Use of laser bathymetry at the German Baltic Sea coast

An article by WILFRIED ELLMER

The German coastal waters are quite shallow. The idea arose to use airborne laser bathymetry (ALB) for hydrographic surveying of near-shore areas of the German Baltic Sea. Since these waters are relatively turbid, it became necessary to investigate to what extent modern ALB systems could be of practical use in an area large enough for hydrographic purposes especially in the Baltic Sea. The basic questions to be answered by the project were: Which areas can be measured by this method? And how expensive will this be in relation to traditional methods? From 2012 to 2014, four test surveys have been accomplished in an area north of the city of Wismar. During these surveys, many relevant questions were solved.

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1 The state of hydrography in Germany

1.1 Hydrographic surveying in Germany

The German Maritime and Hydrographic Agency is mandated to conduct hydrographic surveys in the coastal waters and the EEZ of two different areas:

- North Sea, there are very busy approaches to Hamburg, Bremerhaven, and Wilhelmshaven, with large shallow areas shaped by strong tidal currents, the Wadden Sea area. Due to these currents the water is very turbid, large parts with Secchi depths of less than 0.5 m. The depths of shallow areas are changing very much, so they have to be resurveyed very frequently, partly every year. The deeper areas of up to 70 m are to be resurveyed once in 25 years only.
- Baltic Sea, also quite shallow, up to 50 m. The tidal range is less than 30 cm, so the structure of the bottom is much less dominated by strong currents. Most parts will be resurveyed once in 10 or 25 years only, but it is necessary to achieve full bottom coverage. The visibility of the water is much better than in the North Sea, sometimes better than 5 m.

Surveying is done by single-beam and multibeam echo sounding. In areas of frequent resurvey activities, single-beam echo sounding is the standard procedure.

Wreck search is a very important task in German waters. The obstructions database contains about 2,000 positions. Every year nearly 30 new obstructions are found, and 200 positions have to be revisited in order to examine changes of the position and the least depth; especially in the strong tidal currents of the Wadden Sea, one has to take into account that even large objects may move.

1.2 The question of airborne laser bathymetry

In former times, airborne laser bathymetry (ALB) was assumed to be unsuitable for hydrographic surveys in German waters due to the poor water-visibility conditions. A test flight in 2008 showed poor results, and seemed to validate this assumption. However, recent developments of new ALB systems may lead to better results, and made it necessary to investigate the potential of this technology, and to verify, whether or not ALB has the potential to replace the traditional techniques or at least to complement them.

A project was started in order to answer this question, and to decide on further actions. The basic questions to be answered by the project were:

- Where does it make sense to use ALB for hydrographic surveys?
- How expensive will this be in relation to traditional methods?

The criteria for these answers are those of S-44 (IHO 2008).

2 The laser bathymetry project

2.1 The structure of the project

The project took place in the years 2012 to 2014. Each year one flight was planned and a call for tender was issued. The area to be surveyed was chosen north of the island of Poel, an area with different structures, with some stones, and with depths from zero to a depth well exceeding the capabilities of modern ALB in order to reach the system's maximum depth capability.

The Institute of Photogrammetry and GeoInformation (IPI) of Leibnitz University of Hannover took over a scientific cooperation in the frame of the project. One person processed the ALB data and prepared a report (Niemeyer et al. 2015). Additionally, some Bachelor and Master theses were written on special aspects of the project. Attached to the project a board was installed with representatives of some other German institutions interested in that topic. The board met every year to exchange information on the project and on other activities pertaining to ALB. Coastal protection authorities were especially interested in the project and gave input on their activities (Christiansen 2016). This was very important since ALB cam-

paigns for data production can only be financed through cooperation of all institutions active in the same area.

2.2 The flight campaigns

The *2012 campaign* was planned with three main criteria:

- High resolution (much higher than the 2008 tests);
- In some areas, the tracks had to be in three heights: the optimum, 20 % more, and 20 % less of the optimum;
- The measurements were to be made in fall 2012.

The survey took place in October/November 2012. Some of the measurements could not be processed, so it became necessary to repeat the relevant tracks in April 2013. The sensor was a Riegl VQ-820-G. The Secchi depth was 6.8 m.

The main results in short (Wischow 2013):

- A depth of 5 to 6 m could be reached, in April 6 to 7 m;
- Obstructions could not be found;
- There are some gaps in the data, partly in the same places as with the 2008 test flight.

The *2013 campaign* was planned with three main criteria:

- Two different resolutions: High resolution in the shallow areas, and a depth of 2 × Secchi depth with less resolution;
- The measurements were to be made in fall 2013;
- Additionally to the area north of Poel, two little areas further east had to be surveyed, artificial reefs Nienhagen and Rosenort.

The survey took place in September 2013 in two campaigns, first with Hawkeye II, later with Chiroptera in the shallow areas. The Secchi depth was 7 to 9 m.

