



U.S. ARMY

Bathy Lidar Specifications, Expectations, and Reality

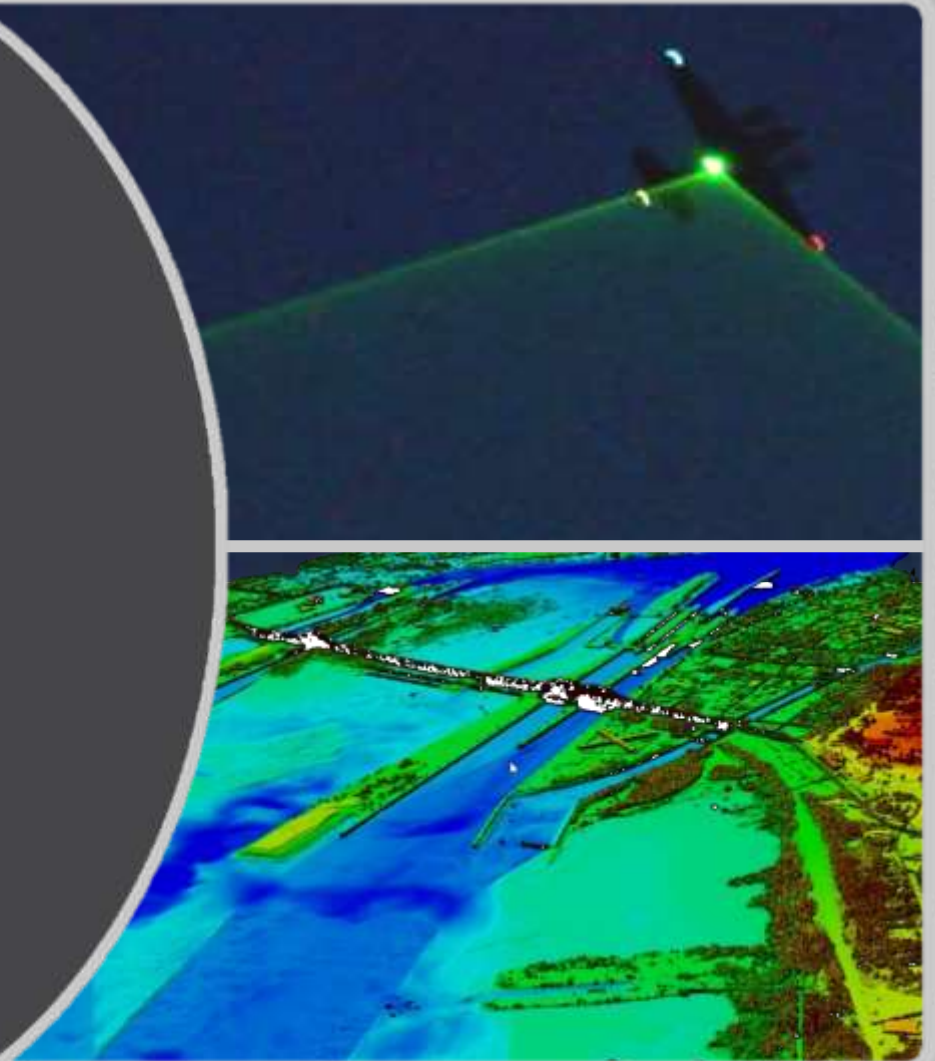
Christopher Macon

US Army Corps of Engineers - Mobile District – Spatial Data Branch

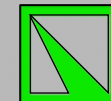
- Joint Airborne Lidar Bathymetry Technical Center of Expertise

Coastal GeoTools

29 January 2025



US Army Corps
of Engineers



JALBTCX
Joint Airborne Lidar Bathymetry
Technical Center of Expertise

Joint Airborne Lidar Bathymetry Technical Center of Expertise



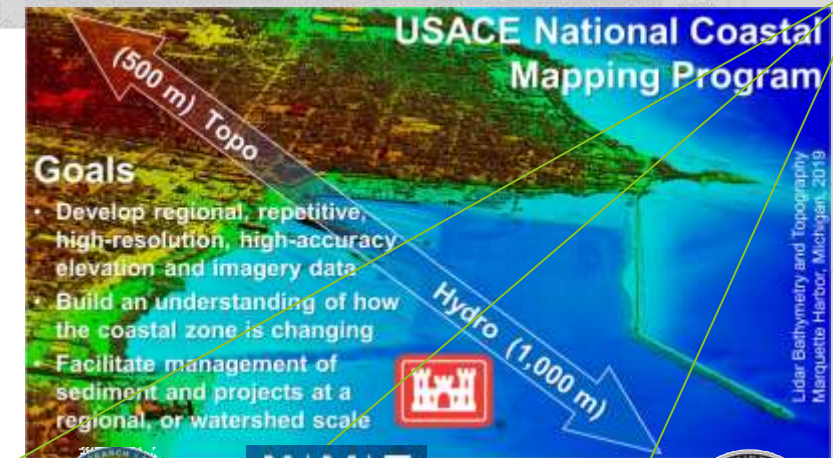
@Stennis International Airport, Kiln, MS

**Mission: Operations and R&D in
airborne lidar bathymetry and
complementary tech for airborne
coastal mapping and charting**

- 25-year collaboration among USACE, Navy, NOAA, & USGS
- Government, industry, and academia partner to advance technology and its application to coastal challenges
- Developed 3 three generations of coastal mapping and charting sensors to meet the needs of the partner agencies
- Government and industry sensors are operated year-round & world-wide to meet JALBTCX partner mission requirements for coastal engineering and science, and nautical charting.

New and Now in Lidar - Part 2

https://www.youtube.com/watch?v=ryRAuuC_Hu4&list=PLpwalEzRB4pi7J29rTrSSGWt582_zs2XU&index=4

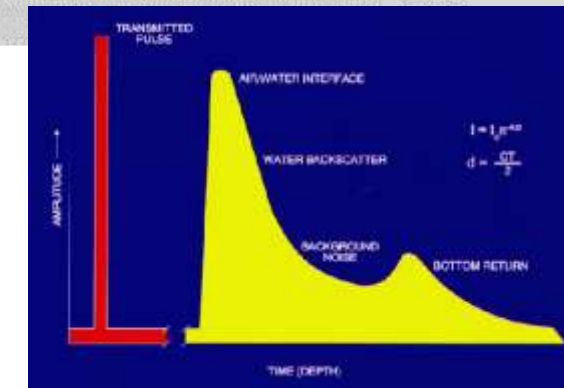
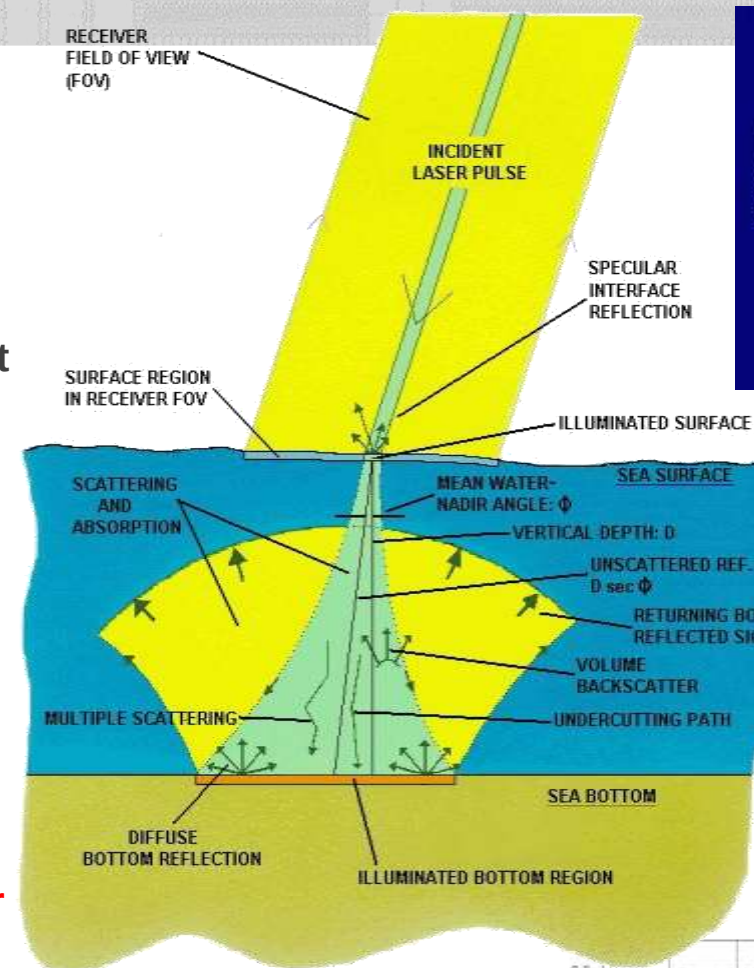


25 YEARS

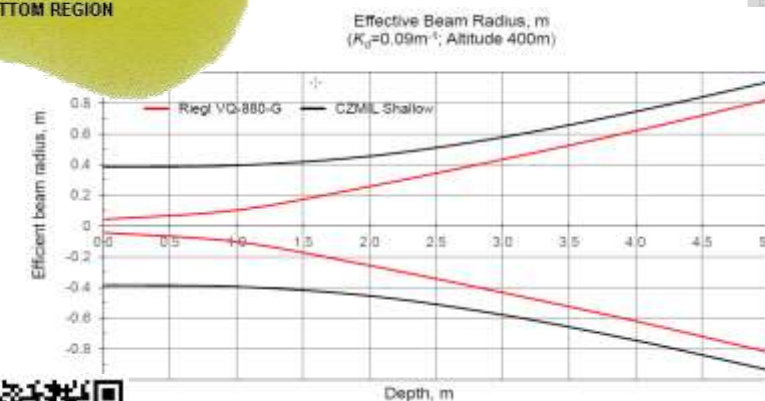


Bathy Lidar Basic Principles

- Location of the water surface is important—light changes speed and direction there(**data bias**)
- You will not get a return for every laser pulse you send out primarily due to turbidity(**expectations**)
- Sensor performance may be less than advertised if bottom reflectance in survey area is less than bottom reflectance assumed on manufacturer specification (bright white sand has 20% reflectivity) (**dependencies?** **best practice?**)
- Propagation induced depth bias is important as water becomes optically deep (4 m in S. FL water) (**understand**)
- Points per square meter becomes less meaningful once laser energy hits the water (validate with ground truth across the depth range of the survey)(**density-depth-water dependent**)
- A deep water system gives better depth capability at the expense of spatial resolution in very shallow water
- A shallow water system can produce higher resolution data at the expense of depth capability
- Deep water systems spatially subsample the laser footprint(**clarify**)



Location	CZML max depth (m)	K_d (m^{-1})
Fort Lauderdale, FL	40	0.1
USACE FRF, Duck, NC	12 20	0.21 0.35
Cat Island, MS	4	0.95



