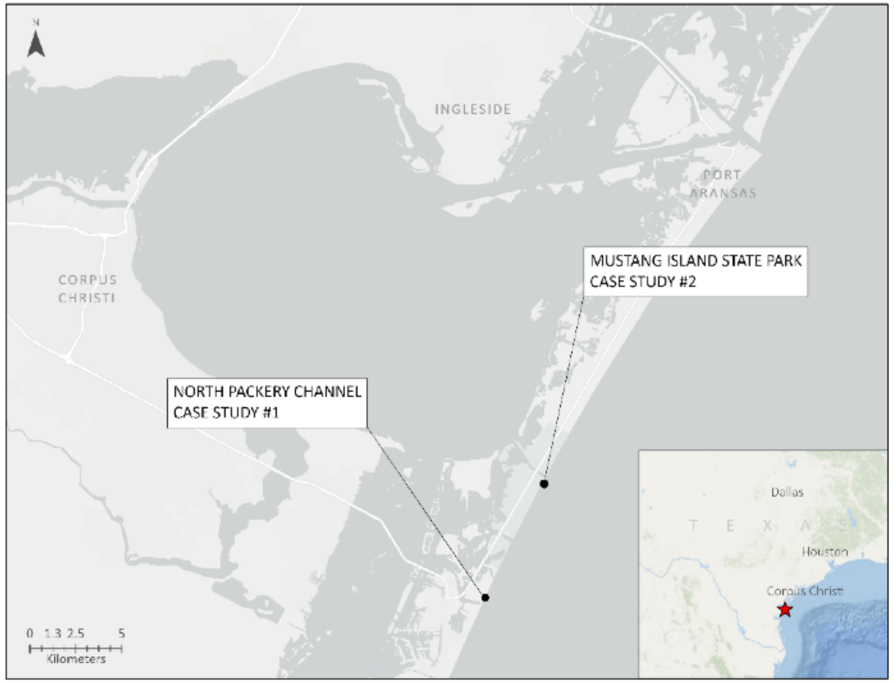
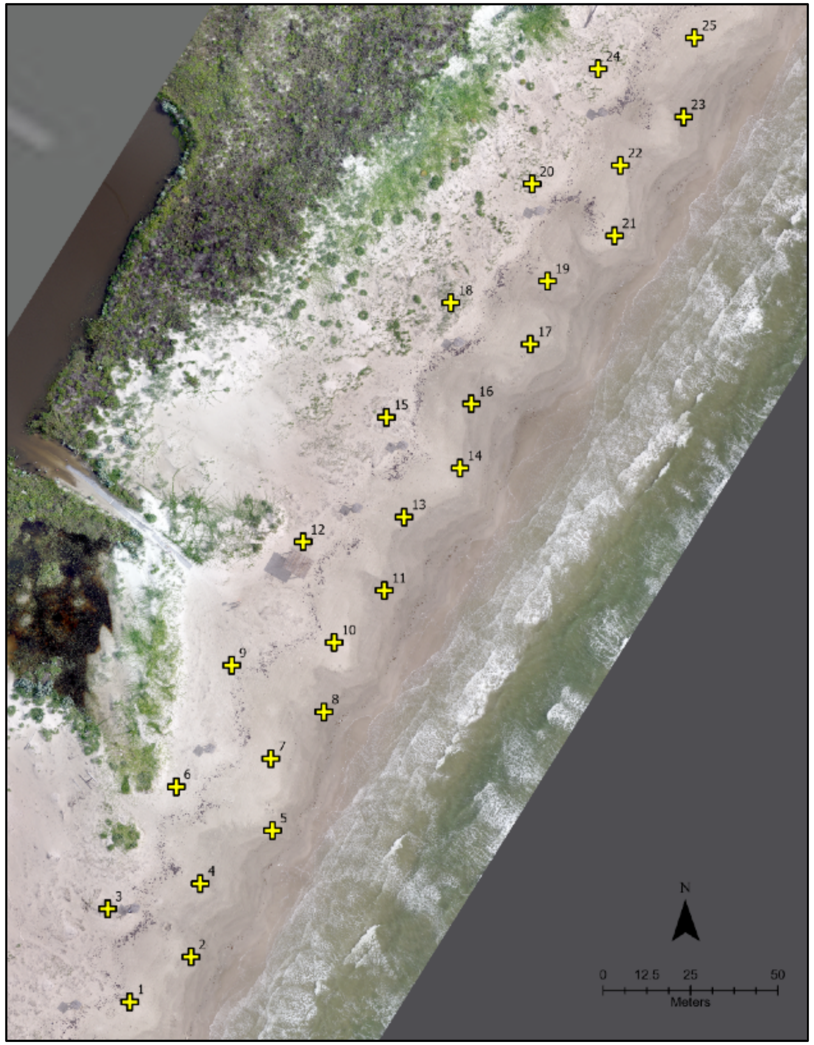


NPC Study Site
- ➢ JP Luby beach
- ➢ Sep/04/2020
- ➢ Area: 1 km²
- ➢ # of GCPs: 7
- ➢ Spacing: 500 m

MISP Study Site
- ➢ Pedestrian beach
- ➢ Jul/13/2021
- ➢ Area: 0.05 km²
- ➢ # of GCPs: 25
- ➢ Spacing: 20 m

North Packery Channel (NPC)

SfM software evaluation only



Mustang Island State Park (MISP)

GNSS & SfM software evaluation

UAS Flights
MISP Study Site

WingtraOne PPK UAS

WingtraOne PPK UAS (VTOL)	MISP flight 1 (lower altitude)	MISP flight 2 (higher altitude)
Altitude AGL	75 m	120 m
GSD	1 cm/px	1.6 cm/px
Sensor	Sony RX1 RII (42MP)	Sony RX1 RII (42MP)
# of photos	271	120
Design	Side/endlap: 80/70	Side/endlap: 80/70

DJI Phantom 4 RTK UAS

Phantom 4 RTK UAS (Quad)	MISP flight 1 (RTK mode)	MISP flight 2 (PPK mode)
Altitude AGL	59 m	59 m
GSD	1.6 cm/px	1.6 cm/px
Sensor	FC6310R, CMOS, global shutter (20 MP)	FC6310R, CMOS, global shutter (20 MP)
# of photos	610	610
Design	Double grid	Double grid

Single WingtraOne UAS flight conducted at NPC (100 m AGL, 1.30 cm/px GSD)

MISP Ground Survey

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Ground control equipment (MISP)

GNSS local base for PPK

- 6 hours of static
- Good Dilution of Precision

Control survey (25 targets)

- RTK GNSS (10s average, TxDOT RTN)
- Leica Robotic TS (2 stations, LSQ adjusted)

Terrestrial Laser Scanner (TLS)

- Riegl VZ-2000i (1200 kHz)
- 3 scan positions (create DSM)

Beach profiles (RTK GNSS)

- 4 transects (~ 100 m intervals, ~ 5 m shots)

Control in NAD83 (2011) TX-S

Establishing static setup for local base at MISP

GNSS Evaluation Results
Baseline Distance & Sample Rate on PPK

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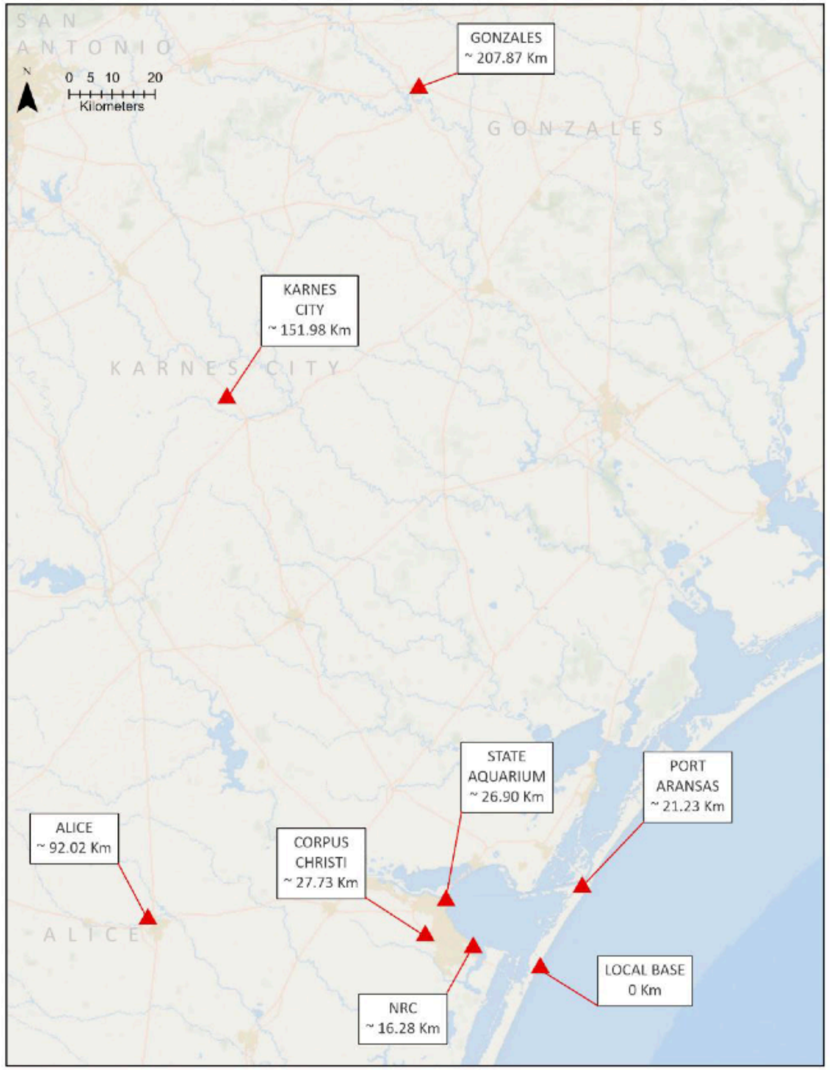
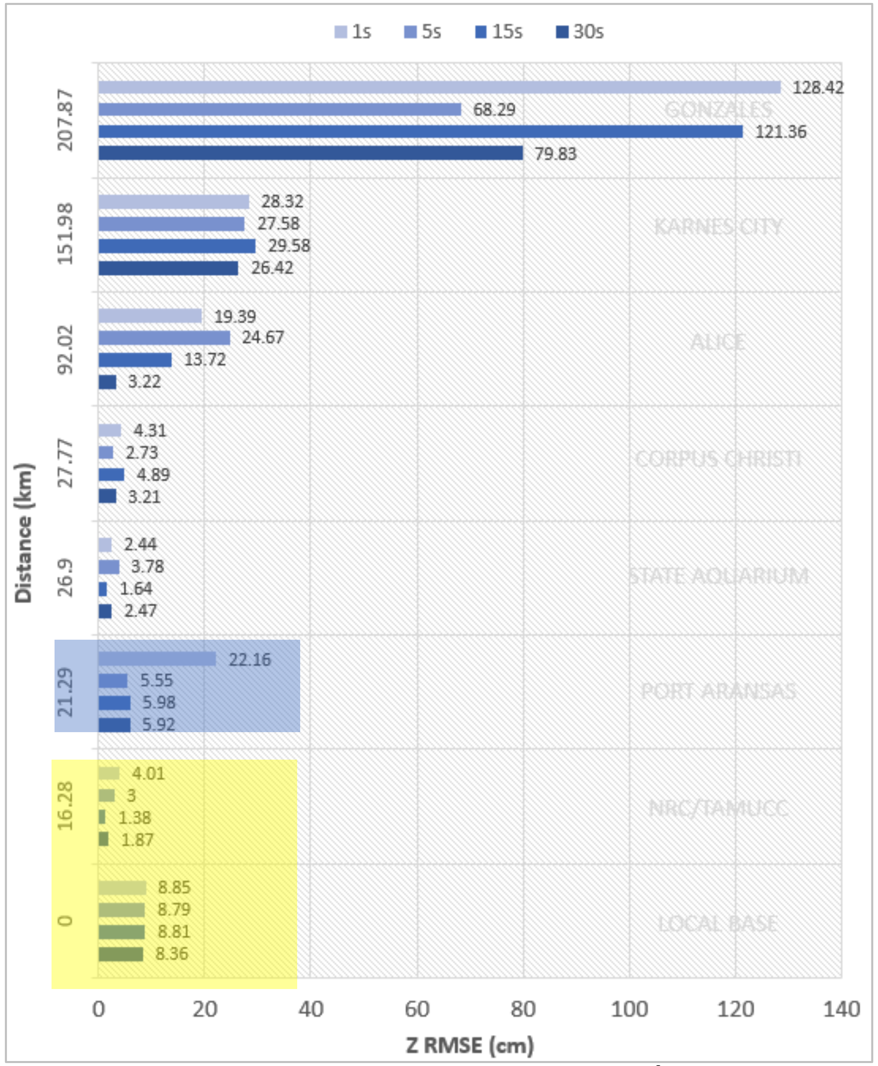


