

Interim Report of the Plymouth Chlorophyll Meeting and Workshops (Extended Antares Network). Sponsored by GOOS, GEO, PML and POGO.

Plymouth, 18-22 Sep 2006.

GEO Task EC-06-07

Executive Summary

The meeting consisted of three components: 1) a plenary planning meeting, 2) a satellite remote sensing technical workshop and 3) an in situ observations technical and inter-comparison workshop. The 44 participants represented Latin America, Southern and East Africa, India, China, Thailand, the Joint Research Centre of the European Commission, and the sponsors: the Plymouth Marine Laboratory, GOOS, GEO and POGO. Over 90% of the participants were under 50 years old and more than half under 40. Most had been previously trained under the auspices of the IOCCG and POGO.

The aim of the project is to deliver products, namely maps of ocean chlorophyll and sea surface temperature, as indicators of the state of the ecosystem needed for ecosystem and fisheries management, and at some sites, a measure of light penetration into the ocean, which is needed, along with the other two variables, to calculate plankton primary production. These are three of the core variables recommended for the Global Coastal Network listed in the GOOS Coastal Panel strategic plan. The value of decades-long time series is illustrated by two case studies relating fish catch fluctuations to inter-annual ocean chlorophyll variations in a spatial context. The meeting and workshops were outstanding successes, resulting in many technical recommendations given in the full report. Amongst the most important general recommendations are: The project should have three initial principal regional centres, in Latin America, southern Africa, and India linked by good communications to three northern centres in UK, the European Commission, and USA. During the first five-year phase, map products would be regularly updated on a web site at each centre, while the infrastructure is improved and personnel trained at new centres. During the second five-year phase, the existing centres would become fully operational with a range of products suited to local needs, and new centres developed. Several case studies of existing uses for remotely-sensed ocean chlorophyll products are given in the full report: 1) Monthly State of Environment Reports for fisheries management (Namibia), 2) Maps of Ocean Chlorophyll around Latin America (Antares Network), 3) Short-term forecasts of harmful algal blooms for fisheries (BCLME programme, South Africa), 4) Directing research vessels to dynamic ocean phenomena for process studies (Plymouth Marine Laboratory, UK), and 5) Fuel-saving by directing fishing vessels to ocean fronts and convergences (India). The meeting concluded that there is enormous synergy to be gained from linking national and regional centres together to form an integrated network including both satellite and in situ observations, and suited to local needs.

Principal recommendations:

- 1) That the network linking participating centres around the world, named Chlorophyll Ocean Globally Integrated Network, or ChlorOGIN, be implemented with immediate effect, linking existing national and regional centres;
- 2) That the appropriate bodies ensure that continuity of satellite ocean colour sensors is achieved to provide inter-calibrated long time series of surface ocean chlorophyll and SST;

- 3) That in situ time-series of surface and sub-surface observations be made at each regional centre to support the satellite measurements by integration/combination in a manner that suits local societal and scientific needs;
- 4) That the need for homogeneity/compatibility of protocols (e.g. for match-ups), procedures and analysis tools/practises be recognised and that members of the network move towards common protocols;
- 5) That physical infrastructure (such as the connection between networks and receiving stations, data distribution, materials required to adopt best practice protocols for in situ measurements) and human capacity be developed in existing and new centres to expand the network in two five-year phases;
- 6) That communications bandwidth be improved in most developing countries, as this limits the delivery of ocean chlorophyll and related products and is more important than satellite ground receiving stations;
- 7) That funding be sought for development of the ChlorOGIN Network from national bodies, the Large Marine Ecosystem programmes, and other sources.

John Field (GOOS) Co-chair
Trevor Platt (IOCCG) Co-chair
Shubha Sathyendranath (POGO) Organiser
Nick Hardman-Mounford (PML) Workshop organiser
Vivian Lutz (Antares) Workshop organiser
Mike Rast (GEO) (for co-sponsor)
Gavin Tilstone (PML) Workshop organiser

List of Acronyms:

Antares: Name of a Latin American network including ocean chlorophyll estimations
BCLME: Benguela Current Large Marine Ecosystem programme
ChlorOGIN: Chlorophyll Ocean Globally Integrated Network
GEO: Group on Earth Observations
GOOS: Global Ocean Observing System
IOCCG: International Ocean Colour Co-ordinating Group
JRC: Joint Research Centre of the European Commission, Ispra, Italy
PML: Plymouth Marine Laboratory, UK
POGO: Partnership for Observations of the Global Ocean

Introduction

As operational oceanography grows scientifically and expands as a practical discipline, the demand will increase for data and information relevant to understanding the marine ecosystem at the global level, unravelling the functions of the marine ecosystem in a changing climate, and sustainable management of marine resources.

At a time when the stewardship of the oceans relies on an ecosystem-based approach to management, opportunities are emerging for observing the ocean ecosystem at unprecedented resolution at the global scale, in a systematic and sustained manner, using satellite data. At the same time, it is well-recognised that combining satellite data with in situ observations in a judicious manner allows extension of applications to domains inaccessible by either method in isolation.

