“2D and 3D SfM Mapping of the Littoral Zone with UAS”

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JALBTCX 16th Annual Airborne Coastal Charting and Mapping Workshop, June 2015

For those that don’t know me…..

Lights & Mirrors Reigning Champion with Kris Shrestha since 2010…

Officially retiring for now so someone else can claim the throne

Outline of Talk

- Brief Overview on Structure-from Motion (SfM)
- Examine UAS/SfM off-the-shelf products (Pix4D)
  - Challenges in shallow water
- Fusion of products to derive seamless topo-bathy DEM

Small-scale UAS (sUAS) “Drones” for Coastal Mapping

- Inexpensive remote sensing/surveying method
  - e.g. GLO Texas – rolling beach easement sets extent of public land
  - Vegetation line surveys with UAS
- Potential of UAS SfM / Optical Inversion for bathymetry
  - e.g. Coastal construction projects ideal
  - Little vegetation
  - Seafloor covered in fresh material – uniform substrate for consistent reflectance to measure bottom

San Luis Pass, TX. UAS topo-bathy map could greatly save on 100km^2 survey
sand bars < ~0.5 m depth

Galveston Island, TX
Marsh restoration post-construction

Potential use of UAS-SfM photogrammetry for marsh restoration monitoring

SfM vs. Photogrammetry

- Photogrammetry relies on a camera model and collinearity condition

  → 2 images + metric camera + camera POSE + bundle adjustment = matched points in 3D.

- SfM

  →many images + non-metric + feature detection + correspondence + adjustment = matched points in 3D

Airborne Lidar vs. sUAS SfM

Lidar

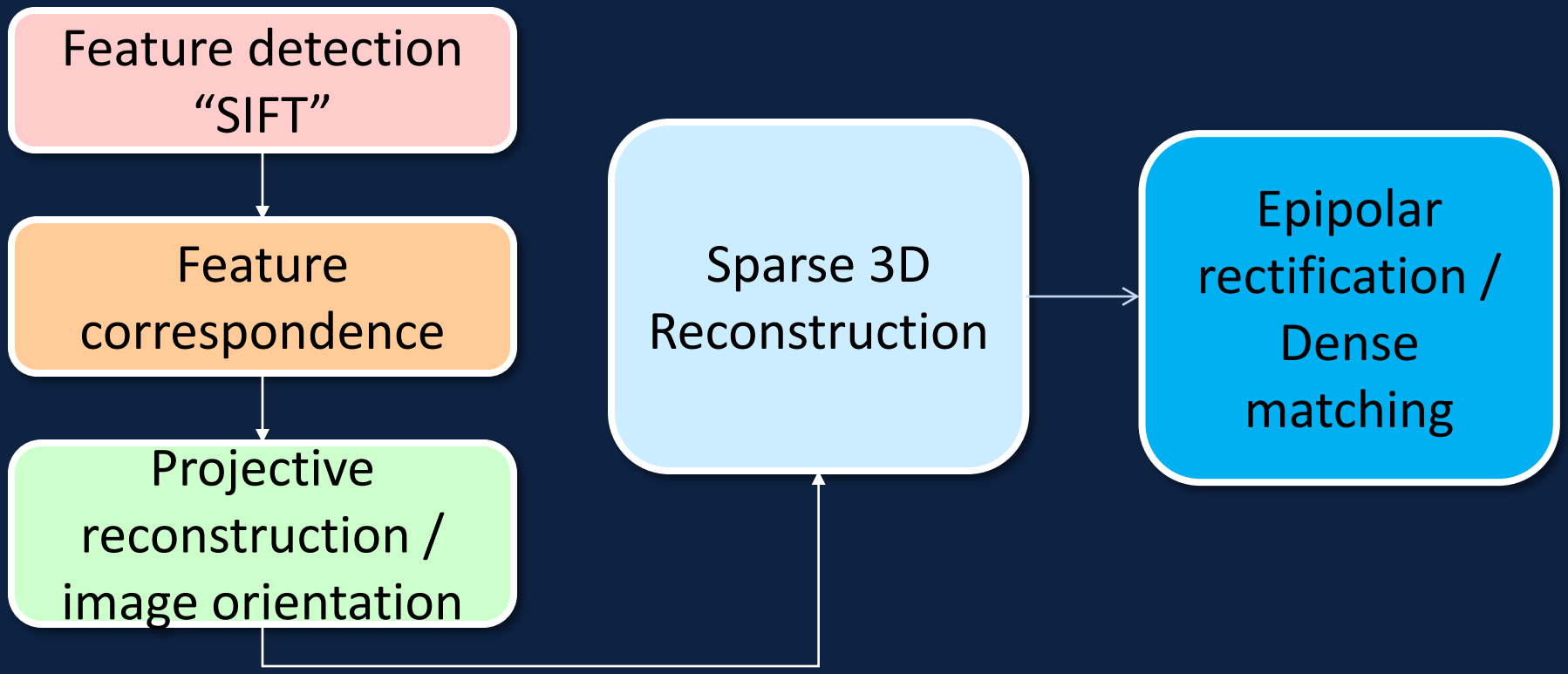
- Multiple returns
- < 10cm flat terrain/calibrat.
- Better precision
- Active
- Costly
- Regional extent

SfM

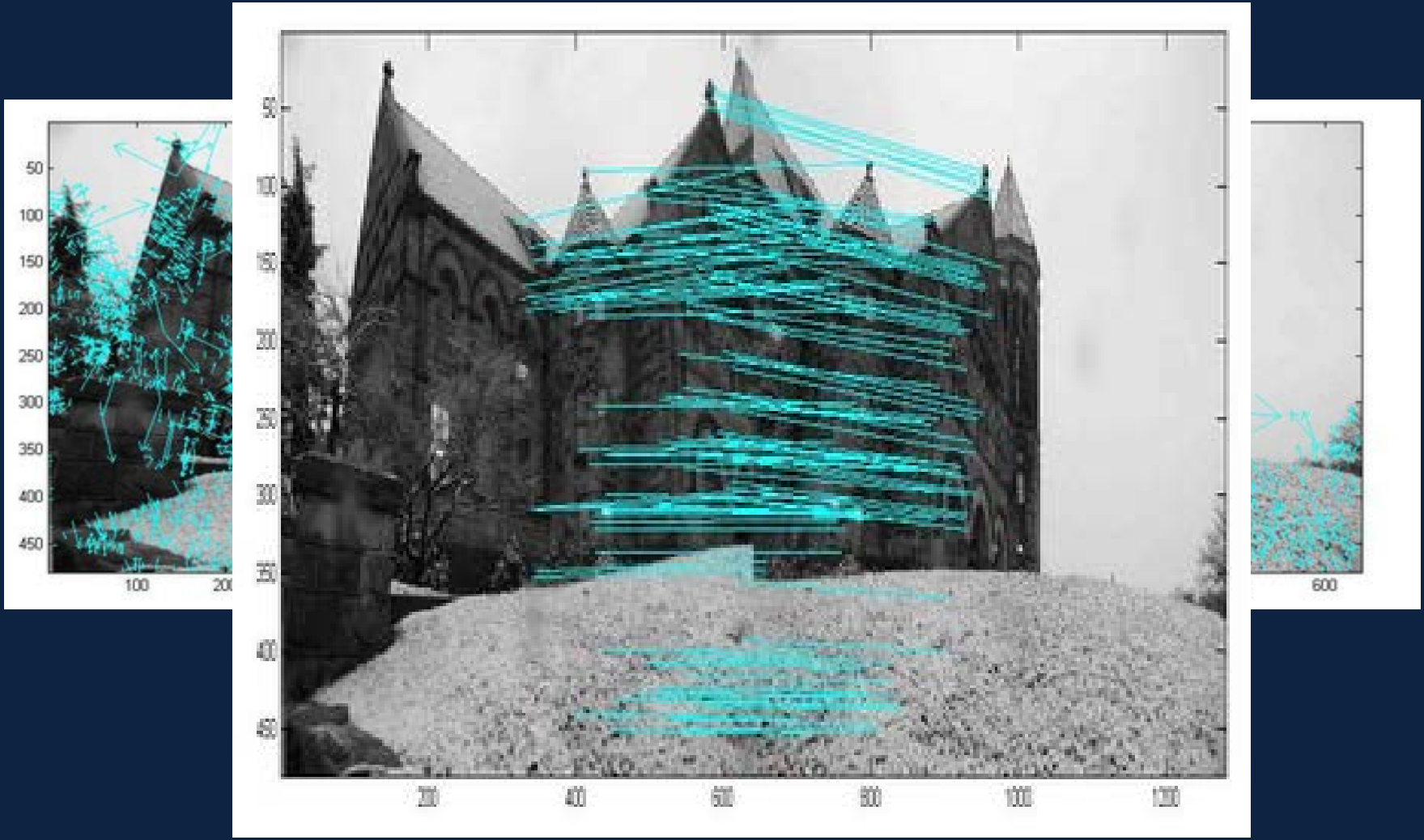
- Single point, DSM
- Accuracy comparable w/ control
- Noisy, tricky data…
- Passive (sun, shadows..)
- Inexpensive camera ($150)
- Localized extent