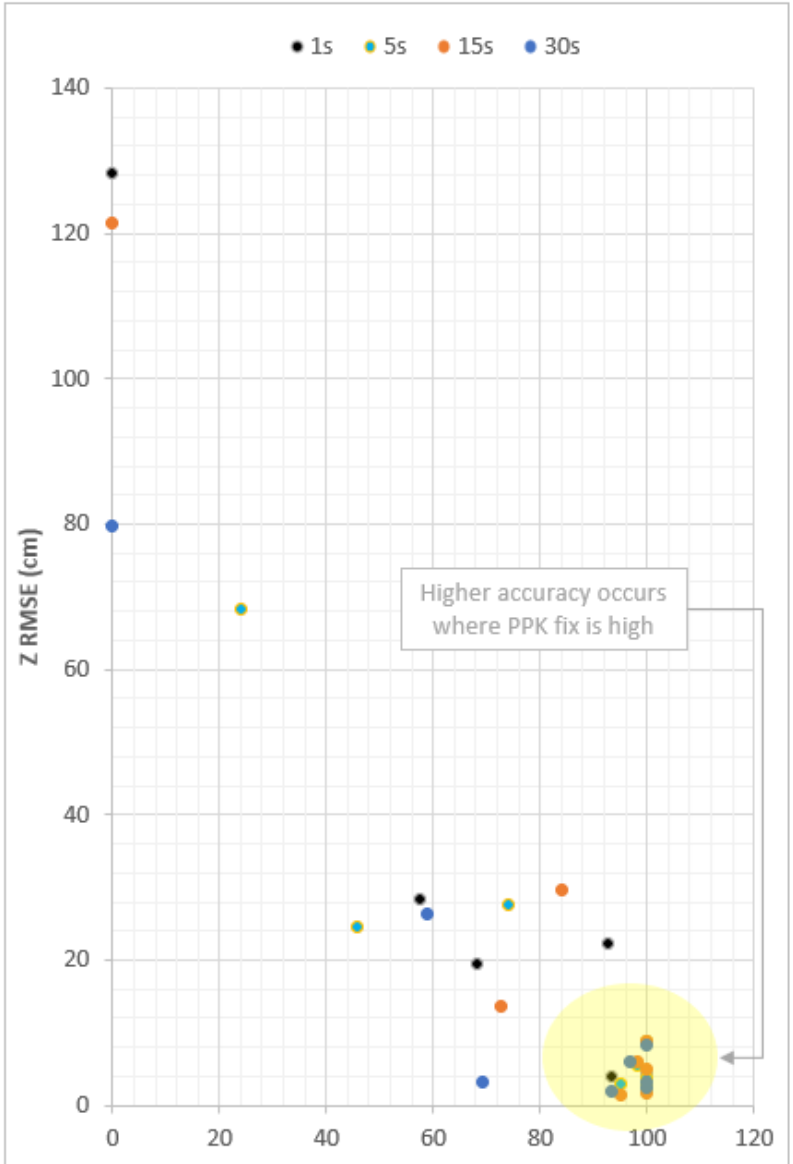
Map of Remote Base Stations



RMSE vs Distance & Sample Rate

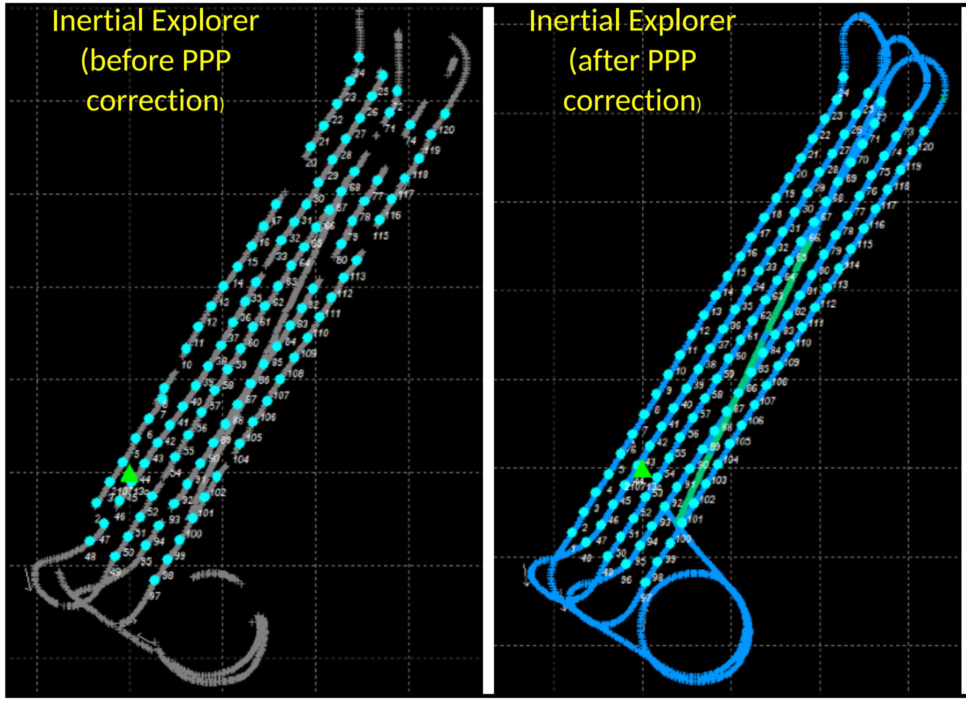
(WingtraOne, high altitude, Pix4D report, TS control)

