Evaluating the USACE's NCMP for NOAA charting operations

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Evaluating the USACE's NCMP data for NOAA charting operations

JALBTCX Workshop
08/06/13

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¹ National Oceanic and Atmospheric Administration, National Ocean Service
² University of New Hampshire, Center for Coastal and Ocean Mapping/Joint Hydrographic Center
³ US Army Corps of Engineers, Joint Airborne Lidar Bathymetry Technical Center of Expertise
Background

The National Oceanic and Atmospheric Administration (NOAA) is mandated to acquire hydrographic data and provide nautical charts.

Typically, NOAA uses a combination of in-house and contracting resources to acquire hydrographic data around the coasts of the U.S. and its territories.

NOAA’s Hydrographic Surveys Division (HSD) within the Office of Coast Survey (OCS) evaluates outside source data sent to OCS and determines if it can be potentially applied to NOAA Charts.
Shallow water bathymetry gap

Coastal shallow-water zone

• 0 to 4 m below the MLLW – Depths shallower than the Navigable Area Limit Line (NALL).
• From 4 to 10 m below the MLLW – Junction area with sonar surveys.

NOAA Chart 13283 (subset over Gerrish Island, ME)

Airborne Lidar Bathymetry (ALB)

Legend
- 4 m
- 10 m

(Courtesy of JALBTCX)
Goal
Evaluate the potential use of USACE Airborne Lidar Bathymetry (ALB) data for updating the coastal portion (0-10m) of NOAA charts

Expected contributions
Based on the study results, recommendations will be provided for different site conditions (geology, water clarity and depth).
Also, this will allow the development of future operating procedures with workflows to incorporate the outside source datasets into NOAA’s current workflows for updating the Nautical Charts and other products.
Unsurveyed areas

NCMP coverage and density with OCS MBES overlap
Methodology and Resources

• Statistical analysis between overlapping NOAA multibeam hydro surveys with ALB NCMP surveys.

• ALB datasets collected by SHOALS and Hawkeye systems.

• Software tools: ArcMap (Spatial and 3D-Analyst modules), and LAStools.
Procedure for Statistical Analysis

1. Calculate the point density distribution (ArcMap).
2. Identify the gaps in the dataset (ArcMap).
3. Generate a surface from the ALB and MBES datasets (ArcMap).
4. Statistical Analysis between datasets (MS Excel/Matlab):
   - Spatial difference map
   - Scatter plot
   - Histogram
Study sites

**Ft. Lauderdale, FL**: 2012 NCMP JALBTCX ALB data and 2009 OCS bathy lidar data (H12118)

**Port Everglades, FL**: 2009 NCMP JALBTCX ALB data, 2008 H11896 OCS MB data

**Kittery, ME**: 2007 NCMP JALBTCX ALB data, 2006 W00178 OCS MB data (CCOM-JHC)

**Pensacola, FL**: 2004 and 2010 NCMP JALBTCX ALB data, 2009 H12061 OCS MB data
Calibration site: Fort Lauderdale

<table>
<thead>
<tr>
<th>Areas</th>
<th>Mean Difference</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort Lauderdale, FL</td>
<td>0.17m</td>
<td>0.32m</td>
</tr>
</tbody>
</table>

Bottom type: hard bottom and sandy coral.
### Density Map (#/m²)

- 0 - 0.01
- 0.01 to 0.03
- 0.03 to 0.05
- 0.05 to 0.07
- 0.07 to 0.09
- 0.09 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6

### Difference Map (m)

- -4 to -3
- -3 to -2
- -2 to -1
- -1 to 0
- 0 to 1
- 1 to 2
- 2 to 3
- 3 to 4
- 4 to 5
- 5 to 6
- 6 to 7

### Area Mean Difference and Standard Deviation

<table>
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</tr>
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</table>
Study Site: Port Everglades

Reported Stats

<table>
<thead>
<tr>
<th>Reported Stats</th>
<th>NCMP ALB</th>
<th>OCS MBES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>2009</td>
<td>2008</td>
</tr>
<tr>
<td>Spacing</td>
<td>4x4m</td>
<td>50 cm – 1 m</td>
</tr>
<tr>
<td>Overlap</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Areas

<table>
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Bottom type: hard bottom and sandy coral.
Statistical Analysis: Port Everglades, FL

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Density Map (#/m²)

- 0 - 0.01
- 0.01 - 0.03
- 0.03 - 0.05
- 0.05 - 0.07
- 0.07 - 0.09
- 0.09 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6

Difference Map (m)

- 4 - 3
- 3 - 2
- 2 - 1
- 1 - 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7

Differences between 2008 OCS MBES and 2009 NCMP Lidar

Differences at depth between 2008 OCS MBES and 2009 NCMP lidar
## Study Site Summary Table

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Seafloor Type/Characteristics</th>
<th>NCMP</th>
<th>OCS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spacing (m)</td>
<td>Coverage</td>
</tr>
<tr>
<td>Fort Lauderdale, FL</td>
<td>Sandy and Hard bottom Coral</td>
<td>4x4</td>
<td>200%</td>
</tr>
<tr>
<td>Port Everglades, FL</td>
<td>Sandy and Hard bottom Coral</td>
<td>4x4</td>
<td>100%</td>
</tr>
<tr>
<td>Kittery, ME</td>
<td>Fine sand with rock outcrop</td>
<td>5x5</td>
<td>100%</td>
</tr>
<tr>
<td>Pensacola, FL</td>
<td>Sand</td>
<td>3x3, 5x5</td>
<td>100%</td>
</tr>
</tbody>
</table>
Mean Differences

