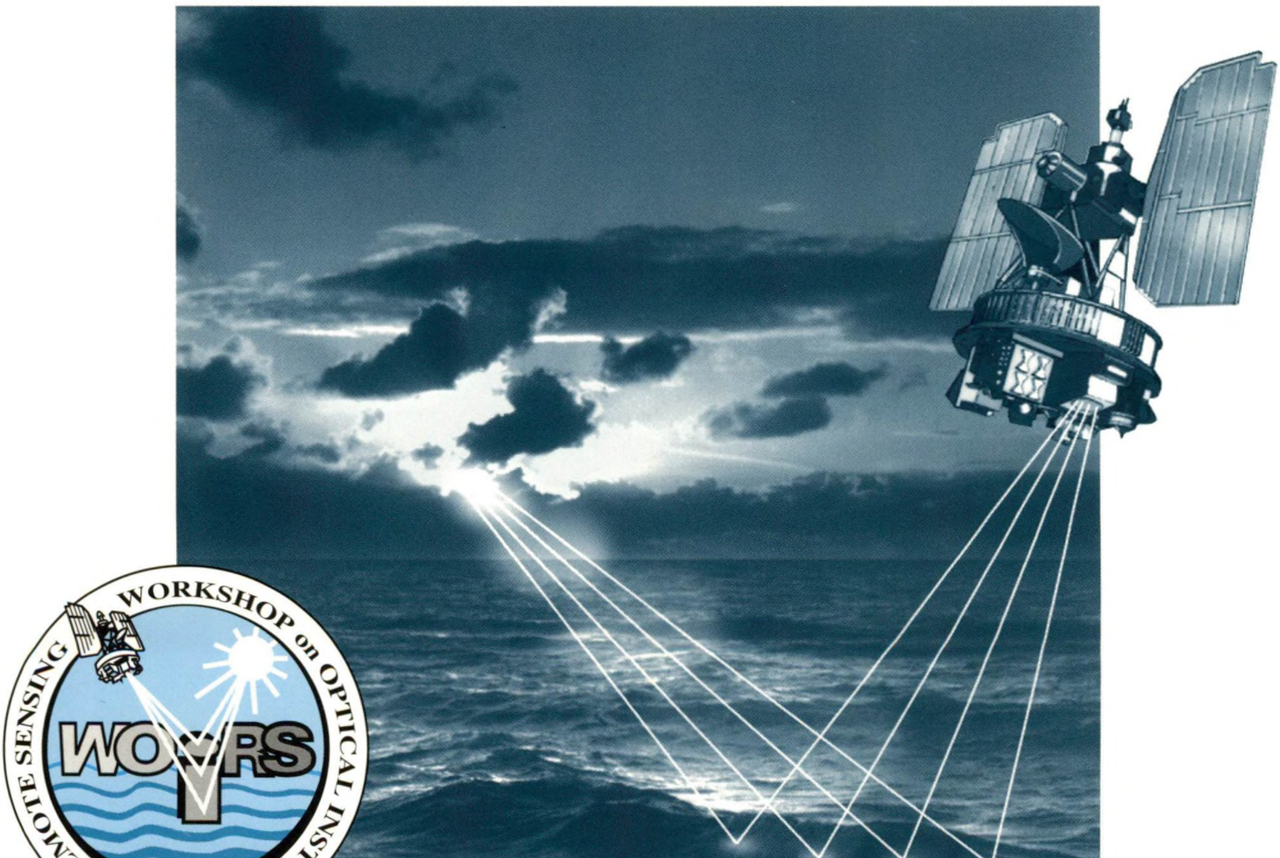
NIOZ -RAPPORT 1994 - 3

EUROPEAN WORKSHOP ON OPTICAL GROUND TRUTH INSTRUMENTATION FOR THE VALIDATION OF SPACE-BORNE OPTICAL REMOTE SENSING DATA OF THE MARINE ENVIRONMENT

