AQUA-USERS: AQUACULTURE USER DRIVEN OPERATIONAL REMOTE SENSING INFORMATION SERVICES

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ABSTRACT

The FP7 project AQUA-USERS provides the aquaculture industry with user-relevant and timely information based on the most up-to-date satellite data and innovative optical in-situ measurements. Its key purpose is to develop an application that brings together satellite information on water quality and temperature with in-situ observations as well as relevant weather prediction and met-ocean data. The application and its underlying database are linked to a decision support system that includes a set of (user-determined) management options. Specific focus is on the development of indicators for aquaculture management including indicators for harmful algae bloom (HAB) events. The methods and services developed within AQUA-USERS are tested by the members of the user board, who represent different geographic areas and aquaculture production systems.

1. INTRODUCTION

With global population expansion, the demand for high-quality protein is rising dramatically, and fish farming is gaining importance to ensure food security. Aquaculture is one of the fastest growing food production sectors worldwide [1]. Environmental conditions determine the growth and health of the produced species, while the production can release large amounts of nutrients to the surrounding environment. Therefore, monitoring is needed on several levels. However, up to now, the available data are often disparate, inconsistent in coverage and of unknown quality.

2. PROJECT OVERVIEW

To support the growth of efficient and sustainable aquaculture production, the FP7 project AQUA-USERS aims at providing the aquaculture industry with user-relevant and timely information based on the most up-to-date satellite data and innovative optical in-situ measurements. The key purpose is to develop a web portal and mobile application that bring together satellite information on water quality and temperature with in-situ observations as well as relevant weather prediction and met-ocean data. A decision support system underlying the applications will link this information to a set of user-determined management decisions.

AQUA-USERS is a highly user-driven project with a user board consisting of companies and organisations from 5 countries representing different European aquaculture production systems. These users are actively participating by specifying their requirements, and by enabling or collecting measurements at their production sites. Together with the user board, the project partners will demonstrate the applicability of the developed methods and tools in three case studies at their production sites: the first dealing with site characterisation and selection based on historic satellite data, the second with operational management using in-situ measurements and the third case study is extending the second but additionally near real-time satellite data are used in combination with in-situ measurements.

An overview of the AQUA-USERS system is given in Fig 1.

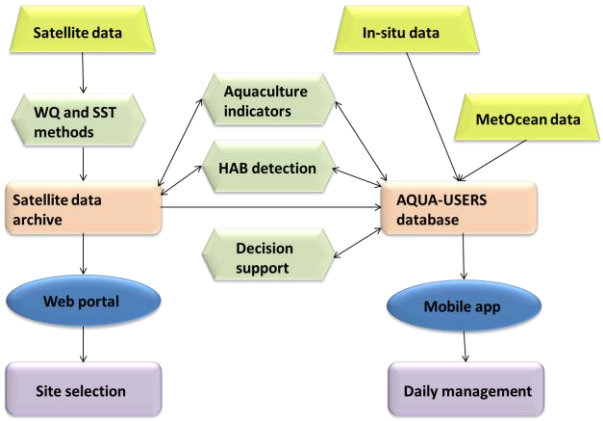

Figure 1. Overview of the AQUA-USERS system

3. DATA COLLECTION

The AQUA-USERS methods and tools are built on optical and thermal satellite data. Hyperspectral and other in-situ measurements provide a strong link between plot-scale phenomena and satellite observations with ample opportunities for further calibration, verification and validation of existing information extraction methods. In addition, met-ocean data from various sources, including environmental models and oceanographic buoys as well as weather forecasts are gathered and used within the system.

3.1. Satellite data

For the study areas, which are the users'production sites, a full archive of MERIS full resolution data has been processed with regionally adapted and validated algorithms for water quality (WQ) parameter retrieval. Together with an archive of sea surface temperature (SST) data based on a number of different sensors, these data serve as a basis for the development of methods for HAB detection and aquaculture indicators as well as for site characterisation and selection. The operational phase in 2016, will preferably be based on Sentinel-3 (S3) OLCI for optical Earth Observation (EO) data. In case these data are not available by that time, a combination of MODIS-AQUA and VIIRS will be used.

