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AlgaRisk '08: A Pre-Operational Tool For Identifying and Predicting the Movement of Nuisance Algal Blooms

Innovation for efficiency science programme

Science report: SC070082/SR1

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Steve Killeen

Head of Science

Executive summary

The Met Office, Plymouth Marine Laboratory (PML) and the Environment Agency have been working together on the Environment Agency-funded AlgaRisk '08 programme, following on from the South West Algal Pilot Project (SWAPP).

The aim of AlgaRisk '08 was to develop a forecasting tool as a demonstration service for forecasting water quality and nuisance algal blooms. The service is being tested in anticipation of the European Union's revised Bathing Waters Directive (rBWD) (2006) that will require the Environment Agency to provide water quality forecasting by 2012.

The pilot service aims to help provide the Environment Agency sufficient forewarning to ensure response teams can anticipate a bloom event and put in place targeted monitoring programmes.

The AlgaRisk tool combines satellite imagery, ecosystem modelling and a decision support spreadsheet, and is available to see on the internet.

This report describes the products underlying AlgaRisk; its service operation in terms of Earth Observation (EO) and model data provision; examples of major developments since the start of the project in April 2008; and reliability of the service.

A further aim of the project was to explore various options for the transition of the tools developed under AlgaRisk '08 to a future operational service. This was achieved by gathering user requirements, which are critically important in defining the terms and conditions of any operational service. These requirements provide the basis to define the operational capability necessary to meet customer needs and run a useful service.

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1 Introduction

A partnership between the Met Office, Plymouth Marine Laboratory and the Environment Agency has developed a demonstration service for forecasting water quality and nuisance algal blooms. The AlgaRisk 08 project follows the successful (unfunded) South West Algal Pilot Project (SWAPP), in anticipation of the European Union's revised Bathing Waters Directive (2006) that will require the Environment Agency to provide water quality forecasting by 2015. The demonstration service aims to assist present Environment Agency activities by providing sufficient forewarning to ensure that response teams can anticipate a bloom event and effectively mobilise targeted monitoring programmes.

2 AlgaRisk Products

The AlgaRisk service is based on a combination of model data from the Met Office, satellite ocean colour observations provided by PML, and a spreadsheet-based decision-support tool developed by the Environment Agency.

2.1 Operational Shelf Seas models

The meteorological and oceanographic (physical, biological and chemical) model fields routinely provided by the Met Office are generated by a combination of operational models:

- the Numerical Weather Prediction (NWP) North Atlantic-European meteorological model (12km resolution);
- the Medium Resolution Continental Shelf (MRCS) (7km resolution); and
- the European Regional Shelf Ecosystem Model or ERSEM, which is coupled on-line to the MRCS model.

The models have 20 vertical levels. Physical boundary conditions are provided to the coupled model by the Atlantic Margin model, a lower resolution model that is also run operationally at the Met Office.

Surface fluxes driving the coupled system are provided by the North Atlantic European NWP model at 12km resolution for the first two days of the forecast, and then at 40km global resolution for the subsequent days. An upgraded advective boundary condition is used in the MRCS model to reduce energy reflection and improve representation of the Norwegian current flow through the model's northern boundary.

ERSEM is one of the most complex lower trophic-level marine ecosystem models currently in use that fully resolves the diurnal cycle. It includes several functional groups of plankton (1 bacteria, 4 phytoplankton and 3 zooplankton), variable carbon:chlorophyll ratios and independent nutrient pools for carbon, nitrogen, phosphorous and silicate.

2.2 Data Provision

The Ocean Forecasting Research and Development team of the Met Office send data to the Environment Agency as a daily data feed, via file transfer protocol (ftp). The data include statistical parameters (mean, median and standard deviation) of satellite observations of ocean colour, and operational model data (analysis and forecast data up to five days ahead) for coastal waters. The live feed was established in September 2008, and the ftp server has been robust and reliable, with no reported downtime.

Model data provided include:

- wind speed;
- wind direction;
- cloud cover;
- photo-synthetically available radiation (PAR);
- mean sea level pressure (MSLP);
- stratification;
- sea surface temperature (SST);
- current speed;
- current direction;
- tidal range;
- total chlorophyll concentration;
- phytoplankton biomass (dinoflagellates, flagellates, diatoms and picoplankton); and
- nutrient concentration (nitrates, phosphates and silicates).

The combined meteorological and oceanographic variables, which are a daily average over specific coastal areas in the North-West and the South-West regions (see Figure 2.1), give the Environment Agency the capability to target beach inspections in response to anticipated or actual bloom development. A subset of the statistical data is displayed in Figure 2.2. The parameters are combined on a “most significant process” basis and revised on the outcome of the forecast performance.

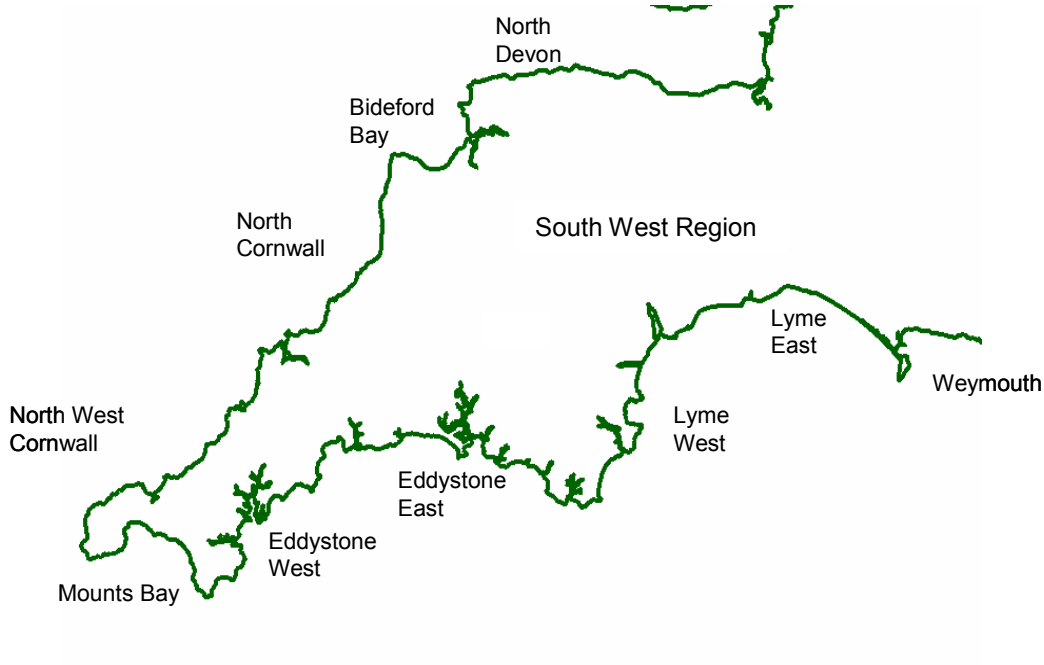
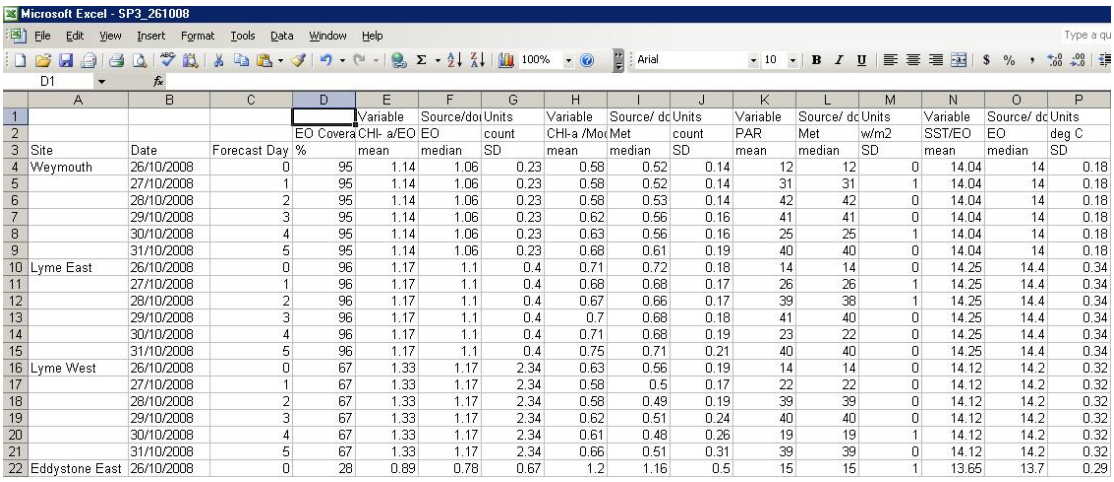


