5TH MEETING OF THE IHO-INTER REGIONAL COORDINATION COMMITTEE
IHO IRCC5

WOLLONGONG, AUSTRALIA, 3-4 JUNE 2013

SATELLITE DERIVED BATHYMETRY (SDB)

Submitted by:	IHB
Executive Summary:	This paper proposes that shallow water bathymetry derived from multispectral imagery, should be considered as a potential technology for obtaining bathymetry for charting purposes in areas where existing surveys are poor or non-existent and where there is little prospect of obtaining the resources required to proceed with extensive surveys using other higher accuracy methods in the foreseeable future. Bathymetric and other useful environmental data can be derived extremely cost effectively from satellite imagery, however the information content of these data must be well understood and not regarded as a replacement for acoustic, LiDAR or other high resolution surveying sensors.
Related Documents:	1. XVIIIth IHC Decision 17 - *Global Status of Hydrographic Surveying*

Introduction and Background

1. In April last year, the XVIIIth International Hydrographic Conference adopted a Decision acknowledging the unsatisfactory state of global hydrographic survey coverage and the diminishing levels of resources being made available to address the situation (see Related document 1). The Decision tasked the IRCC and HSSC, in cooperation with the Directing Committee to progress whatever actions are required to improve the collection, quality and availability of hydrographic data worldwide, monitor and rectify possible deficiencies and shortcomings, cooperate with other international organizations and stakeholders as necessary, and to keep Member States informed on progress on the issue.

2. In its explanatory note proposing the adoption of the Decision, the Directing Committee pointed out that over the last three decades, numbers of surveying vessels owned by Member States and operated by charting agencies has declined by 34% for offshore vessels and 35% for coastal vessels. Furthermore, it seems unlikely that this reduction in numbers has been matched in total by the use of more efficient technology, such as airborne LiDAR or Multibeam depth sounders or through governments opting to use commercial surveying contractors. An examination of IHO Publication C-55 - *Status of Hydrographic Surveying and Nautical Charting Worldwide* shows that progress in the amount of sea area surveyed in most States is slow or non-existent.

3. Against this background, any viable alternative methods of obtaining suitable depth information in a cost effective and reliable manner should be investigated and promoted.

4. Over the past decade, there have been significant advancements in the methods used to derive bathymetry from multi-spectral satellite imagery. **Satellite Derived Bathymetry (SDB) has the potential to make substantial improvements to otherwise inadequate charts** and can provide useful hydrographic data for other purposes in areas where existing charting is based on little or no hydrographic surveying and there is little prospect of conventional surveys being conducted in the reasonable future. Bathymetry derived from multi-spectral satellite imagery should not be confused with satellite-based altimetry or with stereoscopic image analysis.

Brief Description of Bathymetry Derived from Multispectral Satellite Imagery

5. Various water column parameters including water depth can be measured from satellite based earth observation sensors (EOS) if the reflection of light from the seafloor provides a detectable part to the signal measured by the sensor. The method for obtaining this information consists of feeding environmental parameters into a radiance formula and inverting the equation to calculate depth layers while reducing the need for

comprehensive in-situ observations. Only a limited amount of ground-truth data or other local support infrastructure is required.

6. As well as providing water depth values, EOS can reveal other water column and seafloor properties. In addition to providing physical values such as depth and a measure of total suspended matter, EOS can reveal other biochemical water column properties, including the presence of various organisms such as photosynthesizing organisms, and cyanobacteria which can be a measure of water quality. The transparency and turbidity of the water can also be obtained. EOS can also reveal the extent of seagrasses, macro-algae and associated substrates, main species differentiation, density of seafloor cover; biomass, the nature of coral reefs and can discriminate between live or dead coral. In this context, **EOS can serve as a comprehensive maritime environmental sensor package, rather than as a single-focus hydrographic tool**.

History and Current Status

7. For some time, a number of agencies, largely academic, have been researching and developing improved means of determining depth and other water column and seafloor parameters using EOS. Today there is also an emerging commercial market and strong interest in developing EOS for use in the maritime environment.