SfM Processing Pipeline

Pix4D, VisualSfM, Agisoft…similar-type process



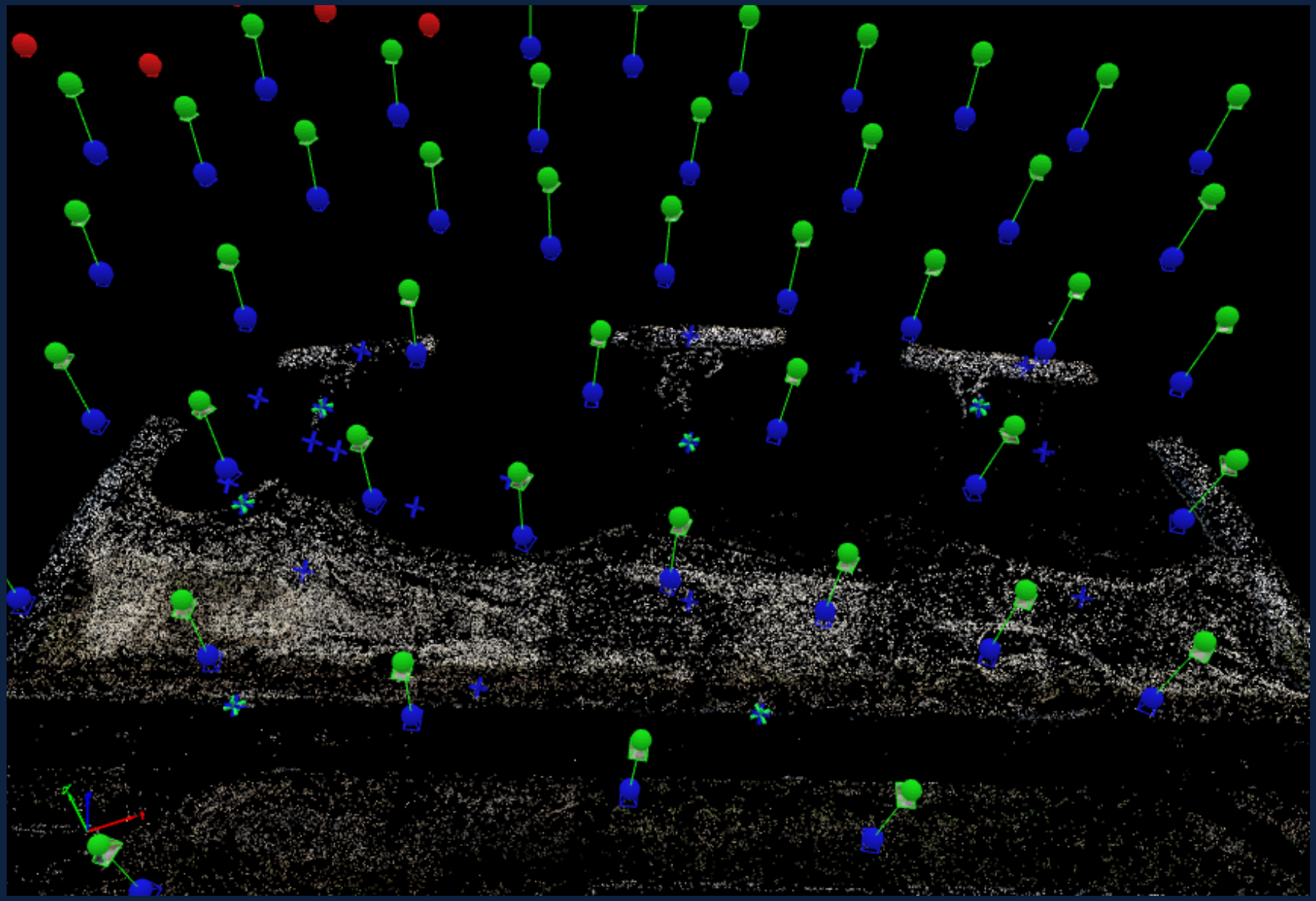
Outputs: 3D point cloud w/texture , DSM, orthomosaic



Images with matched SIFT pairs

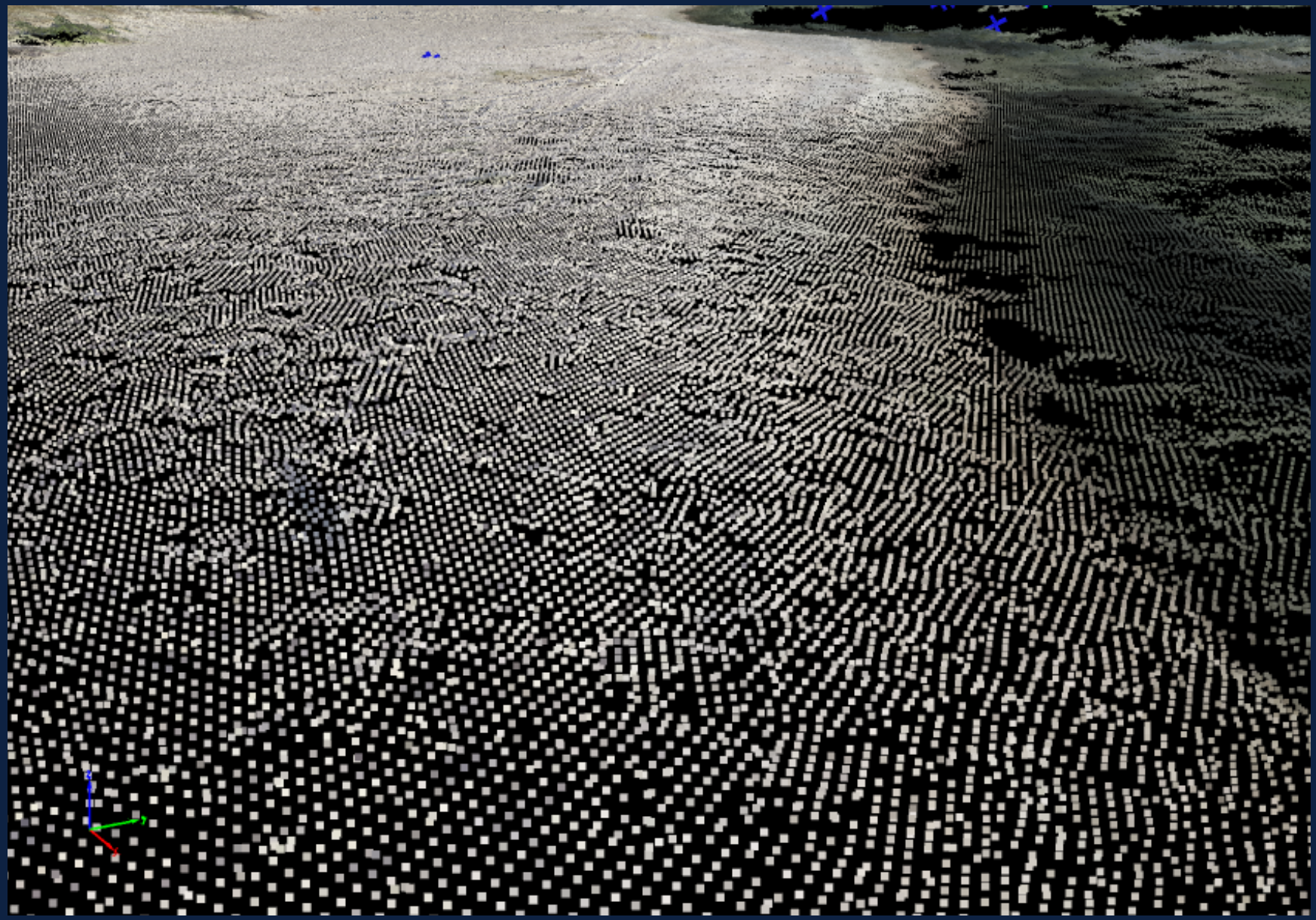
Source: http://www.csee.wvu.edu/~gidoretto/courses/2011-fall-cp/assignments/final_project/results/erdogan/webpage.html

Projective Reconstruction



Example from TAMUCC Beach

Dense Matching

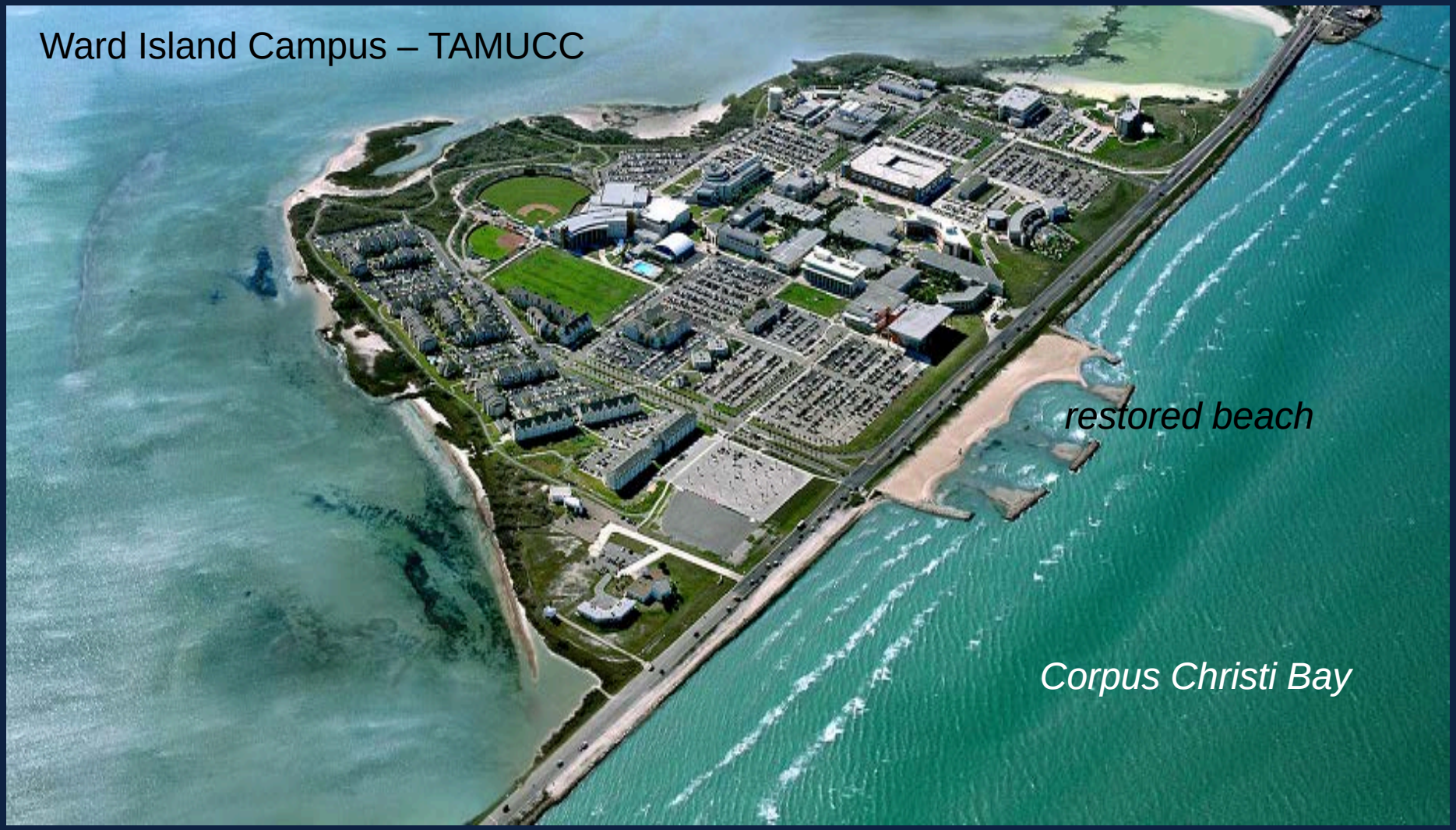


Example: Densification = ¼ image scale (¼ resolution); Point density = 4*GSD

Challenges with SfM in Littoral Zone

- Tidal water coverage
- Specular reflection / glint leads to false matching / large error
- Sand ripples / low texture
- Water is dynamic
- Poor water clarity (< 1m)