In this context, there is a need for establishing a network of observations that rely on existing technology and well-established methods for making the measurements. The approach has to be simple and fast, to allow routine measurements over long time scales, and not to exclude some countries from participating, on the basis of high technological requirements or high operational costs.

It is in this context that the Plymouth Meeting and Workshop was organised, with joint sponsorship from the Group on Earth Observations (GEO) and the Global Ocean Observing System (GOOS). The meeting was organised by Shubha Sathyendranath for the Partnership of Observation of the Global Oceans (POGO), hosted by Plymouth Marine Laboratory (PML) and chaired by John Field and Trevor Platt.

The meeting represented was first-of-its kind, from many perspectives. It was the first time that GEO, GOOS, POGO and the International Ocean Colour Coordinating Group (IOCCG) have met to achieve a common goal. It was the first time that in situ and satellite experts on measurements of chlorophyll have been brought together at the global scale, to discuss operational measurements of chlorophyll. It was the first time that participants from many developed and developing countries have been brought together to assay chlorophyll concentrations using various methods, bearing in mind the need for simple methods and timely delivery of data. As one of the participants mentioned, he had been measuring chlorophyll for twenty five years, but this was the first time he had had the opportunity for in depth discussions with international colleagues on this most fundamental of biological-oceanographic measurements.

At the same time, the satellite experts reached agreement on how to process and distribute satellite data to complement the in situ observations. As part of the inter-comparison exercise, samples will also be shipped to participating laboratories around the world, so that each laboratory can analyse samples using protocols in use at present in the laboratory as well as the adopted common protocol.

The participants met in plenary on the first day of the meeting, at which Mike Rast (GEO), John Field (GOOS), Shubha Sathyendranath (POGO), Trevor Platt (IOCCG), Milton Kampel (Antares Network) and Vivian Lutz (Antares Network) provided background information, and described the goals of the workshop. The existing Antares Network of Latin America was adopted as a model for the proposed chlorophyll network. The goals were:

- (i) to extend the network globally;
- (ii) to integrate in situ and remote observations into a single network, and

- (iii) to work towards timely delivery of data and information for societal benefit, bearing in mind the regional differences in needs and capabilities.

After the plenary, the participants split into two groups, one group concentrating on the in situ measurement techniques, and the other group discussing issues related to satellite mapping of chlorophyll distribution. The participants met again in Plenary for parts of the last two days of the meeting, to share reports, compare notes, and ensure integration of remote-sensing and in situ elements of the network.

Background

Concept

Visible spectrum radiation, or ‘Ocean Colour’, remotely sensed by satellite, provides a means of getting regular (sometimes daily) estimates of chlorophyll *a* and phytoplankton biomass at very low cost. These can revolutionise our ability to forecast harmful algal blooms (red tides) and can aid in fishing operations, fisheries management, and coastal zone management, *inter alia*. The time series generated by years of such observations have already led to explanations of haddock and shrimp recruitment fluctuations in the Northwest Atlantic. Thus, there is great potential for other archives of satellite images of ocean colour to provide similar benefits elsewhere. It is therefore proposed that a few regions (such as the ones suggested below) form parts of a GOOS pilot study to make operational ocean colour observations on a regular basis in support of local and regional needs. Each region would need to have its own operation funded. GOOS has only limited funds for seed money and to link the regional databases, but would be able to help raise funds through its being part of the GOOS pilot study network. It is envisaged that this would be a partnership between GOOS, POGO and the IOCCG, with the IOCCG providing the scientific and technical expertise. It is anticipated that GEO, POGO, SCOR and GOOS could assist with the capacity building needed for the pilot study, and with the co-ordination. The study would also be aimed at contributing to GEOSS.

A series of linked projects would provide a valuable comparison between different types of ecological environment (upwelling regions, western boundary current areas, sub-Arctic and coastal seas). It would probably be of interest to the IOCCP (International Ocean Carbon Coordinating Project) and the IODE (data management) might be able to help in linking data centres together in providing regular ocean chlorophyll images of each region. POGO might be able to assist in capacity building and linking with leading oceanographic laboratories, and with advice on in situ measurements and calibration. It is anticipated that the pilot project will develop in two phases of 5 years each.

GOOS

The GOOS Coastal Panel has recommended that GOOS Regional Alliances produce proposals for Pilot Projects for Coastal GOOS. In this context, Coastal GOOS includes non-physical variables measured in the open ocean. The GSC-8 meeting in Melbourne (Feb. 2005) suggested that estimates of chlorophyll *a* obtained from satellite ocean colour observations might make a good candidate for a GOOS pilot study. The aim would be to provide, to a web server, regular ocean chlorophyll *a* images and associated products (daily, weekly or bi-weekly, depending upon each region’s needs and conditions). GOOS, along with GEO, is a major sponsor of the Plymouth meeting and workshop.