23 - 25 Nov. 1993

Editor: M.R. Wernand



Nederlands Instituut voor Onderzoek der Zee

Netherlands Institute for Sea Research (NIOZ)
P.O. Box 59, 1790 AB Den Burg, Texel
The Netherlands

ISSN 0923 - 3210

cover design: H. Hobbelink

EUROPEAN WORKSHOP ON OPTICAL GROUND TRUTH INSTRUMENTATION FOR THE VALIDATION OF SPACE-BORNE OPTICAL REMOTE SENSING DATA OF THE MARINE ENVIRONMENT

WOIRS-93

23 - 25 NOVEMBER 1993

EDITOR: MARCEL R. WERNAND

This workshop was financially supported by the Commission of the European Communities

NETHERLANDS INSTITUTE FOR SEA RESEARCH

NIOZ-RAPPORT 1994 - 3

THIS REPORT WAS WRITTEN IN CLOSE COOPERATION WITH IR. PAUL GEERDERS
OF GEERDERS CONSULTANCY

Acknowledgements:
I like to thank Maarten van Arkel and Paul Geerders for their assistance in organising the workshop and Joke Hart, Anneke Bol and Elly van Duivenbooden for their administrative help in relation to the workshop.
I would like to thank Henk Spigt and his staff for the creativity devoted to the excellent lunches provided during the workshop.

Special thanks goes out to Alison Weeks, Gerald Moore and Henning Hundahl, who became ad-hoc chairmen of the WOIRS subgroups: optical data bank, (inter)calibration, instrument development respectively, and for their help in completing this report.

EXECUTIVE SUMMARY

BACKGROUNDS

The forthcoming dedicated ocean colour satellite sensors such as SeaWiFS and MERIS are expected to become of great importance to the European marine science community. However, for an adequate interpretation of the data from these sensors it will be essential to implement an operational system for ground truth reference and intercalibration through in-situ optical measurements widely spread across Europe. Such a system needs standardized optical equipment of an acceptable price that can be purchased and operated by a wide community of marine scientists. In view of the present high cost and technical complexity of commercially available marine optical instruments, the design and development of a new 'low cost' and easy-to-use instrument is required. This requirement formed the main incentive for the workshop.

The primary aims of the workshop were i) to define specifications for a multi-band ocean colour ground truth instrument ii) to design a 'low cost', multi-band ocean colour ground truth instrument to be used from ships and other sea-borne or airborne platforms and iii) to achieve common procedures for (inter) calibration of marine optical instruments; such procedures are indispensable to maintain the quality of optical measurements over the years and to ensure compatibility of optical measurement data from different sources. In addition, the possible set-up of a European Optical Databank (ODB) was discussed. Since European coastal waters are largely of Case-2 type, the workshop had its main focus on this type of waters.

The workshop was held at the initiative of The Netherlands Institute for Sea Research, NIOZ and at its premises. It was funded by EC-DGXII and was strongly supported by the Joint Research Centre, Ispra. This report presents the background for the workshop, a summary of the discussions during the workshop as well as the recommendations that resulted from it.

WORKSHOP

The first day of the workshop was devoted to a large number of short presentations by participants describing the state-of-the-art in marine optics in Europe. All participants received abstracts of the presentations as well as a photocopy of the overheads used in the presentations.

In order to obtain the maximum gain from the expertise of the participants in the limited duration of the workshop three subgroups were formed: on instrument development, on the optical data bank and related matters and on (inter)calibration aspects. These subgroups held their discussions during the second, and part of the third day of the workshop. A final joint session summarizing the results of the subgroup discussions as well as the conclusions and recommendations concluded the workshop.

Participants had been given the opportunity to present a poster. Through these posters valuable material had been made available as background information for the discussions. The posters were displayed in the room where the coffee breaks were held. This allowed for a close interaction between the participants and the authors of the posters.

A number of companies active in the field of optics had been invited to provide documentation, posters or demonstrations. Relevant documentation was also displayed.

