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Nautical Chart Adequacy Evaluation using Publically-Available Data

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ABSTRACT

The International Hydrographic Office (IHO) C-55 publication communicates the need to improve the collection, quality and availability of hydrographic data world-wide, while also monitoring and rectifying possible deficiencies and shortcomings that are presented on the chart. This task of evaluating the adequacy of nautical chart products poses a challenge to many national hydrographic offices. This stems from the dearth of readily available spatial information: namely, the lack of reliable and accessible vessel traffic data, and little means to assess the changing nature of both near-shore bathymetry and shoreline in a simple and reliable manner. In this paper, we present the potential use of automatic-identification system (AIS) data, satellite-derived bathymetry (SDB), and airborne-lidar bathymetry (ALB) to provide an operational procedure for evaluating the adequacy and completeness of information of NOAA charts. Preliminary results from three U.S. study sites are presented in this paper: Nantucket Sound, MA; Barnegat Bay Inlet, NJ; and Barataria Bay, LA. Based on the publically-available datasets it was possible to identify changes in the charts and develop a reconnaissance procedure to monitor these changes on a yearly basis.

Introduction

The nautical chart is a tool used by mariners for safe navigation through the seas and guidance for anchoring. Due to limited resources and survey priorities, decades may pass until a new hydrographic survey can be conducted to update the survey measurements that are used to compile a given chart. Even then, the compilation time to transfer survey data into chart soundings and contours may take several years. As a result, shoreline and depth data in some charts are outdated and may have changed over the years due to natural events and/or coastal development. From a global perspective, the International Hydrographic Office (IHO) reviews in its C-55 publication (*Status of Hydrographic Surveying and Nautical Charting Worldwide*) the percent coverage of hydrographic surveying and nautical charting for a country with navigable waters under its jurisdiction. For a cartographer evaluating NOAA charts or a chart produced by a foreign hydrographic office, a similar set of questions are raised:

1. When was last survey conducted over the charted area?

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2. Have there been any changes to the shoreline or the bathymetry since the last survey?
3. Is it possible to prioritize areas on the chart that require more frequent updates?
4. Can we evaluate chart adequacy and update it before we are able to conduct another survey in the area?

In recent years, different types of marine information became accessible to the public with cartographic value. This marine information includes: horizontal positioning of ships, satellite imagery, and shallow-water bathymetry collected in non-hydrographic surveys. This paper presents a Nautical Chart Adequacy Evaluation (NCAE) procedure based on hierarchy of evidence ranging from hydrographic and geodetic standard to best available resources that can provide transitory products for mariners until a survey that can meet IHO standards can be conducted (IHO, 2008). The NCAE procedure has been developed in ArcMap ESRI environment and includes: 1) ranking marine areas based on their usage for navigation, 2) comparison between reconnaissance surveys to charted shoreline contours and shallow-water bathymetry, 3) risk assessment, 4) recommendation for feature updates. In this paper, we focus on the first two steps in the NCAE procedure.

Publically-Available resources and the NCAE procedure

In recent years, NOAA's Office of Coast Survey recognized the potential of publically-available non-hydrographic data sources and products to support policy and cartographic decisions. In this study, Automatic Identification System (AIS), Airborne Lidar Bathymetry (ALB) and Satellite-Derived Bathymetry (SDB) were used to evaluate the shoreline and the bathymetry on the chart:

- AIS data are messages that are broadcast over VHF maritime band at a certain frequency in order to avoid collision. One type of AIS message is a dynamic (position) message that contains key parameters, such as position, time, speed, and course information. An archive of AIS data provides a route map for marine traffic that can be statistically analyzed based on vessel type or traffic density. In response to the Maritime Transportation Security Act of 2002, the U.S. Coast Guard (USCG) had made public AIS data from 2008 till 2011 through NOAA's Digital Coast Archive, referred to as the Nationwide Automatic Identification System (NAIS).
- ALB data are a point cloud of depth measurements collected by a pulsed laser system. The National Coastal Mapping Program (NCMP) of the U.S. Army Corps of Engineers (USACE) provides repetitive, regional, high-resolution, high-accuracy seamless bathymetric-topographic elevation measurements through NOAA's Digital Coast Archive. The NCMP repeats its survey along the U.S. coastline every 5 to 7 year. The survey

standards of the USACE's ALB are collected at a spot spacing of 4 m X 4 m with 100% coverage (i.e., no gaps in the survey flight plan).

- SDB is a bathymetry estimation derived (reconnaissance approach) using a band-ratio calculation. The imagery used in this study are multispectral imagery acquired by the Landsat satellites. Current and historical Landsat imagery are available to the public through U.S. Geological Survey (USGS) archive (earthexplorer.usgs.gov). The swath width of Landsat imagery is 185 km with an average ground resolution of about 28.5 m.

