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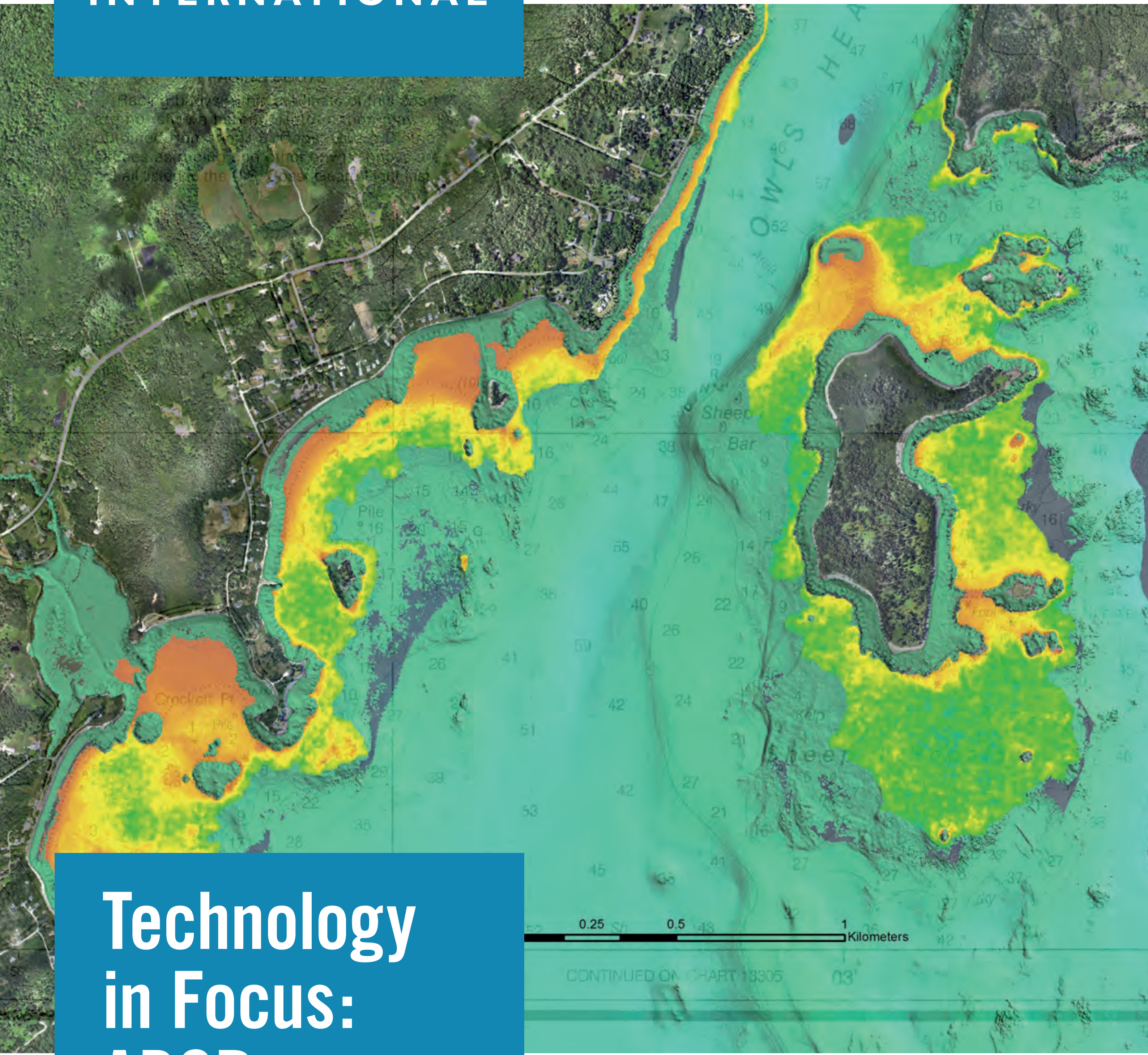
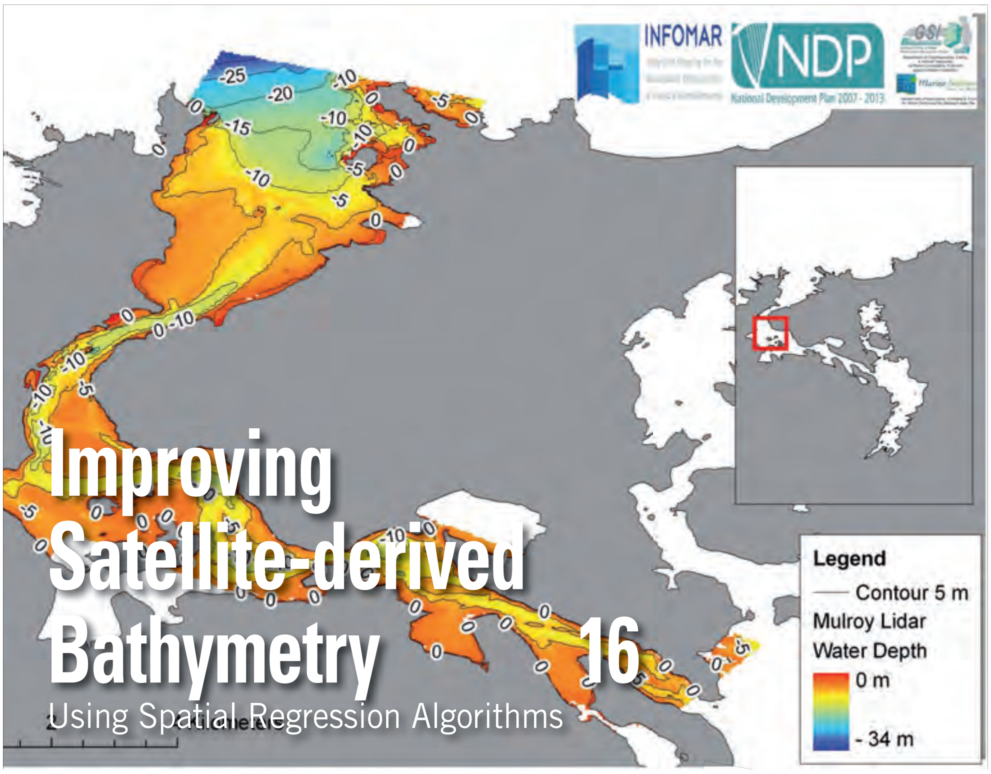
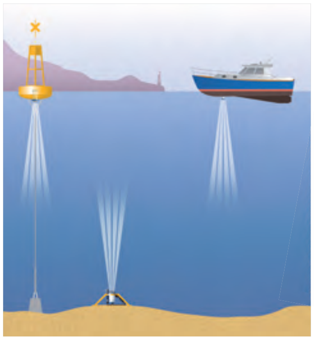


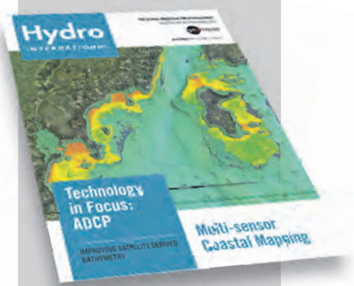
Technology in Focus: ADCP

IMPROVING SATELLITE DERIVED BATHYMETRY

Multi-sensor Coastal Mapping







January-February 2017
Volume 21 #1
A combination of multibeam echo sounder, airborne Lidar bathymetry and highlighted satellite-derived bathymetry coverage. The techiques are covered in the article by José Martinez and Don Ventura from page 23. Image courtesy: NOAA, Fugro.

HYDRO ALPHABETICAL LIST OF ADVERTISERS

PHOTOGRAPHY: ARIE BRUINSMA (WWW.ARIEBRUINSMA.NL)

Data Revolution

Oceans, seas and coastal zones are one of the most, if not the most, important component of the Earth's ecosystem. They cover more than two-thirds of the earth's surface and more than three billion people on the planet depend on marine and coastal resources for their livelihoods. Oceans are crucial for global food security, oceans are one of the most important factors in regulating the global climate and they host the planet's biggest biodiversity. Sustainable development of the oceans, seas and coastal zones is therefore critical, says the United Nations. The UN has set their Sustainable Development Goals (SDGs) to be met in 2030. An ambitious plan for eradicating poverty, decreasing CO2 emissions, increasing literacy, etc. Sustainable Goal number 14 aims specifically to conserve and sustainably use the oceans, seas and marine resources for sustainable development.

The UN World Data Forum was held in Cape Town, South Africa from 15-18 January. It was an inspiring week with statisticians from all over the globe, discussing, learning and sharing ways to open up their data in an accessible way for the purpose of helping to meet the SDGs in the long run and to better the world in the short run. Free and open data, visualisation, connectivity and interoperability - the Cape Town International Convention Centre was buzzing with these words. The crowd, almost 1,400 attendees, made new friends and allies in the world of data that is becoming more complex everyday. On this most southern tip of Africa, at the intersection of two oceans, the Atlantic and Indian Ocean, the first steps were laid out to new foundations of data policy. It struck me that at this special place in the world, indeed between two oceans, the words 'oceans' and 'seas' were never mentioned. I didn't see any tracks or presentations on data of the seas – SDG number 14 was not in the scope and I didn't meet any experts on the oceans amongst the delegates.

Isn't that very strange? Particularly as we identified that the oceans and seas are so important for the sustainable development of the earth and the livelihood of so many of its inhabitants. Yes and no. 'No' because the UN is organising a special conference on SDG number 14, UN Oceans, this June in New York, dedicated to the conservation and sustainable use of the oceans and seas. 'Yes' because it was a missed opportunity for Cape Town! A data revolution is sweeping through the world, but shouldn't stop where the land ends and the sea begins. The community of oceanography and hydrography professionals should interact with the data professionals on land and not miss out on new technologies that will not only change the world, but also the world of the oceans and seas, and especially the coastal zones. There was a call for a data revolution at the UN World Data Forum in Cape Town, as there will be in New York in June as well. Will 2017 be the year of a data revolution in hydrography too? I really hope it will, all the more because I think it is necessary. I therefore urge all policymakers in our field to make it happen!

Durk Haarsma durk.haarsma@geomares.nl

Hydro International is an independent international magazine published 6 times a year by Geomares Publishing. The magazine and related e-newsletter inform worldwide professional, industrial and governmental readers of the latest news and developments in the hydrographic, surveying, marine cartographic and geomatics world. Hydro International encompasses all aspects, activities and equipment related to the acquisition, processing, presentation, control and management of hydrographic and surveying-related activities.

Geomares Publishing
P.O. Box 112, 8530 AC Lemmer, The Netherlands
Phone: +31 (0) 514 56 18 54, Fax: +31 (0) 514 56 38 98
info@geomares.nl
www.geomares.nl

Sea Vision

For most my naval career, senior colleagues bemoaned the curse of sea blindness, a perception that increased in volume around the time of government reviews of defence and the inevitable scrutiny of naval budgets and resources. We thought ourselves to be 'out of sight, out of mind' with few of the general public aware or caring about the value of our service and our contribution to the national wellbeing. And, indeed, it was challenging to build a picture of what was happening in our vicinity; using radars, helicopters and good old binoculars we would persistently monitor fishing vessels and merchant ships differentiating between oil rigs, crossing ferries and the ubiquitous yachties, and sharing our picture with other ships in the task group. Building a 'white picture' of routine shipping activity required constant, 24/7 dedicated monitoring of a plethora of data sources, bowling out conflicting tracks and resolving identities.

AIS is, of course, the game changer. Originally conceived by mariners for mariners to improve safety by providing enhanced situational awareness in busy seaways, AIS (and now satellite AIS (S-AIS)) is at the core of my contention that we are on the cusp of sea vision, an epoch when we will know everything we need to about human activity and maritime operations of all kinds in complex sea basins such as the Mediterranean, the South China Sea, the Gulf of Mexico, the North Sea and many, many more. But AIS is not the end of the story because satellite-derived data sources such as optical imagery and synthetic aperture radar are exponentially improving in performance, offering corroborating information about maritime operations from space. Rapidly improving satellite communications services allied with a bonanza of CubeSats (miniature satellites deployed in low earth orbit) herald cheap, ubiquitous global constellations providing near total coverage of the Earth's terrestrial and marine environments. Fusing these space-derived sources with terrestrial coastal radar pictures and historical datasets such as vessel registers will provide a comprehensive, reliable picture of human activities on our seas and oceans. Nor are these data sources the exclusive preserve of maritime and marine professionals; they are commonly available to the previously sea blind public on their mobile devices via a range of paid and free services.

This rapidly growing sea vision phenomenon has direct implications for hydrography as at the heart of all situational awareness techniques is the human need for a geographical presentation of information; a map, chart or GIS solution that immediately informs the operator and enables accurate decision making. Bathymetry is the essential prerequisite to understanding our seas and oceans, and our ability to exploit their largely unknown resources in an economically viable but environmentally sustainable manner. Notwithstanding the current O&G depression, there is a real need for data about the bathymetry of these water concealed territories and the state of our marine environments. This is an exciting time, sea vision is here and happening, there will be few places to hide, the concept of the High Seas will become anachronistic, and we will manage our global oceans in a much more sensible way for the benefit of the environment and humanity. The onus is on we the hydrographers – what will be our contribution to this unfolding revolution?

SurvTech Selects NEXUS 800 for Aerial Mapping

▲ *NEXUS 800 UAS Powered by HYPACK.*

A NEXUS 800 UAS powered by HYPACK was provided to the US southeastern geospatial solutions company SurvTech. The company will use the device to acquire upland data simultaneous with subaqueous data and make a seamless point cloud of upland and submerged data. The integration with the company's heading RTK GPS, IMU, sonar and HYPACK was experienced as straightforward.

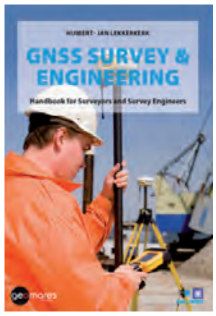
▸ ***bit.ly/2jiriPE***

Most Shared

Most shared during the last month from www.hydro-international.com

1. Wrecks - bit.ly/HYD-wrecks
2. Revised Standards of Competence for Hydrographic Surveyors and Nautical Cartographers - bit.ly/2jAkduM
3. Five Questions to Larry Mayer - bit.ly/2jAfUQf
4. Effective Surveying Tool for Shallow-water Zones - bit.ly/2jAiYMh
5. Satellite-derived Bathymetry Migration - bit.ly/2jAm9Uj

New Book 'GNSS Survey & Engineering'

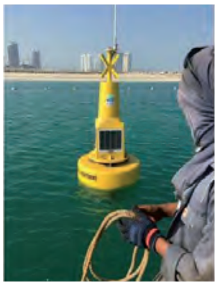


▲ *GNSS Survey & Engineering. Handbook for Surveyors and Survey Engineers.*

Geomares Education is introducing the book 'GNSS Survey & Engineering', written by Huibert-Jan Lekkerkerk. GNSS Survey & Engineering aims to provide the everyday professional GPS user with enough background for the understanding and correct operation of satellite navigation equipment in general and GPS in particular. The book is based on the lectures the author has written for the Skilltrade course in hydrographic surveying as well as a series of articles on satellite navigation systems.

▸ ***bit.ly/2jiCpYQ***

OSIL Installs Buoy Network in UAE



▲ *Deployment of one of the OSIL buoys in the UAE network.*

Ocean Scientific International Ltd. (OSIL) has installed a network of eight monitoring buoys off the coast of Abu Dhabi, UAE, in support of environmental monitoring. The rugged 1.2m coastal buoys are equipped with multiparameter sondes for water-quality monitoring and GPRS telemetry equipment. The buoys are installed in water depths ranging from 6m to 16m, in various locations along the UAE coastline amid extensive coral formations and seagrass beds.