POGO

POGO has an important capacity building initiative in ocean observations: the Nippon Foundation – POGO Visiting Professorship Programme. Under this programme, Dr. Trevor Platt and a team of

experts assembled by him spent several months in India in 2004-2005, training some 25 scientists from India, Thailand, Vietnam and Tanzania on analysis and interpretation of ocean-colour and on applications of the data for marine-ecosystem and climate-change related problems. The motivation for this initiative was regional capacity building and the development of a cadre of capable professionals to carry out such analyses into the future. The pilot project draws on human resources developed under this programme for the creation and development of an Antares-like network in the Indian Ocean region, and in South East Asia. Six of the NF-POGO participants (three Indian, one Tanzanian, one Thai and one Vietnamese) have been directly involved from the beginning in the development of the pilot study, and all of them attended the start-up meeting in Hyderabad.

Recently, in April and August of 2006, Dr Robert Frouin conducted another Nippon Foundation – POGO Visiting Professorship in Brazil. The subject of the training was ‘Evaluation of satellite ocean-colour algorithms and products in coastal regions of Central and South America’ and one of its objectives was to increase the expertise of ANTARES members and other interested scientists from Latin-America in the subject.

POGO has, through its São Paulo Declaration, drawn attention to the observational gaps in the oceans of the Southern Hemisphere. POGO and its member institutions have taken several actions to fill the observational gaps, for example through the BEAGLE 2003 circumpolar expedition, organised by JAMSTEC (Japan) with international participation. Furthermore, POGO has a long-standing commitment to promoting biological observations in the ocean (the POGO Biology Report; <http://www.ocean-partners.org/biolnit.html>). POGO also has a strong track record in capacity building activities in ocean observations. The POGO objectives of promoting ocean observations in the Southern Hemisphere, of promoting biological observations and building capacity in ocean observations all come together in the development of the Chlorophyll Pilot Study and the Chlorophyll network.

IOCCG

IOCCG, along with POGO, has helped establish and maintain Antares. The proposed pilot study meets one of the goals of IOCCG, which is to promote the use of ocean-colour data worldwide. More generally, IOCCG is also committed to increasing the quality of ocean-colour data and to building capacity in this area. IOCCG also provided some travel funds to participants from developing countries at the meeting and workshop.

GEO

POGO, IOC and GOOS are identified as the lead agencies in a work packet related to Ecosystems Societal Benefit Area in the GEO Work Plan for 2006 (Version 2):

EC-06-07: Build upon existing initiatives (e.g. ANTARES in South America for oceans and GOFCC-GOLD regional networks for terrestrial domains) to develop a global network of organization-networks for ecosystems, and coordinate workshops to strengthen observing capacity in developing countries.

This GEO task was identified as a task in capacity building by GEO, and the Plymouth Chlorophyll Meeting and Workshop was realised with sponsorship and support from GEO.

Data integration

The need for an improved understanding of ecosystem processes and dynamics will benefit from the integration of in situ and remotely-sensed data. Whereas the former can give information about, for

example, the vertical structure of the chlorophyll *a* profile, main phytoplankton groups and specific rate constants (e.g., photosynthetic parameters) at a particular geographic location, the latter can provide information about the chlorophyll *a* field at the regional and global scales at daily to weekly intervals. The combination of both approaches can give estimates of important ecological variables, such as of the water-column integrated primary production.

A starting point for integration of in-situ and remotely-sensed data within the network should be a comparison of in-situ vs. satellite surface chlorophyll *a* values at each location. This initial comparison will help, for example, to determine how well the global chlorophyll *a* algorithms are working in the different areas, what the main characteristic scales of variability in a particular system are, and if they are being sampled at the proper resolution. An example of the potential application of this exercise is the characterization and understanding of phytoplankton bloom dynamics and their impacts on other components of the ecosystem. Since phytoplankton blooms can be beneficial (e.g., for the recruitment of species of economic importance) or detrimental (e.g., harmful algae), determining their timing, intensity, duration and spatial extension becomes an important issue.

It is anticipated that, as the network develops, a wider range of in situ data, such as high-frequency automatic bio-optical measurements (e.g., fluorescence, attenuation and reflectance) will be integrated.

Main points of justification for the integration of in situ with remotely-sensed data are:

- it facilitates development of local and regional algorithms;
- it helps interpretation of data for local ecosystem processes;
- it gives oceanographic context for point measurements;
- it allows extrapolation of chlorophyll-*a* and derived fields (e.g., primary production) to three dimensions; and
- it enhances operational work as well as research work.

Network objectives

The network seeks to provide practical information on marine ecosystems for use at national and regional (LME, continental) scales from a combination of Earth observation (EO) data from satellites and *in situ* observations. Currently, for most regions, EO data and *in situ* observations are not generally considered in parallel. To address the issues associated with integration at large scales, the following questions were addressed through the working group:

1. Who are our end users and which regional needs can be addressed with the help of chlorophyll-based products?
2. Is there a common set of chlorophyll-based products that can be used across the network as a basis for addressing regional needs?
3. What complementary products are needed to support these?
4. What are the best mechanisms to deliver these products through the network?
5. What are the key limitations to delivering these products on a sustainable basis?

Who are our end users and which regional needs can we help address with chlorophyll-based products?