8. The availability of air and space borne multispectral and hyperspectral sensors is increasing. The number of spectral bands in suitable high spatial resolution sensors now varies from 4 in multispectral sensors to 8 in fully hyperspectral sensors. The cost of purchasing high resolution (6.5m to 0.5m pixel size) multi or hyperspectral imagery ranges from about 1€ to 25€ / km^2 depending on the resolution, number of bands and the age of the data[1]. The principal additional cost to then obtain bathymetric data from the imagery is for data processing.

9. Some researchers[2] are now suggesting that depth values down to 20m can be obtained from EOS that, in some circumstances are comparable with the higher orders of IHO S-44 - *Standards for Hydrographic Surveys*. However, the ability to locate all navigationally significant seafloor features is not confirmed. Indications are that some EOS bathymetry could meet IHO Order 1b. Such bathymetry might then be acceptable for charting in certain areas where precise under-keel clearance is not critical for the type of surface shipping expected in an area. At least one IHO Member State (France), has been using bathymetry derived from EOS for over 20 years and as a result has published over 100 charts as part of its nautical chart series.

10. While there has been comparatively little engagement from hydrographic offices (other than from France), there is growing commercial interest from specialist EOS data companies[3] and it is likely that conventional hydrographic survey companies may take up the technology in the near future.

11. Most recently, a pan-EU consortium narrowly missed a €2.5M funding grant from the EU Space programme to develop EOS, in particular for bathymetry. In UK, under the government *Space Applications Catapult* initiative, there is an active programme to develop EOS for commercial exploitation and from which

---

[1] Dekker et al, 2011

[2] Some key government science and consultancy based firms researching EOS for bathymetry are:

Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Prof. Arnold G. Dekker
Australia

Sequoia Scientific, Inc.
Dr. Curtis D. Mobley
USA

EOMAP GmbH & Co.KG
Dr. Thomas Heege
Germany

Office of Naval Research (ONR)
USA

University of Massachusetts at Boston
Dr. Zhongping Lee
USA

[3] Some recent surveys undertaken by commercial companies:

ProteusGeo in the UAE and the Republic of Ireland
BMT Argoss on the coast of Mozambique

national hydrographic services will eventually benefit. In addition, the UKHO is planning to conduct a tightly controlled study to ascertain the inherent uncertainty and data quality of bathymetry derived from multi-spectral satellite imagery, in real world conditions. Research and development is also ongoing in Australia, Germany and the USA.

Brief Impact Analysis of SDB

12. The use of aerial remote sensing in hydrography is not new. The use of bathymetry derived from EOS should not be seen revolutionary, but rather, as an extension of existing practices. Mapping the coastline and topography, and obtaining the location of prominent shoals and even an estimation of very shallow depths - obtained from aircraft and more recently from satellite observations, are well accepted as part of the process of preparing for a survey. The initial observations obtained from such aerial observations can then be used to establish the baseline for more detailed surveys using high resolution sensors where required. This initial data can then be used to determine those areas where a greater level of detail is required using higher resolution sensors, such as LiDAR or acoustic depth sounders. The advantage of bathymetry derived from EOS is that it can provide a baseline survey including an initial bathymetric dataset at relatively low cost and with very limited amounts of surface infrastructure being required. In some circumstances the data may be suitable for inclusion directly in charts.

13. Significantly, the base imagery required for one data set, such as bathymetry, can also provide a variety of other data sets for different purposes and for other stakeholder groups. This means that satellite imagery purchased and processed to meet safety of navigation (SOLAS) obligations can also be used to support marine habitat and environmental monitoring and other purposes and vice versa. In this context, **cost sharing and multi-programme support arrangements become a very realistic proposition**. This is particularly relevant in States with limited budgets or for those States that seek external funding to improve their geospatial knowledge.