Bathy Lidar: Harder Than It Looks , Kirk Waters

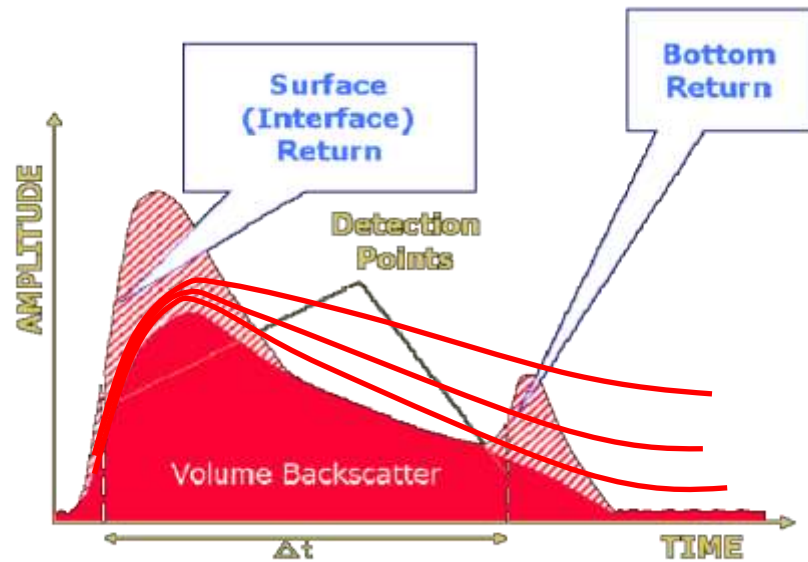
<https://geozoneblog.wordpress.com/2013/09/25/bathy-lidar-harder-than-it-looks/>



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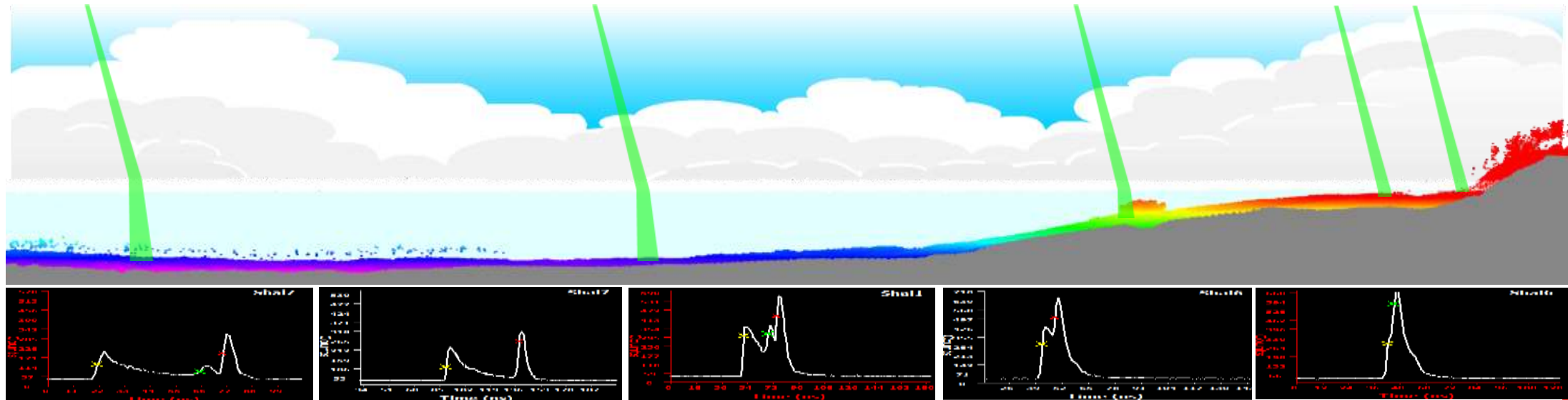
Bathy Lidar Basic Principles



$$P_R = \frac{P_T \eta \rho F_p A_r \cos^2(\theta)}{\pi(n_w H + D)^2} e^{-2n(s, \omega_0, \theta) K_d D \sec(\phi)}$$

$P_R < \text{Detection Threshold} \rightarrow \text{No bathymetry!}$

Kashani, A.G., M.J. Olsen, C.E. Parrish, and N. Wilson, 2015. A Review of Lidar Radiometric Processing: from ad hoc Intensity Correction to Rigorous Radiometric Calibration. *Sensors*, Vol. 15, pp. 28099-28128.



Brief History: *Bathymetric Lidar*

1969: Paper by Hickman and Hogg - airborne bathymetric lidar measurements over Lake Ontario on Turbo Commander aircraft

1977: Successful testing of Atmospheric Oceanographic Lidar (AOL)
Joint NASA, NOAA project

1984: LARSEN-500 bathymetric lidar system (Optech, Terra Surveys Ltd., Canadian Hydrographic Service)

First operational hydrographic system

Designed to support nautical charting missions in Arctic

1986-1989: Development of Australian WRELADS and LADS, and Swedish FLASH systems; USACE begins SHOALS program

1990s: LADS (now owned by Fugro), SHOALS (Optech), and HawkEye (now Leica/AHAB) operational

Commercial ALB gaining momentum

2000s: LADS Mk 2 (and later Mk 3), Optech SHOALS-1000 and -3000TH, AHAB HawkEye II, NASA EAARL (later USGS EAARL-B)

Introduction of narrow-divergence, lower-power, high-rep-rate system with EAARL

2010 - Present: Optech CZMIL SuperNova, Hexagon/ Leica Chiroptera-5 and HawkEye-5, Riegl VQ-880-GH and VQ-840-GL, Arete/Fugro PILLS/RAMMS, etc., etc.



Hickman and Hogg, 1969. Application of Airborne Pulsed Laser for Near Shore Bathymetry Measurements. *Remote Sensing of Environment*



JALBTCX Bathymetry Lidar Base Specification

Status: final comment cleared

Contributors

USACE

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USGS

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Details

- Started at the request of USGS for an inland lidar bathymetry specification
- Also serves as basis for lidar section, bathymetry chapter, Standard Ocean Mapping Protocol for Interagency Working Group on Ocean and Coastal Mapping
- Started with the USGS 3DEP spec
- Maintained details of LAS implementation and Lidar Mapping Report
- LAS Domain Profile (LDP): Topobathy Lidar Version 2.0, The minimum required classification scheme for bathymetric lidar data includes codes 1, 2, and 40(bathy).
- Added sections regarding requirements for seamless data collection, water clarity in rivers, handling data voids, bathy-specific details for Collection Conditions
- Added accommodation for ISO metadata standards, alternate waveform delivery format, and definitions for intensity processing
- Removed requirements for hydroflattening and breaklines
- Topographic data will follow 3DEP spec, with the exception of hydroflattening
- Requires delivery of point cloud data referenced to ellipsoid
- Moved to vertical and horizontal uncertainty like IHO acoustic practices
- Minimum depth, system performance, intensity processing levels, and product grid resolutions were initially specified but eventually left to partners to manage so spec remained product and not sensor focused

Criteria									
THU (Constant, m)	20		4	2					
THU (Variable, % of Depth)		10	5	2					
TVU (Constant, m)		0.5	0.3	0.2					
TVU (Variable, % of Depth)	0.05	0.02	0.013	0.0					
Sample Density (Samples/m ²)	0.04	0.25	2	3					



System performance (secchi factor or Kd*MaxDepth) (@15%reflectance)	5	4	3	2.5	2	1.5	1.25	1	0.75	0.5
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Classification Value	Name	Meaning
40	Submerged Topography	For example, the seafloor or riverbed; also known as bathymetric points or bathymetric bottom.
41	Water Surface	Water surface of sea, river, lake, or other body of water, typically used in refraction. This is distinct from ASPRS Class 9, which is used in topographic-only lidar and only designates "water," not "water surface."
42	Derived Water Surface	Synthetic water surface location used in computing refraction at water surface.
43	Submerged Object	Submerged obstruction or structure, not otherwise specified (e.g., wreck, rock, submerged piling).
44	(Reserved)	(Reserved for potential future IHO classification)
45	Water Column Default	Unclassified submerged (i.e., refracted) returns within the water column not otherwise identified as submerged topography, object, vegetation, or noise; e.g., submerged backscatter.
46	Submerged Vegetation	Submerged aquatic vegetation occurring below the water surface (Class 41) and above the bathymetric bottom (Class 40), especially seagrass; also known as benthic cover or biological cover.
47	Submerged Noise	Noise points resulting from system errors and anomalies, not representative of real objects. Similar to ASPRS Class 7, except that Submerged Noise is below the water surface. Also known as bathymetric noise or submerged low point.



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Bathy Lidar Base Specification – Criteria Matrix

The following table contains a range of reasonable specifications for total horizontal uncertainty, total vertical uncertainty, and sample density for existing and emerging bathymetric lidar systems. Definitions for these terms are in the glossary. Shaded cells outlined in black are minimum specifications to meet interagency requirements. These specifications apply to bathymetric lidar data collected as part of a topobathymetric lidar survey. Topographic data collected as part of topobathymetric lidar survey shall follow specifications and procedures in the 3DEP specification.

Positional uncertainties shall be expressed **at the 95%** confidence level. Uncertainty and confidence levels are used here in practice as outlined in IHO's S-44 Edition 6.1.0 and defined in the *Guide to the Expression of Uncertainty in Measurement*, JCGM 100:2008.

Bathymetric measurements have depth-dependent and depth-independent error sources which are reflected in the matrix table as a constant plus percent of depth for total horizontal uncertainty (THU) and in the total vertical uncertainty (TVU) formula: $TVU(d) = \sqrt{a^2 + (b * d)^2}$

Where **a** is the portion of uncertainty that does not vary with depth, **b** is the coefficient representing the portion that does vary with depth, and **d** is depth.

Table 1. Matrix of uncertainties and sample density for bathymetric data. All uncertainties are expressed **at the 95%** confidence level

Criteria							
THU (Constant, m)	20	10	4	2	1	0.5	0.25
THU (Variable, % of Depth)		10	5	2	1		
TVU (Constant, m) a	1	0.5	0.3	0.25	0.2	0.15	0.1
TVU (Variable, 1, Depth Dependent) b	0.05	0.02	0.013	0.01	0.0075	0.004	0.002
Sample Density (Samples / m ²)	0.04	0.25	2	3	5	10	20

Matrix Description and Guidance

The use of selectable criteria from a matrix table was chosen as the range of sensors and applications of data continue to broaden. As stated in the IHO S-44 Edition 6.1.0 from which this approach was taken, this design allows flexibility in tasking and can evolve with future editions of this specification.