CONCLUSIONS AND RECOMMENDATIONS

The participants found this workshop highly useful and effective. Several participants agreed their willingness and availability to participate in the implementation of the recommendations of the workshop.
The workshop agreed on the conclusions and recommendations below; these have been divided into a specific and a general section.

SPECIFIC RECOMMENDATIONS

The workshop recommended the development of a **'low cost', multi-band ocean colour ground truth instrument for Case-II waters**. Characteristics of such an instrument are specified in Annex D. **Three design alternatives are presented as they came forward during the workshop** (AWI, SOTON, NIOZ). Therefor, three breadboard designs are to be worked out. Prototypes could be ready within six month after the workshop (as a follow up) providing budget and personnel constraints allow. Performance will be compared.

The workshop recommended the compilation and publication of a **European manual for marine optical measurement protocols and techniques** possibly as a joint effort between EC and IOC. This manual primarily should be distributed to the relevant scientists and technicians across Europe but it would also be of great value in other parts of the world. Proposed contents for this manual are presented in annex G.

The workshop recommended the establishment of a **European marine optics calibration facility**. Comprehensive guidelines for this facility are presented in annex H. It is expected that GKSS will proceed with the establishment of this facility.

The participants recommended the establishment of a **European Optical Data Bank (ODB)** to act as central storage and retrieval facility for marine optics data from all European seas. In annex I a more detailed overview is presented of the required performance of the ODB.

The workshop recommended the organization of a **European advanced training course on marine optics** to be sponsored by EC-MAST and to be held towards the end of 1994 or the beginning of 1995. Details of such a course are indicated in annex J.

Proposed standards for deployment of in-situ radiometers are outlined in Annex K.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The participants agreed that this workshop had been a unique opportunity for European experts in this field to meet and discuss relevant matters: **regular (yearly) meetings of this group would certainly be most useful**. Specifically, it was strongly recommended to hold **a meeting of the instrument developers in about six months' time** in order to provide further guidance to the follow-up actions concerning design and development of the proposed instrument. This would include: the choice between the present three design alternatives, the prototype development and the final (industrial?) series production of the required instrument.

The material presented during the workshop provided an excellent overview of the state-of-the-art in the field of marine optics in Europe. In addition the areas where urgent development is needed were identified. In view of the relevance of marine optical remote sensing for several current and foreseeable EC programmes (Framework IV) **the EC is recommended to consider (co)sponsoring (some of) the proposed actions and activities**.

It was be expected that implementation of the proposed actions would **improve the basis for marine optical Remote Sensing** in Europe. Specifically, it will contribute to the availability of more accurate and more regular Remote Sensing dataproducts of the marine environment for European users such as the current and planned European programmes for research and monitoring related to climate and environment.

INTRODUCTION

Earth observation techniques or remote sensing techniques have evolved considerably during the last decade. These techniques, carried out by both satellites and aircraft are of unique importance for marine research. Measurements of radiance in the visible spectrum, known as optical remote sensing, are of special importance as they enable the measurement of parameters below the water surface, such as the concentration of suspended matter including algae and pigment concentration. Parameters derived from optical Remote Sensing are of great value in a number of climate and environment related applications.

Optical remote sensing is complementary to more traditional oceanographic observation techniques carried out from ships or fixed platforms and is of specific importance for observation of spatial distribution patterns, for synoptic mapping and for monitoring the marine environment. This is because remote sensing enables observations on a large scale which cannot be accomplished otherwise.

Several institutes in Europe have specialists working in the field of marine optics. They work mainly on the technical improvement of groundtruth sensors necessary for the interpretation of remote sensing data and on the development of water quality algorithms. But this small number of specialists can only participate in a limited number of oceanographic cruises since their own special instruments cannot be used by untrained people. On the other hand, instruments offered by industrial suppliers are generally very expensive and also need trained staff for handling.

As a result, there is a **shortage of marine optical measurements in European coastal waters carried out on board ships and coinciding with water quality measurements**, which is necessary to correlate water quality parameters with remote sensed data. Consequently there is an urgent need for the design and development of a new 'low cost' and easy-to-use marine optics instrument. This need formed the initial motivation for the workshop.