The main results in short (Sánchez Gámez 2014):

- With Chiroptera a depth of 9 to 10 m could be reached, with Hawkeye II the depth range of 7 to 14 m was covered;

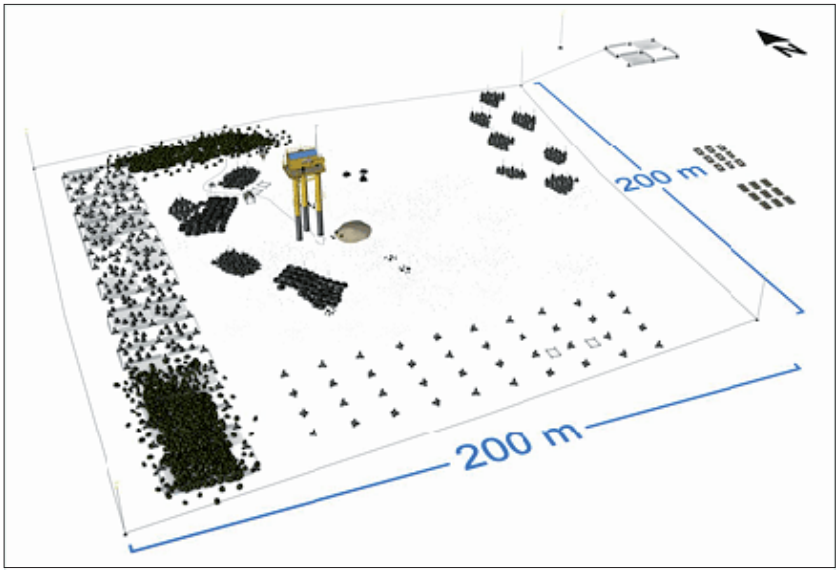

Fig. 1: Reef Nienhagen

- Obstructions again could not be found, even the relative large reefs in Nienhagen (Fig. 1) and Rosenort;
- The object classes »vegetation« and »obstruction« could not be separated.

The *2014 campaign* was planned again with the same main criteria. The main difference was the request to fly in spring 2014. Due to the long-time required for the procurement, the planning took place before the results of the 2013 flight had been delivered.

The survey had initially been planned with the new Hawkeye III, which would have been able to do the high-resolution and the deeper survey in one flight. However, in spring 2014 the system was not available, so the flight was performed in May 2014 with Chiroptera. In September 2014, six selected tracks were resurveyed with Hawkeye III, and seven at the position of the reefs. The Secchi depth was 6 m only in May and in September, somewhat more at the reefs. The areas of the survey are to be seen in Fig. 2.

The main results do not differ much from those of 2013 (Warnke 2015). Even the new Hawkeye III

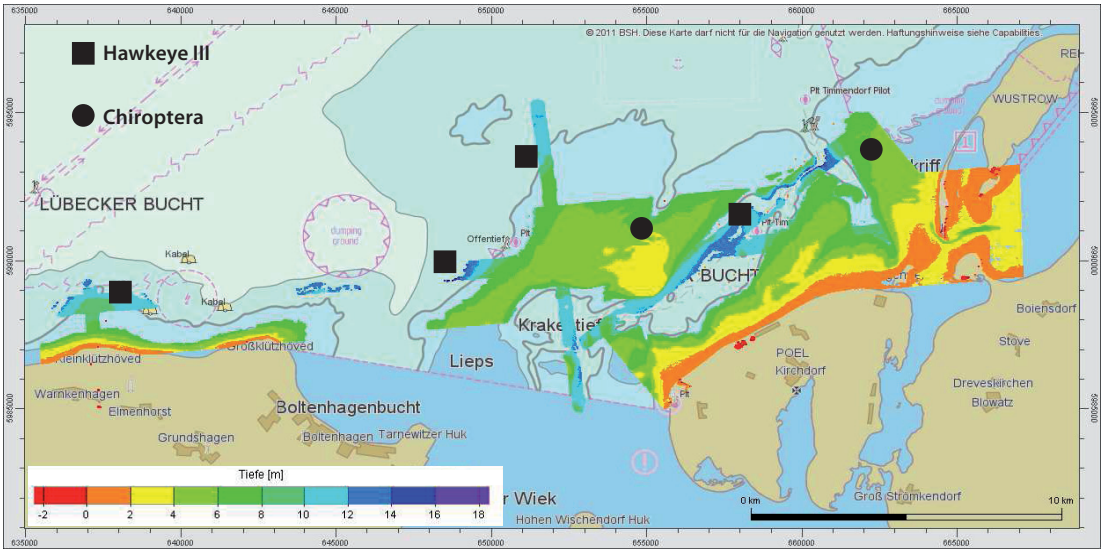

Fig. 2: Area and depths of 2014 campaigns

does not produce results that significantly deviate from the results of Chiroptera and Hawkeye II.

2.3 The investigation of Secchi depths

In order to extrapolate the findings to the whole German coast of the Baltic Sea, it is necessary to investigate the Secchi depths of the whole German waters (Hübner 2014). These depths vary much during the year. There are two time windows of special interest:

- Spring time has the best Secchi depths, but the time window is smaller and depends much on the weather conditions of the months before.
- Fall time has slightly worse Secchi values, but the time is longer and better to predict.