Much of the work of the network of remote sensing partners involves supplying products to a user community. Three major categories of end users were identified:

1. Sections of the general public, such as fishermen, recreational users of coastal areas, the tourism industry and educators;
2. Policy makers and government agencies, for application to issues such as climate change, fisheries, aquaculture, ecosystem monitoring, coastal zone management and state of the environment reporting;
3. The wider research community.

Each of these distinct groups has specific requirements for ocean colour products which, in some cases, correspond to the different technical skills and capabilities of these groups. For example, members of the general public will generally be more comfortable with simple images, maps or textual guidance provided through a basic web interface, or even via fax in the case of some fishermen (see example box A). Policy makers generally require indicator-type products, i.e. data in a form that gives clear information about specific issues, aiding the decision-making process.

Users can also be differentiated according to whether they require rapid access to the latest data, i.e. data delivery in near-real time (NRT) and whether they require access to time series of data, perhaps with a higher degree of accuracy than can be obtained for NRT data, i.e. delayed mode data delivery. The use of these different delivery modes are highlighted in example boxes B and C (HABs, State of Environment reporting).

Users in the wider research community, including both academic research users and applied researchers working for government departments or institutes, can be regarded as added-value users as they provide an added-value service to the data, based on factors such as local knowledge of oceanographic and ecological processes, access to complementary *in situ* data streams, statistical analysis and interpolation/extrapolation, e.g. through numerical modelling. These users may also be capable of basic validation of the supplied data.

The *in situ* data providers in the network are, in many cases, already research users of ocean colour Earth observation (EO) data products. Through the establishment of this network, the products currently provided by EO data can be greatly enhanced through combination with *in situ* data, providing benefits to all groups of users.

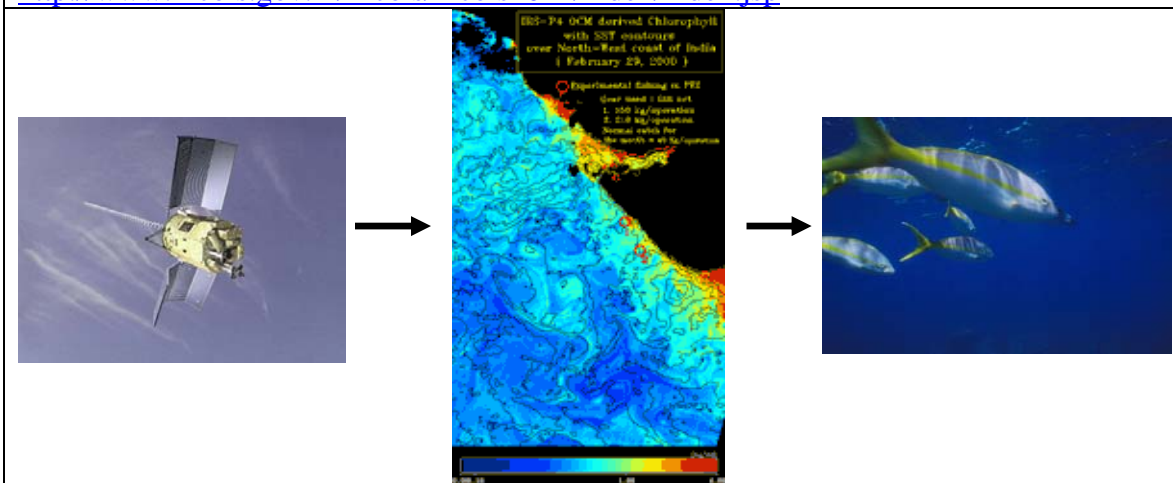
Example Box A. Satellite-based Fishing

Fish account for approximately 7% of the World's total food supply, and are one of the major sources of food in developing countries. Around half a billion people gain their livelihoods from harvesting the oceans. Locating and catching the fish is, however, becoming more challenging as fish stocks dwindle and move further offshore, thus increasing the search time, cost and effort.

Many countries have stressed the need for identifying potential fishing zones to help fishermen locate fish stocks and to increase catch per unit effort. Over the past decade, India has developed a system of scientific indicators of potential fishing zones using satellite-derived information on Sea Surface Temperature (NOAA- AVHRR satellite data) and chlorophyll (IRS-P4 ocean-colour data). Oceanographic features such as temperature fronts, meanders, eddies, rings and upwelling areas, that have proven to be prospective sites for fish stock congregation and migration, are identified from the satellite imagery. These oceanographic features can be successfully mapped in near real time and are used to generate Potential Fishing Zone (PFZ) advisories for the Indian fishing community, which includes almost 6 million fishermen catching both pelagic (*e.g.* sardine, mackerel, tuna) and demersal (*e.g.* cod, flat fish, skates, rays) species.

The Indian National Center for Ocean Information Services (INCOIS) disseminates PFZ advisories, in local languages, three times a week to the entire coast line of India by fax, phone, internet, email, electronic display boards, newspaper and radio broadcasts. These advisories indicate the likely availability of fish stocks for the next 2 days, and provide detailed directions on how to locate the fish stocks. These advisories have helped to reduce search time by up to 70%, and have significantly increased the catch per unit effort. Generally, the fisheries are artisanal and the fishermen who use the data are sometimes illiterate.

