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Hydrographic remote sensing made in Germany

An article by KNUT HARTMANN and THOMAS HEEGE

What links hydrography and remote sensing? What has been developed and integrated in practice? This article addresses these issues with a core focus on the German contribution to hydrographic remote sensing (HRS).

HRS – hydrographic remote sensing | earth observation | SDB – satellite-derived bathymetry
Hydrographische Fernerkundung | Erdbeobachtung | SDB

Was verbindet Hydrographie und Fernerkundung? Welche Möglichkeiten ergeben sich und wie wurden diese bisher umgesetzt? Dies sind die Themen dieses Artikels – mit einem Fokus auf den deutschen Beitrag zur Hydrographischen Fernerkundung.

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Some definitions first

One may argue that remote mapping the seabed and other ocean parameters is a standard procedure to surveyors and hydrographers. The mapping of seabed by acoustic methods or airborne LiDAR can be seen as such remote mapping, as they survey depths and seafloor properties from a distance. However, these methods still require physical presence of equipment and staff at the survey area. A new level of ›remoteness‹ is achieved if the altitude of the sensor platform is increased significantly, by satellite-mounted sensors orbiting the Earth at approximately 750 km altitude. Since the launch of the US Landsat program in the early 70s satellite remote sensing often stands synonymous for remote sensing – or Earth Observation – and will be used in this article in this way. Nowadays there are numerous satellites of various specifications and designed for multiple needs, from communication to positioning. Remote sensing uses those sensors, which have the ability to actively or passively record the composition of the media between sensor and surface. In other words, to record the properties of the earth surface or atmosphere. Most of the HRS applications use data from sensors which either record the returned reflectance of the sunlight (passive sensors), or actively emit a signal and measure its return (active sensors). Generally, the concept of satellite remote sensing has the big benefit to map extended areas without the need to mobilise equipment and staff, and the disadvantage of high requirements on data analytics to correct for quite a lot of environmental error sources.

The hydrographic remote sensing history in a nutshell

The origins of hydrographic remote sensing may date back to the early 70s when researchers first visually identified patterns and shoals from the first satellite imagery. However, it took almost two decades before satellite-derived information found its way into hydrographic applications. In the mid 80s the French Hydrographic Office SHOM digitised shoals from satellite data and integrated those into nautical charts, known as »spatiocartes«, which represents the beginning of hydrographic remote sensing. At that time satellite sensors, computational power and also analytical algorithms were not made to upscale the process and must be considered as crude compared to modern standards (Fig. 1). It required the continuous, iterative improvement and R&D breakthroughs on all these aspects to achieve impactful progress on hydrographic remote sensing. The developments on physics-based shallow water mapping in Germany started in 1998, at the German Aerospace Center (DLR) with Thomas Heege as research scientist, and few years later in Australia with Magnus Wettle at CSIRO.

It took then until 2014 before the UK Hydrographic Office (UKHO) integrated satellite-derived bathymetric information in British Admiralty charts of southern Antigua, almost three decades after the first spatiocartes were published. In many respects this was a milestone in HRS. It was the first time that quantitative bathymetric information from satellites, known as satellite-derived bathymetry (SDB; cf. Hartmann et al. 2017), was integrated into charts and the satellite-derived survey was embedded into a combined survey strategy with acoustic surveys. The hydrographers showcased that this integrated survey concept increases survey efficiency and supports the safety of navigation. More recently this concept was taken up to map the Pacific states of Tuvalu and by the New Zealand Hydrographic Office (LINZ) to update charts on Tonga. In parallel satellite-derived bathymetric information