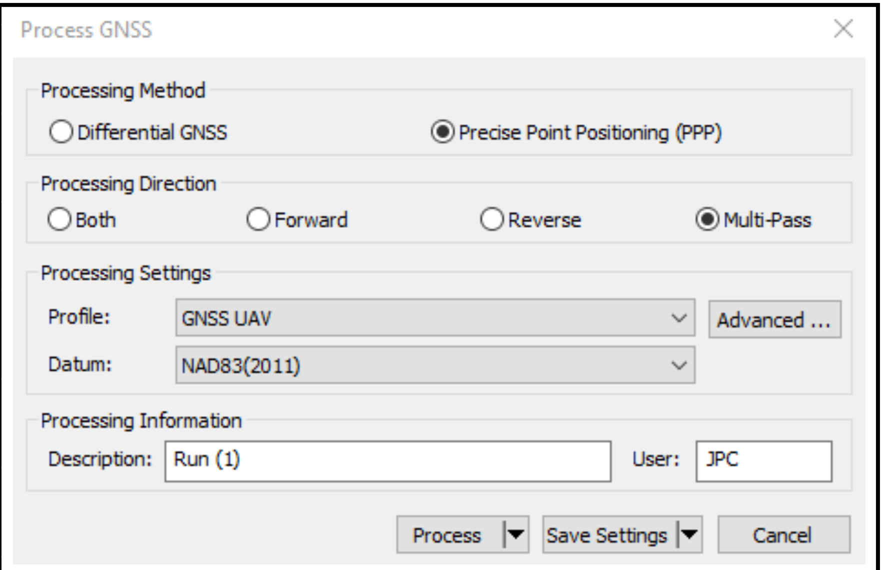
Distance ↑ Accuracies ↓



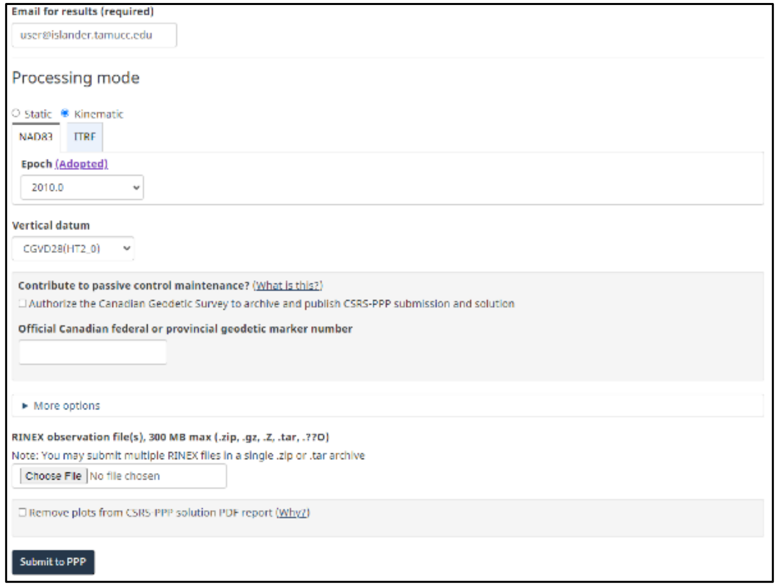
PPK Fix Percentage by Sample Rate

PPP Example





PPP Processing settings on Inertial Explorer



CSRS-PPP processing ilterface

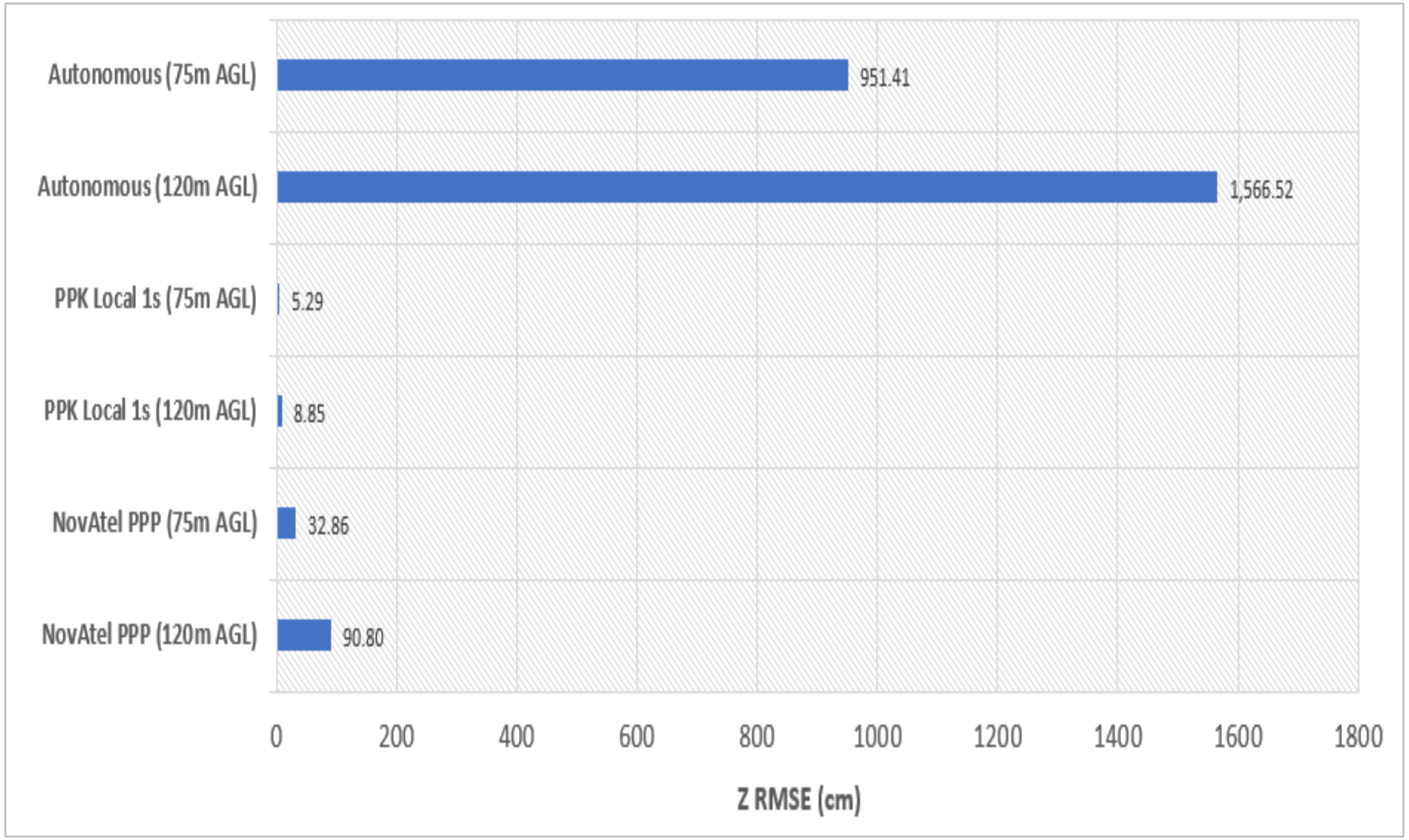
IE Kinematic PPP Processing:

- Start new project and add raw rover GNSS file (.sbf format in this case)
- Time synchronization performed within software, no human input needed
- Create a csv and assign each solution to its corresponding image

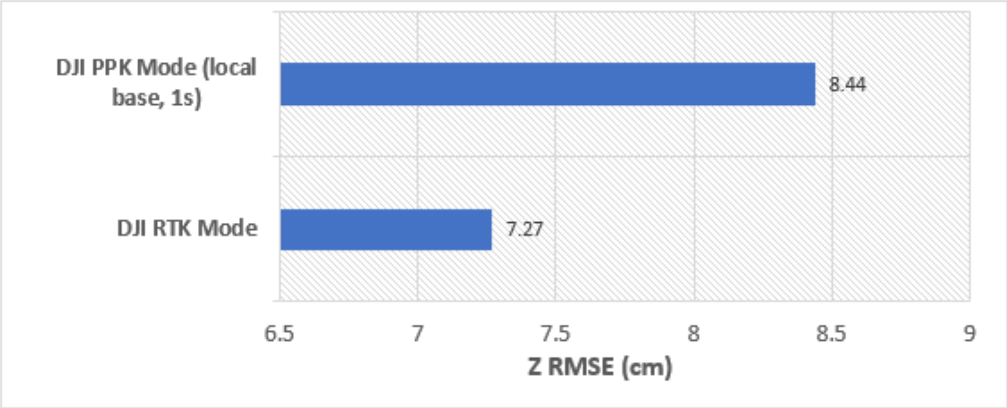
CSRS-PPP and RTKLIB Processing

- Time synchronization still an issue
- UAS has timestamps offset from CSRS-PPP
- Make them equivalent, then interpolate
- Work still in progress

GNSS Evaluation Results
(high vs low altitude, RTK vs PPK)

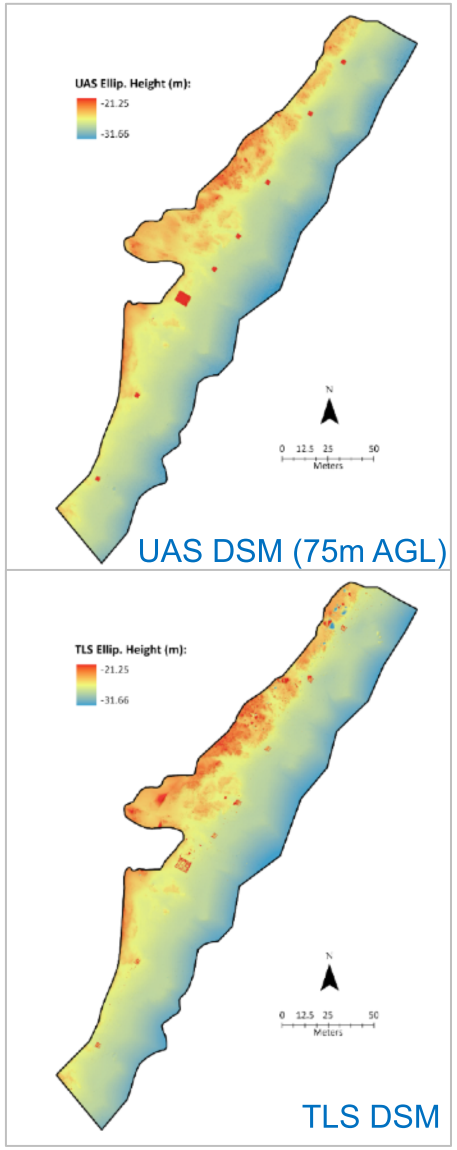


Autonomous, PPK, and PPP results



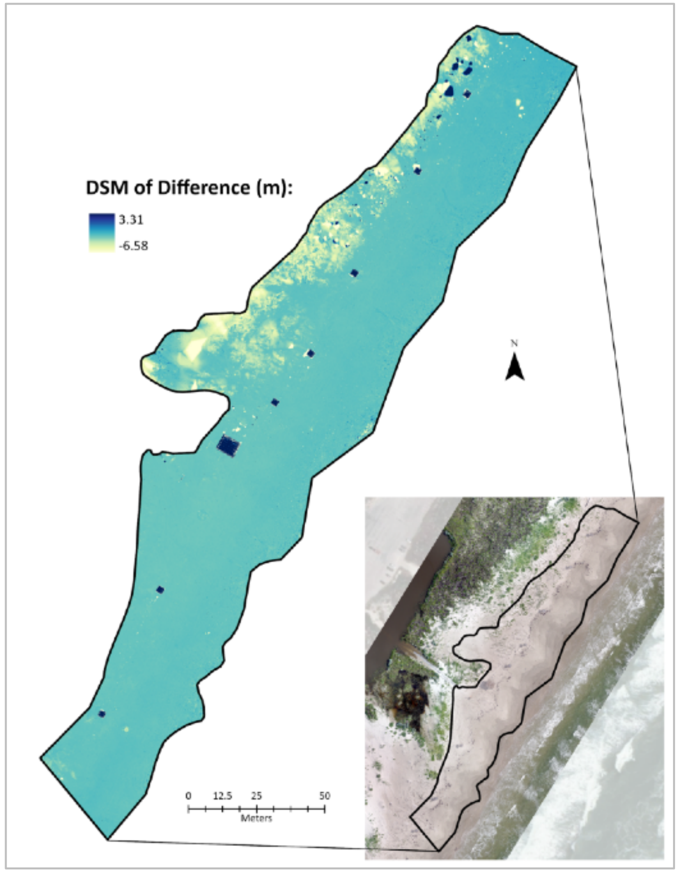
PPK and RTK results
(Phantom 4 RTK)

UAS-SfM Comparability (PPK Only)
TLS & RTK Profiles



UAS DSM (75m AGL)

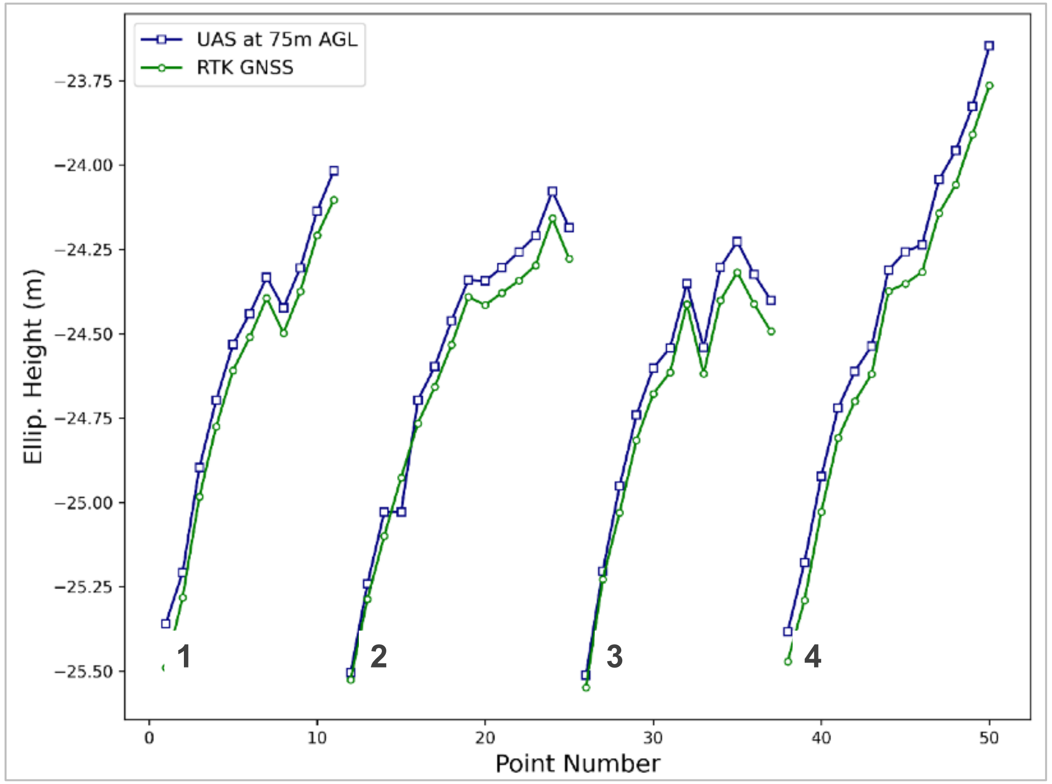
TLS DSM



DSM of Differences [UAS – TLS]