Study Area



2 Flights

August 24, 2014
- 90 m altitude
- 2.9 cm GSD

October 5, 2014
- 116 m altitude
- 3.5 cm GSD

80% side and endlap, grid pattern

UAS overview

Former student Thomas Davis launching the eBee

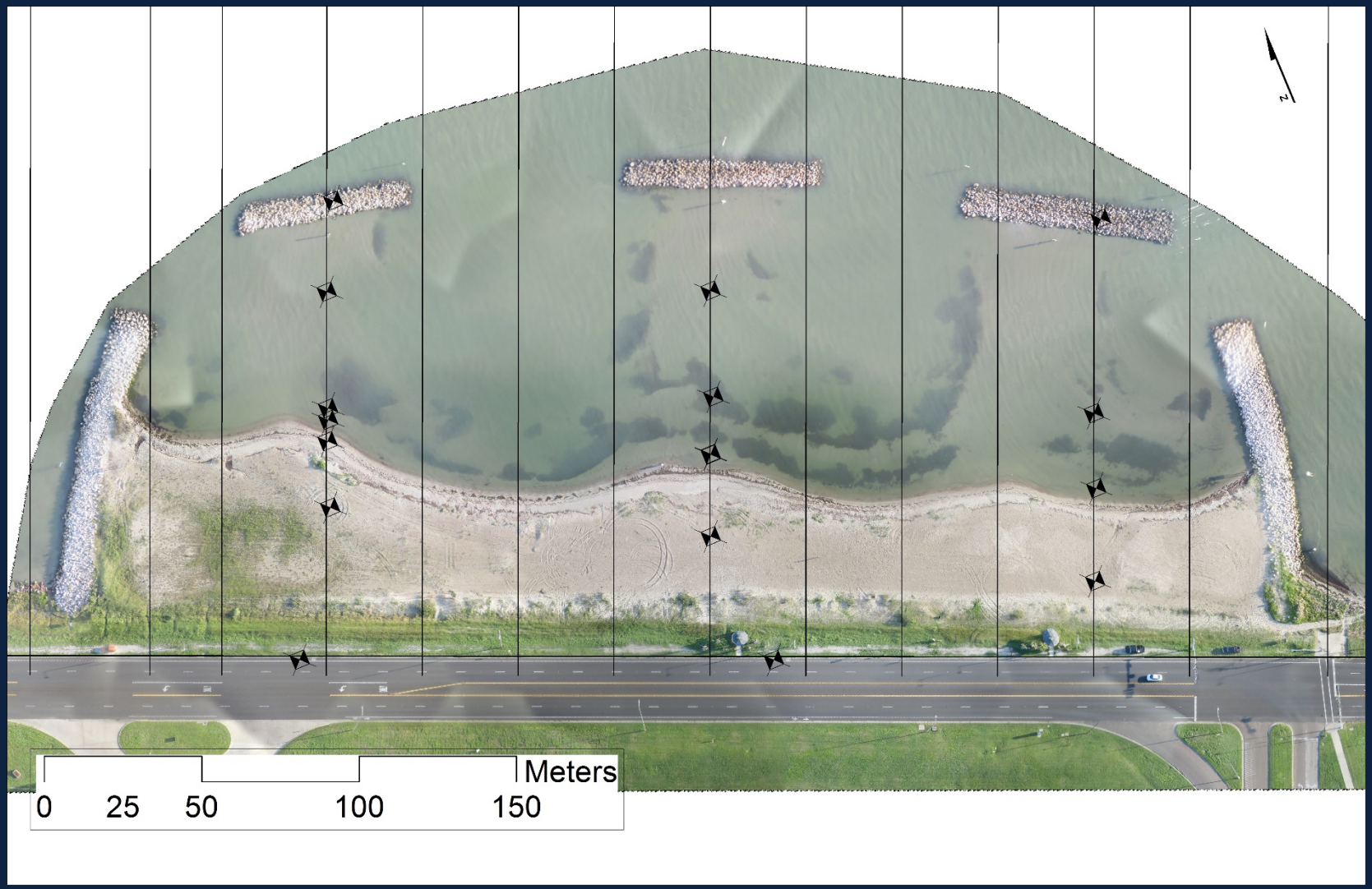
Sensefly eBee

- me
- 1.5 Pounds
- 3-band visible (RGB)
- 16 megapixel
- Fully Autonomous Flight
- smoothed output
- Up to ~43 kmh winds