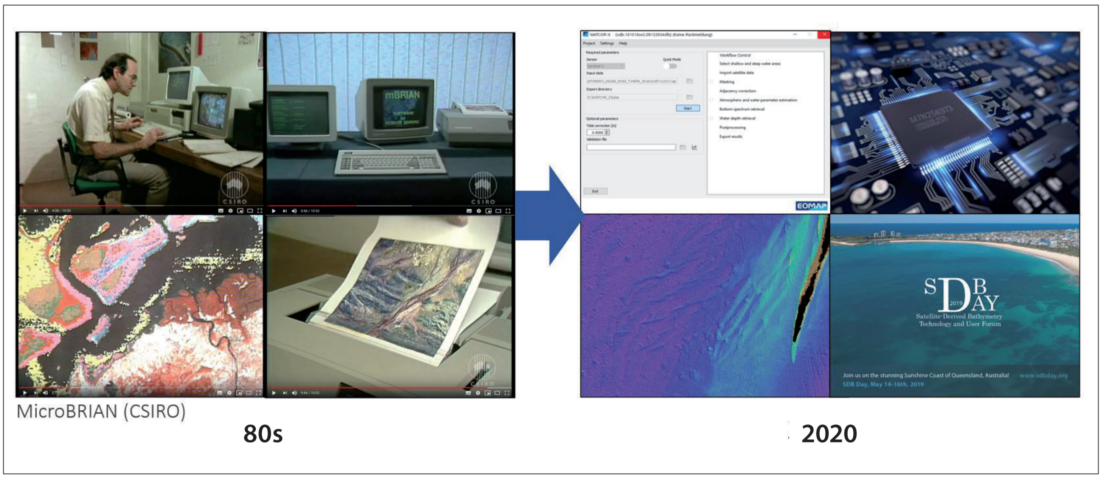

Fig. 1: Time-lapse of the development of hydrographic remote sensing. In the early 80s satellite data were analysed with intense man power efforts and required the best processing capacities which were available at that time. Nowadays analyses are done in operational software workflows with processes being directed to graphic cards and cloud environments. Dedicated conferences deal with this former niche topic of hydrographic remote sensing and data are integrated in different hydrographic and related applications

found its way to different applications, which are outside the standard domain of hydrographic applications. The data are being used by survey and offshore industry in almost daily use, and found in the harmonised European bathymetric grid of EMODnet bathymetry and the global grid of GEBCO. In all these mentioned projects – except the SHOM spatiocartes – the evolving German expertise, with intense involvement of EOMAP, played a major role. Without systematic long-term developments, the current status of hydrographic remote sensing would be different.

Quo vadis hydrographic remote sensing?

As shown, the development of hydrographic remote sensing was initially slow but had an almost exponential increase of R&D progress and data uptake. Other concepts and products have been developed in the last years which contribute to the hydrographic knowledge as well. To name only a few:

- The German Aerospace Centre in Bremen developed solutions to measure wave height from radar satellite data for nearshore sites.