DoD statistics (in meters)

Mean	St dev.	Min	Max	RMSE
0.008	0.16	-6.58	3.31	0.16



Height profiles [UAS vs RTK GNSS]

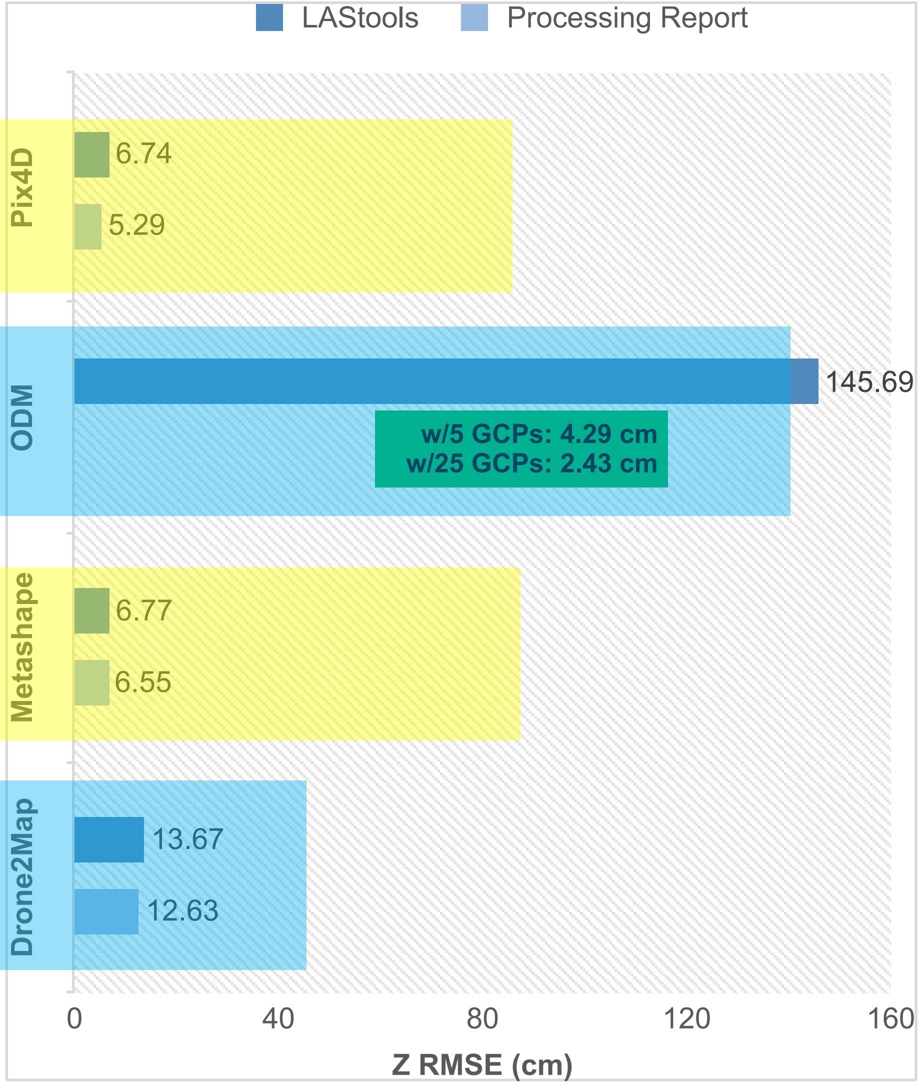
Statistics of height deltas (in m)

	1	2	3	4
Mean of ∆s	0.08	0.055	0.072	0.093
Std. dev. of ∆s	0.018	0.047	0.021	0.014
RMSE	0.082	0.073	0.075	0.094

SfM Evaluation Results
PPK Only Solutions

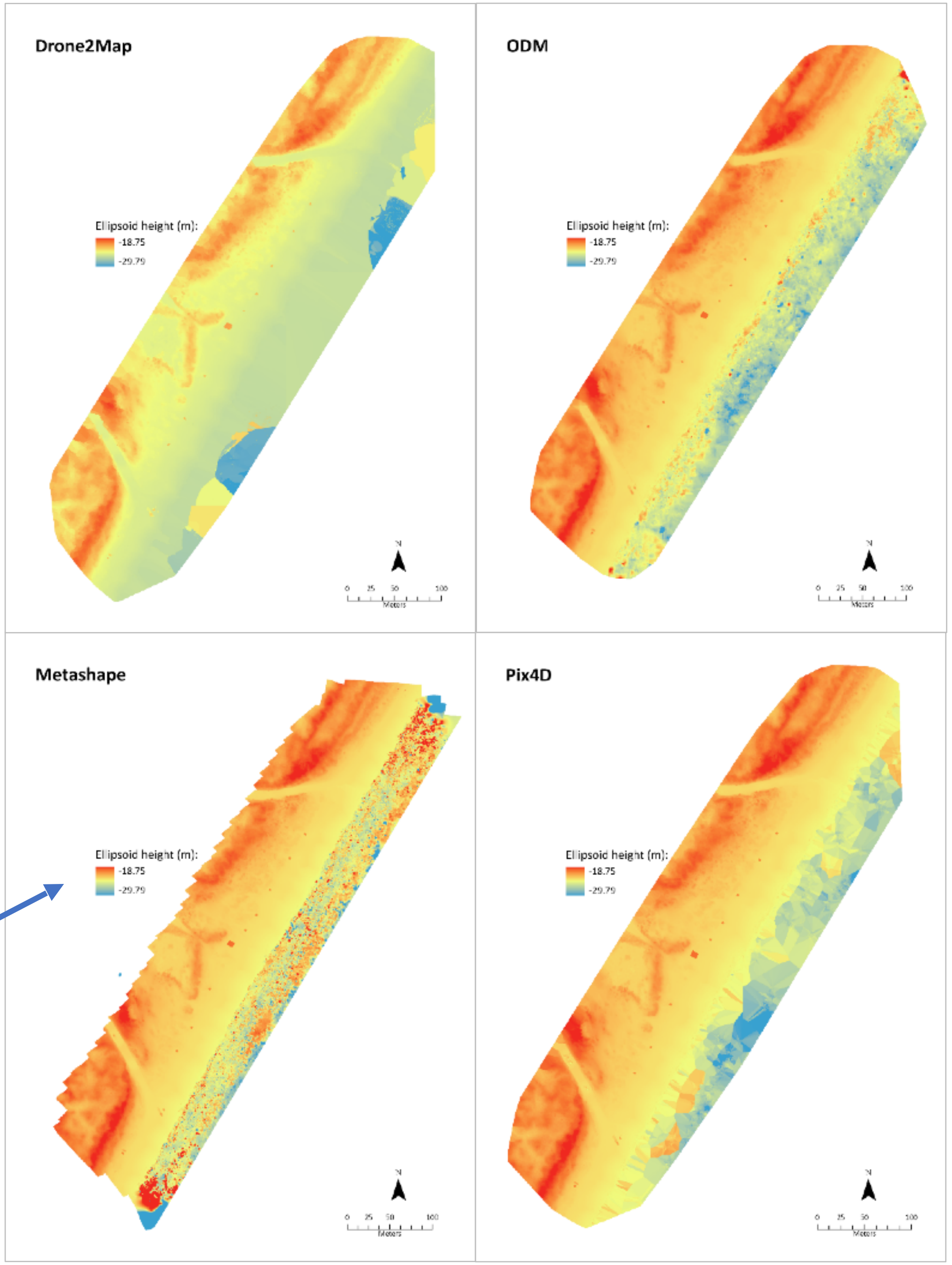
- Processing report
- LAStools
- Delta (CP to model)

Study Site 1: NPC



Study Site 2. MISP

Orthomosaics



DSMs

Summary of Lessons Learned

GNSS Evaluation:

- PPK only solutions ~5 to 8 cm vertical RMSE
  - Base stations < 30 km (local base not always better)
  - No clear pattern for sampling rate, use PPK fix %
  - Results comparable to RTK/TLS
- RTK/RTN accuracy comparable to PPK
  - Recommend PPK to eliminate rover communication
- PPP (achieved decimeter level)
  - Requires more research / initialization tests

SfM Evaluation:

- Best accuracies: Metashape/Pix4D
- Inconsistencies: Drone2Map/ODM
  - Problems handling non-WGS84 datums
  - ODM performance varied by site/texture
- Water masking in Metashape
- Processing report results comparable to dense cloud results in LAStools
- Results environment/version dependent

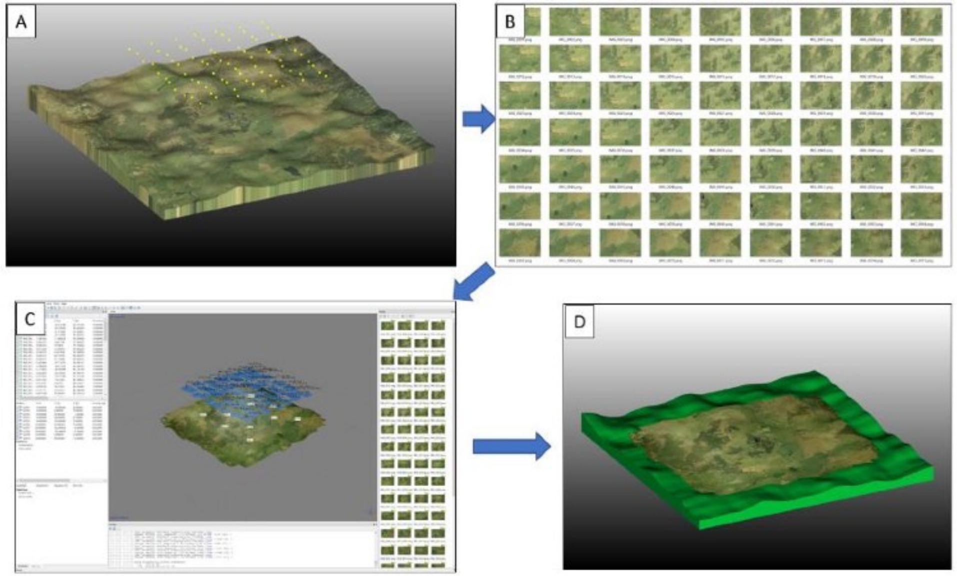
Monte Carlo and Empirical Assessment of SfM Point Cloud Vertical Accuracy as a Function of GNSS Accuracy

