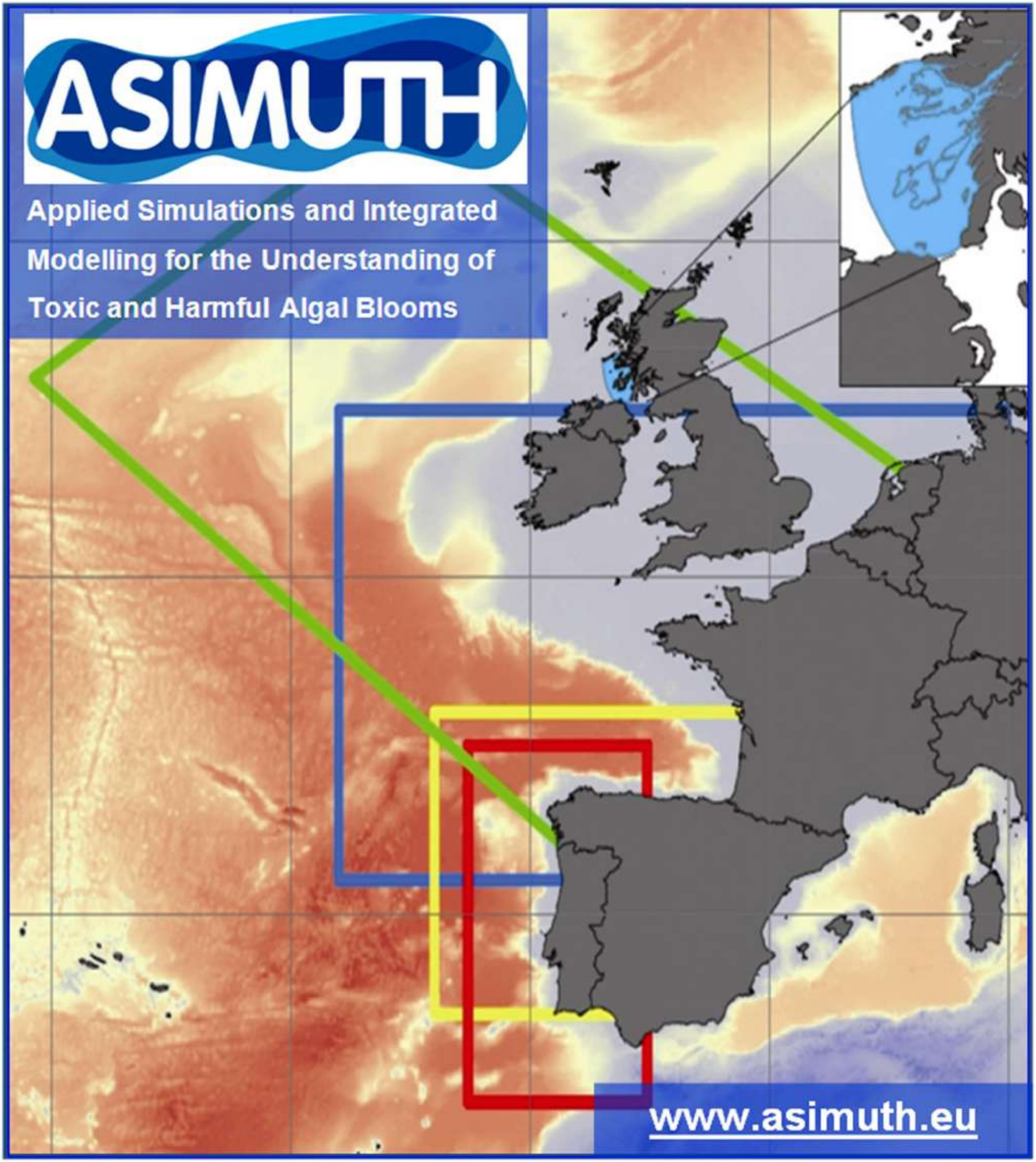
ASIMUTH

Applied Simulations and Integrated Modelling for the Understanding of Toxic and Harmful Algal Blooms



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Toward the development of a HAB forecast system along the NE Atlantic

An Executive Summary **ASIMUTH**, Applied Simulations and Integrated Modelling for the Understanding of Toxic and Harmful Algal Blooms

