Intergovernmental Oceanographic Commission

Workshop Report No. 119

IOC Workshop on Ocean Colour Data Requirements and Utilization

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Introduction

Ocean colour data is essential for monitoring and fostering our understanding of important ocean biological processes. Adequate data pertaining to ocean biological processes is extremely difficult to obtain due to the vast area of the ocean (over 70 % of the earth's area) and to the logistical difficulties of shipboard sampling. Satellite views of ocean colour are our only chance for gaining an overall view of the state of ocean biology at any given time. Ocean colour data is also the most practical way to develop the time-series data that will allow us to separate natural variability in ocean biological processes from secular changes.

Ocean colour data will allow us to monitor at a minimum such important areas as: biogeochemical cycles, direct effects of biology on ocean physics, coastal resources, and fisheries sustainability. The oceans are an important net sink for carbon dioxide released by the burning of fossil fuels. However, because the great spatial and temporal variability of fluxes of carbon dioxide into and out of the ocean are poorly understood, the nature and sustainability of this critical process is insufficiently understood. It is known that the uptake of carbon dioxide is related directly to the abundance of marine algae, which can only be effectively monitored on a global scale through ocean colour. The relative abundance of certain types of marine algae, also affect the ability of the oceans to absorb carbon dioxide by affecting the amount of calcium in the oceans, creating the potential for positive feedback between ocean warming and ocean biology.

Changes in alga abundance and species composition affect the extent to which solar radiation is absorbed or reflected by the surface ocean. Such changes will alter local and global oceanic heat budgets, with implications for both local and global climate. Trace gases produced by marine algae and released from the ocean to the atmosphere can affect local climates directly through their effect on cloudiness.

Half the world's population lives within 100 kilometres of the ocean. This huge population has a large impact on the coastal zone. Rivers discharge large amounts of nutrients and sediments, much of it derived from human activities, into coastal waters, affecting water quality, recreational opportunities and coastal fisheries. Blooms of toxic algae affect human health both directly and indirectly, most notably through their effects on shellfish. Ocean colour will allow us to better detect, monitor, asses and mitigate the impacts of these events.

Ocean colour measurements will provide data to support the rational management of living marine resources including aquaculture. Fish populations aggregate at areas of discontinuity between oceanic water masses; because phytoplankton growth may change across such boundaries, ocean colour gives the capability to map the surface manifestation of structure. Utilizing such information, scientists will be able to understand more fully how fish stocks respond to this structure. They will provide the tools that will give managers enhanced capability to intelligently manage and control these living marine resources. This will contribute to the efficient use and sustainability of these resources.

The deliverables of ocean colour remote sensing reflect the major science issues identified in earlier sections.

These issues are:

(i) the role of the oceans in climate change;
(ii) the assessment of natural and anthropogenic impacts in the coastal zone and shelf seas;
(iii) the monitoring and management of fisheries and the ecosystem of which the fish are part.

These deliverables can be categorized according to their utilization (unprioritized):

(i) Science research products (time series, annual to decadel time scale) ;
(ii) Operational products (short-term, daily to seasonal time scales);
(iii) Methodological validation products.

Within the first category are data for ocean models which will enhance our ability to forecast global change. These global scale observations will lead to the definition of biogeochemical premises and their characteristics which will serve as the basis for operational products. Operational products are required for environmental impact assessment, coastal zone management models, fisheries management and living resources protection.

The third category data is required to validate certain research approaches, and methodologies used in assessing ocean colour. This category also includes inter-comparison of different ocean colour sensors to improve understanding of global scale processes and insure data set interoperability.

The CZCS Experience

An important heritage of the Coastal Zone Colour Scanner (CZCS) experience, in addition to the insight provided on the bio-optical variability of the ocean, are lessons learned regarding how to manage the public interface and mission - science interaction. Recognition of these lessons can greatly improve the utilization of ocean colour data and enhance the social and economic benefits of future missions, as well as their scientific return.

In the area of technical sensor performance, improvements in sensitivity and spectral coverage, the CZCS experience has pointed out many improvements in spectral coverage, sensitivity, and overall approach which have been adopted by most of the second generation sensors, and which will improve the accuracy and relevance of final data products. A major limitation of the CZCS mission was the limited data access, due both to the limited duty cycle (the CZCS was rarely on due to power availability) and long delays in processing data. These limitations are largely overcome in the more “operational” second generation missions through direct broadcast and rapid data processing / distribution systems. Many of the near real time applications of ocean colour data were never fully demonstrated as a result of the data access limitations.