1. Simulation

- Use simUAS (Slocum and Parrish, 2017) to generate simulated UAS imagery for scene
- Monte Carlo approach
  - Vary GNSS accuracy, run through SfM software, assess accuracy of output

2. Empirical Testing

- Actual UAS flights at OSU survey fields and Neptune State Scenic Area on Coast
- High accuracy field surveys to obtain check points



Simulation

Empirical Tests

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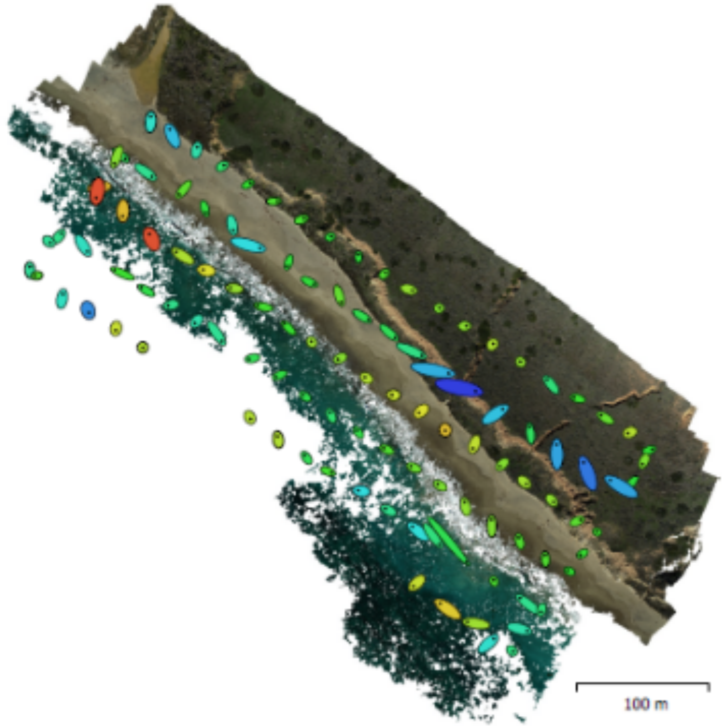
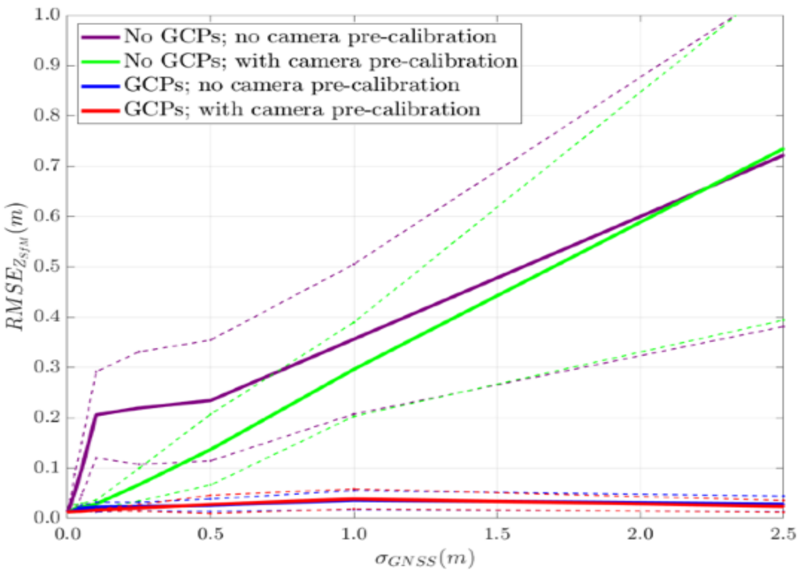
simUAS Monte Carlo

- Simulated photogrammetric block
  - a 9×9; 75% endlap and 75% sidelap
  - 100 m AGL
  - Simulated Sony A6000 camera with a 6000×4000 pixel (24 Mp) sensor, 30-mm focal length lens -> 1.3-cm GSD
- 9 different GNSS quality levels simulated with 15 iterations (Monte Carlo trials) for each
- Analyzed spread in output to quantify uncertainty

Form of modeled relationship: $RMSE_{Z_{SfM}} = \alpha \bullet \sigma_{GNSS} + \beta$





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Conclusions

- Both the simulated (simUAS + Monte Carlo) and empirical results show that:
  - UAS-SfM point cloud vertical accuracy is relatively constant (flat, as a function of GNSS type) if sufficient GCPs are used
  - UAS-SfM point cloud vertical accuracy is well modeled as a linear function of GNSS accuracy in the case of no or few GCPs
    - Slope is significantly steeper in the empirical results
      - Possible causes: not accounting for additional uncertainties (e.g., camera calibration)
  - Best quality remote aircraft GNSS (PPK or RTK) enabled UAS-SfM vertical accuracies (RMSEz) of ~0.2 m, even with no GCPs
    - Matches empirical field experiments

Oregon State University

Paper in Development for Aforementioned Work

drones

MDPI

Article

Simulation and Characterization of Wind Impacts on sUAS Flight Performance for Crash Scene Reconstruction

Tianxing Chu [1,2], Michael J. Starek [1,2,*], Jacob Berryhill [1], Cesar Quiroga [3] and Mohammad Pashaei [1,2]

1 Conrad Blucher Institute for Surveying and Science, Texas A&M University-Corpus Christi, Corpus Christi, TX 78412, USA; tianxing.chu@tamucc.edu (T.C.); jacob.berryhill@tamucc.edu (J.B.); mpashaei@islander.tamucc.edu (M.P.)
2 Department of Computing Sciences, Texas A&M University-Corpus Christi, Corpus Christi, TX 78412, USA
3 Texas A&M Transportation Institute, San Antonio, TX 78213, USA; c-quiroga@tti.tamu.edu
* Correspondence: michael.starek@tamucc.edu; Tel.: +1-361-825-3978

Abstract: Small unmanned aircraft systems (sUASs) have emerged as promising platforms for the purpose of crash scene reconstruction through structure-from-motion (SfM) photogrammetry. However, auto crashes tend to occur under adverse weather conditions that usually pose increased risks of sUAS operation in the sky. Wind is a typical environmental factor that can cause adverse weather, and sUAS responses to various wind conditions have been understudied in the past. To bridge this gap, commercial and open source sUAS flight simulation software is employed in this study to analyze the impacts of wind speed, direction, and turbulence on the ability of sUAS to track the pre-planned path and endurance of the flight mission. This simulation uses typical flight capabilities of quadcopter sUAS platforms that have been increasingly used for traffic incident management. Incremental increases in wind speed, direction, and turbulence are conducted. Average 3D error, standard deviation, battery use, and flight time are used as statistical metrics to characterize the wind impacts on flight stability and endurance. Both statistical and visual analytics are performed. Simulation results suggest operating the simulated quadcopter type when wind speed is less than 11 m/s under light to moderate turbulence levels for optimal flight performance in crash scene reconstruction missions, measured in terms of positional accuracy, required flight time, and battery use. Major lessons learned for real-world quadcopter sUAS flight design in windy conditions for crash scene mapping are also documented.

Keywords: small unmanned aircraft systems; photogrammetry; structure-from-motion; wind impact; turbulence; crash scene reconstruction; traffic incident management

check for updates

Citation: Chu, T.; Starek, M.J.; Berryhill, J.; Quiroga, C.; Pashaei, M. Simulation and Characterization of Wind Impacts on sUAS Flight Performance for Crash Scene Reconstruction. *Drones* **2021**, *5*, 67. https://doi.org/10.3390/drones5030067

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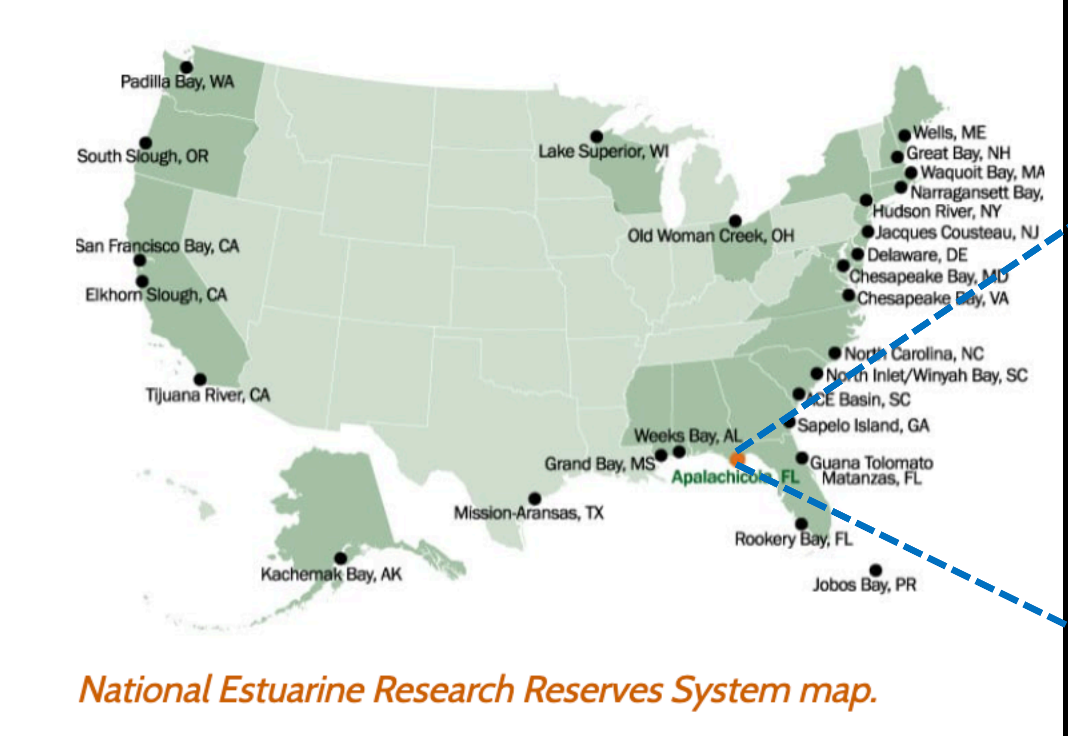
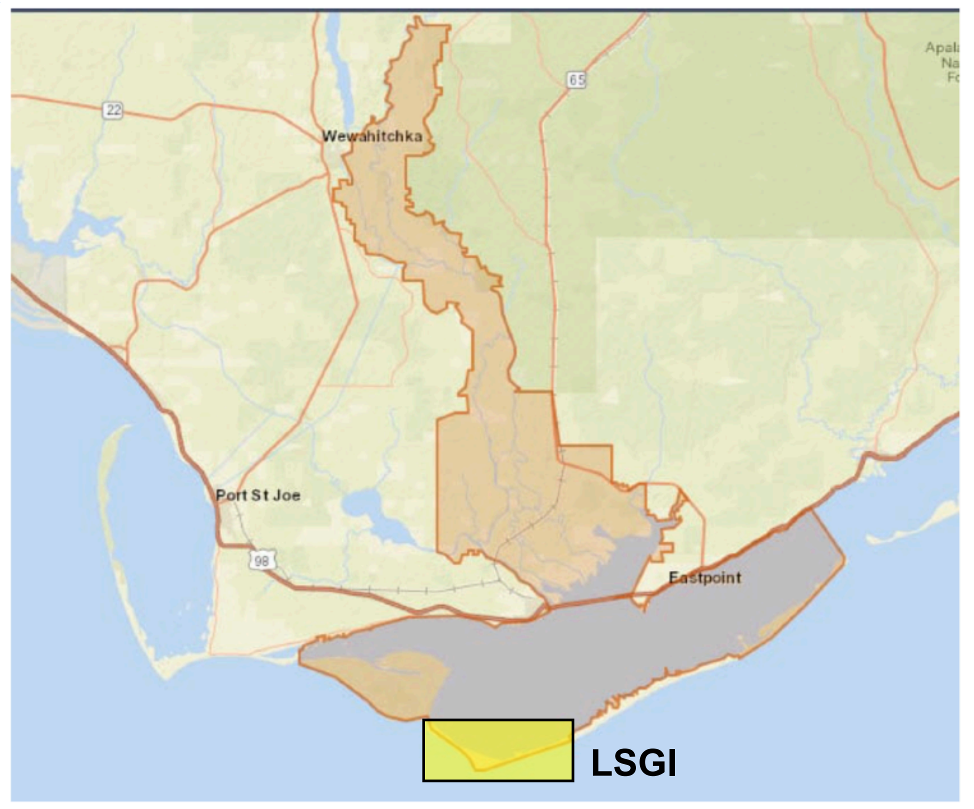
1. Introduction