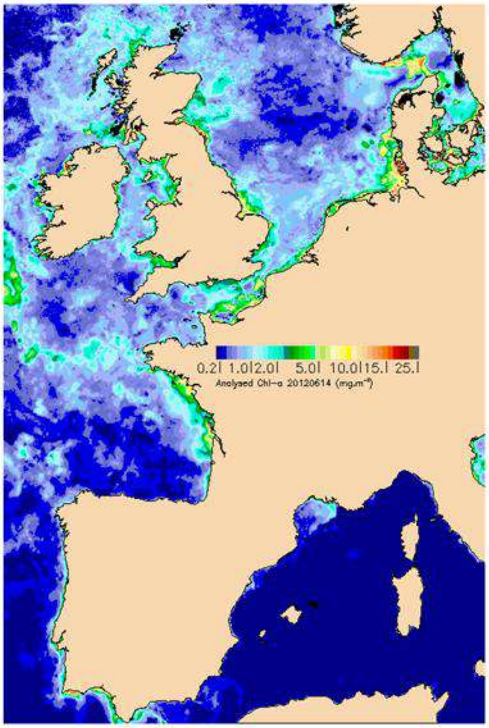
Overview

Harmful Algal Blooms (HABs; a small number of microscopic phytoplankton are responsible for this name) are sporadic, unpredictable and can cause serious disruption for marine stakeholders, particularly those in finfish and shellfish aquaculture.

HAB species are generally harmful in one of two ways; species **directly toxic to humans who eat contaminated shellfish**, and species that form **high biomass noxious blooms** harmful to marine fauna and flora. When filter-feeding shellfish (e.g. mussels) come in contact with HAB species, associated biotoxin levels in their flesh can become dangerously high.

Due to advances in aquaculture food safety practices and regulation across Europe, human safety is now virtually guaranteed. The aquaculture industry can, however, be severely affected through stock losses and closures of bays to shellfish harvesting when HAB events occur. Estimates of global industry losses, and costs associated with people who get sick by eating toxic shellfish cost hundreds of millions of euros per annum.

An early warning of severe harmful algal blooms provides the opportunity for fish and shellfish farmers to adapt culture and harvesting practices in order to reduce potential losses.



Understanding the **onset, intensity and duration** of **HABs** are key economic factors in marine aquaculture and certain leisure activities. Minimising the commercial impact of HABs, by providing time to plan ahead of a HAB event, has the potential to provide significant financial savings.

ASIMUTH (Applied Simulations and Integrated Modelling for the Understanding of Toxic and Harmful Algal Blooms), **aims to provide the first step to develop short term HAB alert systems for Atlantic Europe.**

This goal has been achieved. This HAB warning system provides information on current marine conditions (water characteristics, shellfish toxicity, harmful algal presence etc.) combined with local predictions.

Already, ASIMUTH-based HAB forecasts and bulletins prepared by national experts help aquaculture operators plan their business activities when a HAB event is imminent. ASIMUTH's forecasts and bulletins provide state-of-the-art information to Europeans along the Atlantic seaboard, and allow aquaculturists to plan and manage their farms.

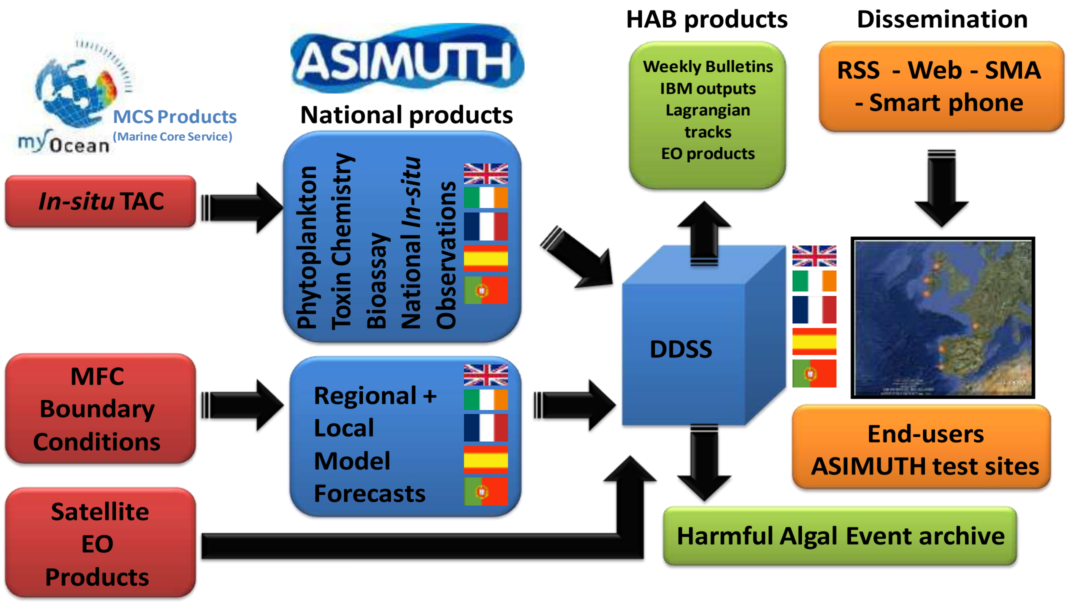
ASIMUTH is co-funded under the EU Framework 7 Programme for Research and Technological Development (2007-2013). Total € 3,237,138

Total Funding awarded € 2,485,244

Project partners

The ASIMUTH consortium brings together a diverse group of partners from Ireland, the UK, France, Spain and Portugal to create forecasting tools and models for the European Atlantic coast.