Figure 2.1: Environment Agency coastal areas in the South-West for which model and EO data are currently provided routinely.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1					Variable	Source/dor	Units	Variable	Source/ dc	Units	Variable	Source/ dc	Units	Variable	Source/ dc	Units
2				EO Covera	CHl- a/EO	EO	count	CHl-a /Mo(	Met	count	PAR	Met	w/m2	SST/EO	EO	deg C
3	Site	Date	Forecast Day	%	mean	median	SD	mean	median	SD	mean	median	SD	mean	median	SD
4	Weymouth	26/10/2008	0	95	1.14	1.06	0.23	0.58	0.52	0.14	12	12	0	14.04	14	0.18
5		27/10/2008	1	95	1.14	1.06	0.23	0.58	0.52	0.14	31	31	1	14.04	14	0.18
6		28/10/2008	2	95	1.14	1.06	0.23	0.58	0.53	0.14	42	42	0	14.04	14	0.18
7		29/10/2008	3	95	1.14	1.06	0.23	0.62	0.56	0.16	41	41	0	14.04	14	0.18
8		30/10/2008	4	95	1.14	1.06	0.23	0.63	0.56	0.16	25	25	1	14.04	14	0.18
9		31/10/2008	5	95	1.14	1.06	0.23	0.68	0.61	0.19	40	40	0	14.04	14	0.18
10	Lyme East	26/10/2008	0	96	1.17	1.1	0.4	0.71	0.72	0.18	14	14	0	14.25	14.4	0.34
11		27/10/2008	1	96	1.17	1.1	0.4	0.68	0.68	0.17	26	26	1	14.25	14.4	0.34
12		28/10/2008	2	96	1.17	1.1	0.4	0.67	0.66	0.17	39	38	1	14.25	14.4	0.34
13		29/10/2008	3	96	1.17	1.1	0.4	0.7	0.68	0.18	41	40	0	14.25	14.4	0.34
14		30/10/2008	4	96	1.17	1.1	0.4	0.71	0.68	0.19	23	22	0	14.25	14.4	0.34
15		31/10/2008	5	96	1.17	1.1	0.4	0.75	0.71	0.21	40	40	0	14.25	14.4	0.34
16	Lyme West	26/10/2008	0	67	1.33	1.17	2.34	0.63	0.56	0.19	14	14	0	14.12	14.2	0.32
17		27/10/2008	1	67	1.33	1.17	2.34	0.58	0.5	0.17	22	22	0	14.12	14.2	0.32
18		28/10/2008	2	67	1.33	1.17	2.34	0.58	0.49	0.19	39	39	0	14.12	14.2	0.32
19		29/10/2008	3	67	1.33	1.17	2.34	0.62	0.51	0.24	40	40	0	14.12	14.2	0.32
20		30/10/2008	4	67	1.33	1.17	2.34	0.61	0.48	0.26	19	19	1	14.12	14.2	0.32
21		31/10/2008	5	67	1.33	1.17	2.34	0.66	0.51	0.31	39	39	0	14.12	14.2	0.32
22	Eddystone East	26/10/2008	0	28	0.89	0.78	0.67	1.2	1.16	0.5	15	15	1	13.65	13.7	0.29

Figure 2.2: A subset of the statistical parameters that are sent daily to the Environment Agency. Mean, median and standard deviation values are displayed for the 27th October 2008.

The daily data feed is activated on the completion of the operational shelf seas model run (typically 0900Z). It incorporates model data and daily composite chlorophyll and SST satellite data from PML as inputs for the calculation of the statistical parameters mentioned above. Additional information is passed, via a dedicated ftp server, to PML in the form of 8-bit model data plots to the AlgaRisk08 web map server (www.npm.ac.uk/rsg/projects/algarisk), where model fields and observations are displayed (see Figure 2.3).

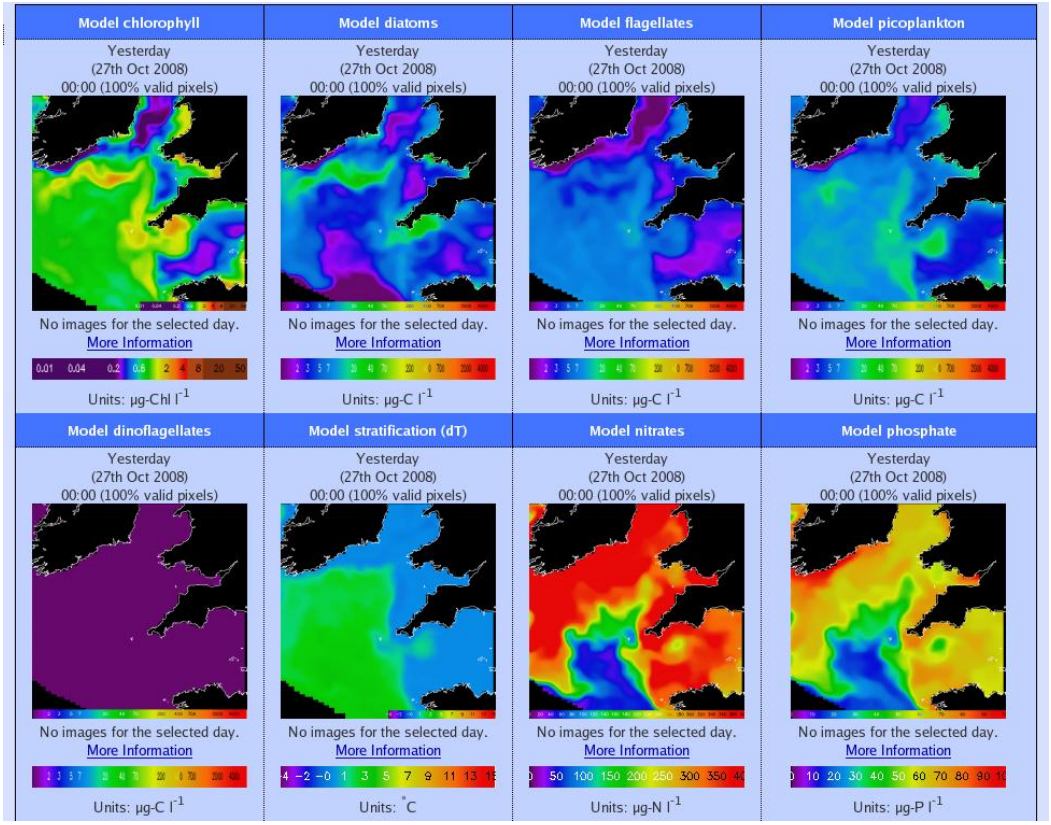


Figure 2.3: An example screenshot of the web map server hosted by PML Earth Observations group. A subset of Met Office model fields are shown for the 27th October 2008.