Optical characteristics of the CZCS, and other optical sensors, changed over time on orbit. This demands concerted and on going effort for calibration and validation of data products which has both retrospective (for science) and predictive (for near-real-time use) components. The sensitivity of the data to atmospheric effects of (desert dust and volcanic aerosols) must be considered.

Many coastal and optically complex waters have unique optical properties, and it was well beyond the capacity of the CZCS mission to validate data in all locations. The importance of contributions from the international community to validation in local waters was very apparent in the CZCS experience, and needs to be expanded for the second generation sensors.

This international and global validation requires consensus on standards and protocols for bio-optical measurements to enable the *in situ* application of the observations to multiple sensors.

In several instances, lack of adequate knowledge of the characteristics of the CZCS sensor limited improvements of data accuracy. This underscores the importance of pre-launch testing of new sensors, and of preserving this documentation.

Access and availability of software tools was also a major limitation to the use of CZCS data. Now there are many groups with excellent processing capability. Access to algorithms for the instrument-specific processing must be provided by the mission project to make use of this capability. Along with this, documentation of sensor characteristics, calibration, and software is very important to preserve the usefulness of the data to study long-term trends.

The most important developments of processing algorithms occur after launch, in order to account for, and take advantage of unique sensors attributes. There now exists broad consensus on most basic ocean colour algorithms, but advanced algorithms which make use of new sensor capabilities to account for gelbstoffe and detritus in coastal waters, and chlorophyll fluorescence, will improve rapidly after launch.

One important role of mission science teams is to provide guidance for optimal operations of the sensor and evaluate engineering trade-offs. In this role the team serves as an executive committee of the larger scientific community.

Many applications of ocean colour data are well documented already, but many new uses are likely, especially for near-real time use, as new data becomes available. The use of remote sensing data has gained wide acceptance in the scientific, commercial and governmental areas in the seventeen (17) years since CZCS was launched. Important areas of application such as for oceanic aerosols, source sinks of atmospheric trace gases, physics of the upper mixed layer and heat budgets, have been identified with CZCS but have not been fully realized in part due to limited data and focus on biological ocean distribution.

A global component in all missions, even those focused on small swaths and specific regions, serves to increase the scientific recognition, adds robustness to local algorithms, and greatly enhances international collaboration and education.

The International Effort

Increased nternational cooperation in satellite ocean colour remote sensing of the global and coastal oceans is very timely owing to the large number of sensors planned for launch over the next 10 years. This cooperation will save money and produce the best possible local, regional and global data products to study daily the interannual changes and trends in the biological characteristics of coastal and open ocean waters. The experience learned from the Japan/U.S. Working Group on Ocean Colour (JUWOC), now in its sixth year of operation, suggests that an expanded effort involving more satellites and space agencies will be successful.

For example, JUWOC led to co-ordination of OCTS and SeaWiFS sensor specifications, inter calibration of the sensors, compatible data products and formats, and cooperative calibration and validation programmes leading to an exchange of key *in situ* observations. In addition, JUWOC meetings and symposia helped develop better ocean colour applications. Other successful models include the U.S. Pathfinder programme for AVHRR measurements and the ISCCP programme for global cloud climatologies based on data from international weather satellites.

The two principal strategies of the cooperative programme envisioned here are to maintain continuity of key observations across multiple satellite sensors at the most important wavelengths, while at the same time promoting enhanced capabilities as more advanced sensors come on line. An important component of this programme is to develop protocols for calibrating sensors and developing relationships among national standards of all cooperating countries. Such a programme will ensure high quality data in the future to study basic scientific questions and to provide information to the practical decisions for managing the ocean environment and its renewable resources. Without a cooperative programme to inter-relate ocean colour measurements from different sensors, we will compromise our ability to detect important long-term changes in the ocean environment, lose opportunities to enhance understanding of important ocean processes affecting biological productivity and waste financial and personnel resources on duplicity of effort. When mission data are inter-related, multiple sensors are not duplicative but enhance applications. For example, the MOS instrument on PRIRODA will give an excellent view of the equatorial ocean, but will not be useful at higher latitudes. Combining MOS with SeaWiFS or OCTS however, will allow an enhanced view of equatorial waters imbedded within a global context.

Another important component of an international programme is to develop and refine programmes and protocols for *in situ* calibration and validation (cal/val) programmes, as well as protocols for exchanging these data. In situ cal/val programmes may involve countries who are not flying ocean colour instruments, but who are interested in developing their own local applications. Internationally coordinated cal/val programmes are valuable even if only one sensor is flying, since regional variations in bio-optical characteristics are significant and must be known for broadest possible applications of ocean colour imagery. Finally, an international group can be called on to recommend specifications and options for future missions.

The Next Steps

The following activities are seen as critical in the near future.

