Hydro INTERNATIONAL

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USV for Bathymetric Dam Imaging

Surveyors Discover World War One Submarine

The Biggest Arctic Expedition of All Time

Hydro INTERNATIONAL

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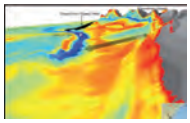

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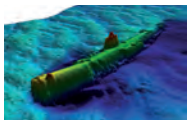

Front cover

On 20 September 2019, the German research icebreaker *Polarstern* left Tromsø, Norway, for what could be the biggest Arctic research expedition of all time. Once she reaches the destination, the ship and her crew will become trapped in the ice and spend an entire year drifting through the Arctic Ocean. **Read more on page 22.**

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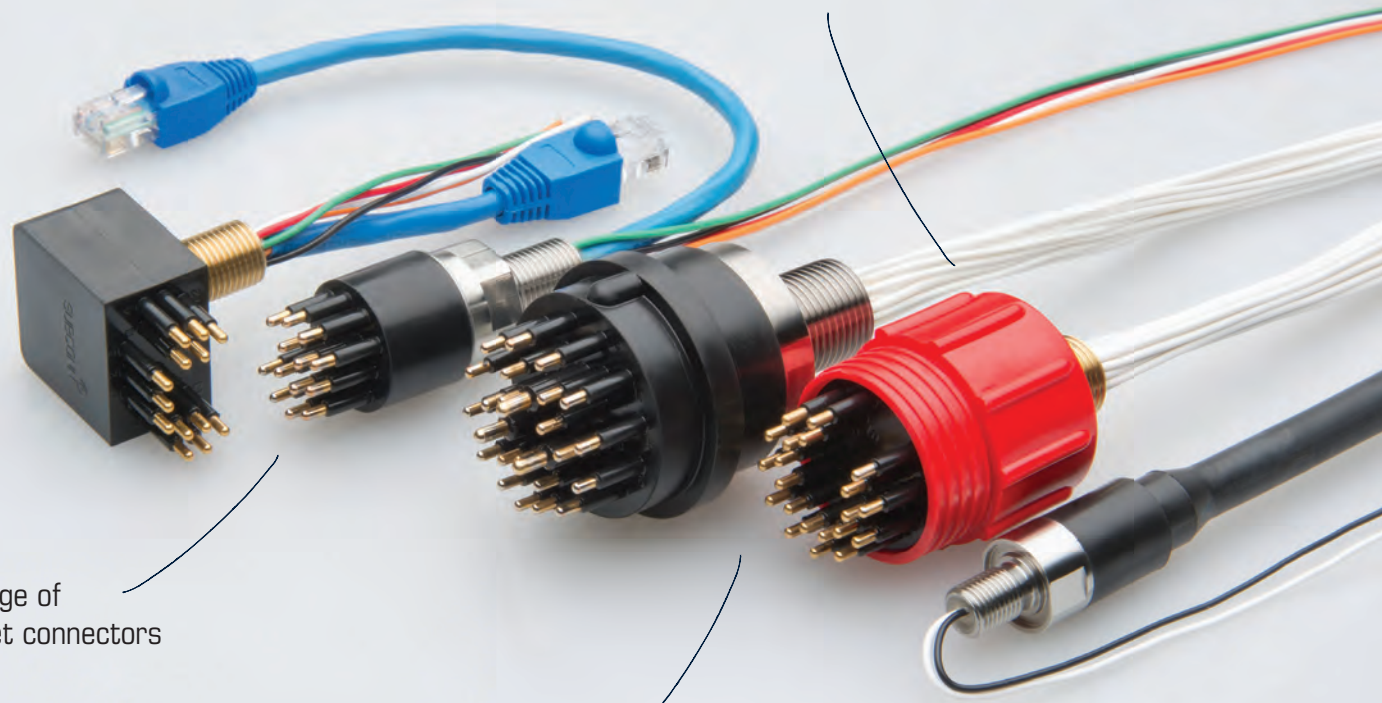

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Threats

▲ *Durk Haarsma.*

Safety of life at sea is sometimes threatened by unusual suspects. Laurent Kerléguer, director general of the French hydrographic office SHOM, highlights two of them in an interview in this issue of *Hydro International* (see page 12). Firstly, Kerléguer mentions the risk that the abundance of data in hydrography and oceanography might pose. The immense amounts of data that will be generated when crowdsourced and remote hydrography really takes off should be accompanied by extra requirements for maintaining the authoritativeness of that data; quantity should not be allowed to replace quality. And he identifies another threat: cybercrime. Whereas the authoritativeness of data can be safeguarded from within hydrography, by hydrographers and their standards, cybercrime might require us to enlist external help. After all, the complex world of data-platform security is really an issue that demands constant attention from top-notch specialists, not least because products derived from hydrographic data need to be 100% trustworthy at all times. If hackers tamper (or worse) with that data, they not only undermine that trustworthiness, but also threaten the safety of life at sea. The potential scale of the damage is unthinkable. So while the overall tone of the interview with the new director general of SHOM is very optimistic, I am pleased that Kerléguer also mentions the dangers. I am an optimist myself, but in this case it is equally important to be a realist. Therefore, both these threats need to be high on the agenda of the international hydrographic community. They need to be discussed – not only behind closed doors, but also openly in fora, in magazines such as *Hydro International*, at conferences and symposia and other gatherings of policymakers. That way, industry professionals and users of hydrographic data will see that the potential threats are being met with measures in order to sustain – and strengthen – their trust.

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Still Much to Be Discovered

▲ *Cees van Dijk.*

More than 70% of Earth is made up of oceans, yet the underwater domain is the least known area of our planet. Even now, only an estimated 10% of the ocean floor has been mapped in detail. There is still much to be discovered. What we do know is that the average depth of the world's oceans is more than 3,600m. The deepest areas are found in oceanic trenches such as the Mariana Trench, which is located in the western Pacific Ocean about 200km east of the Mariana Islands. At nearly 11,000m below the surface, it is believed to be the deepest point on Earth.

At the other extreme is Mount Everest. Technically speaking it is the highest point on Earth, reaching 8,848m above sea level, but if you start measuring from the seafloor there are some much higher mountains. Mauna Loa in Hawaii, stretching 9,170m above the seafloor, is probably the highest, even though only 4,170m of it can be seen above the surface.

You could submerge Mount Everest in the Mariana Trench and still also have space for Mount Washington, which at 1,917m is the highest peak in the northeastern USA, or Tongariro, a compound volcano in the Taupo Volcanic Zone of the North Island of New Zealand. Alternatively, stacked end to end, you could fit 13 times the Burj al Khalifa – the world's tallest building – in the trench. Bear in mind that it's only a century ago that Marie Tharp made major strides in discovering more about the world's oceans and started mapping the entire ocean floor. Despite the barriers of being a female scientist in the early 20th-century's male-dominated scientific community, Tharp's work led to revolutionary discoveries and the relevance of her maps of the ocean can still be felt today.

Step by step, scientists and researchers are revealing more secrets of the deepest points on our planet. But nearly 100 years after Tharp drew her maps of the seabed, more than 90% of the world's oceans still remains unmapped. We probably know more about the universe and the dark side of the moon than we know about the deepest points of our oceans.

There is still much to discover nowadays but, unlike in the time of Marie Tharp, we have high-tech and sophisticated equipment at our disposal. Moreover, both men and women are now involved in the today's worlds of hydrography and oceanography, so there is twice the 'manpower' to conduct the necessary activities. This will undoubtedly accelerate the rate of discovery from now on. Exciting times lie ahead!

Cees van Dijk, content manager
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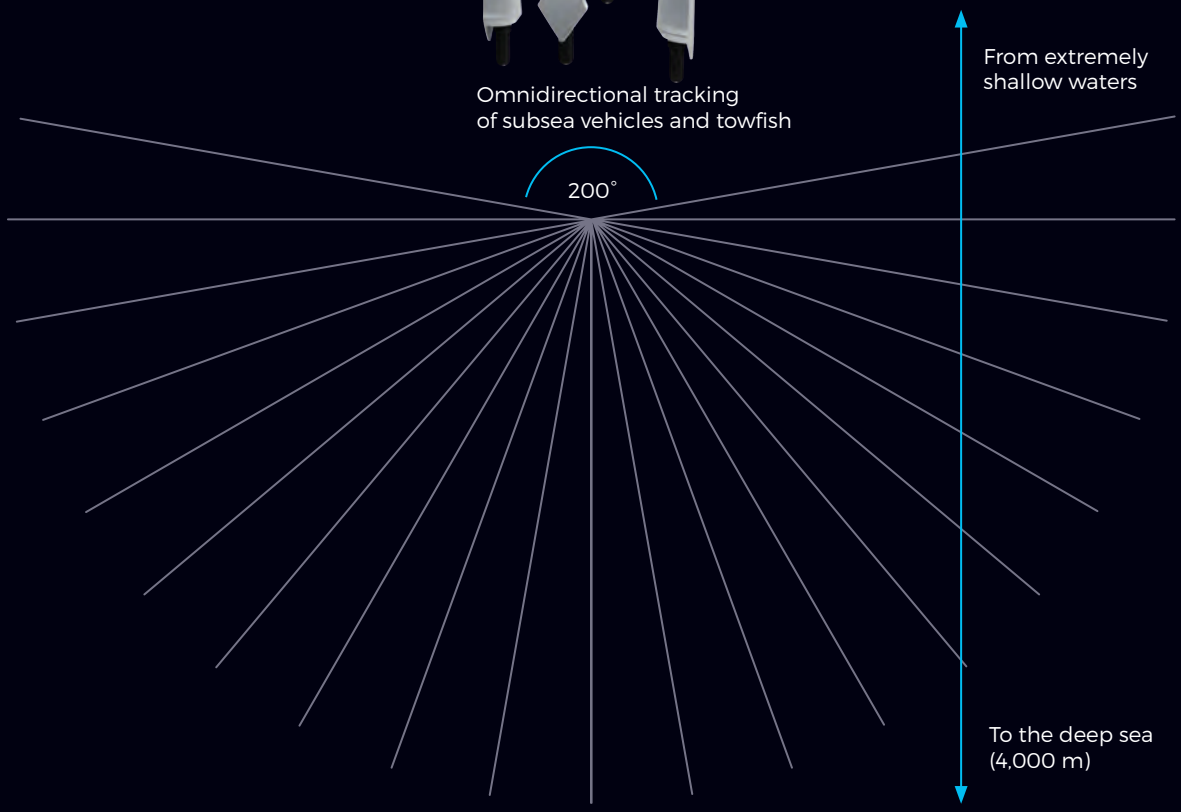

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The Sun Shines on Nautical Charts in Different Ways

Just recently someone reminded me about the 20th anniversary of the finalization of the first official type approval of an ECDIS device. Indeed, it was in summer 1999 that all sea trials and technical tests at the labs of the Federal Maritime and Hydrographic Agency of Germany were completed and, being in charge of this process at the time, I signed the official certificate to confirm that the Transas Navisailor device met all applicable IMO and IHO standards. We did our best to confirm software stability and physical robustness of the device based on the very small range of S-57 ENCs available. After nearly two years of application of all the mandated test scenarios, the manufacturer was enthusiastic and the sun appeared to shine brightly on the glorious future of digital and paperless navigation. As we all know, it eventually turned out that way – but not immediately. I must confess that both the manufacturer and I were naïve about the progression of global ENC coverage. It took another ten years before substantial numbers of ENCs were on offer for major routes and ports. Likewise, we were much less aware of software's nasty habit of never being completely free of errors, quality assurance procedures for software and data production were not mature, and many traditionalists challenged the idea of digital navigation at sea in general. I clearly recall the year-long struggle at IMO to achieve the ECDIS carriage requirement acceptance.

The lack of ENCs was a deterrent, but on the other hand a good number of devices utilizing private data were already in the field and there was great enthusiasm among those mariners who used them. That new means for navigation yielded its own spin-off – well before any other digital track control for transport carriers on land and in the air. Although in hindsight the issuance of the first certificate may seem to have been premature, it generated two outcomes: 1) hydrographic offices began to understand that the ECDIS concept was transforming from a vision into a reality and started to prepare for regular ENC production, and 2) a fully new industry sector was born to create chart data production and dissemination software, and navigational equipment manufacturers increased their engagement to develop IMO-compliant ECDIS systems for certification.

Frankly, on the day of signing the ECDIS certificate I didn't have the strategic foresight to anticipate what would happen. But having lived through this experience, I wonder what we can learn from it based on the current situation. Now, after a 20-year transition period of uptake, establishment and consolidation of ECDIS as the navigation means at hand, the sun is setting on paper charts. Noting the steady decrease in paper chart sales and the digitization of our whole information environment, it seems likely to me that the global paper chart system as we know it today will not be sustained for another ten years. Just like we sometimes print out an e-mail to obtain something tangible on which we can scribble, we may send selected ENC coverage areas to a mid-size A3 or A2 printer through a converter which transforms the ENC content into a paper chart presentation; however, that will be all. Full paper chart folios will probably only remain on navy vessels. I am sure that commercial shipping, fishery and leisure craft will go effectively paperless.

To reduce paper (almost) completely to a back-up position, however, another digital evolution is needed. Practitioners know that safety of navigation requires more information than just what is included in ENCs. Navigational warnings, tides and currents, ice, weather… all this information somehow finds its way digitally onto a ship's bridge nowadays, but – so far – it is difficult to seamlessly integrate it all to create a consistent image of the situation at hand. This has been known for a long time and the concepts to overcome the challenge are no longer sensationally new but, just like in the early days of ECDIS uptake, the standardized 'digital fuel' needs to be provided on regular services – and with substantial coverage – before it can take effect in the field. The IHO S-100 framework offers this promise by concept and has now matured enough to transform from a vision into a reality. As in the early ECDIS/ENC days, it starts with test beds and collaboration between national hydrographic offices and industry. In contrast to the laborious start for ENC services 20 years ago, I see three major differences: 1) there is full awareness among the administrative partners that substantive regional coverage of the various sorts of S-1xx thematic information packages should be available right from the start and elevate to global coverage in a relatively short time; 2) marine spatial data infrastructure including bandwidth for wireless data transmission is in place and can assist; and 3) industry players are ready to upgrade their software for data production systems, data provisions and end-user devices. The sun is about to rise over the fully integrated approach to ship navigation and will shed its first light on IHO's new roadmap for S-100 implementation.

My prognosis is that it will take much less than ten years before transformation of ECDIS to the next level of integration will take effect. And it will be so much more than nautical charting… ◂

▲ *It will take much less than ten years before transformation of ECDIS to the next level of integration will take effect.*

Earliest Boat-building Site in the World Found by Divers?

▲ *Trust director Garry Momber at the site.*

An 8,000-year-old wooden platform has been discovered off the Isle of Wight coast near Yarmouth in the UK. The seabed where the structure was found – at a depth of roughly 36 feet – would have been dry land when the platform was built, and still connected to the European mainland. The platform sits adjacent to and may have been part of Bouldnor Cliff, a submerged Mesolithic settlement first identified in 1999, which – among a number of discoveries – has yielded what is thought to be the earliest boat-building site in the world.