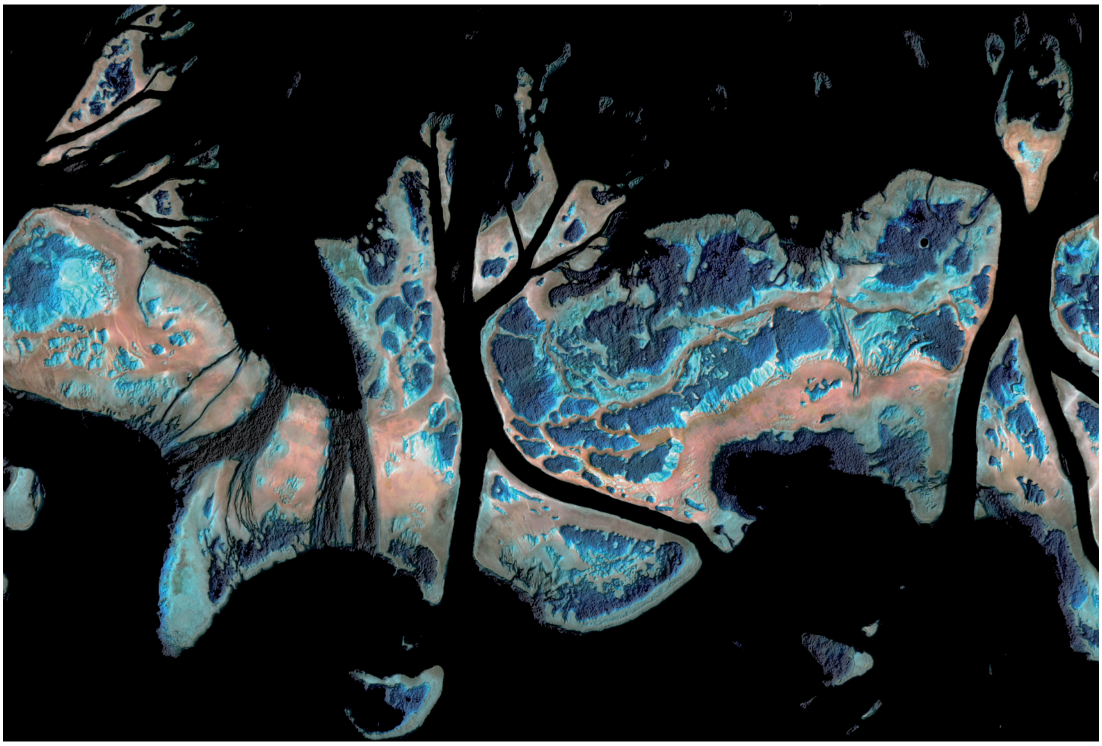

Fig. 2: A small subset of the Great Barrier Reef mapped by satellite data. The brownish areas represent reef crests and plateaus with the blueish colours deeper areas of the atolls which are mainly dominated by coral rubble and sandy bottom. The satellite-derived bathymetric data are shown as hillshaded effects

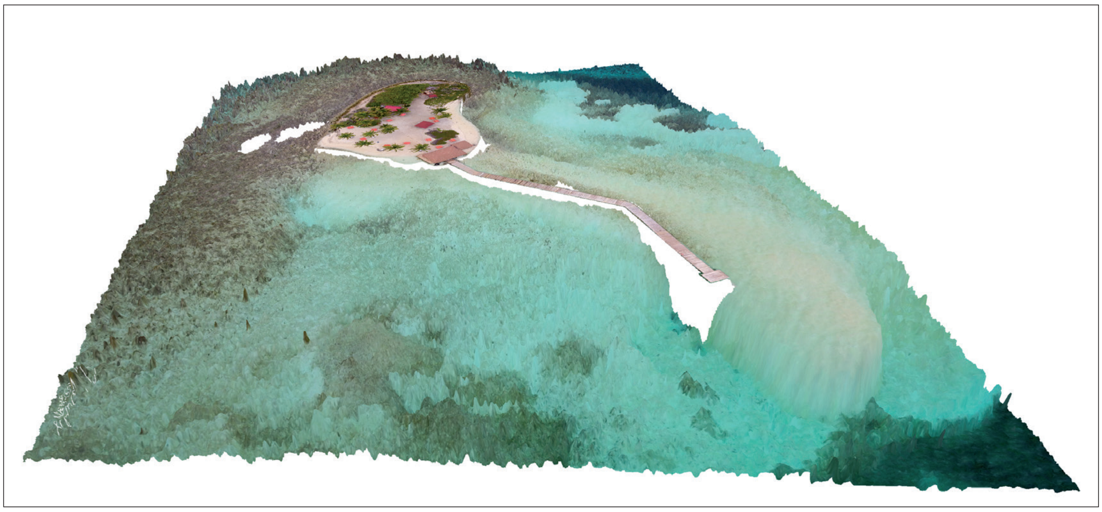

Image courtesy: EOMAP GmbH & Co. KG, 2020

Fig. 3: Combining drone- and satellite-analysis for mapping shallow water environments. The example shows an area of approximately 250 × 250 m in Belize and represents depth at 9 cm spatial resolution overlaid with a realcolour image which shows the different seafloor types from bright sand to coral and hardbottom areas (top left) to sparse to dense seagrass areas (lower right and centre)

- Deltares in the Netherlands published a global analysis on shoreline dynamic using optical satellite data.
- In Australia the habitat and morphology of the world's largest reef system, the Great Barrier Reef which comprises approximately 10 % of the global corals, was mapped in high detail for the first time (Wettle 2019) (see Fig. 2).
- The German Baltic of Schleswig-Holstein made use of the same concept to map the benthic environment (Hartmann et al. 2019).
- The mapping of satellite-derived global water quality parameters was released in 2019 (UNESCO 2018; SDG6 2020).
- Drift and Noise, based in Bremen, provides satellite-derived ice information to increase efficiency and safety of navigation in higher latitudes.