▸ ***bit.ly/2jip9DP***

Investigating Hidden Depths of East Antarctica

▲ *RV* Investigator *multibeam illustration. Image courtesy: Geoscience Australia.*

Geoscience Australia marine geoscientist Dr Alix Post is heading to Antarctica aboard the Marine National Facility research vessel RV *Investigator* to further her work on the unique marine biodiversity of the Antarctic seafloor. A range of geophysical data and seafloor images, including seismic profiles and multibeam bathymetry, will be collected to help predict the nature and distribution of biological communities.

▸ ***bit.ly/2jimU3e***

Port-Log for ABP's Environmental Monitoring

Associated British Ports (ABP) has contracted OceanWise to install Port-Log across all of ABP's 21 UK ports. The project has not required any of ABP's existing sensors to be replaced. A major benefit of Port-Log.net is its ability to accommodate a wide range of sensors from different manufacturers. Consequently, pressing deadlines for installing and testing the system were able to be met.

▸ ***bit.ly/2jiwvXK***

Java Offshore Acquires Asian Geos

Java Offshore, headquartered in Indonesia, has recently completed the acquisition of a majority stake in Asian Geos, a specialist offshore geotechnical and geophysical service provider within the Asia Pacific market, from both Gardline Geosciences and Helms Geomarine. The acquisition will further enhance Java Offshore's existing portfolio of services through the addition of an offshore geotechnical and engineering capability focused in the oil and gas, marine renewables, marine civil engineering and telecommunication sectors.

▸ ***bit.ly/2jiHQXP***

Klein Side-scan Sonar for Gavia AUV

▲ Teledyne Gavia AUV in water.

Teledyne Gavia has released a side-scan/bathymetry module that incorporates Klein Marine Systems' UUV-3500 high-resolution side-scan sonar with optional bathymetry sonar. The system is an option for customers interested in utilising the Gavia AUV for geophysical survey, cable and pipeline survey, environmental survey or under-ice survey, as well as mine countermeasures (MCM), rapid environmental assessment (REA), or intelligence, surveillance and reconnaissance (ISR) surveys.

▸ *bit.ly/2jivRJY*

GEBCO-NF Team in Ocean Floor Challenge

GEBCO (General Bathymetric Chart of the Oceans), which operates in partnership with The Nippon Foundation (NF), Japan's largest private philanthropic foundation, put forward its team challenge for the USD7 million Shell Ocean Discovery XPRIZE in San Diego, California, USA, in December last year. The three-year challenge started with 32 teams from 22 countries as part of XPRIZE's 10-year ocean initiative 'to address ocean challenges and help make the oceans healthy, valued and understood'.

▸ *bit.ly/2jizu2r*

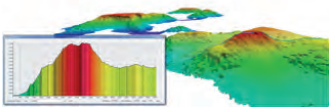
Shom to Improve Marine Mapping in Indian Ocean

On 15 January 2017, RV *Beautemps-Beaupré* took off from Brest in France. It will be on a mission until November to carry out hydrographic surveys for the Shom in the Indian Ocean, aimed at improving the charts for the safety of navigation. A crew of 21 Shom scientists are accompanying the 29 *Beautemps-Beaupré* sailors for this campaign. Two crews will relay during the deployment time.

▸ *bit.ly/2jiwQd8*

▲ *Shom's* Beautemps-Beaupré *leaves for 10 months on the Indian Ocean: Image courtesy: Shom-PY-Dupuy.*

Survey of New Seafloor Features



▲ *Profile of Seamount 5, with a perspective view of bathymetry looking Northwest with 2x exaggeration. Image courtesy: Schmidt Ocean Institute.*

In the last few years, various US Marine National Monuments located in the Pacific Ocean have been expanded to cover approximately four times the previous area, enclosing a great number of additional seafloor features. The Johnston Atoll Unit (JAU) of the Pacific Remote Islands Marine National Monument was an area of particular interest on the latest 'transruise' of RV *Falkor* called 'Eyes below the Surface: Mapping Johnston Atoll'. It will take some time to generate a full analysis, but the seamounts that were uncovered were both unusual and complex.

▸ *bit.ly/2jiAt2R*

Galileo Clocks under Investigation

As first reported last November, anomalies have been noted in the atomic clocks serving Europe's Galileo satellites. They have occurred on five out of 18 Galileo satellites in orbit, although all satellites continue to operate well and the provision of Galileo Initial Services has not been affected.

▸ *bit.ly/2jitua4*

New Research Vessel for VIMS

Virginia Institute of Marine Science (VIMS) of Gloucester Point, VA, USA, awarded a contract to Meridien Maritime Reparation of Matane to construct a 93-foot research vessel. JMS Naval Architects designed the research vessel to replace VIMS's current vessel, the R/V *Bay Eagle*. The new vessel will be capable of conducting fisheries assessments of greater capacity, in deeper waters and with a larger science complement than the *Bay Eagle*. The primary mission of the Institute's fleet is to provide inshore and offshore work platforms for the support of fisheries-related oceanographic research projects.

▸ *bit.ly/2jt1Jih*

▲ *VIMS new research vessel birds eye working deck.*

Saab Seaeye Sees Future Task-driven ROVs

Electric robotic systems will perform all tasks in the underwater domain, including those now undertaken by hydraulic systems, according to Saab Seaeye. They see a future where ROVs and AUVs in their present form will cease to exist and are replaced by transformative e-robotics that can roam, hover, reside and perform all underwater tasks. It is a future where task resolution is key, not class of vehicle, according to the company.

▸ *bit.ly/2jiD7W3*

▲ *Saab Seaeye Leopard - a powerful electric work system of its size.*

Transferring up to Three Times More Data under Water

The RTsys teams, in association with the Higher Institute for Electronics and Digital Training (ISEN) in Brest, France, took it upon themselves to improve underwater communication. In order to do so they adapted the multiple input/multiple output (MIMO) technology, which involves multiplying the number of transmitters and receivers. Tested in the harbour of Brest in April 2016, the system demonstrated a 300% improvement of throughput compared to conventional single input/single output (SISO) technology.

▸ *bit.ly/2jtewRR*

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ADCPs	
1. Nortek – AWAC	bit.ly/AWACadcp
2. SonTek RiverSurveyor M9	bit.ly/SonTekRiverSurveyor
3. Nortek – Vector	bit.ly/NortekVector
4. SonTek – Argonaut	bit.ly/SonTekArgonaut
5. Teledyne Marine - WorkHorse Long Ranger 75kHz	bit.ly/TeledyneWorkhorse

Deep Ocean High Pressure Samplers for India

A delegation of the National Institute of Ocean Technology (NIOT) visited NIOZ to perform acceptance tests for the new NIOZ High Pressure Sampling system. All the tests were performed successfully. The system can take samples of microbes in the deep ocean to a depth of 6,000m, and bring them to the surface while maintaining their ambient pressure.

▸ *bit.ly/2jsVZoS*

▲ *Signing of the acceptance test documents at NIOZ, from left to right Mr De Greef, Dr Kirubagaran, Mr Ramesh, Mr Thiruppathi, Mr Van Heerwaarden and Mr Smit.*

Maria S. Merian Collects Current Data and Samples

▲ *Research crew on* Maria S. Merian *to research currents and samples in the South Atlantic.*

A few weeks after the research vessel *Meteor* left Cape Town with an international research team headed by the GEOMAR Helmholtz Centre for Ocean Research Kiel, RV *Maria S. Merian* is on the same course from Table Mountain to South America. On board is a team of more than 20 scientists from eight countries. Of particular interest is the oceanic heat transport in the region including, for example, the northward transport of warm water masses in so-called Agulhas rings.

▸ ***bit.ly/2jsWVJG***

Subsea Navigation for Pipelay Vessel LV *108*

▲ *McDermott extends capabilities with Sonardyne's acoustically-aided DP technology for LV* 108. *Image courtesy: McDermott International, Inc.*

Sonardyne, based in Houston, USA, has supplied acoustically aided inertial navigation technology to offshore engineering, procurement, construction and installation company McDermott International for its Lay Vessel *108* (LV *108*). The Sonardyne Ranger 2 Pro DP-INS system, the highest specification available from Sonardyne, is being used to support touchdown monitoring surveys of submarine cables, umbilicals and pipelines and as an independent position reference for the LV *108*'s Kongsberg dynamic positioning (DP) system.

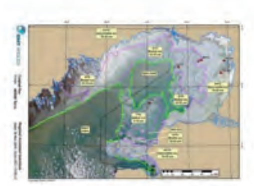
▸ ***bit.ly/2jt410m***

1st Assembly on Mapping our Seas

After nearly a century in Monaco, the IHO will enter its second century under a revised governance structure, with the 1st Session of the IHO Assembly taking place from 24 to 28 April 2017. Over 300 delegates representing its 85 Member States, together with representatives from international and non–governmental organisations and observers from other States and industry will meet in the Auditorium Rainier III in Monaco.

▸ ***bit.ly/2jt0z6w***

BMT ARGOSS Launches Ice Charting Capability



▲ *BMT Ice Charting Capability.*

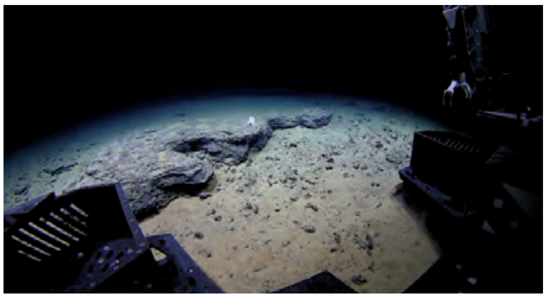
BMT ARGOSS (BMT), a subsidiary of BMT Group, a leading international design, engineering and risk management consultancy, has launched an ice charting capability. Coupled with the company's extensive weather forecasting expertise, this will provide a more enhanced and cost-effective service to customers globally. As part of this new capability, a number of BMT's key senior meteorologists have completed a training programme at the Danish Meteorological Institute.

▸ ***bit.ly/2jt2LLb***

Breeding Ground for Deep-sea Octopuses

Manganese nodules on the seabed of the Pacific Ocean are an important breeding ground for deep-sea octopuses. As reported by a German-American team of biologists in the latest issue of the journal 'Current Biology', the octopuses deposit their eggs onto sponges that only grow locally on manganese nodules. The researchers had observed the previously unknown octopus species during diving expeditions in the Pacific at depths of more than 4,000 metres – new record depths for these octopuses.

▸ ***http://bit.ly/2jtqoDs***



▲ *ROV approaching the manganese nodules and a deep-sea octopus. Image courtesy: NOAA.*

Wide-angle Echoscope

Coda Octopus has presented an addition to its range of real-time 3D sonar systems, a wide-angle 90°x40° 240kHz option Echoscope. This variant has multiple projectors and affords an increased opening angle, thus increasing the field of view and survey area of coverage. The XD dual frequency model will enable large area imaging and mapping to be efficiently and effectively completed in support of a wide range of subsea bathymetry and imaging projects.

▸ ***http://bit.ly/2jtnZZq***

Includes First USA Edition of Catch the Next Wave Conference

Oceanology International Launches in North America

The San Diego Convention Center in California, USA, will host the first Oceanology International North America (OINA) from 14-16 February 2017, bringing together key figures and businesses from the marine science and ocean technologies industry for what is expected to become the leading exhibition and conference in North America in this sector.

As the world's largest marine technology market, North America is home to some of the most eminent academics and government agencies in the ocean science community. OINA's diverse conference speaker programme will focus on key issues affecting the local region, the Americas and the world, providing a platform for these experts to share their knowledge in order to improve strategies for measuring, advancing, protecting and operating in the world's oceans.

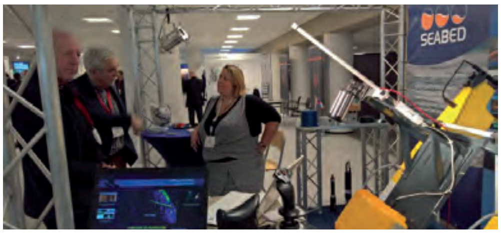
bit.ly/2jA9fFE

The San Diego Conference Center is preparing for Oceanology International North America.

Inaugural International Robotics Week

RoboBusiness Europe and TUS Expo, in collaboration with RoboValley, are organising the first-ever edition of the International Robotics Week, which will run from 19-21 April 2017 in Delft and the metropolitan region of Rotterdam-The Hague. A series of conferences will be held at the World Forum in The Hague and there is an extensive programme of events in and around the city of Delft.

bit.ly/2jAimpM



Marine autonomous vehicles will also be highlighted at International Robotics Week.

EMODnet Stakeholder Conference

The EMODnet Stakeholder Conference, to be held from 14-15 February 2017 in Brussels, Belgium, will bring together EMODnet experts and interested stakeholders to consider whether the marine data collected via current observation and monitoring activities in Europe serves the needs of those who rely on marine knowledge based on observations and monitoring data. During the conference, the findings of a series of EMODnet Sea-basin data stress tests (Checkpoints) will be presented and delegates will consider how to strengthen open data repositories to better serve actual user needs. Finally, the participants will discuss possible solutions and the way forward to improve and better coordinate the existing and future monitoring and observation activities in Europe.

bit.ly/2jA0qvA

New Ocean IT Expo in London

Reed Exhibitions, the organiser of Oceanology International London (OI London), is expanding the event with the launch of the Ocean ICT Expo, a parallel exhibition focusing on the IT, communications and data solutions that form the technical foundation for modern ocean space research and industry. Taking place in conjunction with Oceanology International 2018 at ExCeL London from 13-15 March 2018, the Ocean ICT Expo is to be a showcase for the most innovative enabling technologies, including satellite communication, data and networking services that facilitate safe, high-speed transfer and use of data from the ocean.

bit.ly/2jA9QHH

Hydro International interviews Commodore Min Thein Tint, Commanding Officer of Myanmar Naval Hydrographic Centre, Myanmar Navy

"Hydrographically Developed Countries Should **Reach Out to Developing Countries**"

Oriental countries are dedicated to the profession but don't often beat the drums in order to be heard. There's a lot of work being done, though. One example is Myanmar, a country with several hundreds of kilometres of coastline and many islands as well as inland navigable waters. *Hydro International* interviewed Commodore Min Thein Tint, Commanding Officer of Myanmar Naval Hydrographic Centre, Myanmar Navy on capacity building, offshore and inland navigation, data policy and cooperation with the business.

How is the MNHC improving its capabilities?

Although MNHC became a member of IHO in 2004, the office was founded in 1955 and further developed in the early 1960s. The MNHC's first navigation chart was 'Myeik' Harbour Chart and was published in 1960. The first survey vessel was procured from Yugoslavia and commissioned into hydrographic service in 1965. The ship was named *Thutaythi* and it was decommissioned from service in 2002. The survey ship *Thutaythi-1* was used in hydrographic services for more than 20 years but sunk in 2008 due to cyclone Nagis. There are currently three survey ships in hydrographic service: Offshore Hydrographic Survey Vessel *InnYa*, and nearshore survey vessels *807* and *115*. MNHC had been using traditional surveying methods and manual chart compilation until the early 2000s. After a period of not receiving any hydrographic and cartographic training from the International Hydrographic Organization and regional coordinators, MNHC was able to send an officer to India for an MSc Hydrography and CAT-A Hydrographic Training in 2005. After this first officer, MNHC sent many of its personnel to India for Hydrographic Training. This is how MNHC could build its human resource and on the other hand the scholars brought knowledge of new technologies so that MNHC could upgrade its capability and transform its chart production process from manual compilation to fully digital compilation. In this regard, MNHC had to struggle to obtain funds from the government to procure the modernised instruments, equipment and software required for its revolutionary process from manual compilation to digital compilation. The next step for MNHC was participation in the international Hydrographic Community. MNHC managed to send its delegations to international and regional Hydrographic events and MNHC hosted the 13th North Indian Ocean Hydrographic Commission meeting at Yangon in 2013. Capacity Building efforts, procurement processes and the participation in national, international and regional hydrographic communities subsequently generated the appropriate achievements. In the ten years after 2006, MNHC has managed to build reasonable manpower, has modernised technologies, participates in the international Hydrographic Community and has started Electronic Navigational Chart-ENC production. I have to say that the adopted mission 'Revolution of Chart Compilation Process from Manual to Digital' has now been achieved and the capability is at a reasonable level.