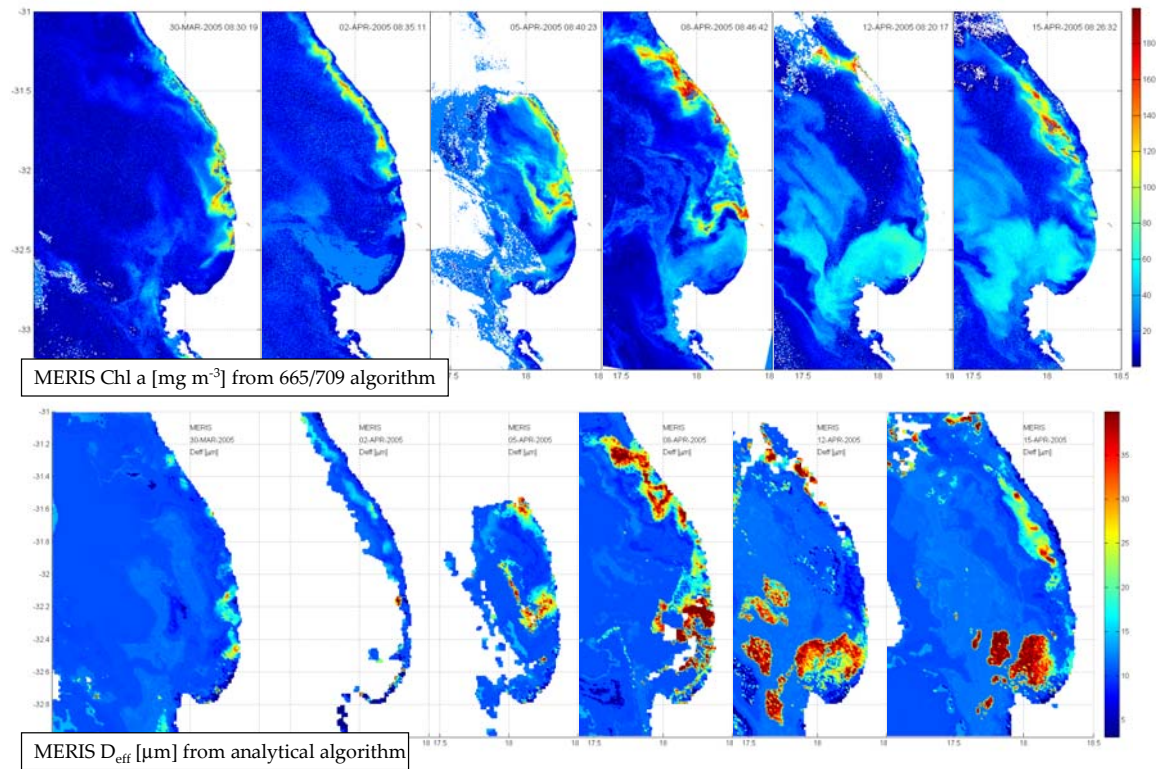
India is thus a prime example of how satellite data can be put to effective use to ensure that the advantages of science and technology percolate down to the common man. See <http://www.incois.gov.in/Incois/incois1024/index/index.jsp>



Example Box B. Harmful Algal Bloom Detection in southern Benguela

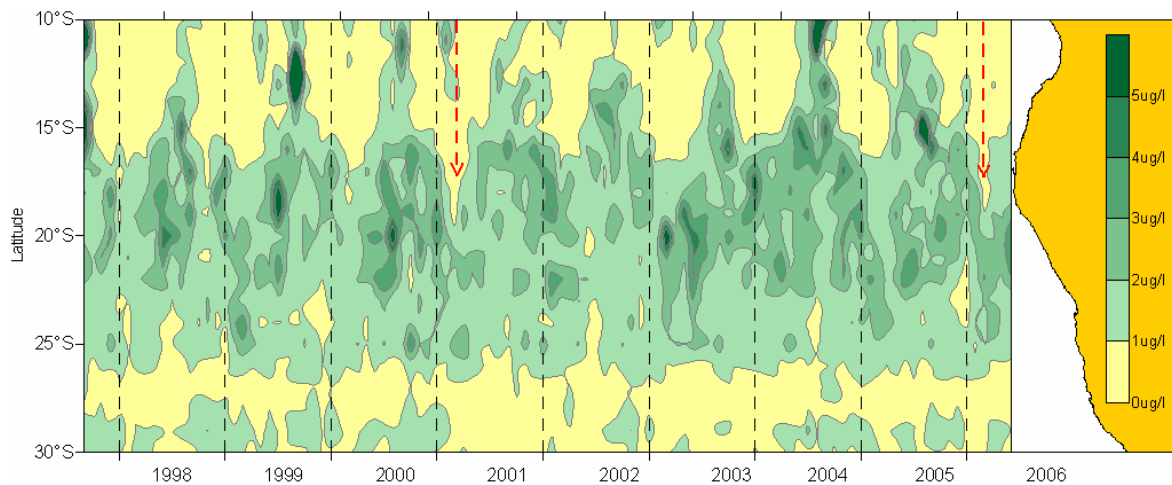
The southern Benguela suffers from the frequent occurrence of a variety of harmful algal blooms (HABs), often resulting in severe negative impacts through both toxins entering the food chain, and hypoxia resulting from bloom collapse. Ocean colour based sensors can offer synoptic data in near-real time for HAB detection and monitoring. Regional empirical and reflectance inversion algorithms offer experimental geophysical products that are specifically designed for HAB monitoring. These include more accurate estimates of algal biomass in high biomass waters, and an algal assemblage size descriptor. These products allows a rapid assessment of bloom extent, magnitude and potential harmful nature, as most toxic or hypoxia-associated species in the region are relatively large e.g. *Alexandrium catenella*. The series of chlorophyll and effective diameter images shown below are derived from the Medium Resolution Imaging Spectrometer (MERIS). They show the complex transport patterns of successive blooms of the small dinoflagellate *Prorocentrum triestinum* and the large dinoflagellate *Ceratium furca* in late summer 2005 on the South African west coast. The change from a small-cell to a large-cell dominated assemblage can be seen in the effective diameter images midway through the time series