ASIMUTH work programme



My Ocean = FP7 project, the GMES « Marine Fast Track » project

TAC = Thematic Assembly Centres
MFC = Monitoring and Forecasting Centres

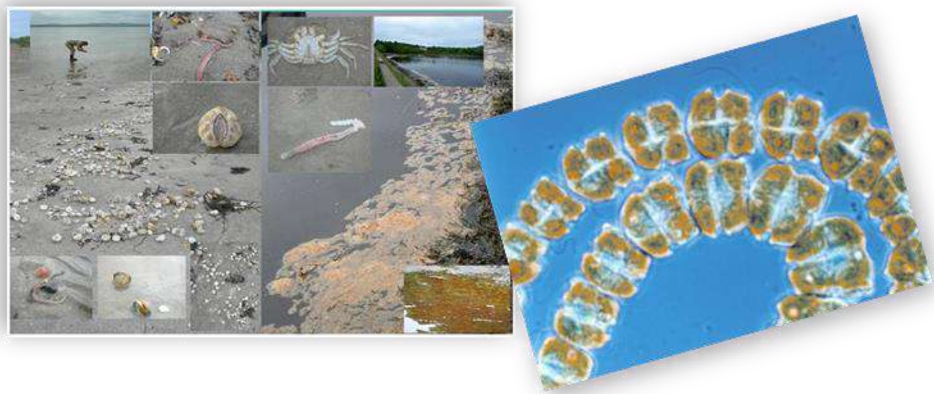
Flow diagram of how ASIMUTH, a pan-European project, planned to develop an online alert system (HAB Forecast) to provide an early warning to the aquaculture industry of imminent harmful algal blooms.

Harmful Algal Blooms

Marine microscopic phytoplankton can cause problems when they either produce biotoxins or accumulate in large numbers, high enough to cause discoloured water (often referred to as red tides although not always red!). HAB

distribution is determined partly by local physical processes (oceanography). Blooms can originate offshore or near shore with seasonal effects varying the species occurring and their abundance. Blooms close to the coast, in some parts of the world, have been attributed to human influences (e.g. eutrophication: agricultural nutrient land run off and ballast water). Physical transport, regulated by sea currents, is the main driver transporting algae populations in and out of coastal areas.

Over the past few decades, the frequency and variety of HAB has increased. Historically, few HAB events were reported, but in recent years numerous coastlines worldwide have experienced negative impacts from them. Possible explanations for this increase could be any of the listed causes above, but also may result from climate change and/or improved phytoplankton and biotoxin monitoring programs and methods.



Examples of some negative effects of HABs:

- marine ecosystem degradation
- increased cost of monitoring programs
- closures of aquaculture production areas
- general reduction seafood sales
  (often unwarranted)
- mortalities of fish and shellfish
- potential human illness

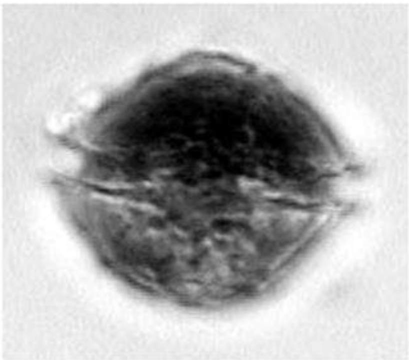
If filter-feeders concentrate algal toxins and are eaten this brings a high risk of human illness that can may be serious. Mild toxicity may cause as little as some nausea, while severe cases may even result in death.

In Europe the most common human syndromes associated with biotoxins produced by phytoplankton include:

Amnesic Shellfish Poisoning with symptoms including gastrointestinal problems, and irreversible **short-term memory loss**. Outbreaks are mainly concentrated in Europe and North America. European legislation has set a limit for this toxin at 20mg of toxin/kg of shellfish meat. The syndrome is caused by a chemical called domoic acid, a biotoxin produced by the diatoms species Pseudo-*nitzschia*.