What is MNHC's policy on making data, more than just charts, available to government departments, commercial developers and the public?

MNHC's chart compilation process could be divided into two categories: classified information and public information. Classified information is only available for the Myanmar Navy and might also be available to government departments for different purposes. The other data is for public use, especially for safe navigation in Myanmar waters. MNHC doesn't share its classified data with the public but only the data required for safety of navigation. As things are only just starting to pick up, MNHC may consider expanding its commercial chart distribution process with resellers later. This process may also require the prior consent of government authorities, but I expect to start this commercial chart distribution process in the near future.

Figure 1: Commodore Min Thein Tint.

Myanmar has a complex and long coastline, which spans over several hundred kilometres and comprises many islands. Could you describe the effort required by the Hydrographic Centre to survey it?

Yes, the statement is correct and it seems to be a challenge for MNHC to complete surveys that cover the entire national waters. MNHC has annual survey plans and chart compilation processes. The priority of the survey area is generally set based on the importance and traffic density of an area in the country. We also try to make our data with competencies that meet the standards of the IHO. The effort required to complete this task is divided into four main categories: in terms of HR, New Technologies, Survey Platforms (Ships) and Budget Availability, which are all brought into a single word 'upgrading capability'. In other words, there are challenges in each and every single category, namely HR, New Technologies, Survey Platforms and Budget Availability and the more we can put the plus factor in each and every category, the more we could carry out the surveys and we are always trying to achieve this.

Myanmar ratified the United Nations Convention on the Law of the Sea (UNCLOS) on 21 May 1996. How does MNHC support the government in the implementation of that convention?

MNHC has been participating and consulting in the adoption of the National Maritime Zone Law in Myanmar. MNHC has been mainly involved in the delimitation of the maritime boundaries with neighbouring countries. MNHC had a leading role in the technical matters involved in the Myanmar-Bangladesh maritime boundary dispute, which was peacefully resolved in 2012. MNHC also took part in a geo-physics survey conducted for the submission of Continental Shelf in 2008. At present, there are Continental Shelf overlapping areas in the Bay of Bengal and MNHC encourages the respective intergovernmental organisations to conduct the process of discussion, negotiating and lawful settlement of the limitations for those overlapping CS areas which could create disputes with neighbouring countries. Discussions on the rights and agreements on grey areas formed after judgement by ITLOS and arbitration between India and Bangladesh are also expected. These are some of the steps being taken by MNHC in complying with and implementing the UNCLOS in the country and with neighbouring countries.

What are the initiatives of MNHC to survey and chart those inland waters, such as lakes and rivers?

The responsibility of hydrographic surveying of areas in the country is shared by several government organisations, such as the Doctorate of Water Resources, Improvement of River System-DWIR and Myanmar Port Authority-MPA. However, MNHC cooperates with those organisations and supports technical suggestions and consultations, where necessary.

What inland water surveys and charting efforts are necessary to keep the navigational information of those waterways up to date?

As mentioned in the previous answer, the hydrographic survey responsibility for all national waters are shared by different government organisations. The Port Authority is responsible for conducting surveys in port limits, DWIR for inland waters and MNHC is responsible for conducting surveys anywhere from the national waters up to maritime boundaries and EEZ. But MNHC is the only organisation authorised to produce nautical charts and various related publications such as Sailing Direction, Annual Tide Table, etc. For example, MNHC conducted surveys in the Yangon River, which falls within port limits, and MNHC produced a nautical chart and ENC. Another deep-sea port in the country, Kyauk Phyu Harbour, is also depicted as chart number 24a and 24b. The survey was done by MNHC and it is now in the process of ENC Production, although it is in the port limits. MNHC receives up to date data from the following organisations: MPA, DWIR, Oil and Gas Enterprise and some private offshore companies as they would like to include their oilrig and pipelines in charts. But there is no legislation to which organisations have to abide for sharing navigational information. The next step for MNHC will be to put more effort into receiving more data in accordance with official and legal assent in the country.

In April 2017, the first Assembly of the IHO will take place in Monaco. This will be a key point for the implementation of substantial changes to the IHO Convention. How do you see those changes?

The IHO conference is a really good opportunity for hydrographers to meet and make friends, it encourages the best cooperation, sharing and exchange of knowledge, helps to establish standards and discuss the difficulties being faced in different parts of the world in terms of hydrographic matters. As we all know how important the Safety of Navigation is, we need more reliable nautical charts and to share information. We need to assist countries that are delighted in being able to open up their hydrographic interests and developing countries in terms of hydrography. Hydrographically developed countries should give a hand to

developing countries in terms of capacity building and other support. This will ensure that all countries reach a similar level and enable them to perform hydrographic tasks and establish worldwide safety of navigation.

What is your opinion about the cooperation of the industry with the governmental Hydrographic Offices and in particular with MNHC?

As a governmental Hydrographic Office, we welcome the industry to cooperate with us to achieve the safety of navigation goal under the same umbrella of the Hydrographic Community. Technology and new instruments are also welcome but this will entail a process of balancing between requirements and budget available for a Hydrographic Office. I would be more delighted to see industries invent more new technologies and equipment that are easy to use.

Do you have a message for the young people who would like to become hydrographic surveyors?

Hydrography is a critically important subject for a country, especially coastal countries. Not very many people become hydrographers in a country. Hydrography and hydrographic surveys are the essential first stage to improving ports and implementing the waterways, which effectively support the national economic sector. It is also a related subject of studying environmental changes, disasters and Law of the Sea matters. The reason that not many people become hydrographers is because there are not many education centers, schools or universities capable of teaching Hydrography in the world. This means that we require more education centres for Hydrographic training and degree courses. Roughly two-thirds of the world is covered by oceans. The exploration and exploitation at sea still requires more highly skilled manpower with knowledge of Hydrographic Science. My heartfelt message for the young people wishing to become hydrographers is "If we only look to the end of land, we only get land but if we look at the land and proceed further to the end of the sea, we get everything". ◂

▲ *Figure 2: Activities of the Myanmar hydrographic service.*

Commodore **Min Thein Tint**, Commanding Officer of the Myanmar Naval Hydrographic Centre (MNHC) joined the Defence Services Academy (DSA) in 1977 and graduated with a BSc in 1981. He completed the local hydrographic course in 1986 and after specialisation, he served as a navigation officer onboard survey vessels. He served as head of Hydrographic Division and also head of the Cartograhic Division at Myanmar Naval Hydrographic Centre. He was assigned as deputy Commanding Officer of Myanmar Naval Hydrographic Centre in 2001. Cdre Min Thein Tint participated as the head of the Myanmar delegation in the 2012 IHO Conference.

Using Spatial Regression Algorithms

Improving **Satellite-derived** Bathymetry

Bathymetry is traditionally acquired using single beam or multibeam echo sounders. This method produces accurate depth measurements along transects but is constrained by operating cost and an inability to survey in very shallow waters. Airborne Lidar is able to produce accurate bathymetric information over clear waters at depths up to 70m, but can be costly and is limited by a relatively coarse bathymetric sampling interval. Experience in Irish waters has resulted in very poor seabed detection along the east coast and limited penetration on the west coast. An efficient and cost-effective alternative is Satellite-derived Bathymetry.

Satellite-derived Bathymetry (SDB), which has been used since the 1970s, can be implemented through either analytical or empirical methods. Empirical methods explore the statistical relationships between image pixel values and field measured water depths. Analytical approaches rely on the general principle that sea water transmittances at near-visible wavelengths are functions of a general optical equation dependent on the intrinsic optical properties of sea water. A number of external factors affect the accuracy of the depth calculation, including the spatial and spectral resolution of the imagery, the viewing angle of the satellite, the solar illumination angle, atmospheric effects, sunlight, tide level and submerged vegetation. Careful selection of satellite imagery and subsequent image processing can mitigate some of these effects.

A 2013 pilot study in Dublin Bay using SPOT satellite data indicated strong potential for bathymetric mapping in coastal environments using geographically weighted regression (GWR) in conjunction with remotely sensed data. GWR is a branch of spatial analysis which has previously demonstrated its usefulness in modelling complex spatial patterns and phenomena. Bathymetry has a strong spatial component, i.e. a measurement depends in part on where it was taken. So instead of using a global model such as Ordinary Least Squares (Figure 1) to fit predictions, a local, spatial regression algorithm is better suited.
GWR enables a local model of the variable that we are trying to predict (in this case depth) by fitting a regression equation at every location in the dataset. Unlike the 'global' regression model which gives equal weight to every observation, GWR gives more weight to those observations near the current regression point than those further away. (Figure 2).

Research Goal

Building on established image processing methodologies for calculating satellite-derived relative depths, the National Centre for

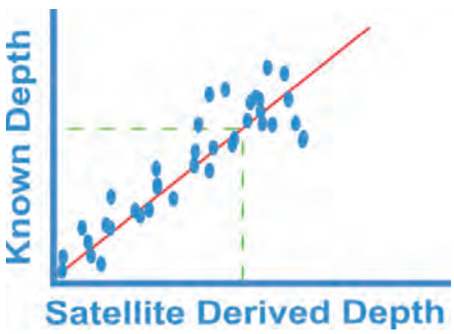


Figure 1: Using regression and ground control to predict water depths and a global, linear model using satellite-derived relative depth.

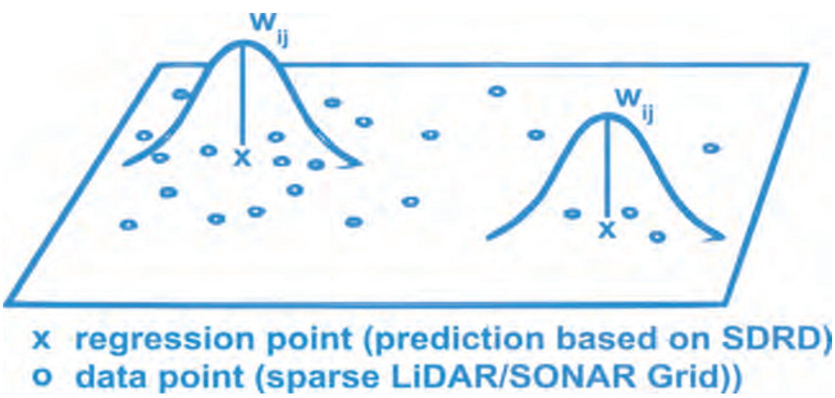
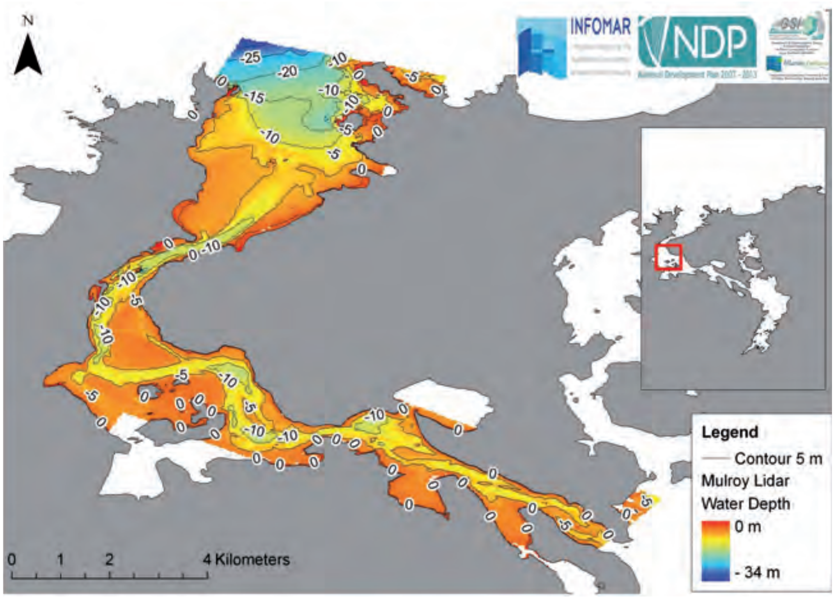


Figure 2: Improving on water depth prediction using a local, geographically weighted regression model for predicting depths.

▲ *Figure 3: INFOMAR priority bays on a Landsat 8 RGB image of Dublin Bay.*



▲ *Figure 4: INFOMAR bathymetric map of Mulroy Bay created using aerial Lidar.*

Geocomputation, TechWorks Marine Ltd. and the Geological Survey of Ireland are exploring the benefits of local rather than global models, improving accuracy when calculating water depth and subsequently decreasing prediction errors in deep or turbid waters.
Our goal in this study was to develop a methodology to improve the prediction accuracy using an empirical approach and geospatial modelling. Results were validated with INFOMAR (Irish National Seabed Mapping Programme) multibeam depth data with an estimated accuracy 0.2% of actual water depth at 0m to 50m.

Testing in Irish Waters

Four of the INFOMAR priority bays were explored in turn: Blacksod Bay in Co. Mayo, Dublin Bay at the mouth of the River Liffey, Tralee Bay in Co. Kerry and Mulroy Bay in Co. Donegal. The four test sites represented very different coastal environments - Dublin and Tralee are affected by significant river deposits. Additionally, Dublin Bay opens onto the Irish Sea and large amounts of sediment wash up the East coast of Leinster and into the bay (Figure 3). Figure 4 displays the INFOMAR bathymetric map of Mulroy Bay created using airborne bathymetric Lidar. One of the key aims of the study was to assess the suitability of imagery captured at a range of spatial, spectral and temporal resolutions. A selection of imagery such as Rapideye, SPOT and Pleiades was provided by the European Space Agency imagery and when combined with existing Landsat 5, 7 and 8 imagery this enabled the application of a range of band combinations, solar illumination angles, temporal, spatial and spectral resolutions.

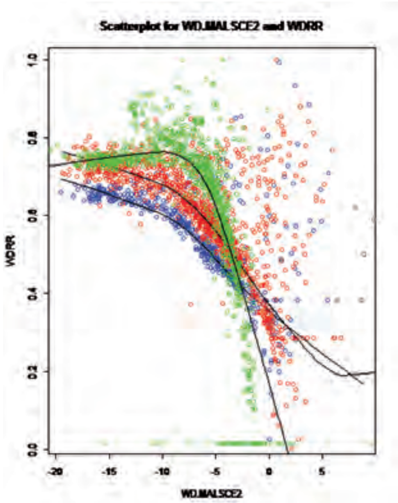
The spatial model showed better adjustments than the traditional non-spatial model

Test Results

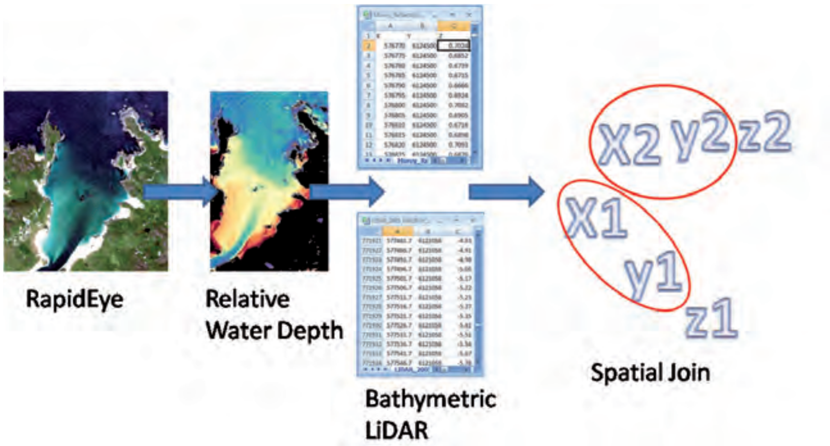
The initial tests in Mulroy Bay using Landsat 8 and RapidEye imagery proved very promising due to water clarity, quality of the images and penetration range. After image corrections and initial processing, Satellite-derived Relative Depths (SDRD) were calculated using existing bathymetric band log ratio algorithms.
The correlation between SDRD and true depth for three image datasets is displayed in Figure 5. The RapidEye (5m x 5m spatial resolution) images for Mulroy Bay were better suited for calculating bathymetry at depths of 10m+, however, the coastal/aerosol band on Landsat 8 (30m x 30m) resulted in a steeper correlation gradient, indicating better potential for discriminating changes in water depths in the 0-10m range.