Flights conducted under FAA COA

What happens when you let undergrads fly a UAV

Target Setup at University Beach

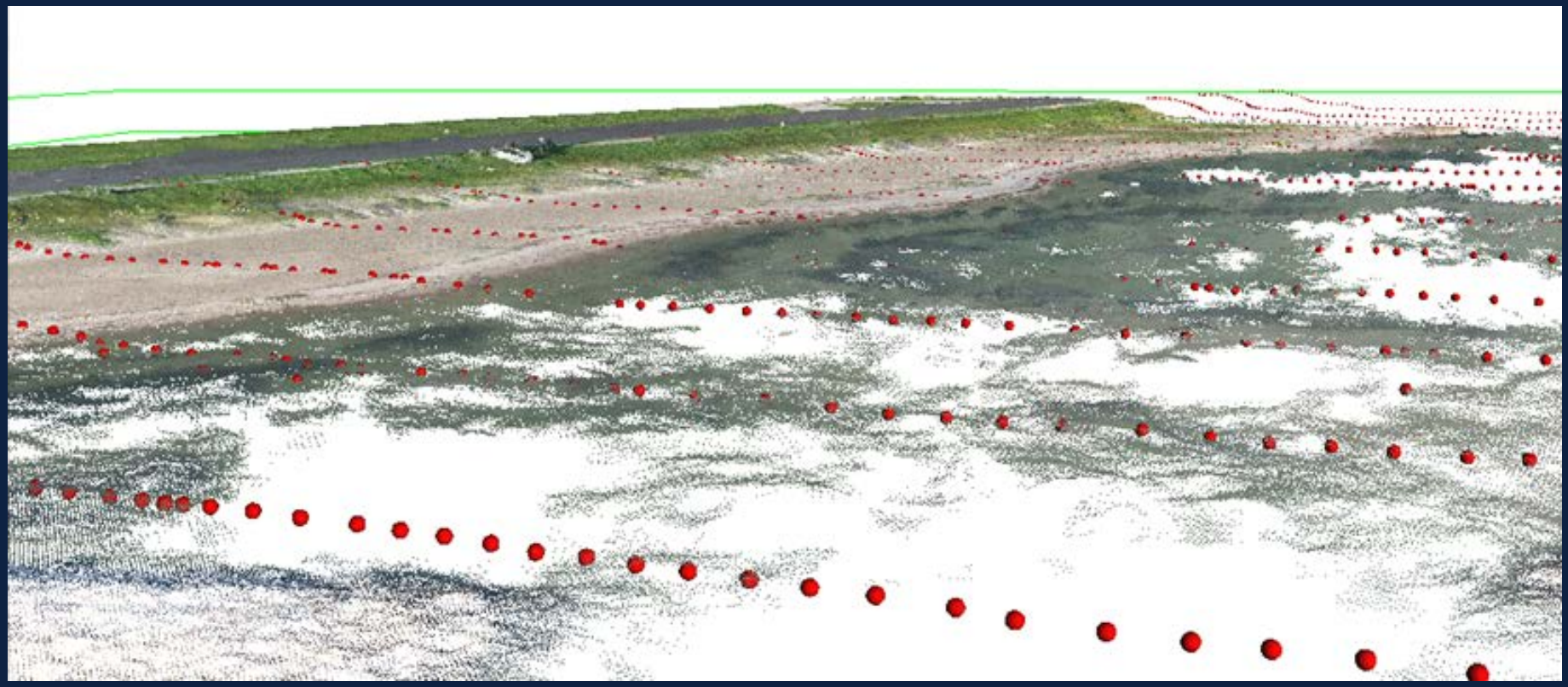


Example Control Targets

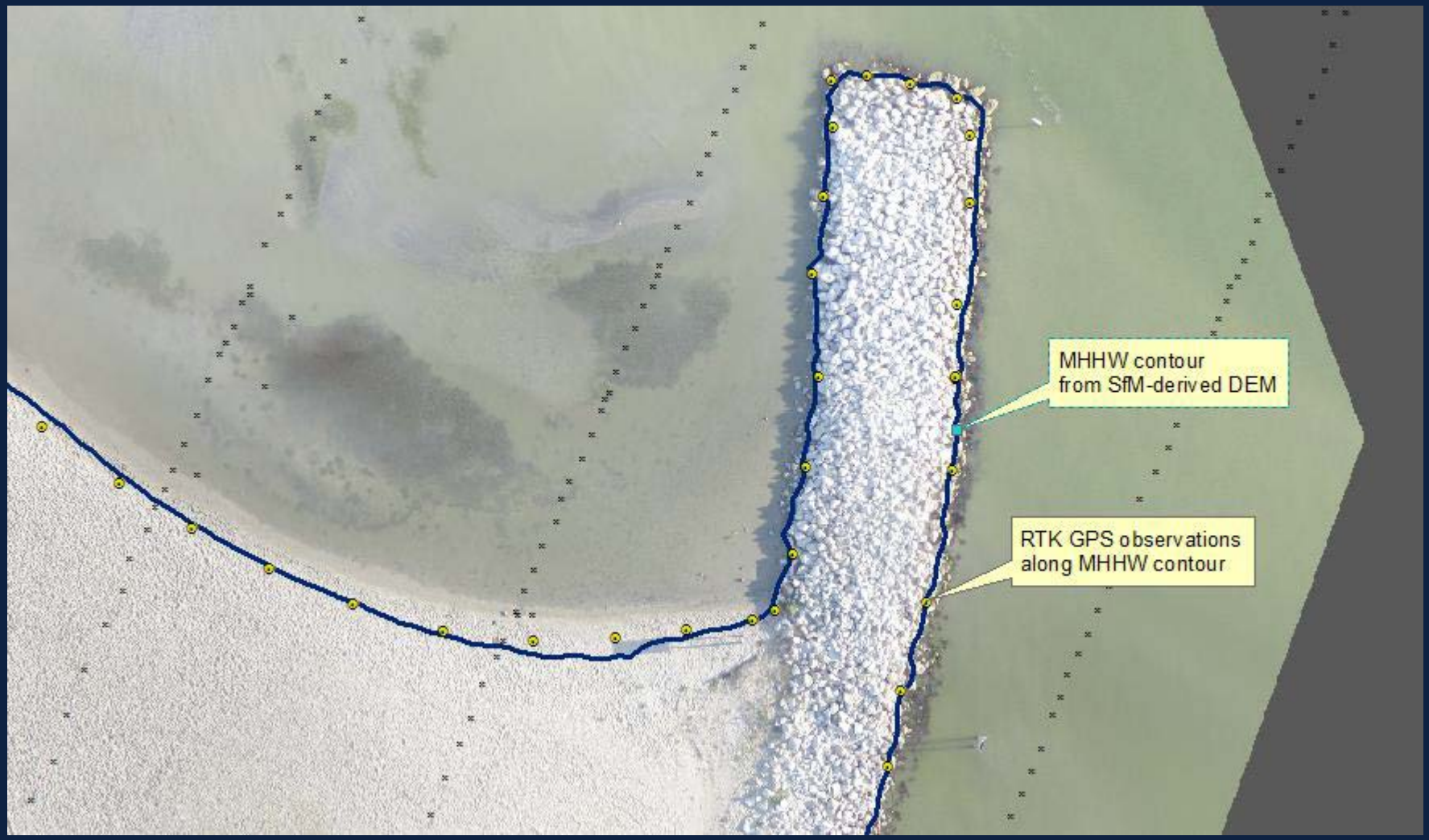
2’ x 2’ Targets

~3.6 cm resolution

SfM results were compared to RTK GPS surveys along transects



SfM MHHW contour versus RTK GPS



SfM shoreline shows good agreement

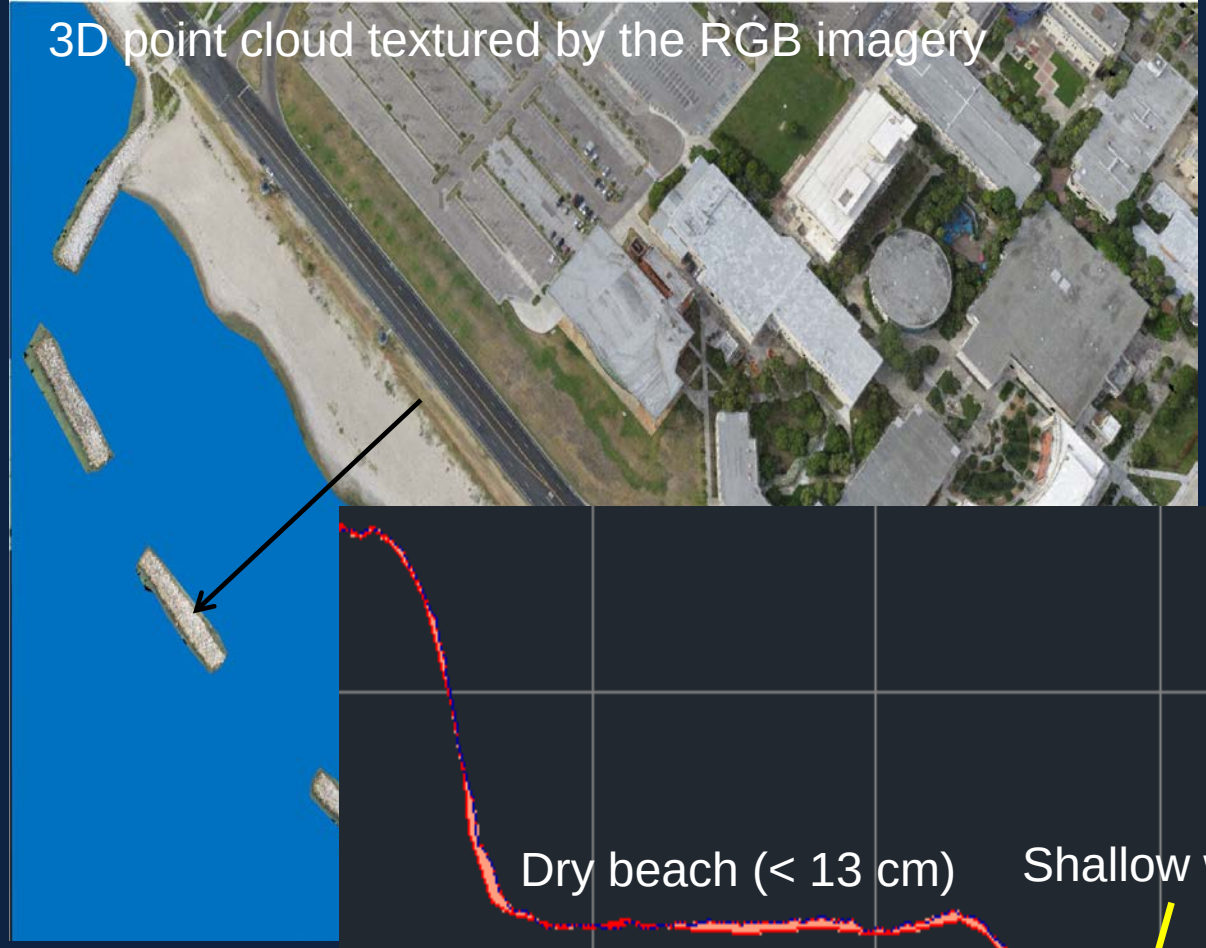
August 24 flight:
Average residual = -0.24 m, σ = 0.48 m

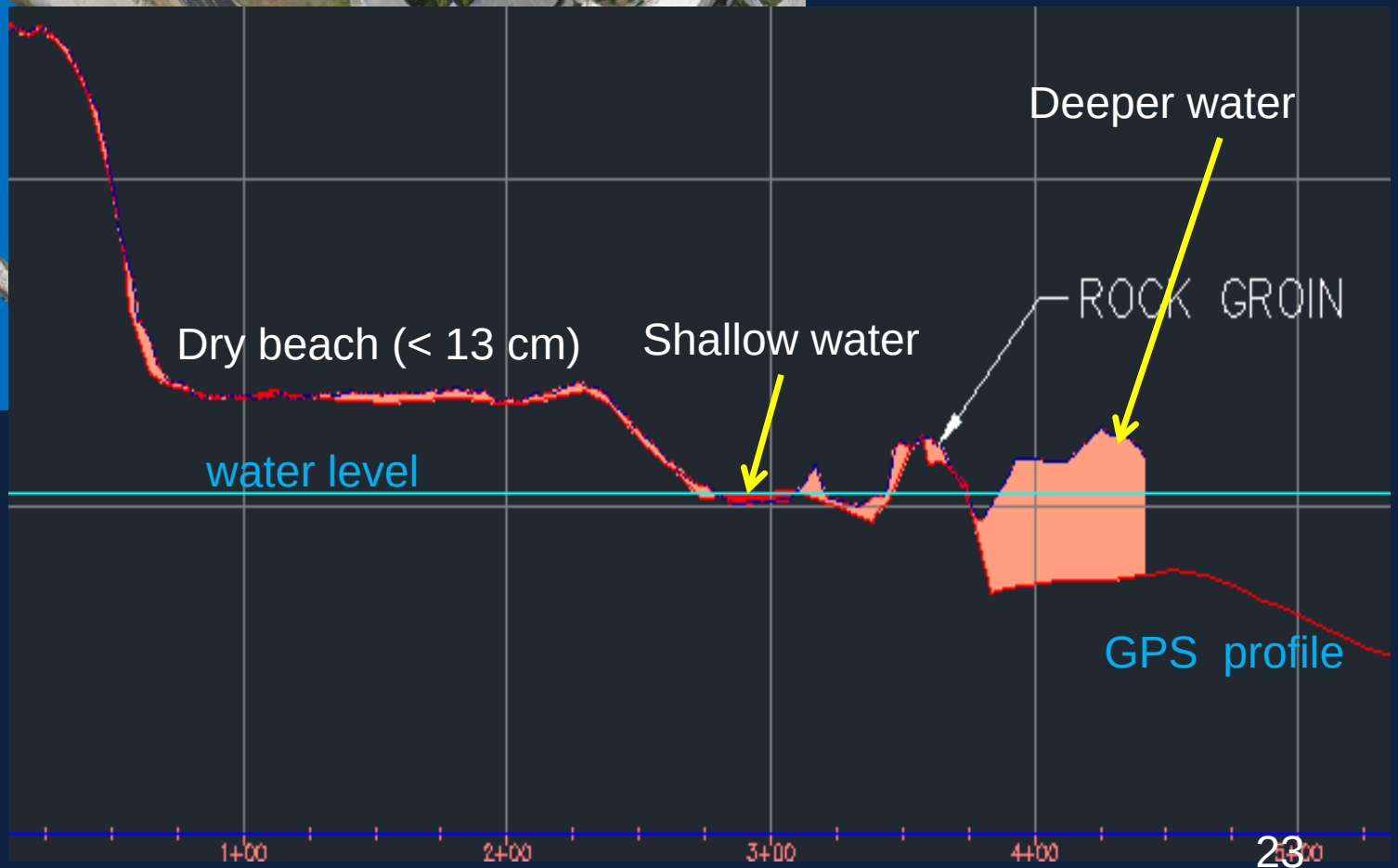
October 5 flight:
Average residual = 0.5, σ = 1.1 m