14. Current hydrographic data gathering operations, using ships or aircraft, rely on labour-intensive relatively slow on-site operations. LiDAR has certain advantages over ship borne acoustic systems in being able to cover large areas more quickly while being able to gather topographic, bathymetric and intertidal data simultaneously but LiDAR is limited by depth and water clarity. LiDAR, like ship surveys, usually requires complex logistic support and organisational requirements to be in place. EOS, whilst currently limited in some respects with regard to the accuracy or the resolution of the depths that can be obtained, can potentially deliver a wide variety of maritime spatial and topographic data in a very short timeframe and in certain circumstances without the need for any in situ support. Importantly, **for areas where no charts exist, EOS can identify areas of shallow water where navigation would most likely be hazardous or impossible**. For this reason, it is particularly relevant in States where there is little or no existing hydrographic or other maritime geospatial data and no realistic prospect of using more conventional methods in the short to medium term.

15. **Costs for the delivery of processed EOS data vary greatly but they are potentially significantly less than using conventional survey methods**. Costs will vary depending on the density of data required, the choice of constellation, the availability of EOS imagery archive data and the amount of ground control that may, or may not, be required. However, using EOS data as a first step in addressing a lack of hydrographic data could be as much as one twentieth of conventional hydrographic survey costs.

16. Noting that there are very significant areas of the world where there is little or no hydrographic or other marine data available, **EOS data may be the only realistic way for States to obtain at least some coverage in the short to medium term**. Notwithstanding any limitations regarding the ability of EOS to determine depths as accurately as existing surveying techniques or to identify all undersea hazards, EOS can still provide a cost-effective baseline survey from which States can then determine priorities and opportunities for further more intensive work to enhance this baseline dataset. Notably, **EOS data has the potential to enable all States to determine where there are areas that may be suitable for safe navigation and at the same time assist in the further development of other maritime activities associated with the "blue economy"**.

17. **In uncharted areas, SDB surveys, perhaps combined with crowd-sourced data where available, has the potential to provide useful nautical charts where otherwise there would be no charts at all**. SDB could also be helpful to qualify crowd-sourced data and vice versa.

18. In order for SDB to be used properly and in a standardised way, States should ensure that it can be properly assessed, evaluated and subsequently used in a logical, structured and safe process. States must be able to consider the balance of liability between using SDB with any inherent limitations that it may have against not being able to provide any charts at all.

19. **The proper use of SDB can enable many, if not most, States to progress from a situation of having serious gaps in hydrographic coverage towards better data to serve national and global interests**. This is in accordance with the mission and the objectives of the IHO and its Member States.

20. **The impact of the IHO recognising SDB** as a potentially viable technology to address the currently serious shortfall in hydrographic data in many parts of the world **is very significant**.

Relevance to IHO Capacity Building Strategy

21. States with a limited capacity or limited funding to conduct hydrographic surveys, as well as many States with large areas of charting responsibility and extensive areas of poorly surveyed waters away from established routes, frequently face the dilemma of not knowing where to plan detailed surveys, while at the same time needing to demonstrate early and effective results. **SDB offers the potential to be a highly cost-effective reconnaissance tool for identifying new areas for surface navigation**. It can help identify areas where higher resolution surveys can then assure routes for transit or entry through otherwise poorly surveyed waters.

22. EOS and SDB are particularly relevant as options in those States where land surveying and environmental monitoring have already led to the development of remote sensing processing capabilities. Existing training and experience can be harnessed by focussing efforts on the use of satellite imagery, MSI and validating SDB data until such time as traditional hydrographic surveys and the inherent requirement to support high cost equipment and unique technologies and methods can be implemented in a sustainable manner.

23. In this way **SDB could act as a "kick start" and "quick-win" way of seeing progress and gaining sustainable investment to improve** the "SDB-based" **charts** by targeting where additional higher resolution surveys are required. In this context, SDB should be seen as one of the data gathering and capacity building options under CB Phases 1 and 2.

24. All States will still require a minimal level of in-country hydrographic surveying capability to obtain high definition surveys of critical and important areas. Any use of SDB data will not change this requirement.

