STANDARDIZED SEA FLOOR AND WATER DEPTH MAPPING USING OPTICAL AIRBORNE AND SATELLITE DATA

Thomas Heege[(1)], Jörg Heblinski[(1)], Halina Kobryn[(2)], Kristin Wouters[(2)], Nicole Pinnel[(2)], Peter Reinartz[(3)]

[(1)] EOMAP GmbH & Co. KG, Sonderflughafen Oberpfaffenhofen, Friedrichshafener Str. 1, D-82205 Gilching (Germany), Email: heege(heblinski)(at)eomap.de
[(2)] Murdoch University, South St, Murdoch WA 6150, Australia; H.Kobryn(K.Wouters)(N.Pinnel)(at)murdoch.edu.au
[(4)]German Aerospace Center (DLR), Oberpfaffenhofen, 82234 Weßling

1. INTRODUCTION

Industrial and environmental agency applications in sea floor mapping require repeatable, standardized monitoring approaches, suitable for long term comparisons of impacts due to human activities as well as natural variability. Therefore, remote sensing approaches applied to the different available sensors should be as independent as possible and not rely on simultaneous field campaigns and external data inputs. Increasingly, there is also a need to map large areas in speedy manner to support the environmental impact assessment processes, which is especially challenging in areas largely inaccessible to boats or divers.
In order to meet these demands, we apply a standardized, physics-based data processing approach integrating sunglitter, atmospheric, water surface and iterative water body corrections, to retrieve both sea floor characteristics and water depth. Exactly the same processing chain is used for data from different multi- and hyperspectral satellite and airborne sensors. We integrate the experience from various inland and coastal water applications in Germany, Armenia, Indonesia and Australia to determine the technical requirements of the standardized physics-based shallow water mapping approach.

2. METHODS

The generation of thematic products for aquatic systems from calibrated remote sensing radiances is performed using the Modular Inversion and Processing System MIP [1,2]. MIP is designed for the physics-based recovery of hydro-biological parameters from multi- and hyperspectral remote sensing data and can be used for environmental mapping of shallow and deep inland waters, coastal zones, and wetlands. The architecture of the program correlates a set of general and transferable computational schemes in a chain, connecting bio-physical parameters in the water column, such as chlorophyll content or dissolved organic matter, with the measured sensor radiances.
The physical background of the hyperspectral and fully transferable system incorporates the Finite Element Method for forward calculations of the radiative transfer in a multilayer atmosphere-ocean system [3]. It is used for the atmospheric, sunglitter, water surface, and Q-factor corrections of the underwater light field as explained in [1]. The different program modules support transferable algorithms. The adjustment of algorithms to sensor specifications and recording conditions is supported automatically in MIP. The inversion itself is based on a spectral matching technique.
The output of the sunglitter and atmospheric correction constitutes subsurface reflectances. The transformation of subsurface reflectance to the bottom albedo (overall reflectance) is achieved based on the equations published by Albert [4]. The unknown input value of depth is calculated iteratively in combination with the spectral un-mixing of the respective bottom reflectance. The bottom reflectance is approximated during this inversion process as a linear combination of three main component spectra. The un-mixing procedure produces the sea floor coverage of three main bottom components and the residual error between the model bottom reflectance and the calculated reflectance. The final water depth, bottom reflectance, and bottom coverage products are generated at the minimum value of the residual error.

The final step of the thematic processing classifies the bottom reflectance according to the spectral signature of different substrate and biota types using a 'Fuzzy Logic' algorithm. Individual probability functions are assigned for each defined sea floor component. For the final seafloor classification, separate benthic classes are identified based on their spectral signatures. The 'Fuzzy Logic' technique combines the identification of different spectral features for each seafloor class with the calculation of probabilities for each of those features. All features related to one specific seafloor class result in one mean probability (by taking into account individually calculated weights for each single feature probability) [5,6].

3. APPLICATION AND VALIDATION

In shallow waters, the MIP system allows the calculation of water depth and the classification of substrate types such as coral reef, seagrass vegetation, and bottom sediments. The processing system has been tested and validated in a range of surveys and satellite observations over German, European, and Armenian inland waters, Indonesian and Australian coastal zones, as well as from data collected by airborne and satellite sensors [2,5,6,7,8].

Although the site specific optical properties of an environment must still be sufficiently described for reliable and repeatable map products, the essential information can also be retrieved directly from optical closure calculations. Therefore, it is not always necessary to have spectral ground truth data at hand. If however, field data are available, they can expedite data processing and improve final results.

We conclude that the key elements in the operational applications of optical remote sensing for depth and benthic cover mapping remain the sensor calibration, stability and sensitivity. The number and position of spectral bands influences the number of parameters to be retrieved independently, but is of additional use after the calibration requirements are fulfilled.

We compare the mapping results of Rottnest Island/WA (HYMAP airborne, QuickBird), of Ningaloo Reef (3400 sqkm HYMAP), of Indonesia (IKONOS) and Lake Constance (HYMAP) with different validation data sets of bathymetry and sea floor coverage.

11. REFERENCES

[1] Heege, T. & Fischer, J., "Mapping of water constituents in Lake Constance using multispectral airborne scanner data and a physically based processing scheme." *Can. J. Remote Sensing*, Vol. 30, No. 1, pp. 77-86, 2004

[2] Heege, T., Häse, C. , Bogner, A., Pinnel, N. (2003): Airborne multi-spectral sensing in shallow and deep waters. *Backscatter* p. 17-19, 1/2003

[3] Kiselev, V.; Bulgarelli, B., "Reflection of light from a rough water surface in numerical methods for solving the radiative transfer equation." *J. Quant. Spectrosc. Radiat. Transfer*, 85, 419-435, 2004

[4] Albert, A. & Gege, P., "Inversion of irradiance and remote sensing reflectance in shallow water between 400 and 800 nm for calculations of water and bottom properties". *Applied Optics*, Vol 45(10), pp. 2331 – 2343, 2006

[5] Heege, T., Hausknecht, P, & Kobryn, H., "Hyperspectral seafloor mapping and direct bathymetry calculation using HyMap data from the Ningaloo reef and Rottnest Island areas in Western Australia". *Proceedings 5th EARSeL Workshop on Imaging Spectroscopy. Bruges,* Belgium, p. 1-8, 2007

[6] Pinnel, N., "A method for mapping submerged macrophytes in lakes using hyperspectral remote sensing". *PhD thesis Technische Universität München*, 2007

[7] Harvey, M., *PhD thesis Murdoch University* (to be submitted) – personal communication, 2009

[8] Kobryn, H., Pinnel, N., Heege, T., Beckley, L., Harvey, M., Long, S., "Mapping the habitats and biodiversity of Ningaloo Reef, Western Australia using hyperspectral imagery"**,** *Proc. 11th Int. Coral Reef Symposium*, Fort Lauderale July 7-11, 2008