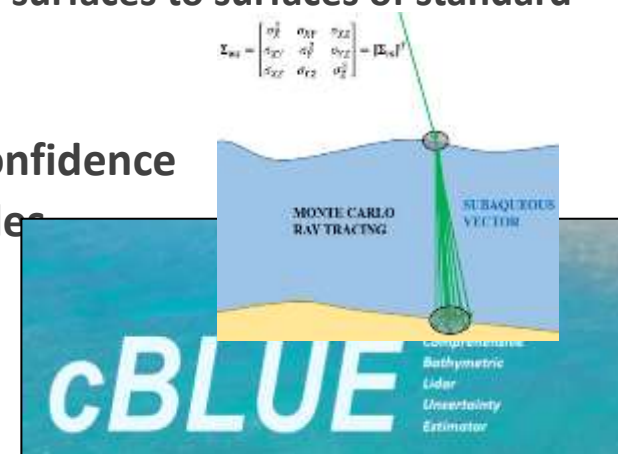


Bathy Lidar Base Specification – TPU

- The preferred form of data assessment is computation of Total Propagated Uncertainty (TPU). In absence of validated TPU, an acceptable alternative is computation of standard deviation. Requirements for TPU and standard deviation for precision are defined below.

Total Propagated Uncertainty

- TPU may be calculated using parametric uncertainty estimates, such as those in NOAA's TPU tool "cBlue" (<https://research.engr.oregonstate.edu/geomatics/noaa-tpu> , <https://github.com/parrishOSU/cBLUE.github.io>).
- ([https://github.com/ASPRSorg/BWG/wiki/Total-Propagated-Uncertainty-\(TPU\)-in-Bathymetric-Lidar](https://github.com/ASPRSorg/BWG/wiki/Total-Propagated-Uncertainty-(TPU)-in-Bathymetric-Lidar))
 - Video link – see 7.12.2024 BWG webinar
https://drive.google.com/drive/folders/1pgZrV4Ob_x38Vi7OETJ8yJDtR4fr6WOj
- Manufacturer computed TPU may also be acceptable but must be validated by comparing TPU surfaces to surfaces of standard deviation.
- Delivery will be:
 - Outputs from the cBlue tool or manufacturer software (expressed at the 95% confidence (see tiling scheme) Tiling scheme shall be consistent with other raster deliverables
 - ...
 - Xm x Xm band stacked raster models (GeoTIFF format). Cell size(X) equal to (1/√Sample Density), rounded up to the next integer, then doubled (Cellsize=CEILING (1/√Sample Density) ×2)
 - ...
 - Band 1 shall be THU.
 - Band 2 shall be TVU.
 - ...
 - Class 40 shall be used.
 - Use of class 43 and 46 will be project dependent.
 - Non-valid data shall be set as "nodata."
 - ...
 - THU and TVU will be delivered with the las records as attributes using extra byte variable length records as specified by the LAS Domain Profile Topobathy Lidar version 2.0 (ASPRS, 2023)



* Requirement for absolute vertical accuracy assessment and reporting in wading depths may be specified.

Bathy Lidar Base Specification – Positional Accuracy Validation

- Prior to classification and development of derivative products from the point data, the absolute accuracy (if required) and data internal precision of the point data shall be verified, and a detailed report of the validation processes used shall be delivered.

Standard Deviation

- Data shall be qualitatively evaluated using standard deviation rasters.

- Deviation rasters at adjacent, overlapping parallel swaths and lifts as well as cross-tie swaths show internal precision concerns related to calibration, navigation, processing, surface modeling, and classification. As a majority of the bathymetric lidar systems use some form of an elliptical scanner, the deviation rasters also support within-swath evaluations.
 - GeoTIFF format raster with a cell size equal to $(1/\sqrt{\text{Sample Density}})$, rounded up to the next integer, then doubled ($\text{Cellsize} = \text{CEILING}((1/\sqrt{\text{Sample Density}})) \times 2$).
 - (see tiling scheme) Tiling scheme shall be consistent with other raster deliverables.
 - Class 40 shall be used.
 - Use of class 43 and 46 will be project dependent.
 - Non-valid data shall be set as "nodata."

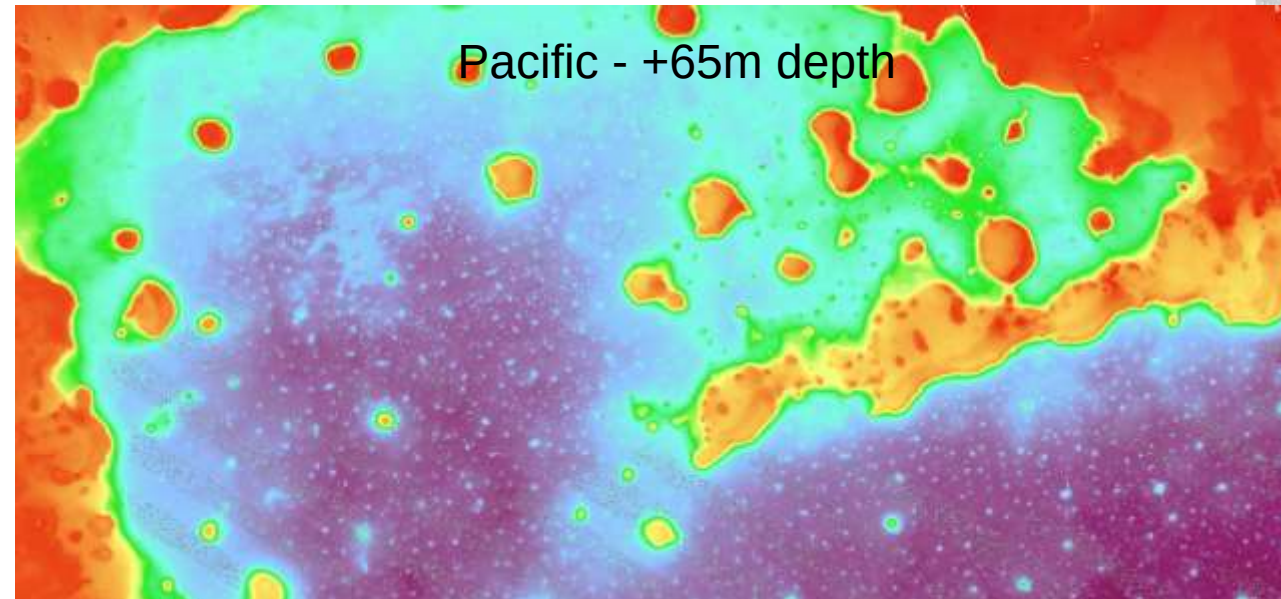
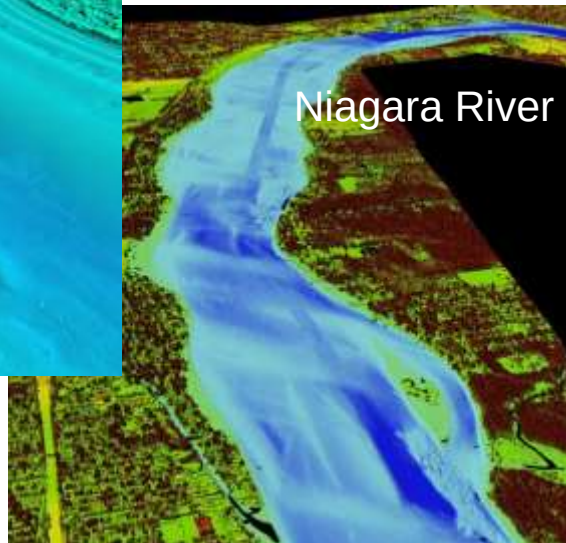
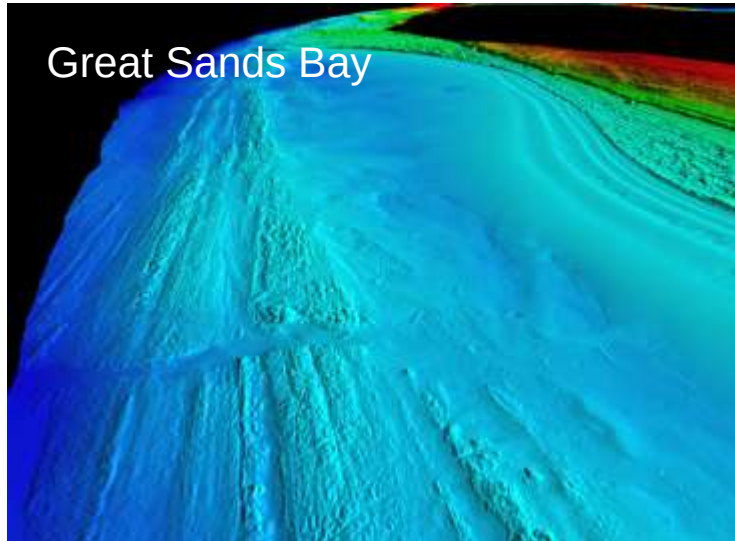
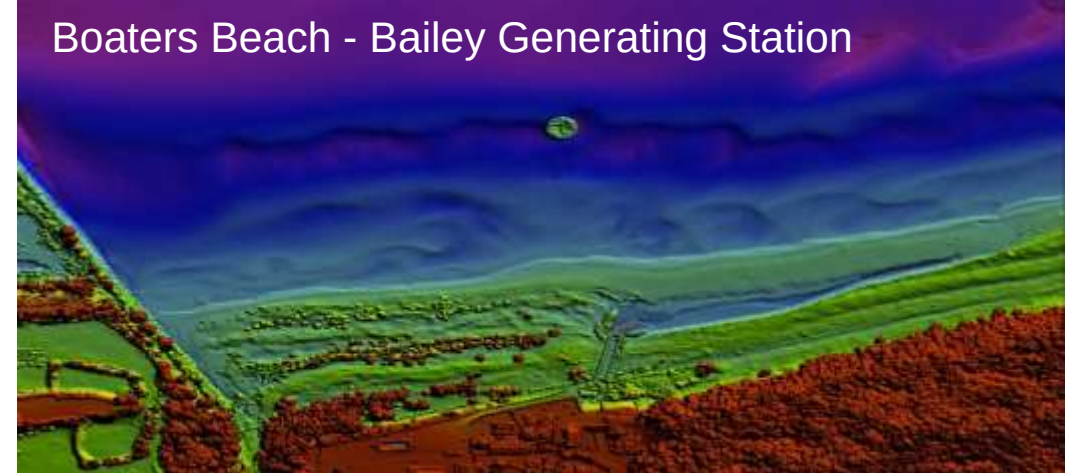
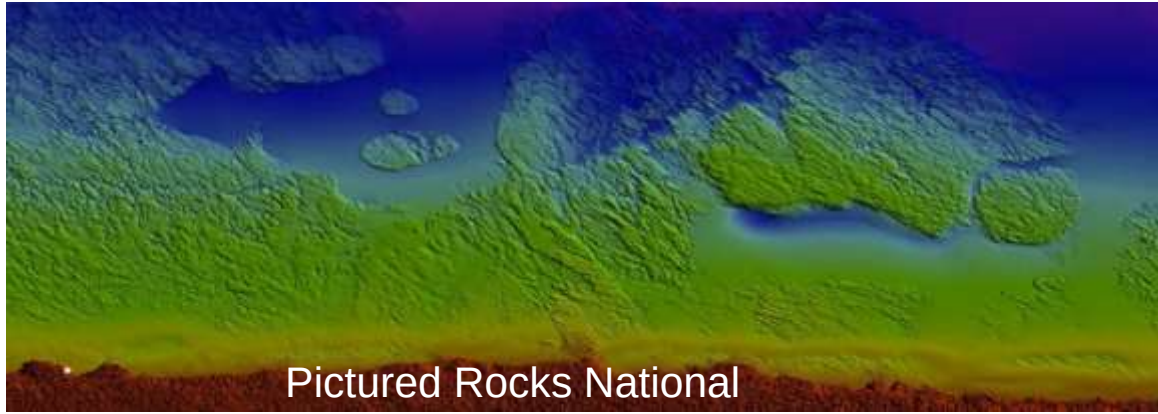
Swath Separation Images

Description: Swath separation images (figure 4) use color-coding to illustrate differences in elevation (z-) values where swaths overlap. The color-coded images are semi-transparent and overlay the lidar intensity image. They are ancillary metadata used as visual aids to more easily identify regions within

- Breaks are:
 - 0-8 cm: GREEN;
 - 8-16 cm: YELLOW;
 - > 16 cm or > last additional color ramp bin value: RED (for example, addition of ORANGE pixels for the range of 16-24 cm would require red pixels to represent > 24 cm).