Azaspiracid Shellfish Poisoning (AZA) is a recently discovered toxic shellfish syndrome. First diagnosed in 1995 in the Netherlands, Europe is the most affected area. Symptoms are mainly gastrointestinal disturbances. Studies show the chemicals, azaspiracid, target organs e.g. liver, spleen and small intestine, it is also implicated with increases in cancer. The dinoflagellate, *Azadinium spinosum*, produces this biotoxin. The limit for azaspiracids is 160 µg/kg of shellfish meat.

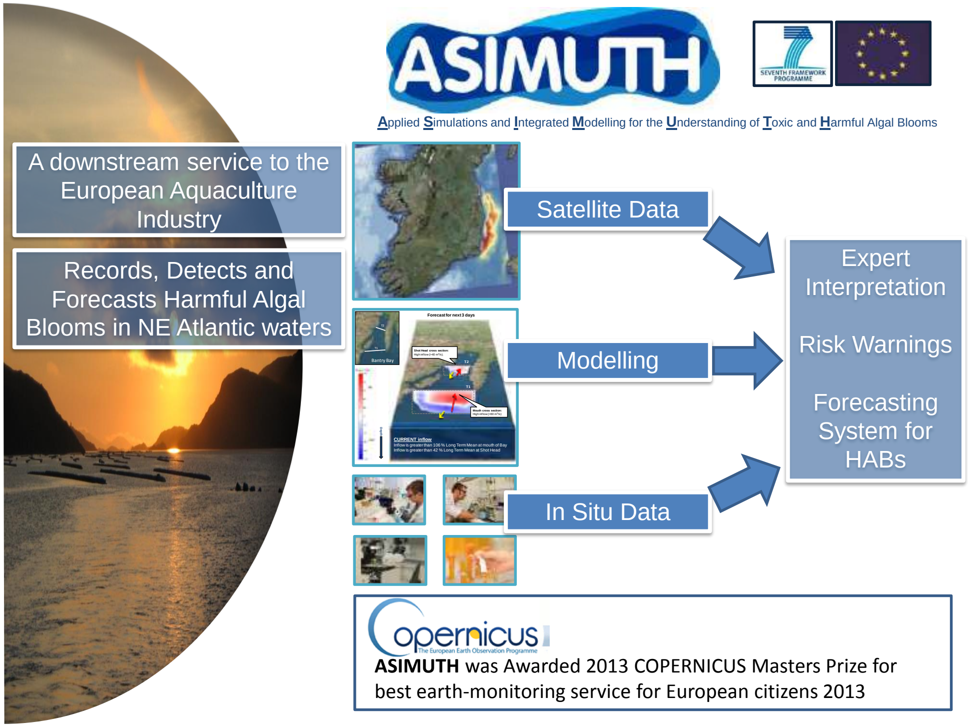
Diarrheic Shellfish Poisoning (DSP)** can be caused by a number of biotoxins including okadaic acid, dinophysis toxins and pectenotoxins. These are produced by dinoflagellate species belonging to two groups: *Dinophysis* and *Prorocentrum.* Symptoms of DSP include diarrhoea, vomiting, nausea and abdominal pain. DSP occurs in mussels at concentrations as low as 100 cells per litre. The EU regulatory limit for okadaic acid is 160 µg/kg of shellfish meat.



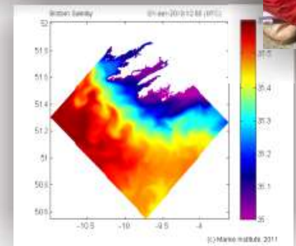
Alexandrium **cf.** *minutum*

Paralytic Shellfish Poisoning (PSP) is caused by a group of biotoxins of which saxitoxin (STX) is the most toxic. STX is produced by three dinoflagellate groups: *Gymnodinium, Alexandrium* and *Pyrodinium*. PSP symptoms include “pins and needles” and, numbness around the lips and mouth spreading to the face and neck which may be accompanied by nausea and vomiting. In severe cases the victim may die from respiratory failure (lack of oxygen). The regulatory limit for STX is 800 µg/kg of shellfish meat.