HAB detection and scales of measurement: March/April 2005



Example Box C. State of environment reporting

The Ministry of Fisheries and Marine Resources in Namibia has the responsibility to safeguard the marine resources and establish fishing quotas every year. Furthermore, fishing is the second largest contributor to the country's GDP and a very important source of employment. Remote sensing provides a quantitative and cost effective technique for producing sea surface temperature maps and ocean colour products such as chlorophyll_a concentration that are useful for marine resources and coastal managers. NatMIRC, the government's marine research centre is tasked with conducting a monthly in situ environmental monitoring programme, the results of which are used for the continuation of a time series of various indicator parameters including chlorophyll_a concentration as measure of ecosystem health. Delayed satellite data from MODIS/SeaWiifs is used in the compilation of the State of the Environment (SoE) and Total Allowable Catch (TAC) reporting. SoE presents a range of physical, chemical and biological parameters over the marine area of Namibia. Ocean colour is presented as the observed average colour and relative difference with the aim to show spatial and temporal variability in primary productivity. TACs are the basis for fish quota allocation. This information is in turn used in establishing linkages between variability in primary productivity and fluctuations in abundance and distribution of pelagic fish stocks. Sulphur eruptions (caused by decomposition of plankton on the sea floor) and harmful algal blooms may have a detrimental effect on the developing aquaculture industry and this requires further research support from ocean colour community.



Satellite derived chlorophyll-a concentration along the Namibian and southern Angolan coastlines since September 1997.

Is there a common set of chlorophyll-based products that can be used across the network as a basis for addressing regional needs?

Chlorophyll-based data products from network partners are already used by a number of the stakeholder groups above for applications ranging from the identification of potential fishing zones in India (useful to both fishermen and fishery-resource managers), to warning coastal users and mariculturists of Harmful Algal Bloom (HAB) development in South Africa, production of state-of-the-environment reports in Namibia and support of scientific research cruises from the UK. Several of these examples are further described in the case study boxes.

The requirements for these user specific applications vary between regions and rely on a fundamental capacity for retrieval and processing of a core set of satellite-based, ocean-colour data products, coupled in some cases with *in situ* observations of chlorophyll.

What complementary products are needed to support these?

Although SST is recommended as a minimum requirement for complementary data sets, it is recognised that a number of other EO-derived data sets are currently used in parallel to the ocean-colour products recommended, such as surface winds and sea-surface height (SSH). Advanced ocean-colour products are also derived by some groups (e.g. inherent optical properties of absorption and scattering). These products may continue to be produced by individual groups for specific regions but are not suitable for distribution across the network at this stage. However, they will be evaluated for future recommendation as core products.

A strong requirement was identified for a number of user groups to have error products that provide uncertainty estimates compatible with the Level 3 core products. However, it is acknowledged that this is not a trivial task and is outside the current scope of the network. Rather, a recommendation is made that the IOCCG address this issue at some point in the near future.

What are the best mechanisms to deliver these products through the network?

Successful implementation of the network will require both (1) an appropriate structure for the network and (2) appropriate capabilities for delivery of data and products across the network and to end users. Delivery of data and products encompasses the capability to retrieve and process EO data as routine as well as being able to deliver those products in an appropriate form to users of the network. More details of the proposed mechanisms are given in the section below, 'Structure and capabilities of the network'.