2.3 The AlgaRisk Web Portal

PML host a web portal providing the Environment Agency continual access to EO and model data for the South-West and North-West regions (Figures 2.4 and 2.5). The web portal provides an interface where all of the data generated can be viewed simultaneously, showing historical, most recent and forecast data. The web portal is driven by a suite of data processing chains, which are run through a 12 machine GRID engine. These systems automatically retrieve and process data 24 hours a day, 7 days a week. They download and process approximately 200 GB of data every 24 hours and automatically update the website with new data as they become available.

Both the web portal and processing systems have been maintained throughout the project, with less than 5 days downtime over the last 12 months.

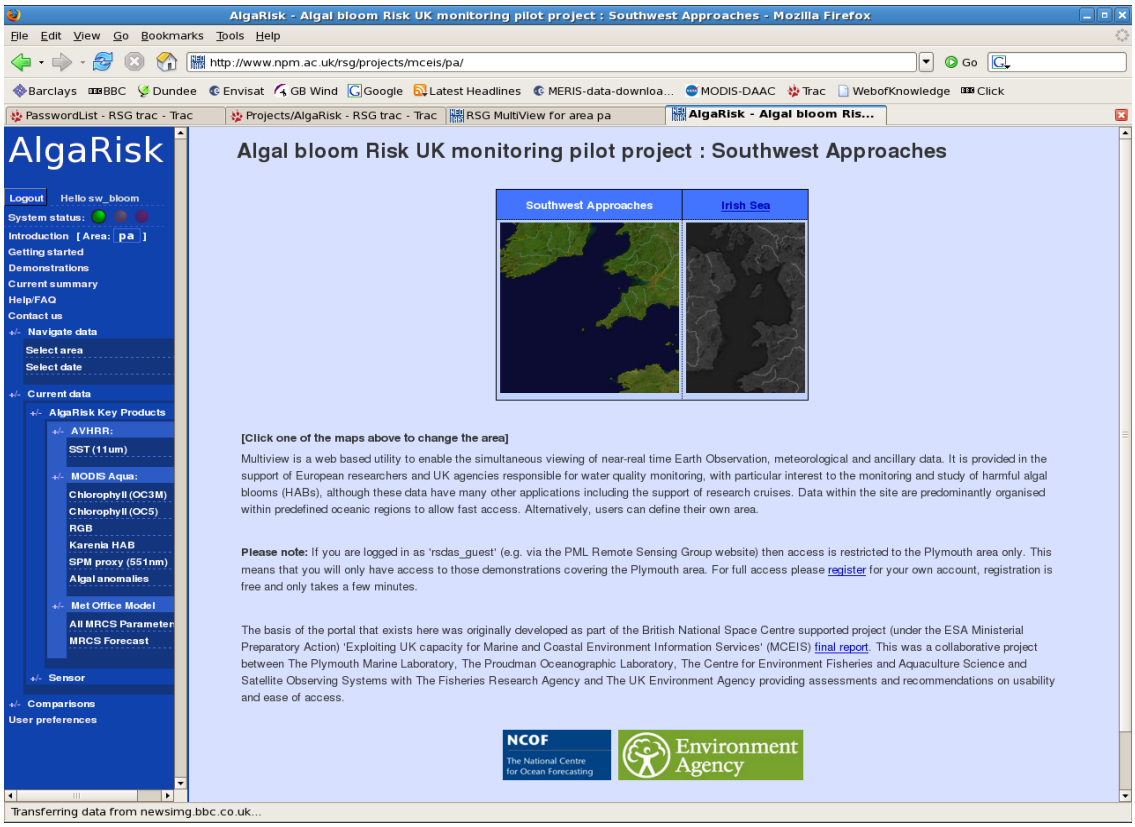


Figure 2.4: AlgaRisk portal showing the two different monitoring regions and the selection of sensor and model products available via the left hand menu.

The available EO data include:

- chlorophyll-a estimates (Case 11 and Case 22 water specific algorithms),
- water leaving radiance,
- a specific Karenia harmful algal bloom product, and
- an algal anomalies product.

1 Case 1 water is open-ocean, very transparent water where all of the optical properties are determined by the concentration of phytoplankton and its associated chlorophyll.

[2] Case 2 water is essentially any other water, where other particles affect the optical properties, such the turbid waters found at the mouths of estuaries.

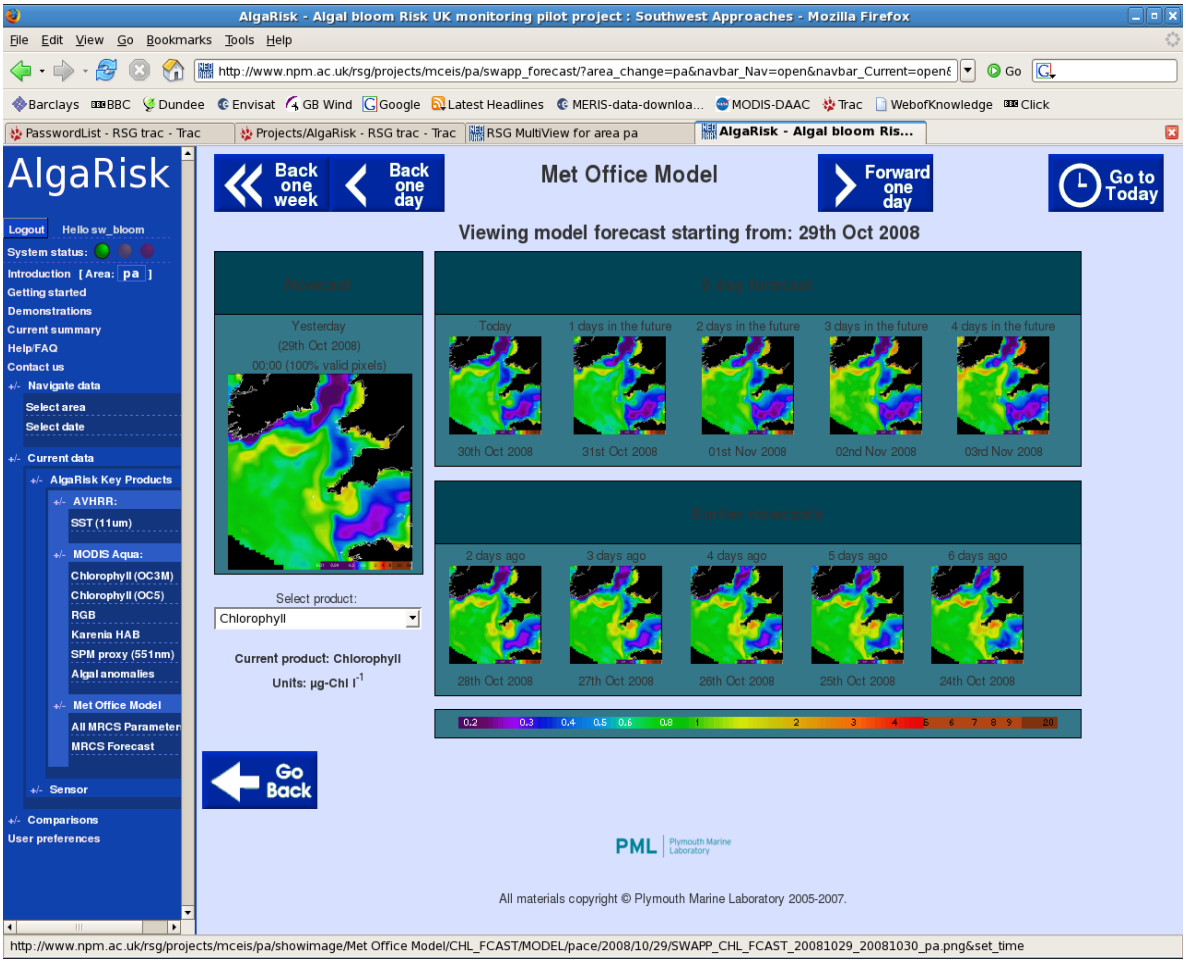


Figure 2.5: AlgaRisk portal showing modelled chlorophyll forecast data

Some example products produced in near-real time are shown in Figure 2.6. All of these data can be viewed on-line as images. Through the use of the web-based image viewer, the geophysical parameters at any given latitude or longitude can be easily determined. The web-based image viewer also allows users to overlay products. For instance, the chlorophyll-a data can be overlaid with current vectors, wind vectors or anomaly maps. An example of this is shown in Figure 2.6c.