Furthermore, it should be noted that **present marine optical data lacks the necessary intercalibration and standardization**. This is because different institutes use very different instruments and no international (or European) standards for acquisition and dataprocessing of marine optical data are available. Improving these aspects formed a second incentive for WOIRS.

European ocean colour policy started in the late eighties by an initiative of the Joint Research Centre, Ispra, Italy with support from DGXII, Commission of the European Communities (CEC) and the European Space Agency (ESA), in the form of a project called OCEAN (Ocean Colour European Archiving Network). The main purpose of the project was to revalidate archived CZCS data collected over European waters for a better understanding of bio-geo-chemical and dynamical processes in the sea. The project would also serve to prepare software tools and network structures for processing and distribution of future ocean colour data collected with new remote sensors.

At present plans are underway to launch new space-borne ocean colour sensors, SeaWiFS (NASA) (1994), MERIS (ESA) (1998), OCTS (NASDA) and MODIS (NASA). In view of these plans a new European programme named OCTOPUS has been launched (Ocean Colour Techniques for Observation, Processing and Utilization Systems, supported by DGXII), with the intention of establishing the basis of a new approach towards European ocean colour data management and research. As one of its aims OCTOPUS will facilitate the inclusion and operational usage of end user-oriented ocean colour data products in current and planned European and global research and monitoring programmes related to climate and environment.

The Netherlands Institute for Sea Research, NIOZ, developed the initial ideas for WOIRS in the beginning of 1992. After consultation with the relevant experts in Europe and with several EC officials a proposal was submitted on 29 September 1992 to EC-DGXII. The requested support was granted on 1 January 1993.

Strong support for the workshop was also obtained from the European Joint Research Centre's Institute for Remote Sensing Applications in Ispra, Italy.

The workshop was held at The Netherlands Institute for Sea Research, NIOZ, on the island of Texel, The Netherlands, 23 - 25 November 1993. The workshop participation was made up exclusively of invited participants. These were experts (oceanographers, instrument-designers, technicians) working in the field of optical oceanography and strongly related to Remote Sensing of ocean colour. Apart from the European experts, one expert from the USA was invited to ensure a close link with the SeaWiFS programme. A list of the participants is presented in annex B. NIOZ provided all organizational and logistic support for WOIRS.

AIMS AND STRUCTURE OF WOIRS

The first aim of the workshop was **to design a 'low cost', multi-band ocean colour ground truth instrument** to be used from ships and other (sea-borne and air-borne) platforms. It might also be mounted on a CTD frame to measure Eu, Ed and $R(\lambda)$, could be towed to measure $R(\lambda)$ or could be placed in a flow-through system for measurement of $c(\lambda)$. In this context a decision had to be made as to what to measure: apparent or inherent optical properties. It was hoped that the workshop would be able to identify manufacturers interested and able to build the required instrument.

The second aim of the workshop was **to achieve common procedures for (inter) calibration of marine optical instruments**. These are indispensable to maintain the quality of marine optical measurements over the years and to ensure compatibility of marine optical measurement data from different sources.

As a third aim, discussions were devoted to **the establishment of a European databank (ODB)** with optical data from European waters. Such a facility would form an important asset for both research in marine optics and operational applications related to climate and environment.

The first day of the workshop was devoted to a large number of short presentations by participants describing the state-of-the-art in marine optics in Europe. Abstracts of these presentations are presented after this section. All participants received abstracts of the presentations as well as a photocopy of the overheads used in the presentations.

In order to obtain a maximum gain from the expertise of the participants within the limited duration of the workshop **three subgroups** were formed: **on instrument development**, **on the optical data bank** and related matters and **on (inter)calibration aspects**. These subgroups held their discussions during the second, and part of the third day of the workshop. A final joint session summarizing the results of the subgroup discussions as well as the conclusions and recommendations concluded the workshop. The full programme of the workshop is presented in annex A.