The HAB nowcast / forecast system



The project used a **combination** of monitoring data, modelling and satellite image analyses **to produce short-term forecasts of harmful algal events along the European Atlantic coasts and deliver warnings**



Project prerequisites

In order to develop a HAB forecast system the ASIMUTH consortium needed a number of things to create integrated, meaningful and useful outputs. These are listed below:

- The co-operation of scientists, policy makers and other stakeholders, especially aquaculture producers.
- Knowledge of regional, physical oceanographic processes and HAB movements (ASIMUTH Oceanographers).
- A selection of test sites where HABs are well understood (information from National Monitoring Programmes - NMPs).
- A suitable selection of target HAB phytoplankton species to research and model (selected by ASIMUTH biologists).
- Integrated understanding and use of all available resources e.g. NMP, observations and simulated data.
- Historical data to develop, validate and fine tune the model(s) of HAB behaviour and movement (ASIMUTH Modellers)

Combining all this know-how and information, the project progressed to hindcast (predict past conditions with model simulations and validate with recorded data) and, finally, forecasting HABs. This approach allows the forecast models to improve with time, essentially “learn” from previous events.

Monitoring

EU regulations require controls are put in place during bivalve mollusc production to protect the consumer from eating toxic shellfish.

European food safety legislation requires member states to designate a National Reference Laboratory (NRL) to ensure these regulations are implemented. In order to monitor biotoxins both water samples and shellfish samples are taken on a regular basis.

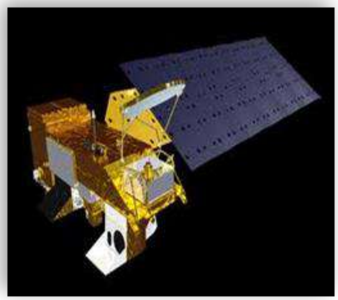
The sampling frequency is reviewed regularly and changes in response to phytoplankton blooms and the current risk status of an area.

A site closes if the biotoxin levels exceed the limit in the legislation and only reopen once there have been two clear samples. Only shellfish from open sites may be harvested and put on the market.

There are a number of methods to detect and measure the levels of biotoxins present in shellfish with legislation regulating the recognised methods of testing for each toxin type. There are a number of kits now available to allow faster and easier analyses.

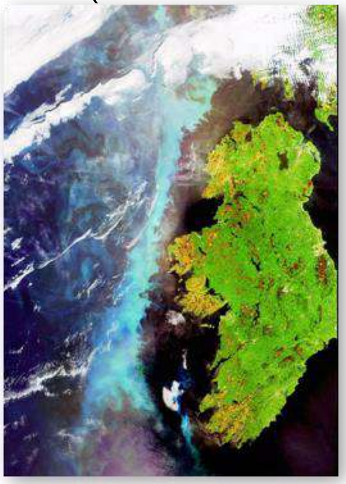
Monitoring programmes collect vast amounts of data, including water quality, phytoplankton cell counts, presence of toxins in shellfish and nutrient levels. These data feed directly into the ASIMUTH forecasting system.

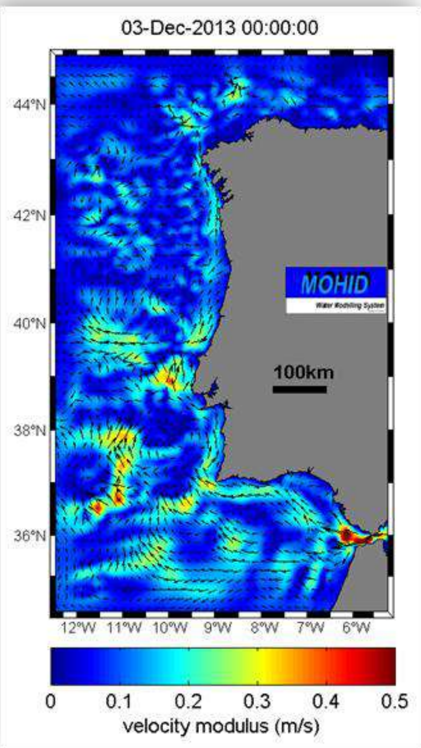
Satellites



Satellite remote ocean colour sensing is used to detect and track high biomass phytoplankton blooms from Space. Sensors detect variation in the amount and colour of light from the water surface, **the variation in reflectance at the sea surface gives an indication of the phytoplankton biomass** in oceanic and coastal areas. This satellite data is then entered into complex formulas allowing the green colour of the pigment chlorophyll (found in phytoplankton) to indicate the presence of high biomass blooms from space observations.

The ASIMUTH project uses ocean colour data from the **NASA's MODIS** (Moderate-resolution Imaging Spectroradiometer) instrument aboard the **Aqua satellite**. Satellite derived Sea Surface Temperature (SST) is also used by the project. The advantage of satellites is that large spatial areas can be covered in one image and this gives the big picture on the current state of the water surface.





When a large bloom is detected then scientists investigate further on the ground to determine the causative phytoplankton species.