Swath separation and deviation-precision quantitative pass-fail values for bathy lidar TPU criteria are not defined. While agreement that Topo USGS QL2 swath to swath separation images generally work for expected navigation and surface related error, best practices and guidelines for swath separation and deviation need work to support applicable, acceptable ranges for the selected uncertainty allowances.

Bathy Lidar Basic Pretty Pics Break



Bathy Working Group – Goals

ASRPS Community Mission - Collaborate with peers to share strategic advice, solve challenges and develop new approaches.

Bathy Working Group Mission - **Advance** the ~~bathy spec~~ **bathy lidar** through coordination with related specifications and updates, define clear goals, **promote** industry **standard practices**, **enhance** user **understanding**, and continuously **improve** the **practice** through a productive feedback mechanism.

Foster collaborative, forward leaning attitude to tackle community barriers
“A rising tide lifts all boats”

Bathy Lidar Barriers

- Different systems, difference processes, different results = my problem. What do I do? Tell me.
- I don't understand the data dependencies and why do we have to repeat such a complicated conversation? I just want good data, now. Help.
- This looks different than I expected. I thought it was like topo lidar. I thought it was like sonar.



Bathy Lidar Basic Practice



“It is relatively easy today to build a lidar system that can detect the sea bottom. It continues to be **very difficult to build an accurate lidar bathymeter**. Accuracy is attained by thoughtful design of hardware capability and software algorithms and by establishing procedures for limited manual interaction with the data.” Guenther 2000

“The hardware and software may change, but the physics doesn’t”
Guenther 2019

Hardware optimization, algorithm implementation, and processes through products must be carefully considered for the application.

Airborne laser hydrography : system design and performance factors. 1985 Guenther,G
<https://repository.library.noaa.gov/view/noaa/2811>

MEETING THE ACCURACY CHALLENGE IN AIRBORNE LIDAR BATHYMETRY.
Proceedings of EARSeL-SIG-Workshop LIDAR, Dresden/FRG, June 16 – 17, 2000.
Gary C. Guenther¹, A. Grant Cunningham², Paul E. LaRocque², and David J. Reid²

Philpot, W. (Ed.), 2019. *Airborne Laser Hydrography II*, Ithaca, NY: eCommons.
<https://ecommons.cornell.edu/handle/1813/58722>

Bathy Working Group – Problems? GOOD!

Foster collaborative, forward leaning attitude to tackle community barriers

“A rising tide lifts all boats”

Bathy Lidar Barriers

- ~~Different systems, difference processes, different results = my problem. What do I do? Tell me.~~

GOOD! We are leveraging advancements in science to do more. We have several UAS options, evolving linear lidar systems, space-based platforms, pushbroom imaging style lidars, 10,000ft AGL sensors, and competition in the market for unique solutions and data needs.

BUT

We share challenges and need to understand them.

*“Advances in technology in the next decade could conceivably provoke alterations in design concepts. The four following examples are problem areas in which specific solutions will need to be carefully developed: **propagation-induced bias correction, surface uncertainty, signal processing, and spurious responses**. All are related to a single primary concern -- depth measurement accuracy.”*

“These problems must be properly addressed and solved for each individual system if international hydrographic accuracy standards are to be met. Prospective contractors should be directed to provide detailed solutions in their proposals.” 1985 Guenther

<https://lidarmag.com/2014/11/28/10-commandments-for-the-lidar-data-user-from-myths-to-utilization/>

Bathy Working Group – Problems? GOOD!

Foster collaborative, forward leaning attitude to tackle community barriers

“A rising tide lifts all boats”

Bathy Lidar Barriers

- ~~• Different systems, difference processes, different results = my problem. What do I do? Tell me.~~

GOOD! HELP!

- “With geospatial mapping practices and technologies evolving quickly, users need guidelines on how to keep up.” Change #8 to ASPRS Accuracy Standards.
 - **Support** Best Practice efforts
- Continue to **share** our common challenges but also those unique to a particular sensor.
 - Accept and appreciate customs solutions but know their limits.
 - Keep your secret sauce, you’ve earned it.
- Help enhance our **understanding**.
 - Translate and summarize all the great papers on bathy lidar(info overload)
 - Simplify challenges for our users
 - Obey the 10 Commandments for the Lidar Data User(They apply to bathy lidar. Horses for courses)

Bathymetric Lidar Best Practices

[Calibration and Validation](#)

[Acquisition](#)

[Data Processing & Handling](#)

[Deliverables](#)

<https://lidarmag.com/2023/10/06/the-asprs-positional-accuracy-standards-edition-2/> Dr. QassimA. Abdullah

<https://lidarmag.com/2014/11/28/10-commandments-for-the-lidar-data-user-from-myths-to-utilization/>

<https://coast.noaa.gov/data/docs/geotools/2017/presentations/Nayegandhi.pdf>

Bathy Working Group – Problems? GOOD!

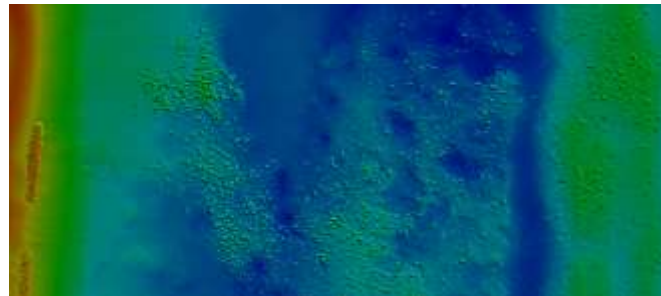
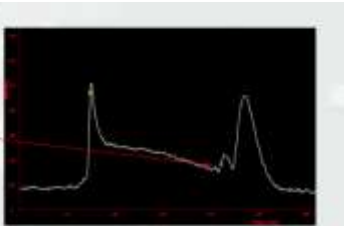
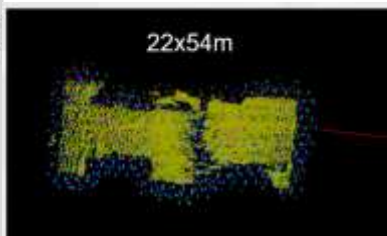
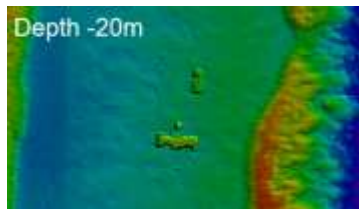
Foster collaborative, forward leaning attitude to tackle community barriers

“A rising tide lifts all boats”

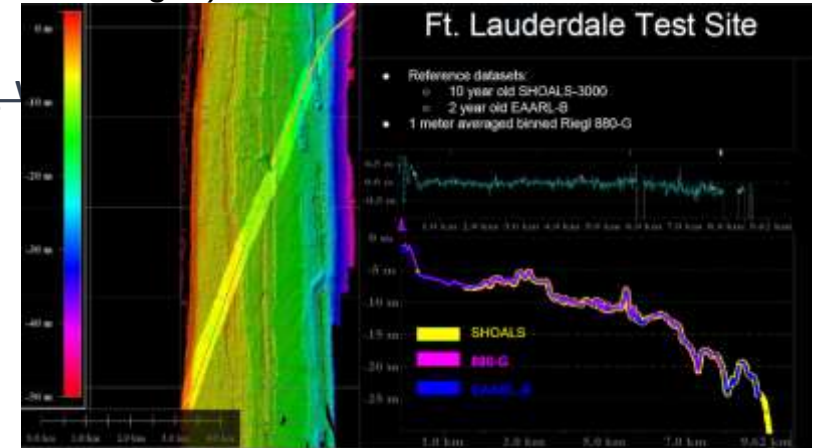
Bathy Lidar Barriers

~~• Different systems, difference processes, different results = my problem.~~

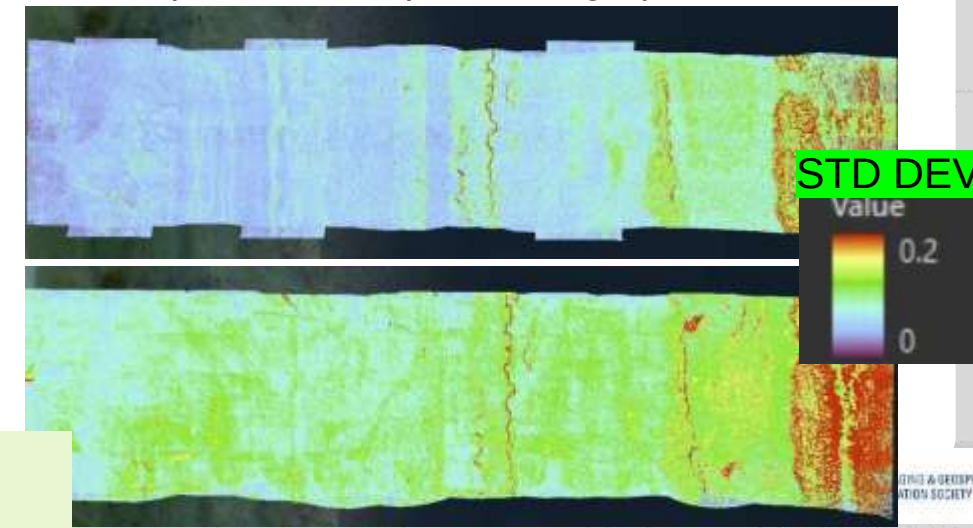
- Use of common test ground to **understand, characterize**
 - Don't think system bake off.
 - MBES Patch test equivalent for repeatability
 - Share data for understanding
 - Leverage(and update) expensive reference and GT data
 - Coordinate research
 - Test grounds chosen for stability and features
 - Large flat area
 - Rich features
 - Install targets?