Divers from the Maritime Archaeology Trust, which oversees the site, first spotted the new structure earlier this year, and excavations have now revealed it to consist of a series of split timbers resting on round wooden foundations. According to director Garry Momber, the platform doubles the amount of worked wood from the Mesolithic period that is known in the United Kingdom and provides new evidence of technology that was not previously thought to have been developed for at least another 2,000 years. The wood has now been taken to a laboratory at the National Oceanography Centre in Southampton for analysis and conservation. Many of the wooden artefacts are being stored in the British Ocean Sediment Core Research facility (BOSCORF), operated by the National Oceanography Centre.

Kīlauea Lava Fuels Phytoplankton Bloom off Hawaii Island

When the Kīlauea volcano erupted in 2018, it injected millions of cubic feet of molten lava into the nutrient-poor waters off the Big Island of Hawaii. The lava-impacted seawater contained high concentrations of nutrients that stimulated phytoplankton growth, resulting in an extensive plume of microbes that was detectable by satellite, as research by the School of Ocean and Earth Science and Technology (SOEST) shows.

A study led by researchers at the University of Hawaii (UH) in Mānoa and University of Southern California (USC) and published in the Science journal revealed that this biological response hinged on unexpectedly high concentrations of nitrate, despite the negligible amount of nitrogen in basaltic lava. The research team determined that nitrate was brought to the ocean surface when heat from the substantial input of lava into the ocean warmed nutrient-rich deep waters and caused them to rise up, supplying the sunlit layer with nutrients.

▲ *The Kīlauea volcano erupted in 2018.*

Arctic Ice Approaches Second-lowest Minimum

The sea-ice extent in the Arctic is nearing its annual minimum at the end of the melt season in September. Now, just approx. 3.9 million square kilometres of the Arctic Ocean are still covered by sea ice, according to researchers from the Alfred Wegener Institute and the University of Bremen. This is only the second time that the annual minimum has dropped below four million square kilometres since satellite measurements began in 1979. Until mid-August, it looked as though the all-time record would be reached: the area of the Arctic Ocean covered by ice (defined as the area with a sea-ice concentration of more than 15%) from late March to early August was the smallest measured by satellites since 1979.

"Our satellite data shows that between March and April 2019, there was an unusually large decrease in the ice extent, from which the Arctic sea ice was unable to recover," according to Professor Christian Haas, a geophysicist and head of the Sea Ice section at the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI), and Dr Gunnar Spreen from the University of Bremen's Institute for Environmental Physics. Since the second half of August, however, the seasonal reduction has slowed down, overlaid by short-term fluctuations. The lowest value so far for 2019 was 3.82 million square kilometres, observed on 3 September. This means that this year, the September average could be below four million square kilometres for only the second time. (Read more about the MOSAiC expedition on page 22.)

▲ *Scientists are seeing an unusually large decrease in the ice extent.*

Broadcast Spawning of Coral Reefs Are under Threat

▲ *Coral reefs may now be under threat of extinction.*

Coral reefs are among the most diverse and productive ecosystems on our planet. But due to climate change and other human stressors, reef-building corals that reproduce by means of broadcast spawning – the simultaneous release of eggs and sperm into open water – may now be under threat of extinction. A recent Tel Aviv University study finds that the highly synchronized, iconic spawning events of certain reef-building corals in the Gulf of Aqaba, Red Sea, have completely changed over time and lost their vital synchrony, dramatically reducing chances of successful fertilization.

According to the research, led by Prof Yossi Loya and PhD candidate Tom Shlesinger of TAU's School of Zoology and published in Science, the breakdown in coral spawning synchrony has led to a dearth of new recruits and stagnant ageing populations, creating circumstances for extinction. "Coral spawning, often described as 'the greatest orgy in the world', is an example of synchronized phenomena in nature and it is in danger," explains Prof Loya. "Once a year, thousands of corals along hundreds of kilometres of a coral reef release their eggs and sperm simultaneously into the open water, where fertilization will later take place. Since both the eggs and the sperm of corals can persist only a few hours in the water, the timing of this event is critical." Successful fertilization, which can take place only within this narrow time window, has led to the evolution of precise spawning synchrony. Such synchronicity relies on environmental cues: sea temperature, solar irradiance, wind, the phase of the moon and the time of sunset.

Strong Gulf Stream System Does Not Contradict Models

▲ *A Gulf Stream system around ten million years ago was almost as strong as today's.*

Differences in salinity of water masses drive the global ocean circulation. Model simulations show that the circulation can be weakened by high freshwater input in key regions. Until now, a strong Gulf Stream system in the Miocene about ten million years ago seemed to contradict this assumption. At that time, the land bridge between North and South America was not yet closed and relatively fresh water from the Pacific reached the Atlantic. A study by scientists from the GEOMAR Helmholtz Centre for Ocean Research in Kiel (Germany), published in the international journal *Nature Communications*, resolves this contradiction. In the Earth's complex climate system, the global ocean currents play an important role, for example as energy distributors. For this reason, it is a major goal of ocean and climate research to understand how they work – both in the present and in the past. Only on the basis of such knowledge can future developments be predicted reliably. Among the so far unsolved mysteries of the past is the behaviour of the North Atlantic Ocean circulation, including the Gulf Stream system, in the Miocene about ten million years ago. "In a phase in which, according to today's understanding, a weakened North Atlantic overturning circulation could be expected, climate archives show a Gulf Stream system that was almost as strong as today's," says Dr Anne Osborne of GEOMAR. GEOMAR Helmholtz Centre for Ocean Research Kiel (Germany) is an institute for marine research. It investigates chemical, physical, biological and geological processes of the seafloor, oceans and ocean margins and their interactions with the atmosphere. The institute also bridges the gap between basic and applied science in several areas. The GEOMAR is a foundation under public law jointly funded by the German federal (90%) and Schleswig-Holstein state (10%) governments. GEOMAR has a staff of approximately 1,000 employees.

Taiwan Boosts its Current Ocean Research with New Fleet

▲ Legend *is Taiwan's fifth-largest research vessel.*

A new fleet of oceanographic research vessels is expected to be launched in the first half of 2020. This means a boost to Taiwan's ocean current research and homeland security protection. The fleet will comprise four ships, three of which are to be delivered by early next year, including two 500-ton vessels and one 1,000-ton vessel. The new ships are domestically developed and manufactured through a collaboration between academia and industry, sponsored by the Ministry of Science and Technology, reports CNA, the Central News Agency of Taiwan.

Legend is Taiwan's fifth-largest research vessel and was built by Triyards Marine Service, a Singaporean company based in Vietnam. The vessel features a remote operated underwater vehicle (ROV) – capable of operating at depths of 3,000m – and a gravity core sampler that can work in waters 20m deep, and is equipped with a 360° electric propulsion system. Its building costs were nearly US$30 million , the *Taipei Times* reported in 2017.

While the existing 2,000-ton vessel, *Legend*, is operated by the National Applied Research Laboratories (NARLabs), the new ships will be managed by National Taiwan University, National Taiwan Ocean University and National Sun Yat-sen University. *Legend* is tasked with national-level research missions, and the other ships will be fitted with equipment that reflects the needs of the academic institutes, said the report. A commission will be established to help coordinate operations and resources for the fleet.

Titanic Wreck Being Consumed by Ocean Microbes

▲ *A team of experts and scientists examined the remains of the Titanic.*

For the first time in 14 years, the RMS *Titanic* wreck has been visited by a human-occupied vehicle: the Triton 36,000/2 (known as *Limiting Factor*). This manned submersible, capable of diving to full ocean depth, reached the bottom of the North Atlantic Ocean (3,810 metres/12,500 feet) in early August. An exploration team from Triton Submarines completed a total of five dives at the *Titanic's* final resting place 370 miles south of Newfoundland. The last time a human-occupied submersible dived to the *Titanic* was in 2005.
Following established US legal protocols and under the observation of an onboard NOAA representative, the team of experts and scientists examined the remains of the ship, capturing the wreck in a way it has never been seen before. Using the submersible camera systems, the team performed dedicated photogrammetry passes on the wreck, allowing highly accurate and photo-realistic 3D models of RMS *Titanic* to be produced. These assets will help assess the wreck's current condition and project its future, as well as making it possible to visualize the wreck using augmented reality (AR) and virtual reality (VR) technology.

Lying almost 4,000 metres beneath the surface in bitterly cold 1°C water, the wreck has become vulnerable to sweeping eddies and subjected to ever-changing sea currents. Salt corrosion, metal-eating bacteria and deep current action are having the greatest impact on the wreck. While on the site, the team laid a wreath and held a ceremony in honour of those who lost their lives on that fateful night in 1912.

Russian Arctic Team Maps Five New-found Islands

A Russian Arctic expedition has mapped five small islands in the Far North, discovered by Marina Migunova, a student analysing a glacier's retreat in satellite photos, the BBC reported recently. Before her discovery in 2016, the islands were hidden under the Nansen Glacier, also known as Vylka, in the Novaya Zemlya archipelago. The islands Marina found are in Vize Bay, on the northeastern coast of Novaya Zemlya and range in size from 900 to 54,500 square metres.

Marina's discovery was part of her final coursework at the Admiral Makarov State Maritime Academy in St Petersburg. Marina received an honorary diploma from the Russian Hydrographical Society for her discovery. She is now a naval oceanographical engineer in the Russian Northern Fleet.

The University of Maritime and Inland Shipping in St Petersburg is considered to be the oldest and largest centre for the education and training of shipping industry personnel in the Russian Federation, providing education and training for maritime as well as inland water operators. The university, also known as the GUMRF, was founded in the early 1800s.

▲ *The islands were hidden under the Nansen Glacier (courtesy: Russian Ministry of Defence).*

7 Questions to the New Director General of the French Hydrographic Office

'Hydrography is Both a Science and a Technique'

Chief weapons engineer Laurent Kerléguer was appointed director general of Shom, the French hydrographic office, in July 2019. In this interview, *Hydro International* asks him about the latest developments regarding the world of hydrography, climate change and artificial intelligence. "It's becoming more urgent than ever to measure the ocean."

Laurent Kerléguer was born in Brest, France, and has always lived by – or close to – the sea. Although he never had a 'dream job' as a child, he always had the feeling that his career would be linked to the sea. "For me as an engineer, hydrography is the perfect combination of science and technology applied to the sea, plus a great opportunity to visit the world and survey the ocean," he says.

He regards his appointment as director general of such a prestigious hydrographic office which originated almost 300 years ago (*the Dépôt des Cartes et Plans de la Marine was created in 1720, Ed.*) as a great honour. "This achievement is the culmination of my whole career dedicated to hydrography and oceanography in the many positions and fields of interest that Shom can offer: development, technology, operations at sea, international cooperation and also budgets, human resources and administration in general."

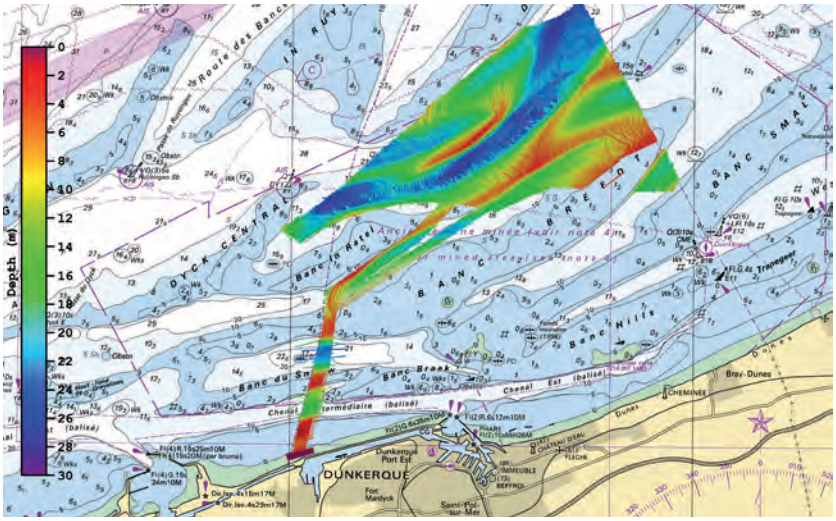
WHICH DEVELOPMENTS DO YOU REGARD AS MOST PROMISING IN THE WORLD OF HYDROGRAPHY?

Hydrography is both a science and a technique. Technology has done a lot to improve our methods and efficiency over the past 300 years and since the time of the 'hydrographic circle'. There have been major breakthroughs such as sonar, global positioning, multibeam echosounders, Lidar and the innovations are set to continue. Autonomous underwater vehicles (AUVs) are on their way to becoming a standard asset for hydrography, and we are now only just beginning to envisage what artificial intelligence (AI) will bring to our discipline. AI will improve the efficiency and speed of data processing, for example, but it may also help to assess risks and prioritize which areas to survey first. But AI is also changing navigational practices; for example, massive autonomous surface shipping will certainly create the need for hydrographic offices to develop and provide new products and services.

Moreover, there is a general trend – driven by the digital-native generation and perhaps also linked to climate change – to contribute to a global effort using limited capacity but in great numbers. For hydrography, this is crowd-sourced bathymetry. I don't believe this is going to replace professional hydrography, but it's an interesting complement. Under the auspices of IHO, hydrographic offices are fostering the development of crowd-sourced bathymetry by

▲ *Work on board a survey boat of BHO Beautemps-Beaupré. (Courtesy: Marine nationale - J. Braescu)*

▲ *Laurent Kerléguer is director of Shom.*



▲ *Survey data of offshore Dunkerque (France) in preparation for a future wind farm. (Courtesy: Shom)*

▲ *Shom assisted OCEA shipyard with installation and performance assessment of a multibeam echosounder on OSV190 ship for the Indonesian navy. (Courtesy: Shom - S. Beuchard)*

providing guidance, but they must also be able to combine data that is not acquired in accordance with hydrographic standards with their own professional data.

WHAT OPPORTUNITIES AND THREATS DO YOU SEE FOR THE HYDROGRAPHIC PROFESSION?

One great opportunity is definitely 'blue growth'. Ocean transport, exploitation of the sea's natural minerals and energy resources, leisure activities, protection of the sea, maritime spatial management… these are all major opportunities for the future, because people's awareness of the ocean has never been so high. As a consequence it is becoming more urgent than ever to measure the ocean; we still know so little about it, except for very limited navigation corridors and harbours. The good news is that some major stakeholders such as the European Union are investing in knowledge programmes, providing a welcome addition to national investments.

In terms of threats, from the perspective of the safety of life at sea, we have to make sure that navigation documents continue to be based on authoritative data and to prevent a situation in which quantity might replace quality at a certain point. This is not so different from what happens with general information; you can access a lot of different sources, but ultimately you want to be sure that the 'breaking news' is not fake news. Cyber threats are also a real issue in today's digital world. It is not sufficient to produce reliable data and products; it's also necessary to make sure that they can't be corrupted along their journey to the end user.

