Ocean & Coastal Observation Using Airborne Systems

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Introduction of Airborne Lidar Bathymetry (ALB) System

Accuracy

Performance

Data Fusion

Conclusion

Optech Latest News
The Need for ALB Mapping

A large percentage of the world’s population and commercial centers are in or near the coastal environment.

Understanding near shore habitats is critical for management decisions, disaster planning, environmental impacts and the challenges from growing populations and rising sea levels.
Population 248m, 4th largest on the planet
Approximately 42m people live in areas less than 10m above average sea level
17,508 islands, 6,000 of which are inhabited
Coastline length of > 81,000km
Maritime claims, 12nm territorial sea, 200nm exclusive economic zone
Territorial sea 3,205,695sqkm which represents 17% of the world’s total
Land boundaries 2,830km with Timor Leste, Malaysia and Papua New Guinea
Percentage of worlds coral reefs 18%
Mangrove forests area 23,901sqkm which represents 14% of the world’s total
National Coastal Mapping Program

The U. S. Army Corps of Engineers (USACE) National Coastal Mapping Program (NCMP) is designed to provide high-resolution elevation and imagery data along U.S. shorelines on a recurring basis.

The NCMP is executed by the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX).
Not only the USA…Australia too.

- Coastal inhabitants
  - Australian population highly coastalized
    85% of Australians (22M) occupy 1% of the continent.

- Climate change
  - Rising sea levels
  - Increased storm frequency and surges (sea and river)

- Widely recognised need to model and understand the changes and impacts.

- Action’s being taken (Victoria State ~2,500km)
  - High resolution DEM and Seabed mapping required; 10m above and 20m below contours respectively.
Example: Sale – Gippsland, AU

Legend:

- more than 2 m below sea level
- 2 - 1 m below sea level
- 1 - 0 m below sea level
- 0 - 1 m elevation
- 1 - 2 m elevation
- 2 - 3 m elevation
- 3 - 4 m elevation
- 4 - 5 m elevation
- 5 - 6 m elevation
- 6 - 7 m elevation
- 7 - 8 m elevation
- 8 - 9 m elevation
- 9 - 10 m elevation
- greater than 10 m

Lidar data resolution 1m, with vertical accuracy of +/-10cm @ 1 sigma.
2012-14: Four awards for best bathy technology
Accuracy
Elevation/Depth Data Acquisition near Shore

Practical Example: Cat Island, MS

GPS Wheel

6.5 km

Fish Habitat

Haven
Sonar Coverage Comparison

Cat Island, MS

CZMIL data

SONAR data
Sonar Surface - CZMIL Surface: ROI Statistics

Histograms: elevation_difference.png

Filename: C:\dps_wks_manual\wks_local\EFFORT_Stennis\STENNIS ALL\CZ01MD1200
ROI: Region #1 [Red] 42735 points

Basic Stats

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<th>Band 1</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Stdev</th>
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<td>0.656988</td>
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Histogram

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<th>Percent</th>
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CZMIL data collected over multiple days were compared and extensively validated against ground truth. Here, we show a single flight line collected by CZMIL System No: 1 in May, 2012.
For the sample space described in the table ~98% of shots are within the red curve

CZMIL data collected over multiple days were compared and extensively validated against ground truth. Here, we show a single FL collected by CZMIL System No: 1 in May, 2012

IHO standards: http://www.iho.int/iho_pubs/standard/S-44_5E.pdf
Seamless Topo/Bathy measurement

Illustration of CZMIL’s dynamic range: Capability to capture tall buildings and deep water during the same mission.
Performance in Shallow and Turbid Water
CZMIL Survey in Clear Water

Maui October 2013
CZMIL Survey in Clear Water

MAUI October 2013

Depth 45 meters
CZMIL Survey in Clear Water
CZMIL Survey in Clear Water
Fundamental Question

- Why do we need Airborne Bathymetric Lidar systems?
- Where do we need Airborne Bathymetric Lidar systems?
AQUA-MODIS Data:

Annual 2013 Diffuse Attenuation Coefficient at 490/532nm
As a rough measure of water clarity, people use a Secchi Disc (Angelo Secchi, 1865)

Two types: 20 cm (black and white) and 30 cm white

Note: Secchi Depths are not considered meaningful below a 3 meter value
Performance Test in Turbid Water

Water conditions for test in Gulf Coast area off the Mississippi in US

Digital Camera Image
20cm resolution
Performance: Depth Penetration

- **Kd*Dmax = 3.5 (day) ; 5.0 (night)**
  - Diffuse Attenuation Coefficient (Kd)
    Ocean optical indicator regarding to scattering and absorption of light in water.

<table>
<thead>
<tr>
<th>Coastal waters</th>
<th>K(m(^{-1}))</th>
<th>D(_m)(day)</th>
<th>D(_m)(night)</th>
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<tbody>
<tr>
<td>Very Clean</td>
<td>0.07</td>
<td>50m</td>
<td>71m</td>
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<tr>
<td>Clean</td>
<td>0.10</td>
<td>35m</td>
<td>50m</td>
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<tr>
<td>Typical</td>
<td>0.15</td>
<td>23m</td>
<td>33m</td>
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<tr>
<td>Typical</td>
<td>0.20</td>
<td>18m</td>
<td>25m</td>
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<tr>
<td>Dirty</td>
<td>0.30</td>
<td>12m</td>
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<tr>
<td>Very Dirty</td>
<td>0.50</td>
<td>7.0m</td>
<td>10m</td>
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</table>
A slide courtesy of Wayne Write, Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) workshop 2014

