# Recent advances in Operational Phytoplankton Monitoring System Alg@line

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**Abstract: Alg@line is a forerunner in the field of monitoring research using commercial ferries. In 1992 the Finnish Institute of Marine Research started systematic measurements on board ferry Finnjet, crossing the Baltic Sea Proper, using unattended recording and sampling system. Alg@line co-operation project nowadays uses several approaches to integrate operationally ecological and environmental information of the Baltic Sea such as chlorophyll-a and turbidity observations with flow through systems and MODIS satellite monitoring for the water quality.**

**Keywords**: chlorophyll, turbidity, monitoring, satellite validation

## INTRODUCTION

Alg@line has monitored and reported the phytoplankton community dynamics and the state of the Baltic Sea (www.balticseaportal.fi) for 12 years (Rantajärvi et al. 2003). Nowadays, Alg@line is a co-operation between several research institutes and shipping companies. Alg@line monitors the fluctuations in the Baltic Sea ecosystem in real-time using high-frequency automated sampling on board six merchant ships (ship of opportunity, SOOP). Alg@line participates also in the EU project FERRYBOX (2002-2005) with 10 other partners around the Europe (www.ferrybox.org). Furthermore, three Finnish Frontier Guard vessels provide also SOOP and CTD-data (Fig. 1). Annually, 1,5 to 2 million flow-through observations (*in vivo* chlorophyll *a*, turbidity, salinity and temperature), 7 000 phytoplankton species observations and 1000 nutrient observations are gathered.

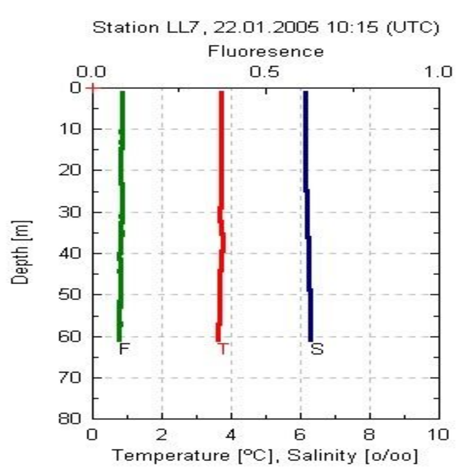


*Fig. 1. CTD profiles take on the Frontier Guard vessel Merikarhu after a winter storm in the Gulf of Finland.*

## METHODOLOGY

The Ship of opportunity (SOOP) monitoring system onboard Finnpartner ferry operating across the Baltic Proper from Helsinki to Travemünde forms the backbone for the Alg@line monitoring. The ferry sails every week from Helsinki to Travemünde and back, so the route is monitored twice a week. The *in vivo* chlorophyll-a measurements are carried out in a flow through water system with Turner Scufa fluorimeter. The seawater is taken from the piping system of the ferry. The chlorophyll-a fluorescence and turbidity are recorded with a spatial resolution of about 200 m. The data recording has the geo-reference logging from GPS (Fig. 2 and 3).

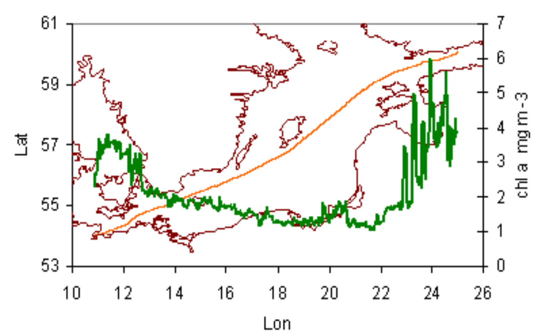


*Fig 2. Concentration of chlorophyll-a in the surface layer along the route of the ferry Finnpartner from Travemünde to Helsinki on the 14th March 2005.*

The flow-through measurements of *in vivo* chlorophyll *a* fluorescence are validated with the *in vitro* chlorophyll *a* values obtained from the water samples. The detailed description of the unattended algal monitoring system is given in Ruokanen et al. 2003. Besides the water flow-through monitoring, the SOOP system includes an automated refrigerated sequential water sampler, which collects waters samples of 1 liter volume for supplemental analysis of inorganic nutrients, phytoplankton species composition and *in vitro* chlorophyll *a* analysis with extraction method in the laboratory. Waters samples are collected about every 30 nautical miles along the route (24 samples) from Travemünde to Helsinki once a week. Thus the Alg@line database forms an unparalleled dataset for studies on satellite image validation in the Baltic Sea area. For further development feasibility studies have been made to sample CDOM records.