The SDRD values were spatially joined (Figure 6) to the nearest Lidar/sonar depth (max distance = image spatial resolution). The new grid dataset containing both fields of information were then reduced (only 0.005% of data required) for calibration purposes. Predictions were performed in the rest of the bay independently of the calibration data, relying solely on the SDRD and the local model. These tests were carried out using a variety of grid patterns and the initial tests demonstrated accuracies of +/- 1m across the bay even in water depths up to 20m. Performance was good at the narrow channel entering the south of the bay (Figure 7) and importantly, even near the partially submerged rocks in the centre of the bay, Bar Rocks and High Rock. Larger errors were encountered near the submerged kelp in the north east of the bay but this had also proved problematic and had been noted in the report from the airborne bathymetric Lidar surveys.

Subsequent tests after the research mentioned have incorporated other geospatial algorithms and included seabed type and backscatter data as additional predictor variables. TechWorks Marine have developed a network of sensor buoys that can also provide information on



▲ *Figure 5: Correlation between SDRD and true depth for three multispectral images of Mulroy Bay - June RapidEye in blue, September RapidEye in red and July Landsat 8 in green.*



▲ *Figure 6: Performing a spatial join linking the SDRD values and the calibration SONAR/Lidar points.*

turbidity and this is being incorporated in the later stages of the methodology.

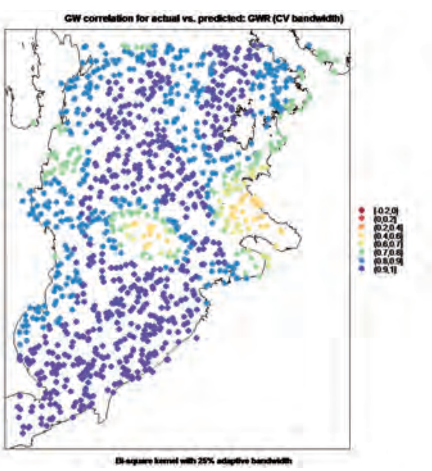
Conclusion and Further Research

The Mulroy tests were able to clearly demonstrate that the spatial model showed better adjustments than the traditional

Bathymetry has a strong spatial component

non-spatial model in the water depth predictions for turbid regions using the same image processing workflow. Furthermore, spatial regression algorithms have the potential to significantly improve the prediction accuracy of SDB in coastal waters and its quality assessment.

Additional funding has been provided by the GSI to assess the application of very high-resolution imagery captured by light aircraft and unmanned aerial vehicles (UAVs). The proven benefit of a multi-resolution imagery approach will also be extended to include imagery from Sentinel 2a.



▲ *Figure 7: GW Correlation map (actual vs predicted depth). 1 is ideal, area in the centre is partially submerged rocks, in the east and north east kelp cover.*

Acknowledgements

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More information

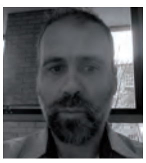
INFOMAR: The INtegrated Mapping FOr the Sustainable Development of Ireland's MArine Resource; www.infomar.ie .

Dr. **Conor Cahalane** performs applied research using satellite, airborne and UAV data for coastal mapping and monitoring at the National Centre for Geocomputation (NCG), Maynooth University and the Irish Centre for Research in Applied Geosciences (iCRAG) at University College Dublin. His background is in surveying, mapping and spatial analysis and he sits on council for the Society of Chartered Surveyors Ireland promoting remote sensing in the Irish geomatics community.

✉ Conor.Cahalane@nuim.ie

Dr. **Jenny Hanafin** was awarded a PhD in Meteorology and Physical Oceanography by the Rosenstiel School of Marine and Atmospheric Science, University of Miami and joined TechWorks Marine in 2014. She has experience in many aspects of remote sensing, from operating satellite sensors for EUMETSAT at Imperial College London, to developing a system to retrieve atmospheric humidity from a network of GPS receivers for use in the Met Éireann forecast model. TechWorks works closely with the European Space Agency to produce satellite earth observation data products and services for public and commercial marine users.

✉ jenny@techworks.ie



Mr. **Xavier Monteys** is a marine geologist at the Geological Survey of Ireland where he joined the marine and geophysics mapping programme in 2001. Since 2005, he has been working in the INFOMAR programme (Integrated Mapping for Sustainable Development of Irelands Marine Resource) where he has been coordinating marine research.

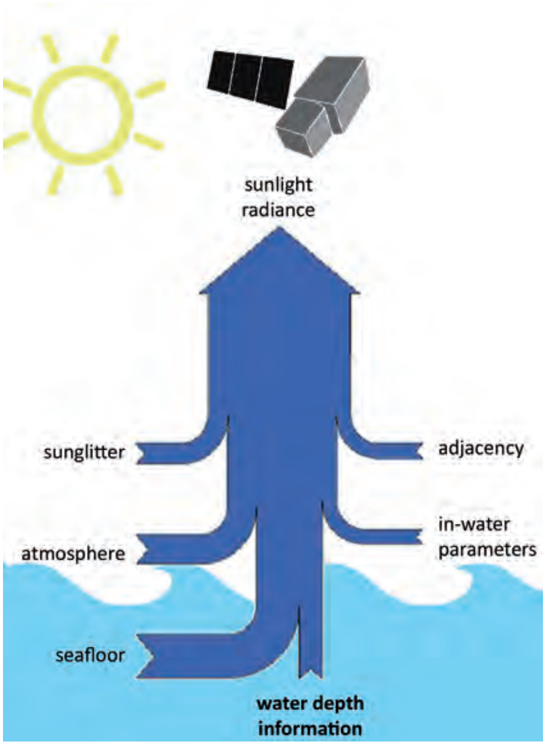
✉ xavier.monteys@gsi.ie

Satellite-derived Bathymetry

Effective Surveying Tool for Shallow-water Zones

The objective of this article is to provide an overview of Satellite-derived Bathymetry methods, how data can be integrated into survey campaigns and finally to showcase three use cases. Bathymetric data in shallow-water zones is of increasing importance to support various applications such as safety of navigation, reconnaissance surveys, coastal zone management or hydrodynamic modelling. A gap was identified between data demand, costs and the ability to map with ship and airborne sensors. This has led to the rise of a new tool to map shallow-water bathymetry using multispectral satellite image data, widely known as Satellite-derived Bathymetry (SDB).

Strictly speaking, the methods to derive information on seafloor topography using reflected sunlight date back to the 1970s but it has required iterative improvements of algorithms, computational power, satellite sensors and processing workflows to provide the current state of the art tool. Today, a range of different methods exist under the umbrella of the SDB term. However, as with traditional survey methods, it is imperative to understand the advantages, disadvantages and overall feasibility in order to evaluate the suitability and fit-for-purpose of a given SDB application.



▲ *Figure 1: The diagram shows the relative amount of measured light energy that contains water depth information.*

Bathymetric Data Production using Optical Satellite Imagery

Historically, empirical methods were used, which require known depth information over the study area. By comparing these known depths with the satellite signal, a statistical relationship can be derived that adequately describes depth as a function of the signal. Aside from requiring known depth data, these methods will only work for a given satellite image. A subsequent satellite scene, even of the same location, may contain different atmospheric and in-water parameters, and thus the statistical relationship needs to be re-calculated. Another aspect of these methods is that the statistical relationship is only valid for one water type and one seafloor type. Therefore, if an area contains different types such as coral, sediment, algae and rubble, the statistical relationship needs to be calculated for each of these substrate types. The correct formula then needs to be applied to each pixel in the image, i.e. the algorithm needs to be informed a-priori which substrate type it is encountering in that image pixel. This brings the problem full circle back to one of the fundamental challenges of satellite-derived bathymetry: how do you know whether a darker signal is due to deeper water, a darker substratum, or a bit of both? These methods can still be useful as they are relatively straightforward to implement (see The IHO-IOC GEBCO Cook Book, 2016).

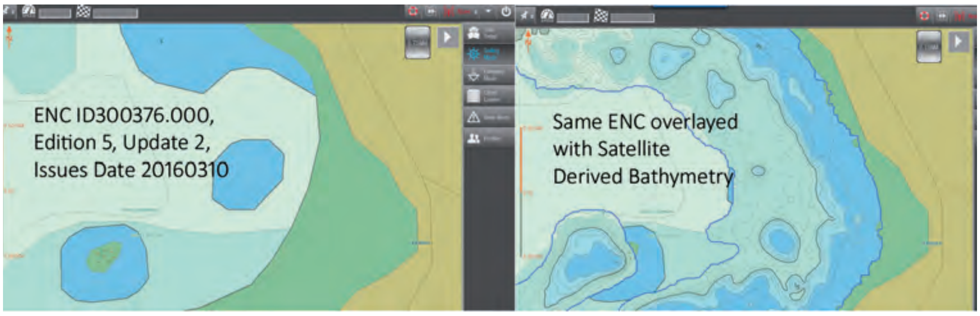
Physics-based methods on the other hand, do not require known depth information for the study area, and can therefore be applied independent of satellite data type and study area. These methods rely on fully describing the physical relationship between the measured light signal and the water column depth. Optical variability in the atmosphere and water column is accounted for within the algorithm inversion, and no 'tuning' to known depths is required. Therefore, an area which is physically inaccessible and for which there is no previous information known can be targeted. Not surprisingly, these physics-based methods require more sophisticated algorithms and powerful processing capacity. The benefit is that they typically prove to be more accurate, especially in areas with varying substrate types, turbidity and/or atmospheric conditions. This is of particular importance because only a small fraction of the sunlight recorded by the satellite's sensor originates from the source that can be associated with water depth. Depending on the wavelength channel, this fraction varies typically between less than one and up to a maximum of 20%, going from near-infrared to green/blue light energy. It is critical to accurately account for the other sources of light energy in order to separate out the relevant water column depth contribution to the measured signal.

Data Integration

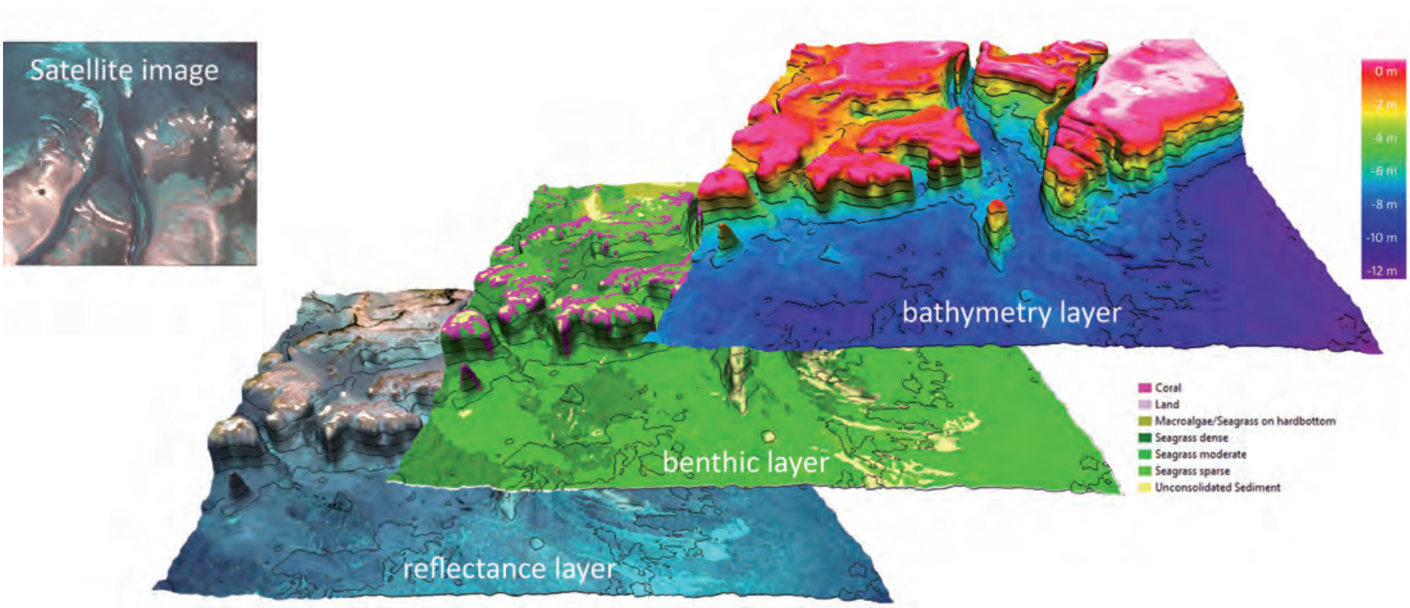
The integration of SDB data into daily use can be straightforward if the bathymetric data quality and delivery formats follow best practice. Hence the file formats typically follow industry standards (OGC) and enable a direct use in current GIS or online visualisation tools through Web Mapping of Coverage (WMS, WCS) interfaces, hydrographic software or scripting tools. ISO conform metadata including important information on tidal corrections, processing levels and date and time of satellite recording are essential for geodata and are mandatory for all SDB data.
Furthermore, it is important to understand the uncertainties in the data as well as the limitations of SDB for a given application in order to integrate the data appropriately. Such information needs to be expressed in uncertainty layers which should ideally include quantitative information. For some applications, such as safety of navigation, additional information such as the ability to identify obstructions of different sizes needs to be included as well.