PRESENTATIONS (Abstracts)

INTRODUCTION

MARCEL R. WERNAND
Netherlands Institute For Sea Research, Texel, The Netherlands

Why organize this workshop? Oceanographers have been working with the "secchi disk" for over a century and in my opinion the time has come to develop a new, inexpensive, tool for measuring the transparency of the water column. Furthermore, within Europe, a new approach towards the exploitation of ocean colour data is under way in the form of a programme called "Ocean Colour Techniques for Observation, Processing and Utilisation Systems (OCTOPUS). For this programme there is a need for standardized ground truth instrumentation for the inter calibration of satellite sensors and the validation of remotely sensed data.

After the launch of the CZCS sensor, the ground truth equipment for inter-calibration purposes as designed by people working in this field was limited to specialised optical laboratories, although high cost radiometers could be purchased from a few US based companies. During the eighties new companies such as Kahlsico, Seatech, Dansk Havteknik, Biospherical Instr., Li-Cor, and Chelsea Instr. developed their "off the shelf" underwater instruments. Prices for full spectrum devices varied from $15,000 US to $50,000 US and for single band transmissometers and fluorometers from $8,000 US to $15,000 US.

The high cost of such instruments has meant that during the operational period of the CZCS, optical inter-calibration measurements were extremely limited. For example, at the Netherlands Institute for Sea Research, numerous reflection measurements were collected in the Indian and Atlantic Oceans i.e. Case 1 waters during 1975 and 1985; coastal waters were however poorly sampled optically.

In the near future, a standard optical water qualification device will be a necessity for ground truth inter-calibration of the forthcoming new satellite sensors SeaWiFS and MERIS. Such a device measuring diffuse attenuation or reflection could be mounted on rosette frames which already house CTDs, transmissometers and fluorometers for standard data collection. The main problem with this approach is the possibility of a shadowing effect from the mounting platform. A similar device can be used to detect "on deck" solar radiation. Numerous research vessels are already equipped with an automatic on board logging system (ABS) for continuous storage of flow-through beam attenuation and fluorometer data, which can be used for other optical data.
As only a few well funded scientists or instrument builders collect optical data of the ocean it is preferable to design an accurate, low-cost, multi-channel instrument. Hence scientists from all disciplines would be able to use such an instrument to help them interpret ocean colour data and eventually build up a large data bank of optical measurements from all water types.

A SIMPLE METHOD FOR RADIANCE CALIBRATION

EYVIND AAS

Institutt for Geofysikk, Universitetet i Oslo, Norway

It is demonstrated how the effective solid angle of the marine radiance meter's field of view may be determined by means of only an ordinary halogen lamp. If the spectrum of the lamp is known, the instrument will be spectrally calibrated in the same process. No diffusing surfaces are needed.

This method is described in Annex E

INHERENT OPTICAL PROPERTIES OF EUTROPHIC WATERS

ARNOLD G. DEKKER

Institute for Environmental Studies, Vrije Universiteit, Amsterdam, The Netherlands

Research has been carried out into the development of a physical model which allowed the development of analytical, multitemporally valid, high spectral resolution remote sensing algorithms for remote sensing of turbid, eutrophic inland waters.

For this purpose laboratory spectrophotometric measurements were performed from which the spectral absorption (a), scattering (b) and backscattering (b_b) properties (i.e. the inherent optical properties) were determined. Samples from a multitude of water bodies, with a large variation in water quality, in the central western Netherlands were taken. The inherent optical properties were determined for aquatic humus (gelbstoff, yellow matter), tripton (the non-phytoplankton suspended matter) and phytoplankton. From these measurements the specific (= per unit) absorption, scattering and backscattering properties were determined.

In situ measurements of the subsurface irradiance reflectance measurements (R(0-) were made during the sampling. The relationship between R(0-) and a, b, and b_b was determined to be $R(0-) = r_1 b_b/(b_b+a)$ for inland waters as was already determined for coastal zone colour remote sensing models. The variation in the volume scattering function $\beta(\theta)$, however was found to be much more variable and, thus r_1 was found to be much more variable for inland waters than for coastal and ocean waters.