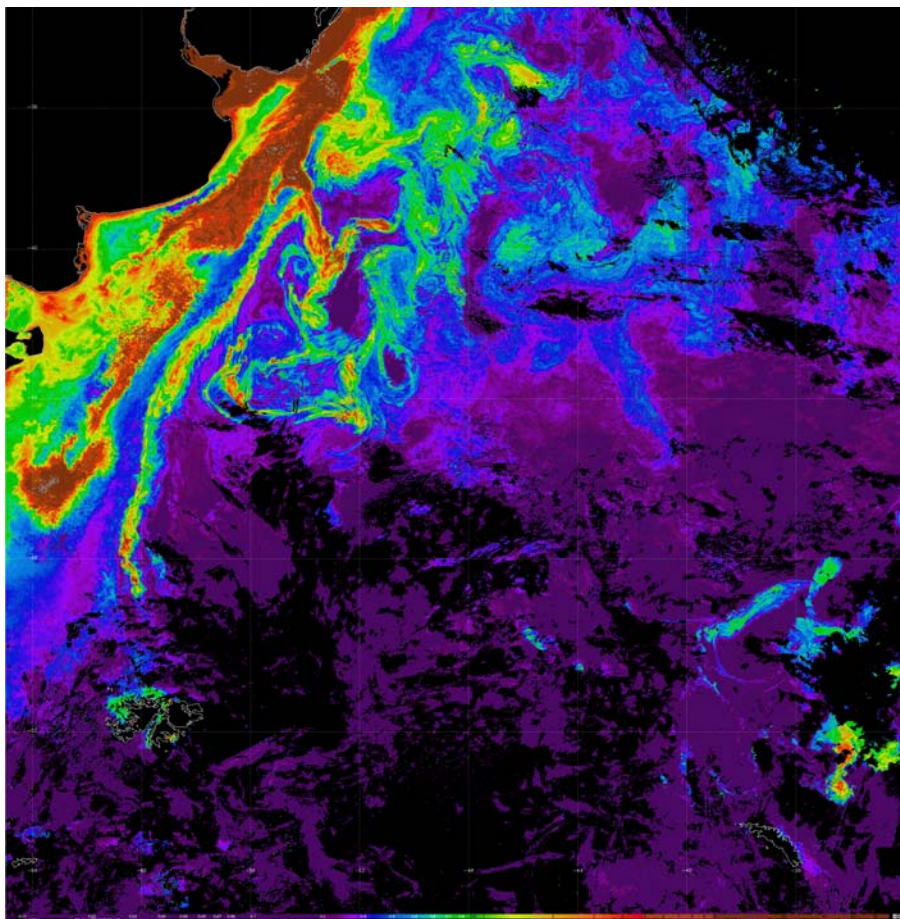
What are the key limitations to delivering these products on a sustainable basis?

There are three main limitations to delivering ocean colour products on a regular sustained basis:

- a) the need for personnel at each centre who are dedicated to producing ocean colour products as an important component of their jobs;
- b) a good communications network with sufficient bandwidth at each centre;
- c) continuity of satellite ocean sensors by the major space agencies

D. Case Study: Near-Real Time support of research cruises

PML provides ocean colour images in near-real time to UK and some European scientific research cruises around the world. The aim is to guide the in situ sampling by providing information on the location and chl-a concentration (or SST) of short-lived or dynamic features such as algal blooms or fronts, currents and eddies. This maximise science time as opposed to time spent searching for the feature of interest. Since the UK research fleet has global capability the NRT ocean colour support is also global with cruises supported in, for example the Southern Ocean. Prior to the cruise departure near-real time and 7-day rolling composite data are supplied; Fig 3 shows an example 7-day composite image in support of a research cruise, in this case to compare with in situ $p\text{CO}_2$ measurements.



MODIS chl-a image (7 day composite 11-18 September 2006) between the South American coast and South Georgia

Structure and capabilities of the network

The following structure is proposed for the network. The global network is composed of regional sub-networks, focused around a regional EO processing centre with the capability to provide the fundamental network products to the rest of the regional partners for support of *in situ* time series observations, further development into more locally applicable products and application by the wider user community. In turn, the regional partners would provide their *in situ* data and derived products back to the regional processing centre.

The regions currently represented sufficiently to initiate regional sub-networks are: South America (ANTARES), Northern Indian Ocean, South East Asia and China, North Atlantic, Southern Africa (South East Atlantic and South West Indian Ocean).

There are a variety of processing capabilities currently within the network. For NRT products, there are some existing regional satellite receiving facilities (e.g. South Africa and India) and a few groups that also have the ability to provide NRT data on a global basis (PML and University of South Florida). A pragmatic approach for the short term is to **make best use of current practice and existing services**, minimally adjusted where necessary. For example, the easiest way of bringing into the network new *in situ* partners, which are not covered by any regional receiving and processing capacity, is to use existing global EO capabilities, while striving to improve local and regional capabilities. In the medium-to-long term we will need to develop regional centres-of-excellence to promote sustainability and capacity building.

The initial suggestion of implementing new X-band receiving stations is no longer thought to be necessary for implementation of the network. Rather, adequate internet bandwidth is the major hardware limitation to overcome to ensure all regions are provided with satellite products. Access to the internet via PCs is now widely available to most of the users identified. Therefore, web delivery of data and products is recommended as the most practical mechanism to implement across the network. In the few cases where internet access is not available to users, other mechanisms already exist for data delivery (e.g. faxes to fishing cooperatives in India) and it is recommended that these are continued as long as they are required.