Use Case: Safety of Navigation

Satellite-derived Bathymetric information supports safety of navigation by providing up-to-date and high-resolution grids of the shallow-water zone. This is of particular importance in areas with outdated charts or dynamic seafloor. In addition to the bathymetric information, of particular importance is the identification of obstructions which could be a risk to navigation.
Ideally the bathymetric data are provided in the form of digital nautical charts (ENCs) and ECDIS (Electronic Chart and Display System) as the main navigation device which represents the standard for the majority of vessels. Satellite-derived Bathymetry data cannot immediately be used for navigation with ECDIS – however, it can serve as an additional data source when updating the bathymetric information of nautical charts (paper or digital). ENC Bathymetry Plotter, a recently finished software product of SevenCs' chart production suite, represents a powerful tool to create depth-related information objects for inclusion in ENCs which fulfill all relevant IHO quality standards. SevenCs and EOMAP have teamed together to provide an innovative service, the combination of up-to-date shallow water bathymetry provided as a standard ENC. This can therefore be used immediately onboard vessels. An update of official ENCs which include Satellite-derived Bathymetric data, is therefore possible at the commencement of a voyage, but also during the vessel's journey - via satellite communication - and therefore allows for the planning of more efficient shipping routes, increased safety as well as an improved situational awareness to react to a forced change of the shipping route (e.g. weather events or other threats).
It is obvious that the need for updating ENCs for safety of navigation is of importance for poorly mapped areas. It should not be understood to replace recent, high-resolution and quality ENCs if available.
In 2016, bathymetric data was provided to Van Oord covering several atolls in The Maldives. The data were used to enhance safe navigation by charting all shoals which might or might not be indicated on Electronic Navigation Charts. This contributed to efficient planning of the



▲ *Figure 2: Current ENC (March 2016 ,left) and overlaid by SDB data (right) showing shoals misplacement and low details of the ENC compared to the Satellite-derived Bathymetry-ENC.*



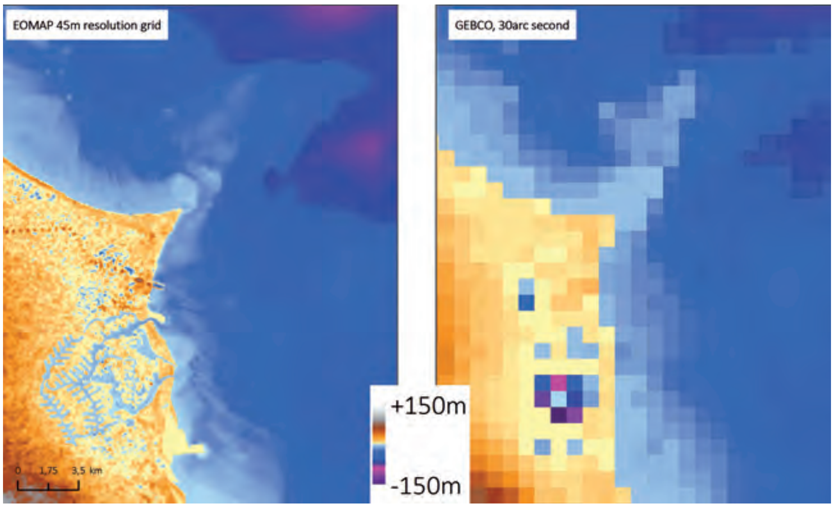
▲ *Figure 3: Baseline data on seafloor information based on satellite images and physics-based algorithms.*

project's activities. Data were provided within a few days of ordering covering, an area of several hundred sq. km, which showcases the flexibility of the technique.

Use Case: Reconnaissance Survey

Satellite-derived Bathymetry can play a role as a reconnaissance survey tool in applications ranging from shallow-water seismic surveys, coastal engineering to optimal planning of acoustic surveys. Although different in usage, all of these applications have in common that they require bathymetric data which is (a) spatial, (b) high resolution, (c) rapidly available and (d) affordable within a typical planning phase budget. Reconnaissance surveys are usually relevant for areas which are poorly surveyed, where charts are outdated or where bathymetric data are simply not accessible. Many examples for these kinds of applications have already been published and two showcases are summarised in the following paragraphs.

In 2013, EOMAP mapped the shallow-water bathymetry of the entire Great Barrier Reef, Australia, at 30m grid resolution. This was the first depth map of its kind for the entire Great Barrier Reef, and also the largest optical SDB dataset ever made. In 2014, Shell published a paper on the use of EOMAP's Satellite-derived Bathymetry (delivered at 2m grid resolution) to support their shallow-water seismic campaign in northwest Qatar (Siermann et al. 2014). Shell summarised the benefits of using the satellite techniques over more traditional methods by citing a 1 Million USD costs savings and very timely delivery of the data.



▲ *Figure 4: Example of the seamless multisource bathymetric grid for the Persian Gulf, including Satellite-derived bathymetric data (left) and the GEBCO dataset (right).*

Use Case: Basis Data for Hydrodynamic Modelling

Hydrodynamic modelling exercises, such as generating tsunami forecast models, are typically not the type of applications with budgets that allow for purchasing bathymetric survey campaigns using more traditional methods. Commonly, very coarse resolution bathymetric grids such as GEBCO are used instead, but this has limited validity in coastal areas. By using Satellite-derived Bathymetry, shallow-water depth data can be derived at fit-for-purpose grid resolution to within a limited budget. As a standalone dataset it does not fulfil the modellers requirements but when merged with up-to-date information on the coastline –(also derived from the satellite imagery), survey and chart information, a seamless shoreline-to-deep-water dataset can be created, which greatly improves on currently available datasets. Such a dataset was created for the Gulf region, which now serves as bathymetric dataset for tsunami modelling in the area.

Future Perspectives

Over the intermediate term it is expected that satellite-derived mapping of the seafloor will continue to be increasingly accepted and integrated as a survey tool - as is now already the case for a number of innovative user groups. Developments are still needed in areas such as how to best quantify uncertainties and small scale obstructions. One likely development will be the mutlitemporal and sensor agnostic mapping approach, which can be oversimplified as: use all available image data to the best possible extent and quality. With the advances of cloud computing, physics-based algorithms and an increasing selection of image data, this would be a natural evolution for Satellite-derived Bathymetry. ◀

Dr. **Knut Hartmann** is director Client Services for EOMAP. During his educational and professional background in environmental science and remote sensing he was involved in projects for O&G and engineering, HOs and environmental agencies.

✉ hartmann@eomap.de

Dr. **Thomas Heege**, CEO, founded EOMAP in 2006 as spin-off from the German Aerospace Center DLR. He has more than 20 years of research, development and industry experience in satellite-derived products and methods.

Dr. **Magnus Wettle** is managing director for EOMAP Australia Pty Ltd. With more than 15 years experience in aquatic remote sensing, he has previously held positions at the University of Queensland, Geoscience Australia and CSIRO.

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Integrating Active and Passive Sensors Provides Major Gains

Multi-sensor Coastal Mapping

Coastal mapping programmes are quickly becoming a priority for government agencies across the globe. The desire to better define and understand the land/sea interface is based on several interrelated factors, including sea level rise and its impacts on coastal populations, the growth of and reliance on a blue economy, and the need to maintain critical nearshore habitats in the midst of a changing landscape. Fugro recently tested a multi-sensor approach to balance growing data needs with limited agency budgets.

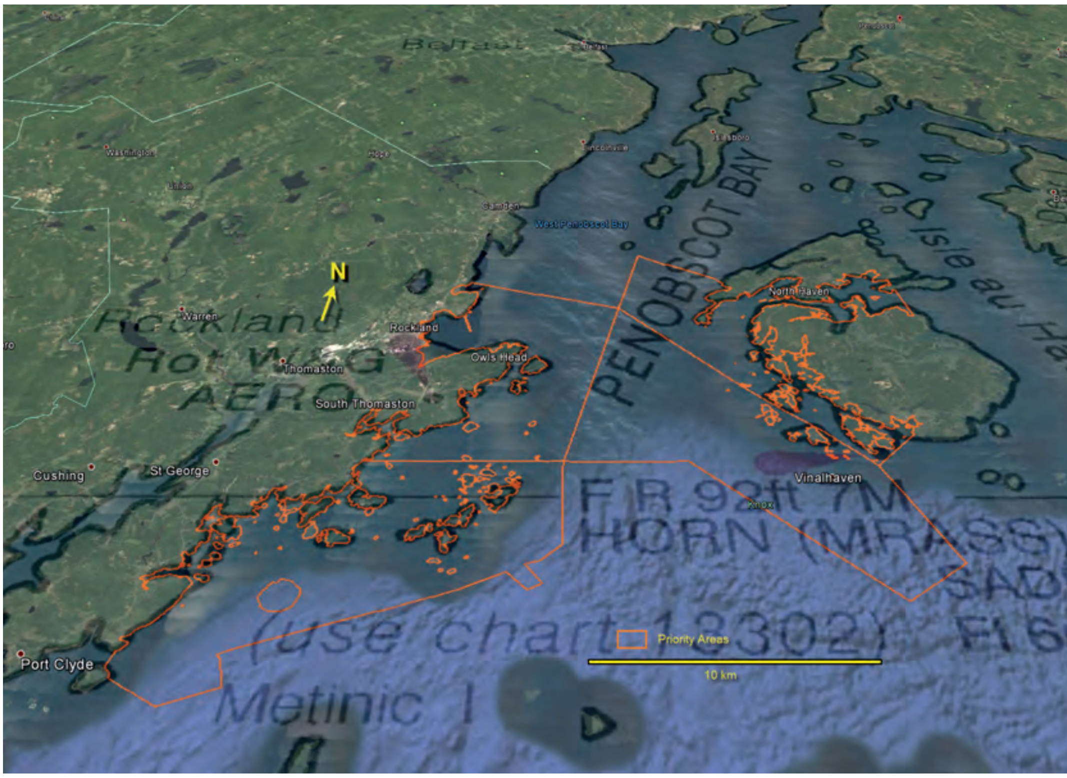
In support of its hydrographic charting programme, the US National Oceanic and Atmospheric Agency (NOAA) Office of Coast Survey contracted Fugro to provide surveying services in Penobscot Bay, Maine, USA during the summer and autumn months of 2016. The project site encompassed approximately 370 square kilometres in an area characterised by a vibrant lobster fishing industry and high vessel traffic. According to NOAA, most of this area had not been surveyed in more than 60 years and a modern hydrographic survey was needed to update official nautical charts (Figure 1).

ALB and SDB both rely on the physical properties of light transmission through the atmospheric and aquatic media

The original task order called for data acquisition using multibeam echo sounder systems (MBES) mounted on coastal-capable vessels. But given the bay's jagged and rocky shoreline, Fugro considered that a vessel-based survey of the nearshore waters would prove time-consuming and potentially dangerous. While large numbers of submerged rocks were previously marked on existing charts, these vintage datasets were created before the age of full-bottom coverage ensonification. As a result, crews would need to navigate slowly to avoid uncharted hazards. Additionally, the survey was scheduled to take place at the peak of the lobster season, which would further hamper productivity due to the high density of lobster trap rigging and the constant need to avoid entanglement.

Alternative Approach

In an effort to streamline the survey schedule, reduce the number of required personnel and mitigate property damage and personnel safety, Fugro worked with NOAA to develop a survey plan that would combine vessel-based MBES with airborne Lidar bathymetry (ALB), exploiting the benefits of each sensor system for a faster, more cost-effective programme. The use of ALB was focused on shallow-water areas with a depth of less than 8 metres. This portion of the survey met NOAA charting requirements for least depth information in a safe and efficient manner. Additionally, reflectance imagery generated from the full-waveform ALB was used to extract natural and manmade coastal features near and above the water surface, allowing for the extrapolation of the mean high water line, used to represent the land boundary on nautical charts. Digital imagery acquired with ALB data



▲ *Figure 1: Survey area polygons in Penobscot Bay.*

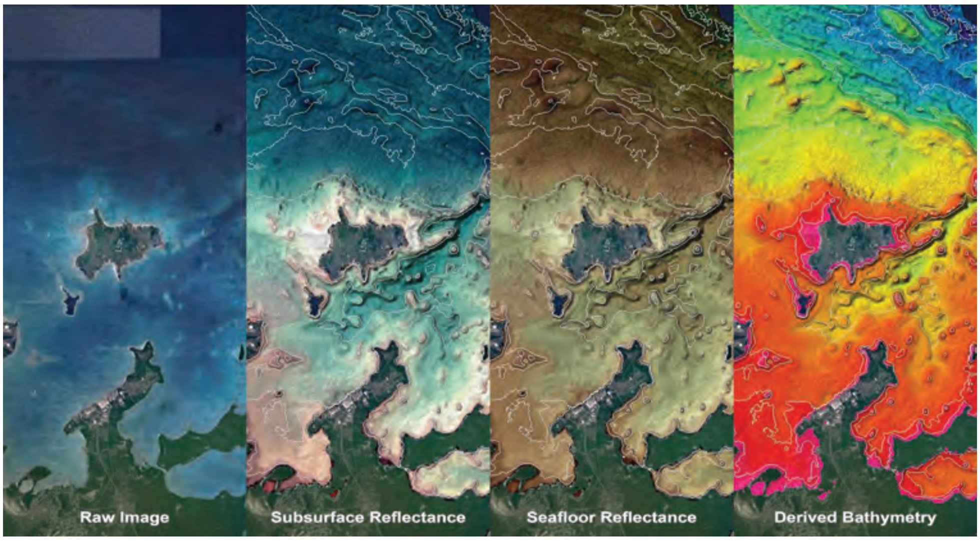


Figure 2: Example of EoMap's SDB process correcting raw imagery for atmosphere, water surface and water column conditions.

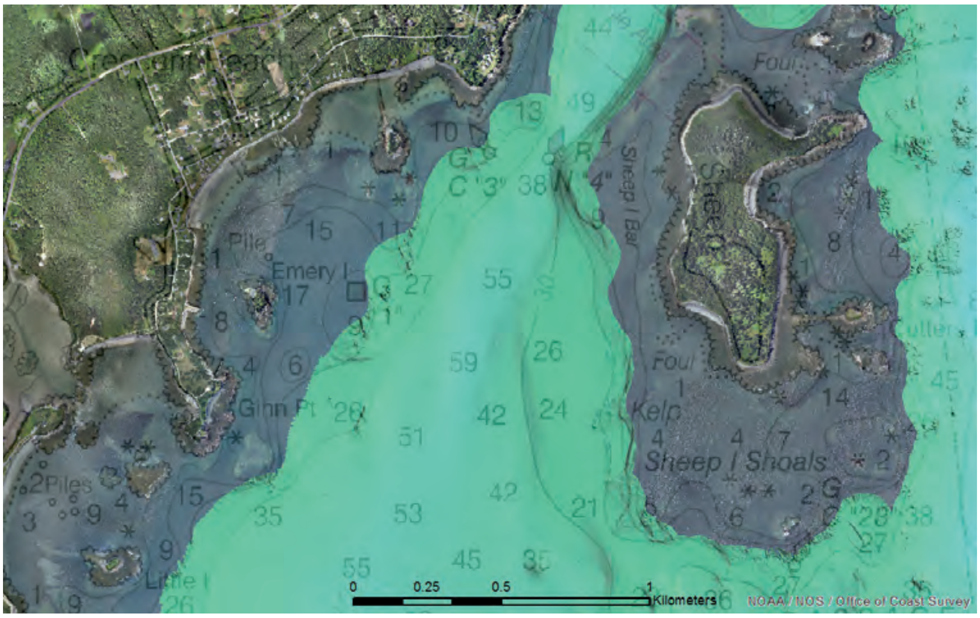


Figure 3: MBES coverage.

collection also produced orthorectified imagery mosaics showing the features and conditions present at the time of survey.

Surveying with MBES and ALB technologies also motivated Fugro to undertake, at no additional cost to the client, the generation of satellite-derived bathymetry (SDB) data in concert with partner EoMap GmbH, of Seefeld, Germany. The purpose of the SDB survey was to evaluate its deliverables against fully attributed and quality-assured active sensor data from the ALB and MBES surveys. This represented the latest in a considerable library of real-world data comparisons conducted by Fugro and EoMap to help quantify results in various regional scenarios and develop a strategy for the future employment and utility of the technology.

SDB Methodology

There are multiple ways to generate bathymetry from multispectral imagery sources. EoMap uses a physics-based method aimed at reconstituting the loss of visible and near-infrared spectral information that occurs when light from the satellite sensor travels through the atmosphere and water. By resolving these light-transfer issues, EoMap can retrieve the optical properties of the environment to normalise seabed reflectance measurements and provide water depth estimations.

There are multiple ways to generate bathymetry from multispectral imagery sources

A thoroughly designed workflow of specialised algorithms correct the raw satellite imagery for environmental artefacts — atmospheric aerosol content, land adjacency (high albedo - reflectivity of the earth's surface) and sun-glitter on the water surface, etc.— and then employ optical models derived for various regional water types. In this way, more accurate water depth estimations and seabed reflectance are produced. This process far exceeds what is possible by using empirical methods or photogrammetric techniques; the former being much degraded due to the reliance on uncorrected raw imagery, and the latter on sheer cost- and time-effectiveness (Figure 2).