The spatial variation is very large (0.5 to 9 m). This leads to a consideration of the relationship (depth/Secchi depth) instead of the Secchi depth itself. The result of this investigation is a chart (Fig. 3) showing areas of:

- 0.7 × Secchi depth for Riegl VQ-820-G or similar;
- 1.3 × Secchi depth for Chiroptera or similar;
- 2.0 × Secchi depth for Hawkeye III or similar.

3 Conclusion

3.1 The findings of the project

The main conclusion is that bathymetric airborne laser scanning will not replace traditional hydrographic surveys as such, but will be an important supplement in shallow areas with minor importance for mariners. It is a strong improvement against single-beam hydrographic survey, since the survey is compliant with S-44 order 1b instead of order 2 (IHO 2008). Within the German part of the Baltic Sea, 2,500 km^2 may be surveyed with ALB with full coverage up to a relation depth/Secchi depth of 1.3 and with minor resolution up to a relation of 2 (Fig. 3).

These areas are mostly to be resurveyed every 25 years. It makes sense to do the survey in parts of this area in order to limit the size of data sets to be processed. In order to improve the efficiency it is necessary to coordinate a flight campaign with all stakeholders of the area to be surveyed, especially between the hydrographic office, the coastal engineers, the coastal protection authorities, and the ordnance survey.

There are still some questions remaining, especially:

- The detection of obstructions,
- Data gaps due to vegetation or other material with bad backscattering.

Solving these questions would significantly improve the use of ALB for hydrographic purposes. Particularly at the German Baltic Sea coast, lots of stones, dangerous for shipping, could be detected.

3.2 The next step

Following this project it becomes necessary to update the general plan of surveys in the Baltic Sea. An area of 2,500 km^2 may be described as ALB area. This gives the possibility to concentrate the multibeam capacity to other areas where the frequency of surveys must be increased in order to improve the safety of shipping (Helsinki Commission 2010). The next steps will be to arrange the financing and the coordination of the projects.

The ALB campaign will be organised with a public call for tenders. The project has shown that the area should be described between some distance landwards from the coastline up to a line described by the relation depth/Secchi depth. Thus, it is necessary to organise shipborne Secchi measurements together with shipborne control check lines very close to the ALB measurements. The time of survey should be open, but with good communication in order to coordinate the flights with the shipborne measurements. ⚓

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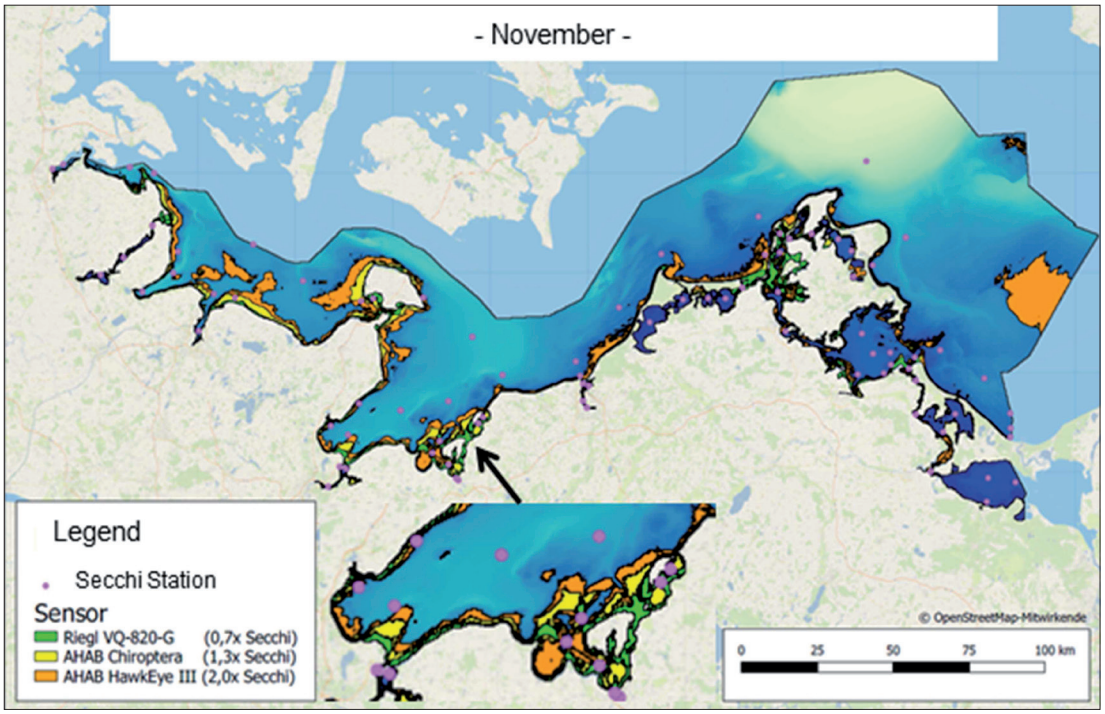

Fig. 3: Possible areas for ALB in November