ASIMUTH: Applied simulations and integrated modelling for the understanding of toxic and harmful algal blooms.

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Abstract:
GMES (Global Monitoring for Environment and Security) is the European Initiative for the establishment of a European capacity for Earth Observation. Through the ASIMUTH project, scientists and industry from 5 countries along Europe’s Atlantic Margin will form a network to produce the first realistic HAB advisory and forecasting capability as a GMES downstream service to the European aquaculture industry. The early warning of severe blooms will allow fish and shellfish farmers to adapt their culture and harvesting practices in time, in order to reduce potential losses.

In recent years there has been much discussion of satellites being able to track surface algal blooms. Understanding biological phenomena in the ocean requires a more complex approach than this, though there is some merit in using satellite derived chlorophyll images to delineate high biomass near surface algal blooms. Much cutting edge HAB research work has focused on subsurface profiles, where certain HAB species are present in thin layers of limited geographical extent often associated with strong density interfaces. Clearly, in order for a toxic/harmful algal bloom forecast to be realistic, physical factors including changes in water column structure and transport pathways are necessary. ASIMUTH is the next step towards providing an operational advisory service by integrating these physical drivers (derived from GMES downstream services) with all available biotoxin, phytoplankton count and bioassay data. A distributed advisory manned service desk and thematic experts distributed across the participating countries will network to provide regular advisory products and forecasts of impending toxic and harmful algal events.

Introduction:
Harmful algal blooms are known to periodically produce toxicity in shellfish and to kill farmed fish throughout Europe. The Atlantic coast of Europe is often affected by such blooms causing devastation to aquaculture industries due to closures of farms and large scale fish kills. There has been an increasing frequency and duration of HAB events off Northern Europe and several Mediterranean countries reported in recent years leading to requirement for intensive management of the problems and attempts at forecasting and mitigation against shellfish and finfish mortalities. (EUROHAB, 1999). This management of shellfish toxicity is well developed along the Atlantic margin in response to EU Directives, and the caged fish culture has also developed protocols to react to harmful blooms. Identification of the origins of HAB events is essential to policy makers and industry since the only mitigation action possible lies in their prediction as these are naturally occurring. Having the ability to forecast when such events might occur to give advanced warning of the impending problem to the aquaculture industry could be a very valuable tool. Many studies have elucidated the ocean circulation patterns along Europe’s Atlantic coast and today, mathematical models produce acceptable hindcasts of previously observed circulation patterns and short term prognostic forecasts. Satellite remotely sensed
images of chlorophyll and temperature are also extremely valuable in detecting high biomass surface blooms of plankton and the oceanic features that often delimit their extent. Using a combination of both modeling and satellite image analysis the ASIMUTH project will produce short-term forecasts of harmful algal events along the European Atlantic coasts and deliver these data using mobile phone and internet technology. Aquaculturalists will be able to use these forecasts to plan harvesting operations or to alter husbandry practices at finfish sites temporarily while a harmful algal bloom passes through a particular area.

A collaborative project entitled Applied Simulations and Integrated Modeling for the Understanding of Toxic and Harmful Algal Blooms: “ASIMUTH” has been accepted for funding under the FP7 Theme 9 (Space) and will commence in the next year involving partners from Ireland, France, Spain, UK and Portugal.

GMES and Marine Core Services
Over the past few years there has been much discussion of satellites being able to track surface algal blooms. While surface discolourations due to algal blooms may be in many cases important to report, there are many non-harmful surface blooms, and alternatively, many examples of sub-surface harmful Bloom that may be missed by the sole use of satellites. Understanding the specific dynamics associated with various harmful species and assimilating information from historical bloom development and trajectories of these species in response to physical oceanography is necessary to forecast their movement. Much cutting edge HAB research work in recent years has focussed on thin layers, where HAB species are present in thin (<1m in thickness) layers of limited geographical extent often associated with strong density interfaces in the water column (Donaghay et al. 1997; Xie et al. 2007). Clearly, a HAB forecast needs to factor in changes in water column structure (including likely areas where HAB species will be retained) and transport pathways in order for such a forecast to be realistic. The forecast should also include all available biotoxin, phytoplankton count, bioassay data and satellite imagery of a bloom to support the model forecast.