(i) Continuation of the inter-calibration round robins. Closely associated with this is the intercalibration of national calibration standards.

(ii) Development of multi-sensor calibration and validation campaigns and test sites.

(iii) Integration of *in situ* measurement programmes and sensor development programmes.

(iv) Development of multi-sensor data streams and products.

(v) Increased co-ordination between data providers (*in situ* and remotely sensed) and data users.

SUMMARY REPORT

1. OPENING

1.1 WELCOME

The IOC Workshop on Ocean Colour Data Requirements and Utilization was opened at 9:00 am on Thursday 21 September 1995 in the Institute of Ocean Sciences, Sidney, British Columbia by the Chairman Dr. Trevor Platt. The Chairman welcomed the participants and briefly stated the purpose of the workshop. Dr. John Garrett then welcomed the participants on behalf of the Institute of Ocean Sciences. He noted the importance of ocean colour to the understanding of the ocean ecosystem and pointed out the programmes ongoing at IOS in this regard. Mr. John Withrow welcomed the participants on behalf of Dr. G. Kullenberg, Secretary of the IOC. He thanked the Institute of Ocean Sciences who along with the Department of Fisheries and Oceans Canada offered to host this workshop. He noted the excellent facilities that had been provided and the support that had been received from the Institute in planning the workshop.

1.2 CONTEXT OF THE MEETING

Mr. John Withrow presented the context of the meeting. He reviewed the organizations who were involved in the effort, the background that led up to this workshop and the approach that was envisioned to meet the objectives. The two main organizations involved were the Intergovernmental Oceanographic Commission and the Committee on Earth Observing Satellites. He described the activities of these organizations as they relate to ocean colour. In bringing the participants up to date on the background, he particularly noted the close relationship between the IOC and the CEOS and how with the imminent launch of several ocean colour sensors these activities had come together to work toward the most efficient and productive use for this data. He noted with interest how three almost independent initiatives within the organizations involved had come together to produce this workshop.

The objective of the workshop was to produce a document and an international framework in which the international ocean colour data requirements and utilization system could develop. The immediate audience for this document would the 9th plenary of the Committee on Earth Observing Satellites. This framework would serve as a coordinating body within the framework of CEOS (IOC is an affiliate of CEOS) for the enhancement and expansion of the international ocean colour programme. Through this mechanism maximum use would be made of existing activities with the IOC and CEOS.

1.3 APPROVAL OF THE AGENDA

Dr. Platt reviewed the agenda and pointed out that the first day had been developed to permit a review of the status and plans for each of the sensors along with the plans of the various programmes that would use the data. Presentations would be given on the CZCS experience, the NASA Ocean Colour Workshop (Miami, February 1995), data access, algorithm/software development, and training and capacity building. The second day would be devoted to the preparation of the document and framework. The workshop felt that the agenda item on the NASA Ocean Colour Meeting in Miami would best be used to start the discussion on the second day and inserted it prior to the discussion of the plan. With this modification the Agenda was approved and is included in Annex I. Dr. Platt noted that the first day was very ambitious and that each presentation should adhere to the time schedule set forth and include just the essentials. He reminded the participants that these presentations were to form the background against which the plan would evolve.

2. BACKGROUND

2.1 THE CZCS EXPERIENCE.

Dr Esaias presented this agenda item pointing out that an important heritage of the Coastal Zone Colour Scanner (CZCS) experience, in addition to the insight provided on the bio-optical variability of the ocean, are lessons learned regarding how to manage the public interface and mission - science interaction. Recognition of these lessons can greatly improve the utilization of ocean colour data and enhance the social and economic benefits of future missions, as well as their scientific return.

Dr. Esaias pointed to lessons learned in technical sensor performance, optical characteristics of the sensor, calibration and validation, protocols and intercalibration, access to data, access to software and tools, documentation of sensor characteristics, algorithms, operations, data processing and application development. He particularly emphasized the need for a global programme that emphasized continuity and intercomparability across sensors along with an open data policy that permits the maximum possible use of the data.

2.2 STATUS OF OCEAN COLOUR PROGRAMMES

Short presentations were given on each of the following ocean colour sensor programmes.

SeaWiFS - Dr. Robert Frouin and Dr. Alan Webb described the current status of the SeaWiFS mission. The workshop was concerned about the ongoing delays in the programme and especially about the fact that no launch date was envisioned. Dr. Webb assured the participants that when the spacecraft was ready (est. November 1995), the launch schedule could be modified to provide for the launch of the instrument. He noted that they felt that the problems with the launch vehicle had been identified and that should not delay the deployment.

OCTS - Dr. T. Saino presented the current status of the OCTS mission. He noted that the mission was developing smoothly with an launch envisioned in August 1996.