Models

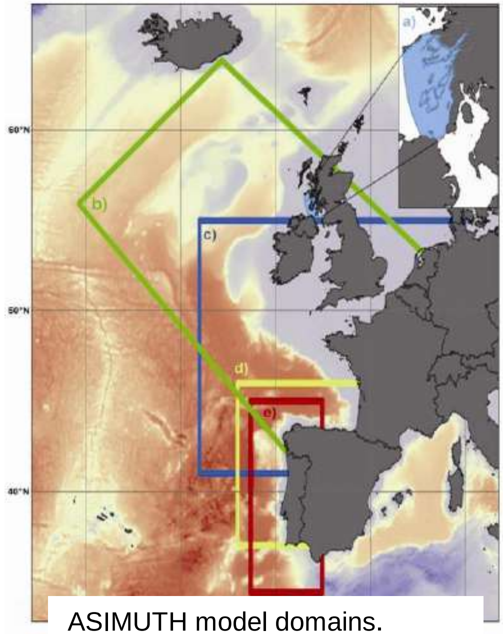
In ASIMUTH two types of models are used to simulate the HAB events: Lagrangian models and Eulerian models. A **Lagrangian model** provides a reliable and fast short-term forecast of the **physical movement** of particles representing **HAB** events. This enables a focus to be given to specific target areas.

Eulerian models, are used to forecast targeted **HAB** species by predicting their **concentration in water** as if it was a dissolved substance. They include information on the behaviour and life-cycle of HAB species and are more complex, uncertain and computationally expensive than Lagrangian models.

All models are limited by the number of processes being modelled, and by the quality of the mathematics being used to cover processes in the ocean.

However when fine-tuned, Eulerian and Lagrangian models are very powerful tools, leading to the ASIMUTH project's effective, consistent value in providing forecast information on HAB development and movement.

A small set of previous economically important HAB events were selected from each country in the ASIMUTH project to create a ***hindcast*** model. A hindcast is essentially a prediction based on data from the past, which allows its accuracy to be checked immediately. These hindcasts were then used to tune and develop a ***nowcast*** and forecasting system.



ASIMUTH model domains. Where a) = Scottish model; b) = Irish model; c) = French model; d) = Spanish NW model; e) = Portuguese model.

The nowcast is a prediction of what is expected to be happening currently based on recent data. Nowcasts allow the next step – development of a forecast. Data from all available resources on this set of HAB events were integrated to build nowcast models (water monitoring, satellites, data buoys, etc.).

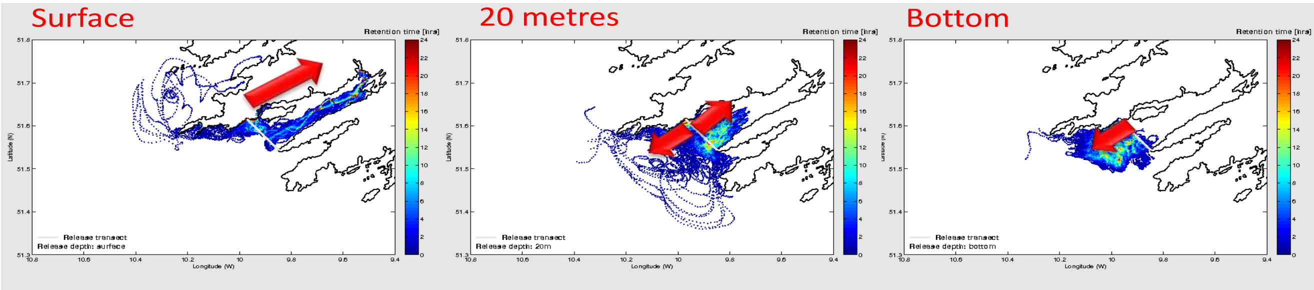
Regional modelling systems were run for specific phytoplankton species and areas corresponding to each of the ASIMUTH partner countries (Scotland, Ireland, France, Spain and Portugal).

The information was validated and fine-tuned based on results of different modelling methods. Then regional models were combined to allow information from each regional model domain to be passed on to adjacent ASIMUTH model domains.

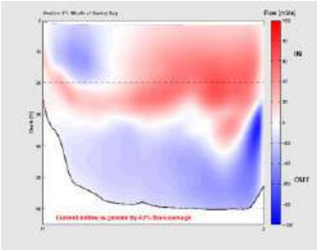
The **models plot projected HAB routes** and **acquire satellite and locally-measured (National Monitoring) data** which all feed into the HABs Distributed Decision Support System (HAB-DDSS, essentially the over-arching tool that forecasting is finally based on, more below).