A motor vehicle crash can cause considerable economic loss, serious bodily injuries and loss of human life. Crash scene investigation and reconstruction are considered crucial being part of the major concerns in traffic incident management (TIM) [1]. Traditional coordinate and triangulation methods have long been adopted by investigators at a crash scene. They use mechanical measurement tools such as tape measures and roller wheels to acquire baseline measurements and delineate crash scene diagrams [2]. While relatively low cost, these methods have limited efficiency to document measurements and pose safety risks to investigators due to possible exposure to traffic. In order to automate accurate documentation of distance and angle measurements, total stations have started to play a key role at crash scenes since the early 1990s [3]. The ability to collect digital data off the roadway eases investigators' exposure risk to traffic and reduces entire surveying time. Close-range photogrammetry, which emerged around the same time in accident investigation, is able to recover accurate two-dimensional (2D) and three-dimensional (3D) measurements and diagrams by taking overlapping photographs from different viewpoints around crash scenes [4]. Over the past two decades, the potential of terrestrial

Other Examples
(time permitting)

ANERR





We collaborate with the Apalachicola National Estuarine Research Reserve (ANERR).
Conduct annual UAS surveys of beach and wetland sites.

UAS Survey Campaigns at Little St. George Island (LSGI)

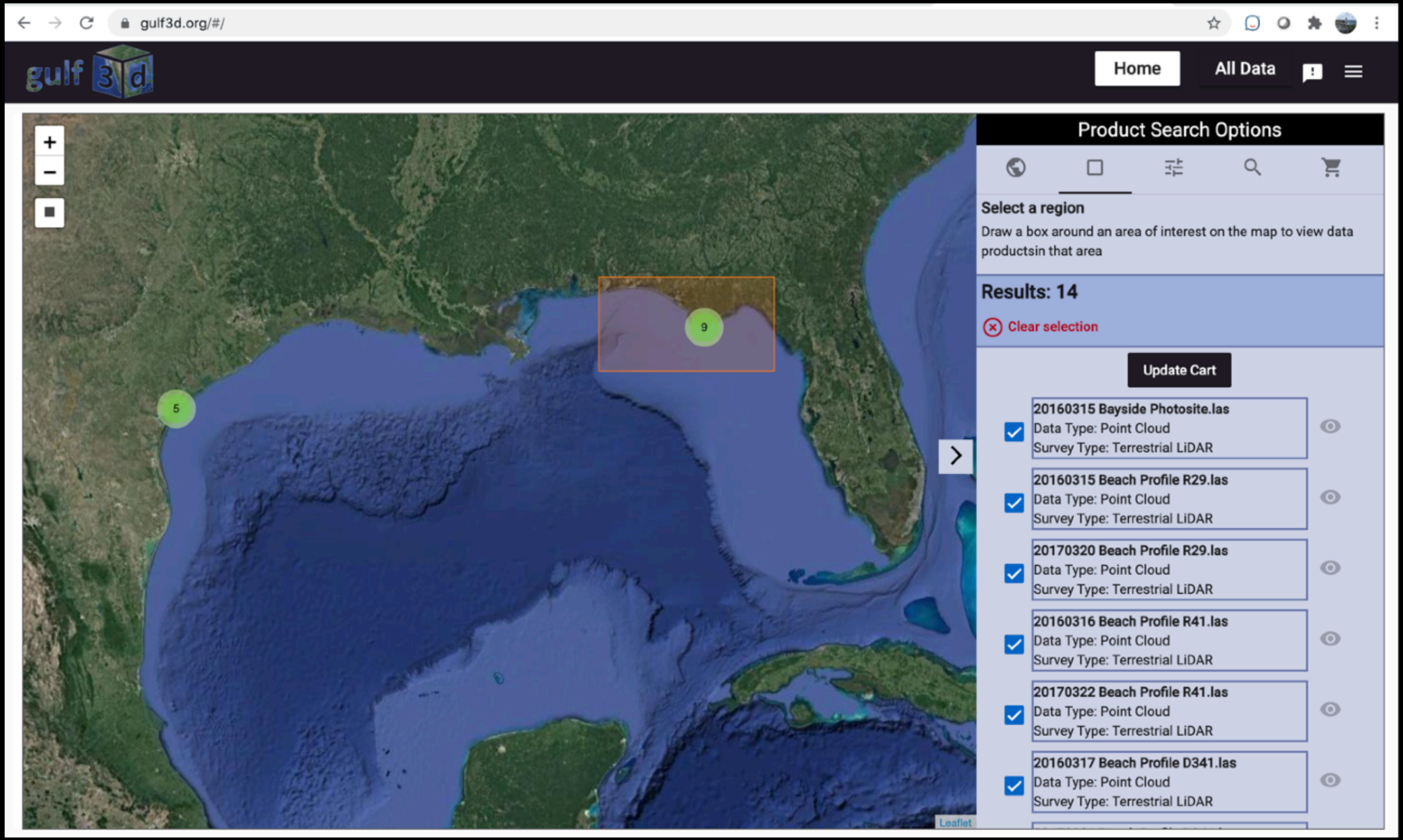
Survey Dates

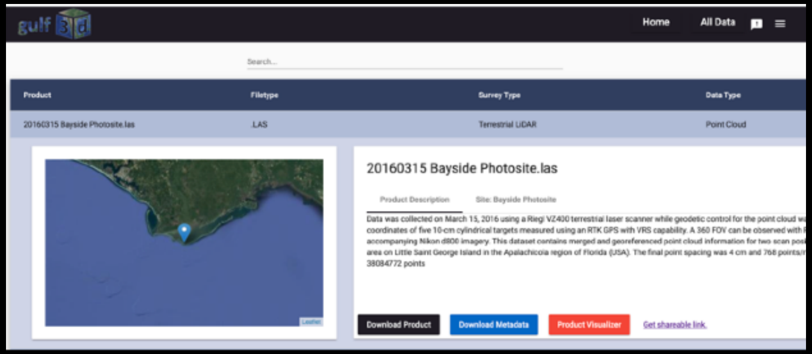
- March 2016 – primarily terrestrial lidar
- March 2017 - mapped western segment
- July 2018 - mapped entire beach (4 days)
- May 2019 - mapped entire beach (2 days)
- Sep. 2020 - mapped entire beach (1 day)
- May 2021 - mapped entire beach (1 day)
- May 2022 - mapped entire beach (1 day)

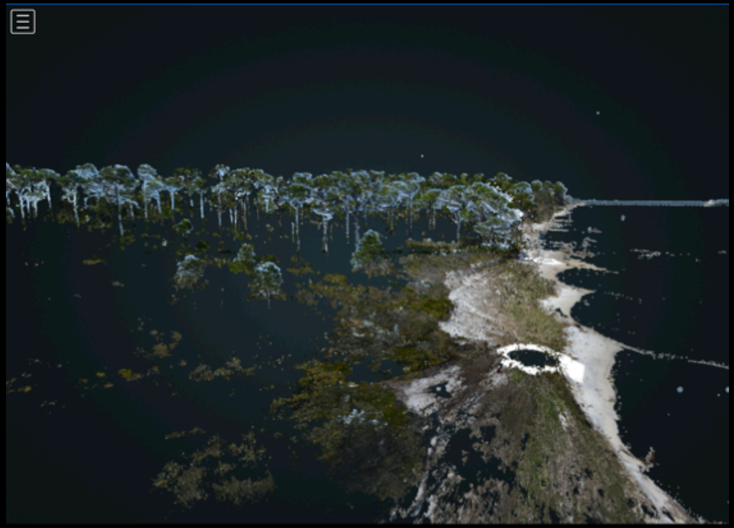
July 2018 survey occurred ~2 months before Hurricane Michael

*additional UAS–SfM & UAS-LiDAR surveys conducted at wetland sites

Data Hosting: Gulf3D.org







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Examples

Pre-Covid Era

Study Objectives

- Hurricane Michael made landfall on October 10, 2018 near Mexico Beach, FL (~33 miles to west)
- Use UAS surveys to quantify impact of Hurricane Michael on LSGI
- Assess impacts to beach and foredunes

Pre-Michael UAS-SfM DEM (western side near inlet)