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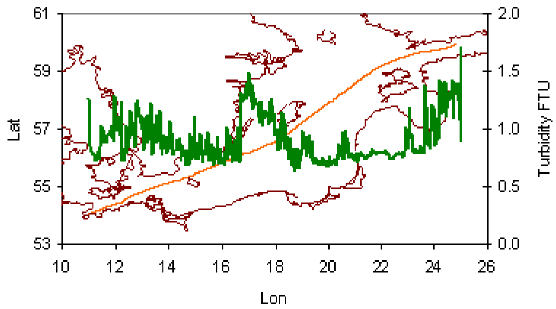


*Fig 3. Turbidity (FTU) in the surface layer along the route of the ferry Finnpartner from Travemünde to Helsinki on the $26^{th}$ March 2005.*

Phycocyanin is a specific pigment for filamentous cyanobacteria, and thus its fluorescence characteristics can be used to assess cyanobacterial distribution. Alg@line starts to detect operationally phycocyanin fluorescence with Turner 10 AU fluorimeter together with chlorophyll a fluorescence in the Baltic in the summer 2005.

To demonstrate the fluorescence characteristics of of light harvesting pigments in photosystem II (PSII) in eukaryotic algae and filamentous cyanobacteria, the absorption and fluorescence spectra were observed for Nannochloropsis sp (green algae) and Nodularia spumigena Mertens (cyanobacteria). PSII may consist different kind of pigments, but the main fluorescence source for filamentous cyanobacteria is phycocyanin and for green algae chlorophyll-a (Fig. 4). The observations of the fluorescence characteristics of natural phytoplankton communities are given by Seppälä et al. 2004.

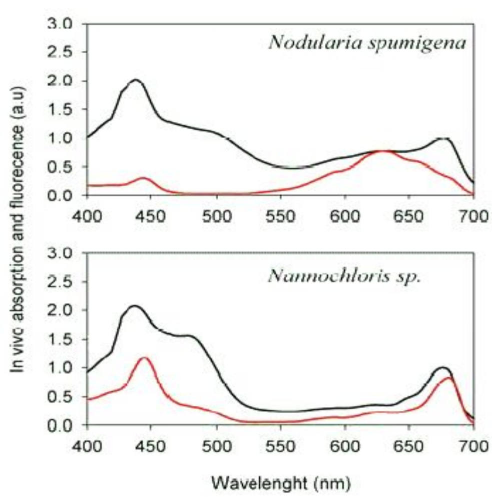


*Fig. 4. Absorption (black line) and fluorescence excitation (ex.400-700nm/em.730nm, red line) spectra of phyto-plankton cultures. Absorption spectra were normalized by the red absorption peak (at 680 nm) of Chla and excitation spectra were scaled to absorption so that no overshoot took place in the wavelengths from 500 to 690 nm. Peaks for Nodularia spumigena around 630 nm are principally due to phycocyanin.*

A fast repetition rate fluorometer (Chelsea FRRF) has been installed on board the ferry Finnpartner. This method is based on variable fluorescence of chlorophyll-*a* and provides information of algal photophysiological characteristics. This approach provides direct information about the photosynthetic potential of phytoplankton. The relation between FRRF based ($P_f$) and 14C based ($P_b$) primary productivity has been showed to be well correlated but FRRF method gives slightly higher estimates to Pf than $P_b$ , when irradiance levels are higher than 200 mmol quanta $m^{-2}$ $s^{-1}$(Fig. 5, see Raateoja 2004 for details). Because the absorption of the photosystem (PSII) in the dominant cyanobacteria *Nodularia spumigena* and *Aphanizomeneon* sp. is restricted beyond 550 nm (see Fig 4 and Raateoja et al. 2004), the FFRF method can not be applied in productivity studies of these filamentous cyanobacteria in the Baltic Sea.