MOS - Dr. Andreas Neumann and Dr. Narandra Nath made presentations the present status of this sensor. This instrument will be flown on two missions, the PRIRODA-module and the Russian space station MIR and the Indian IRS-P3 spacecraft in a polar orbit. Both launches are envisioned for 1996. Dr. Nath presented an interesting summary of applications developed or being developed for this data by the Indian Space Agency.,

POLDER - Dr. Robert Frouin present the status of Polder on behalf of Dr. Anne Lifermann. He noted that this instrument was due be launched on the same platform as OCTS in August 1996 and be complementary to OCTS.

MERIS - Dr. J. Aiken presented the status of the development of the MERIS mission envisioned for launch in 1998.

MODIS - Dr. W. Esaias presented the status of the development of the MODIS mission envisioned for launch in 1998.

The workshop expressed support for the increased co-ordination of missions to permit the maximum intercomparability and interoperability of the data. The meeting recognized the opportunity of having multiple sensors in space and the opportunity that it presented for higher temporal resolution data especially from the coastal zones. The community has had to work with a data gap extending since 1987 and having multiple sensors concurrently in space provides needed redundancy and insures the unbroken data set required for global change studies.

3. OCEAN COLOUR DATA UTILIZATION

3.1 APPLICATIONS AND PROGRAMMES

Dr. Platt introduced this agenda item with a presentation showing potential applications drawn from the CZCS experience. He used examples drawn from work in the North Atlantic to demonstrate the variability seen in ocean colour in those waters and how that variability related to the ocean ecosystem.

JGOFS - Dr. Yoder presented the summary and conclusions of the JGOFS Remote Sensing Task Team (Annex II). He reviewed the role of remote sensing in the JGOFS programme. Continuity of measurement is a major issue for JGOFS scientists. It is imperative that space agencies flying ocean colour scanners expend time and effort to understand how the different sensors compare with each other. He emphasized the synergism between *in situ* and satellite measurements and the role that JGOFS can play in calibration and validation of satellite measurements. For JGOFS, the principle regional and global data products from the SeaWiFS and OCTS missions will be individual satellite swaths at 4 x 4 km pixel resolution (possibly 0.7 by 0.7 km pixel resolution at nadir for OCTS), and global 9 km gridded products at daily and annual temporal resolution . JGOFS will require unrestricted access for research users at the cost of the transfer medial and standardization of data products and data formats. Ocean margin studies will require full resolution ocean colour imagery to resolve the strong pigment and other gradients found in continental shelf and slope waters. This will require a global effort to assemble this data set because the acquisition of this data is only possible through down linkings through independently operated HRPT stations.

LOICZ - Dr. Aiken described the IGBP LOICZ programme. LOICZ along with JGOFS is part of a set of linked projects to investigate the life-driven interactions within and between the land, atmosphere and ocean components of the Earth system. He reviewed the nature of the changes occurring at the land-ocean boundary including the type of change, scale of impact and environmental recovery time. The research foci of LOICZ were listed and the contribution of ocean colour to those foci was described. Extensive liaison with the LOICZ framework activities would be required to insure the best possible use of ocean colour data. One application of ocean colour data will be in the analysis of sedimentation and associated carbon burial resulting from the outflows from major world river basins.

GCOS - Mr. J. Withrow reviewed the needs for ocean colour for GCOS coming from the final report of the Ocean Observing System Development Panel (OOSDP). Satellite measurement of ocean colour provide global scale coverage of phytoplankton biomass. Experience with the coastal zone colour scanner (CZCS) sensor has shown that it is possible to estimate phytoplankton biomass from ocean colour, at least in open ocean waters. Introduction of the new sea-viewing wide field sensors (SeaWiFS) and its successors will considerably improve the sensitivity and accuracy of chlorophyll estimates. These data are central to establishing and using transfer functions for the extrapolation of *in situ* surface measurements of pCO2 and CO2 fluxes to regional and global scales. Satellite measurements of SST and of the surface wind field are also used in the transfer functions and are thus necessary complementary measurements.

GOOS - Mr. J. Withrow presented the current state of the development of Global Ocean Observing System. He pointed out that GOOS would grow out of studies conducted in WOCE, TOGA and JGOFS and use existing programmes such as IGOSS, IODE and GLOSS. The structure of GOOS would consist of two parts, the Intergovernmental side which would focus of implementation of the observing system and the Scientific side that would assemble the requirements based on results coming from the scientific community. The close relationship between the various global observing programmes was illustrated by the joint GCOS-GOOS climate panel. The five modules of GOOS were described along with the envisioned contribution of Ocean Colour to each of the modules. The newly formed CMM-IGOSS-IODE sub-group on Oceanic Satellites and Remote Sensing was seen as an important element of GOOS in the evaluation of satellite requirements including those of ocean colour. GOOS is in the process on developing its space and data management plans.