Post-Michael UAS-SfM DEM

Mexico Beach
Source: Getty images

Results: Shoreline & Dune Crest Change

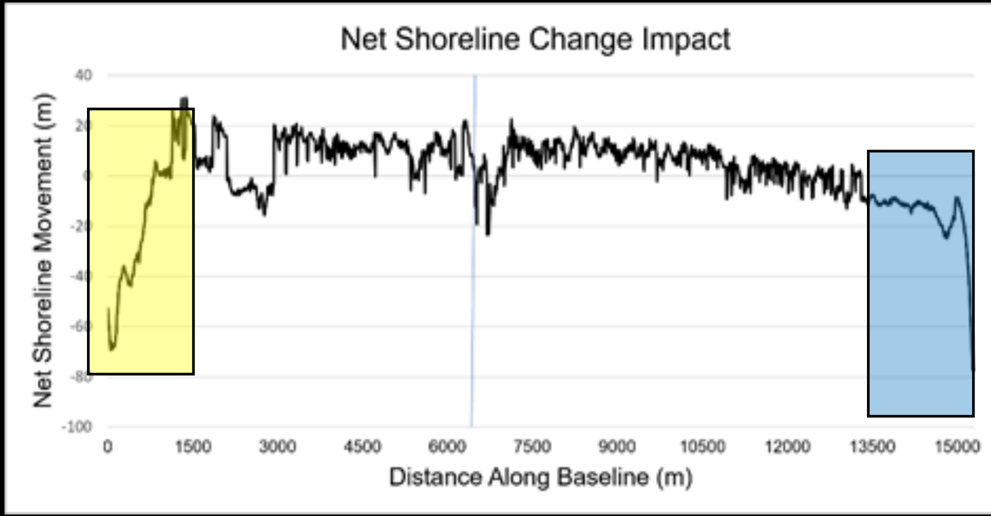
- Shoreline Change
  - Substantial erosion of the far western and eastern segments of the island after the storm

Shoreline Change (UAS 2018 to UAS 2019 survey)

	West	East
Average net shoreline movement (m)	-6.0	11.15
Maximum shoreline retreat (m)	-82.9	-22.9
Maximum shoreline accretion (m)	20.6	22.5

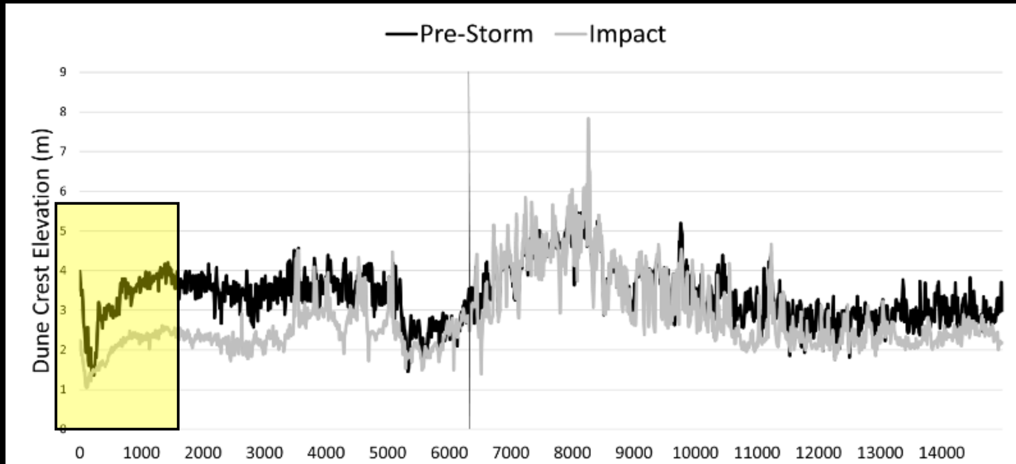
- Dune Crest
  - Max loss of -2.3 m in places
  - Western side hit hardest

Wester segment of the island is left of the vertical line



West

East



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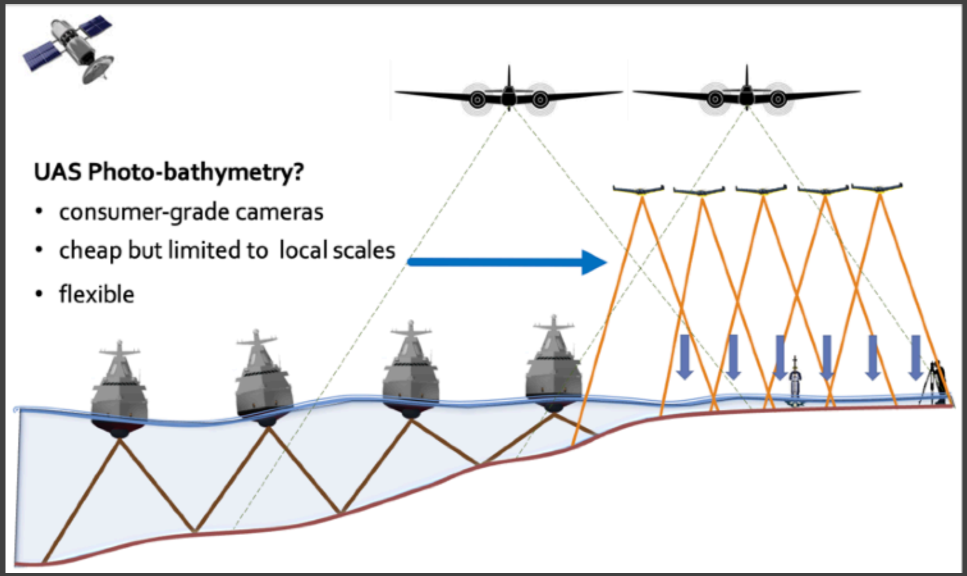
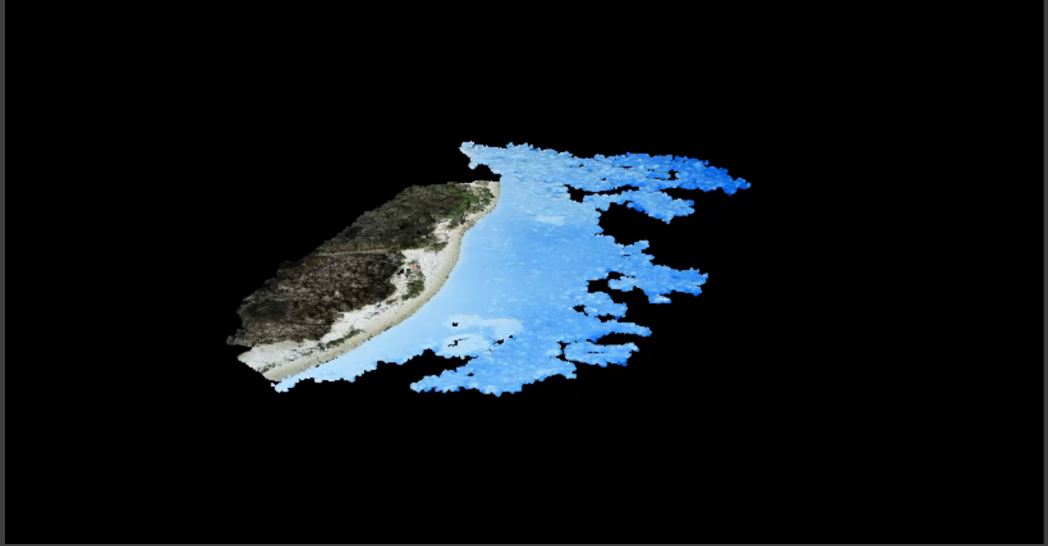
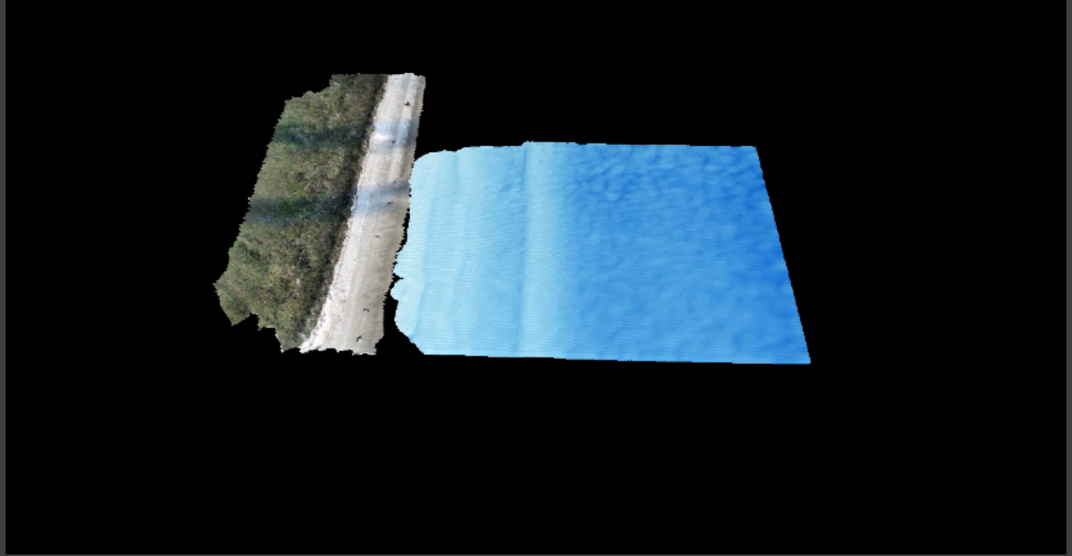