So, what is next? We believe that the cycle of improvement on sensor technology, processing capacities and algorithm developments will continue, and lead to further significant improvements and also increased integration of all those into workflows of the hydrographic community. To name just a few examples, current activities of EOMAP focus on developing integrated survey concepts of autonomous underwater vehicles and satellite-derived bathymetric data (Syrius project, co-funded by the European Space Agency), and to transfer and combine the strengths of satellite-data analysis with airborne drones (see Fig. 3).

Again, we see Germany well positioned with those developments. Thanks to the innovation co-funding of Federal Ministry of Transport and Digital Infrastructures, current activities are focusing on multi-temporal data processing on FGPAs (field programmable gate arrays) and graphic cards (SDB2030 project) to reduce uncertainties and upscale the complex data analysis of satellite-derived aquatic information, or the integration of satellite-derived information in hydrographic practice, which was addressed in the MARSAT project.

With respect to new satellite capabilities we see potential in the current and future micro satellite fleets which are equipped with radar and optical sensors. Those constellations allow multiple recordings per day and if combined with programmatic interfaces will have their strength in improving the knowledge, especially for maritime surveillance. Furthermore, the recent US satellite IceSat 2 supports the satellite bathymetric mapping. It holds a green photon-counting LiDAR with a 10 kHz pulse repetition rate, which records the earth in regular but sparse tracks. Although the instrument was not intended for bathymetric analysis. the data can be used in this way and – in combination with satellite-derived bathymetric data from multispectral information – allow a further improvement of the mapping and surveying from space (Fig. 4).

And last but not least, next to various commercial satellite providers which will launch satellites in the next years, also the European Space Agency will double the number of its very impactful multispectral Sentinel-2 satellites from two to four in the next years. All that leads to the fact that the amount of satellite remote sensing data continuously increases. But satellite data are worthless without the capability to analyse them and bring them into value. Thus, with respect to new algorithm packages and data integration we see recent and future advances in increasingly automatic analysis of satellite data for the offshore industry and hydrographic entities. We believe that this trend will continue and, thanks to decades of sound algorithm developments, the hydrographic community will increasingly make use of hydrographic remote sensing solutions. This development runs in parallel with the development of cloud processing platforms such as the Google Earth Engine, Amazon cloud or European DIAS centres which are capable to speed up big data analytics to an amazing degree – as long as the implemented data analytical capabilities provide the base with robust information products.

Conclusion

Hydrographic remote sensing has performed an impressive rise in the last years and satellite-derived information is used in multiple applications and programs nowadays. The journey will continue and innovations are being developed on different levels, which altogether will provide more precise and up-to-date spatial information for hydrographers and the offshore stakeholders. We see Germany with its strength in the maritime industry and engineering and remote sensing expertise well positioned to continue being a leading nation in this topic. //

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Big thanks

Hydrographic remote sensing made in Germany would not have been possible without the excellence and passion of individuals and the fertile environment for developing innovations. That said, we at EOMAP have to be thankful for the support given to us all these years by the DLR Space Agency and the innovative state governments implementing these new data services: we would like to name Schleswig-Holstein in special. We wish to highlight the passion brought into this topic by Peter Dugge (Atlas Elektronik), Dr. Marco Filippone (Fugro Germany) and many others who all surely contributed to pushing the limits of HRS.