European community - Dr. Peter Schlittenhardt described the Ocean Colour European Archive Network (OCEAN) project, a joint IRSA / ESA initiative that was established to promote the use of ocean colour data towards an improved understanding of the European marine environment. The main goals of the project are the exploitation of historical data - collected by the CZCS, in the period 1978/1986, over marine regions of European concern - in support of current research activities, as well as the development of tools and structures in preparation for the future ocean colour missions.

To take advantage of the OCEAN project and the upcoming SeaWiFS mission and to prepare for the MERIS mission, IRSA has proposed, in a joint venture with ESA and in collaboration with other European partners an European SeaWiFS Programme on Ocean Colour Techniques for Observation, Processing and Utilization Systems (OCTOPUS). The OCTOPUS Programme is centered on (I) the use of scientific tools developed by the OCEAN Project and (ii) the availability of high-resolution SeaWiFS data to European receiving facilities.

Other activities of IRSA/ME that are particularly relevant to Ocean Colour studies:

(i) The Coastal Atmosphere and Sea Time-Series Project (CoASTS) which aims at the collection. analysis and application of reference data sets of atmospheric and oceanic measurements taken from an oceanographic tower in the Adriatic Sea. Over a two year period ((95 - 97) optical and bio-geo-chemical data will be collected in agreement with protocols suggested for SeaWiFS and suitable for calibration/validation of future ocean colour sensors (i.e. SeaWiFS, OCTS, MOS).

(ii) The development of a software environment for the simulation of an end-to-end ocean colour remote sensing systems (SeaWiFS, OCTS, MOS). This simulator will couple the geometry, the target and “exact” radiative transfer models and compute pigment/sediment concentrations from corrected radiance.

(iii) The design and implementation of a World Wide Web (WWW) “Ocean Colour” page for the community of the Committee on Earth Observation Satellites (CEOS). The prototype of this page will help to access all matters related to the general field of remote sensing of marine waters in the visible and near-infrared spectral range, as well as related *in situ* measurements and theoretical modeling of optical processes in the sea, for the determination of bio-geochemical.

IRSA/ME is also prepared to promote intercalibration activities at Ispra in support to the SeaWiFS mission. A first intercalibration round could be organized in collaboration with the NASA SeaWiFS team in spring 1996.

3.2 DATA ACCESS

Dr. Glover presented this agenda item. He covered a number of areas that will affect the users ability to access ocean colour data. Identification of data access points will be important as well as the interface access software. Once the data is accessed, efforts should be made to reduce the number of formats among the different sensors to permit the most efficient utilization of the data. Accuracy and precision numbers for the various instruments are well presented in the space agency literature but these are bench standards. Actual numbers for precision and accuracy should be made available as soon after launch as possible and easily accessed along with the data itself. The level to which the data is processed is generally a function of the user. Level 2 seemed to be appropriate for most research purposes but level three (gridded products) were necessary for some global studies. In all cases the processing algorithms used to take the data to the level at which it was accessed should be available to the user. The availability of derived products would be a function of the user community. Examples would be CZCS pigment, Chlorophyl-a, attenuation coefficient, aerosol optical thickness, chlorophyll fluorescence, coloured dissolved organic matter, coccollith concentration, primary production, etc.

3.3 ALGORITHM AND SOFTWARE DEVELOPMENT

Dr. Platt opened this agenda item with a presentation on algorithms and software developed during the CZCS experience. He echoed Dr. Esias words in that much experience had been gained and that it was important to carry this experience forward to the new sensors.

Dr. McClain described a new image analysis software package that has been developed for processing SeaWiFS Ocean Colour imagery. The SeaWiFS Data Analysis System (SeaDAS) provides researchers with an easy to use cost effective method for processing SeaWiFS and other satellite imagery using up-to-date hardware and software technologies.

4. TRAINING AND CAPACITY BUILDING

Brief descriptions were given of training activities conducted to expand the use of ocean colour data and insure that countries were able to effectively utilize the present CZCS ocean colour data set and new ocean colour data sets when they became available. Dr. Platt discussed his experience in conducting courses both in Canada and India. Dr. McClain discussed courses that were offered through the SeaWiFS programme and taught at NASA GSFC. Mr. Withrow described IOC activities in training, noting several important factors that contributed to a successful training experience, which had been covered in the discussions. In order for training to be successful, the participants had to have access to the data at the place where they are working. Without that the training experience would not be sustainable. There also must be follow up and a way for the trainee to interact with others after the course. Without a support environment the training would again not be sustainable.

