Monitoring eutrophication in the North Sea: an operational CHL-P90 tool

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Summary

The satellite-based chlorophyll a 90 percentile product (CHL-P90) is an important indicator used to monitor for the eutrophication state of the North Sea. The accuracy of the CHL-P90 is impacted by the irregular availability of satellite chlorophyll a (CHL) observations both in space and time due to cloudiness, quality flagging, sensor malfunction, etc. A detailed simulation study enabled the development of advanced methodologies to generate CHL-P90 products taking into account the quality of the considered CHL time series and correct for possible sampling irregularities.

Introduction

The Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) are important drivers for monitoring the coastal and offshore waters in Europe with the objective of reaching a 'good environmental status' [1]. Human-induced eutrophication is one of the considered criteria of the good environmental status and is assessed monitoring the chlorophyll a concentration (CHL) as it is a proxy of phytoplankton biomass. More specifically, for countries such as Belgium, the CHL-P90 over the phytoplankton growing season (i.e. March – November incl.) is the parameter of choice as it describes the intensity of the algal blooms during the year. A satellite-based CHL-P90 tool was developed in the framework of the Aquamar project (EU-FP7) which is available in the open-source toolbox and development platform BEAM (VISAT, Brockmann Consult, Germany). This tool allows for an optimal analysis of satellite-based CHL time series taking into account the irregular sampling by satellites during the growing season.

Discussion

Ocean color satellite data enables the calculation of CHL-P90 pixel-by-pixel resulting in a map product which is expected to provide more accurate CHL-P90 estimates compared to the *in situ* data due to an increased temporal and spatial resolution. However, satellite remote sensing is subject to one major limitation: cloud presence can totally or partially cover the area of interest [2]. For the North Sea this generally results in a high percentage of missing data in the daily images. This missing data is not evenly distributed over the year, and thus impacts the standard percentile calculation. This impact is two-fold and dependent on (1) the availability of observations during the actual phytoplankton bloom and (2) a proportional distribution of observations in the bloom and non-bloom periods.

This study has focused on the additional errors generated in multi-temporal products. A detailed sensitivity analysis was performed using simulations techniques (e.g. MIRO&CO-3D ecosystem model) to generate realistic CHL time series for the Belgian part of the North Sea with high temporal resolution ensuring the availability of sufficient reference data for a variety of algal bloom dynamics (i.e. bloom intensity and timing). These CHL time series were subsequently sub sampled using actual pixel specific MERIS sampling frequencies during the growing season 2003 to 2011 and used for the standard CHL-P90 product generation. A direct comparison of these CHL-P90 products with the reference data showed that with the current observation density of the MERIS satellite relative errors of up to 30% on Chl-P90 estimation due to the effects of irregular sampling are not uncommon. The results of this study were used to improve the CHL-P90 algorithms by the use of an interpolation procedure taking into account the CHL time series quality. The interpolation method was used to compensate for sampling irregularities by filling the gaps in the CHL time series. Both methods were compared to the standard CHL-P90 products and reduced the relative errors caused by the irregular availability of MERIS data to 10%-15%.

Conclusions

The proposed interpolation approach provides a method to take into account sampling issues resolving a significant part of this problem without the need for additional data. This method was translated to an operational BEAM-tool. The open source software BEAM is both a toolbox supporting a wide range of optical sensors for Earth Observation and a development platform that allows users to easily create their own visual and data processing tools. The BEAM Graph Processing Framework (GPF) allows users to create EO data processors, and thus facilitates evolutionary processor development. In combination with a number of analysis tools, BEAM supports the full circle of creating and updating an algorithm, (re-)processing data products, validating the results, and deriving new requirements that in turn affect the algorithm's design.

The gap-filling strategies have been made accessible in BEAM by means of the Temporal Percentile Operator, which has been implemented as operator based on the GPF. Its purpose is to compute the 90th percentile threshold for a time series of EO data products. For a given input set of EO data products, the operator produces a new data product which contains a band containing the respective percentile thresholds for each pixel of the input time series. See figure 1 for an example displayed and analyzed in BEAM VISAT. Additionally, the operator creates a per-pixel time series from the daily means of the input products. This time series can be visualized and analyzed in VISAT using the dedicated Time Series Tool extension.

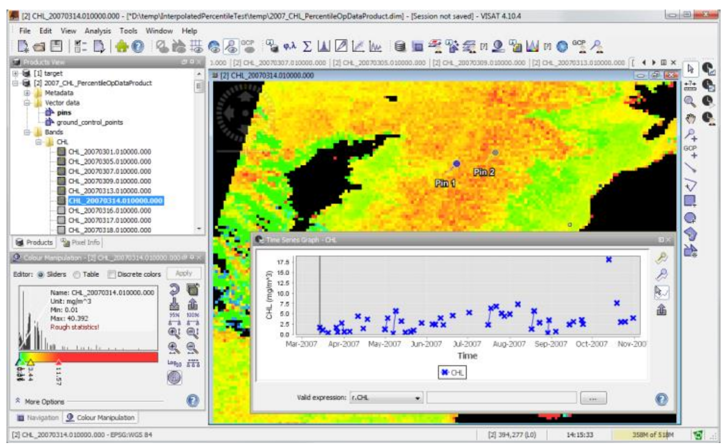

Fig 1. Screenshot of VISAT showing interpolated percentile product

References

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