(a) (b) (c)

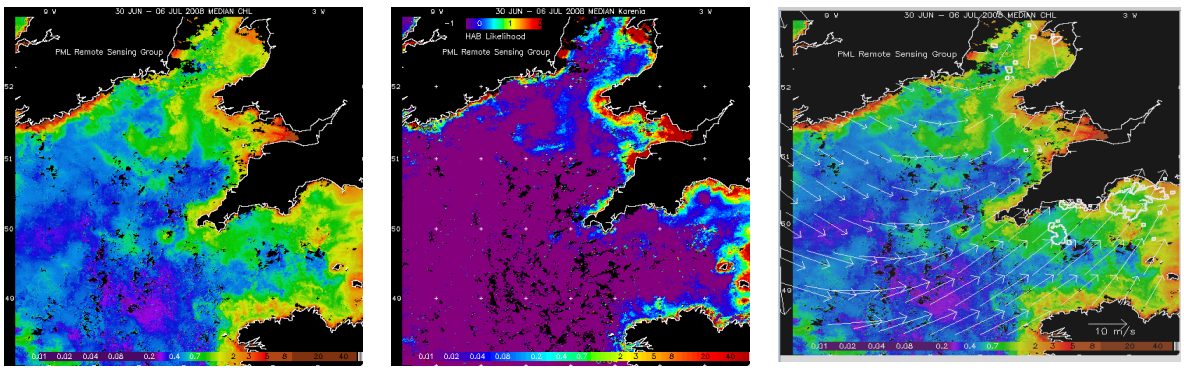


Figure 2.6: Example products available through the web portal.

In addition to the data provided on the web portal, data are also automatically extracted at specific geographic points (i.e. longitude and latitude) from the most recent datasets, for inclusion in the Environment Agency's monitoring spreadsheet (see Figure 2.2). The points from where data are extracted are provided by the Environment Agency and were chosen to represent the different areas within each monitoring region. The spreadsheet is used as a decision-making tool and requires input values from the various EO and model datasets. As soon as new data become available, the values at the coastal sites are extracted and made available on an ftp server. These data are then downloaded by the UK Met Office for inclusion in the latest version of the spreadsheet.

3 Developments

The AlgaRisk '08 project aimed to further develop the algal bloom detection and modelling tool developed under SWAPP. The main developments in the AlgaRisk project are listed below. Amongst the most important achievements are:

- the automisation of the forecasting spreadsheet run at the Environment Agency's Exeter office (South West Region);
- provision of extra model parameters including cloud cover, mean sea level pressure (MSLP) and tidal range;
- implementation of the Ocean Colour 5 (OC5) algorithm (Gohin *et al.*, 2002) to derive chlorophyll from earth observation (EO) data in turbid shelf-waters; and
- extension of the regions of interest to include the North West of England.

3.1 EO data

Below is a list of the main developments in ocean colour algorithms and harmful algal bloom (HAB) classification.

3.1.1 Ocean colour algorithms

- Implementation of the OC5 algorithm (Gohin *et al.*, 2002), which improves chlorophyll-*a* estimation in turbid (Case 2) waters (Figure 3.1). This algorithm was applied to the archive of Aqua-MODIS data for 2007-2008 for both regions of interest, producing a significant improvement particularly for the Irish Sea.
- Implementation of multi-sensor combined products (Moderate Resolution Imaging Spectroradiometer [MODIS], Medium Resolution Imaging Spectrometer [MERIS] and Sea-viewing Wide Field-of-view Sensor [SeaWiFS]) to increase near-real time coverage of ocean colour maps.

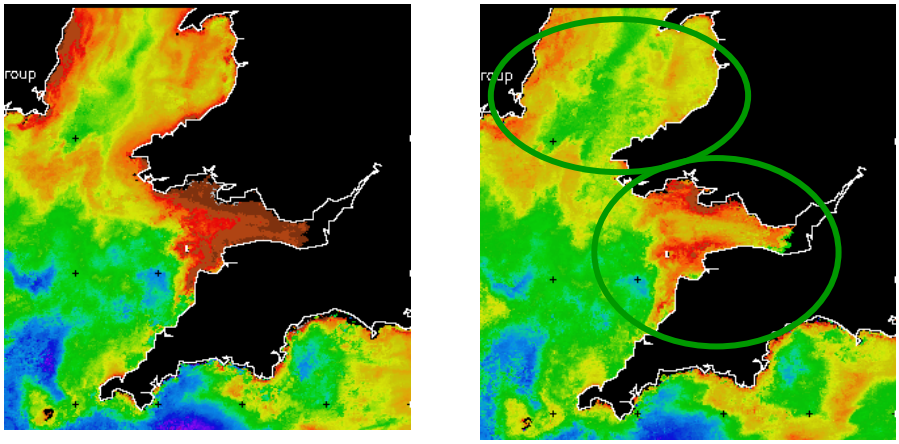


Figure 3.1: Differences in chlorophyll-a between the standard NASA OC3 algorithm and the OC5 algorithm developed by IFREMER for turbid, Case 2, waters. Green circles highlight areas where the OC3 algorithm overestimates chlorophyll values as a result of suspended sediment present in surface waters.

3.1.2 Harmful Algal Bloom (HAB) classification

- Sir Alistair Hardy Foundation for Ocean Science (SAHFOS) and Food Standards Agency (FSA) datasets obtained for HAB species such as *Alexandrium, Dinophysis* and *Pseudo-nitzschia*. A number of matchups were found with between high in situ concentrations and a distinct bloom in EO ocean colour data. These will be used to train further species classifiers to provide EO HAB indicators.
- Further training and testing of *Karenia mikimotoi* classifier on Aqua data.

3.2 Forecasting models

Developments include improvements to the POLCOMS-ERSEM[1] models as well as data provision and delivery.

[1] Proudman Oceanographic Laboratory Community Model System – European Regional Seas Ecosystem Model

3.2.1 Improvements to POLCOMS-ERSEM

- Light parameterisation in the POLCOMS-ERSEM model.
- Improvements to the parameterisation of sediment settling velocities and particle aggregation/disaggregation.
- Validation of ecosystem fields and sediments (Figure 3.2).
- vRe-initialisation of biological fields in ERSEM to address excessive nutrient concentrations.
- Impact of climatological boundary conditions for nutrient fields in ERSEM tested and assessed.