Evaluate depth bias(different systems - common challenges)

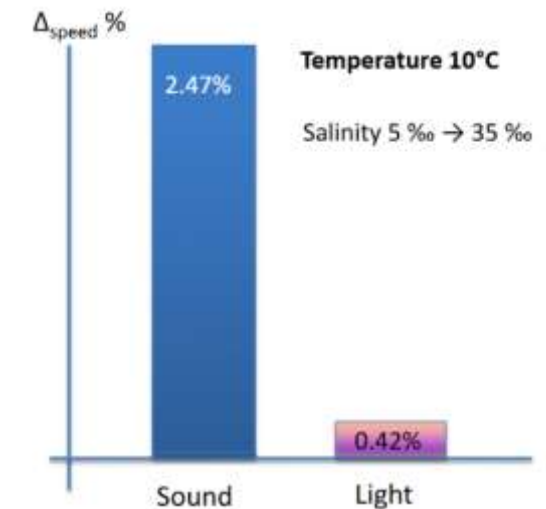
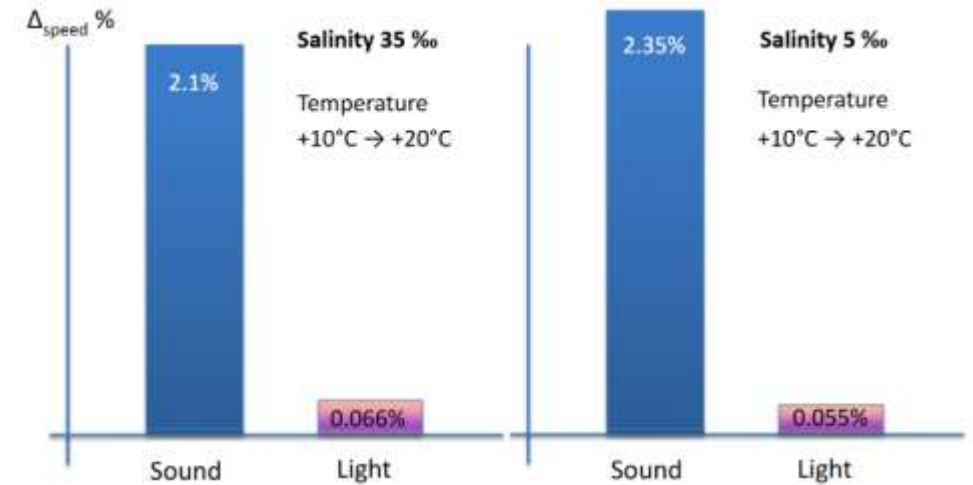


Evaluate algorithms and processes (same systems different process – unique challenges)



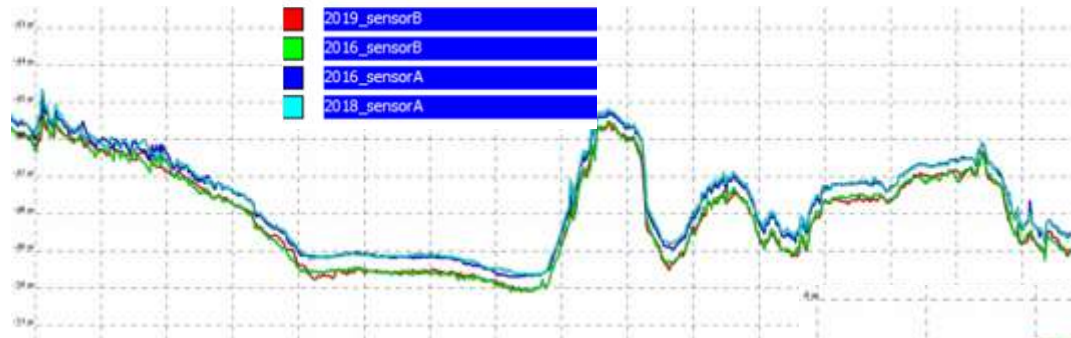
Q: Why don't we just empirically test the accuracy through comparison against independent, higher-accuracy reference data, as is done in topo lidar?

- A: we do, when possible, but it's much more difficult with bathymetric lidar
 - “Boots-on-the-ground” field data typically can't be collected, except in the very shallowest areas in which someone can stand
 - Accuracies determined using these data are typically not representative of the entire depth range
 - Sonar (e.g., multibeam echosounder (MBES)) data can be used where available
 - Logistically very difficult to collect concurrently with ALB
 - Does it meet *ASPRS Positional Accuracy Standards for Digital Geospatial Data, 2nd Ed.* requirement to be twice more accurate than the tested product?



Bathy Lidar – Propagation Depth Bias

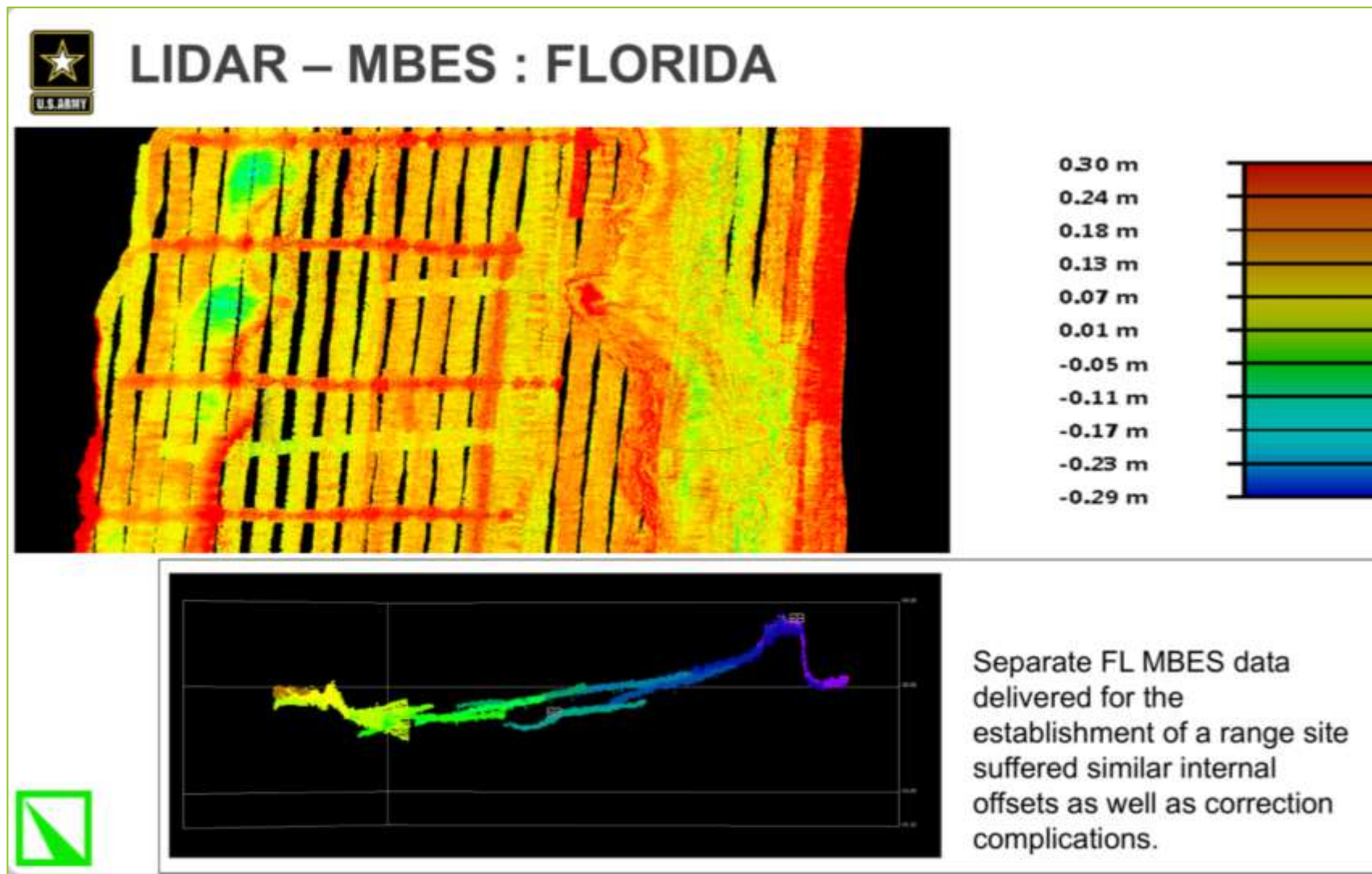
4 collects, 3 different years, 2 different sensors that both align with another 20cm difference between the sensors at 10m



Depth bias between sensors is over 2% of the depth measured, 35cm at 17m depth. Aligns on land.



Bathy Lidar – Propagation Depth Bias



Bathy Lidar – Propagation Depth Bias

Bathymetric Lidar Vertical Accuracy
Comparison of four CZMIL collects to 2.2cm RMS nearshore sonar collects

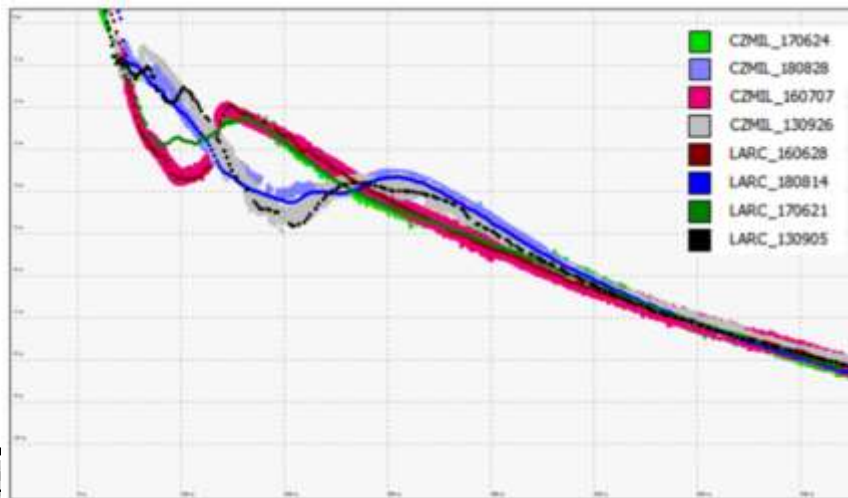
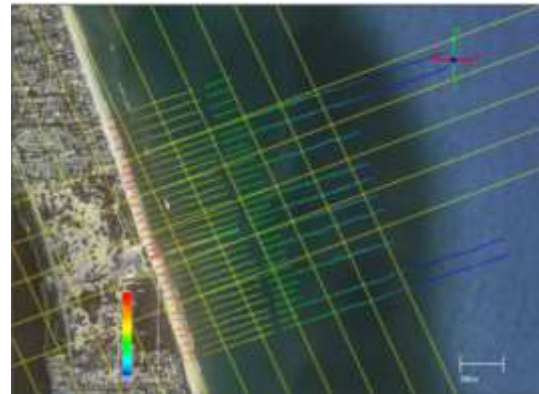
ERDC/CHL TR-17-19