Based on these measurements and modelling, algorithms were developed for estimation of chlorophyll a (0-200 $\mu g1^{-1}$), cyanophycocynanin (a gyanobacterial pigment) (0-160 $\mu 1^{-1}$), seston dry weight (0-40 mg $^{-1}$), vertical attenuation of irradiance (0-5 m^{-1}) and Secchi depth transparency (0-500 cm). All algorithms were based on R(0-), thereby avoiding most influence by surface reflectance, atmospheric distortion, surface effects, solar angle, ratio of diffuse to direct solar light etc. The models allow sensitivity analysis of algorithms to extraneous influences (e.g. resuspension of bottom material causing increased backscattering). It was found that only five spectral bands, between 10-15 nm wide centred at 600, 624, 648, 676 and 706 nm were sufficient to determine all these parameters. Inclusion of an algorithm for phycoerythrin estimation would entail incorporation of an additional two bands. With the physical, analytical model it was also possible to predict the required signal-to-noise ratio for the remote sensors to estimate a unit quantity or dimension of one of the optical water quality parameters.

A DEVICE TO MEASURE IN SITU VISIBLE LIGHT ABSORPTION IN NATURAL WATERS

J.B.M. HAKVOORT, A.E.R. BEEKER & J. KRIJGSMAN

Faculty of Civil Engineering, Delft University of Technology, Delft, The Netherlands

A submergible absorption meter was built to measure in the field visible light absorption coefficients of natural waters. The instrument measures radiance attenuation in an artificial diffuse light field along the direction of the net vector irradiance. It can replace laborious sample handling used to determine the optical characteristics of particulate matter. The performance of the absorption meter was tested in the laboratory working with several simple test suspensions and in the field in estuarine and in marine water. Radiance attenuation and absorption by clear water closely match. The radiance attenuation of algae increased linearly with concentration in the measured range of 0-70 µg m^{-3}, while the attenuation spectrum was very close to the absorption spectrum of the algal sample. An offset between these spectra remained. This was not observed when field data from estuarine and marine water was compared to laboratory measurements.

POSTER

EXTENDING THE ROLE OF THE CPR ON OCEAN MONITORING

GREAME C. HAYS

The Sir Alister Hardy Foundation for Ocean Science, The Laboratory, Citadel, Plymouth PL1 2PB, UK

Continuous Plankton Recorders (CPRs) have been towed for several decades in the surface waters of the North Sea and north-east Atlantic from ships of opportunity. The CPR is designed specifically to catch larger zooplankton, but may also give an indication of the abundance of smaller zooplankton and phytoplankton. Plans to upgrade the CPR by incorporating various electronic sensing packages and a modernised internal plankton sampling mechanism are described. CPRs may play a role in future validation of satellite images of, for example, sea surface temperature and chlorophyll abundance.

ON THE ORIGIN OF THE KATTEGAT DEEP WATER

NIELS KRISTIAN HØJERSLEV

The Niels Bohr Institute, Geophysical Department, Copenhagen, Denmark

The Kattegat bottom water is found to have an oceanic origin whereas its intermediate water occasionally and mainly during spring time can be traced back to the German Bight.

These findings strongly contradict the generally accepted ones, stating that about 2/3 of the bottom water below the pycnocline in the Kattegat is most likely to originate from the German Bight. The above conclusion agrees however excellently with the optical transparency and light scattering measurements made during a couple of years in the so-called Danish Belt project initiated in 1973.

The conclusions in this context are based on experimental data like UV-transparency (yellow substance), transparency and light scattering, spectral daylight penetration into the sea and standard profiling hydrography. Measuring sites are the Baltic proper, the Belt sea and the Sound, the Kattegat, the Skagerrak, the Danish Wadden Sea, the German Bight, the North Sea, the Norwegian Sea during a 25 year period of measurements having a total duration of one year spread over all four seasons and 20 expeditions in which the author took active part.