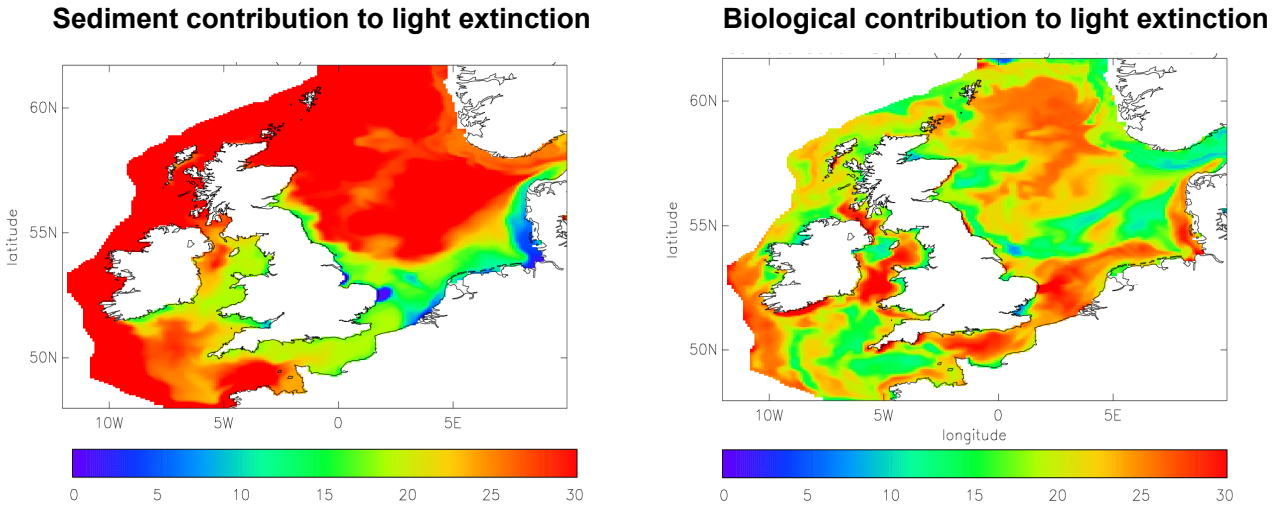


Figure 3.2: Snapshot of the different contributions to light extinction from sediments only (left) and from biological activity only (right) as modelled by the POLCOMS-ERSEM system. Noticeable differences are observed in the North West part of England (Liverpool Bay) and the English Channel.

3.2.2 Data provision and delivery

- Daily delivery to PML of modelled forecast (8-bit graphics) for SW and NW regions.
- Provision of additional modelled parameters: cloud cover, MSLP and tidal range.
- Provision of model forecast datasets for demonstration in WebMapServer (WMS) browser.
- Support to PML/Environment Agency in adapting datasets for WMS compliance.

3.3 AlgaRisk Web Portal and WebMapServer

The main developments to the two AlgaRisk websites were:

- the pre-operational Web Portal that provides access to EO/model products mapped to separate regions; and
- the demonstration WebMapServer (WMS) that presents EO and model fields on a wider UK region for more interactive zooming and selection of layers (see Figure 3.3).
- New 'Model vs. EO' facility added to Web Portal, allowing up to eight model or EO products to be compared for a range of dates.
- High-resolution MODIS (500 m) and MERIS (300 m) chlorophyll-a products included in WMS.

The MultiView SWAPP07 system has been rebranded as AlgaRisk and extended to include the Environment Agency NW region.

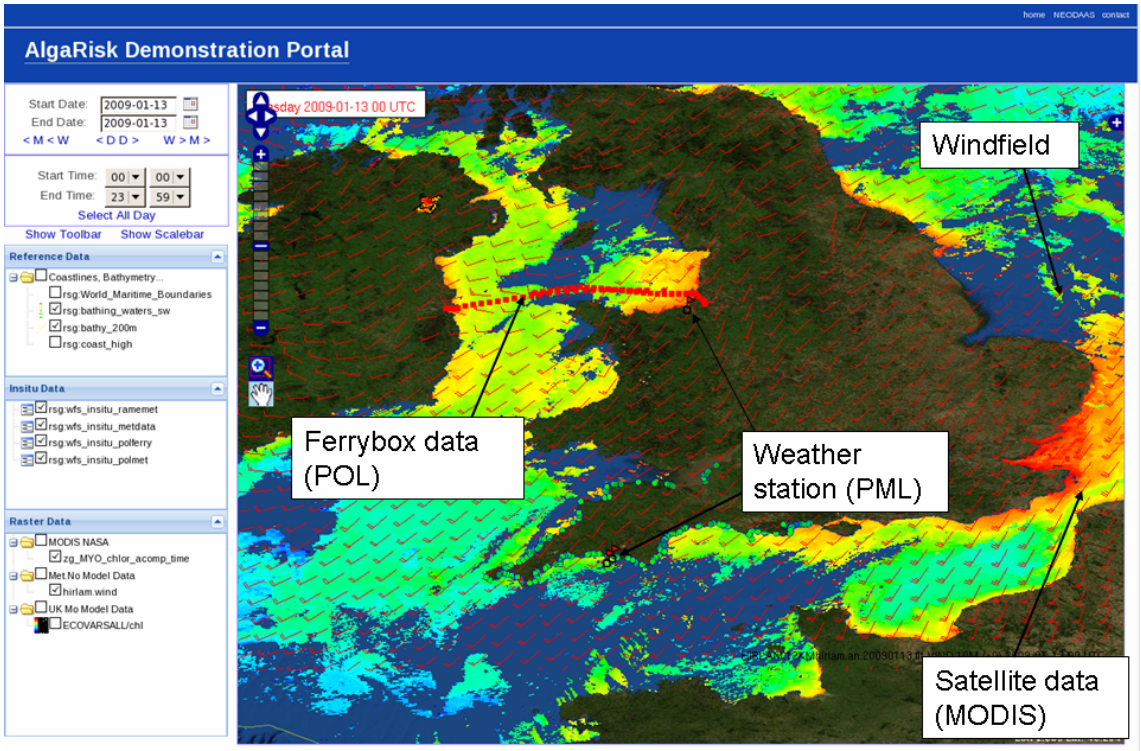


Figure 3.3: Demonstration AlgaRisk WebMapServer showing wider coverage and interactive choice of grid and vector layers from multiple EO, model and in situ sources. The screenshot includes EO chlorophyll-a data, modelled wind, a ferrybox track and a weather station.

3.4 Performance analysis of bloom risk indicators

PML expertise on Receiver Operator Characteristic (ROC) analysis was shared with the Environment Agency via Excel spreadsheets and charts linked to their indicators spreadsheet. This has enabled Environment Agency staff to carry out objective performance analysis and optimisation of the indicators model for each bathing area.

4 Assessment of service provided

Model and EO data were extracted and supplied to the Environment Agency and included in the web portal for assessment. Initially, regional Environment Agency offices in the NW were tasked with assessing the forecasting tool's performance in this area, but resourcing issues prevented their full engagement. At an AlgaRisk workshop (see Section 8), Environment Agency participants raised concerns about the limited testing done outside the SW region and highlighted the need for the forecasting system to be tested in several other regions before it could be considered suitable to roll-out at the national scale.

The Sea Fish Industry Authority (SFIA) has shown interest in developing a similar warning system, integrating EO techniques and forecasting models, to detect HABs of interest to the shellfish industry. Such a system would be based on the provision of daily optical, physical and chemical indicators of the water column and meteorological parameters. A proposal was finalised in November 2008 and submitted to SFIA for funding. Letters of support for this initiative were given by the Shellfish Association of Great Britain (SAGB), the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), the Scottish Shellfish Marketing Group (SSMG), the Association of Scottish Shellfish Growers (ASSG), the Environment Agency and SFIA. Unfortunately the application for funding was unsuccessful, although the shellfish industry are still keen to develop a system for shellfish waters.

Unfortunately, the weather during 2008 was not conducive for the formation of large algal blooms, which prevented the team from testing the system thoroughly. The spring, summer and autumn of 2008 were characterised by cold, wet and stormy weather, which translated into a bathing season lacking algal blooms and, hence, made it impossible to assess the forecasting tools developed in AlgaRisk. Below is a summary of the final assessment[1] of the weather experienced across the UK during spring (March/April/May), summer (June/July/August) and autumn (September, October, November) 2008 and how it compared with the 1971 to 2000 average (period used for the seasonal forecast).