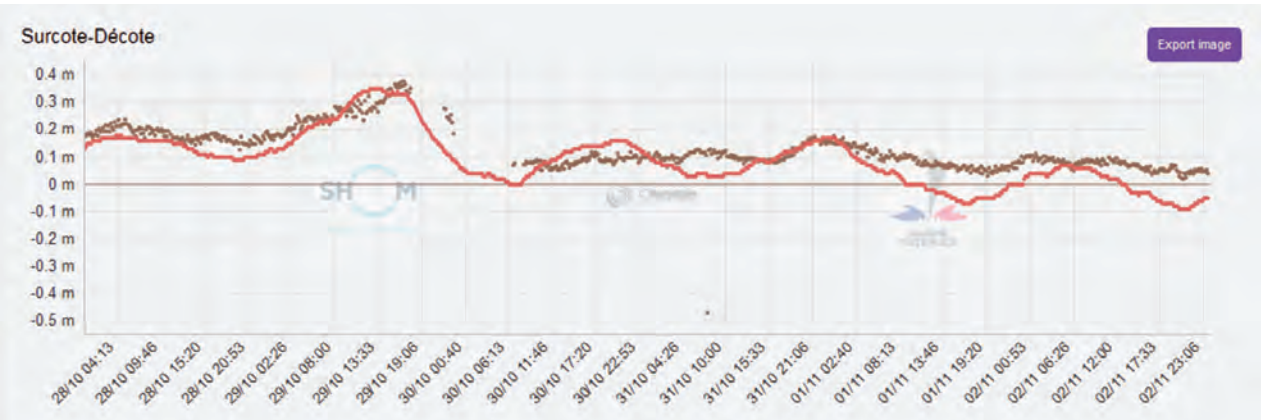
WHICH TECHNOLOGY WILL CHANGE THE HYDROGRAPHIC PROFESSION THE MOST?

I already mentioned the role of technology in advancing hydrography. But no matter what technology we use, we need to keep qualified, trained and certified hydrographers in the loop.

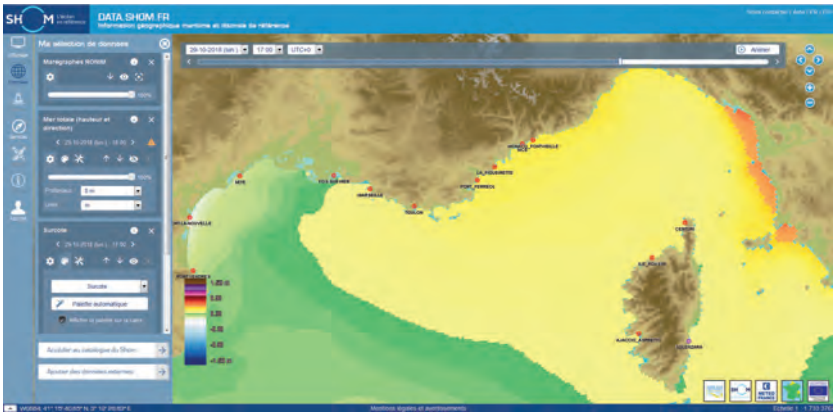
The profession has already adapted to major changes in the past (e.g. satellite-based localization requiring no effort from hydrographers, enhanced productivity and the use of multibeam echosounders for surveying). It's a bit early to tell how AUVs and AI will change our profession, but I don't hope – and nor do I expect – that hydrographers will be land-based in the future rather than being sailors. Even though autonomous devices might make that a possibility, I think we would end up missing out on something. AI should be seen as an opportunity to raise the hydrographer's position in the value chain by eliminating laborious and repetitive work that a machine can do better.

WHAT ARE YOUR FUTURE PLANS FOR SHOM?

Shom is the French national hydrographic office, but it is also in charge of supporting



▲ *Tidal surge in Ajaccio on 28 October 2018. (Courtesy: Shom)*



▲ *Submersion forecast along Corsica computed for the submersion warning system. (Courtesy: Shom)*

military defence activities in the marine environment, plus it develops products and services in support of public maritime policies. This is a very large scope due to the size of the French national exclusive economic zone and its even bigger area of interest in terms of defence. As the national hydrographic office, Shom is very much involved and active within the IHO. We will continue our efforts to reach our common goal of making navigation safer by developing and harmonizing the worldwide ENC coverage. The next challenge is to implement the new S-100 framework that will allow users to receive the additional services that they need. Indeed, nowadays a navigator wants more than just to navigate safely from port A to port B; he also wants additional information on currents to optimize cruising operations, on tides to maximize the ship's possibilities to enter a harbour, on meteorology, on services available at the harbour, and so on. In recent years Shom has endeavoured to provide products that meet the precise needs of its users in order to make things easier and more convenient for them. It will continue to do so by developing new products and services and improving the organization of its processes to provide such products and services more rapidly.

This is even more important in terms of supporting defence. The challenge here is to provide support to the navy in an ever-more complex world. The navy is improving its capacities at a good pace and it requires the environmental support to be developed at the same pace in order to take the best advantage of its systems.

WHICH INNOVATIONS ARE PLANNED, AND DOES THE AVAILABLE BUDGET OFFER ENOUGH ROOM FOR THEM?

One major innovation for the coming years will be the renewal of the hydrographic and oceanographic data acquisition capacities. This programme is aimed at replacing the oldest coastal hydrographic ships. It will be designed in terms of capacity, i.e. it is not necessarily a direct ship-for-ship replacement, so the result will possibly be a set of ships, AUVs, USVs, etc. Furthermore, in order to have a coherent system – from mission preparation and data acquisition up to data qualification – particular attention will be paid to the overall architecture including data processing, because there is no sense in data acquisition without being able to process it in the workflow.

WHAT IS YOUR VIEW ON INTERNATIONAL DEVELOPMENTS, E.G. IN TERMS OF MAPPING THE OCEAN FLOOR?

There are huge gaps in our knowledge of the oceans. The first responsibility for hydrographers and more generally for Earth observers is to make sure that no available data is lost. That's why GEBCO or SEABED 2030 initiatives to gather existing data are so important. In that context, Shom participates – along with many European states and with the financial support of the European Union – in the successful EMODNET programme that allows production of databases and digital terrain models of European seas.

The second responsibility for hydrographers is to acquire missing data at sea or complement acquisition in areas surveyed using old methods (lead lines, singlebeam echosounders, etc.). Shom is very active in this too. Our survey ships spend an average of 800 days at sea per year performing bathymetry, hydrology, sedimentology and so on.

We also have to be innovative and make as much use of the technology as possible to fill in the gaps, e.g. in high latitudes or in scarcely populated areas of the Pacific Ocean. Satellite-derived bathymetry can certainly add something here but, although it has been used for many years (in fact, Shom produced its first space chart back in 1983), it is still not yet commonplace.

DO YOU SEE A SPECIFIC ROLE FOR HYDROGRAPHIC SERVICES RELATED TO REDUCING WORLDWIDE CLIMATE CHANGE?

Hydrographic services are regular observers of the sea and supporters of the UN goals for a sustainable ocean. The time series gathered over many years have already proven their value

▲ *Acoustic buoy on deck of BHO Beautemps-Beaupré, ready for launching. (Courtesy: Shom - F. Le-Courtois)*

▲ *BHO Beautemps-Beaupré hydrographic and oceanographic survey vessel. (Courtesy: Shom - F. Julou)*

in assessing climate change, such as water-level observations from tide gauges which enabled 300 years of data to be reconstructed from archives for Brest, for example. More generally, the bathymetric data produced by hydrographic offices is also useful for running climate models. By carrying out surveys in preparation for wind farms or any other kind of marine renewable energy system, hydrography indirectly contributes to reducing carbon emissions. And in terms of routing, the future S-100 framework will make it easier to combine navigational safety data with additional information layers, so it will help merchant ships to reduce their energy consumption during their voyages using information on currents, sea state and winds. ◀

About Shom

The mission of Shom, a public authority under the supervision of the French Ministry of the Armed Forces, is to describe and forecast the ocean. As the National Hydrographic Service, Shom collects, processes, archives and disseminates maritime and coastal geographical information in support of public bodies and all users of the sea. Its areas of expertise include: bathymetry, sedimentology, coastal hydrodynamics, oceanography and offshore acquisition systems engineering.

Facts and figures

- French maritime areas: 10 million square kilometres
- 524 employees, with offices in Brest, Toulouse, Saint-Mande, Noumea and Papeete
- Annual budget: €58 million
- 5 French navy ships at its disposal (including one shared with Ifremer)
- 874 maps, including 67% in electronic format.

About Laurent Kerléguer

Laurent Kerléguer graduated from ENSTA Paris (National School of Advanced Techniques) in 1988 and joined Shom in 1989 as assistant director of the Atlantic Hydrographic Mission. He then held various positions, including on land at Shom's headquarters in Brest, at Shom's local offices (Toulouse, Papeete), as well as on board the hydrographic vessels made available to Shom by the French navy for the accomplishment of its missions. His roles have included: chief of the Applied Oceanography Section of the Military Center of Oceanography, technical director of the Oceanographic Mission of the Pacific, head of the Shom-Météo Research and Study Bureau, director of Institutional Missions and Relationships, and deputy director of Shom (since June 2015). On 12 July he was appointed as general director of Shom, taking over from general engineer of armament Bruno Frachon.

Tackling the Land-sea Interface Challenge in the South West Pacific

A Strategic Partnership of Specialists

It will come as no surprise to most readers of this magazine that many regions of the world remain poorly charted. This is particularly true for the South West Pacific region, where mariners today rely upon navigational charts that were compiled over a hundred years ago using data that was collected using lead lines and sextants. Without taking anything away from the extraordinary efforts and feats of those pioneering hydrographic surveyors, the work performed all those years ago can no longer be relied upon by mariners navigating the waters of the South West Pacific for safe passage. This article outlines how a strategic partnership of specialists is tackling this challenge.

This problem has long been recognized by the International Hydrographic Organization (IHO). For many decades, the IHO has been developing and managing a hydrographic capacity-building programme which has aimed to increase the quality and coverage of bathymetry across the globe. This programme has been implemented on a regional basis with the South West Pacific member states keen to increase their hydrographic coverage and expertise.

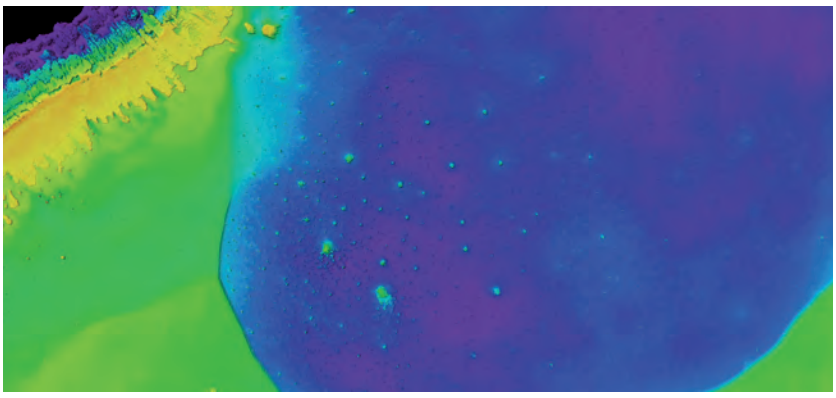
RISING DEMAND FOR HIGH-QUALITY BATHYMETRIC SURVEY

In addition to the IHO's efforts in improving the quality and coverage of bathymetry across the South West Pacific, a number of high-value hydrographic projects have been funded by various aid organizations such as the Asian Development Bank and Western governments. These have seen bathymetric coverage extended across parts of Papua New Guinea (PNG National Maritime Safety Authority Project) and Tonga (LINZ Pacific Regional Navigation Initiative Project), to name but two projects. The national hydrographic offices of the USA, France, UK, New Zealand and Australia regularly fund or deliver hydrographic surveys across the region which contribute to the coverage.

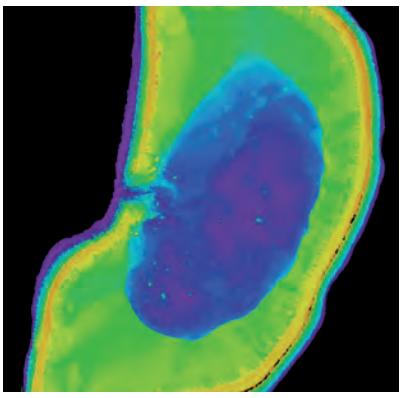
The opportunity to collect high-resolution topographic and hydrographic data in a seamless dataset has never been better. The value of this data chain to inform on climate change, sea-level rise and coastal inundation modelling is higher than ever before. The potential economic benefit of this work is staggering when one considers the recent growth of the cruise-line industry in this region alone. There is no doubt that more surveying and greater coverage will generate more visits from cruises carrying thousands of passengers, and with this will come greater revenue for smaller nations.

COMBINING AIRBORNE LIDAR BATHYMETRY WITH MBES

The two survey projects mentioned above featured the combined use of airborne Lidar bathymetry (ALB) and vessel-mounted multibeam echosounding (MBES) to deliver a high-quality, high-resolution seamless dataset to customers. The combined use of aerial and vessel-mounted sensors for



▲ *The resolution of the latest ALB sensors allows IHO Order 1a feature detection.*



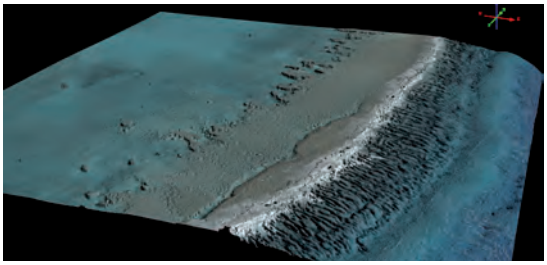
▲ *An image of ALB bathymetry over Beveridge Reef, SW Pacific.*

KEY DIFFERENCES:	
Airborne Lidar Bathymetry	**Multibeam Echosounding**
• Shallow-water surveys up to 50m or 3 times Secchi depth (subject to water clarity)	• Inefficient and expensive in shallow waters
• Rapid and efficient data collection over shallow and navigationally dangerous areas	• Can reliably map the seafloor in most environmental conditions, regardless of water clarity
• Capable of identifying 2m objects down to 20m depth; able to meet IHO Order 1a survey standard.	• Generates data in addition to bathymetry such as backscatter that is useful for seafloor characterization and deeper-level marine science
	• Capable of meeting the feature detection requirements of IHO Order 1a survey standard to any depth.

bathymetric survey of the coastal zone is particularly cost-effective when the water clarity is high and there are extensive areas of shallow water across the survey area. The problem here is that there are significant differences between ALB and MBES surveys, with each requiring a unique set of specialist survey sensors and expertise (see Table 1).

A STRATEGIC AERIAL MAPPING PARTNERSHIP

Clients are time-poor and want a one-stop shop for their needs. There are very few survey firms who have the in-house expertise to cost-effectively undertake both ALB and MBES surveys in parallel. To help solve this shortage of firms who can offer a multi-sensor approach to coastal survey in the South West Pacific region, Woolpert and iXblue Sea Operations division, part of the iXblue Group based in France, have formed a strategic partnership to provide aerial mapping services to clients in Australia, New Zealand and across the South Pacific. The pairing combines the reputation and regional business development expertise of iXblue, a global marine survey and technology firm, with Woolpert's internationally known aerial topographic Lidar, bathymetric Lidar and geospatial capabilities. Under this partnership, Woolpert and iXblue will collect, process and deliver airborne digital imagery, topographic Lidar and bathymetric Lidar operations to commercial and government clients. Both companies own and operate industry-best survey sensors and software and offer customers the highest possible data quality and value for money. In the case of iXblue, many of the survey sensors and tools used are designed and developed in-house. The two partners are looking forward to delivering many surveys in this region in the coming decades. This will not only help to guarantee a safe passage for mariners through the pristine waters of the Pacific, but will also help marine scientists to better understand the marine geomorphology and marine ecosystems so that they can be preserved for future generations. ◀



▲ *An image of reef collected with high resolution ALB.*

About iXblue

iXblue is a global high-tech company specializing in the design and manufacturing of advanced marine, photonics and autonomy technologies. The group in-house expertise includes innovative systems and solutions devoted to inertial navigation, subsea positioning, underwater imaging, as well as shipbuilding and test and simulation.

https://ixblue.com.au/

DriX, iXblue's game-changing USV

The iXblue DriX is one example of how several technologies are being packaged to solve a number of hydrographic survey problems in order to benefit the customer. The recent adoption of unmanned survey vessel (USV) technology by iXblue has seen the DriX deployed across the globe on several and varied survey missions. Whether for positioning a jack-up oil rig in Azerbaijan or collecting bathymetry in the South West Pacific, the DriX has delivered valuable data to clients at a fraction of the traditional cost. The iXblue-Woolpert partnership has the potential to significantly enhance the bathymetric and topographic coverage over much of the South West Pacific. The combined use of the latest ALB, terrestrial photogrammetry and MBES sensors by highly experienced hydrographers and the ability to employ DriX as a force multiplier means that vast areas of seafloor and shallow coastal regions can now be surveyed at rates of effort and price points better than previously thought possible.