Taken from the Irish bulletin, the figures below show the predicted water movement in Bantry Bay over three days. Using downwelling events and relevant results from the National Monitoring Programme, the plots show a Lagrangian model prediction of water transport at the time a downwelling event was expected to occur. This prediction is at three selected depths across the mouth of Bantry Bay, an area where ~70% of Ireland's long line rope mussel are produced.

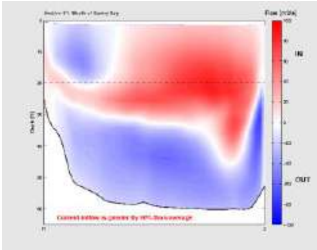
Bantry mouth: 3 day Water Movement Forecast (22 – 24 July 2013)



A Eulerian model of water transport at the mouth of Bantry Bay mouth shows predicted volumetric inflow and outflow of water.



19 -21 July: Volumetric Flux

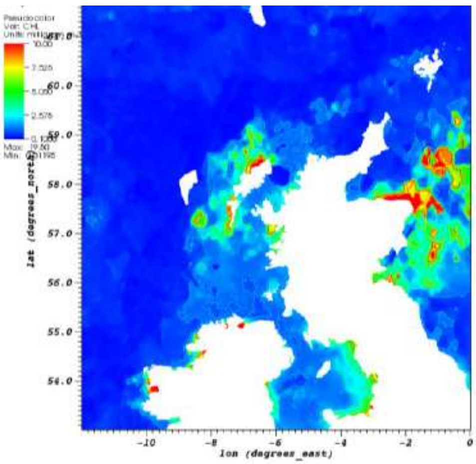


20 -22 July: Volumetric Flux

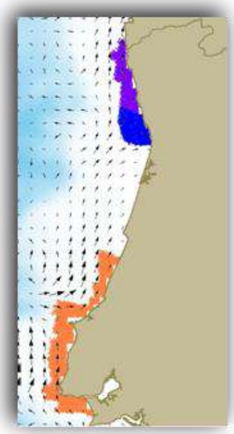
Inflow rates into the bay at the time were 42 % (19 to 21 July) and 90 % (20 to 22 July), greater than long term mean.

Because of the nature of HABs, there will never be an extremely precise predictor of the occurrence of HABs. However, the ASIMUTH forecast provides information on HAB size and likely location, serving as an aid in focusing sampling programs, allowing an efficient and timely response to HAB events and often giving producers time to address imminent threats to stock.

How it all comes together



In ASIMUTH, expert interpretation is considered vital, so the model results are always viewed together with all other available data before a HAB bulletin forecast is generated. **The results are compared with actual measured information and readjusted and re-run to provide the most realistic simulations of HABs**. The ASIMUTH models are constantly refined by experts to make future predictions more precise. The forecast bulletins produced present to the public and aquaculture industry the current state of HABs in each area and the likelihood of a toxic or harmful event of target species over the following week.



