Improving Satellite Derived Bathymetry and Supporting Safety to Navigation in Canadian Waters through Remote Sensing

CHS Remote Sensing Group: René Chénier, Ryan Ahola, Marc-André Faucher, Khalid Omari, Yask Shelat, Mesha Sagram and Bradley Horner
Category Zone of Confidence (CATZOC) of Hydrographic Survey
Qualité générale des données bathymétriques (CATZOC)

Source: DFO-Science, CHS / MPO-Science, SHC
chsnfo.XNCR@dfo-mpo.gc.ca
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Ent. Garmir, CEGOC, NOAA-NGOs, and other contributors.
Chart 5510 (Povungnituk, QC). White areas are unsurveyed.

Chart 5510 overlaid on RapidEye image (July 12, 2011).
Government Related Initiatives Program

- Funded through the Canadian Space Agency (CSA)

- Extraction of accurate Coastline and Intertidal Zones
  - Radar and optical data
  - Improve accuracy of chart representation

- Satellite Derived Bathymetry (SDB)
  - Survey planning
  - Identification of new shoals
  - Extraction of bathymetry surface

- Change Detection
  - Determining areas and rates of change

- Water Clarity Analysis
  - Light Detection and Ranging (LiDAR) planning

- Shipping Corridor Determination

- Data Integration in CHS Processes and Products
Data Utilization and Application Plan

Additional funding through the CSA Data Utilization and Application Plan (DUAP) to further integrate GRIP objectives with the RADARSAT Constellation Mission (RCM).

• **RCM Data Simulation**
  – Single and dual polarizations
  – Compact polarimetry parameters

• **Synthetic Aperture Radar (SAR) Bathymetry**
  – Wave and current simulation
  – Wave retrieval

• **Shorelines, Intertidal Zones and Tidal Height**
  – Interferometry
  – Polarimetric decomposition

• **Charting and Surveying Priorities**
  – Automated Identification System (AIS) detection
Oceans Protection Plan

- Multibeam and LiDAR surveys for priority and high risk areas across Canada
- Support for remote sensing projects
Shoreline and Intertidal Zone Extraction with RCM

- RCM compact polarimetry parameters may potentially be used to detect changes in rapidly changing costal areas such as intertidal zones due to the larger coverage and the high frequency revisit.

- RCM simulated products used for intertidal zone characterization: example of random forest classifier for different RCM dual polarization options.
Change Detection

September 4, 1972
Satellite Derived Bathymetry: log-ratio

Using pixel values, depth can be calculated in shallow waters following empirical models.

SDB offers a quick and cost efficient way for CHS to assess depth in coastal environments.
### Satellite Derived Bathymetry: LookUp Table

The training data is used to generate a LookUp Table (LUT) to link the pixels band values to a characteristic depth for each specific set of values.
Support Vector Machine

- Supervised Machine learning algorithm
- Robust model for large number of variables and small samples
- Most cases avoids “overfitting”
- Finds an optimal solution for separating “hyperplane” (Linear decision surface)

Lots of possible solutions for a, b and c

decision boundary: \( ax + by - c = 0 \)

- SVM finds hyperplane that can separate two different classes and maximizes the margin between two border class objects (called “support vectors”)
- Very effective for high dimensional spaces
Satellite Derived Bathymetry: Photogrammetry
Band Ratio Model: Cambridge Bay

SDB Absolute Error (m)
- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00 +

BR SDB Depth (m)
High : 14
Low : 0
LookUp Table Model: Cambridge Bay

**SDB Absolute Error (m)**
- 0.00 - 0.25
- 0.25 - 0.50
- 0.50 - 1.00
- 1.00 - 2.00
- 2.00+

**LUT SDB Depth (m)**
- High : 14
- Low : 0
SA Model: Cambridge Bay
SVM Model: Cambridge Bay
Satellite Derived Bathymetry: Photogrammetry

![Graph showing Relative Frequency and RMSE for different depth ranges and methods: LUT, BR, SVM, S-A. The x-axis represents Error (m) and Depth Range (m) for RMSE. The y-axis shows Relative Frequency and RMSE (m). The graph compares the performance of different methods across various depth ranges.]
Wave Kinematics Bathymetry (WKB) from SAR

Bathymetry modulated surface wave features

Retrieved wavelength from SAR image

Retrieved bathymetry
Water Clarity: In support of LiDAR survey planning

May

June

July

August
Concluding Remarks

- CHS is actively exploring multiple remote sensing approaches to support its chart production activities.

- Using optical and radar information.

- Aiming to assist with increasing use of remote sensing within international hydrographic offices.

Additional Slides
First inclusion of SDB within a CHS source classification diagram.
Example of Shoreline Extraction for Chart 5375 – Ungava Bay
| RapidEye | July 17, 2014 | 16:52 UTC | 5375 | Riviere Koksoak | 11.385 m |

Image © 2014 Planet Labs Netherlands BV. All Rights Reserved
Sentinel-1 | October 20, 2016 | 22:05 UTC | 5375 | Riviere Koksoak | 0.483 m
Red line = Low tide

Blue line = High tide

Total Ungava Bay high tide length of ~11,276 km
Final Extraction - High Tide Shoreline Change
Final Extraction – Low Tide Shoreline Change