Using Cutting-edge Technology and High-resolution UAS

Mapping Submarine Groundwater Discharge with Thermal Infrared Imaging

Submarine groundwater discharge (SGD) is a significant part of the water cycle that delivers anthropogenically derived and naturally occurring nutrients to coastal waters. As part of the drive to develop methods for preventing the degradation of coastal water quality, research conducted at the University of North Carolina Wilmington attempts to address the ambiguity associated with SGD point source locations. This case study outlines how cutting-edge high-resolution unmanned aerial system (UAS) thermal infrared (TIR) imaging methods have been coupled with the newest technology for continuous and autonomous SGD monitoring.

Submarine groundwater discharge – the process in which groundwater flows down-gradient through a connected coastal aquifer from land into the ocean – is recognized as a significant pathway of dissolved components from land to the coastal ocean. Locating sources of SGD is important because SGD often carries pollutants from anthropogenic sources, e.g. nutrients from sewer systems or agricultural activities on land.

UAS-TIR IMAGING METHODS

However, precisely locating SGD is challenging because the distribution of these sources along the coastline is not uniform, and the same is true about the magnitude of groundwater discharge. This allows high-resolution UAS-TIR imaging methods to be implemented to observe SGD mixing characteristics. Prior to UAS-TIR imaging, spatial and temporal ambiguity made SGD difficult to evaluate.

NARROWLY AVOIDING A DRONE CRASH

During the project, the researchers were involved in a near-miss with a Lidar surveying plane while piloting the eBee. The unmanned aerial vehicle (UAV or 'drone') was being flown on Masonboro Island just a week after Hurricane Florence had passed through Wilmington. This was a standard flight that had been completed several times before. Of course, the researchers had checked the airspace to make sure there were no conflicting flights. Everything was going exactly as planned until, on the horizon, they noticed a large recreational aircraft approaching at an alarmingly low elevation. Immediate evasive action was required to land the drone safely and avoid a crash. The situation was particularly intense because of the study site's location on a barrier island that is only 300m wide. There were two options for landing: to either make a rapid spiral descent at the eBee's current location, or to return to the take-off location for a predetermined landing with a modified approach direction. The researchers quickly decided on the second option, given the limited room for error when flying expensive electrical equipment so close to open water. Luckily the drone made a safe landing, just moments before the plane – which was assessing the post-hurricane Florence impact on the island – passed directly overhead.

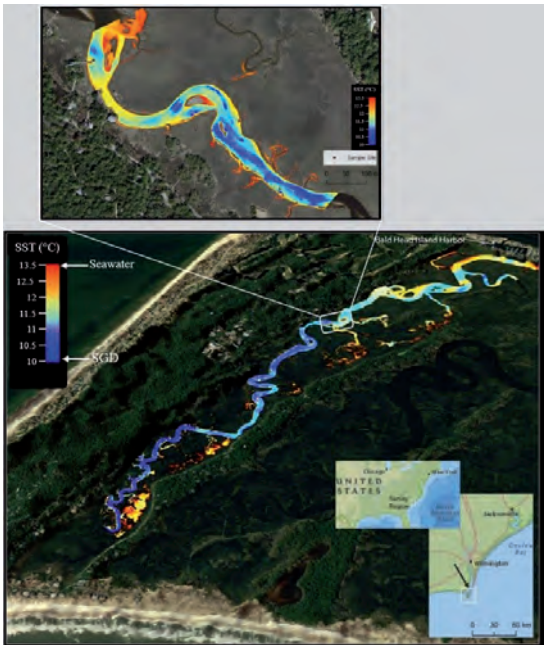
METHODOLOGY

All imagery collected from the field was stitched together using Pix4D processing software to create accurate orthomosaics of UAS-TIR data which identified SGD plumes within the survey region. An eBee Plus professional drone equipped with a high-resolution senseFly thermoMap sensor, capable of detecting 0.1 °C was used for image reconnaissance. Upon collecting UAS-TIR imaging data, in-situ water conductivity, temperature and depth, and groundwater tracer isotopes were recorded with a YSI and RAD-7. The RAD-7 Aqua circulates seawater from an intake valve from the sample site into an air-water exchanger by a peristaltic pump, enabling positively charged radium isotopes to be released into a closed-air loop that is attracted to a ground potential semiconductor in the RAD-7 where it is measured. Measurements were logged continuously and autonomously at 30-minute intervals over multiple tidal cycles. Measurements were recorded within the SGD plume to ground-truth the sea-surface temperature (SST) measurements recorded by the UAS-TIR imagery. Calculations for converting 222Rn volume measurements into groundwater seepage flux were applied using the Burnet and Dulaiova (2004) mass balance model. Further calculations were made using the SGD plume contour area in addition to the shoreline area.

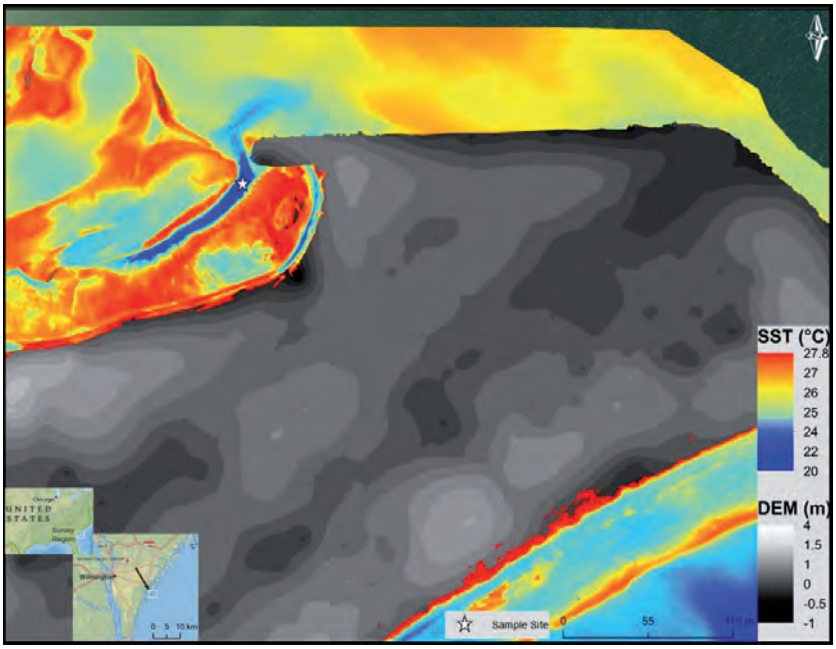
UAS-TIR IMAGING OF BALD HEAD ISLAND TIDAL CREEK

Results from the UAS-TIR flight conducted on 7 December 2018 over Bald Head Island Tidal Creek are shown in Figures 2 and 3, including the position of stationary radon sample

▲ *Figure 1: Reference map of North Carolina displaying the research locations (red squares) Masonboro Island North and Bald Head Island South.*



▲ *Figures 2 and 3: Top: Nadir view of a clipped section of the UAS-TIR imagery focused on the geochemical tracer sample site at Bald Head Island Tidal Creek. Bottom: Off-nadir view of Bald Head Island Tidal Creek UAS-TIR survey region overlaid on a 3DEP-derived DEM.*



▲ *Figure 4: Nadir view of Masonboro Island UAS-TIR survey region overlaid on a UAS-derived DEM.*

platforms. The imagery was collected at approximate low tide to capture maximum groundwater discharge because of greater hydraulic head difference between the discharge location and the riverbank. The reconnaissance mission entailed multiple flights due to the limited flight time of the UAS and the broad aerial extent of the survey region.

The results from the Bald Head Island UAS-TIR survey (shown in Figure 1, overlaid on a 10m digital elevation model (DEM) generated from USGS 3DEP) enable a direct correlation to be observed between hydraulic gradient and groundwater discharge. This is possible because groundwater discharge along North Carolina's coastline is predominantly colder than ambient ocean water and, because a significant proportion of the discharge is fresh, it floats buoyantly on the ocean surface.

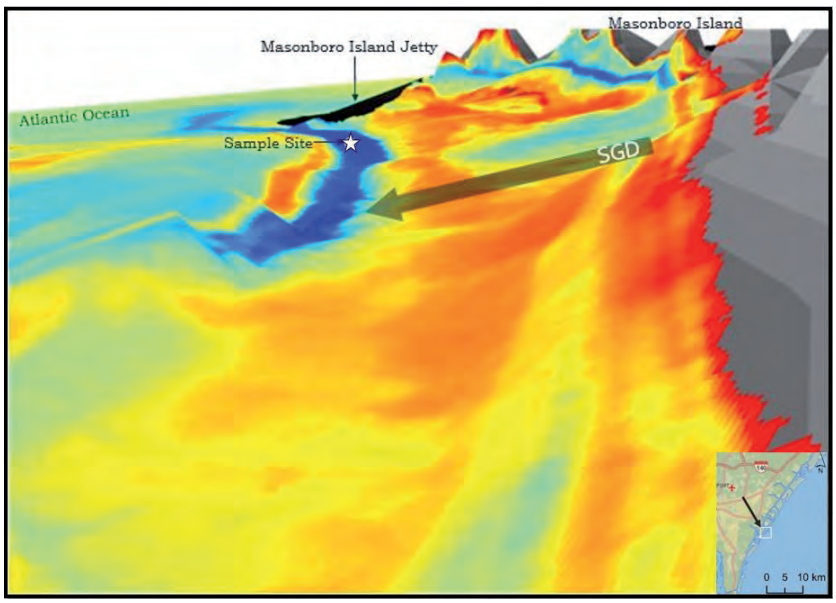
UAS-TIR IMAGING OF MASONBORO BARRIER ISLAND

The UAS-TIR flight conducted on 20 June 2018 over Masonboro Island was performed at low tide to capture the maximum groundwater seepage. The reconnaissance mission took place early in the morning. The results from the Masonboro Barrier Island UAS-TIR survey (shown in Figure 4, overlaid on a 5cm/pixel digital elevation model generated from UAS RGB imagery) enable a direct correlation to be observed between hydraulic gradient and groundwater discharge.

A scour feature exists where the prominent cooler groundwater discharge plume is observed. To further investigate the scour at the sample site, bathymetry was modelled (Figure 5) using a vertically exaggerated spatial interpolation created using continuous control points recorded below the water surface with an R8 RTK unit. The results were overlaid with the UAS-TIR imagery to enable interpretation of the effect of hydrologic gradient on groundwater discharge.

UAS-TIR CONTOUR

To calculate a $\Delta T1$ contour surface area, the plume surrounding the radon sampling platform



▲ *Figure 5: Off-nadir view of Masonboro Island UAS-TIR survey region appended to a spatial interpolation produced using continuous topographic RTK survey points below the water surface to enable hydrologic gradient and SGD flux to be modelled.*

was contoured by processing in ENVI using the ROI tool. The calculated ΔT1 contour surface area (shown in Figure 6A) at this location was 2,315.739m². This area is represented by the darker blue anomaly shown in Figure 6B. This anomaly represents groundwater discharge at the sampling site.

GEOCHEMICAL TRACER RESULTS

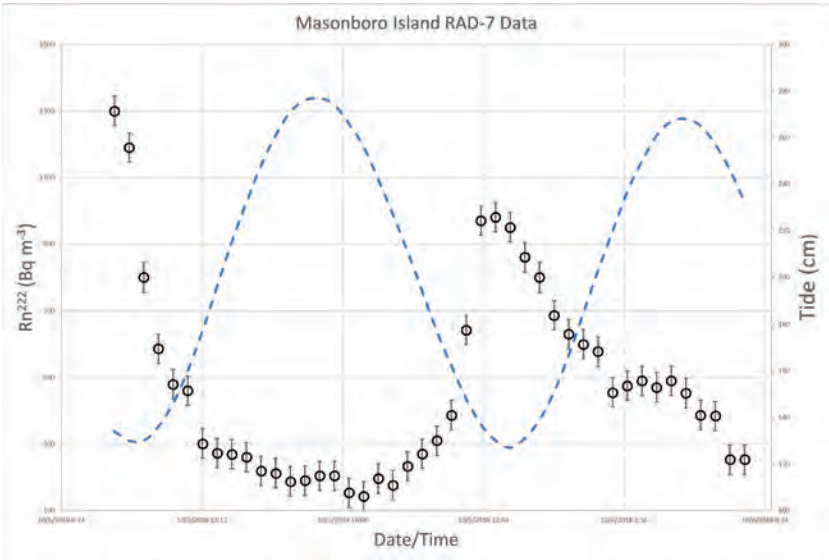
The data recorded by the continuous autonomous RAD-7 displays an inverse correlation between tidal stage and 222Rn (Bq m^{-3}) observed at the Bald Head Island Tidal Creek sample site. This relationship (shown in Figure 7) is typical because of water level inversion with a change in the tidal stage.

Using the mass balance approach, 222Rn (Bq m^{-3}) inventories can be converted into a flux calculation in m day^{-1}. This volumetric discharge estimate allows for comparison to literature as well as adjacent sample locations. It is important to calculate a volumetric flux to compare sample locations because hydrogeological settings vary with location and can significantly impact geochemical tracer results.

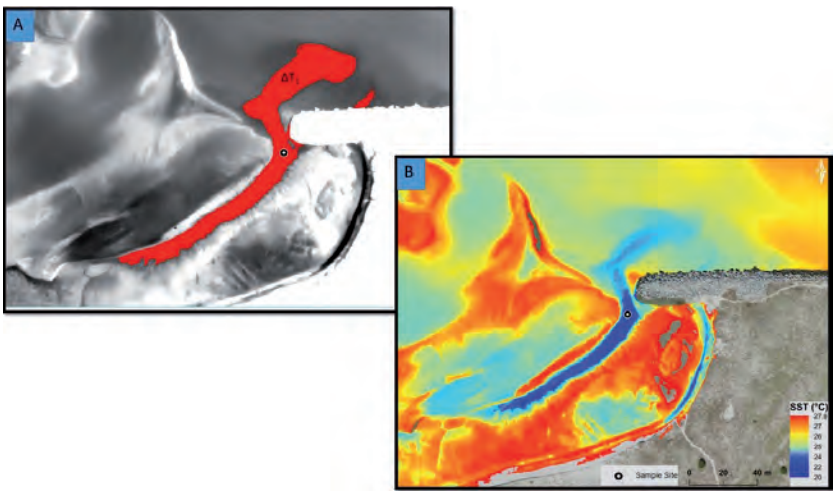
CONCLUSION

The results of this study demonstrate the utility of UAS-TIR imaging in quantitatively modelling SGD in coastal North Carolina. YSI data from both sample sites demonstrates that SGD contributes to an overall decrease in salinity and pH. The larger ΔT1 contour surface plume area at the Masonboro Island survey site of 2,315.739m² responded with a mean discharge volume at the sample point of 0.8962m day^{-1}. This compared to ΔT1 contour surface plume area at the Bald Head Island Creek study site of 1,391.31 m² yields lower mean discharge volume of 0.6097m day^{-1}. The difference in the SGD flux correlates to UAS-TIR plume area contour mapping at each sample location.