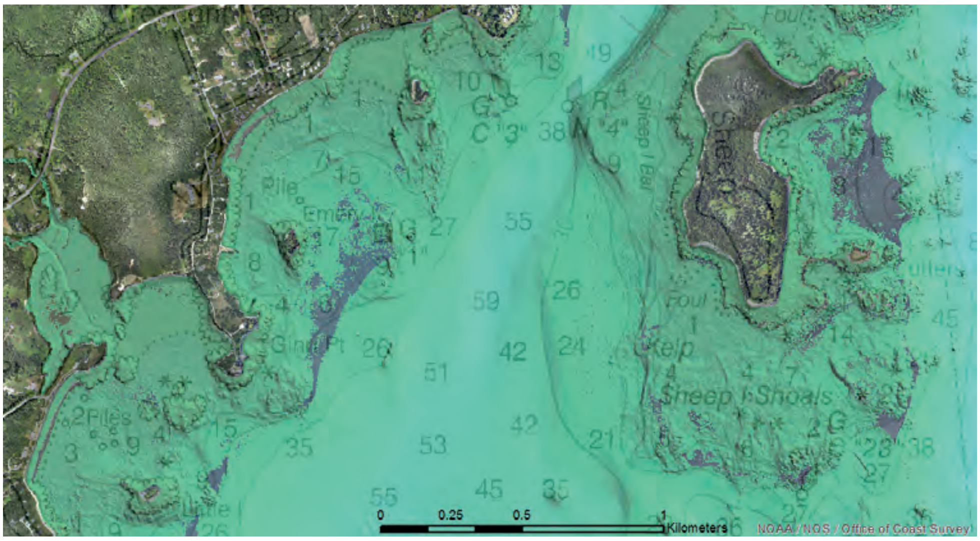
Results

The comparison of ALB and SDB was especially useful given the systems' complimentary technical origins. Although ALB is an active sensing technique and SDB is a passive one, both rely on the physical properties of light transmission through the atmospheric and aquatic media. As such, both are able to achieve bathymetric results that overlap to a significant extent, mostly governed by SDB maximum depth detection. Correlation of bathymetric depths on the overlapping areas is one of the main points of interest in the evaluation of SDB methodology: at a minimum, the results achieved by SDB validate its use as a tool for survey project planning, complementing MBES and ALB surveys. Figure 3a, 3b and 3c show a sample area where all three data types overlay.

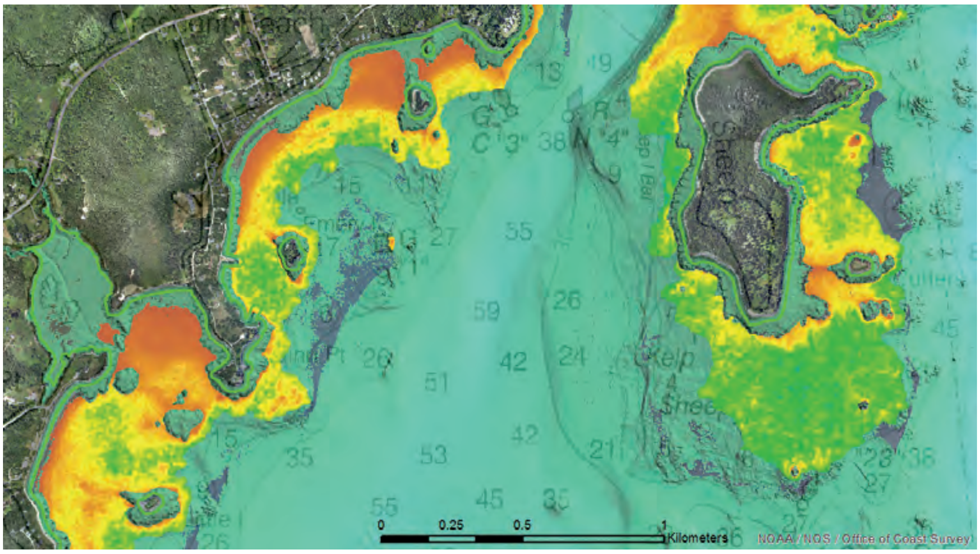
For NOAA, the primary benefit of SDB is the ability to generate data without the overheads inherent in active sensor surveys. The downside is that the absolute vertical accuracies of water depth extraction algorithms cannot yet satisfy nautical charting requirements in the stand-alone product. Users can, however, take the initial results from SDB and do at least three things:

- Use the data to provide reconnaissance information for follow-on, more efficiently quantifiable MBES and ALB survey techniques (put an otherwise poorly charted area in focus)
- Conduct more discrete, higher resolution surveys of the most critical areas for development or coastal defence/monitoring
- Use active sensor data to refine the original SDB results to create a better defined, integrated product which can start to attain accuracies acceptable to a wider stakeholder group.

It also enables recognition of the benefits of well-developed algorithms of satellite imagery to extract more robust seabed classification for habitat characterisation from the multispectral analysis. Notwithstanding the limitations of coverage with respect to depth and optical water clarity, habitat classification from SDB is at least on a par with similar modelling using MBES backscatter, interferometric sonar or bathymetric Lidar. There is logic to this supposition. A physics-based approach workflow, such as that developed by EoMap, aims to extract seabed reflectance as its primary result; in achieving that result, extraction of the water column (which we illustrate as water depth) is but an element of the process. Therefore, the algorithms associated with habitat mapping are not an addendum but fundamental to the entire imagery analysis effort. Coupled with other, higher-order survey data, however, SDB can also assist in creating hydrographic survey datasets that meet client specifications in a very cost-effective manner.



▲ *Figure 4: MBES and ALB coverage.*



▲ *Figure 5: MBES, ALB and highlighted SDB coverage.*

Continued Improvement

At the time of writing, the comparative analysis between SDB and the active sensor datasets is ongoing. The ability to mobilise multiple survey sensors from multiple platforms, acquire data from sensors that complement and reaffirm each other, and process data into a diverse range of data products and derivatives fulfils and surpasses the expectations of focused hydrographic surveying for nautical charting updates. It also offers results seminal for other applications derived from large-area baseline mapping. In the last decade, the hydrographic community has experienced the increased efficiencies of MBES surveys complemented with ALB for shallow-water and shoreline delineation. SDB furthers these gains by providing the information needed to plan safer and more cost-effective nearshore surveys. ◀

More Information

A joint Fugro and NOAA paper titled *Multi-Sensor Coastal Mapping: Hydrographic Surveying and Beyond*, which further explores the following project and processes will be presented at the Oceanology International North America 2017 conference and exhibition, taking place 14 – 16 February 2017 in San Diego, California.

José Martínez Díaz's paper on *Multi-Sensor Coastal Mapping: Hydrographic Surveying and Beyond* will be presented by Patrick Keown, physical scientist at NOAA during the Hydrography, Geophysics & Geotechnics session on 14 February 2017 at Oceanology International North America.

José Martínez Díaz is a survey products supervisor with Fugro, working extensively on ALB projects. He is an NSPS/THSOA Certified Hydrographer with more than 15 years of experience in the hydrographic surveying field and holds a M Eng degree in Geomatics, Ocean Mapping from the University of New Brunswick.

✉ jmartinez@fugro.com

Don Ventura is a hydrographic business development manager with Fugro, helping to lead the company's SDB service offering. He is a Charge IHO Category 'A' Surveyor with more than 30 years' experience, including tenure with the British Royal Navy and 3-year exchange with the US Navy at NAVOCEANO.

✉ dventura@fugro.com

Widespread Applications Stem from Diverse Measurement Capabilities

Technology in Focus: Acoustic Doppler **Current Profiler** (ADCP)

Rather than a spinning propeller, the Acoustic Doppler Current Profiler (ADCP) - like dolphins and bats - uses sound to explore its environment. Operating underwater, the method works like hand-held radars used by police to catch speeding motorists. This article explains the technique of this frequently used type of instrument and some of its applications.

A sound burst is emitted by the ADCP along beams angled downward. Echoes are returned due to scattering off particles carried by water currents. A second burst can be used to track movement over the seabed. By analysing these sound echoes, the ADCP makes four different measurements at once.

- o Speed and direction of water currents at many levels through the water depth--a 'current profile'
- o Spatial distribution of sediments or plankton carried by the water (e.g., a sediment plume)
- o ADCP's speed-over-ground and path of travel (revealed by echoes scattered from the bed)
- o Range to boundary. This can be water depth (like an echo sounder) or, when the ADCP's beams are directed upward, range to surface. The latter provided a new way to measure surface waves.

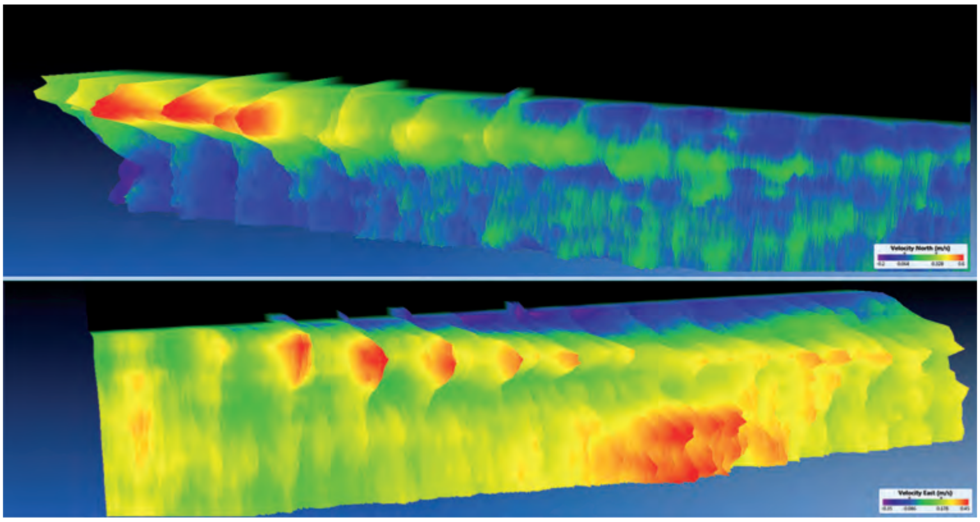
This collective of data types used individually and together permits a single ADCP to make a diverse range of measurements.

ADCP Origins

First conceived in the mid 1970s, the technology of ADCPs took about a decade to gain traction. Within another decade, it had become widely accepted. It is now used for measuring water currents in oceans, rivers and even pipes.

The ADCP combines two prior views of water in motion. Since the 1960s, exploring time variability of ocean currents required self-recording current meters. Their time series described the history of concurrent motions at a few depths. A complementary fine-scale view came from velocity profilers like Pegasus and Electromagnetic Velocity Profiler. Their datasets provided snapshots of how water currents change through depth at a few times – typically hours apart.

Simply put, ADCPs were a confluence of these two instrumentation streams - current metering and velocity profiling. Each of these techniques provided an inherently 1D view of motion in the ocean - high resolution in time or depth. In contrast, the ADCP offered a 2D view - time and depth. ADCP datasets reveal the time history of water in motion throughout the water column - or at least a good fraction of it. Profiles can be taken just seconds apart and lower frequency devices (75kHz - 38kHz) can observe hundreds of metres. In fact, increased measurement range was the most requested development after the technology had been widely accepted.

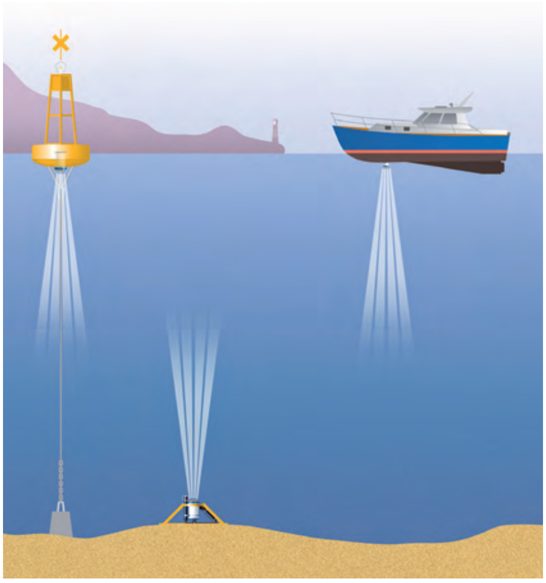


▲ *Figure 1: ADCP-based record of water currents at 20 depths over one week in 400m water depth. Top: north-south currents, lower: east-west motions. North and East currents are depicted in hot colours (red, orange, yellow) whereas South and West motions are shown in cool colours (blue, purple).*

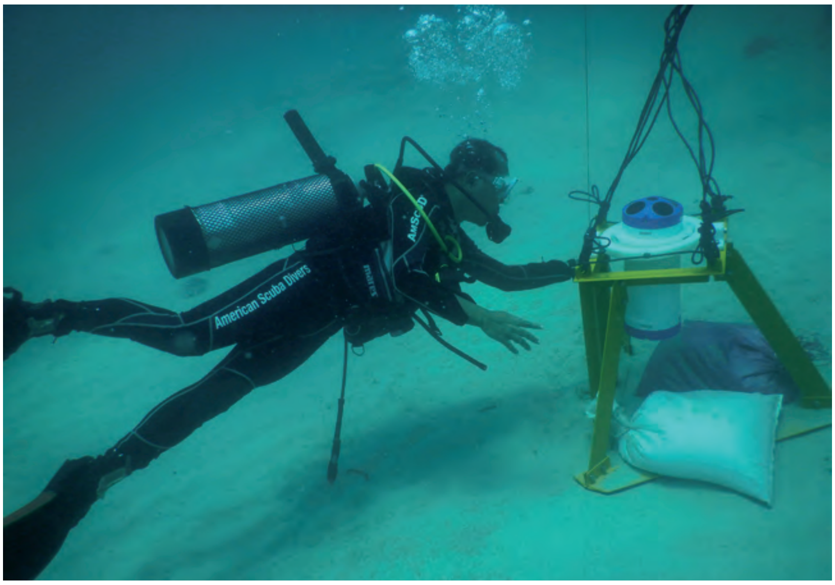
Current Profiling

Moving waters often carry small particles such as zooplankton or sediments. Sound waves sent through these waters undergo scattering. The resulting echoes carry a change in pitch. This well-known effect is called the Doppler shift. You will recognise it from the change in a wailing siren when it passed.

This change in pitch provides a measure of how fast water currents are moving and in what direction. Sound waves propagate through a water column. Thus echoes are continuously



▲ *Figure 2: Applications of ADCP technology.*



▲ *Figure 3: In coastal waters, seabed mounted ADCPs have largely replaced current meter moorings.*

created en route due to encounters with moving particles.

ADCPs send out sound waves along several beams that angle downward. The time series of returning acoustic echoes are analysed within the device. This provides water current velocities at many different depths. Calculating the relevant measurement depth for a segment of the echo record uses the elapsed time since the sound waves' emission. Such a breakdown of the data is a water current profile.

ADCP Advantages

Besides measuring water currents accurately and with high resolution in time and depth, ADCPs have some other compelling advantages. ADCPs can measure currents remotely. Thus they can record all the action while looking down from a ship or a surface buoy or looking up from a subsurface mounting or mooring. In the latter case, the ADCP is safer from loss due to high drag forces in strong currents. Plus there is reduced risk from vandals or collisions by ships.

ADCPs were among the first oceanographic instruments to include significant onboard signal processing. Combining this with a real-time link resulted in valued time savings for users and timely data for decision making.

ADCPs were a confluence of the instrumentation streams current metering and velocity profiling

Furthermore, ADCPs can provide a more complete view of an underwater situation. They can aid safety, efficiency, reduced risk and better decision making in operational situations, such as on offshore platforms. To boot, ADCPs do not have any moving parts. This is a bonus for maintenance and for operating in icy waters. ADCPs introduced the groundbreaking capability of measuring moving water while operating from moving platforms. These ADCP datasets are 2D spatial transects—along the boat path and through depth. As well as saving survey time for users, this capability enabled unseen views of water in motion. Survey companies could efficiently map horizontal circulation patterns of current systems. Others captured detailed spatial views of tidal current variation within busy ports and shipping channels. By now, an impressive range of moving platforms have been used for ADCP survey work including ships, boats, floats, underwater vehicles and towed bodies.