USGS
C.W. Wright wwright@usgs.gov

Performance Comparison of ALB Systems

Method to compare Potential Bathy Lidar Performance independent of Water Column Measurements

\[ S = \left( \log(A \times W) - 4 \right) \times 11 \]

Where:

- \( A \) = Area of Receiver in cm\(^2\)
- \( W \) = Peak Pulse Power (Watts)

Single Pulse Bottom Detection Figure of Merit (S)
Performance Comparison of ABL Systems

A slide courtesy of Wayne Write, Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) workshop 2014
Short System Response with 2ns laser pulse width

CZMIL Technology

- Better SNR from shorter system response
- Detect bottom deeper
- More accurate input to algorithms
- Better shallow water discrimination
Results from Turbid Water Module

Spatial profile plot:
- **Green** = with mud bottom detection
- **Red** = without
- Depth of about 12m in the newly detected areas

Depth of about 12m in the newly detected areas

Color coded elevation image
Depth < 1-2m
Traditional peak detection failed to detect any depth

CASi true color image, shows some bottom structure

Calumet lake area, Michigan
13 flight lines ~15km²
Shallow & Muddy Bottom

CZMIL elevation image with the bottom features marked.
Data Fusion
System Layout

- Operator Rack
- Laser Rack
- Control Rack
- Thermal Rack
- CZMIL Sensor Head
- CASI-1500 (Spectrometer)
- RGB Camera
CZMIL Products from Fort Lauderdale, FL
CZMIL Products

Elevation images

Digital Camera mosaic image
CZMIL Products

Sea surface spectral mosaic image

Seafloor spectral mosaic image
Lidar Bottom Reflectance | Spectral Bottom Reflectance | Classification Draped over Shaded Relief Elevation Image

Processing Level | Optech HydroFusion Data Product
--- | ---
Level 2 | Lidar point cloud
Auto Processing | Lidar depth grid
Lidar topo/bathy DEM, 1 m
Lidar topo/bathy bare earth DEM, 1 m
Lidar and hyperspectral surface reflectance image mosaic
Lidar and hyperspectral bottom reflectance image mosaic
Lidar and hyperspectral water attenuation images
Hyperspectral bottom fraction images
Hyperspectral water quality image mosaics (Chl, SSC, CDOM)
RGB ortho image mosaic, 0.2 m

Level 4 | Image Generation
Image Generation | Benthic habitat classification map
Land cover classification map

Level 5 | EnvironmentalProducts
Features/Classify | NAVD 88 shoreline vector
USGS dune height elevations
Building footprint vector
CZMIL is designed by Optech for the U.S. Government, under the auspices of the U.S. Army Corps of Engineers and the Joint Airborne Lidar Technical Center of Expertise (USACE and JALBTCX), and validated by USACE and Navy.

ABL System performance can be estimated by area of receiver and peak pulse power, independent of water column measurements.

Smoothed and sharp waveform generation is critical to improve accuracy of depth from range computation.

The Turbid Water Module for CZMIL HydroFusion enables processing of data from shallow (depth <1-2 m), turbid waters (K_d >0.5 m^{-1}) with dark, muddy bottoms (reflectance = 3-5%), opening new areas to bathymetric lidar.

Advanced data fusion techniques using a pulsed, high-power green lidar and a hyperspectral sensor provide critical ocean environment information — including the high-resolution diffuse attenuation coefficient, change of water depth, chlorophyll, and colorized dissolved organic matter (CDOM) — for emergency response and rapid decision making.
BREAKING News
Announcing ALTM Titan

Multi-spectral active imaging system

Objectives

- To enable day/night mapping and 3D modeling of various target types for improved classification success
- To enable simultaneous, high-resolution, high-precision mapping of the near and on-shore environment
- To explore new applications spaces made possible via multi-wavelength lidar configurations

The Solution

- Dual laser system with 2 or 3 (optional) wavelengths 532, 1064, 1550nm
- Passive image support, CSxxxx series cameras
  - 29Mp, 80Mp, thermal or multispectral
  - 300kHz per channel with maximum total 900kHz!
  - Gyro stabilised mount optional

One sensor, Many applications
ALTM-Titan: Depth Profile

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ALTM-Titan: Vegetation Discrimination
Riverbed and Riverbank Survey

Teledyne Reson and Optech Incorporated Sonar and Lidar combined!
Recently National Oceanic and Atmospheric Administration (NOAA), released a final report titled “Socio-Economic Study: Scoping the Value of NOAA’s Coastal Mapping Program” from which the following key points are extracted:

- Of every **US$1.00 tax dollar spent** on NOAA’s coastal mapping program, taxpayers receive **US$35 in benefits**

- The program provides critical **baseline data** for accurately mapping America’s official shoreline important for national security, maritime shipping and navigation, and provides geographical reference data needed to manage, develop, conserve and protect coastal resources.

- The study demonstrates the program’s contributions in marine safety, geographic information, resource management, and emergency response and the wide range of economic and societal activities it support.

- NOAA derives the shoreline data through various remote sensing technologies including aerial imagery, satellite imagery, **Light Detection and Ranging (LiDAR)**, and **Synthetic Aperture RADAR (SAR)**.

- Through partnerships with other federal agencies in **LiDAR acquisition** and with continued technological advances, National Geodetic Survey (NGS) has demonstrated the ability to **achieve a threefold increase in efficiency** in some of our coastal projects.
Thank you!

Questions?

david.collison@optech.com

Please visit the Optech booth for further questions.