Isolating the sample locations utilizing the UAS-TIR imagery within the survey area enables a quantitative evaluation of the daily SGD flux contributing to the tidal inversion. The resulting Bald Head Island tidal creek sample area mean discharge contribution is qA = 0.0281m day^{-1}. The resulting Masonboro Island sample area mean discharge contribution is qA = 0.0496m day^{-1}. This value also correlates with the surface area extent of the ΔT1 contour surface plume captured with UAS-TIR imagery. In conclusion, this study has demonstrated the effective use of UAS-TIR as a utility for observing SGD discharge plume mixing characteristics which allowed for reconnaissance of more precise locations of SGD.



▲ *Figure 7: Total 222Rn from 5 March 2018. Error bars indicate the standard error.*



▲ *Figure 6: Masonboro Barrier Island showing SST plume at the radon time series sampling location. A) displays the ΔT1 contour surface area represented by the red region. B) displays the Masonboro Barrier Island SGD plume above the radon monitoring station as well as the SST.*

Acknowledgements
The inspiration for this research project stems from being an undergraduate research assistant under the supervision of Dr Henrietta Dulai at the University of Hawaii (UH) at Manoa, where autonomous radon monitoring techniques were implemented in a coastal pond to sample submarine groundwater discharge.

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The Biggest Arctic Expedition of All Time?

600 Researchers to Spend a Whole Year Trapped in the Ice

On 20 September 2019, the German research icebreaker *Polarstern* left Tromsø, Norway, for what could be the biggest Arctic research expedition of all time. Once she reaches the destination, the ship and her crew will become trapped in the ice and spend an entire year drifting through the Arctic Ocean.

Over 600 scientists and surveyors from 19 countries are on board *Polarstern* for the MOSAiC expedition, and several times that number of researchers will subsequently use the data gathered in further climate and ecosystem research. The mission is being spearheaded by the German Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI). More than 70 institutes have pooled their resources in a research consortium, resulting in an expedition budget of over €120 million. The purpose of the MOSAiC expedition is to conduct studies at a major long-term monitoring station in the Arctic: the AWI's Hausgarten observatory in the Fram Strait. There, experts from various disciplines are investigating all aspects of the ecosystem, from the water's surface to the ocean depths, in order to determine the impacts of climate change on biodiversity in the Arctic.

HARD TIMES IN THE ARCTIC

Struggling on the sea ice off Alaska during their training in April 2019, the participants of the MOSAiC expedition got a taste of how tough their task will be. They could steel themselves for the hard times that lie ahead in the Arctic: profound isolation and protracted darkness, laborious experiments, temperatures that can plunge to minus 45 °C. There are countless ways the Arctic might thwart and threaten them

▲ *Crew at work under severe circumstances (Courtesy: Stefan Hendricks)*

at every turn, according to a journalist of the US newspaper *The Washington Post*. "But if we can do this right," Melinda Webster, a participating sea ice expert at NASA's Goddard Space Flight Center told the reporter, "it's going to give us a huge leap forward in our understanding of Earth and how it's changing." Shoulders scrunched, beards of frost forming on their balaclavas, she and her colleagues will collect what information they can. They will have no choice but to keep going, Webster said in the report. The world attempts an expedition of this size, expense and risk only "once in a generation" – and hers might be the last generation that can do it.

UNIQUE EXPEDITION

The first-ever drift expedition dates back 125 years, when Fridtjof Nansen departed on board his sailing ship *Fram*. But there has never been an expedition like the one currently underway. For the first time, MOSAiC will take a modern research icebreaker brimming with cutting-edge scientific instrumentation close to the North Pole in winter. Four additional icebreakers will provide logistical support, and a dedicated landing strip will be created for use by resupply flights and two research aircraft. Helicopters, snowcats and snowmobiles will also be used.

This elaborate polar mission is necessary in order to gather data on the region – which is virtually inaccessible in winter – that is urgently needed for climate research. Although the Arctic regions have a tremendous influence on our climate, that influence remains poorly understood. The expedition's data will offer new insights into the interactions between the ocean, ice and the atmosphere.

DRIFTING SEA ICE

During the MOSAiC expedition, the drifting sea ice alone will determine the research icebreaker *Polarstern's* route just beyond the Arctic Circle. Icebreakers from Russia, China and Sweden will visit the ice floe to provide the expedition with fuel and exchange personnel. "An undertaking of this scale can only succeed through international collaboration," explains Professor Antje Boetius, director of the AWI. A network of research camps will be formed on the 1.5-metre-thick floe surrounding *Polarstern*. There, the various teams will set up monitoring points to investigate the ocean, ice and atmosphere, as well as life in the Arctic winter.

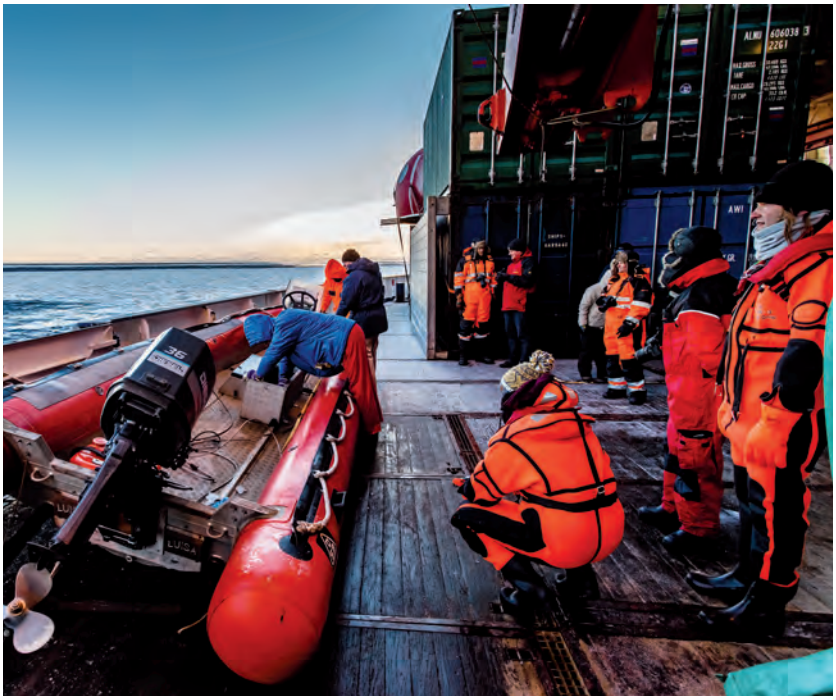
"What happens in the Arctic doesn't stay in the Arctic. The climate development in our latitudes greatly depends on what weather the Arctic 'cooks up'. We now need to take a closer look, and explore the interactions between the atmosphere, ice and ocean there," says Professor Markus Rex, head of Atmospheric Research at AWI as well as expedition head and coordinator of the MOSAiC project. Gauging the major project's significance, Boetius adds, "The polar night in the Arctic plays a pivotal role for the adaptation of life forms; as such, we also expect to gain wholly new biological insights." The expedition has five focus areas: the physics of sea ice and snow cover, atmospheric processes, ocean processes, biogeochemical cycles, and the ecosystem of the Arctic.

▲ Polarstern *operating while stuck in the Arctic ice (Courtesy: M. Schiller)*

▲ *Crew at work in the Polar night, taking samples. (Courtesy: Mario Hoppmann).*

EARLY WARNING SYSTEM

The Arctic is generally considered to be an early warning system for climate change. The dark water absorbs more energy than the ice, which reflects solar radiation, and thanks to the thinner ice, more heat is making its way from the comparatively warm ocean to the surface and into the atmosphere. As a result, feedback effects are significantly amplifying the warming of the



▲ *RIB is being prepared four launch (Courtesy: Mario Hoppmann)*

Arctic. But further observations are needed to grasp the interrelations between individual processes in the ocean, sea ice and atmosphere, and to quantify them in climate models.

"The dramatic scale of Arctic warming isn't adequately reflected in today's climate models, and the uncertainties in climate prognoses for the Arctic are enormous," says Professor Rex with regard to the remaining gaps. "That's why we have to comprehensively study the processes involved in the climate system, especially in the winter." The effects of what transpires in the Arctic can already be felt in Europe, Asia and North America; the smaller differences in temperature between the Arctic and the Tropics are destabilizing the typical atmospheric pressure patterns. As a result, cold polar air is finding its way to the moderate latitudes, while warm, moist air is pushing into the Central Arctic and increasingly accelerating the warming.

Organisms living in the dark ocean depths rely on the sun-filled surface, where phytoplankton can grow, for food. In this regard, there are major fluctuations between warm and cold years. Accordingly, an interdisciplinary team of researchers – led by Chief scientist Dr Katja Metfies from the AWI, Helmholtz Centre for Polar and Marine Research – will comprehensively investigate the marine ecosystem in the survey area: from the atmosphere to the water column to the ocean floor. The marginal ice zone has proven to be especially productive in the context of long-term research conducted at the AWI's Hausgarten observatory (which is located between Svalbard and Greenland).

▲ *Arctic research vessel* Polarstern *(Courtesy: H. Grobe)*

UAV PAUL

The researchers surmise that the high biological productivity there is the result of physical and chemical processes in the upper water column, as well as exchanges with the atmosphere. To examine the connections between physics, chemistry and ecology in the front systems of the marginal ice zone in detail, they use an autonomous underwater vehicle (AUV) named Paul. It not only records fundamental physical parameters (temperature, salinity, depth), but also various types of ecological data – including Chlorophyll A as an indicator of photosynthesis as well as organic substances and nutrients such as nitrate.

In previous expeditions Paul remained in the upper water layers, but it is now set to dive to the ocean floor. Equipped with a camera and sidescan sonar, its task is to map the seafloor in high resolution. Its sonar will expand the spatial coverage offered by the AWI's towed camera system OFOS, because it can scan farther from side to side instead of simply 'looking' straight down. At depths down to 2,600 metres, Paul will hover five metres above the seafloor, recording its characteristics in approx. 10-15cm resolution. Those maps will then provide the basis for determining the sample collection sites for the 'multicorer', a device that extracts samples from the sediment for microbiological testing.

That sediment will pave the way for studies supplementing the microbiologists' year-round investigations with the help of an autonomous tracked vehicle ('crawler'). The AWI's crawler, Tramper, is now rounding off its third full year spent exploring the Arctic seafloor, where it regularly measures things like oxygen consumption as an indicator of microbiological activity. During the current *Polarstern* expedition, the crawler will be retrieved and immediately prepared for its next mission. Tramper will be supported by a second crawler named Nomad, which was successfully tested at the deep-sea observatory in 2018. This time, the two robots will be equipped for a two-year operation, since *Polarstern* will not be available for an expedition to Hausgarten next year. ◀

▲ *Researchers taking samples of the ice (Courtesy: Mario Hoppmann).*

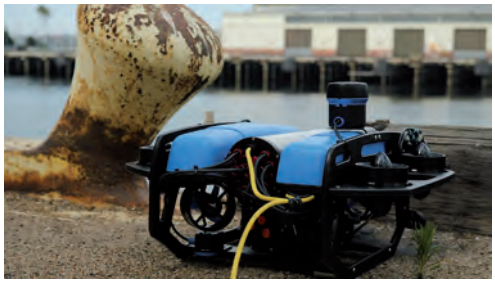
▲ *Rough conditions in Artic waters (Courtesy: T. Ronge)*

About the Alfred Wegener Institute (AWI)
The AWI is named after the German polar explorer Alfred Wegener, who discovered the continental drift. The institute was first launched in 1980 with only a handful of employees, but since then that number has risen to more than a thousand. The AWI is a foundation under public law and member of the Helmholtz Association – the largest scientific organization in Germany. In addition to its base in Bremerhaven, it also has facilities in Potsdam, on Helgoland and in List on the isle of Sylt. As the Helmholtz Centre for Polar and Marine Research, the institute is primarily active in the cold and temperate regions of the world. Working together with numerous national and international partners, the centre is involved in unravelling the complex processes at work in the Earth system.

Acknowledgements
This article has been produced in collaboration with the Alfred Wegener Institute, Germany.

Cees van Dijk is the content manager at *Hydro International*. Following on from his career as a liaison officer at the Netherlands Coastguard, Cees became the editor in chief of several nautical magazines before joining Geomares in 2019.

Operating in Low Visibility



US-based Blue Robotics has launched the Ping360 Scanning Sonar, which offers small ROVs the ability to navigate in low-visibility water conditions. The Ping360 is a mechanical scanning sonar – it uses a small acoustic transducer mounted on a motor that rotates it in one-degree increments. As it rotates, it transmits and receives acoustic pulses to build a 360-degree image of the surroundings. This is similar to laser scanners and Lidars used for ground robotics and autonomous cars but using sound waves instead of light.

Ropeless Fishing System

The EdgeTech Ropeless Fishing System with embedded acoustic release technology was developed to eliminate vertical lines connecting a surface buoy to bottom fishing gear. The system was designed from the ground up with the input of fishers with the intent of alleviating possible whale entanglement and other negative effects of seafloor-to-surface fishing and trap lines.

Flight Trials of Unmanned Air System

Schiebel's Camcopter S-100 vertical takeoff and landing (VTOL) unmanned air system (UAS) performed a five-day maritime surveillance demonstration aboard offshore patrol vessel (OPV) *Turva*. The flight trials by the Border and Coast Guard Division of the Finnish Border Guard took place at the end of August in the Gulf of Finland. Day and night, the S-100 completed given scenarios including searching, locating and recognizing objects as well as surveillance for maximum situational awareness.

Flexible Acoustic Modems

The Subnero acoustic modems provide a flexible platform for a variety of underwater networks and applications. All modems come with arbitrary waveform transmission and recording function. The software at the heart of the technology, UnetStack 3, provides a comprehensive set of APIs and commands for maximizing innovation.

Dual-frequency Multibeam Imaging Sonar

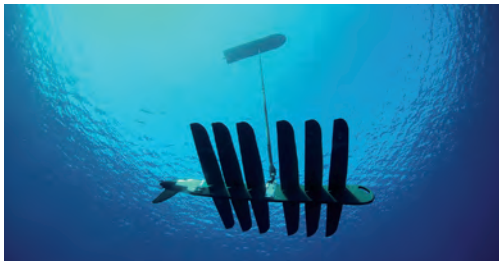
Tritech International has launched the Gemini 1200ik dual-frequency multibeam imaging sonar designed for target identification and obstacle avoidance at long range and extremely detailed imaging when using the high frequency of 1200kHz. Switching frequencies can be set to automatically switch over at a specific range or can be done manually.

Especially for Divers

The Aqua-Metre D100NG is a portable and fully immersed metrology-class positioning and cartography system for divers. The system is controlled through an Android underwater tablet and is dedicated to scientific applications like biology, archaeology and oceanography.