Vehicle-based Measurements

Since 2000, unmanned underwater and surface vehicles have rapidly advanced from experimental prototypes to reliable tools. On many of these vehicles, acoustic Doppler technology has been part of much improved navigation by providing the Doppler Velocity Log. As well as aiding navigation, these devices can also operate as ADCPs aboard the unmanned vehicles. In other cases, the ADCP itself is carried. Combining the ADCP's diverse measurements with the flexible operation of the unmanned vehicles can lead to safer and more productive environmental surveys. One example was the use of a REMUS-100 to examine spatial changes in coastal waters during floods. These vehicles are equipped with up and down looking ADCPs to see as much of the water column as possible. Another innovative vehicle that carries ADCPs is the Wave Glider. A recent study used the ADCP's current and echo profiles to examine sediment transport and dredge plumes around shallow sandbanks. Likewise, work has been completed to add ADCPs to Slocum gliders in support of ocean observatories.

Moored Measurements

Self-contained ADCPs contain internal memory, processing and power supplies. They are used worldwide for observing coastal and deepwater currents. One recent example is a large Chinese research programme titled WPOS - Western Pacific Ocean System. This multi-national effort is studying oceanic changes that link to major meteorological events. Examples include the East Asia summer monsoon and El Niño. WPOS aims to reveal a more complete view of ocean currents in this region, notably the Kuroshio Current and the Indo-Pacific Warm Pool. The findings will be particularly valuable to climate modellers.

More than two dozen moorings, distributed among six arrays, are off the Philippines and

Indonesia. The arrays will record ocean currents in water depths to 6,000m. Each mooring includes lower frequency 75kHz ADCPs, as well as higher frequency ADCPs ranging from 150 to 600kHz.

Ship-based Measurements

For measuring currents from a moving platform, two different types of measurements need to be combined. The first is the apparent velocity of the water when seen from the moving boat. The second type is the velocity describing the boat's motion. When the seabed or riverbed is within its acoustic range, the ADCP can make both types of measurements in quick succession. In deeper waters, a GPS system supplies the motion of the surface platform. The ADCP combines these data types internally to compute the actual water velocities, sometimes called speed-over-ground.

An impressive example of using ADCPs on ships is a long-standing programme in the Southern Ocean. Since the late 1990s, research scientists have been using ADCPs on Antarctic supply ships for ocean and climate studies. Transects across Drake Passage are collected several times per month. While the ship is underway, hull-mounted ADCPs measure upper-ocean currents at 30-40 depths. One ADCP measures the upper 300m of the water column whereas a second lower-frequency ADCP profiles to 1000m depth.

More information

Geo-matching.com

For an overview of characteristics of ADCPs see Geo-Matching.com: http://bit.ly/geomatchingADCPs

Hailing from the land downunder, Dr. **Peter Spain** completed his dissertation in Ocean Physics in 1988 at the Applied Physics Laboratory, University of Washington, after which he worked at Scripps Institution of Oceanography. He worked with new instruments used for measuring ocean currents. Since joining RD Instruments in 1990, Peter has been in sales & marketing where he progressed from sales staff to department management and business unit management. Today, the common theme to his diverse activities is technical marketing. Since 1998, Peter has been manufacturer's liaison for the IEEE / OES Current Metering Technology Committee.

peter.spain@teledyne.com

▲ *Figure 4: For environmental surveys, REMUS 100 carries up and down looking ADCPs.*

▲ *Figure 5: ADCPs mounted on boats and floats are now used worldwide for measuring discharge of large rivers and small streams.*

ADCP data have provided results about transport of the Antarctic Circumpolar Current, changes in upper ocean heat content, and oceanic frontal regions.

River Measurements

ADCP technology enabled accurate river discharge (volume transport) measurements from moving boats. Later followed stream flow measurements from floats. Early adopters of this new method were the United States Geological Survey. Advantages of the ADCP technology are that it is accurate, safer, samples rapidly and displays discharge results as soon as the river transect is completed. The ADCP profiles reveal how water currents vary with depth and across the river or estuary. By repeating the same sections at later times, operators can see how current distributions are changing across the river and through time.

A great example of the power of ADCP technology for studying rivers is work in the Amazon. Introduced there in the mid-1990s, the new method permitted crossing the river in much less time. Thus wide estuarine sections carrying the largest river discharges in the world were measured accurately (tidal changes during the time-consuming measurement transects had biased earlier methods). As well, the ADCP's echo data aided efficient sampling of suspended sediments. Plus the ADCP-based method is safer from collisions with flotsam and produces more complete data sections.

Looking Ahead

Plans for the road ahead seem paved with ideas that build on the ADCP's fundamental capabilities. For three decades, researchers have tried using ADCP echoes for looking at suspended sediments and zooplankton. And still the push continues. Potential advantages abound from adding modern computing power and techniques to the ADCP. Dormant ideas like adaptive sampling and more sophisticated onboard processing are seeing new life. System control ideas that resemble recent work in autonomous vehicles are being aired. Using techniques from Big Data might efficiently reduce ADCP data to information for decision-makers. Some common trends in the industry point to increasing demand for smaller size, improved performance, reduced power consumption and more integrated technologies. More applications of ADCP technology will likely follow when these opportunities are grasped. ◂

ADCPs can measure currents remotely

A Valuable Supplementary Device

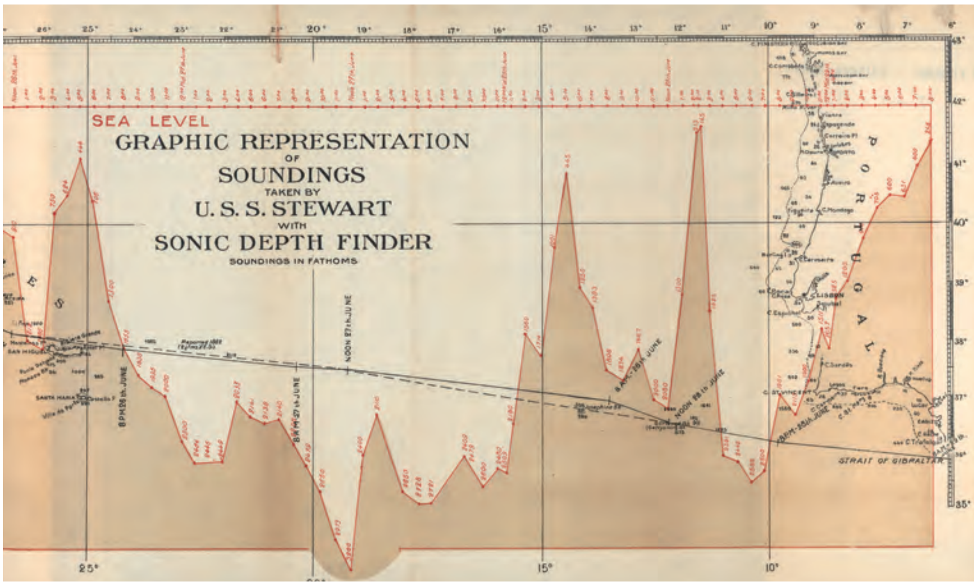
Early Acoustic Sounders in the Coast and Geodetic Survey

Between 2 and 20 August 1920, a group of scientists met in Honolulu, Hawaii, for a two and a half week conference devoted to the science and scientific problems of the Pacific Ocean. Scientists from Australia, New Zealand, the Dutch East Indies, the Philippine Islands, Japan, the United States and Canada met for a convocation of Pacific scientists at the First Pan-Pacific Scientific Conference. Papers were presented on such matters as volcanology, seismology, oceanography, ethnography, entomology, agriculture and fisheries science.

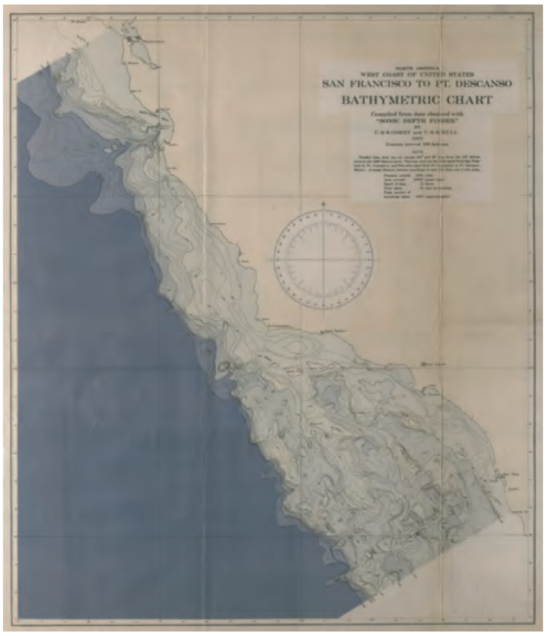
Among the various thematic sections of the conference was one on ‘Mapping the Pacific’. Papers in this section were *Ascertaining the Configuration of the Pacific Basin* by George Littlehales of the United States Navy Hydrographic Office, *Research in Geodetic Work in the Pacific* by William Bowie of the United States Coast and Geodetic Survey, and *Survey of Shoreline and Coastal Waters* by Commander John T. Watkins of the Coast and Geodetic Survey.

These three papers occupied 44 pages of the conference proceedings, but only one sentence mentions the possibility of using acoustic means for determining depths. With few exceptions, in spite of World War I advances in ocean acoustics, the hydrographers and bathymetrists of the world were still locked into the mindset of line and sinker sounding technology. Littlehales was primarily concerned with assuring no major features were missed during deep ocean piano-wire sounding operations. Accordingly, after going through a mathematical analysis, he arrived at the conclusion that most large features would be discovered with a stuttered sounding interval consisting of eight miles followed by two miles thence eight miles and so on such that two soundings were obtained along each ten-mile line segment. Thus if a major change in gradient occurred between the ten mile end-points of a section, it was likely to be discovered. Thirty years before, he had written a paper concluding that ten-mile spacing was sufficient. In thirty years this concept had changed only by adding an intermediate 2-mile interval. Commander Watkins was the only presenter to address acoustic soundings. His one sentence devoted to acoustic sounding was perhaps one of the worst predictions made in the history of hydrographic surveying. Watkins reported the following: “Depth determinations by means of reflected sound from the bottom are reported to be feasible; and though it may never supplant the standard method of sounding, there is a possibility of it becoming a valuable supplementary device.” In 44 pages of the proceedings of this conference devoted to mapping the Pacific, despite being attended by some of the best scientific minds of the era, no further mention was made of acoustic sounding.

Not quite two years later, the hydrographic world was astounded by a line of soundings run across the Atlantic Ocean by the USS *Stewart*, a destroyer equipped with the first deep ocean acoustic sounding instrument. Dr Harvey Hayes, inventor of the Hayes Sonic Depth Finder, accompanied the *Stewart* on this first acoustic sounding expedition to make sure all went well. A New York Times article dated 5 July 1922, was titled ‘New Navy Invention Tells Ocean Depths’. The subtitles



▲ *Figure 1: Graphic Representation of Soundings taken by USS* Stewart *with Sonic Depth Finder in* ‘Hydrographic Review’*, Vol. 1, no. 1. 1923.*



▲ *Figure 2: Acoustic depth survey by USS* Corry *and USS* Hull *from San Francisco to San Diego. This was the very first bathymetric map produced solely from acoustic soundings.*

▲ *Figure 3: Herbert Grove Dorsey, chief physicist of the Coast and Geodetic Survey. With Dorsey Fathometer. Dorsey came to work with C&GS in 1926.*

were 'Device of Dr Hayes Measures Time of Sound from Ship to Ocean Bed and Back; Action Is Instantaneous; Great Value to Navigation Is Predicted by Acting Secretary Roosevelt.'

Acting Secretary Roosevelt referred to Theodore Roosevelt III, son of former President Theodore Roosevelt and a cousin of future President Franklin Delano Roosevelt. In contrast to Watkins' words, Roosevelt saw the future: "… Vessels using this invention will not have to use the lead. The device automatically records the depth, in deep or shallow water, and does it instantaneously. It will revolutionize sailing and navigation. It will enable us easily to find the depth of the ocean where it is now undetermined. It is altogether probable, after ocean depths have been better mapped, that the use of this device will enable ships to determine their positions at sea merely by sounding out the ocean depths."

Following this triumph, the Navy equipped two additional ships, the USS *Corry* and the USS *Hull*, with Hayes sonic depth finders. Working in tandem they surveyed the California coast from San Francisco to just south of San Diego (Figure 2). The resulting map of the California continental shelf, slope, and borderlands was the first bathymetric map produced solely from acoustic soundings.

In 1923, the United States Coast and Geodetic Survey equipped the USC&GS Ship *Guide* with a Hayes Sonic Depth Finder. The ship was a converted minesweeper and outfitted on the East Coast of the United States but was slated for West Coast operations. Thus, while in transit to the West Coast, the ship took numerous soundings and made piano-wire comparisons at numerous locations including the Puerto Rico Trench. Commander Nicholas Heck was in charge of this first C&GS acoustic cruise and was assisted by a young officer, Ensign Jerry Service. From their comparisons they computed and published the first velocity tables in 1924, C&GS Special Publication 108, Velocity of Sound in Sea Water. These were later superseded by the British Tables computed by D. J. Matthews.

In spite of these accomplishments, the Hayes sonic depth finder was a cumbersome instrument to use. It was hardly automatic as reported by Secretary Roosevelt. The system was built around a Fessenden oscillator that emitted an audible signal. The operator wore headphones, one side listening for the outgoing signal the other side listening for the incoming echo. He used a variable-speed mechanism to vary the interval between transmitted sound signals, until the transmitted sound and echo were heard simultaneously. The position of the dial on the variable-control mechanism served to indicate the depth. A skilled operator could measure individual soundings at approximately one-minute intervals but usually depths were observed at a much greater time interval. Effectively, it still obtained point soundings but at greatly reduced intervals as compared to the old line and sinker technology. This system was subject to many sources of error. Different operators had different personal 'equations' which basically meant systematic personal error. Rough topography, side echoes and changing slopes exacerbated the human observational element associated with use of the Hayes Sonic Depth Finder. Further reducing its usefulness as a hydrographic survey tool, it was highly inaccurate in water depths less than the continental shelf break.

In spite of these shortcomings, the hydrographic world and commercial world took notice. Among those who became interested in making acoustic sounding a viable depth measuring technique was a middle-aged physicist, Dr Herbert Grove Dorsey. Dorsey had been an itinerant scientist and inventor having worked in both academia and private industry. In 1922, he was working for Submarine Signal Company, a forerunner of today's Raytheon Corporation. He had previously invented an improved amplifier for radio and loudspeaker use. He applied similar principles to developing an amplifier that would convert the weak echo returning from the sea bottom into sufficient electrical energy to energise a small neon light. This ultimately became the basis for the development of the modern single beam echo sounder. The first of these instruments was named '312 Fathometer', a name coined by Dr Dorsey. The Fathometer was registered by Dorsey under US Patent No. 1,667,540. Although the fathometer incorporated an early method called the white-light method, in which a constantly rotating white light illuminated a circular scale painted on a glass surface. An operator was still required to use earphones to hear the incoming echo and simultaneously note the location of the light on the dial to observe the depth. Eliminating the need for a 'listening' operator with attendant potential errors, further development resulted in the 'red-light' method, in which the echo's acoustic energy was amplified sufficiently such that a rotating red neon tube flashed adjacent to the depth scale at the instant of arrival of the echo, thus acting as an index to the depth.