Coastal Field Data Collection Program

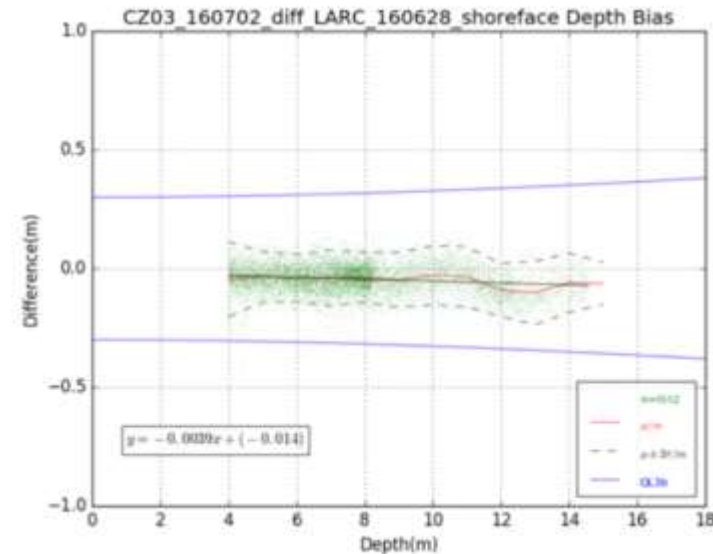
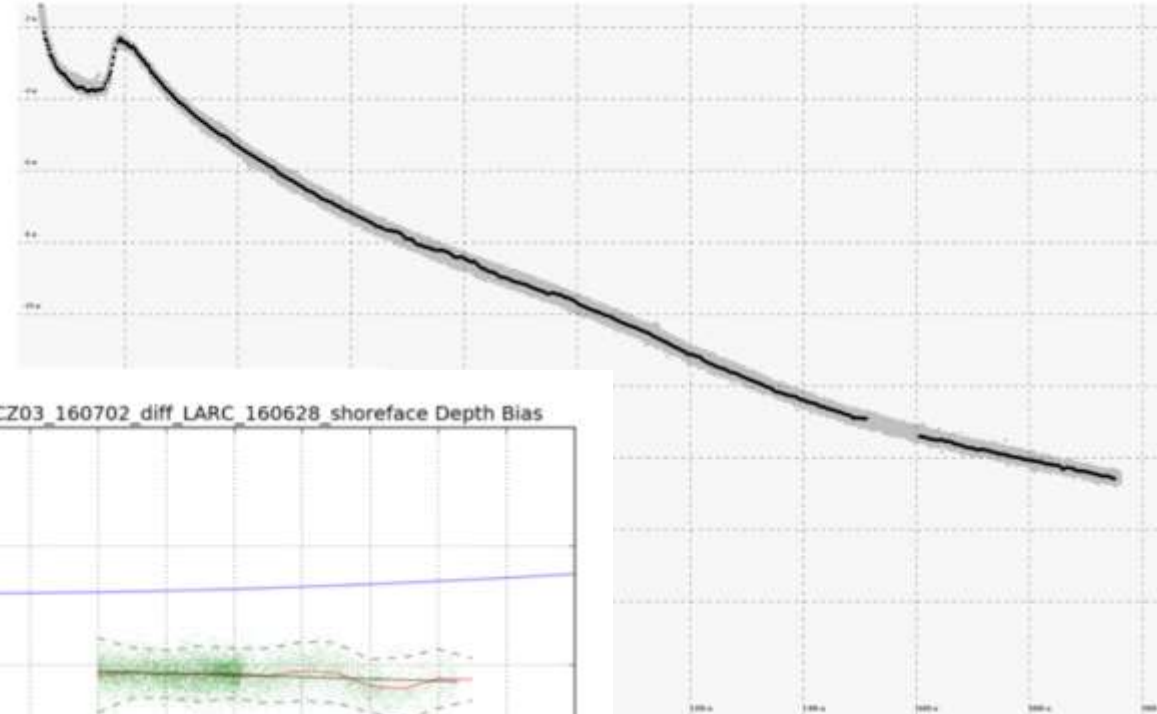
Nearshore Survey System Evaluation

Michael F. Forte, William A. Birkemeier, and J. Robert Mitchell

December 2017



2016 CZ03 – LARC (4 AND 9 DAYS BETWEEN)



JAL
Joint Airbo
Technical C



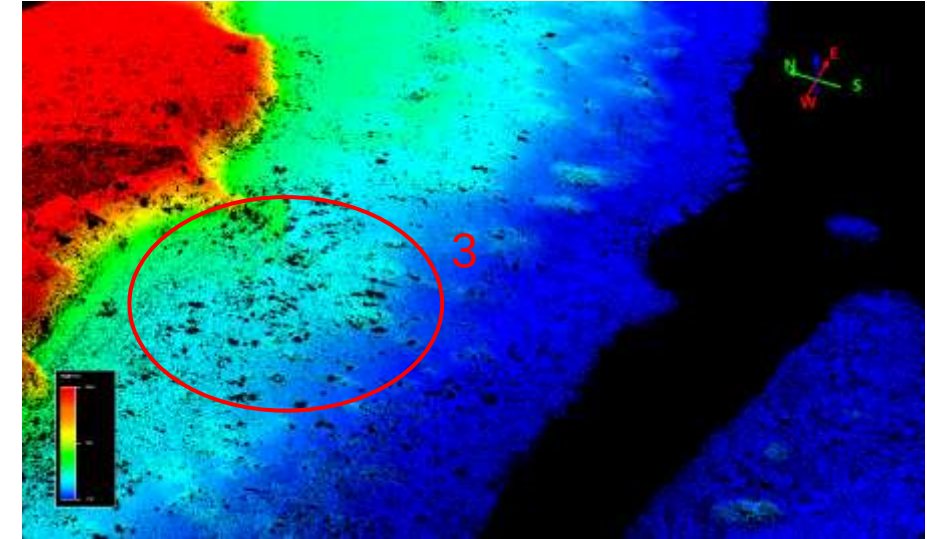
Bathy Lidar - Effective Footprint: Shallow vs Deep FOV

FL Keys, 0-3m depth, "clear" water

Puerto Rico, 0-12m depth, less clear

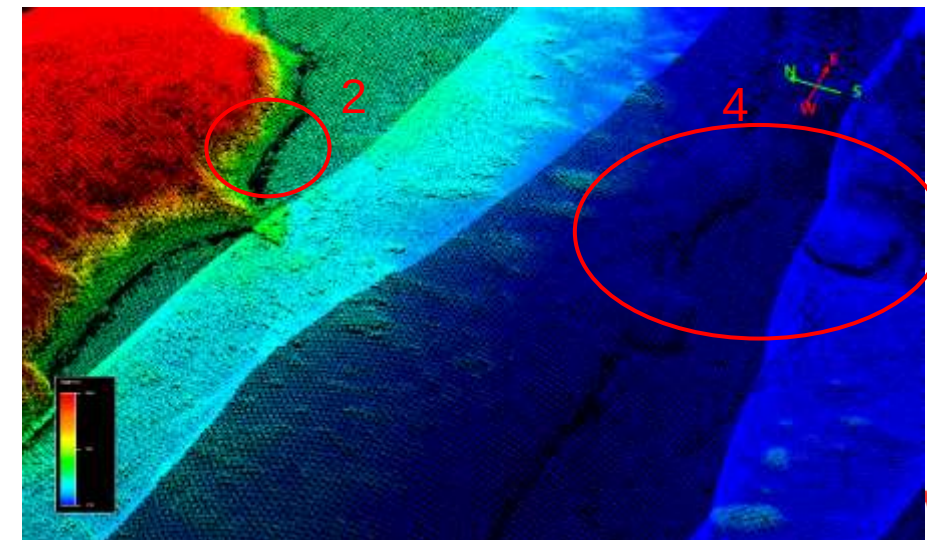
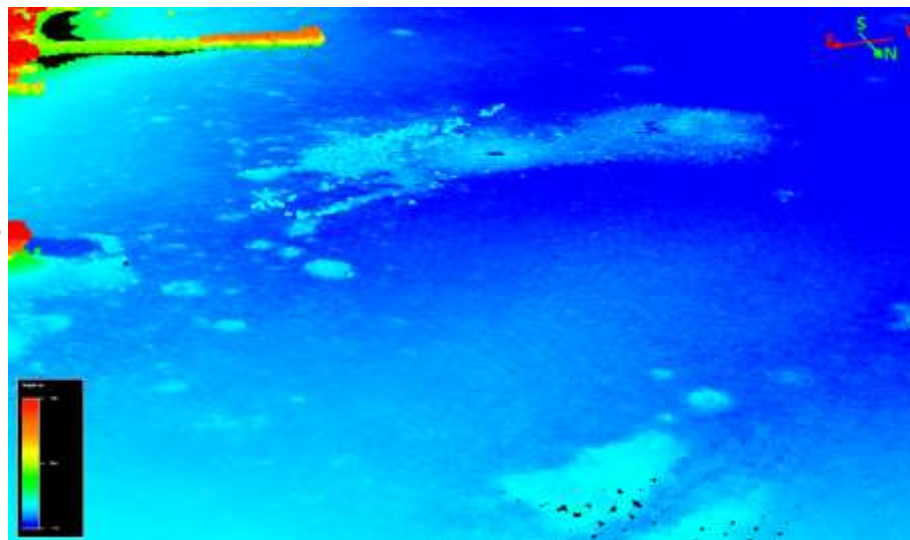
Smaller FOV and high point density reward in clear, optically shallow waters. Smaller feature resolution, precision(1) and easier land water interface depth extraction(2)

"Shallow" system



Larger FOV and high pulse energy reward, optically deep waters. Increased signal to noise(3*) and depth performance(4).