New Wave Glider Platform Introduced

Liquid Robotics' newest Wave Glider features advancements to shoreside operations and in-water performance enabling customers to mobilize, deploy and operate fleets of vehicles more efficiently, the company states.



Positioning and Communication

Gaps is an ultra short baseline (USBL) positioning and communication system dedicated to subsea assets localization. It combines a USBL antenna and a fibre-optic based Inertial Navigation System (INS) in the same housing. Acoustic techniques ensure maximum performance in the most challenging conditions. Its 3D acoustic array enables tracking and communication, from shallow water to the deep sea.

Light, Portable and Compact

The ARCboat Lite is a portable and compact version of HR Wallingford's award-winning remote-controlled survey vessel, the ARCboat. Weighing only 15kg and just 1.3m long, the ARCboat Lite can be carried and deployed by a single person and easily fits inside the boot of a typical family hatchback. It can operate in flows of up to 2.5m/s, in water as shallow as 22cm, and it costs less than the larger ARCboat.

Remote Vehicle Mother-ship

Sea-Kit has been designed to be the first unmanned mother-ship for remote vehicles such as large AUVs or ROVs. This ability allows for missions such as deep-water bathymetry or mine clearance without placing any human personnel in harm's way and at significantly reduced costs compared to traditional manned vessels. Data can be transmitted via broadband link or via satellite following on-board processing and compression. Alternatively data can be stored on-board for retrieval at a later date if required.

Low-cost Wave Buoy

The ToughBoy Panchax 1.2 version comes in four different models. The choice of model depends on which ADCP you wish to include in the solution – or if you wish to purchase the wave buoy without an ADCP, which is the case for this model. Additional sensors can be fitted as optional extras, creating a wave buoy that perfectly matches the setup you're looking for.

Product News Editor's Choice

This time we have chosen a variety of products (more of them can be found on Geo-matchting.com). In our next issue we will focus on sonar systems. Please send us your news about product innovations or technical developments (product name, high-resolution product image, description – informative, not commercial – no direct links to your website, max. 50 words. Include your Geo-matching URL in your message. Please send us your product news before 15 November (cees.van.dijk@geomares.nl). If you want to be sure your product news is published on these pages, contact Feline van Hettema in our sales and marketing department (feline.van.hettema@geomares.nl).

A North American Case Study with Wide-ranging Applications

Using Unmanned Surface Vehicles for Bathymetric Dam Imaging

Inspection of dams is a high-risk task for divers because of strong currents and eddies. Using emerging technologies such as unmanned surface vehicles equipped with echosounders and sonars can lower those risks. Such systems can perform subsurface dam inspections quickly and effectively without putting humans at risk, as this US case study shows.

Overused roads, outdated railway systems, brittle power grids, crumbling bridges and suchlike all take a toll on the economy and, tragically, sometimes even lead to loss of life. Failing infrastructure is an issue for most countries, and likely more so in developed nations that still depend on infrastructure that is centuries old. In Europe, for example, some of the infrastructure dates back to Roman times. Most nations therefore have systems in place to evaluate bridges, roads, dams, railways and other important components that are part of daily life. In the USA, the nation's civil engineers provide an assessment of the nation's 16 infrastructure categories using an A-to-F report format. While the USA is a relatively 'new' nation compared to most countries in Europe, it nevertheless has some old infrastructure that is showing its age – and that includes dams. Among the 16 infrastructure categories, the country's 90,000 dams fared even worse than the overall national average (D+), attaining a grade of D.

POTENTIALLY CATASTROPHIC FAILURES

Dams are critically important to many people's daily lives and local communities, providing essential benefits such as hydropower, flood control and irrigation. It is no exaggeration to say

▲ *An unmanned surface vehicle was combined with a high-resolution multibeam imaging echosounder/sonar.*

that, without a dam, many communities, cities or towns would simply not exist. The condition of dams receives a great deal of attention – and rightly so. While a road buckling or a bridge collapsing might injure or even kill a few people, a dam failing could suddenly flood entire communities, potentially causing scores or even hundreds of deaths and untold financial loss.

In January 2019, for example, the failure of a Brazilian iron-ore mining company dam – the second dam failure there in just over three years – flooded the town of Brumadinho. Several hundred people died in the event, and the disaster dominated international headlines for months. But what was lost in most of the reporting of the tragedy was how better dam inspections could avert such failure – because that dam failure was not a unique event. In 2018 alone, there were major dam failures in Kenya, Afghanistan, Laos and Myanmar with a total of almost 100 fatalities between them. Europe has also had its share of dam failures. In fact, a recent academic study ranked Europe second in worldwide dam failures. The list of causes included sub-standard construction, long-term use, geological instability, war and human factors.

In the USA, part of the challenge of managing and sustaining this important part of the nation's infrastructure is the fact that, by 2025, seven out of ten dams in the country will be over 50 years old. Half a century ago, dams were built in line with the best engineering and construction standards of the time, but that cannot compare with the stringent design criteria used today. It is perhaps no surprise, then, that civil engineers have identified over 15,000 US dams as a high hazard, and over 11,000 more as a significant hazard.

EXPENSIVE AND HAZARDOUS

But while there is the desire and need to inspect dams, the process of doing so can be daunting. One major challenge in determining the condition of a dam – let alone deciding what shoring up or repair work is needed – is the difficulty of surveying the underwater portion of the dam. Such dam inspection work currently involves divers, which is slow, expensive and hazardous.

▲ *The survey was performed jointly by a MANTAS remote operator working alongside a hydrographer.*

▲ *The final survey took less than two days to complete.*

▲ *An operator and a hydrographer worked closely together using the USV.*

▲ *The team coupled the USV track and the real-time display of the echosounder.*

In fact, the danger of using humans to survey the underwater portion of dams is often underestimated. Many dams have violent, high-speed, high-volume currents that even the strongest divers cannot cope with. The human risk factor can therefore be seen as a likely obstacle to thorough dam inspections worldwide, but until recently there was no reliable method of surveying the underwater portion of a dam without putting humans at undue risk. Now, however, there is a viable alternative, in the shape of emerging technologies such as unmanned vehicles equipped with echosounders and sonars. These systems can perform subsurface dam inspections quickly and effectively without risk to human life.

DAM INSPECTION TECHNOLOGY

In one example of how that new technology has been used to survey dams in the USA, an unmanned surface vehicle was combined with a high-resolution multibeam imaging echosounder/sonar to conduct a surface and underwater survey of the Keokuk Dam on the Mississippi River. The Keokuk energy plant was graded as a 'nine out of ten' on the scale of inspection difficulty due to the strong high currents and dangerous eddies caused by water flowing through the dam. The facility's owner and operator therefore contacted a Florida-based unmanned surface vehicle manufacturer, Maritime Tactical Systems (MARTAC) Inc., in order to conduct a thorough survey of the underwater portions of this dam using an appropriately equipped USV. MARTAC produces a family of MANTAS unmanned vessels built on a catamaran hull. The owner of the Keokuk Dam selected a 12-foot MANTAS for this underwater bathymetric imaging task, and it was equipped with a Teledyne Reson T20 multibeam echosounder/sonar.

The objective of the Keokuk Dam hydrographic survey was to use the USV to map underwater structures and perform the survey of the upstream and downstream sections of the dam. This comprehensive hydrographic survey would provide the input for a complete high-resolution bathymetric map and inspection report that was necessary to meet the imaging and scanning requirements of the safety group responsible for certifying the dam.

Earlier maps of the Keokuk Dam had been developed using divers and manned surface vehicles. Not only did this technique put divers and other operators in harm's way, but the data also lacked the resolution to detect and identify areas of scouring, defects or hidden structural problems. Use of the autonomous USV equipped with the multibeam echosounder/sonar was expected to correct these issues. The USV solution performed as expected with excellent resolution. The final survey took less than two days to complete and was performed jointly by a MANTAS remote operator working alongside a hydrographer. Operating as a team, they coupled the USV track and the real-time display of the echosounder imaging to achieve the best possible images of the dam, including the underwater section.

26,000 DAMS

Based on the results of the Keokuk Dam hydrographic survey, additional proof-of-concepts were requested and demonstrated, and the technique is now being studied for use in many American cities and towns where there is concern about local dams. With over 26,000 dams deemed structurally unsound in the USA alone, there is a virtually limitless market for this safe surveying method. This approach can readily be extrapolated to other countries and especially European nations, many of which have dams older than those in the USA.

COMMERCIAL PROSPECTS FOR USVS

The continued introduction of unmanned surface vehicle technology into the commercial arena will further spread the need for USVs in a number of other areas beyond dam inspections. In view of the average D+ grade for the USA's infrastructure in general, USVs will likely be in increasing demand for survey operations for ports, inland waterways, bridges, dams, levees, canals and other infrastructure that cannot be effectively or safely inspected by humans.

CONCLUSION

It is clear that the stakes of dam failure are high. The ability to use commercial off-the-shelf technology such as MANTAS for rapid and comprehensive bathymetric imaging is a potentially life-saving solution for all nations in terms of safely conducting successful dam inspections and undertaking the necessary infrastructure upgrades to prevent future disasters. ◀

George Galdorisi is a career naval aviator whose 30 years of active duty service have included four command tours and five years as a carrier strike group chief of staff. He began his writing career in 1978 with an article in the US Navy's professional magazine.
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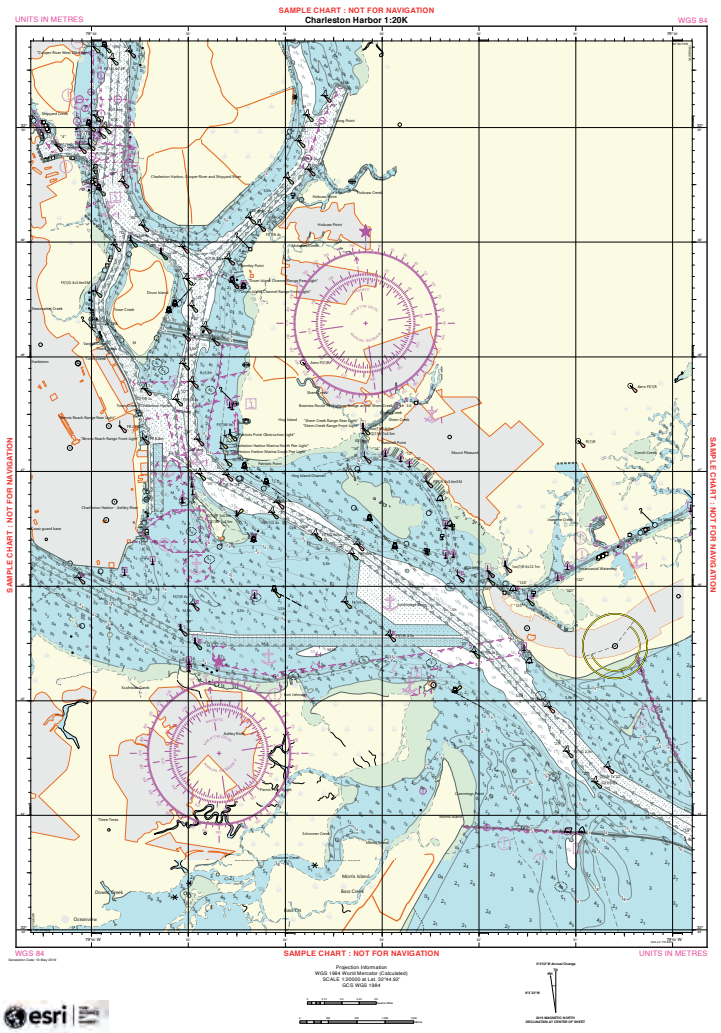
Scientists, Fishermen and Miners to Benefit from Better Navigational Charts

As Greenland's Glaciers Melt, Denmark Charts the Changing Waters

To keep up with rapid changes in Greenland's melting landscape, the Danish Geodata Agency (GST) is working to automate and standardize navigational charts. It recently made the move to the Esri ArcGIS for Maritime platform to create an end-to-end workflow to streamline chart production. Electronic Navigational Charts (ENCs) give ship captains accurate, timely information.



▲ *With the Products on Demand functionality in the ArcGIS for Maritime: Server solution, users can create a paper chart, like this one of Charleston Harbor in South Carolina, from Coast Survey's electronic chart database.*

Denmark once experienced its own '*Titanic* moment'. On its maiden voyage on 30 January 1959, Danish liner MS *Hans Hedtoft* struck an iceberg off the coast of western Greenland. All 95 passengers and crew on board were lost, and the wreckage of the ship has never been found. Like the *Titanic*, the ship had been described as unsinkable. This tragic event sparked a flurry of navigational charting activity by GST. Prior to the incident, the world had long needed good charts for all of Greenland. "In the 1960s, we used all available bathymetric and topographic sources in order to create the first set of Greenlandic charts," said Rune Carbuhn Andersen, head of the Arctic Division of the Danish hydrographic office, a department within GST. "The coastline for the charts was established in the 1940s and 50s, and it still forms the foundation for the majority of the Greenlandic charts available today. Though the charts were accurate for the time, we now have to georectify old data with new data to produce an update."

This renewed charting effort comes at a time when the world's eyes are on Greenland. In the context of climate change, many compare the country to a canary in the coal mine because of its rapidly melting ice sheets. Greenland's navigational charts need to be updated to reflect the country's changing coastline,

and scientists – eager to monitor the melting ice – need to know how to safely navigate the waters.

RESOURCE CHALLENGES

The possibility of ice-free Arctic waters is creating a growing demand for the region's natural resources; previously blocked by sea ice, resources such as minerals, energy resources and fish are now accessible and can become a part of global markets. The largely untouched fish stocks drew interest first in view of increasing pressure to feed the world's growing population. A recent historical agreement on fishing prevents an unregulated and chaotic free-for-all. On the signing of that new accord, Denmark's Minister for Foreign Affairs Anders Samuelsen commented, "When the ice melts, we will face new challenges but also new opportunities. We need to manage both."

ECONOMIC OPPORTUNITIES

The melting has brought other new economic opportunities to the isolated island of Greenland. Mining has recently emerged as a growth sector, for example. A ruby and pink sapphire mine operated by Norway's LNS Group opened in 2017 and an anorthosite mine (a source for both calcium and aluminium) run by Canada's Hudson Resources opened in February 2019. China has expressed interest in mining and other natural resources extraction and has framed the idea of a 'Polar Silk Road' to develop shipping lanes and build infrastructure throughout the Arctic.

This growing global economic interest fuels the need for updated charts that can enable safe passage and navigation. "It's very important for us to get all of the navigationally significant information that we have in the charts as soon as possible," Andersen said. "We have one primary demand, and that's safety at sea."

MEETING THE SAFETY MISSION

Arctic waters are inherently dangerous due to sea ice obstacles and unseen underwater rocks, frigid water temperatures and swiftly changing weather. "Fog and snow can come in very quickly," Andersen said. "If you're on a big ship on a big route, it doesn't matter that much. If you're on a smaller boat, then it gets dangerous." The large size of Greenland's land mass and surrounding waters makes frequent surveying impossible. The goal for Andersen and his team is to define and survey navigational routes. They work to provide more than one route in a given area because fast-moving glacier ice often fills up an entire fjord, making the waters of a route unnavigable.