Challenges over Water

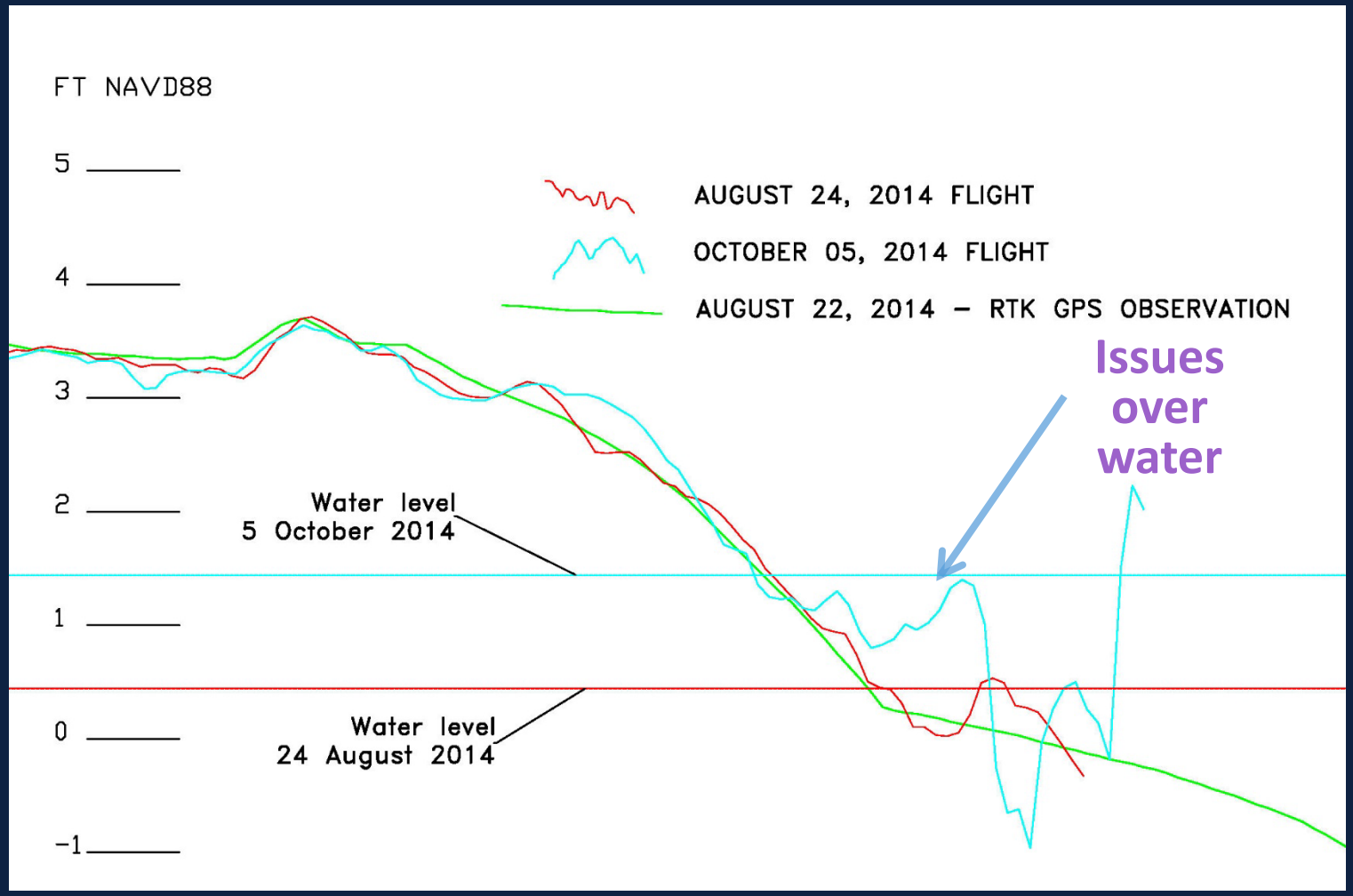
Beach Profile Comparison

(RTK GPS vs eBee)