- 95% CI for mbes data < 0.5m
Statistical Analysis

- Fort Lauderdale (Sandy and Hard bottom Coral) JAL lidar 2012 - DCS lidar 2009
- Port Everglades (Sandy/Coral) JAL lidar 2009 - MBES 2008
- Kittery, ME (Sandy/Rocky) JAL lidar 2007 - MBES 2006
- Pensacola (Sandy Bottom) JAL lidar 2010 - MBES 2009
- Pensacola JAL lidar 2004 - MBES 2009
Results

The NCMP ALB data were found to correlate well with MBES datasets. Largest differences were between 0-2m. The NCMP ALB data can be potentially successful for updating OCS nautical charts under the following conditions:

- coastal areas up to 10 m.
- Most seafloor types (e.g., rocky/sandy/coral areas), excluding vegetated and muddy areas.

In general the majority of differences are well within the combined uncertainty of the systems (MBES and lidar) that generated the data being compared.
Discussion

- It is important to note that the consistency between the datasets is affected by the seafloor type and the survey period:
  - For example, sandy seafloor near tidal inlets and along-shore bars varies with time.
- The bottom detection success (bathymetry) of NCMP datasets over muddy seafloor is very low.
- The procedure used here is transferable to the NOAA Hydro processing branches and will work within the current workflow.
- This procedure is currently in the process of being expanded to examine other ALB datasets inside (e.g. RSD Sandy ALB) NOAA and can be used for those outside (e.g., CZMIL, EARRL) NOAA.
Questions?

For more info: NOAA Technical Memorandum NOS CS 32
(http://www.nauticalcharts.noaa.gov/hsd/lidar.html)
Thank You!
Background - data
NCMP

- Acquires topo-bathy lidar data every 5-7 years.
- Bathy data exists for many areas along the continental US coastal areas.
- Internal USACE ALB systems: SHOALS and CZMIL.
- External (contractors) USACE ALB systems: Optech SHOALS, LADS MKII and AHAB Hawkeye.
- NCMP Data is publically available.

NCMP coverage map (JALBTCX, 2012)
Seafloor type: fine sand, gravel with rocky outcrop.
Statistical Analysis: Kittery, ME

Density Map (#/m²)

<table>
<thead>
<tr>
<th>Area</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kittery, ME</td>
<td>0.17m</td>
<td>0.39m</td>
</tr>
</tbody>
</table>

Difference Map (m)

Differences between 2007 and 2006 NCMP lidar

Differences at depth between 2007 OCS MBES and 2006 NCMP lidar
Study Site: Pensacola, FL (2010)

Reported Stats | NCMP ALB | OCS MBES
--- | --- | ---
Date | 2010 | 2009
Spacing | 3x3 | 1x1, 2x2
Overlap | 100% | 200%

Areas | Mean | Standard Deviation
--- | --- | ---
Pensacola, FL | 0.12m | 0.94m

Bottom type: sand

<table>
<thead>
<tr>
<th>Area</th>
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<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pensacola, FL</td>
<td>0.12m</td>
<td>0.94m</td>
</tr>
</tbody>
</table>
Study Site: Pensacola, FL (2004)

Bottom type: sand

<table>
<thead>
<tr>
<th>Reported Stats</th>
<th>NCMP ALB</th>
<th>OCS MBES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>2004</td>
<td>2009</td>
</tr>
<tr>
<td>Spacing</td>
<td>5x5</td>
<td>1x1, 2x2</td>
</tr>
<tr>
<td>Overlap</td>
<td>100%</td>
<td>200%</td>
</tr>
</tbody>
</table>

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<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pensacola, FL</td>
<td>0.57m</td>
<td>1.72m</td>
</tr>
</tbody>
</table>

<table>
<thead>
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</table>

Density Map (#/m²)

Difference Map (m)
Summary plot

![Graph showing mean differences in depth measurements for different locations and time periods.]

- Port Everglades, FL (Sandy/Coral) NCMP lidar 2009 - OCS MBES 2008
- Fort Lauderdale, FL (Sandy and Hard bottom coral) NCMP lidar 2012 - OCS lidar 2009
- Kittery, ME (Sandy/Rocky) NCMP lidar 2007 - MBES 2006
- Pensacola, FL (Sandy Bottom) NCMP lidar 2010 - OCS MBES 2009
Recommendations for Future Work

• Additional work recommended for new systems:
  – Use QA procedures as a starting point
  – Patch test
  – Comparison/analysis between new and older systems
  – Error uncertainty analysis
Lidar/MBES swath comparison in shallow waters

Plan view

Multibeam swath

Lidar swath/coverage

Side profile

Office of Coast Survey
<table>
<thead>
<tr>
<th>Order</th>
<th>1b</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description of areas.</strong></td>
<td><strong>Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.</strong></td>
</tr>
<tr>
<td><strong>Maximum allowable THU</strong> 95% <strong>Confidence level</strong></td>
<td>5 metres + 5% of depth</td>
</tr>
</tbody>
</table>
| **Maximum allowable TVU** 95% **Confidence level** | \( a = 0.5 \) metre  
\( b = 0.013 \)  
**Full Sea floor Search** |
| **Feature Detection** | **Not required** |
|  | **Not Applicable** |