Research Executive Agency

Marie Curie Actions – Life Long training

Project No.: 255396

Project Acronym: AQUALIGHT

Project Full Name: New methods of aquatic hyperspectral light field analysis for the concurrent characterisation of physical and bio-optical processes at small scales

Marie Curie Actions

IEF Final Report

Period covered: from 01/07/2010 **till** 30/11/2012

(with 5 months suspension from 11/2011 till 04/2012)

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Project Scientist in Charge: Dr Jaume Piera

Host institution: CSIC, Spain

Date of submission: 31/01/2013

1. Final Publishable Summary Report

This section normally should not exceed 2 pages.
This is a comprehensive summary overview of results, conclusions and the socio-economic impacts of the project. The publishable report shall be formatted to be printed as a stand alone paper document. This report should address a wide audience, including the general public.
Please ensure that it:
- Is of suitable quality to enable direct publication by the REA or the Commission.
- Is comprehensive, and describes the work carried out to achieve the project's objectives; the main results, conclusions and their potential impact and use and any socio-economic impact of the project. Please mention any target groups such as policy makers or civil society for whom the research could be relevant.
- Includes where appropriate, diagrams or photographs and the project logo, illustrating and promoting the work of the project.
- Provides the address of the project Website (if applicable) as well as relevant contact details.

The EU funded research project AQUALIGHT (www.aqualight.info) was focused on the marine environment of Alfacs Bay, an important aquaculture site in the NW Mediterranean where recurring outbreaks of harmful algal blooms (HABs) lead to severe economic impacts for the local fishermen, mussel farmers (who lose their harvest), and the tourism industry. HABs are a global phenomenon. In Alfacs Bay they are caused by small algae (phytoplankton) that release toxins into the water. These toxins are harmful to fish and mussels and can become lethal to humans if such contaminated seafood is consumed. There are thousands of known and mostly non-toxic phytoplankton species in the world's oceans but due to their small size (often only a few micrometres) they are difficult to detect.

Phytoplankton are plants, which means that they harvest the available sunlight and convert it through the process of photosynthesis into organic compounds. One elegant and nonintrusive method to detect the presence of phytoplankton is to measure this light absorption at a high spectral resolution (hyperspectral). As different phytoplankton species or groups have slightly different absorption spectra, the hyperspectral data can be used to detect and distinguish different phytoplankton groups. Our original aim was to further develop already existing methods based on hyperspectral optical data and apply them to the site of Alfacs Bay and the harmful species present there. This original approach had to be modified, however, as the necessary equipment to carry out hyperspectral measurements was not available at the institute hosting this project. The scientific focus was therefore shifted towards characterizing the recurring phytoplankton blooms in Alfacs Bay using other observational methods in combination with a 3D modelling approach, which resulted in newly formulated objectives: (i) increase our understanding of how these blooms are formed, by studying the small scale processes which govern phytoplankton growth in Alfacs Bay; (ii) detect which environmental conditions facilitate bloom development and maintenance; and (iii) identify the driving factors that govern bloom dynamics (in particular the observed species succession over the course of a year).

During several cruises we collected large amounts of field data and set up several models to study the small scale processes such as turbulence mixing and light availability and variability in Alfacs Bay. Unlike terrestrial plants, phytoplankton are not rooted in place at the earth's surface but are being mixed through a turbulent and often turbid ocean. Light, their primary resource, is not as constant in such an environment as on the earth's surface, as the ocean itself absorbs part of this solar energy, the ocean is turbid. A more turbid ocean will absorb light more rapidly than a less turbid one. Coastal oceans (due to their proximity to land and the rivers which carry large amounts of sediments with them) are typically more turbid than the open ocean. In Alfacs Bay the turbidity is therefore quite high.

The photosynthetic performance of a cell greatly depends on the light environment, and in particular the intensity, and variability of the light. Vertical mixing by turbulence causes the cells to move up and down through the water column and if this water column is very turbid, these vertical movements can lead to rather large variations in the light availability over short periods of time. Phytoplankton possess mechanisms which allow them to adapt to the ambient light in order to make the best possible use of it. If, however, the light environment changes too rapidly, phytoplankton cannot adapt to the changes in time and may therefore experience sub- or supra-optimal light intensities which can damage the cells. We therefore studied how the turbulent intensities can affect the photosynthetic performance of a cell. By coupling an individual based turbulence model with a radiative transfer model we found that the light variability can indeed be very large with cells experiencing jumps of over 1000 µmol photons m^{-2} in the available light intensity in time periods as short as 1 minute which can lead to significant stresses for the cell. Also the overall light dose (amount of light received by a cell over a certain amount of time) depends on the turbulence intensity. As these quantities are impossible to measure on a cellular basis *in situ*, it is necessary to employ numerical models. To our knowledge we have carried out the first study of this kind, providing new insight into the small scale processes that govern not only phytoplankton growth but many other related processes: the light dose, for instance, is relevant for climate studies as it affects not only the uptake of the know greenhouse gas, CO_2, but also the production of countering agents such as DMS (dimethylsulfide - a cloud producing gas that may alleviate part of the temperature increases). Other fields for which these results are relevant include some of the more fundamental aspects of photo-physiology as the amount of ultraviolet light received by a cell directly affects processes such as photo-inhibition.