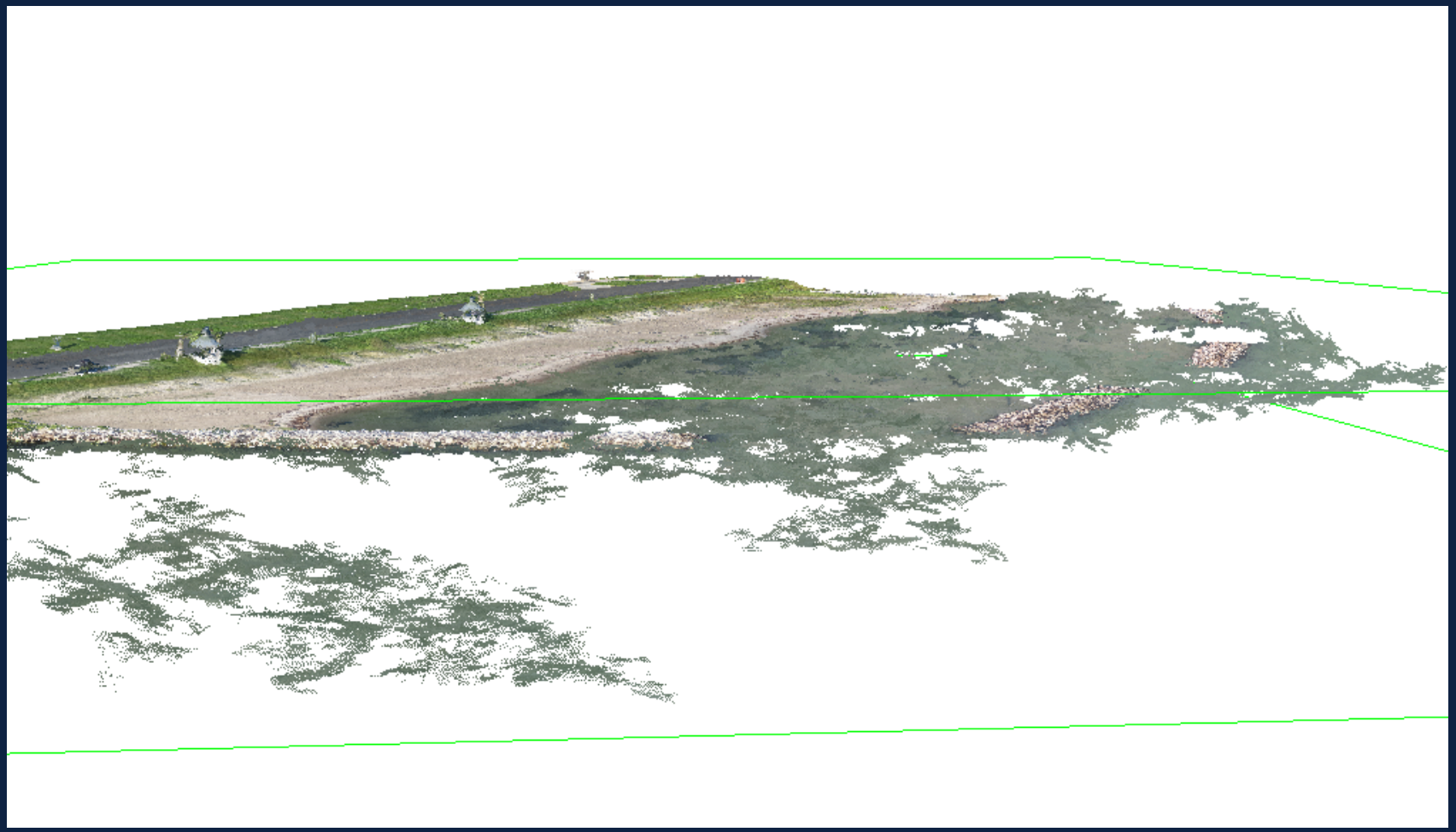
Profile Comparison across Surveys



October flight windier & higher altitude

Sub-surface SfM

Typical SfM densification over water



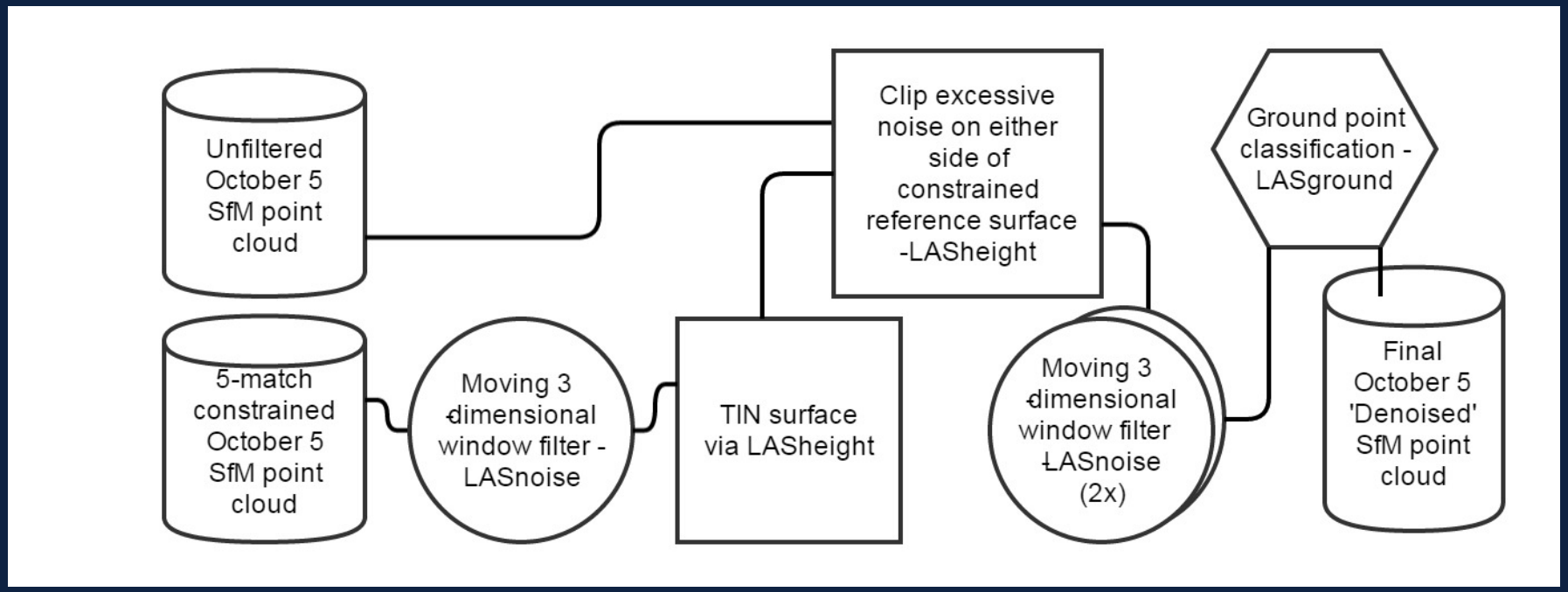
Lots of spurious returns and gaps due to glint, poor matching, surface water dynamics

Water Observations

- Matching successful in areas with visible texture (seagrass)
- Image scale did little to improve 3D densification
- 4+ and 5+ matched images reduces outliers at cost of reduced density
- 4+ and 5+ results nearly identical

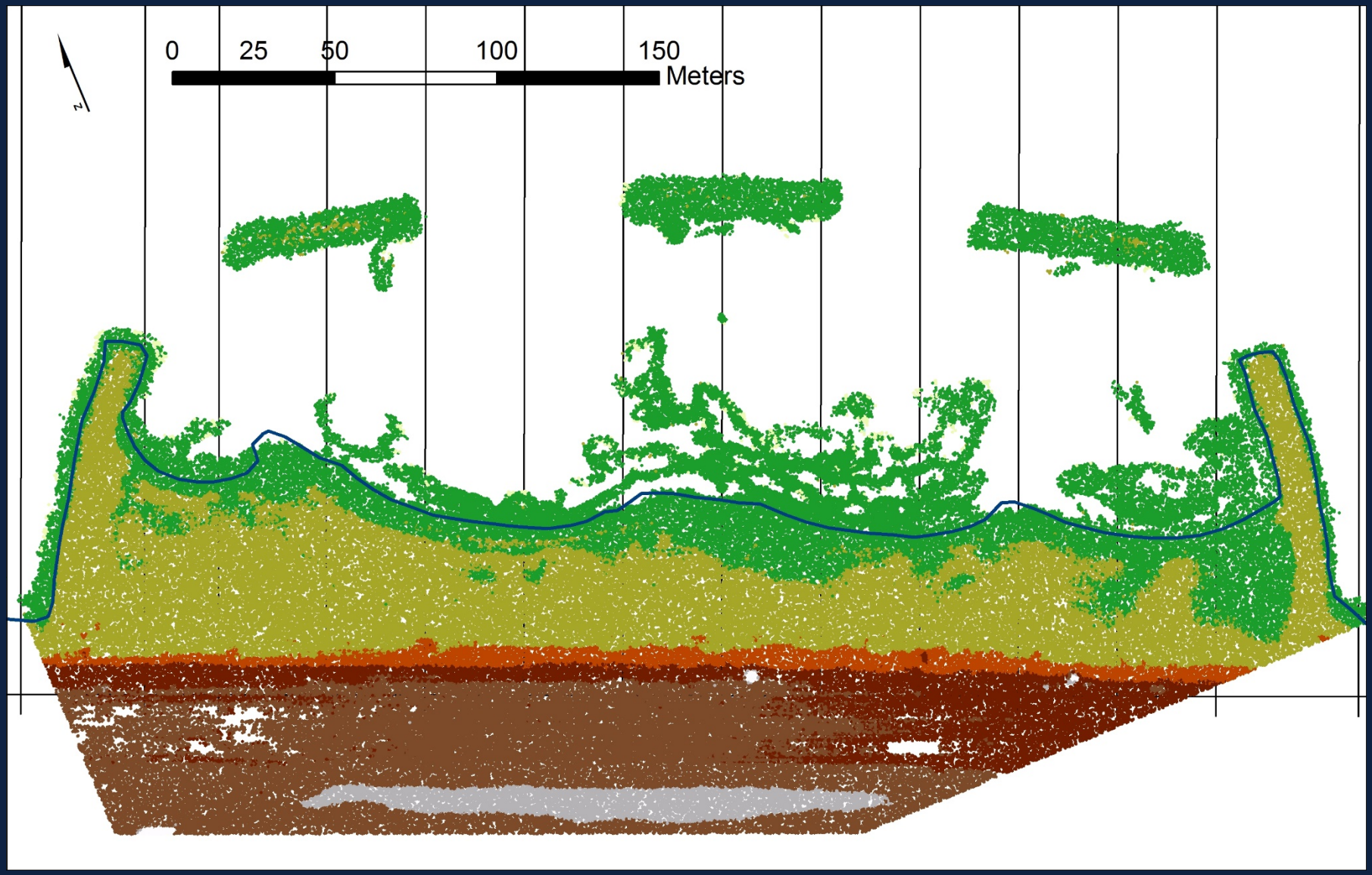
max depth ~1.5 m

Denoised filtering scheme for isolating “good” SfM substrate matches. Limited success



- Use 5-match point set to derive low res surface
- Remove spurious returns
- Apply TIN densification filter to segment bottom points