Relevance to IHO Standards

25. **S-44**. In the light of further experience with SDB data, some existing IHO standards may need review to ensure that SDB data can be satisfactorily classified against the various levels of survey indicated in S-44, particularly in relation to feature detection. To ensure that the reliability of SDB data can be classified and depicted in a standardised way on charts, in publications and in metadata, using either existing or possibly new classification indicators, development of specific guidance on data portrayal and metadata may also be required. UKHO's independent research and close involvement with the work to be conducted on industry standards and specifications for SDB through the Space Applications Catapult will assist in understanding SDB's place in the current S-44 orders and any amendments that might be required to accommodate passive (EOS) data gathering methods.

26. **S-4, S-52**. The IHO standards for the portrayal and the classification of the reliability of hydrographic data may require review to provide better guidance on how data such as SDB might be assessed and portrayed. For example, while IHO S-4 - provides guidance on how to "*distinguish soundings of less reliability amongst better data*", it is less clear on how to portray the reliability of a set of data such as SDB that could cover a much wider area. This may also have an impact on the criterion and descriptors used in source or reliability diagrams and the S-57 Zone of Confidence (CATZOC) reliability indicator. France has already developed some methodology for using SDB data in charts.

IHO Role

27. The role of the IHO is to encourage the development of new and cost effective technologies that will improve the global state of surveying and charting.

28. Noting the long-term use of SDB by at least one Member State and the renewed and active developments now underway in other States, in industry and in academia, it is timely for the IHO to ensure that all States are made aware of the potential of EOS and SDB to help address the critical lack of hydrographic information in many parts of the world and to encourage Member States and representatives of industry and academia to work together to ensure that the best possible use is made of the technology to help address the unsatisfactory state of global hydrographic survey coverage in many parts of the world.

29. The IHO should ensure that appropriate standards are in place so that any relevant new technology, such as SDB, can be shown to meet those standards. It is then up to the developers of new technologies to demonstrate how they meet these IHO standards. As with other sensor developments such as LiDAR or multi-beam depth sounders, it is not the role of the IHO to technically assess or develop SDB technology, nor is it the role of the IHO to develop specific standards for SDB.

Conclusion

30. SDB may offer **a viable interim solution** at least for those areas of shallow coastal waters **where there is little or no existing hydrographic data and no prospect of obtaining the resources required to proceed with extensive surveys using other higher accuracy methods in the foreseeable future**.

31. However, the characteristics of SDB data must be taken into account when it is used for charting purposes. In the light of further experience with SDB, **IHO standards and specifications may require to be reviewed and revised** to ensure that SDB data can be assessed, classified and portrayed systematically and in a standardised way, as is already the case for data obtained using other established surveying sensors.

32. Industry and Academia should be encouraged to continue to develop methods of obtaining bathymetry from EOS and to conduct independent comparison trials to confirm the results against the relevant IHO standards.

Recommendations

33. The recommendations of this paper are to:

a. **acknowledge** that Satellite Derived Bathymetry, with appropriate accuracy and reliability indicators, may be a way to address the current limitations on maritime development due to extensive areas of unsurveyed and very poorly surveyed shallow waters,

b. **acknowledge** that Satellite Derived Bathymetry could be an effective way of identifying certain sea areas for further maritime development, including more detailed hydrographic surveys where the principal objective is for safe navigation,

c. **encourage** Member States and representatives of industry and academia to work together to ensure that the best possible use is made of Satellite Derived Bathymetry to help address the unsatisfactory state of global hydrographic survey coverage in many parts of the world.

d. **invite** RHC Chairs to promote Satellite Derived Bathymetry as one possible means of addressing the lack of survey data for appropriate areas in their region, and

e. **acknowledge** that the cost effectiveness of Satellite Derived Bathymetry may encourage States to more quickly recognize the benefits of investing in an effective national hydrographic survey programme.

Action Required of IRCC

34. The IRCC is invited to:

a. **Note** the contents of this paper,

b. **Agree** the recommendations contained at sub paragraphs 33.a to 33.e, and

c. Take any other action as it considers appropriate.