3.2. In-situ data

During the whole project all users together with their respective project partners have a WISP-3 field spectrometers at their disposal to additionally measure some of the optical parameters, such as chlorophyll-a (Chl), Total Suspended Matter (TSM), Colored Dissolved Organic Matter (CDOM) and the attenuation coefficient (Kd) as well as the spectral reflectance and inherent optical properties (IOPs). These data are used for algorithm calibration and validation, validation of S3 data and enable continuity of information collection during cloudy days or days without any satellite overpass. The project partners and users also collect additional in-situ data to characterize algal species composition and to distinguish harmful from non-harmful
species

Figure 2. Location of the study sites

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4. METHOD DEVELOPMENT

Based on satellite and in-situ data, a method has been established to derive indicators for potential benefits and risks for aquaculture production based on biogeochemical variables. To improve the detection of HABs with optical methods, two approaches have been pursued: training a detection algorithm with multi-spectral satellite images of known blooms of certain species and modelling of hyperspectral HAB data based on laboratory instruments. We intend to apply these methods in a near real-time case study on operational aquaculture management using OLCI in 2016.

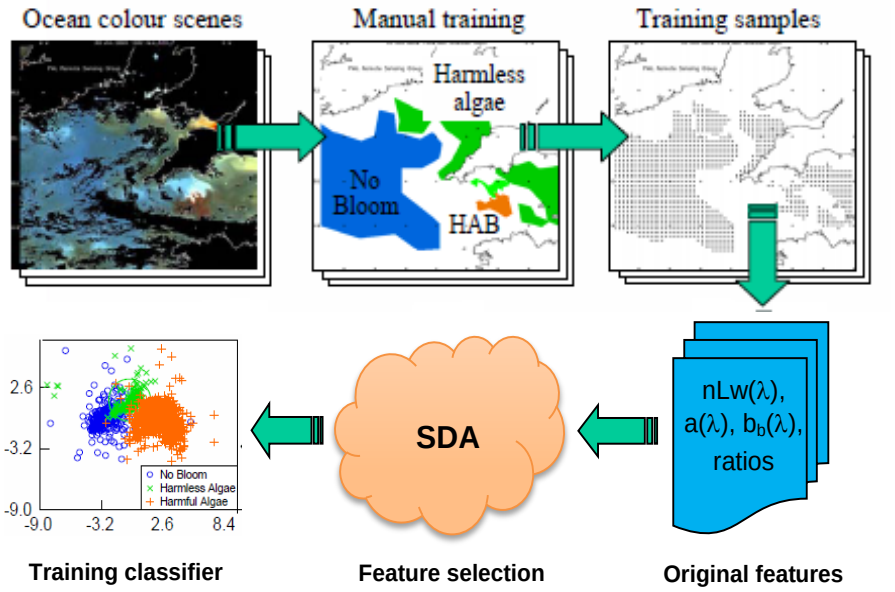

Figure 3. Training of the HAB classifier based on satellite observations (SDA: Stepwise Discriminant Analysis)

4.1. Detection of harmful algal blooms

To improve the detection of HABs with optical methods, the classification algorithm developed by Kurekin et al. [2] is used and developed further. It uses the specific characteristics of water leaving radiances and derived quantities of particular HAB species for automatic detection of HAB events. It uses a fully automatic approach by allowing the classifier to recognize and train itself to the specific characteristics of a HAB. This method can be easily adapted to discriminate different HAB species and extended to work with different sensors, such as MODIS, MERIS or OLCI in future.

Two alternative approaches have been developed for training of the HAB classifier. The first one is based on using multispectral measurements of HAB events provided by satellite ocean colour sensors (see Fig. 3). The image scenes with HABs were identified using case studies and historical records of HAB events. These scenes were applied to train a HAB classifier to discriminate *Karenia mikimotoi* HAB in the UK Southwest Approaches, *Phaeocystis globosa* in the Southern North Sea and *Lingulodinium polyedrum* in Portuguese coastal waters.

The second approach is based on constructing a simulated dataset of HAB measurements using harmful algal cultures grown in laboratory conditions; this research is being prepared for publication.

4.2. Aquaculture indicators

Based on satellite and in-situ data, a method has been established to derive indicators of potential benefits (e.g. food availability as could be indicated by Chl, abundance) and risks (e.g. blooms as generators of hypoxic conditions, presence of toxic species, suspended particulate matter) for the aquaculture production.

The in-situ and satellite data were used to establish the natural variability of several biogeochemical parameters in the regions of interest. Five different regions were considered (i.e. south coast of Portugal, west coast of Scotland, the entire Dutch coast, the Baltic coast of Denmark and the northwest coast of Norway). In-situ data were gathered for each region and statistical analyses were performed to determine natural variability of the areas and to understand region-specific correlations among parameters. Satellite data were also used for the same purpose. For instance, a 10-year time-series of Chl data was analysed to determine phytoplankton bloom phenology from an annual climatology [3]. The Chl climatology was calculated for Chl records (OC-CCI and MERIS-FR) for each region of interest. Several phenology characteristics were calculated, namely, the day of the bloom initiation and end, bloom duration, bloom maximum and day of occurrence, bloom range, day of maximum growth and value, and finally, the perimeter and area of the bloom (example in Fig. 4, from [3]). Integration of all