Different SfM Processing Examples



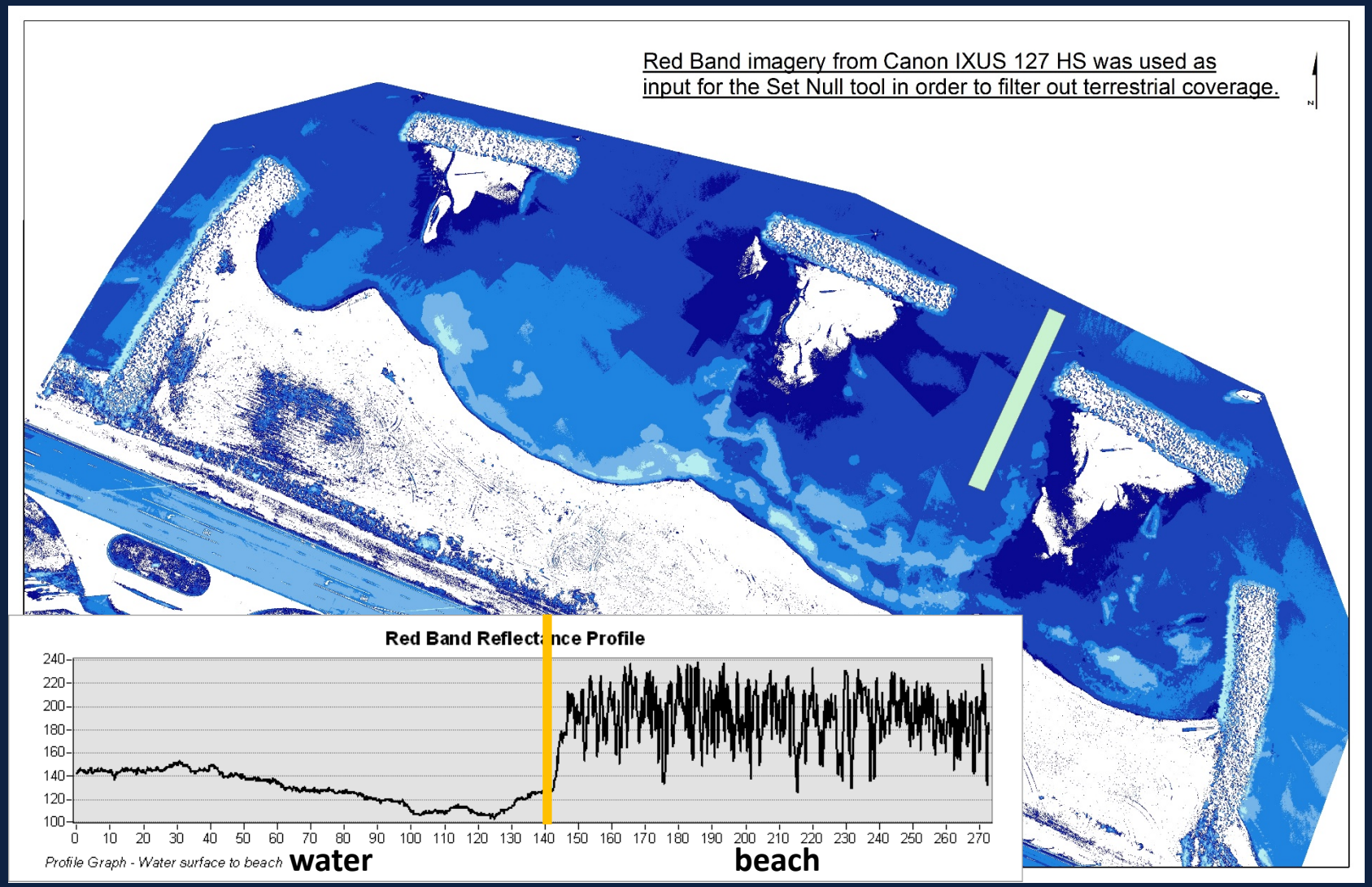
Undefined Ground
Defined Ground

Optical Inversion for use in Combination with SfM

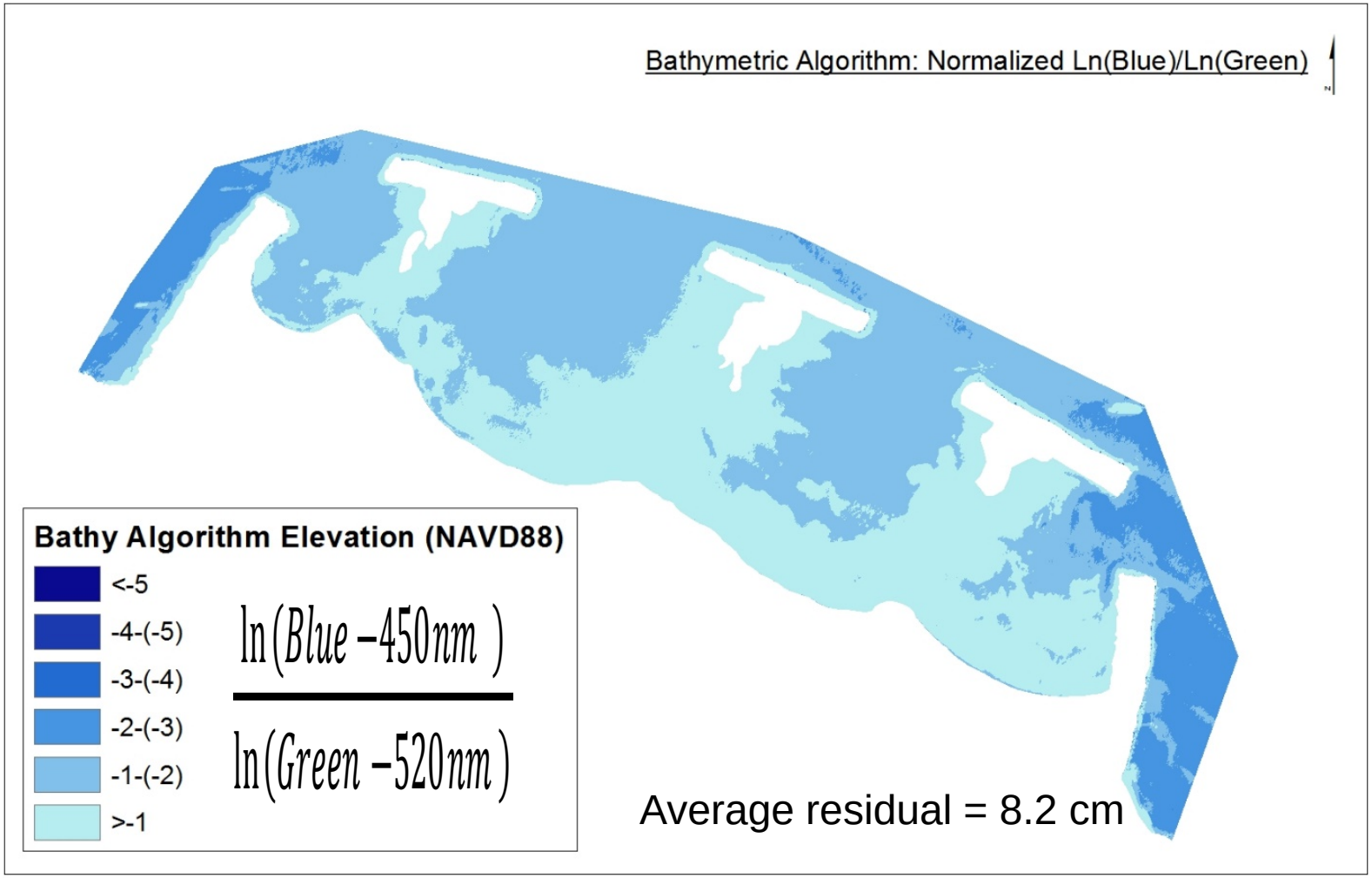
- Optical Inversion to derive depth map through calibration of band reflectance ratios
  - Linear fit to RTK GPS elevation
- Combine SfM denoised point cloud and optical inversion
  - Seamless DEM