In an effort to improve out field sampling, we also set up a different model which examined the validity of current methods for measuring phytoplankton growth and productivity. The standard approach sees phytoplankton suspended in clear plastic bottles at a fixed depth in the water column for a fixed period of time (typically 24h). Growth is determined by measuring the increase of either carbon or chlorophyll in the bottles (sometime also cell numbers). We could show that these traditional methods have to be used with caution and careful planning as they can have large errors associated with them. Incubating the cells in bottles, neglects any effect on growth due to turbulence which would normally prevent phytoplankton from remaining at a fixed depth. This has led to improved sampling protocols in the field which now aim to minimise this error.

Furthermore we employed a 3-dimensional physical model of Alfacs Bay in order to examine the role that physics plays in the development and maintenance of blooms inside the bay. By simulating different meteorological scenarios (the main forcing for vertical mixing is due to the meteorology as the Mediterranean only exhibits very small tides). We could demonstrate that under low wind conditions, the bay shows a typical estuarine circulation in which salty Mediterranean water enters the bay at depth and fresher water (introduced as run-off from the adjacent rice fields) exits near the surface. In such a situation the loss of phytoplankton cells from the bay is rather large resulting in a reduced residence time and a reduced chance for bloom development. If the wind speed is high, on the other hand, the estuarine circulation breaks down and the residence time of cells inside the bay is greatly increased. This is generally advantageous for the cells, as Alfacs Bay is relatively rich in nutrients compared to the rather oligotrophic (low nutrient) open Mediterranean Sea, and a longer residence time in the bay therefore means better growth conditions and a higher probability of bloom formation and maintenance.

The long term goal for Alfacs Bay is to reach a level of understanding which would eventually allow for predictions to be made and the establishment of early warning systems. This could assist local policy makers to reach informed and timely decisions which would help reduce the economic impact on local fishermen and the tourism industry. Due to the ubiquitous nature of HAB events, the knowledge gained in this project is also of relevance to other locations around the globe which suffer from recurring HAB outbreaks.

2. Use and Dissemination of Foreground

Section A (public) – Dissemination measures

This section should describe the dissemination measures, including any scientific publications relating to foreground and specify any applications for patents etc. Its content will be made available in the public domain thus demonstrating the added-value and positive impact of the project on the European Union.

Dissemination activities

Part of the work has been published in scientific articles which are either submitted/under review:

1. ML Artigas, C Llebot, ON Ross, NZ Neszi, V Rodellas, J Garcia-Orellana, P Masquéd, J Piera, M Estrada, and E Berdalet, 2013. “Understanding the spatio-temporal variability of phytoplankton biomass distribution in a microtidal estuary: is Alfacs Bay a phytoplankton bloom incubator?”. Deep Sea Research, *submitted*.
2. E Berdalet, ML Artigas, C Llebot, ON Ross, NZ Neszi, J Piera, M Estrada, 2013. “Phytoplankton variability modulation by hydrodynamics regime in Alfacs Bay (NW Mediterranean). A combined experimental and modelling study”. ISSHA Proceedings, *submitted*.

or already published (all as **open access articles**):

3. ON Ross, RJ Geider, E Berdalet, ML Artigas and J Piera, 2011. “Modelling the effect of vertical mixing on bottle incubations for determining in situ phytoplankton dynamics. I. Growth rates”. Mar Ecol Prog Ser 435:13-31, doi:10.3354/meps09193.
4. ON Ross, RJ Geider, and J Piera, 2011. “Modelling the effect of vertical mixing on bottle incubations for determining in situ phytoplankton dynamics. II. Primary production”. Mar Ecol Prog Ser 435:33-45, doi:10.3354/meps09194.
5. G Llaveria, E Garcés, ON Ross, RI Figueroa, N Sampedro and E Berdalet. 2010. “Small-scale turbulence can reduce parasite infectivity to dinoflagellates”. Mar Ecol Prog Ser 412:45-56.

Furthermore, there are currently two more articles in preparation which will be submitted this year.

Part of the results have also been presented at the following international conferences:

1. ON Ross, RJ Geider, E Berdalet, ML Artigas and J Piera "Modelling the effect of vertical mixing on bottle incubations for determining *in situ* phytoplankton growth rates" 15th International conference on Harmful Algae, Changwon, S Korea. November 2012.
2. ON Ross, E Torrecilla, M Ramírez-Pérez and J Piera "Hyperspectral variability of photosynthetically active radiation experienced by phytoplankton in the oceanic surface mixed layer" XXI Ocean Optics conference, Glasgow, Scotland. October 2012.
3. ON Ross, E Torrecilla and J Piera "New Methods of Aquatic Hyperspectral Light Field Analysis for the Concurrent Characterisation of Physical and Bio-optical Processes at Small Scales" 2012 ASLO Aquatic Sciences Meeting, Lake Biwa, Shiga, Japan. June 2012.
4. ML Artigas, ON Ross, R Quesada, J Piera, E Berdalet. "Swimming and sinking in Alfacs Bay: survival strategies in a weakly turbulent and stratified water column" 14th International conference on Harmful Algae, Hersonissos, Crete, Greece. November 2010.

As member of the GEOHAB scientific sub-committee of the Core Research Project "HABs in Stratified Systems", the project beneficiary co-organised a workshop in August 2012 at the Monterey Bay Aquarium Research Institute in California, USA, and presented part of the result in 2 oral presentations.

In addition, a website has been set up in 2010 at: http://www.aqualight.info/ where the final results including this report will be published.