For estimation of the German Bight water contribution to the deep water in the Kattegat a Knudsen relation approach has been chosen in accordance with earlier attempts but here applying yellow substance and salinity as conservative properties. Moreover, yellow substance/salinity diagrams resembling the classical temperature/salinity diagrams have been constructed. They normally depict rather small likelyhood to

observe German Bight water in the Kattegat intermediate water. The bottom water has in all cases oceanic origin. The plausible average of German Bight water into the deep water in Kattegat amounts 10% of the total.

Yellow substance combined with salinity are most suitable tracers for the case in question since the Baltic water is characterized by a low salinity in combination with a high yellow substance content, whereas the North Sea and the Norwegian Sea water have high up to extremely high salinities but low yellow substance content, and finally, the German Bight water has an intermediate to high salinity and a high yellow substance content exceeding the one in the Baltic proper. This implies that the Knudsen relation approach can be applied under the most reliable conditions. Thus yellow substance offers more advantages than nutrient or radio-chemical tracers in the environment for this study.

MARINE APPLICATIONS OF REMOTE AND IN SITU OPTICAL MEASUREMENTS IN EUROPEAN WATERS

D.K. MILLS

Ministry of Agriculture, Fisheries and Food, Fisheries Laboratory, Lowestoft NR33 0HT, UK

Applications of optically derived data in fisheries and marine management and in biological oceanography are considered and the range of currently available in situ (IS) optical instruments (non-Imaging) is reviewed. Remote sensing (RS) provides the only truly synoptic measure of certain key physical and biological variables but a major problem with RS of European waters from space is the limit imposed by cloud cover. RS from space or IS optical measurements cannot detect fish directly. There are, however, indirect, benefits such as measurement of surface phytoplankton biomass and distribution and surface temperature which allow characterisation of the fisheries environment. New developments in optics may allow us to distinguish between algal classes and measure primary production and other photosynthetic parameters. Both RS and IS optical measurements contribute directly to the study of key questions in marine management and biological oceanography concerning natural and human impacts on the marine environment. These include identifying the causes of variability of plankton production and distribution over a range of time and space scales and in particular the increase in nuisance and toxic algal blooms. Optical techniques are part of a range of new and developing technologies that allow us to make observations on appropriate time and space scales for the comprehensive study of marine ecosystems. Data obtained through optical techniques will form an important part of databases required for model validation.

APPARENT OPTICAL PROPERTY MEASUREMENTS AND INHERENT OPTICAL PROPERTY ESTIMATION WITH THE MARAS SYSTEM

E. O'MONGAIN, R. DOERFFER*, K.D. MOORE & M. BREE

Physics department, University College Dublin, Balfield, Dublin, Ireland

**GKSS Forschungszentrum GmbH, D-2054 Geesthacht, Germany*

The MARAS system is an underwater spectral radiometer which measures the apparent optical properties of ocean waters from 400 to 800 nm at depths down to 100 m. Light from scalar and vector collectors sensitive to up welling and down welling irradiance is relayed locally by fibre-optic cables to the slit position of a sealed spectrometer. By simultaneously measuring all these irradiances at two depths and at all wavelengths, the system becomes impervious to changing ambient light levels and requires relative rather than absolute calibration of its collector/sensor sensitivities. Results from the deployment of MARAS in North Sea, Baltic and Atlantic waters are used to illustrate the process of estimation of the inherent optical properties, particularly the absorption coefficient, of marine waters. The effects of collector relative calibration errors on these estimates is illustrated.

THE USE OF A TOWED UNDULATING SENSOR (UOK) TO DEVELOP SEAWIFS ALGORITHMS

GERALD MOORE

Plymouth Marine Laboratory, University of Southampton, UK

With the forthcoming launch of SeaWiFS in July 1994 the Undulating Oceanographic Recorder (UOR) provides an ideal platform for optics sensors, and data suitable for the development of bio-optical algorithms. Towed undulators have the advantage of providing synoptic information over a large area, and UOR can be deployed on a ship of opportunity basis; however there is the disadvantage of obtaining synchronised sea-truth, since only surface samples are available.