The Danish navy does the bulk of the surveying using a multibeam echosounder instrument. For the deeper and rougher waters, an inspection vessel equipped with multibeam is used. This type of sonar system emits sound waves that bounce off the seabed and return to the vessel identifying water depth, undersea canyons and submerged rocks that can aid or impede navigation. Icebergs, free-floating chunks broken from glaciers and ice shelves also present an ongoing problem, although onboard ship radar has helped dispel some of that danger. "When we have an accident it's usually due to a lack of experience," Andersen continued. "We had an accident on a very well-known rock close to Greenland's capital Nuuk, which is an area where new and georectified charts have been released. The accident wasn't the result of old or incorrect charts; it was probably more related to human errors on the bridge of the ship."

DIGITAL TRANSFORMATION OF SURVEYS

Starting in the 1990s, GST spent much of its time and resources getting the charts of Danish waters ready for ENCs. This next-generation data product drove the adoption of digital workflows, allowing charting agencies to make chart updates with data collected by modern survey instruments such as GPS receivers and

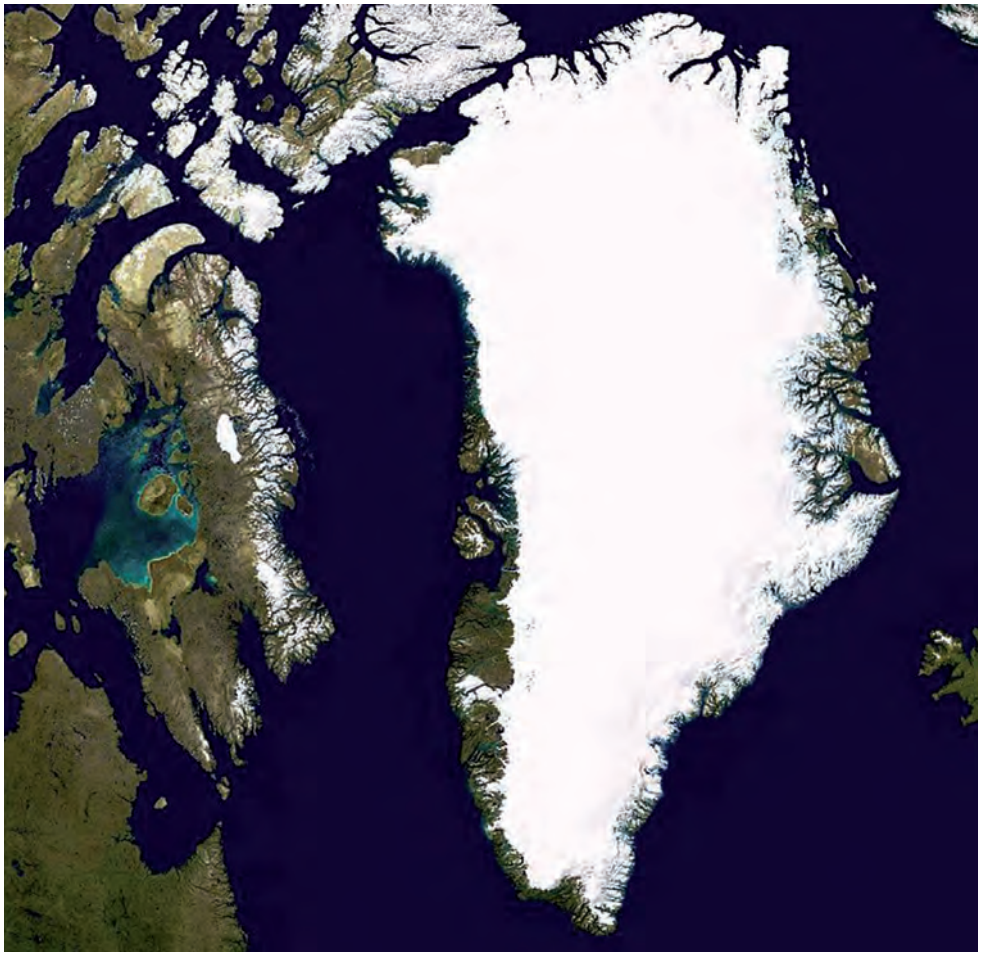
▲ *Margin of the Greenland ice sheet (Courtesy: Hannes Grobe, Alfred Wegener Institute for Polar and Marine Research).*

▲ *Greenland ice sheet AMSL thickness (Courtesy: Eric Gaba).*

multibeam soundings. "My department recently toured the bridge of one of the supply ships from Royal Arctic Lines to see how they navigate," he said. "They use the old paper charts along with radar, and they feel relatively safe. The problem is, we can't fit new data within these old charts and the world has long been moving to ENCs."

Capturing Greenland's latest coastline data is an important part of GST's latest mission. "Recognizing that we're behind on Greenlandic chart production and not wanting to just sit on the latest data, we've tested an ENC Simple product," Andersen added. "Where we have strong confidence on our coastline data, we have auto-generated depth data for ENC Simple using multibeam readings and soundings. We gave that to a few pilots in the summer and they liked it for its added security. If they saw an iceberg in the middle of their route, it gave them confidence that they could route around it without hitting any rocks compared to just using an old paper chart with very limited depth information."

This test has led to further experiments. GST can be sued if an accident results from a poor chart, so further work needs to be done to verify this new automated method. While automation has proven helpful to both sea captains and the agency, it has yet to pass the test of becoming the authoritative charting source. "It's a big task to reproduce all the Greenlandic charts and ENCs, given the complexity of the data and the large geographic area of sea surrounding Greenland," Andersen said. "Despite the challenge, it's a matter of years before we can release new charts with new GPS-correct information. In the meantime, we hope to supplement them with alternative products like ENC Simple. But right now, we are focused on improving automation and production to get there."



▲ *Map showing Greenland's melting ice sheet (Courtesy: Wikipedia).*

MODERN ENTERPRISE CHART CREATION

The Danish Geodata Agency recently committed to standardize chart making using the Esri ArcGIS for Maritime platform. The agency chose this software, in part, because it allows them to create an end-to-end workflow that streamlines chart production. "We see a huge potential in putting our entire production line in one system," said Andersen.

The new charting system allows users to prepare source data, integrate information from many different sources, and compile that information into an authoritative nautical information system database. It also provides the means to distribute products in many new and different ways, including ENCs, web services and fit-for-purpose applications. "I spend probably 80% of my time and resources on data sources," Andersen explained. "I need to work in a GIS environment to do this, so it makes sense for us to use Esri to not necessarily automate but at least standardize all of these tasks. Esri is wonderful on geoprocessing in general, which is extremely relevant to these tasks."

GST staff created two nautical charts using the ArcGIS for Maritime: Charting solution and were able to automate 70% of the production work. This most recent development in the production of nautical charts supports an agreement GST made with Greenland to produce updated, safe navigation products for Greenlandic waters. ArcGIS for Maritime: Charting software provides GST with a GIS-based platform that helps staff improve, standardize and expedite data and workflow management. It allows GST staff to produce charts in less time and will help the agency share information both across departments and to external agencies. ◀

Steve Snow is an industry specialist at Esri with over 18 years of experience in GIS/remote sensing. Prior to joining Esri, Steve was a commissioned Army engineer officer and NOAA Corps officer focusing on remote sensing and charting. Steve's main focus is on applying remote sensing capabilities to solve mapping challenges.
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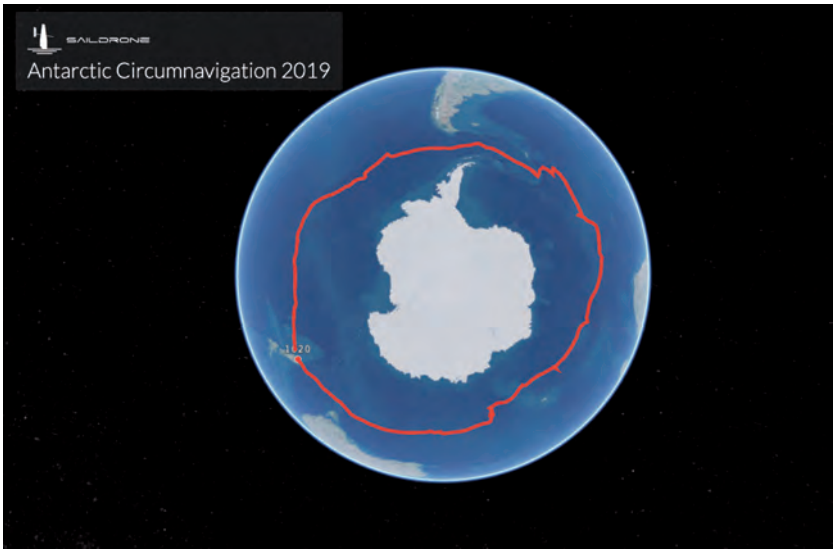
High-quality and Reliable Data Needed for Research Use

USV Completes First Autonomous Circumnavigation of Antarctica

A 7m (23ft) long, wind-powered unmanned surface vehicle (USV) has become the first unmanned system to circumnavigate Antarctica. Known as SD 1020 and equipped with a suite of science-grade sensors, the vehicle collected data in previously uncharted waters, enabling new key insights into ocean and climate processes.

USV SD 1020 left for the 196-day mission from Southport in Bluff, New Zealand, on 19 January 2019. It returned to the same port on 3 August after sailing over 22,000km (13,670 miles or 11,879 nautical miles) around Antarctica. During the mission, the vehicle survived freezing temperatures, 15m (50ft) waves, 130km/h (80mph) winds and collisions with giant icebergs.



▲ *Mission map showing completed Antarctic Circumnavigation track.*

▲ *The sea state in the Southern Ocean as captured by SD 1020's onboard camera.*

REGULATING HEAT AND CARBON

The Southern Ocean plays a key role in regulating heat and carbon on our planet. It is so remote and inhospitable that even big ships try to avoid it in the winter. However, the Saildrone SD 1020 not only survived a winter in the Southern Ocean but also streamed back vital new data from previously unsampled territory. "One of our largest 'blind spots' in terms of our climate knowledge and its future prediction lies in the Southern Ocean. This is mostly due to the serious lack of observations, in particular in winter, in this remote and harsh environment. This leads to a poor understanding of how these polar oceans function," said Sebastiaan Swart, co-chair of the Southern Ocean Observing System (SOOS). "These high-resolution observations from the Saildrone during its circumnavigation of the Antarctic provide valuable ground-based datasets for scientists to understand the Southern Ocean better and evaluate the models we use to predict weather and climate."

"There's a lot left to be learned about the ocean's uptake of CO_2 emissions, especially in the Southern Ocean. Up until a few years ago, the Southern Ocean was understood to be a large CO_2 sink. Yet, that understanding was based primarily on observations made from ships that steer clear of the harshest weather in the Southern Ocean, leaving winter months under-sampled," explained Dr Adrienne Sutton, an oceanographer with the NOAA Pacific Marine Environmental Laboratory (PMEL) Carbon Group.

DISTRIBUTION OF OBSERVATIONS

According to Sutton, the deployment of carbon sensors on profiling floats as part of the

▲ *SD 1022 and SD 1023 with the standard Saildrone wing in Point Bluff, New Zealand.*

Southern Ocean Carbon and Climate Observations and Modelling (SOCCOM) project gave scientists a broader seasonal distribution of observations. As a result, they found less of a CO_2 sink than previously thought. The SOCCOM floats measure seawater pH and use empirical relationships to calculate seawater partial pressure of carbon dioxide (pCO_2), which introduces some uncertainty relative to a direct measurement. This has generated an active discussion centred on the uncertainty in the calculated pCO_2 from the float measurements and whether the weakened CO_2 sink, which was observed by the floats from 2014-2017, was just natural variability.

OCEAN CO_2 SINK PUZZLE

Over the course of the mission, the USV rendezvoused with a few of the SOCCOM floats. "Having another autonomous platform that can survive the Southern Ocean is both a technological feat and an opportunity to get us closer to solving the ocean CO_2 sink puzzle. Preliminary results suggest that we also observed CO_2 outgassing during winter months in the same region as the floats measured previously. CO_2 outgassing from the ocean to the atmosphere occurs when ocean pCO_2 levels are higher than atmospheric levels," explained Sutton.

"Our initial findings are that the SOCCOM floats match the Saildrone pCO_2 to within their stated uncertainty," said Nancy Williams, assistant professor at the University of South Florida College of Marine Science. "These crossovers provide great opportunities for validation and context between two very different and complementary datasets. Sustaining both of these types of observations will be extremely helpful for improving our understanding of the Southern Ocean's role in the global carbon budget and I can't wait to dive into this new dataset." The SD 1020 also took reference measurements near moored buoys.

SURFACE MOORINGS

"High-quality and reliable data is needed for research use. For the Saildrone sensors, careful calibrations are done before deployment, and other checks are made against similar measurements from a limited number of moorings and profiling floats in the region. The most recent comparison occurred south of Tasmania, Australia, where the Saildrone passed near one of only two Southern Ocean surface moorings equipped with similar sensors," explained Dr Bronte Tilbrook, a biogeochemist studying ocean acidification and the global carbon cycle at the Commonwealth Scientific and Industrial Research Organisation (CSIRO). CSIRO is an independent Australian federal government agency responsible for scientific research. "The Saildrone technology is revolutionizing how data can be collected in the Southern Ocean, providing for the first time a way for crucial data to be collected throughout the year and in places that ships rarely visit. Applications include a better understanding of the amount of carbon dioxide taken up by the Southern Ocean and determining the changing environmental conditions and processes driving change," said Tilbrook.

IN-SITU OCEAN OBSERVATIONS

Saildrone USVs are designed for long-term ocean deployments of up to 12 months. Because they burn no fossil fuels, they have a zero carbon footprint once deployed. They are powered exclusively by the wind for propulsion and solar energy for the onboard instruments. The USVs carry a suite of science-grade sensors to collect meteorological and oceanographic data critical to understanding the changes taking place in the Antarctic ecosystem. The standard sensor suite includes instruments to measure air and sea temperature, barometric pressure, wind speed and direction, and wave height and period, as well as sky, sea, and horizon cameras. In addition to the $ASVCO_2$, SD 1020's enhanced sensor package includes an acoustic doppler current profiler (ADCP) to measure ocean currents.

SECRET WEAPON

The standard configuration of a Generation 5 Saildrone includes a 7m (23ft) hull, a 2.5m (8ft) keel, and a 5m (15ft) tall solid wing. This regular wing has an operational wind range of up to 60 knots. Even so, the massive waves of the Southern Ocean were too much for this tall and

▲ *SD 1020 approaching Point Bluff, New Zealand, in stormy conditions.*

slender wing on two previous occasions, in 2015 and 2017, when the USVs were deployed in the Southern Ocean to attempt the circumnavigation. In both cases, the mission was compromised after a short period of time and the USVs had to sail back for repairs. The team learned a huge amount from these failures and designed a new type of wing specifically for the Southern Ocean. The lower-aspect 'square rig' is incredibly strong and is designed to deal with the huge forces of being rolled and submerged by 15m (50ft) breaking waves. "While the square rig has less performance range than the regular wing and struggles to sail upwind, it does a great job of sailing downwind and can still get you where you need to go in the Southern Ocean," said Saildrone founder and CEO Richard Jenkins. "You inevitably sacrifice manoeuvrability for survivability, but we have created something that gets the job done and that the Southern Ocean just can't destroy."

