Overview of existing and emerging lidar technologies and applications to continuous topo/bathy DEMS

Mapping Sciences Committee
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Agenda

• What is bathymetric lidar?
• topo/bathy data from existing systems
• What’s under the hood of a bathy lidar
• Emerging trends
\[ \begin{bmatrix} \phi & \lambda & h & r & p & h \end{bmatrix} \]

\[
\begin{bmatrix}
\phi_P \\
\lambda_P \\
h_P
\end{bmatrix} = F([\phi \lambda hrph], l_a, l_w, \theta, \phi_A, \phi_W)
\]
Bathymetric lidar: radiometric view

Laser pulse → optics → atm → Sea surface → Water column → seafloor

Detector → digitizer

Optical domain ↔ Electrical domain
Inversion enables 3D reflectance images
Malibu, California

Courtesy of David Millar, Fugro Pelagos, Inc.

SHOALS seafloor reflectance images
Existing commercial systems

Teledyne/Optech CZMIL
Teledyne/Optech Aquarius
Leica/AHAB Hawkeye 3
Leica/AHAB Chiroptera
Fugro/LADS Mark 3
Reigl-880-G
Finistère Ile de Batz

Courtesy of Yves Pastol, Service Hydrographique et Océanographique de la Marine

Lads MK3 + RIEGL VQ820G (2012)
Indian Ocean, Glorieuses Islands

Courtesy of Yves Pastol, Service Hydrographique et Océanographique de la Marine

Hawkeye 2b (2009)
Chincoteague, Virginia

Courtesy of Mike Aslaksen, NOAA, National Geodetic Survey

RIEGL VQ820G
Fort Jefferson, Dry Tortugas

Courtesy of Mike Aslaksen, NOAA, National Geodetic Survey

RIEGL VQ820G
What’s under the hood of a bathy lidar?

- Telescope
- Laser
- Scanner
- IMU
- Receiver (detectors + amplifiers)
- Onboard computer (algorithms + software)

GTRI’s Bantam Real-time Dual-use Lidar (BRDL)
What's under the hood of a bathy lidar?

Telescope
- large aperture
- wide FOV ~40 mrad

Laser
- high energy
- high frequency
- short pulse length

IMU
- high accuracy
- covariance matrix available

Cables
- short and well-shielded

Onboard computer
- signal conditioning
- ranging
- coordinate computations

Receivers
- multiple channels
- low noise
- high bandwidth
- high dynamic range

Scanner
- high frequency
- large aperture

GTRI’s Bantam Real-time Dual-use Lidar (BRDL)
Importance of Shoreline

- **AL, AK, CA, CT, FL, GA, MD, MS, NJ, NY, NC, OR, RI, SC, WA**
- **Privateley Owned**: Uplands
- **State Owned**: Tidelands, Inland Waters, State Submerged Lands
- **Territorial Seas**: Contiguous Zone, Exclusive Economic Zone, Federal Submerged Lands, High Seas
- **3 n mi.**, **12 n mi.**, **24 n mi.**, **200 n mi.**

- **MHHW or Highest High Water**
- **MHW**
- **MLLW**

- **Tidal Datums**: MHHW = Mean Higher High Water, MHW = Mean High Water, MLLW = Mean Lower Low Water
- **3 marine leagues (9 n mi.)** for Texas and Florida in the Gulf of Mexico
$H = h - N$

- $h = \text{ellipsoid height (height above the ellipsoid)}$
- $N = \text{geoid undulation (height of geoid above (+) or below (-) the ellipsoid)}$
- $H = \text{orthometric height (height above the geoid)}$
Emerging trends

Future topo/bathy systems

- Lower Cost Data:
  - less expensive lidars and platforms
  - higher performance systems on high flyers

- Higher Value Data:
  - real time computations
  - quantified accuracy
  - multi-use data

SWAP
- Price
- detectors
- software

mixed-mode computers
- total propagated uncertainty
- sensor and data fusion
detectors: SiPM

BRDL data collected 10/13/15
Accuracy: Total Propagated Uncertainty (TPU)

\[ \Sigma_P = \begin{bmatrix} \sigma_N^2 & \sigma_{NE} & \sigma_{ND} \\ \sigma_{NE} & \sigma_E^2 & \sigma_{ED} \\ \sigma_{ND} & \sigma_{ED} & \sigma_D^2 \end{bmatrix} = J \Sigma_M J^T \]
Results of GmAPD testing

Study sponsored by Dewberry, LLC, as part of their work for NOAA
Multi-use data: Data Fusion

CZMIL data courtesy of Heath Harwood and Chris Macon, JALBTCX
THANKYOU!

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