Recommendations

General

1. GEO and GOOS should encourage Space Agencies to ensure continuity of satellite sensors to measure ocean colour. This should include approaching governments that have the capacity to measure ocean colour but do not at present release the data for international co-operative use.
2. It is essential that national space agencies with existing or planned ocean colour missions, within the 2006-2015 window, maintain ocean colour capabilities within the payload, that sensor specifications are not reduced and that launch timescales are not significantly delayed.
3. It would be of great benefit to the functioning of the Network, with immediate advantage to the international user community, if data-sharing agreements could be reached with the relevant national space agencies to enable common access to data streams from current and future ocean-colour missions. The Network cannot function without data.
4. A pragmatic approach for the short term is to make best use of current practice and existing services, minimally adjusted where necessary. For example, the easiest way of bringing new

partners into the network is to use existing global capacities, while striving to improve local capabilities. In the long term we need to develop regional centres of excellence to promote sustainability and capacity building.

Web interface

1. Access to the web interface should be through a web-portal. The network requires both a global portal linking to each of the regions and regional portals linking to each of the regional network partners.
2. There should be a common style for these portals that strongly identifies them as part of the network. This should be achieved through a unique cascading style sheet file, but with enough flexibility to cover the needs of all regions (e.g. multilingual information).
3. Online toolkits for manipulating images and data are also a basic requirement of many users and several of the network partners already provide these.
4. Consideration was given to the use of Google Earth for web dissemination of network data products. This is an excellent tool for outreach activities (particularly to the general public) as it is widely used and is simple to display. It is recommended that Google Earth data files be produced as demonstration products of the network for further evaluation.
5. Access to the internet via PCs is now widely available to most of the users identified. Therefore, web delivery of data and products is recommended as the most practical mechanism to implement across the network.
6. In the few cases where internet access is not available to users, other mechanisms already exist for data delivery (e.g. faxes to fishing cooperatives in India) and it is recommended that these are continued as long as they are required.
7. To facilitate access to the full range of users, the front-end web system must be simple, fast (accessible through a 56k dial-up connection), compatible with Microsoft Internet Explorer (IE) and Mozilla FireFox (FF) web browsers and not require any additional plug-ins.

Remote sensing

1. Processing centres should archive all levels used but for network use a minimum requirement is Level 2 data, to be made available and archived.
2. Software used should be open source (i.e. free to users as opposed to commercial and supported by an active user community).
3. Integration of Indian OCMDAS processing capability into an open source software system should be considered.
4. Ocean colour products should be distributed as images and data, to allow use by both non-specialists and specialists in remote sensing.
5. The recommended image format is PNG. This is a modern and compact image format which can be viewed on all recent web browsers.
6. The recommended data format is HDF 4.0 because all the remote sensing partners in the network are familiar with this format through its use in NASA's SeaDAS software.
7. Images should be displayed through the web interface; both data and images should be available for download, at least via FTP.
8. It is recommended that regional processing centres should archive all data levels produced but the minimum requirement for network is for level 2 data to be archived and made available.
9. Appropriate metadata should be provided with all products.
10. IOCCG should investigate the feasibility of providing uncertainty estimates compatible with Level 3 core products.

In situ observations

1. Minimum requirements for the application of the simplest method are a fluorometer, a spectrophotometer and a scientific freezer.
2. Equipment needed for each centre in the medium term includes a probe sonicator, a temperature controlled centrifuge, liquid nitrogen containers, and (taking account of the model of fluorometer available) a Welschmeyer kit.
3. The recommended protocol for Chla measurements is HPLC analysis. However, it is expensive equipment and requires qualified personnel. For that reason it is recommended that there be at least one HPLC system for each region, with the aim that each regional network can share the instrument.
4. To facilitate sharing of in situ data, it is recommended that a secure web access is provided for participants to upload their *in situ* data to the regional network hub.
5. The data format should include appropriate metadata, as a minimum GPS position, date and time of sampling, measurement units. It is also necessary to specify the protocol used for chlorophyll a analysis and SST measurement.

Follow-up Activities

A ChlorOGIN Africa web portal has now been established along the same lines as the Antares portal (www.atares.ws). The web site is at:

<http://www.npm.ac.uk/rsg/projects/chlorogin>

It integrates outputs from the Plymouth Marine Laboratory, the Joint Research Centre, Ispra, and the University of Cape Town. It also links to the Antares portal for South America.

It is anticipated that similar web portals will be established for other regions, and then linked to make ChlorOGIN truly global.

A large set of replicate samples of filtered seawater and filtered phytoplankton cultures were analysed for chlorophyll concentration using different protocols at the Plymouth Marine Laboratory during the workshop. Subsets of samples were also sent after freezing to the participating centres for analysis in their own laboratories after the workshop was over. Sending frozen biological samples to various international destinations turned out to be a major undertaking, with various logistical and administrative hurdles to be overcome at many destinations. All samples are now delivered, and some of the results from the local analyses have come in. These results are now being analysed, and recommendations based on the analysis will be prepared and distributed to the participating centres.