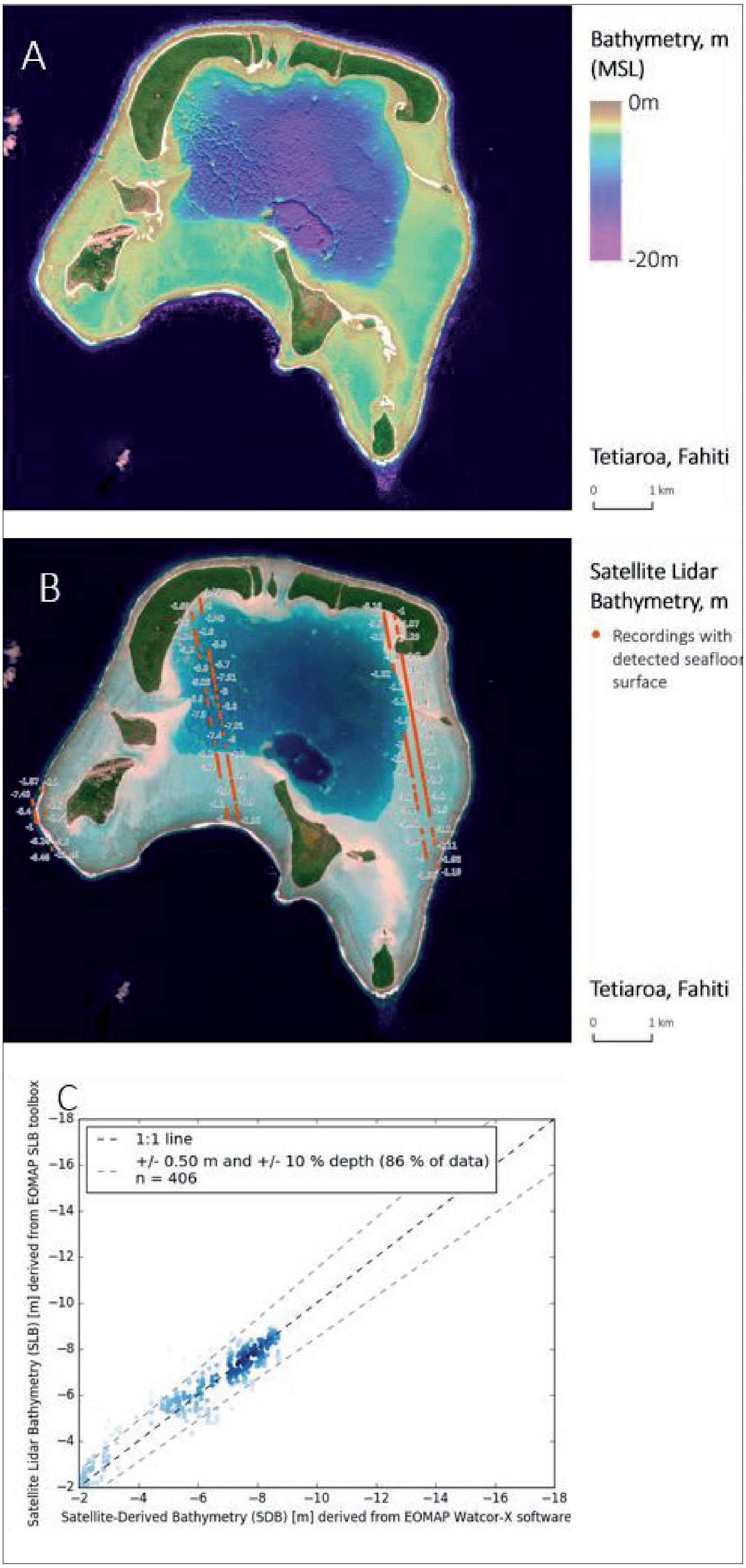

Fig. 4: A: Bathymetric grid derived from multispectral satellite-derived bathymetry analysis. The map shows a 10 m dense bathymetric grid for Tetiaroa atoll. B: Orange dots represent track lines of the IceSat 2 photons which were returned by the seafloor. C: Scatterplot of data shown in A and B. Combining both methods allows to define the vertical uncertainties more precisely and improve overall accuracies without being on site