October 5 flight

Analysis of red channel (660 nm) for segmentation of areal water cover

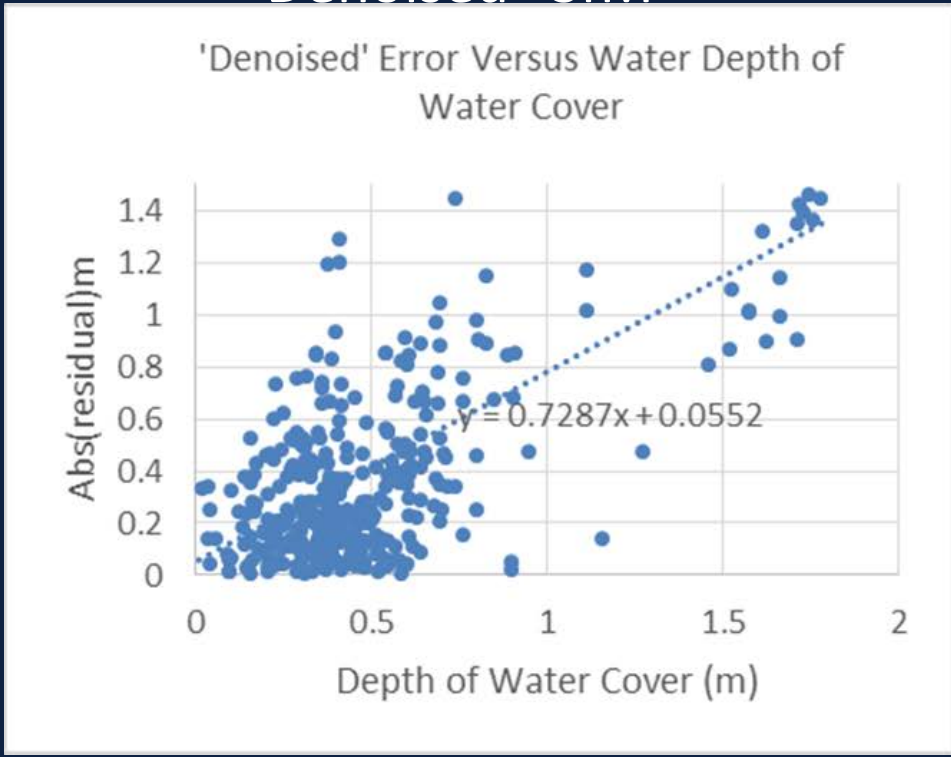


Bathymetry through Optical Inversion



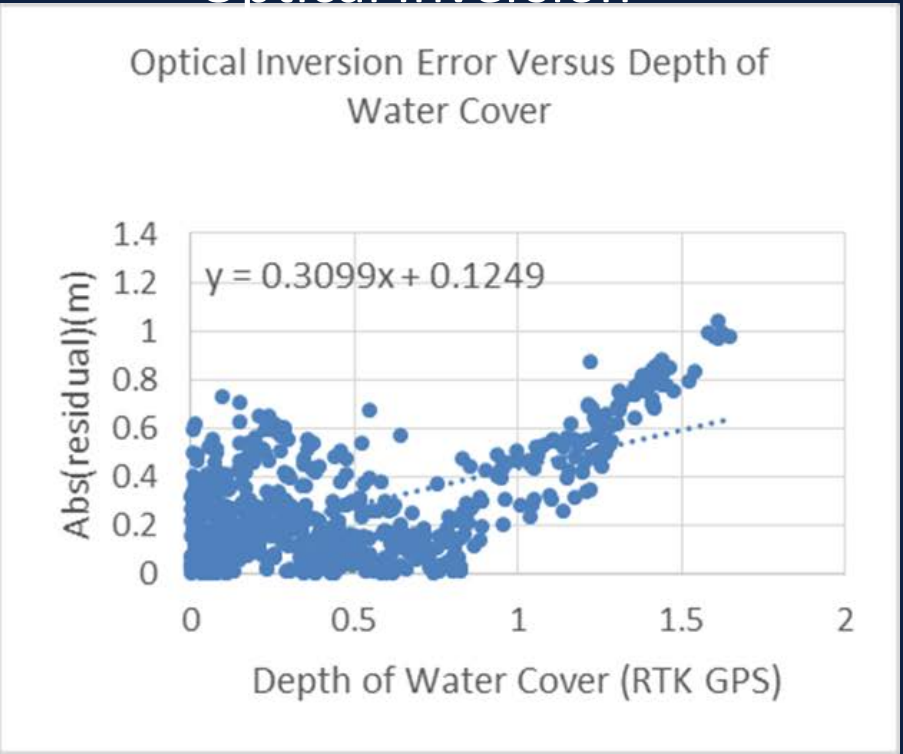
Error with depth

“Denoised” SfM



Larger slope
Mean error = -24 cm, σ = 25.4 cm

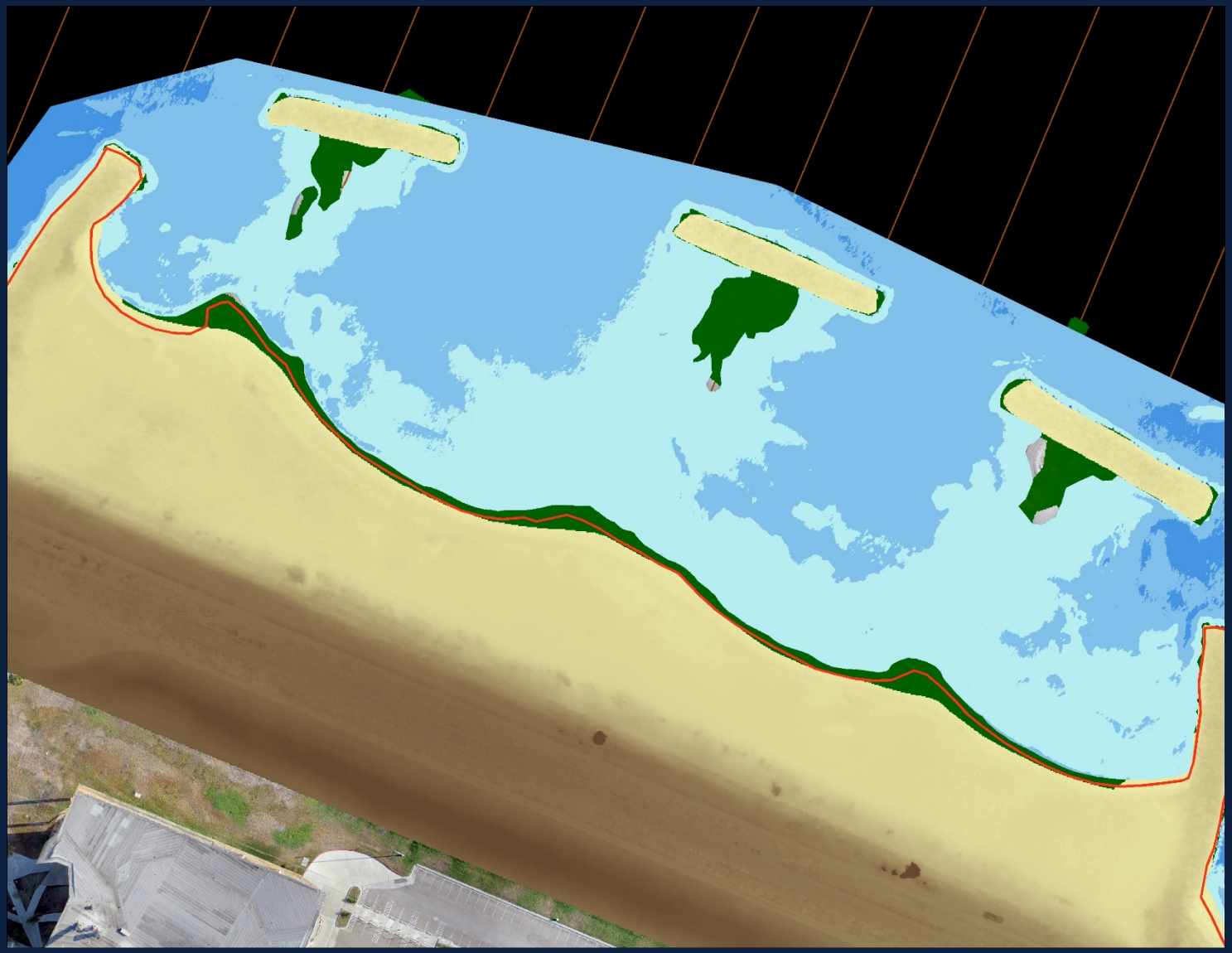
Optical Inversion



Smaller slope
Mean error = 8.2 cm, σ = 34.8 cm

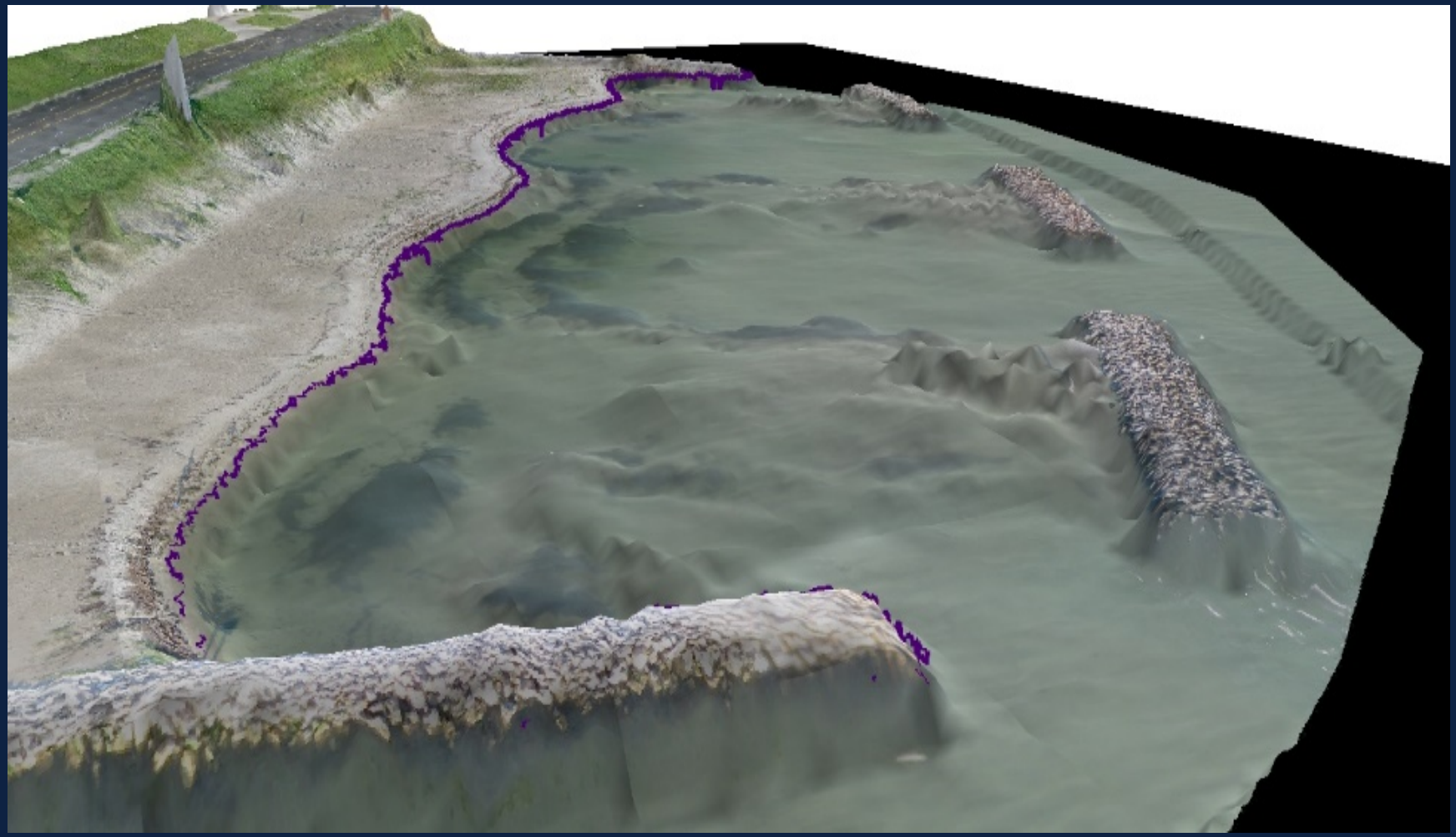
Hybrid Model

example of final product



Fused topo-bathy DEM

sub-aerial SfM beach +
SfM denoised bottom points +
optical inversion depth



Conclusions

- SfM for below water, even in shallow water is challenging…
- Best results from hybrid model but optical inversion limited due to 3 bands & calibration
- For certain applications…results promising
- Future work→ frequency filtering prior to SfM, refraction, blue channel only

Thank you JALBTCX

Questions??

Contact

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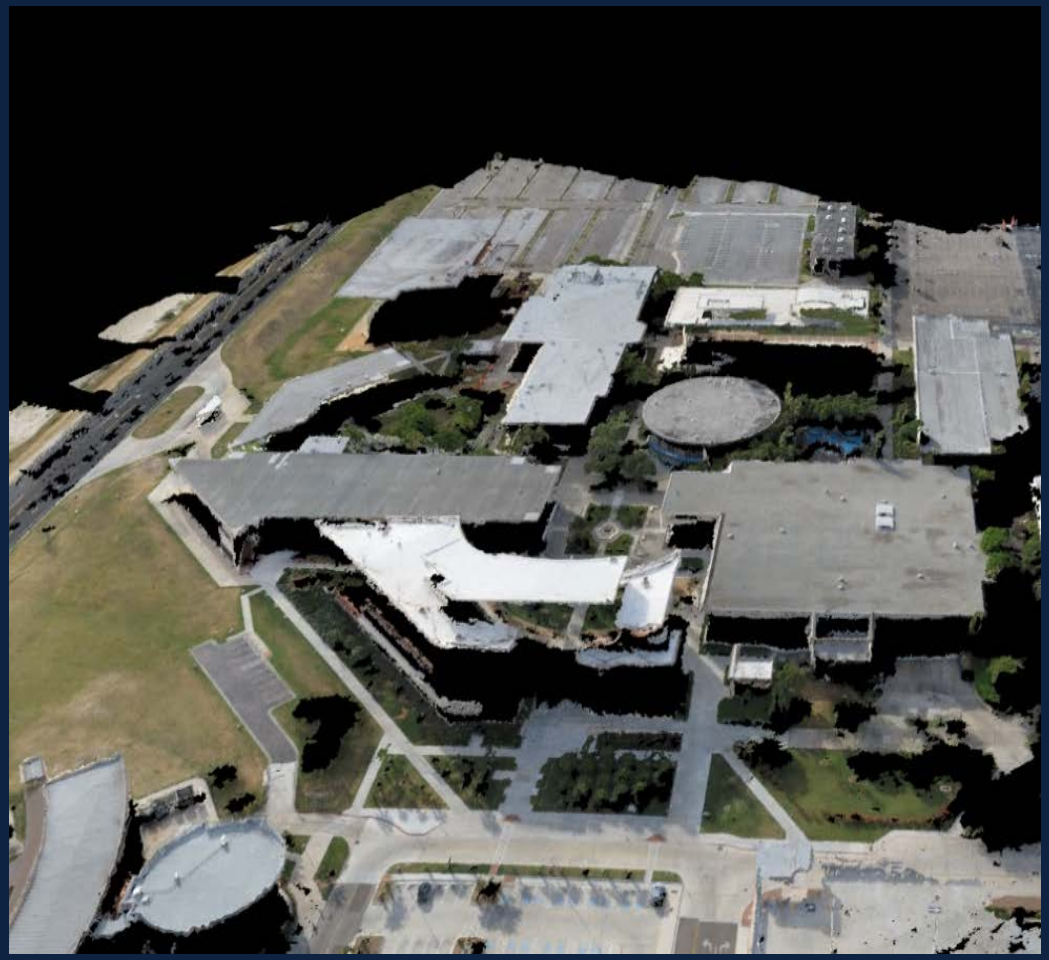

Example 3D point cloud; fly through