The NCAE procedure is conducted in an ESRI ArcMap environment and includes a few key steps:

Ranking the offshore areas – Polygons around the AIS data were generated based on the traffic density. Areas outside the traffic were given the lowest rank, while traffic route areas were ranked based on traffic density (independent of vessel type). AIS polygons with the most dense traffic were attributed with the highest rank .

Shoreline comparison – Infrared imagery was used to discriminate dry land from submersed areas. Although this inferred shoreline is not tide coordinated, it can identify if sediments and vegetated shorelines have horizontally changed.

Bathymetry comparison – Based on water clarity in the charted areas, it is possible also compare SDB results to the chart contours. Discrepancies between the between two may indicate that bathymetry has changes since the last hydrographic survey.

Data compilation – A compilation of shoreline and bathymetry changes with the vessel traffic can provide a spatial evaluation of the adequacy of the chart. Areas with shoreline and bathymetry changes become a priority if they overlap with AIS polygons of the vessel traffic. Otherwise, these areas with shoreline and bathymetry changes receive a low priority. In addition, the chart adequacy approach can validate reported shoals.

Preliminary results

Nantucket Sound, MA– Most of the bathymetry of Nantucket Sound, presented in NOAA Chart 13237 (*'Nantucket Sound and approaches'*), is compiled from hydrographic surveys conducted from 1940 till 1969. Strong currents in Nantucket Sound are causing the seafloor in this area to constantly change and there have been numerous reports of shoals over the past decades by vessels passing in the area. AIS and SDB were used to monitor changes in the bathymetry and validate the reported shoals (Figure 1).

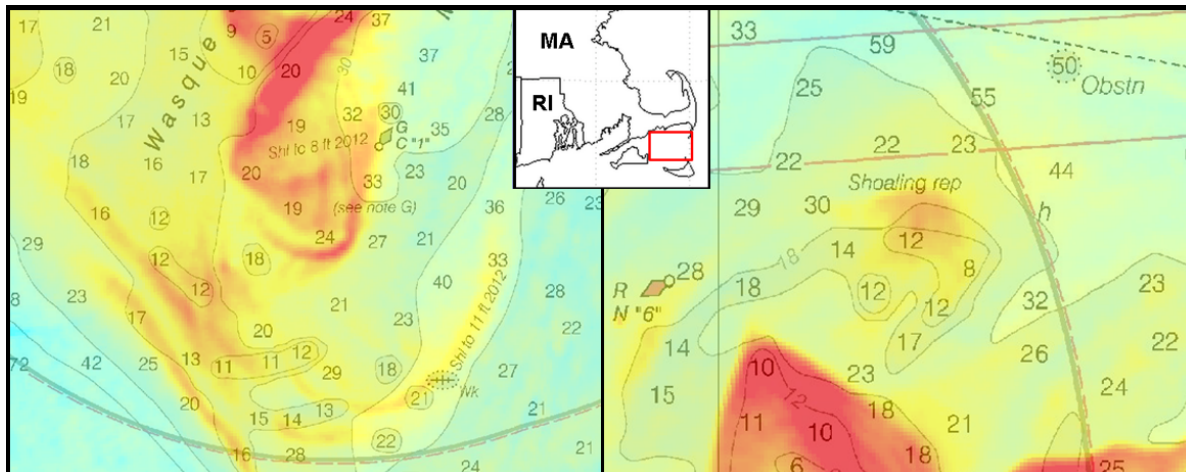


Figure 1. Nantucket Sound, MA: SDB confirming reported shoals (NOAA Chart 13237).

Barnegat Bay, NJ – The bathymetry of Barnegat Bay Inlet in NOAA Chart 12324 (*‘Sandy Hook to Little Egg Harbor’*) has not been updated since the 1930s. The bathymetry in this flood-tidal inlet changes continuously on a seasonal and annual basis. In October, 2012, Barnegat Bay Inlet was also impacted by post-tropical cyclone Sandy (known as, Superstorm Sandy). The use of the datasets goes beyond routine operations for chart adequacy to also emergency response operations by guiding the survey teams (Figure 2). For example, the marine traffic passes through Barnegat Inlet into the Atlantic intracostal waterway (ICW).