5. THE PLAN

5.1 THE OCEAN COLOUR MEETING
(Miami, USA, February 1995)

Dr. McClain discussed the recent international workshop on ocean colour that had been conducted in Miami and reviewed the SIMBIOS plan that came out of that workshop. He described the contents of that plan and suggested that it could provide useful input to the discussion to be conducted during this Workshop.

5.2 DEVELOPMENT OF THE PLAN

The workshop reviewed the SIMBIOS plan and noted that it was a very detailed plan that could not be adequately addressed at this meeting. The participants recalled the objective of the meeting which was to produce an executive summary describing the way forward for Ocean Colour and indicating a framework to accomplish that. The Workshop broke the work envisioned down into the following categories and formed working groups during the session to draft the appropriate text:

- (i) Introduction - Application of Ocean Colour.
- (ii) The CZCS Experience.
- (iii) Why International cooperation?
- (iv) Ocean Colour Deliverables.

The Workshop then identified the following as important activities that needed to be addressed in the next six to twelve months:

(i) Continuation of the inter-calibration round robins. Closely associated with this is the intercalibration of national calibration standards.

(ii) Development of multi-sensor calibration and validation campaigns and test sites.

(iii) Integration of *in situ* measurement programmes and sensor development programmes. Provision for integration of *in situ* and remotely sensed data streams.

(iv) Development of multi-sensor data streams and products.

(v) Increased co-ordination between data providers (*in situ* and remotely sensed) and data users.

The workshop then formulated a simple and cost effective international structure to facilitate the above activities and insure the maximum effectiveness of the international ocean colour effort. This structure takes advantage of existing structures within the international oceanographic and space communities allowing for a higher level of investment in data system development (Fig. 1). The workshop decided that the expert group should consist of 10 - 12 members with the appropriate international balance. The expert group should have the following terms of reference:

1. Co-ordination of Calibration and Validation activities in cooperation with the CEOS Working Group on Calibration and Validation.

2. Co-ordination of Data Management activities relevant to the user community including merging of data, data access and product development in cooperation with the CEOS WGD.

3. Providing advice on Programme direction based on feedback from activities and developments in the user community.

4. Development of international Ocean Colour activities geared toward expanding the use of ocean colour data and products including Training.