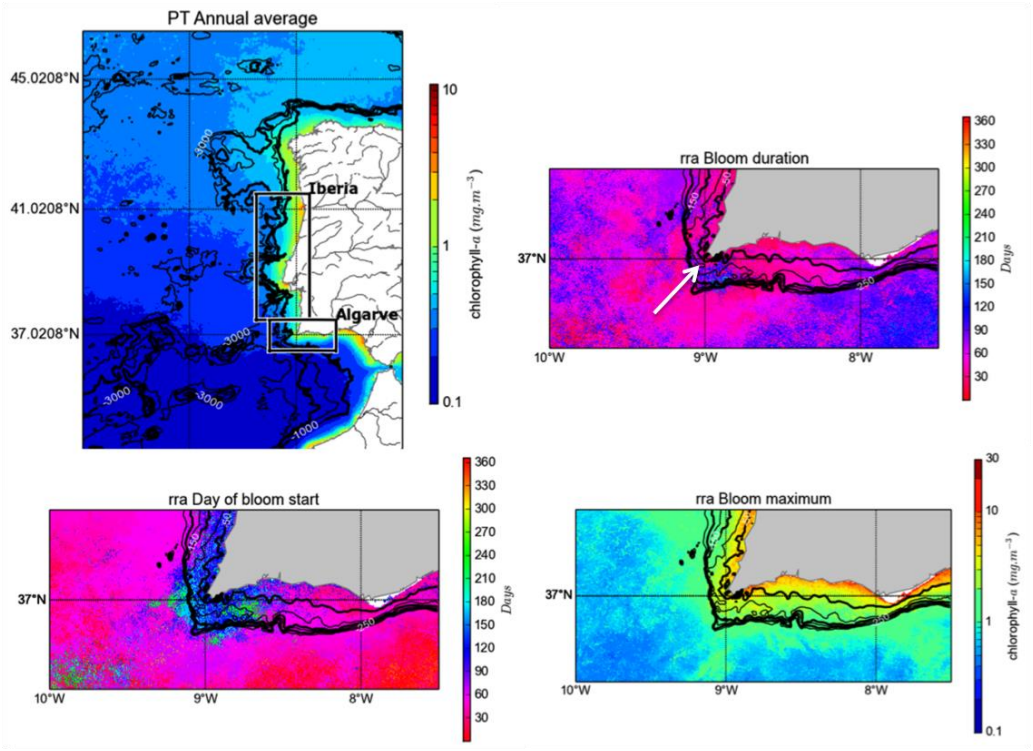

Figure 4. Climatological annual averages of chlorophyll a for the Portuguese coast (top left, from OC-CCI data). Bloom duration (top right, from MERIS-FR), day of bloom start (bottom left, from MERIS-FR) and, maximum (bottom right, from MERIS-FR) for Algarve sub-region. Arrow shows Cape S. Vicente.

information was tested in a case study for the Algarve area in the South of Portugal.

5. TECHNICAL IMPLEMENTATION

All data collected and produced within AQUA-USERS are stored either in the distributed satellite data portal (satellite images and derived maps) or in the project database (in-situ measurements and extracted met-ocean data). The methods developed are mostly implemented as python scripts that interact with these data sources via well-defined standard interfaces. The web portal and mobile app provide two entry points for the users of the system to data stored in the AQUA-USERS database and EO data archive. The web portal gives access to the spatial data contained in the satellite EO data archive as well as the data in the AQUA-USERS database. The mobile app is used for site management tasks providing access to the data in the database and to support management decisions generated by decision support tool.

5.1. Web portal

The AQUA-USERS web portal is a simple-to-use web application which allows users, both scientific and non- the context of a background map and generate plots showing the variation of the selected datasets over time. A screenshot of the map viewing interface is given in Fig. 5.

The complete portal is actually a combination of several distinct applications. The web map interface, the plotting application and data service middleware. The web map interface acts as the front end, i.e. what the user interacts with. When the user requests analysis of data the configuration is passed to the plotting application that makes use of the python middleware to fetch the data and produce summary statistics. Finally the plotting application responds with the actual plot and control is returned to the web map interface.