Dorsey left Submarine Signal Corporation in 1926 and joined the United States Coast and Geodetic Survey (C&GS) as an electrical engineer, ultimately rising to become first head of the C&GS Radio-Sonic Laboratory. As the early fathometers were accurate only to depths of 12 fathoms under the best of conditions, in 1933 Dorsey turned his attention to developing a fathometer capable of measuring depths as shoal as only a few feet for inshore survey work. This resulted in the design and production of the instrument that became known as Dorsey Fathometer No. 1. This instrument incorporated near supersonic frequencies, was able to measure depths to within a few tenths of a foot, and displayed discrete soundings 20 times per second, giving the illusion of a near continuous profile. The instrument was designed for use in depths ranging from a few feet to twenty fathoms, thus sounding the death knell for lead-line surveys.

The final step in developing a ‘modern’ survey echo sounder was to marry a graphic recording unit to the sounding system. To accomplish this, the C&GS wrote specifications for a new echo sounder that was designed and manufactured by Submarine Signal Corporation. The result was the 808 Fathometer, a semi-portable unit (it weighed 400 pounds) that could either be permanently installed or temporarily installed on a small boat and was used by the C&GS for the next 25 years. Prior to development of the 808, all echo sounder recordings in the Coast and Geodetic Survey were (with the exception of the early Sonic Depth Finders) observed by eye on the circular dial of the various fathometers and manually recorded. An issue with graphic recorders was the medium used to record the bottom trace. Smoked paper, wax-coated paper, ink and paint traces, charring or perforating the paper, and chemically treated paper known as electrolytic paper were used with varying degrees of success. The C&GS decided on a black-bodied paper whose surface was covered with a light-coloured coating. This coating disintegrated when an electric current was passed through it exposing the black background. Successive rotations of the stylus would cause further disintegration and leave a trace of the bottom configuration.

It is noted that paralleling C&GS uses and development of echo sounding equipment, European investigators – notably English, French, and German engineers and hydrographers - were moving ahead as well. European manufacturers included the French Societe de Condensation et d’Applications Mecaniques, Henry Hughes and Sons Ltd., Marconi, Atlas Werke, Behm, and Signal-Geffelschaft. Although crude by today’s standards, these instruments revolutionised the ability to define the nature of the seafloor. They also forced new data-processing methods, particularly in deep water. The *Challenger* Expedition acquired 504 soundings over a 4-year period in the 1870s. In the sixty years since, the ability to acquire sounding information had increased exponentially to hundreds of thousands per ship in an equivalent time interval. It would seem that Commander Watkins had been wrong when he predicted that although acoustic sounding would “never supplant the standard method of sounding, there is a possibility of it becoming a valuable supplementary device.”

Figure 4: Lieutenant Commander Franklin R. Gossett and Chief Petty Officer Savage operating sounding equipment aboard the USC&GS Ship Oceanographer.

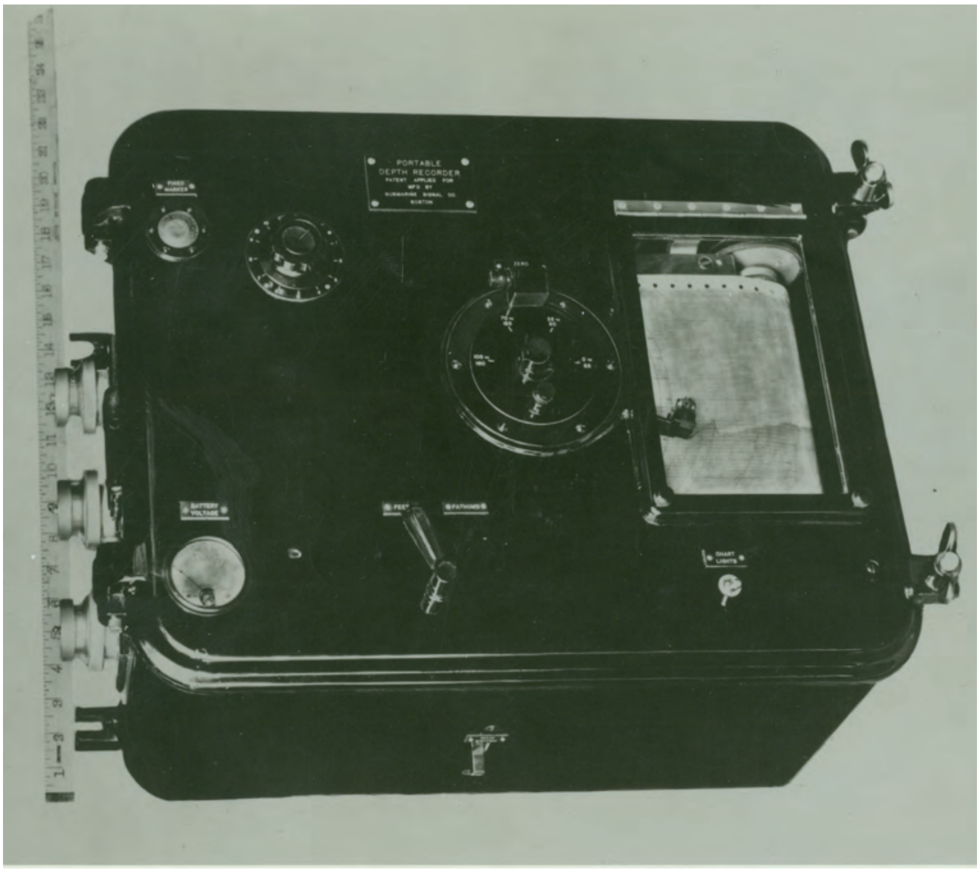
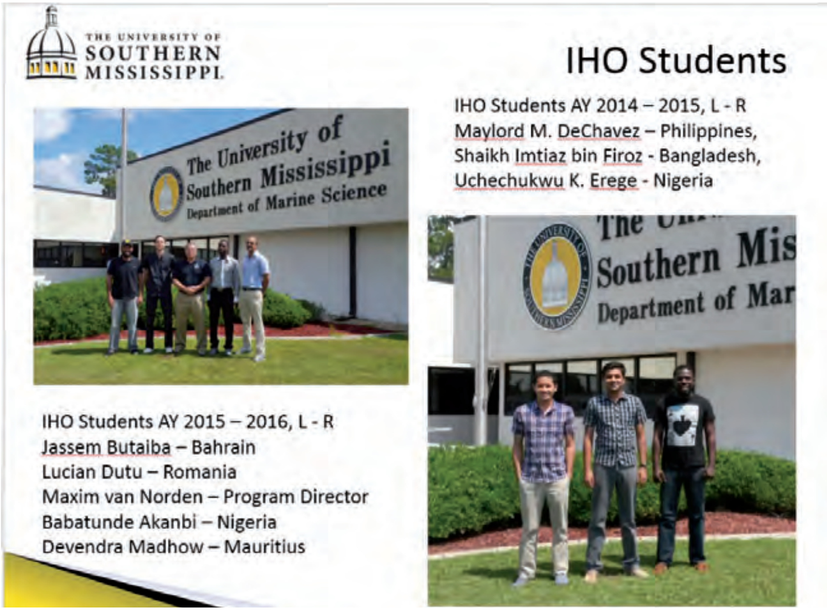


Figure 5: Portable depth recorder.

IHO 2016 in Review

In 2016, the International Hydrographic Organization continued to pursue its wide and varied programme. Here are some highlights for 2016.



▲ *Figure 1: Capacity Building Students.*

The extension and use of the IHO S-100 framework, based on and compatible with the ISO 19100 series of geographic standards, continued apace. Version 2.1 of the IHO geospatial information registry was implemented (registry.iho.int). Several IHO working groups, as well as developers in other international and commercial organisations, moved forward with developing S-100-based product specifications and test datasets; including S-101 (ENCs), S-111 (Surface Currents), S-121 (Maritime Limits and Boundaries), S-122 (Marine Protected Areas), S-124 (Navigational Warnings), S-129 (Under Keel Clearance Management Information), S-411 (Ice Information) and S-412 (Weather Overlays), all of them being expected to contribute to the implementation of the E-navigation concept.

Capacity Building

The IHO capacity building programme continued to provide a wide range of development training and education, both to Member States and to other countries that need to improve their national hydrographic capabilities. The training ranged from short courses on the provision of improved Maritime Safety Information services to degree level courses, such as the Category 'A' hydrographic surveying programme at the University of Southern Mississippi, that 12 IHO sponsored students attended.

New GEBCO Vision and Crowdsourced Bathymetry Projects

In June, coinciding with World Hydrography Day, the IHO-IOC General Bathymetric Chart of the Ocean (GEBCO) project held a forum in Monaco to set out its vision for the next few decades. As a result, it set itself the ambitious target to see complete bathymetric survey coverage of the world's oceans at a 100 metre resolution by 2030. Innovative new methods such as the use of autonomous roaming vehicles fitted with swath echo sounders, satellite-derived bathymetry, and a crowdsourced bathymetry project using the infrastructure of the IHO Data Centre for Digital Bathymetry, are all options to help realise the GEBCO aim.

New Edition of the Standards of Competence for Hydrographic Surveyors

The IHO, in cooperation with the FIG and ICA, adopted new editions of the Standards of Competence for Hydrographic Surveyors that came into effect from 1 January 2017. The standards govern the minimum level of training and education that programmes must offer in order to achieve recognition at the international category 'A' or category 'B' level. The new editions introduced a significant change of concept by separating the category A and category B standard as opposed to the previous concept where category 'A', in effect, built upon category 'B'.

Outreach

Eight more international organisations were accredited as Observers during the year: the Arctic Expedition Cruise Operators, the International Cable Protection Committee, INTERTANKO, the International Seabed Authority, the Maritime Organisation of West and Central Africa, the Open Geospatial Consortium, and the World Ocean Council. Having observer organisations such as these provides the IHO with valuable stakeholder input to its activities as well as enabling collaboration in areas of mutual interest, especially capacity building and standards' development and the over-riding requirement to improve global recognition of the value of hydrography. They join the existing observer organisations and individual experts from industry and from academia that bring their expertise and experience to bear on the development of the IHO standards by participating in the various working groups and meetings during the year. Equally, IHO representation at the meetings of partner organisations remained at a high level. ◀

▲ *Figure 2: IHO Publications.*

More information
www.iho.int

Hydrographic Society Benelux

Call for Papers Hydro17 Rotterdam

The Hydrographic Society Benelux (HSB) invites professionals on behalf of the International Federation of Hydrographic Societies to submit a conference paper for the Hydro17 conference. The conference will be held on board of the luxurious steam ship *SS Rotterdam* between 13 and 16 November 2017. *SS Rotterdam* is permanently moored on the south bank of the port of Rotterdam, the Netherlands.

Hydro17 will focus on strengthening the internal connection within the hydrographic world and seeking connection with adjacent disciplines. 'Connection' will therefore be a common theme throughout the conference, but we will also be celebrating our 25th anniversary of Hydro conferences! This call is open to abstracts addressing a hydrographic theme, but not limited to the following topics:

- Innovations in acquisition techniques
- Data processing
- Data management & integration
- Cost-effective solutions
- Geophysics of the marine environment
- Subsea surveying
- Dredging & Offshore
- Marine renewables
- Accurate hydrodynamics
- Oceanography
- Education & training
- The future of the hydrographic profession

Abstract Requirements

Authors are invited to submit abstracts of 300 words or less before 28 February 2017. The abstract must include the following:

1. Title of the proposed presentation;
2. The names and affiliations of all authors;
3. Identification of intended presenter, including contact details.

Contributions from young people (including students) and developing countries are especially encouraged. Contributions that are very commercial in nature, rather than innovative, will not be accepted.

Abstract Submission

Abstracts can be submitted to submissions@hydro17.com. Authors submitting abstracts that are accepted will be notified before 30 April 2017. Guidelines for submitting the full conference paper and presentation material will be sent with the notification and made available on www.hydro17.com. During the conference, the abstracts will be available in the conference book.

Conference Registration

It is necessary to register for the conference separately from the abstract submission process. At the time of publication of this call for papers, registration is not yet possible. Online registration can be completed at www.hydro17.com. If you have any questions regarding the above, please contact us via submissions@hydro17.com.

The SS Rotterdam *is a permanently moored cruiseliner, already proven to be a good venue for Hydro conferences. Image courtesy: Holger Klindt.*

FEBRUARY

North American Dredging Summit
Houston, USA
→ 8-9 February
wplgroup.com/aci/event/dredging-summit-america/

Seabed Mapping and Inspection Conference
Geilo, NO
→ 8-10 February
www.tekna.no/en/events/seabed-mapping-and-inspection-2017-32947/

Oceanology International North America 2017
San Diego, USA
→ 14-16 February
oceanologyinternational-northamerica.com

MTS/Underwater Intervention
New Orleans, USA
→ 21-23 February
underwaterintervention.com

Underwater Technology
Busan, KR
→ 21-24 February
ut2017.org/ut/

Wave & Tidal 2017
London, UK
→ 23 February
events.renewableuk.com/wave-tidal-overview

Marine Data Infrastructure
Dubai, UE
→ 27-28 February
www.marinedatainfra-structuregcc.com

MARCH

VLIZ Marine Science Day
Bruges, BE
→ 3 March
www.vliz.be/vmsd/en

Arctic Shipping Summit
Montreal, CA
→ 8-9 March
wplgroup.com/aci/event/arctic-shipping-summit

US Hydro 2017
Galveston, USA
→ 20-23 March
ushydro2017.com

Seanergy
Le Havre, FR
→ 22-23 March
seanergy-convention.com/

APRIL

Ocean Business
Southampton, UK
→ 4-6 April
oceanbusiness.com

Gastech
Chiba-City, JP
→ 4-7 April
gastechevent.com

International Robotics Week
The Hague, NL
→ 19-21 April
tusexpo.com

IHO Assembly (A-1)
Monaco
→ 24-28 April
iho.int

SMI Annual Conference 2017
Dartmouth, UK
→ 26-27 April
maritimeindustries.org/SMI-Annual-Conference

MAY

73rd Multibeam Sonar Training Course
Stockholm, SE
→ 15-20 May
bit.ly/2eAXK2i

UDT
Bremen, DE
→ 30 May-1 June
www.udt-global.com

JUNE

EWEA Offshore
London, UK
→ 6-8 June
ewea.org/events/ewea-offshore

CARIS 2017
Ottawa, CA
→ 19-22 June
caris.com/caris2017

MTS/IEEE OCEANS 2017 Aberdeen
Aberdeen, UK
→ 19-22 June
www.oceans17mtsieeeaberdeen.org

JULY

International Cartographic Conference (ICC)
Washington, DC, USA
→ 2-7 July
icc2017.org

RIO Acoustics
Rio de Janeiro, BR
→ 25-28 July
rioacoustics.org

SEPTEMBER

MTS/IEEE OCEANS 2017 Anchorage
Anchorage, US
→ 18-22 September
www.oceans17mtsieeeanchorage.org

OCTOBER

Offshore Energy
Amsterdam, NL
→ 9-11 October
offshore-energy.biz

Teledyne Marine Technology Workshop
Dan Diego, US
→ 15-18 October
www.teledynemarine.com/events/teledyne-marine-technology-workshop-2017

NOVEMBER

Oceanology International China
Qingdao, CN
→ 1-3 November
www.oichina.com.cn

PLOCAN Glider School
Telde, Spain
→ 6-11 November
gliderschool.eu

Marine Autonomy and Technology Showcase
Southampton, GB
→ 13-17 November
conference.noc.ac.uk/matshowcase

Hydro17
Rotterdam, NL
→ 14-16 November
hydro17.com

Calendar Notices
For more events and additional information on the shows mentioned on this page, see www.hydro-international.com. Please send notices at least 3 months before the event date to: Trea Fledderus, marketing assistant, email: trea.fledderus@geomares.nl.