Chlorophyll-a observations of have been used to develop a local algorithm for the Baltic Sea (Vepsäläinen et al. 2005) and data assimilation has been applied to improve the spatial accuracy in the regional water quality mapping (Pulliainen et al. 2004). Several attempts has been made to develop empirical algorithm to estimate chlorophyll-a distribution with optical remote sensing data. Conventionally, chlorophyll-a estimates are obtained using empirical reflectance ratios. In the case of the Baltic Sea high concentrations of colored dissolved organic matter (CDOM) and high turbidity due to high contents of suspended matter make the predictions difficult. Also specific structure of phytoplankton communities as blue-green algae blooms creates extra challenge for predictions. In these multi-component cases complex hyperspectral models are needed. For that purpose in this study multivariate calibration was applied to validate MODIS satellite data against automated fluorescence records of chlorophyll-a on board the ferry Finnpartner with regular route from Travemünde to Helsinki (Alg@line data).

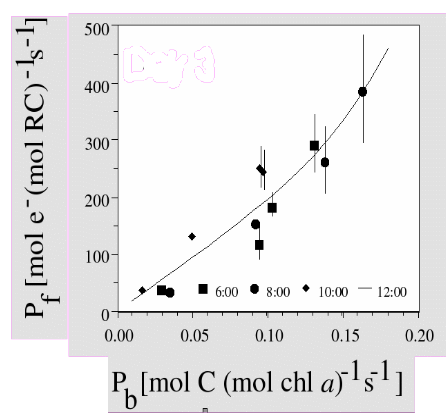


*Fig 5. The relation between FFRF based (Pf) and 14C ($P_b$) based primary productivity in the Gulf of Finland, 26 July 1999.*

Partial least square (PLS) regression analysis was used to validate chlorophyll-a records against 1 km resolution bands. Satellite data was received from NASA GES Distributed Active Archive Center (DAAC ) Data Pool through Internet. For validation the MODIS-Terra data on the 28 of July, 2004 at 9:50 UTC was used against the chlorophyll-a records along the route ± 3 hours from the satellite recording.

The satellite data was received in HDF-EOS format. Data for each band was extracted with HDFLook-Modis (Gonzalez and Deroo 2004) software and further analyzed together with chlorophyll-*a* data with GRASS-GIS software (Neteller and Mitasova 2004). Statistical analysis was done with PLS and PCR analysis (Martens and Naes 1989) with the R statistical software (R core team 2004).

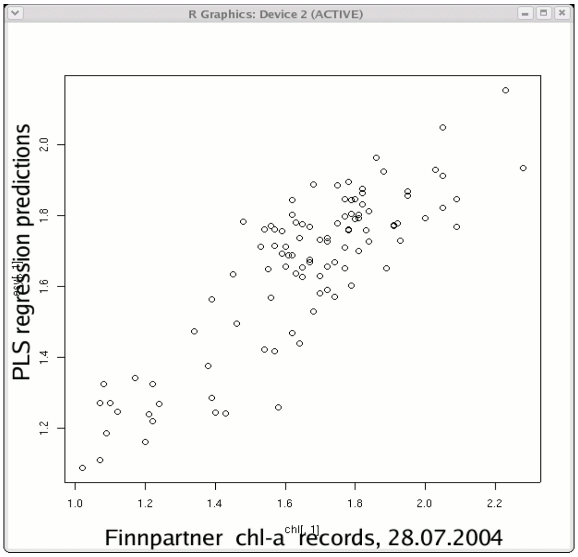


*Fig. 6. PLS regression predictions against observations in 28 of June 2004.*

PLS analysis showed that only the bands with the wavelengths from 562 to 920 nm (ie b11, b12, b13L, b13H, b14L, b14H, b15, b16, b17) had contribution to chlorophyll-a variance. The $R^2$ reached 72 % with 6 latent variables recommended by the analysis for the modeling (Fig. 6). The chlorophyll-a distribution maps evaluated according to the model are shown for 29 August 2004 (Fig. 7).

## CONCLUSIONS

The ship of opportunity (SOOP) monitoring systems onboard commercial ferries are cost effective in observation of oceanographical parameters. With such system Alg@line project collects extensive spatial and temporal database of the Baltic Sea, which can also be used for studies on satellite image validation. In the case of high concentrations of colored dissolved organic matter (CDOM) and high turbidity, e.g., in the Baltic Sea, hyperspectral models are needed in the satellite data analysis for validation. For that purpose, multivariate calibration can be applied to validate MODIS satellite data against automated fluorescence records of chlorophyll-*a*.