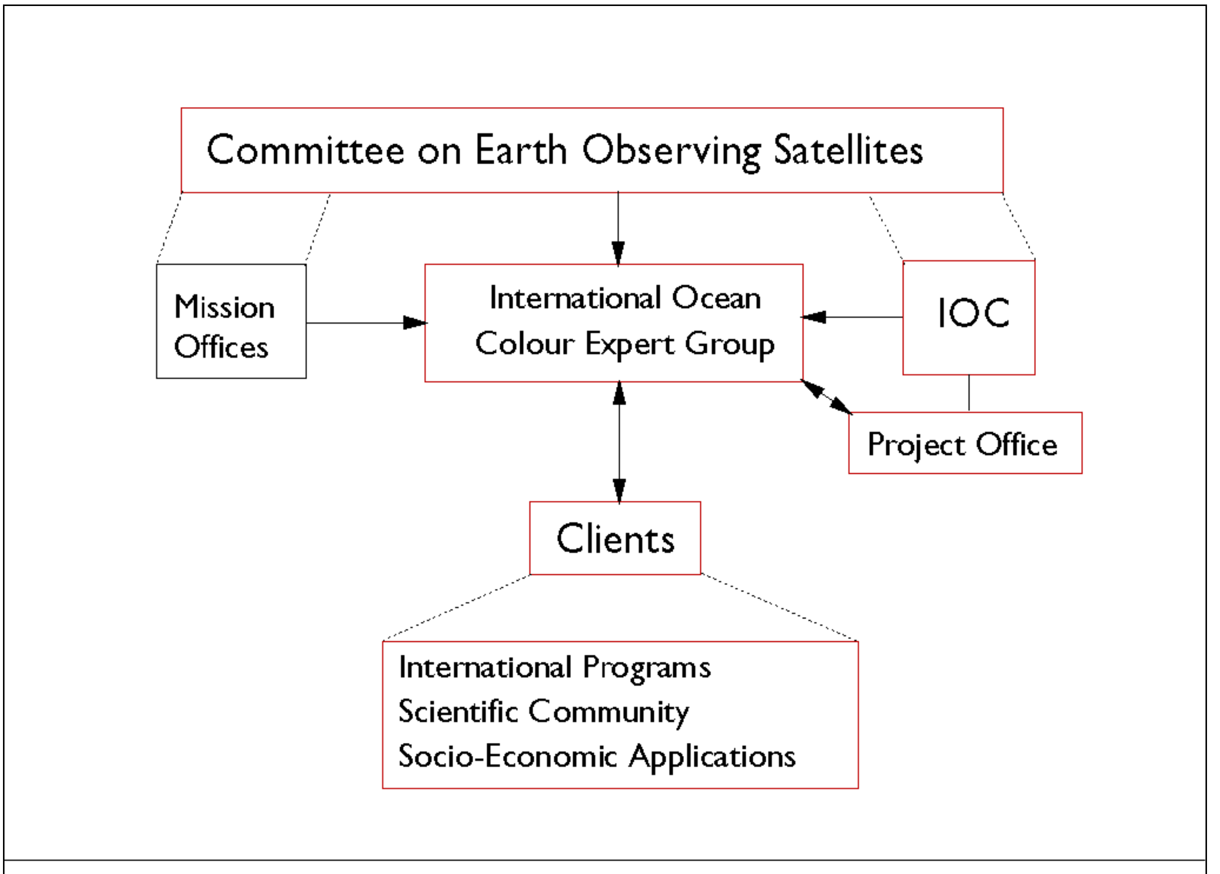

Figure 1 - International Context

The project office would support the activities of the expert group and have the following terms of reference.

1. Support for the Ocean Colour Expert Group and serve as a point of contact for the distribution of information regarding its activities and the ocean colour community at large.

2. Promote and facilitate training and mutual assistance.

3. Provide day to day project supervision. Make required reports to governing bodies and funding agencies.

6. CLOSURE

The Chairman thanked the participants for their efforts in making this workshop a successful activity. The IOC Workshop on Ocean Colour Data Requirements and Utilization was closed at 5:00 pm on 22 September 1995.

ANNEX I

AGENDA

1. **OPENING**

    1.1 WELCOME

    1.2 CONTEXT OF THE MEETING

    1.3 APPROVAL OF THE AGENDA

2. **BACKGROUND**

    2.1 THE CZCS EXPERIENCE

    2.2 STATUS OF OCEAN COLOUR PROGRAMMES

3. **OCEAN COLOUR DATA UTILIZATION**

    3.1 APPLICATIONS AND PROGRAMMES

    3.2 DATA ACCESS

    3.3 ALGORITHM AND SOFTWARE DEVELOPMENT

4. **TRAINING AND CAPACITY BUILDING**

5. **THE PLAN**

    5.1 THE OCEAN COLOUR MEETING (Miami, USA, February 1995)

    5.2 DEVELOPMENT OF THE PLAN

6. **CLOSURE**

ANNEX II

**SUMMARY AND CONCLUSIONS EXTRACTED FROM:
A REPORT OF THE JGOFS REMOTE SENSING TASK TEAM
(Narragansett, USA, 27 July 1995)**

A. Roles of Remote Sensing in the JGOFS Programme

1. Satellite-derived near-surface phytoplankton pigment (biomass) fields will be used to initiate and validate numerical models of ecosystem and biogeochemical processes.

2. Satellite-derived near-surface phytoplankton chlorophyll fields are one of the key components of the algorithms used to calculate primary and new production at regional to global scales.

3. Satellite ocean colour measurements will be used to extrapolate in space and time those constituents of seawater that are well correlated with phytoplankton chlorophyll a or other optical parameter detected by measurements.

4. Real-time satellite ocean colour and SST imagery will be used to support and direct ship-based measurement programmes.

5. Wind velocity, sea level and other products derived from satellite altimeters, scatterometers and other space radars will be used to force circulation fields in upper ocean numerical models of biogeochemical cycles.

B. Continuity of Ocean Colour Measurements

During the 1990s, JGOFS scientists plan to use data from several different ocean colour sensors operated by at least four different space agencies (CNES, ESA, NASA and NASDA) . Continuity of measurement is thus a major issue for JGOFS scientists. Specifically, JGOFS scientists need a continuous, calibrated record of global observations of water-leaving radiance and chlorophyll a. For satellite ocean colour measurements to be useful for JGOFS purposes, it is imperative that space agencies flying ocean colour scanners expend time and effort to understand how the different sensors compare with one another.

C. Synergism of *In Situ* and Satellite Measurements

SeaWiFS and OCTS project and science teams are planning major programmes to ensure that these instruments are accurately calibrated and reliably validated. JGOFS is the only global programme that can provide calibration and validation samples over the global oceans. For calibration and validation of ocean colour sensors, highest priority is for measurements of water-leaving radiance and pigment measurements. However, other in situ measurements are required if the JGOFS programme is to take full advantage of satellite measurements. For example, we need a much better global data base for the parameters of the photosynthesis versus irradiance relation, if we want to use global ocean colour measurements to improve estimates of the mean and fluctuating components of primary production.