5.2. Mobile app

The main function of the mobile app is to allow the users access to the data stored in the AQUA-USERS database and to the decision support tool for on-site management. The app allows the user

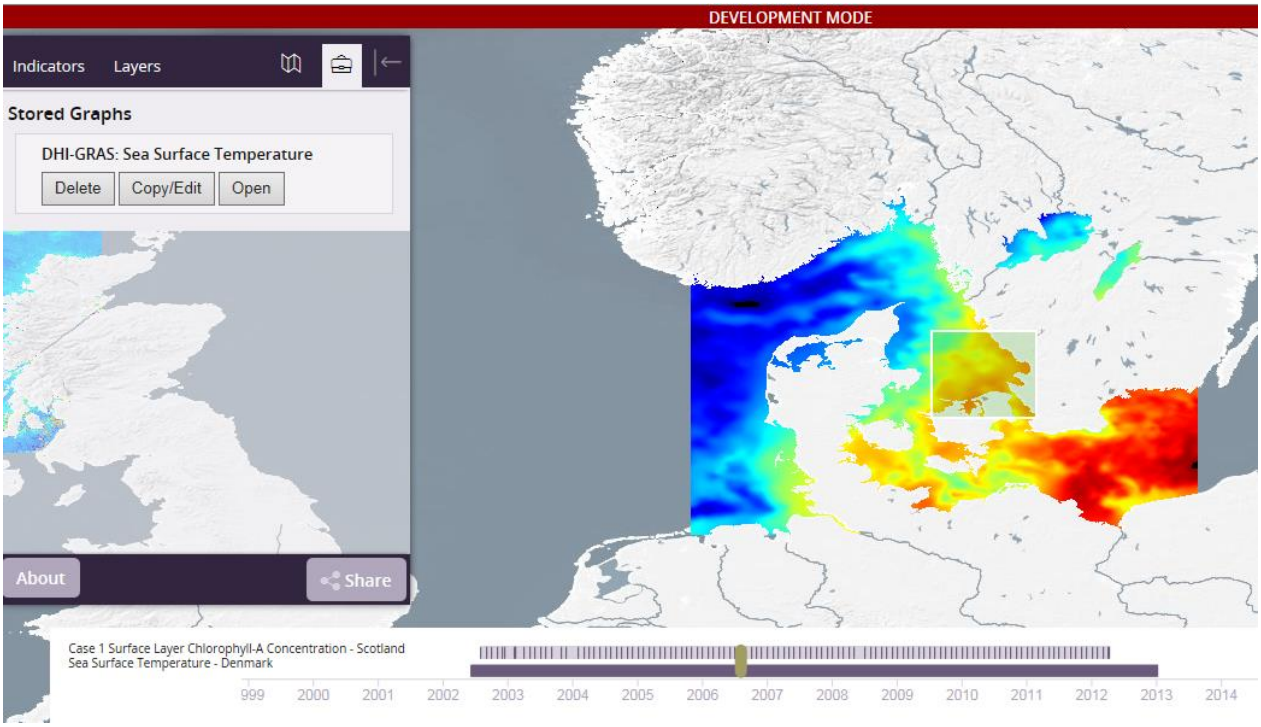

Figure 5. Screenshot of the AQUA-USERS web portal

- to view recent water quality and met-ocean data at their site including temporal evolution of selected parameters as well as how they compare to long-term time series
- enter their own measurement values
- record management decisions taken
- review decisions taken earlier

Once a substantial database of management decisions, the conditions under which they were taken and the evaluation of their effectiveness by the user is available, the app can also suggest decisions based on these records.

6. CASE STUDIES

Three case studies are conducted in close collaboration with the user board to test and improve the developed methods and tools.

Case study 1 is focussed on site characterization and selection based on the processed archive of the ENVISAT satellite and historic in-situ observations. The results will allow the users to critically analyse the wider area around their sites and select potential new locations based on criteria which will be developed in accordance with the user requirements.

Case study 2 is focused on daily management using optical in-situ measurements. For this case study, the users will be provided with the AQUA-USERS app, which will in this phase be run mainly with optical in-situ measurements taken with the WISP-3. These measurements will help to characterise the conditions at the users' sites. The app will be tested and tailored in particular with regard to the potential management options. Feedback will be integrated back into the app to improve decision support.

Case study 3 will bring together all AQUA-USERS developments. The app will be run in operational mode combining high-quality EO data provided by the AQUA-USERS consortium, met-ocean data from third parties as well as the in-situ data measurements taken by the users to provide the most complete as possible picture of the environmental and ecological conditions at users production sites. The wealth of data will help the users to make well-informed decisions in their daily management. The decision support system will further assist them in recording and critically assessing the effectiveness of the measures they take.

7. STATUS AND FUTURE WORK

The method development and implementation is almost completed and the first case study is well under way. In the second and third case studies, the developed methods and tools will be applied, verified and refined in close collaboration with the user board.

8. ACKNOWLEDGMENT

The research leading to these results has received funding from the European Community's Seventh Framework Programme ([FP7/2007-2013]) under grant agreement N° 607325.

For more information: http://www.aqua-users.eu/

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