SfM Photogrammetry



cBathy: Depth Inversion



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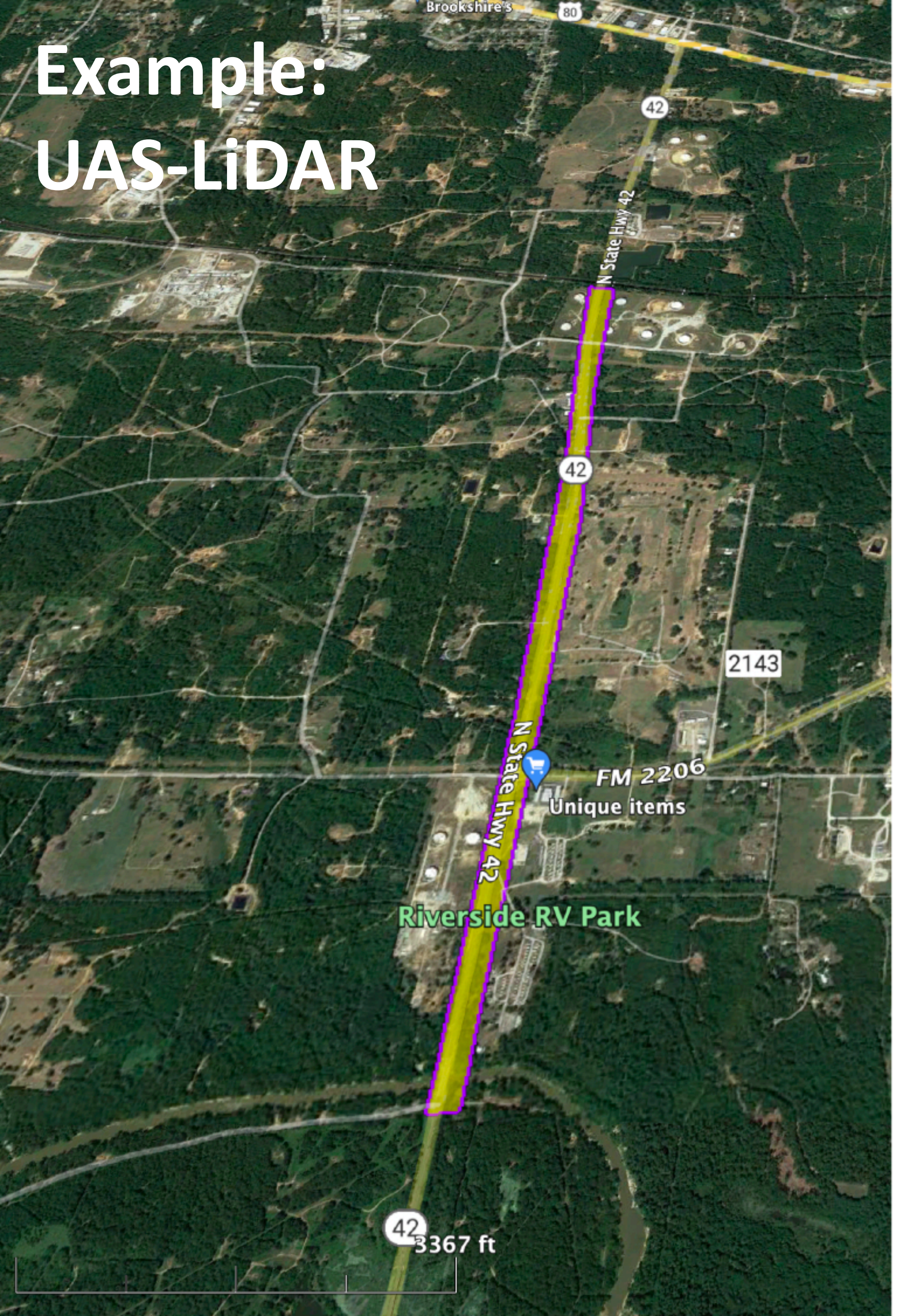
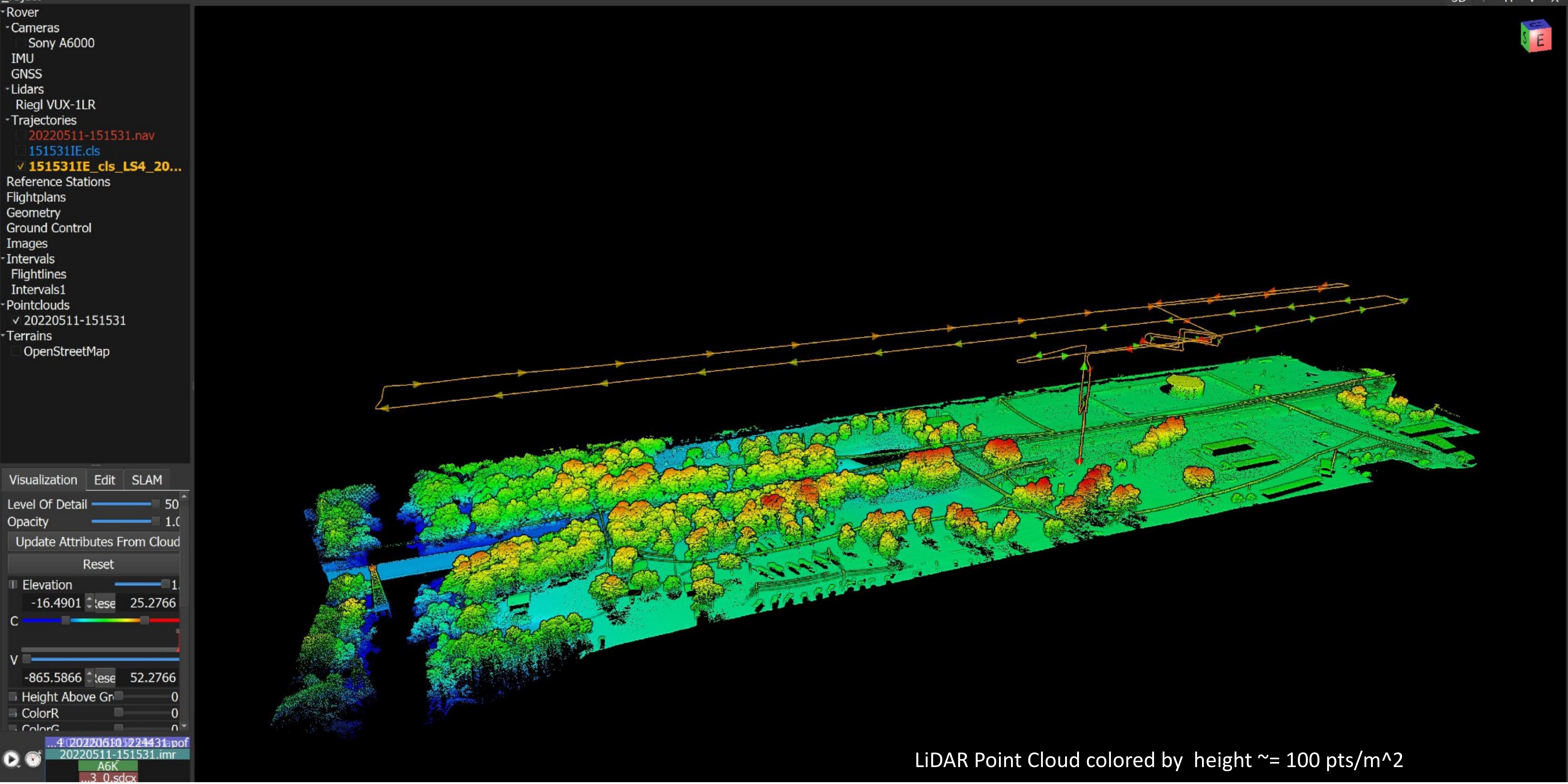
MANTIS MEASUREMENT ANALYTICS

Example: UAS-LiDAR



- SH 42, Longview, TX
- Survey conducted for TxDOT
- Establish local GNSS base for data post-processing


Rover
Cameras
Sony A6000
IMU
GNSS
Lidars
Riegl VUX-1LR
Trajectories
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151531IE.cls
151531IE_cls_LS4_20...
Reference Stations
Flightplans
Geometry
Ground Control
Images
Intervals
Flightlines
Intervals1
Pointclouds
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Terrains
OpenStreetMap
Visualization
Edit
SLAM
Level Of Detail
Opacity
Update Attributes From Cloud
Reset
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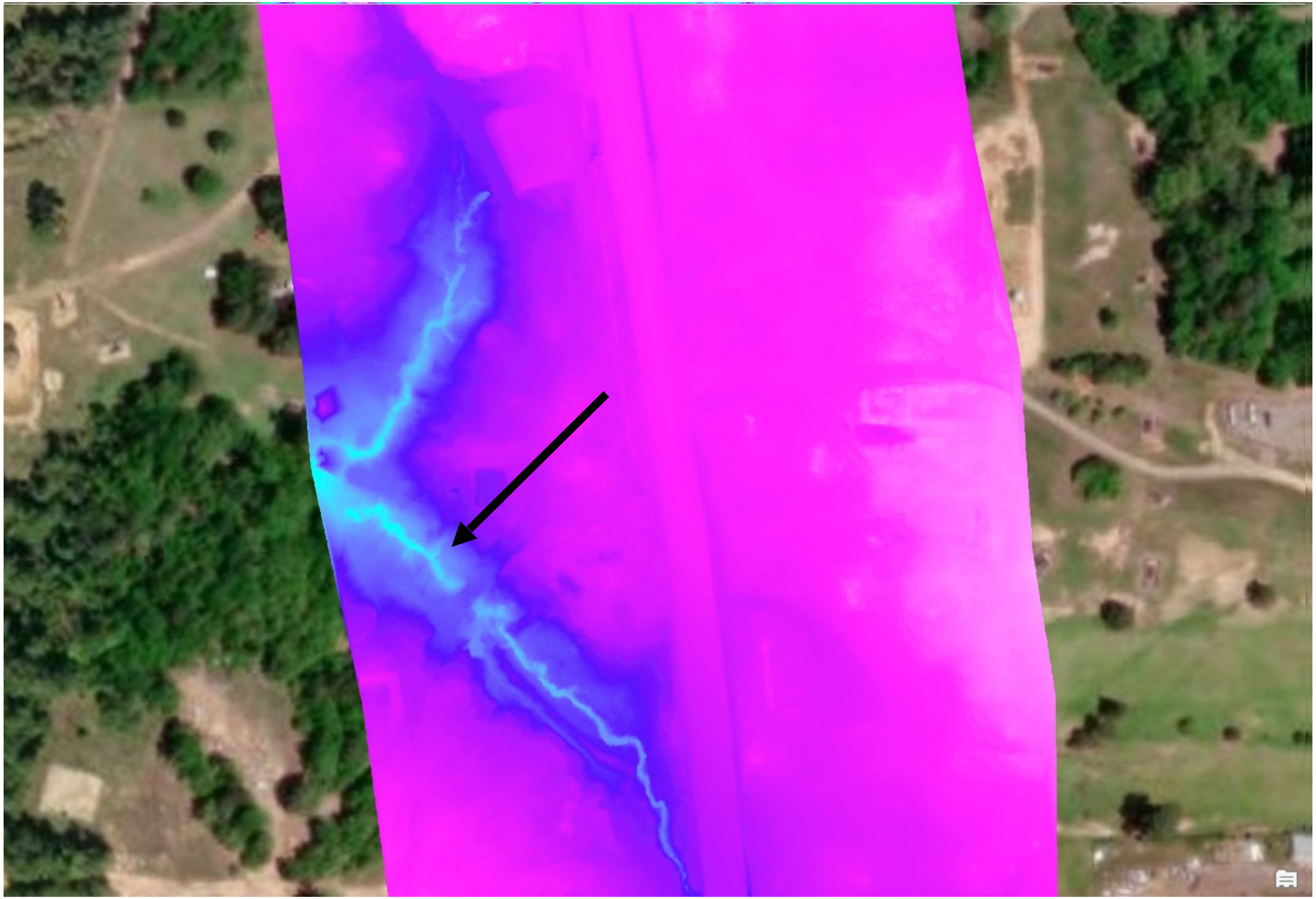
-865.5866
52.2766
Height Above Gr
ColorR
20220511-151531.imr
A6K
LiDAR Point Cloud colored by height ~= 100 pts/m^2

Raster DTM from UAS-LiDAR, ground point class



Thank you SCOAR!

Contact

Dr. Michael J. Starek
Conrad Blucher Institute
College of Engineering
michael.starek@tamucc.edu, www.mantisresearch.org