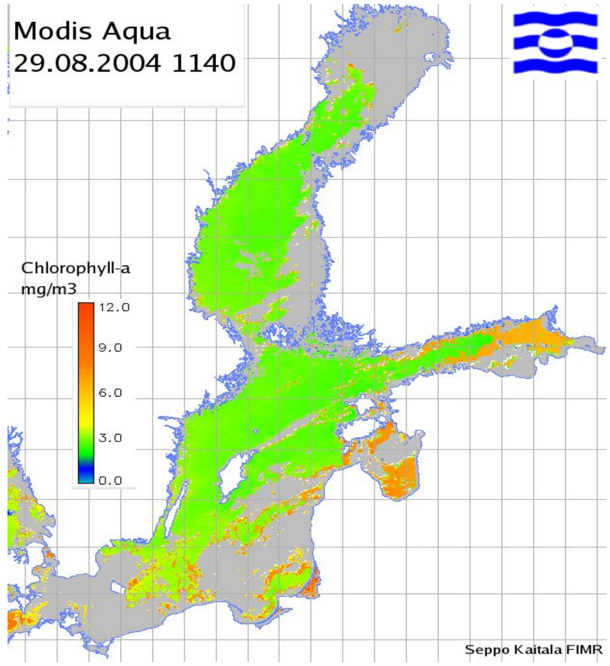


*Fig 7. Chlorophyll-a distribution in the Baltic Sea according to PLS prediction.*

## REFERENCES

Gonzalez L, Deroo C. 2004. HDFLook/HDFLook MODIS Handbook. http://www-loa.univ-lille1.fr/Hdflook/E_HDF.html

Martens H., Naes T., 1989. Multivariate Calibration. Wiley, New York.

Neteler M, Mitasova H., 2004. Open Source GIS: A GRASS GIS Approach, 2. Ed., Springer, Boston

Neteler M. 2004. MODIS time series remote sensing for epidemiological modeling. In Proc. GeoInformatics for Spatial-Infrastructure Development in Earth & Allied Sciences: GIS-IDEAS. 2004, Sept. 16-18, Hanoi, Vietnam, 2004. http://gisws.media.osaka-cu.ac.jp/gisideas04/viewabstract.php?id=81

Pulliainen J., Vepsäläinen J., Kaitala S., Hallikainen M., Kallio K., Fleming V. and Maunula P., 2004. Regional water quality mapping through the assimilation of spaceborne remote sensing data to ship-based transect observations, J. Geophys. Res., 109, C12009, doi:10.1029/2003JC002167. 2004.

R Core Team 2004. An Introduction to R. http://www.r-project.org/

Raateoja M. 2004. Fast repetition rate fluorometry (FRRF) measuring phytoplankton productivity: A case study at the entrance to the Gulf of Finland, Baltic Sea. Boreal Environment Research 9:263-273.

Raateoja, M., Seppälä J., Ylöstalo P. 2004: Fast repetition rate fluorometry is not applicable to studies of filamentous cyanobacteria from the Baltic Sea. Limnol. Oceanogr., 49(4): 1006–1012.

Rantajärvi E. (ed.) 2003: Alg@line in 2003: 10 years of innovative plankton monitoring and research and operational information service in the Baltic Sea - Meri – Report Series of the Finnish Institute of Marine Research No. 48. - 55 p. http://www.fimr.fi/en/itamerikanta/bsds/1731.html

Ruokanen L, Kaitala S, Fleming V., Maunula P. 2003: Alg@line – joint operational unattended phytoplankton monitoring in the Baltic Sea. In: Dahlin H et al. (eds) Building the European capacity in operational oceanography. Elsevier Oceanography Series 69, Elsevier, pp. 519-523.

Seppälä J., Ylöstalo P., Kuosa H. 2004. Spectral absorption and fluorescence characteristics of phytoplankton in different size fractions across a salinity gradient in the Baltic Sea. Int. J. Remote Sens., vol. 26, No. 2, January 2005, pp. 387-414.

Vepsäläinen J., Pyhälahti T., Rantajärvi E., Kallio K., Pertola S., Stipa T., Kiirikki M, Pulliainen J., Seppälä J. The combined use of optical remote sensing data and unattended fluorometer measurements in the Baltic Sea, Int. J. Remote Sens.,Vol. 26, No. 2, January 2005, 261-282.