> *"England, Wales and UK all had their coldest April since 2001 (Figure 3.1). April began with low pressure bringing rain or showers and cold fronts dominated. March and April both had above-average rainfall over the UK, with March having 128 per cent and April 109 per cent of average rainfall. May 2008 had below-average rainfall over the UK at 72 per cent. There were notable rainfall variations across the UK during May 2008, with well above average rainfall across southern areas of England and Wales.*
>
> *All three summer months had above-average rainfall across the UK, with August being the wettest month; well above average summer rainfall across most areas; three contrasting months for sunshine over the UK, with June being above average, July close to average and August having exceptionally below average sunshine. Summer sunshine levels were below average across many areas and well below average across South-East Scotland.*
>
> *In the autumn, mean temperatures were 0.2°C above the 1971-2000 average during September, 0.5°C below average during October and 0.3°C above average during November. Mean temperatures for the autumn were very close to average and it was the coldest for the UK since 1993; a very cold end to October*

[1] www.metoffice.gov.uk/climate/uk/2008

with some areas having their coldest daily maximum October temperatures (in a daily areal series back to 1960) on the 28th or 29th. A cold end to November too, with Northern Ireland having its coldest November daily maximum on the 30th (in a daily series back to 1960) and many other areas having their coldest daily maximum since autumn 1993 on the 29th or 30th.

Sunshine durations were 14 per cent below the 1971-2000 average during September, October was 22 per cent above average and November was three per cent below average".

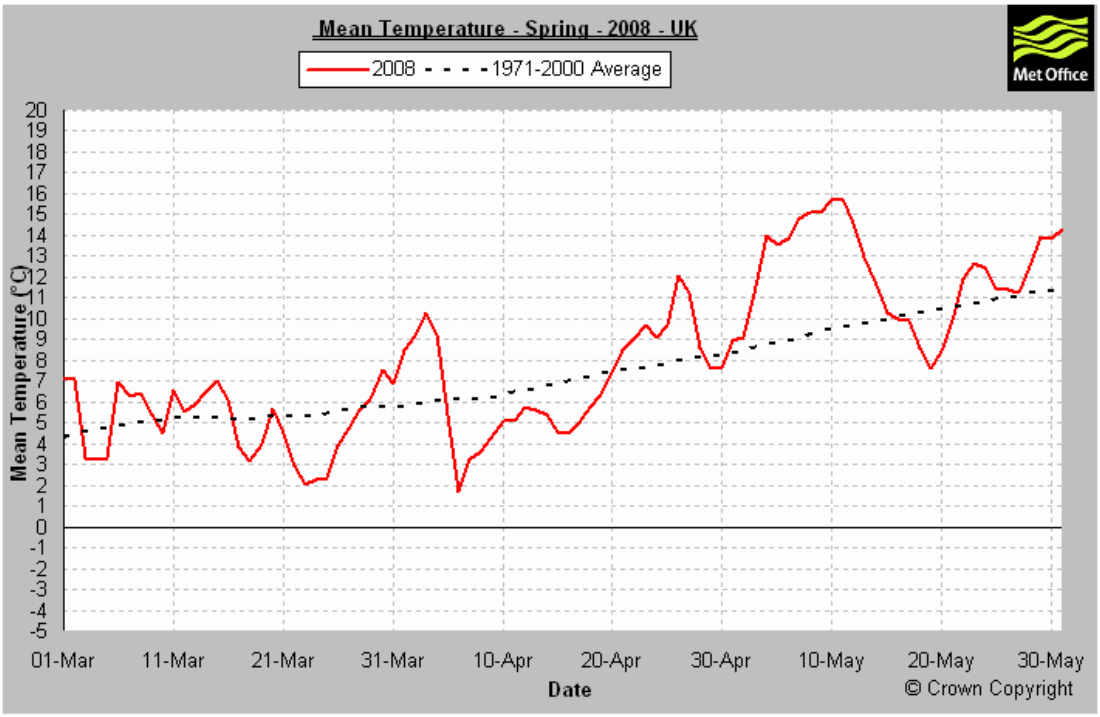


Figure 4.1: Mean temperature during spring 2008 compared to the 1971-2000 average.

5 Options for an operational service

The Met Office has a long history of operational service provision and is one of the world's leading providers of environmental and weather-related services. It partners the Environment Agency in the new Flood Forecast Centre (FFC). Met Office capabilities comprise:

- An ongoing, 24 hours a day, seven days a week, 365 days a year service, with underpinning support.
- Web service hosting and direct data services.
- Cross-hall resilience[1] – providing high service availability.
- Redundant communication circuits to the Environment Agency in place (routers located in IT halls).
- Established processes for fault reporting, business continuity, customer feedback, change management and more.
- Service monitoring and performance reporting.

A meeting was held on 6 January 2009 at the Met Office in Exeter to initiate discussions on the future of the AlgaRisk ’08 project and transition of tools developed in AlgaRisk to an operational service to the Environment Agency. The meeting was attended by PML, the Environment Agency and a Met Office team that included service managers experienced in providing a wide range of services to the Environment Agency, from Weather and RADAR services to the Storm Tide Forecasting system (STFS) and surge ensemble system.

The aim of the meeting was two-fold: to provide an initial set of options (A, B and C) to promote discussion on operational implementation in 2009/2010 and to get a clear understanding of the Environment Agency’s user requirements.

5.1 Option A – A fully managed service by the Met Office

This option offers a complete Met Office service delivered via the web and through direct provision of all data needed, from Earth Observations (EO) to models (Figure 5.1).

[1] duplicated servers on completely separated systems, including power supply, so that should one system fail, another totally independent system is still available

The benefits of this option are:

- “One-stop shop” for service provision, where the Environment Agency is provided with a single package as all the elements of the service are provided via a single web portal and/or operational files.
- A single point of contact through a “service desk” for all service issues.
- Continuous expert support (available 24 hours a day).
- Exploitation of existing, resilient communication links to the Environment Agency.
- Exploitation of operational, resilient Met Office infrastructure through cross-hall resilience.
- Consistency with provision of wider services to the Environment Agency Flood Risk Management (FRM).
- Technical and contractual efficiency.
- Feedback and changes to service managed through existing processes with the Environment Agency.
- Service continuity can be implemented through up-front design.

The disadvantages of this option are:

- One-off setup cost is likely to be higher than Options B and C.
- Implementation time is likely to be longer than Options B and C.
- Requires tight definitions of roles and responsibilities through Service Level Agreements (SLAs).