D. Data Products

The principal regional and global data products from the SeaWiFS and OCTS missions will be distributed as individual satellite swaths at 4 X 4-km pixel resolution (possibly at 0.7 x O.7-km pixel resolution at nadir for OCTS), and as global gridded products at daily to annual temporal resolution and at approximately 9-km resolution. Measurements and derived products include water-leaving radiance at various spectral bands, one or more estimates of chlorophyll a (using different algorithms and approaches), aerosol radiance, and attenuation coefficient at 490 nm.

E. Data Access

A major role for the JGOFS programme is to monitor data access policies of the various national space agencies and where needed, lobby for unrestricted access for research users at the cost of the transfer media Secondly, JGOFS should lobby for some standardization of data products and data formats. Finally, JGOFS should lobby for technical support for data users, including software development and distribution.

Ocean margin studies require full resolution ocean colour imagery to resolve the strong pigment and other gradients found in continental shelf and slope waters. NASA's SeaWiFS Project will not routinely process 1 X 1 km imagery (although NASDA plans to process and distribute OCTS products at 0.7 X O.7-km pixel resolution at nadir). At present, the task of developing full spatial resolution regional time series is left to those groups operating HRPT type antennas capable of down linking SeaWiFS data. This could make it very difficult to synthesize satellite observations of ocean margin waters beyond the regional scale, since acquisition of full resolution data over the qlobal margins will not be a trivial task

F. Primary and New Production

Primary production and new production are not directly measured from space. To improve current estimates requires satellite ocean colour measurements, as well as various in situ measurements. To take full advantage of satellite derived global chlorophyll fields, JGOFS needs to develop a better data base of the physiological parameters that characterize phytoplankton photosynthesis.

G. Aircraft Sensors

Aircraft sensors may prove to be very useful for JGOFS ocean margin studies. Most ocean margin waters are generally located relatively near airports, which simplifies the logistics involved in deploying aircraft instrumentation thus reducing the costs of operation. Active sensors, such as NASA's AOL, can operate at low altitude (150-m) beneath clouds and thus can acquire data when satellite sensors are blind. Some aircraft sensors (e.g. NASA's AVIRIS) have much higher spectral and spatial resolution than will be realized in satellite ocean colour sensors for the near future.

ANNEX III

LIST OF PARTICIPANTS

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ANNEX IV

LIST OF ACRONYMS

AOL	Airborne Oceanographic Lidar
AVIRIS	Airborne Visible and Infrared Imaging Spectrometer
CEOS	Committee on Earth Observing Satellites
CEOS WGD	CEOS Working Group on Data
CMM	Commission for Marine Meteorology
CNES	Centre national d'études spatiales (France)
CoASTS	Coastal Atmosphere and Sea Time-Series Project
CZCZ	Coastal Zone Colour Scanner
ESA	European Space Agency
GCOS	Global Climate Observing System
GLOSS	Global Sea-Level Observing System
GOOS	Global Ocean Observing System
GSFC	Goddard Space Flight Center
HRPT	High Resolution Picture Transmission
IGBP	International Geosphere-Biosphere Programme - A Study of Global Change
IGOSS	Integrated Global Ocean Services System
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
IODE	International Oceanographic Data and Information Exchange
IOS	Institute of Ocean Sciences (Canada)
IRSA	Institute for Remote Sensing Applications
IRSA/ME	Institute for Remote Sensing Applications/Marine Environment
ISCCP	International Satellite Cloud Climatology Project
JGOFS	Joint Global Ocean Flux Study
JUWOC	Japan/US Working Group on Ocean Colour
LOICZ	Land-Ocean Interaction in the Coastal Zone
MERIS	Medium Resolution Imaging Spectrometer
MODIS	Moderate-Resolution Imaging Spectrometer
MOS	Marine Observational Satellite (Japan)
NASA	National Aeronautics and Space Administration (USA)
NASDA	National Space Development Agency (Japan)
OCTOPUS	Ocean Colour Techniques for Observation, Processing and OCTS Utilization Systems
OCTS	Optical Colour and Temperature Scanner
OOSDP	Ocean Observing System Development Panel
POLDER	Polarization and Bidirectionality of the Earth's Reflectance
PRIRODA	Russian Space Station
SeaWiFS	US Sea-Viewing Wide Field-of-View Sensor
SIMBIOS	Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies
SST	Sea-surface Temperature
TOGA	Tropical Ocean and Global Atmosphere (WCRP)
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCRP	World Climate Research Programme
WOCE	World Ocean Circulation Experiment
WWW	World Wide Web

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