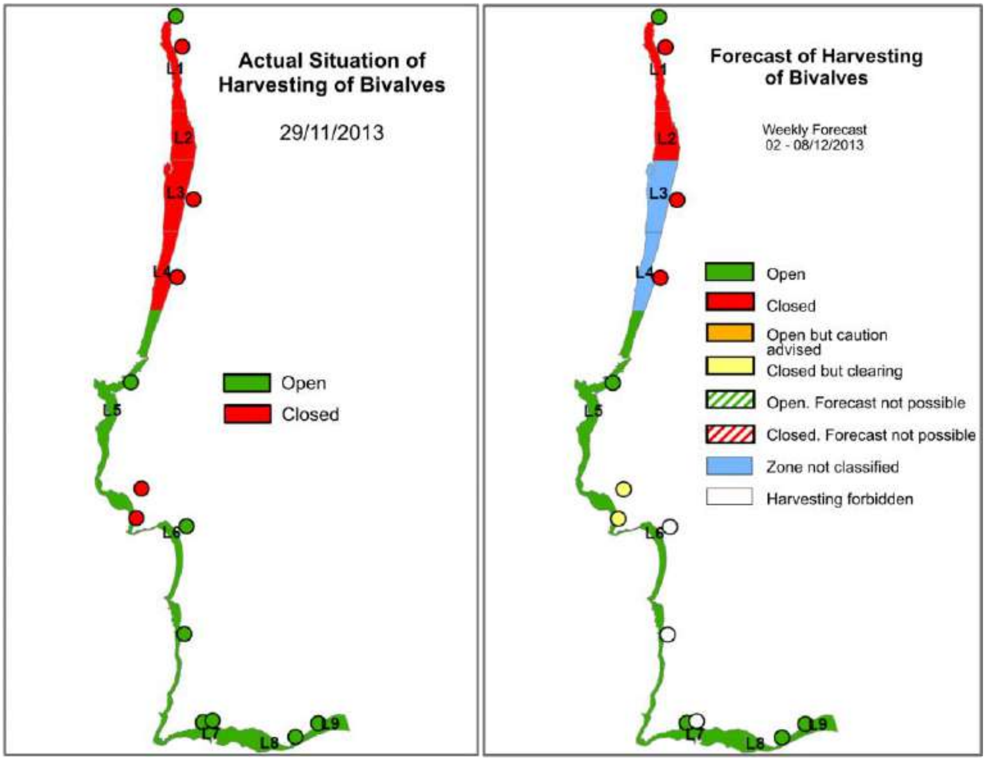
HAB-DDSS

As mentioned previously, the established HAB-DDSS (HABs Distributed Decision Support System) includes model outputs, satellite data, sampled local in-situ data (biological samples including biotoxin chemistry, and phytoplankton counts). The DDSS is designed to provide experts with the tools for straightforward access to all relevant data required in a HAB nowcast or and forecast for each of the 5 partner countries.

Forecast reports

Currently, the primary means for distributing ASIMUTH forecast data is through the project's "**pilot HAB bulletins**" (see: www.asimuth.eu/en-ie/HAB-Bulletin) where expert interpretations of relevant information is reported. The forecast system developed is a marketable tool, and so may be commercialised in the future.

The primary use will be by aquaculture farmers using the forecast and management recommendations to improve farming practices and make informed decisions.



Excerpt from the Portuguese bulletin of actual conditions and forecast for week 49.

Benefits to industry

There are many benefits of a HAB forecasting system, particularly to those in the aquaculture industry:

- **Optimisation of ongrowing and harvesting**, reducing mortalities due to low oxygen levels allowing farmers to harvest stock (particularly shellfish) before production area closures.
- Removing the guesswork on when bay closures will start or end, allowing **informed management choices**.
- Time to move or harvest stock to **avoid imminent blooms**.
- **Planning of husbandry work** in relation to future blooms or HAB-free periods.
- **Reduction of processor downtime** if product can be stockpiled in advance of a HAB event or bay closure.
- **Improvement of service to farmers' customers** allowing a more reliable supply of product.

Outputs from the system will also benefit scientists and government/control agencies, allowing them to adjust sampling times and frequency to coincide with severe or unusual blooms.

ASIMUTH product uses

A survey of current ASIMUTH HAB bulletin users found that 100% of respondents find it useful in decision making. The area they find it most useful in is harvest planning.

While already available online through the ASIMUTH website (www.asimuth.eu/en-ie/HAB-Bulletin) there are further output developments planned, which include SMS messages and perhaps a dedicated smartphone application. For shellfish farmers the warning of an approaching HAB means that any fully-grown shellfish may be harvested before a prolonged bloom arrives. Similarly, fish farmers who have knowledge of an imminent HAB have time to put optimal aeration systems in place or to tow the cages out of the path of the bloom.

The key message of the ASIMUTH project is that using its forecast bulletins, aquaculture producers now have the potential to make informed decisions in the management of their farms and husbandry practices.

Dissemination

ASIMUTH has received publicity in a variety of forms, including reports, peer-reviewed journals, newspapers and conference proceedings. Detailed below are the methods of dispersal relating to the project:

Mode of publicity/publication	Number
Peer-reviewed journals	9
Conference proceedings/presentations	11
Presentations	8
Reports	37
Newspapers/online magazines	3
Books	4
Newsletters, leaflets, posters	6
Website	1

Copernicus masters
the European Earth Monitoring Competition

In 2013 ASIMUTH was awarded “Best Service Challenge Winner”. Awards are given based on innovative solutions for business and society based on earth observation data.

Contacts

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3	Institut Français de Recherche pour l'Exploitation de la MER, France	**Marc Sourisseau**
4	Instituto Español de Oceanografía, Spain	**Manuel Ruiz Villareal**
5	Scottish Association for Marine Science, Scotland	**Keith Davidson**
6	Instituto Superior Técnico, Portugal	**Marcos Mateus**
7	Instituto Português do Mar e da Atmosfera, Portugal	**Maria Theresa Moita**
8	Hocer, France	**Matthieu Jouan**
9	Nowcasting, Ireland	**Mark White**
10	Starlab, Spain	**Elizabeth Gil-Rodán**
11	Numerics Warehouse Ltd., Ireland	**Marcel Curé**

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