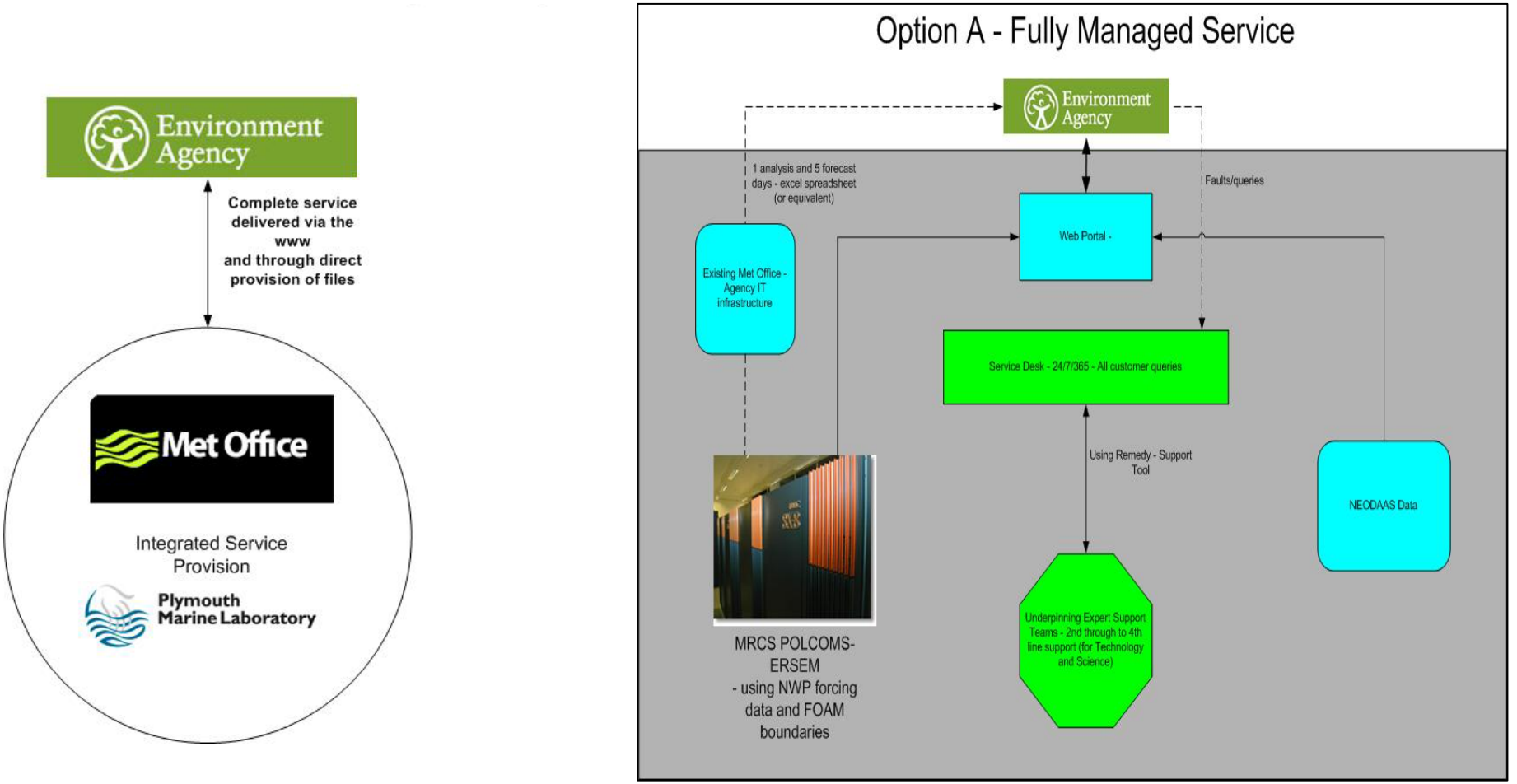


Figure 5.1: Schematic of a full service provision managed by the Met Office, (Option A).

5.2 Option B – A separate suppliers-single customer service

This option is based on current research provided by Met Office and PML to the regional South West Environment Agency office. The responsibilities are split as follows (Figure 5.2):

- Met Office generates MRCS POLCOMS-ERSEM fields and delivers them to PML for inclusion in AlgaRisk web portal.
- PML delivers EO SST and ocean colour data to Met Office for post-processing.
- PML updates web portal with model and EO data.
- Met Office populates Environment Agency forecasting spreadsheet with model and EO data.
- Met Office delivers spreadsheet to Environment Agency.
- Environment Agency processes spreadsheet information and accesses EO and model data on web portal.
- PML hosts AlgaRisk web portal.

Data delivery is via file transfer protocol (ftp).

The advantages of this option are:

- It is a relatively straight forward option to implement.
- It is likely to be less expensive to implement than Option A in the short term, although longer term it may be more expensive.

The disadvantages are:

- Possible confusion over roles and responsibilities, particularly when problems occur.
- Risk of uncoordinated service provision to the customer.
- The Environment Agency will need to know whom to contact when each aspect of the service fails.
- Overall availability of the service needs to consider resilience and underpinning support for each component of the service.
- Can the required service level be provided by all suppliers to the service?
- Reduces opportunities for synergy and greater partnership between supplier organisations.
- Customer contacts required with different suppliers.

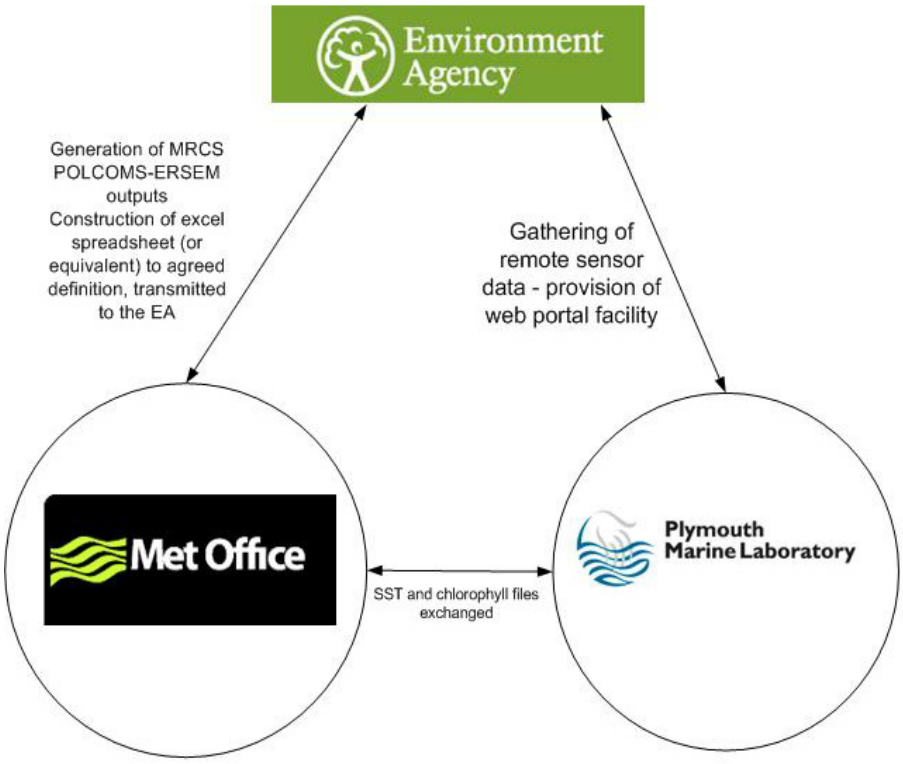


Figure 5.2: Schematic of a separate suppliers-single customer service (Option B).

5.3 Option C – A "hybrid" service partly managed by the Met Office and PML

This service is a hybrid of the two previous options and relies on all the data streams from the production centres being delivered to the Met Office. Data supply to the customer and handling of service faults are managed by a service desk hosted at the Met Office (Figure 5.3).

The advantages of this option are:

- Met Office is the single point of contact for the customer, offering a 24 hours a day, 7 days a week, 365 days a year support.
- A relatively easy option to make operational
- Likely to be less expensive to implement than Option A in the short term but, like Option B, could be more expensive in the longer term.

The disadvantages are:

- Possible confusion over roles and responsibilities, particularly when problems occur.
- The service desk requires a sophisticated understanding of how the service functions.
- It needs tightly written SLAs defining responsibilities, including response times, for each party.
- Customer contract required with different suppliers.