"Deep" system



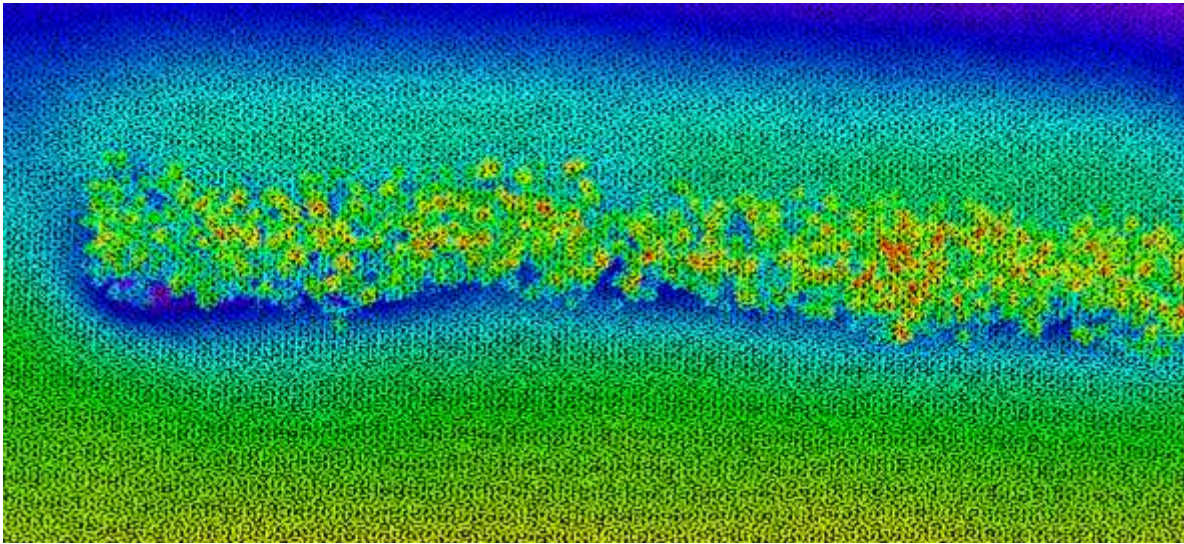
3 – returns in feature rich area are present in shallow system here but extracting features from noise is difficult



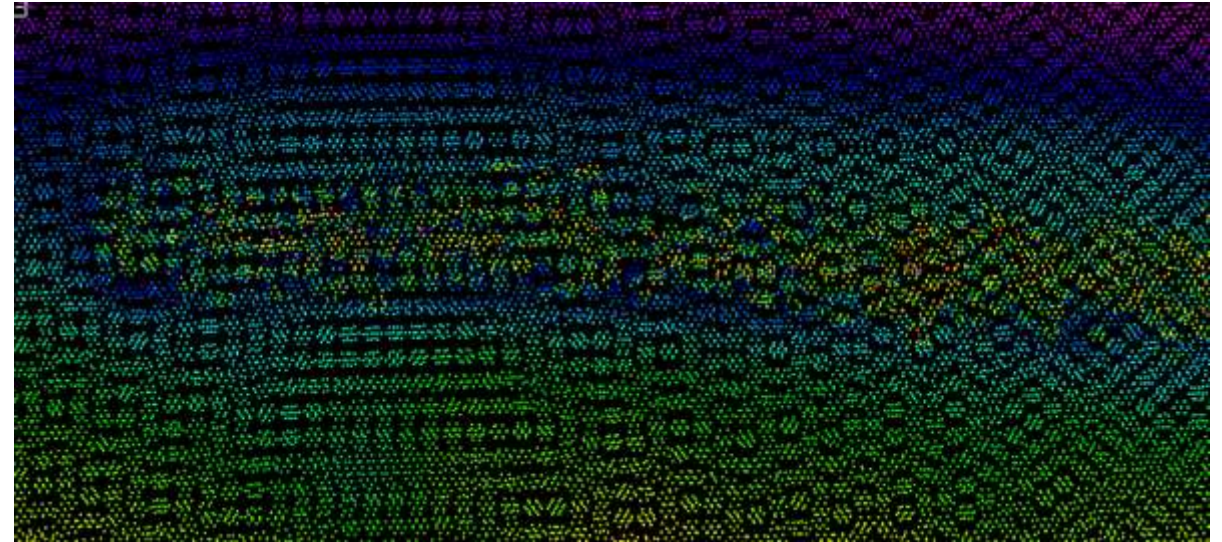
Bathy Lidar – sampling and feature resolution questions

1. Why would anyone ask for 20 samples per square meter with the effective received FOV of sensors that exist?
10 x 100m pile of 1-1.5m rocks sitting between 1.5-2.5m of water

Sensor B– 2 lines, 12pts/m²

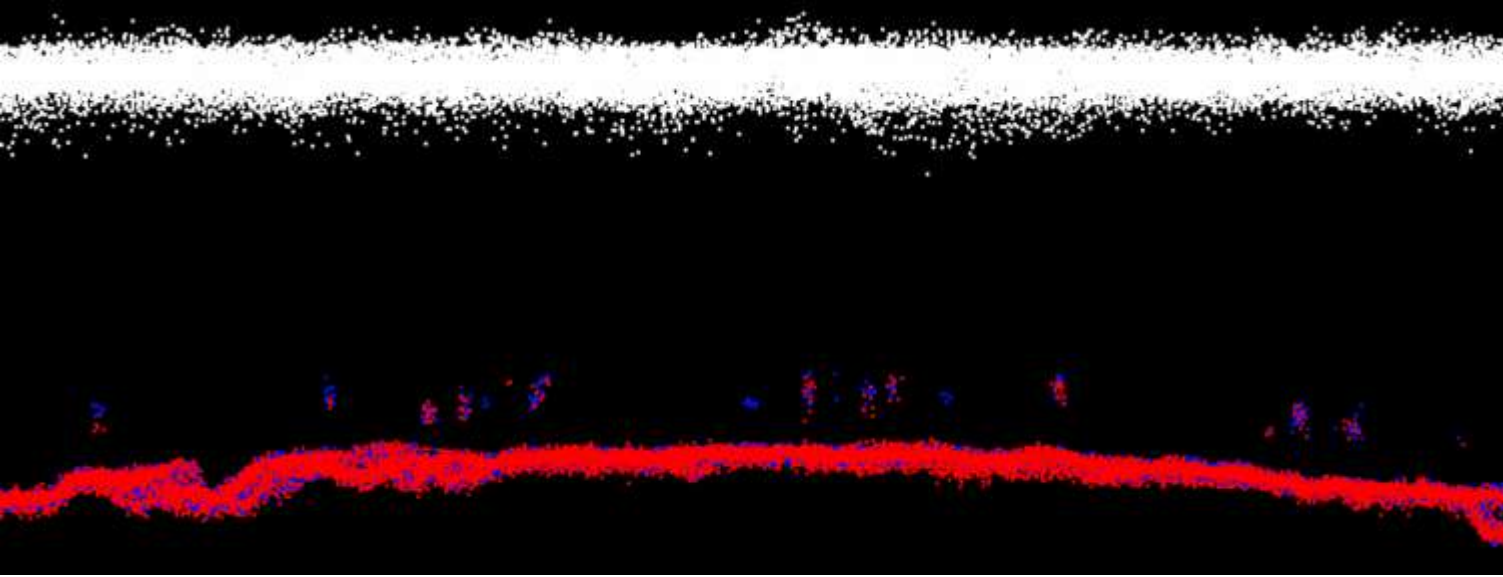


CZMIL NOVA– 1 line, 2pts/m²



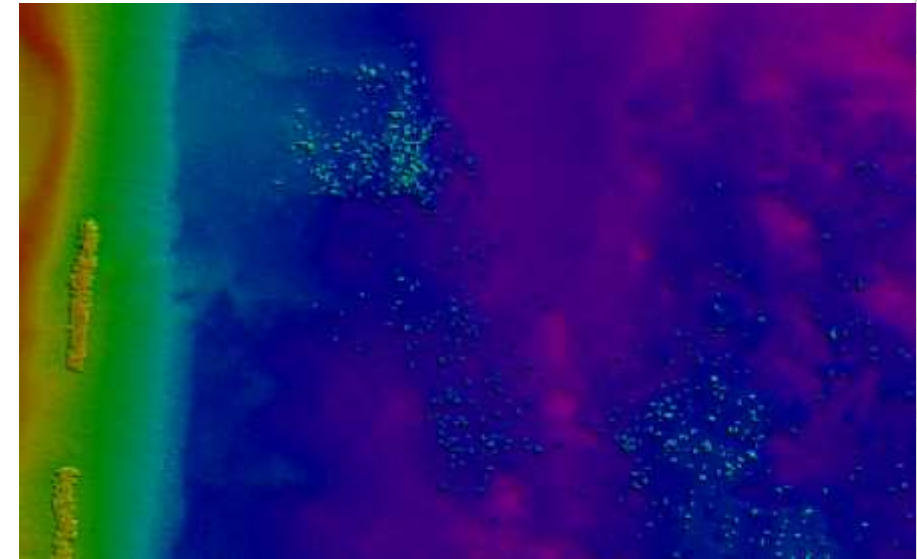
1. Does more sampling improve feature detection? ... more to the story

Sensor A(2pts/m), color by year . Red 2022, Blue 2018

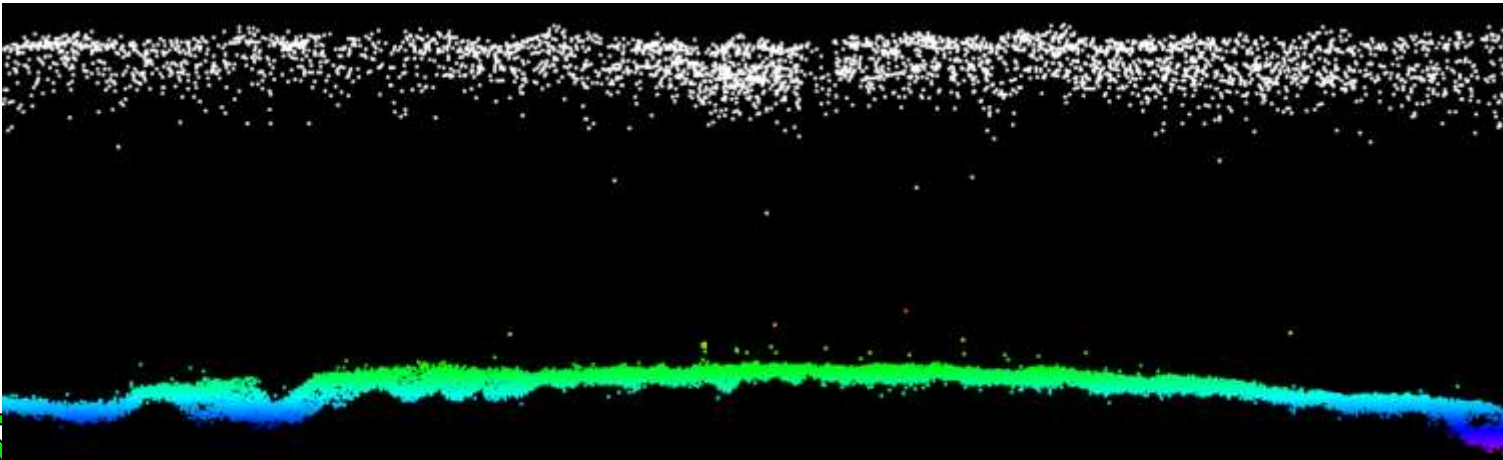


There is a ~ 50cm gap between bottom of 1m feature and the seafloor. Features are 1m tall in 5m of water.