GMES has developed and is overseeing the implementation of the Marine Core Service (MCS) as one of a number of fast-track operational services in Europe. The MyOcean project will deliver the key elements of the MCS to the intermediate user community. There has been significant progress made within the intermediate user community through the establishment and effective working of Regional Operational Oceanographic Systems (ROOSes) under the EuroGOOS umbrella, such as the North West Shelf Operational Oceanographic System (NOOS) and the Iberia, Biscay, Ireland Regional Operational Oceanographic System (IBI-ROOS).

There is now scope to provide a worthwhile HAB forecasting downstream service to the aquaculture industry using the combined model forecasts, satellite imagery and in-situ networks that the MCS and intermediate users will provide, combined with an array of biological samples collected and the expertise provided by HAB biology experts. ASIMUTH scientists and industry in 5 European countries will design and implement a realistic HAB forecasting capability as a GMES downstream service to users, in this case the European aquaculture industry along Europe’s Atlantic Margin. The early warning of severe blooms will allow fish and shellfish farmers to adapt their culture and harvesting practices in time, in order to reduce potential losses and in turn increase their productivity.

Objectives
The novel scientific aspects of ASIMUTH are summarised as:
• Objective 1. The identification of key past events which will be re-analysed and used for training the modelling system
• Objective 2. Incorporation of Kopernikus (GMES) Marine Core Services (MCS) with the above selected events will be used to develop model based hindcast products. These will be used to tune the system and move towards an operational model for forecasting events.
• Objective 3. Design of regional model systems and delivery of nowcast for specific HABs and Location information, transport pathways, remote sensed data.
• Objective 4. Population of HAB-TAC (Thematic Assembly Centre) from relevant data streams (phytoplankton, biotoxin, satellite, in-situ, etc).
• Objective 5: Provision of expert interpretation of the available data by way of the web-portal which will be carried out on a periodic basis depending on risk. This assessment will be then issued via a warning system to end users.

Benefits of the Project

This project is firstly intended to complement the information already published and advisory bulletins issued by competent authorities and other institutes regarding micro-algal events that are detrimental to shellfish and finfish. The Institutes collaborating on this project are already at the forefront of international research activities in the area of harmful algal blooms having completed several EU and nationally funded research projects in the past. The EU are currently making changes to the testing procedures for the detection of algal toxins and several of the Institutes have been involved very closely with the development and validation of many of these new methods. ASIMUTH is a very important project to complement these new methods in adding extra information to the monitoring programmes by the integration of GMES downstream services and making these accessible to the shellfish industry. The project will combine all available information in an accessible and easily understandable guide to the situation regarding risk from impending blooms will be prepared and published in the form of a regular bulletin. The project takes the approach that using sophisticated and state of the art technology to assess current and impending HAB events is only beneficial if the focus is on operational useable outputs rather than high end scientific modeling.

Progress beyond state of the art:

The existing difficulties in predicting algal blooms are various. There is huge field variability within even small geographic areas that may result in very significant and localised patchiness in the impact of a HAB. This makes the provision of operational advice and prediction difficult to provide. The utilisation of models, satellite data and in situ data in combination are essential in advancing this. There have been a number of excellent related projects in recent years. ASIMUTH aims to build upon the excellent science conducted as part of various previously funded EU research projects including:
• HABES: attempting to develop an expert system for HABs based on the fuzzy logic approach.
• HABIT: examining the development and dispersion of HAB populations in sub-surface thin layers.
• FINAL: examining the factors that lead to the development of blooms of two harmful species, Alexandrium and Pseudo-nitzschia.