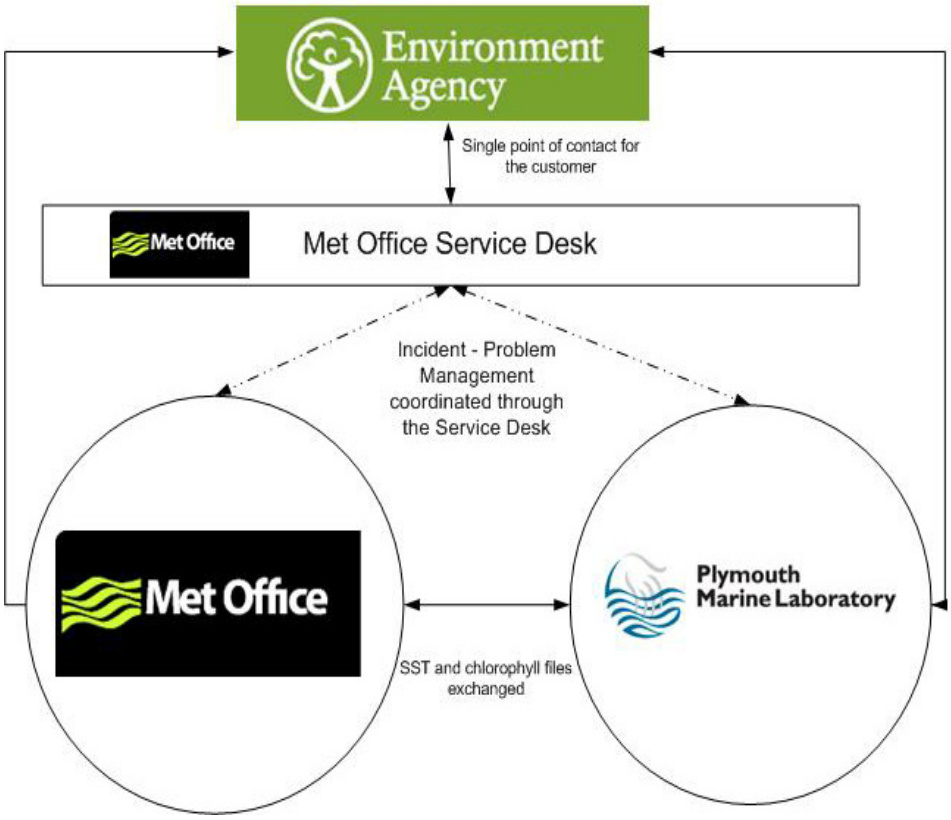


Figure 5.3: Schematic of a "hybrid" service partly managed by the Met Office and PML (Option C).

6 Requirements

Establishing the required service for transition to operational application needs a clear understanding of user requirements. User requirements should drive the technology solution and the level of service provision (SLA) and hence, a number of questions need to be answered before deciding on the final solution. These questions are:

- What are the user requirements?
- How will the service be used within the Environment Agency?
- What specific tasks/actions will users be undertaking?
- Is the service essential for provision of information to local authorities, industry and the public or will it be used alongside other services?
- What is the schedule for issuing algal bloom forecasts/warnings to organisations and the public? For example:
- Will a daily forecast be issued?
- Are updates/amendments required?
- What is the forecast period for the warnings, six hours ahead or two days ahead?
- Will warning be issued seven days a week?
- How crucial is the capability to enable forecasts/warnings to be issued? The user will need to think about how this evolves, especially when users become conditioned to the capability being available.
- What availability of the capability is required?
- What outages (frequency and duration) are acceptable to the user?
- What is the maximum acceptable ‘break’ in service? Are breaks in service at 02:00 (for example) acceptable?
- Do the users require continuous support? If not, do normal working hours suffice?
- How is the service to be verified? Verification can include quality/accuracy, availability, timeliness, completeness and other measures.
- How important is security to the customer?
- Is provision of an operational service via the internet acceptable?

The user needs to consider all aspects of the service, as these become more important as service matures into “business as usual” activity.

The cost of the operational service will depend on the final technological solution adopted as well as the service continuity standards required by users.

7 Outreach activities

The following is a list of outreach activities carried out in the project to promote the forecasting system development and to obtain feedback from potential users.

These are:

- Linking Marine Policy and Marine Science Meeting, Plymouth, April 2008. Presentation by Peter Miller (PML).
- Our Coast and Public Health Conference: Sustaining South West Coastal Habitation. Plymouth, April 2008, Presentation by Peter Miller (PML).
- EuroGOOS annual conference, Exeter, May 2008. Presentation by Peter Miller (PML).
- Environment Agency Marine Focus Group, Bristol, September 2008. Invited presentation by Rosa Barciela (Met Office).
- CEFAS, October 2008. Invited presentation by Rosa Barciela (Met Office).
- CEFAS, November 2008. Invited presentation by Peter Miller (PML).
- GlobColour and Medspiration Annual meeting, Frascati, November 2008. Invited presentation by Rosa Barciela (Met Office).
- Water Bathing Directive Symposium, Llandudno, December 2008. Invited presentation by Rosa Barciela (Met Office).
- AlgaRisk Workshop, Bristol, January, 2009. Presentations given by Neil Murdoch (Environment Agency), Peter Miller (PML) and Rosa Barciela (Met Office).
- IBIROOS Annual Meeting, Toulouse, February 2009. Invited presentation by Rosa Barciela (Met Office).
- AlgaRisk brochure was produced in January 2009.

8 Recommendations

To address limitations in the current forecasting tool, following advice gathered at the AlgaRisk workshop (held in Bristol in 2009) from policy and operations Environment Agency managers, the following recommendations are made:

- Extend the project for another bathing season and roll it out to two more regions in the NW and the NE, in order to test the forecasting system's performance in a variety of hydrodynamical and environmental conditions.
- Roll out the forecasting tools to two other regions in the NW and NE of England.
- Further work on Receiver Operator Characteristic (ROC) curves to improve their skill, which currently for many locations is no better than chance.
- EO data to include error characteristics, and the improved OC5 chlorophyll-a algorithm tested for possible application to Water Framework Directive requirements.
- Further POLCOMS-ERSEM model validation.

In terms of implementing an operational service, we recommend gathering user requirements at an early stage, to help shape the technology solution adopted.

9 Concluding summary

This report has given a brief outline of the overall progress in the life of the AlgaRisk project and has outlined initial options to implement an operational service to help the Environment Agency meet revised Water Framework Directive requirements. It has highlighted the need for a clear definition of user requirements before such a system can be costed or designed. However, the Met Office and Environment Agency have well-established processes for service provision which can be exploited for an operational AlgaRisk service in the future.

Significant progress has been made since SWAPP07, precursor of AlgaRisk, in terms of the quality of the EO and modelled data provided to the Environment Agency for the SW and the NW regions, developments to the WMS and the now automated forecasting software run at the Environment Agency. However, there remain questions on the performance of such forecasting systems at nationwide scales, given that the system hasn't been assessed anywhere other than in the SW region, mainly due to a combination of bad weather and lack of Environment Agency internal resources. Attendees to the AlgaRisk workshop stated the need to further improve the performance of the forecasting system and made the following recommendations:

- Bloom Risk Indicator should be improved as ROC curves do not show the desired skill for many areas.
- EO data to include error characteristics, and the improved OC5 chlorophyll-a algorithm tested for possible application to WFD requirements.
- Further POLCOMS-ERSEM model validation.
- Further testing of forecasting tool in a variety of areas across England and Wales.

The service is currently being tested in its pre-operational phase for the two regions of interest to the Environment Agency (South West and North West regions).

10 References

GOHIN, F., DRUON, J.N., AND LAMPERT, L., 2002. A five channel chlorophyll concentration algorithm applied to SeaWiFS data processed by SeaDAS in coastal waters. INTERNATIONAL JOURNAL OF REMOTE SENSING, Volume: 23, Issue: 8, 1639-1661.

Abbreviations and Acronyms

EO	Earth Observation
ERSEM	European Regional Seas Ecosystem Models
ESA	European Space Agency
FSA	Food Standards Agency
ftp	File Transfer protocol
HAB	Harmful Algal bloom
IFREMER	Institut français de recherche pour l'exploitation de la mer (French Research Institute for Exploitation of the Sea)
MERIS	Medium Resolution Imaging Spectrometer (ESA)
Met Office	Meteorological Office
MODIS	Moderate Resolution Imaging Spectroradiometer (NASA)
MSLP	mean sea level pressure
NASA	North American Space Agency
NWP	Numerical Weather Prediction
PML	Plymouth Marine Laboratory
POL	Proudman Oceanographic Laboratory
POLCOMS	POL community model system
rBWD	revised Bathing Waters Directive
ROC	Receiver Operator Characteristic
SAHFOS	Sir Alistair Hardy Foundation for Ocean Science
SeaWIFS	Sea-viewing Wide Field-of-view Sensor (NASA)
SLAs	Service Level Agreements
SWAPP	South West Algal Pilot Project
WMS	WebMapServer

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