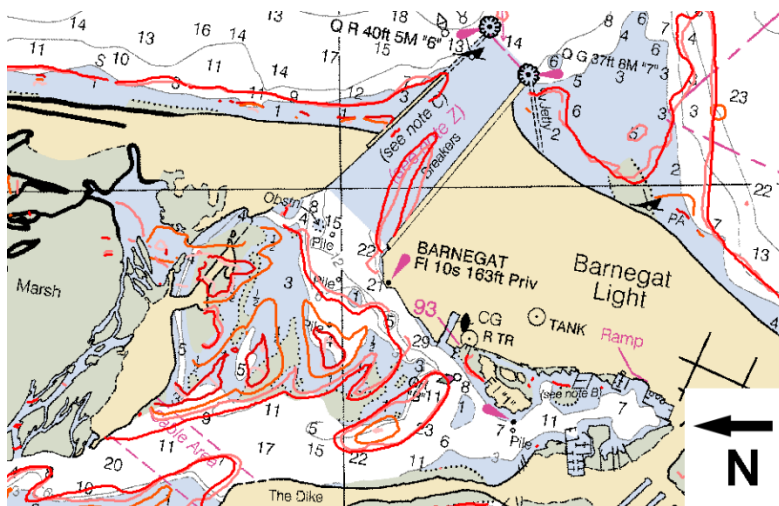


Figure 2. Barnegat Inlet, NJ: 0-m contour lines at MLLW of SDB products (3 Landsat images collected during the June to August, 2014) overlaid on NOAA Chart 12324.

Barataria Bay, LA – A 9 mm/yr trend of the relative sea-level rise has been calculated for Brataria Bay using water level measurements since 1950. In addition, NOAA Chart 11358 (*Barataria Bay and Approaches*) has not been updated since the 1940s. The area is characterized by very turbid shallow waters and most of the charted shoreline is vegetated. Two major marine-vessel traffic routes pass through the Bay out into the Gulf of Mexico. Although it is not possible to utilize SDB due to the turbid waters, AIS data is used to identify changes in bathymetry and shoreline (Figure 3).

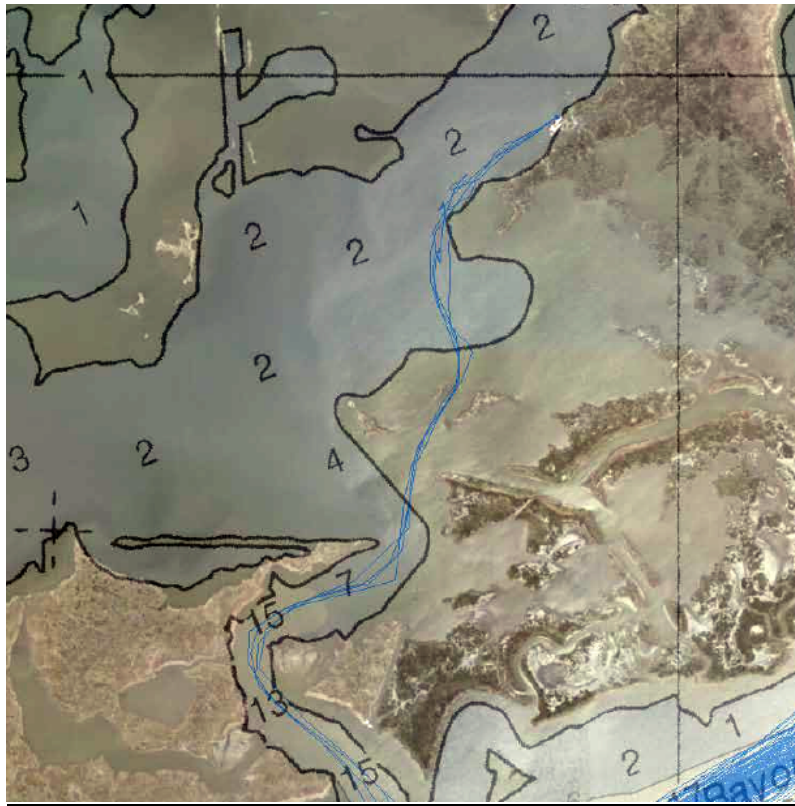


Figure 3. Barataria Bay, LA study site: AIS tracks in overlaid on NAIP imagery and NOAA Chart 11358.

Discussion

Development of chart adequacy assessment procedure has been named a top priority by NOAA's MCD leadership. The methodology has incorporated into MCD's chart specifications and regional evaluation before charts are published as new editions. Thus, the NCAE provides an additional quality control to the current protocols used by NOAA's cartographers. A policy for the acquisition of the use of publically-available datasets is currently under review. In addition to NCAE, the tools developed from the publically-available datasets can be used in other applications that can support

the needs of an hydrographic office, such as the development of a new nationwide hydrographic survey priorities model. The procedures and tools will be available for public use in the next year.

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