The consortium is acutely aware of the productive research overseen by GEOHAB and indeed the ASIMUTH consortium comprises GEOHAB members who have taken part in many of the key recent workshops on HABs. Some previous projects (e.g. INTERREG funded FINAL project, ECOHAB Gulf of Maine Project, FP6
HABES) have attempted to use models in the prediction of blooms and their impacts. The products of these efforts have gone part of the way in addressing the advisory mandate of regulatory authorities. Other projects such as ECOHAB in Gulf of Mexico have gone operational and produce regular forecasts of impending events. These projects have shown the benefits and potential of incorporating models in prediction of harmful algal events.

The ASIMUTH project takes the output of the Marine Core Service of GMES, synthesizes these using models, and along with other sources of information, including in situ monitoring data, will apply a human layer of expert evaluation in the prediction of potentially harmful events. This human expert intervention is a Unique Selling Point of the ASIMUTH project. This is different to earlier projects because they were limited due to restricted or specific geographical areas and/or unique sets of events. In other cases modelers are developing very specific and detailed small scale aspects of HAB processes. These approaches will refine future models, but the ASIMUTH project takes the approach that a human layer is necessary in the process of turning data into knowledge and advice, and can rapidly assimilate, through application of experience and awareness of current and historical events a valuable forecast of HAB impact. In the context of core marine services of GMES, the MyOcean project is a potential source of very important in situ, satellite and model outputs that will be incorporated into ASIMUTH. The interpretation of these data into advice products make this a unique approach to forecasting along the west coast of Europe.

Fig 1: Concept of ASIMUTH from information synthesis to advice products.

**HAB models in Europe:**

Physical processes have been reported as the primary transport mechanism controlling bloom transport in all HABs (Anderson et al., 2005). Coastal currents driven by wind, density, or other physical forcings can transport these developing blooms hundreds of kilometers along the coast. Understanding and observing these pathways is vital in the mitigation of potential harmful impacts and the provision of
sound management advice. Along the west coast of Europe the shoreward delivery of offshore water has been shown in several instances to be an important preliminary mechanism leading to the establishment of harmful blooms in areas of aquaculture (Fraga et al. 1988, Raine and Mc Mahon 1998, Silke et al. 2005)

The ASIMUTH partnership includes HAB scientists who have developed and worked on understanding the processes that lead to harmful impacts on aquaculture and other coastal activities due to blooms of microalgae. A number of key locations of important aquaculture activity have been selected as demonstration areas where Models, satellite imagery and local monitoring information may be assimilated and nowcasts and advisory bulletins will be produced. For example studies of the oceanographic conditions at the end of the upwelling season in the NW coast of the Iberian Peninsula have shown that an inshore poleward current advecting warm water is present following upwelling events. It is suggested that the inshore current, could advect initial populations of dinoflagellates to the Rias from northern Portuguese waters. Harmful blooms such as the PSP producer G. catenatum have been found usually in Portuguese waters several weeks before the Galician Rias, which concurs with the northward current. Furthermore, cells of this species have not been found in waters of the offshore poleward counter current (Sordo et al. 2001).

In SW Ireland, The effects of coastal currents, upwelling, and estuarine entrainment in transporting blooms have been acknowledged for some time. More recently, the influences of coastal and tidal fronts, wind forced water exchanges in bays, coastal jets and gyres have been studied in relation to HABs. The presence of a tidal front and its role in controlling the northward flow of water and subsequent advection into shellfish growing areas of the south west have been described (Raine and Mc Mahon 1998). Further development of these concepts will be tested during the ASIMUTH project. In developing predictive models, the availability of satellite remote sensing, phytoplankton counts from multiple sites, meteorological data and some water chemistry, as well as information on the physical characteristics of the sampling sites, provide essential spatial and temporal data sets. A bloom of the fish killing dinoflagellate Karenia mikimotoi in the sea waters surrounding Scotland in 2006 was studied using remotely sensed chlorophyll-a data from Aqua-MODIS. This study indicated that this parameter is a useful early warning indicator of K. mikimotoi in shelf waters off the Scottish west coast, and suggested that the bloom developed in this region prior to its advection to coastal waters.

This paper is an initial introduction to the project and between 2011 to 2013 there will be regular updates on the progress of the project including the ICES Annual Science Conference and at the ICES-IOC working group on harmful algal bloom dynamics.
References


