Satellite activities in NOAA:

Satellite-derived bathymetry (SDB)

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National hydrographic offices need to periodically assess the adequacy of information on existing nautical charts for survey planning and prioritization.

One of the key factors is the adequacy of the charted bathymetry.

Hence, there is a need for low-cost, up-to-date reconnaissance surveys.
Several approaches have been developed for SDB:

**Analytical methods** that are usually designed for a specific data set.

**Optimization approach** that assumes vertically invariant water column and bottom conditions that requires to fix all but one parameter. A sub-category of this approach is a ratio approach that derives bathymetry based on the log ratio (or ratio of logs) of two bands.

**Look-up tables (LUT)** that use a comparative method for bathymetry classification based on large database generated from radiative transfer models.

Note:
For an algorithm that can be used by the hydrographic community on a COTS GIS software, a ratio transform algorithm based from an optimization approach provides a robust solution that does not require to sample the environment or generate a database.
Historical Review

2003 – Stump’s algorithm for SDB
2010 – Developing the SDB (Nigeria and Belize)
2012 – IHO-IOC Gebco Cook Book
2013 – Integration of single-image SDB approach
2014/2015 – Development and integration on multi-image SDB approach
Activities within NOAA

- **Reconnaissance tool**
  - Chart adequacy and survey planning
  - Magenta line

- **Chart Adequacy**
  - Risk assessment (incorporated with AIS datasets)
  - Monitoring dynamic seafloor regions

- **Emergency response**
  - Sandy response efforts

- **International collaboration and outreach**
  - Gebco (cook book and short-term internships)
  - Haiti
  - Graduate programs (Brazil, Nigeria and Ghana)
Available resources

Landsat 7
Launch Date: 4/1999
Organization: NASA/USGS program
Swath: 185km
Ground resolution: 28.5m

Landsat 8 (LDCM)
Launch Date: 2/2013

WorldView2
Launch Date: 10/2009
Company: DigitalGlobe
Swath: 18 km
Ground resolution: 2m

(Images from landsat.gsfc.nasa.gov and www.digitalglobe.com)
Single-image approach

Identifying the land/water

Satellite-derived bathymetry

Referencing to chart datum

Masking the blue and green bands

Applying the algorithm
Chapter 11.0 LANDSAT 7 Satellite-Derived Bathymetry

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Since the 1970’s, satellite remote sensing has become increasingly recognized as a useful reconnaissance tool to map near-shore bathymetry, characterize a coastal area and to monitor seafloor changes that may have occurred since the last hydrographic survey was conducted. Satellites allow for the capturing of images over broad expanses of the Earth. The following procedure provides the user with an inexpensive and quick approach to derive bathymetry from satellite imagery. The data sources used in the procedure below are publicly-available imagery collected by LANDSAT 7 satellite using the Enhanced Thematic Mapper Plus (ETM+)

instrument and chart soundings.

The key steps in the procedure include:

1. Pre-processing – Satellite imagery is downloaded based on the geographic location and environmental conditions (e.g., cloud coverage and sun glint) had to be used.
2. Water separation – Dry land and most of the clouds are removed.
3. Spatial filtering – ‘Speckle noise’ in the Landsat imagery is removed using spatial filtering.
5. Identifying the extinction depth – The optic depth limit for inferring bathymetry (also known as, the extinction depth) is calculated.
6. Vertical referencing – A statistical analysis between the algorithm values to the chart soundings references the Digital Elevation Model (DEM) to the chart datum.

For more details on satellite-derived bathymetry and hydrographic applications, please refer to Pe’er et al. (2013).


Stumpf, R., K. Holderied and M. Sinclair, 2003, Determination of water depth with high-resolution satellite imagery over variable bottom types, Limnology and Oceanography, 48, 547-556.
Reconnaissance tool
Chart Adequacy

Will be presented at US Hydro 2015
Thursday 11:30 am
Reconnaissance tool
Magenta Line

SDB (Landsat 8) over Bogue Inlet, North Carolina.
SDB in turbid waters

Identifying the land/water

Masking the blue and green bands

Applying the algorithm

Referencing to chart datum

Satellite-derived bathymetry
Satellite-derived bathymetry (WV-2) from March 2013 over Bechevin Bay, AK.

Blue/green algorithm

Green/red algorithm

Direct measurement of the bathymetry

Mapping of the turbidity

Clouds

Clouds
Satellite-derived bathymetry (Landsat 8) from March 2014 over Bechevin Bay, Alaska. The bathymetry is overlaid on a NOAA chart and the channel (red outline) from 2013 is depicted using USGC’s aid-to-navigation (ATONs).
What can be done with multiple images over the same area during a given period of time?
Single-image approach

(Acquisition date: July 18, 2002)

Extinction depth: 4.5 m (15 ft)
Multiple-image procedure

... (I'll be happy to explain the full procedure workflow offline).

... Six dataset were produced from the four available images (three pairs). All the dataset were merged into one dataset.

The data set was referenced to the chart datum.
Final result

Bathymetry derived from Landsat 7 and Landsat 8 imagery over the Arctic north slope

Presented at CHC 2014
Emergency Response
Superstorm Sandy


Will be presented at
US Hydro 2015
Tuesday 2:00 pm
NOAA-NGA’s 2013 efforts supporting the Service Maritime et de Navigation d’Haiti (SEMANAH).
NGA Chart 26148, Baie de L'Acul and Approaches, 1:20,000

Sources
A – US Navy Survey 1982
B – US Navy Survey 1915-16

Depth (m)

Value
High : 16
Low : 0

International collaboration
Haiti
International collaboration
Haiti

Satellite derived bathymetry over NGA Chart (26148)
Baie de L'Acul and Approaches
(Scale:1:20,000)

Depth (m)

Landsat 8
International collaboration
Big Creek, Belize
Discussion: Swath coverage

Four Landsat 7 images (RGB) covering most of the US Arctic North Slope.

Landsat 8 versus WV-2 coverage over Port-au-Prince, Haiti. A WV-2 image (IR band) overlaid on NGS Chart 26184 (1:50,000). The NGA chart is overlaid on a Landsat 8 image (RGB image).
Discussion: Resolution

Landsat 8
(28.5 m)

Worldview 2
(2 m)
Discussion: reference sources

Elevation difference over Buck Island study site between satellite-derived bathymetry (Landsat 7) and the lidar reference bathymetry (LADS MK-II)

Referencing to chart datum using lidar

Referencing to chart datum using chart soundings
Discussion: Turbidity
Summary

• Landsat imagery is publically-available and free.

• Procedures for different hydrographic applications are being developed (some are already available).

• In addition to work conducted at NOAA the procedure can have a broader impact.
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