Some vegetation or reef features always present at the calibration site.



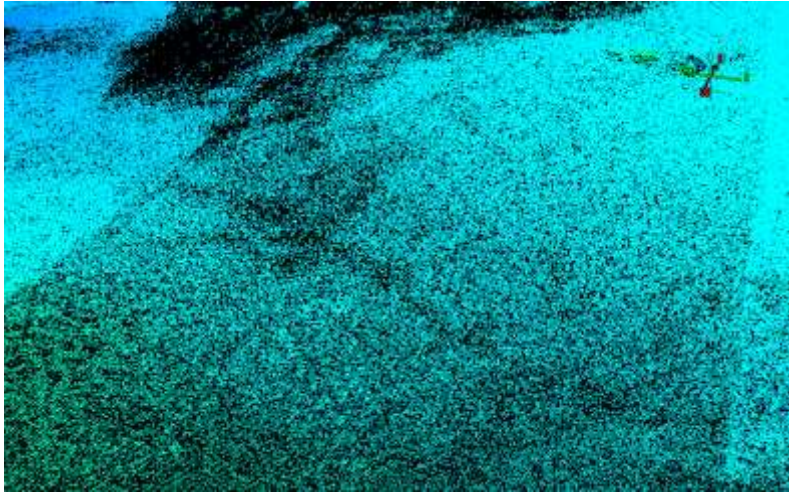
Sensor B(6pts/m), color by elevation.



Bathy Lidar – Sample density and distribution

Some view distribution, sample density, and probability of a bottom return all in one. Different Talk...maybe...

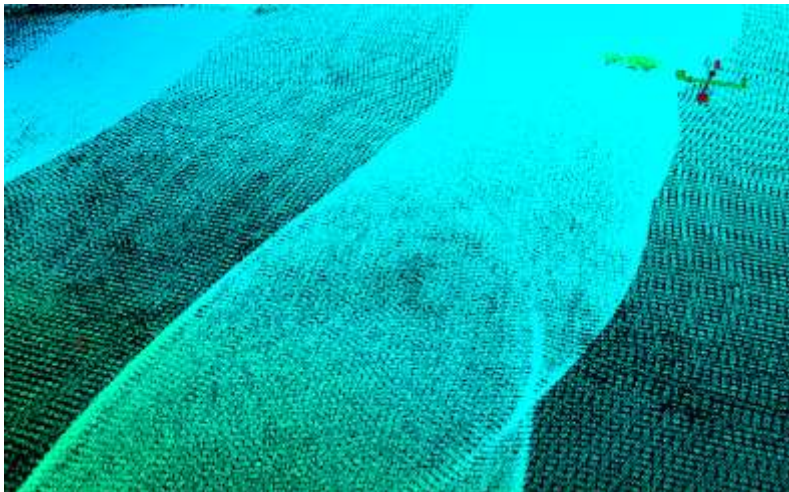
2016



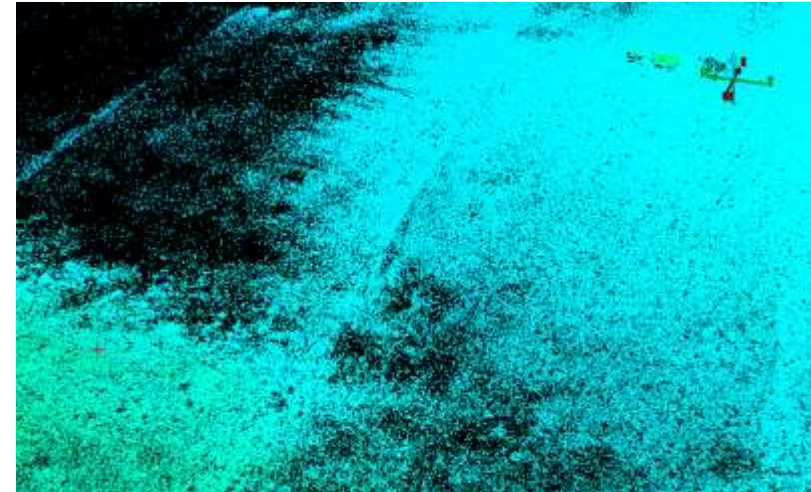
2016



2018



2019



Bathy Working Group – Problems? GOOD!

Foster collaborative, forward leaning attitude to tackle community barriers

“A rising tide lifts all boats”

Bathy Lidar Barriers

- ~~• I don't understand the data dependencies and why do we have to repeat such a complicated conversation? I just want good data, now. Help.~~

GOOD! We have customers who want data and want to understand.

BUT

Do they know what they want? Do you know what they want?

- **Help** Others? Continue to **share experiences** and lessons learned for specific applications.
 - I to share experiences or expand on lessons learned via the BWG monthly meeting.
- Bring up the **education** baseline
 - Opportunity to expand on subjects from the ASPRS Bathy Lidar 101 workshop
 - Hosted online BWG Learning Sessions to dive a little deeper, to explain dependencies
 - Potential topics (TPU, Sample density vs FOV/Hor. Uncertainty, propagation theory to practice, SNR-sensitivity, filtering and interest point algorithms, surface detect and modeling)

Bathy Working Group – Problems? GOOD!

Foster collaborative, forward leaning attitude to tackle community barriers

Bathy Lidar Barriers

- ~~• I don't understand the data dependencies and why do we have to repeat such a complicated conversation? I just want good data, now. Help.~~

contractors should be directed to provide detailed solutions

BUT

the responsibility for understanding the data and its intended purpose lies jointly with the users and providers

AND

it is complex

“The error functionalities are entwined with system and environmental parameters such as scan angle, altitude, receiver field of view and optical bandwidth, transmitter pulse characteristics, pulse location algorithms, wind speed, and water clarity in a complex web which requires careful compromises in system design and operation to minimize the resulting errors.” 1985 Guenther

- “I only trust team A with system C for job X.” This doesn't help lift all boats. How can we help the users?
- **?Certified Bathy Lidar Scientist/Tech?** Would it help? Are we that unique? Are we close enough to sonar to require those credentials? Does it depend on the job?

UKHO - HYDROGRAPHIC SURVEY SPECIFICATION (LIDAR):

<https://data.admiralty.co.uk/portal/sharing/rest/content/items/cbaef11d0e40471ca8a0d75286cb9b37/data>

US - Hydrographic Survey Specifications and Deliverables:

https://nauticalcharts.noaa.gov/publications/docs/standards-and-requirements/specs/HSSD_2021.pdf



JALBTCX
Joint Airborne Lidar Bathymetry
Technical Center of Expertise



BWG – Learn More & Support



ASPRS Annual Workshops – Airborne Bathymetric Lidar

Dr. Christopher Parrish - Oregon State University /
Amar Nayegandhi, CP, CMS, GISP - Dewberry

<https://community.asprs.org/bathywg/>

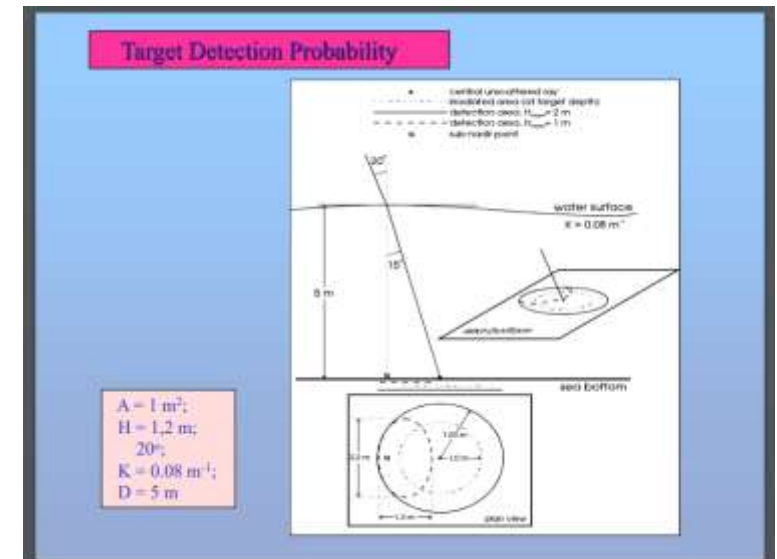


Annual JALBTCX Airborne Coastal Mapping and Charting Workshop
July(ish) 2025, ~Corpus Christi, TX

20+ years of bathy lidar presentations



<https://jalbtcx.usace.army.mil/>



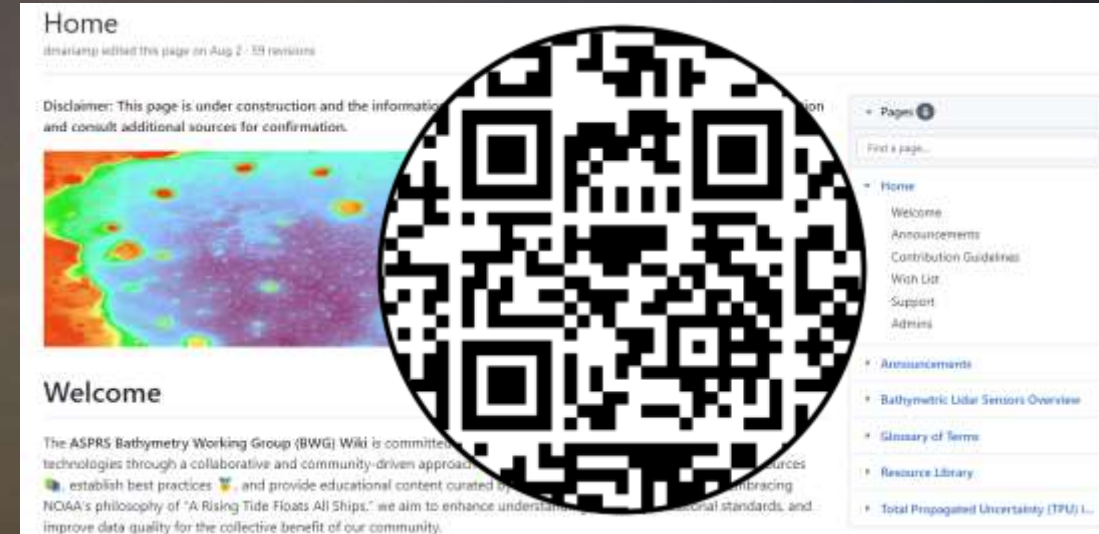
Questions?

<https://community.asprs.org/bathywg/>



Answers!!!

<https://github.com/ASPRSorg/BWG/wiki/>



US Army Corps
of Engineers

Nicholas.D.Johnson@usace.army.mil
Time-lapse of a night flight, Long Island, NY, September 2017 (G.Twiley)



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