SD 1022 and SD 1023 were released with 'toughened' regular wings along with SD 1020 in January but, like their predecessors, both suffered storm damage in the first few days, while the square sail ploughed on despite stormy conditions. SD 1022 and SD 1023 navigated back to New Zealand for repair and were redeployed in May with square wings similar to SD 1020. These two USVs have recently successfully navigated winter conditions through the Drake Passage and entered the South Atlantic Ocean. Unlike SD 1020, SD 1022 and SD 1023 are equipped with scientific echosounders to study fish biomass in addition to the standard atmospheric and oceanographic standard instruments.

FUTURE PLANS

Jenkins says his company is building a global fleet of unmanned surface vehicles, targeting planetary coverage. "In terms of carbon and heat, the Southern Ocean is by far the most important ocean. Globally, the Southern Ocean takes up about half of all carbon and 75% of all heat that enters the ocean. This makes it disproportionately more important to place efforts and resources, such as those occurring by robotic platforms like our USV, into obtaining more scientific measurements in this polar region." For Jenkins this means the Southern Ocean is a key priority to instrument. The company plans to deploy a fleet of vehicles to monitor the Southern Ocean on a persistent basis, with a fleet of 10 to 20 Saildrone USVs sailing around Antarctica year-round. "A monitoring system for the Southern Ocean is one of our highest priorities," stated Jenkins. "Understanding heat and carbon fluxes, fish populations and ocean acidification in the Southern Ocean is absolutely key to improve the understanding of our climate, and to the sustainability of life on this planet. Only very significantly increased measurement will enable meaningful predictions for the future." ◀

Multidisciplinary Collaboration

Scientific collaborators on this First Saildrone Antarctic Circumnavigation mission include experts from the following institutions: the US National Oceanic and Atmospheric Administration (NOAA), the US National Aeronautics and Space Administration (NASA), Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Palmer Long-Term Ecological Research (LTER), the Scripps Institution of Oceanography, the Southern Ocean Observing System (SOOS), the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), the Korea Polar Research Institute (KOPRI), the Norwegian Polar Institute, the University of Exeter, the University of Gothenburg, the Department of Marine Science at University of Otago, and the New Zealand National Institute of Water and Atmospheric Research (NIWA).

Series of STEM Lesson Plans

The mission was sponsored by the non-profit Li Ka Shing Foundation and all data made publicly available at no cost in order to accelerate the understanding of critical processes affecting humanity. It is also an educational outreach initiative, aiming to expose future generations to the rapid changes taking place in the Antarctic. Saildrone and the 1851 Trust have partnered up to develop a series of science, technology, engineering and mathematics (STEM) lesson plans, which are available to teachers free of charge at saildrone.com/antarctica. All data from this mission has been made publicly available to the global scientific community and its use for science publications is encouraged.

Shipwreck Monitoring in the North Sea

Surveyors Discover World War One Submarine

In order to guarantee nautical depths, the Rijkswaterstaat survey department runs an annual seabed monitoring programme. In July 2019, research vessel MS *Arca* left its home port of Scheveningen, the Netherlands, to conduct a shipwreck survey that included a World War One submarine.

As an executive agency of the Dutch Ministry of Infrastructure and Water Management, Rijkswaterstaat facilitates smooth and safe maritime traffic in the Dutch North Sea. One of its activities is an annual seabed monitoring programme. Apart from a few deeper spots, the Dutch part of the North Sea is in general 35 metres deep, while the coastal zone is characterized by shallow areas (<20m). The entire area is home to international shipping lanes with heavy nautical traffic. Shipwrecks often protrude from the seabed, posing risks to safe maritime navigation. Hydrographic surveys are therefore conducted to ensure the nautical depth is guaranteed in this relatively shallow sea.

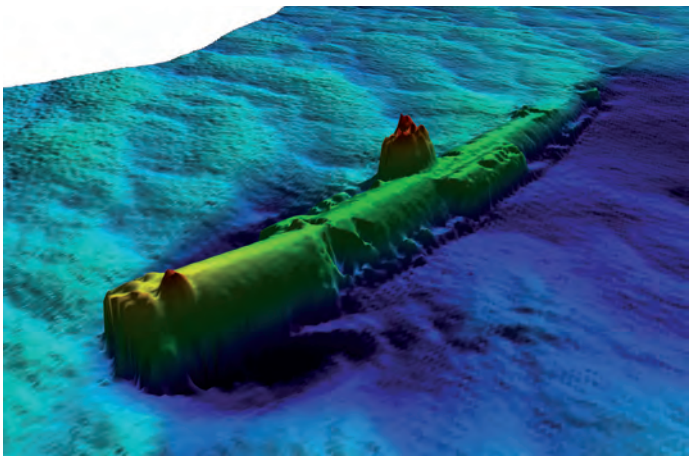
Such surveys have to be repeated periodically because shipwrecks are far from static. The combination of tidal movement and resulting currents often creates accumulation of sediment on one side of a wreck, while erosion occurs on the other side. Over time, these banks and gullies cause the wreck to become buried – sometimes to the extent that little is left of what used to be a hazardous obstacle. In that case the marking buoys around the wreck can be removed. In view of the fact that there are around 850 marked objects in the Dutch North Sea alone, this can save considerable time and resources. In areas with high (≥6m) sediment waves, the opposite can happen; the sediment waves can shift over the years, transforming what was originally just a small protrusion into a fully exposed wreck.

COMBINED SURVEY

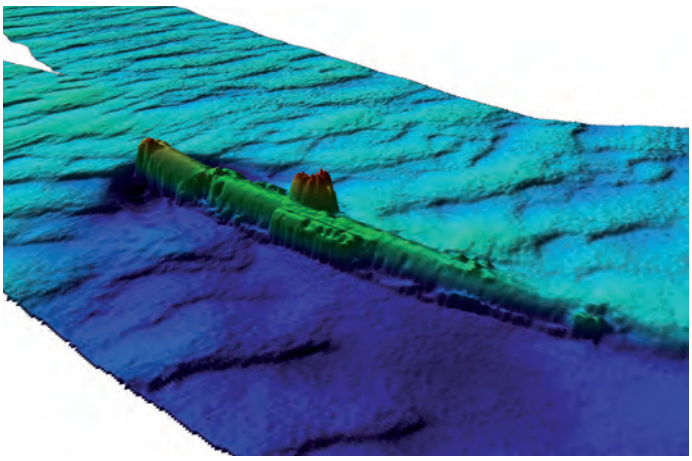
Rijkswaterstaat's MS *Arca* has a multi-purpose role. Built as a pollution control vessel, it is equipped with sweeping arms for combatting oil spills. But when not deployed for cleaning environmental spills, it is put to use as a survey vessel. For surveying purposes it is fitted with a dual-head Kongsberg EM2040c multibeam echosounder (MBES), a Klein 5000 sidescan sonar and a Saab Seaeye Panther XT. Its motion sensors are the Xblue Phins and Octans IV, and position is provided by two Trimble GPS receivers. All in all, at 84 metres long, it forms a stable platform for offshore operations such as shipwreck monitoring.

Wrecks are monitored by means of a combined survey with multibeam and sidescan sonar. For wrecks that are protruding from the surrounding seabed, several side lines are carefully surveyed. It is not uncommon to survey a wreck in water depths of 12 metres or less, in which case there is always the chance that the sonar itself – if it passes straight over it too deeply – could end up joining the wreck on the sea bottom.

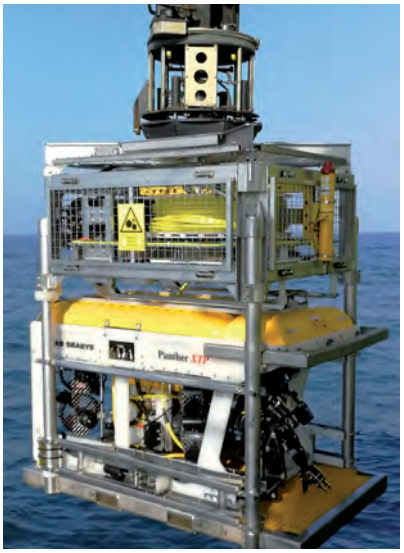
Rijkswaterstaat applies an additional method called water column imaging (WCI) – which is



▲ *Picture of the wreck made by the MBES.*



▲ *Another picture of the wreck made by the MBES.*



▲ *ROV used for the survey by Rijkswaterstaat.*

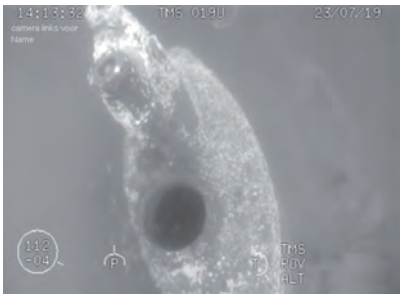
▲ *Dutch survey vessel* Arca.

commonly used in commercial fishing activities (i.e. to find fish) – for midwater detection of small or thin objects such as masts, pipes or structures that protrude from the wreck and form the actual shallowest point. Such objects are not normally visible in regular multibeam data or are filtered out as spikes. Since the WCI method is still in the developmental phase, a mechanical check (railing) is conducted. However, promising results have already been obtained in practice.

After the combined survey has been conducted, the data is processed and stored on board. In perfect conditions (i.e. sea state, current and underwater visibility), wreck surveys like these can take up to a day. Once all the data has been secured, the MS *Arca* can move on to the next wreck on the list.

ROV INSPECTION

On request, an ROV inspection can be conducted using the work-class remotely operated vehicle (ROV) that can be deployed for a wide range of subsea operations, including inspections. Positioning to the ROV is provided by Kongsberg's hull-mounted HiPAP 502, in short base line (SBL) configuration. Underwater visibility in the North Sea is often poor (≤0.5m), especially in early summer when the algae bloom is at its peak. To navigate in poor visibility, the ROV has an acoustic camera. Images and videos are recorded by the camera in black and white. Additionally, an HD camera can be mounted if needed.



▲ *Pictures of the shipwreck made by the ROV.*

ROV shipwreck surveys are not entirely without risk. Due to the low visibility it is often necessary to hover close to the wreck for clear images, which increases the risk of entanglement of the ROV's umbilical. Wrecks with a military background may also still contain various types of unexploded ordnance (UXO), in which case it is essential to not physically disturb the wreck.

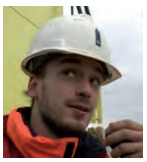
WORLD WAR ONE SUBMARINE

One of the more remarkable shipwrecks surveyed by MS *Arca* was the remains of a World War One submarine. The submarine is one of the roughly 25,000 objects that are located in the Dutch North Sea. The majority of those objects are qualified as low-priority objects (i.e. manmade objects and natural objects such as boulders). Others are listed as shipwrecks, including those with historical value such as the submarine. Most military wrecks have been given war grave status, meaning items may not be removed from them without explicit permission from the wreck's home state. Extra efforts are made to monitor the condition of such wrecks.

This particular submarine was hit by a mine just off the Dutch coast while underway to its patrol area in 1917. None of the 34 crew members survived the event. The high-detail multibeam and sidescan sonar measurements indicated that the submarine was still surprisingly intact with little risk of entanglement and no UXO was visible. This created the opportunity to move closer to the wreck and perform a complementary ROV inspection. It revealed that the submarine rests in a vertical position, with the impressive bridge rising several metres above the seabed. However, its shallowest point is still well below the area's guaranteed depth.

CONCLUSION

Shipwreck surveying can take up several weeks of the annual schedule, but the effort is well rewarded with diverse and interesting results such as the World War One submarine. More importantly, regular surveying guarantees minimum nautical depths to ensure safe passage for maritime traffic in the North Sea. ◀



Ben Frederiks studied marine biology and hydrography and started working at Rijkswaterstaat in 2015. His current position is as hydrographic surveyor at Rijkswaterstaat's Survey Department. His main work area is the Dutch North Sea.
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Janneke Bos, BSc, is Rijkswaterstaat's asset manager of the North Sea. She worked at the Netherlands Hydrographic Office for seven years before she joining Rijkswaterstaat 11 years ago. She is the competent authority for shipwrecks in salt water (North Sea and Zealand).
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XPRIZE Winners Meet with Japanese Prime Minister Shinzo Abe

A Shared Vision for Mapping the Ocean Floor

Members of the GEBCO-Nippon Foundation (NF) Alumni Team met with Japanese Prime Minister Shinzo Abe in Tokyo in August to explain the concept that won them the US$4 million Shell Ocean Discovery XPRIZE for seafloor mapping. They also talked about their shared vision for mapping the entire seafloor by 2030.

The GEBCO-NF Alumni Team, made up of international graduates of The Nippon Foundation/GEBCO postgraduate training programme at the University of New Hampshire (UNH), USA, spoke with Prime Minister Abe about the technology that they developed, and how their model for international scientific cooperation can help to fill in the gaps that still remain in the current understanding of the ocean floor.

Scale replicas

The team members demonstrated their winning concept to Prime Minister Abe using scale replicas of the vessels that they had used as well as 3D visualizations of the data that they had collected during the competition. Additionally, they presented a copy of the General Bathymetric Chart of the Oceans (GEBCO) 2019 – the most recent version of the definitive map of the world's ocean floor.

The GEBCO-NF Alumni Team prevailed over all other teams from around the world to win the Ocean Discovery XPRIZE with their concept for fast, efficient and cost-effective seafloor mapping. Their entry utilized the SEA-KIT unmanned surface vessel (USV) Maxlimer, alongside the Kongsberg Maritime HUGIN autonomous underwater vehicle (AUV) system, leveraging new and existing technologies to optimal effect. In Round 2 of the competition, the SEA-KIT was able to autonomously launch and recover the Kongsberg Maritime HUGIN AUV, rated to operate at depths down to 4,500 metres, and act as a communication link during the latter's subsea survey operations.

Innovative data processing

The team applied innovative approaches to data processing, with a newly developed automated workflow, remote data processing and a rapid data-to-information pipeline using web services to allow global access to data within the competition timelines. The team comprised Dr Evgenia Bazhenova (Russia), Aileen Bohan (Ireland), Dr Mohamed Elsaied (Egypt), Andres Fitzcarrald (Peru), Tomer Ketter (Israel), Christina Lacerda (Brazil), Jaya Roperez (Philippines), Azmi Rosedee (Malaysia), Ivan Ryzhov (Russia), Hadar Sade (Israel), Neil Tinmouth (South Africa), Dr Rochelle Anne Wigley (USA) and Dr Yulia Zarayskaya (Russia).

▲ *From left to right: Mitsuyuki Unno, Masanao Sumiyoshi, Sattiabaruth Seeboruth, Prime Minister Shinzo Abe, Yohei Sasakawa, Dr Rochelle Wigley, Dr Karolina Zwolak and Hisataka Hiragochi. (Courtesy: GEBCO-Nippon Foundation Alumni Team)*

All around the world

Due to the international nature of the team, members communicated with each other by videoconferencing and email, from offices and vessels all around the world, to coordinate the various aspects of their entry and process the data that they collected. Four months down the line, the team members are still working together as they continue to develop aspects of their winning concept and build on the skills gained during the last three years. ◀

About GEBCO

The General Bathymetric Chart of the Oceans (GEBCO) partners with The Nippon Foundation in the Seabed 2030 Project. GEBCO is a joint project of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO – the United Nations Educational Scientific and Cultural Organization. It is the only intergovernmental organization with a mandate to map the entire ocean floor.

About The Nippon Foundation

The Nippon Foundation (founded in 1962) is a private, non-profit foundation that is jointly spearheading international efforts to map the entirety of the world's ocean floor by the end of the next decade. More than 100 organizations are now contributing to the goal of producing a complete map, which is vital to exploration.

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