The NASA SeaWiFS optics protocol demand a higher specification of calibration than has often been used to data i.e. relative calibration to ±5%. In this context the sensors on the UOR system, and its deployment will be discussed with reference to the NASA SeaWiFS optics protocols, and the UOR critically evaluated as a case study for other systems.
Remote sensing algorithms are required terms of water leaving radiance (Lw) or the derived product from remote sensing normalised water leaving radiance (Lwn). Results from Monte Carlo models and example profiles from undulators will be presented to illustrate the problem is achieving generating remote sensed algorithms from in-water optical data.

SeaWiFS provides two more bands in the blue (412 nm and 490 nm) than CZCS, results from two BOFS cruises (NABE 1989 & Sterna 1992) indicate that the use of the 412 nm band enable algorithms to be developed that provide a better estimate of biomass than the CZCS blue/green ratio.

THE OCTOPUS PROGRAMME

PETER SCHLITTENHARDT & VITORIO BARALE

IRSA, JRC CEC, 21020 Ispra VA, Italy

The OCTOPUS Programme is devoted to the exploitation of ocean colour data for applications concerning marine basins of European interest. It is based on the use of scientific tools developed by the Ocean Colour European Archive Network (OCEAN) project and on the available data from new space missions (SeaWiFS and others). The joint CEC/ESA OCEAN project was set up in order to produce an environmental data base as derived from the historical CZCS data available in Europe and has generated the scientific tools needed for its exploitation. In addition the project has promoted the use of the OCEAN archives in applications devoted to European seas. Finally the project has developed a 'network' of institutions, facilities and competences capable of supporting and exploiting in Europe future ocean colour missions. The OCTOPUS Programme shall continue the collaboration between CEC and ESA in the fields of data acquisition and management as well as in that of value-added data application.

The realization of a complete archive of high resolution SeaWiFS (and other) data on European marine regions shall be achieved through the implementation of a framework agreement between CEC, ESA and individual European research groups. The network of ground stations supported by ESA will provide the capability of collecting the data. These will be processed and integrated along the scientific lines developed by the JRC CEC in analogy to what has been done for the OCEAN project. The value-added ocean colour data will then be provided to a number of European institutions to conduct marine environmental studies. The collaboration with European research groups will allow to obtain results beyond the capabilities of single participants, while providing a forum for the co-ordination of all actions - such as sensor calibration or data integration -related to ocean colour science. Further, a framework agreement between the programme and NASA will allow data exchange and cooperation for scientific application.

The OCTOPUS programme integrates three main components, devoted respectively to (i) Science Support for data processing and applications, and Research Co-ordination; an (ii) Information System, for data collection, management and distribution; and (iii) Research Activities, that will be conducted in various European institutions.

OPTICAL MEASUREMENTS IN THE INSTITUTE OF BALTIC SEA RESEARCH

HERBERT SIEGEL

Institut für Ostseeforschung, Rostock, Germany

Measurements of the spectral reflectance and inherent optical properties as the absorption of yellow substances and phytoplankton pigments as well as of the volume scattering function, carried out in the open Baltic Sea and in coastal areas for different seasons demonstrate the regional and seasonal variability of the spectral optical properties in the Baltic. Calculated ground-truth algorithms for the determination of water constituents using the channels of several satellite sensors show the dominant wavelength and the variation in different seasons. Examples of images from the Coastal Zone Colour Scanner represent first applications of the algorithms.

OVERVIEW OF TNO-ACTIVITIES IN REMOTE SENSING AND OPTICAL MEASURING SYSTEMS

B. SNIJDERS

TPD, Delft, The Netherlands

The development of remote sensing instruments is not trivial. TNO has developed CAESAR; CCD Airborne Experimental Scanner for Applications in Remote Sensing. Major aspects are the development of an optical head (including spare model), and a facility for radiometric (+ geometric + spectral) calibration. For this work a special CCD test-setup had to be build. Based on experience during tests and operational flights adaptations were made, as well as refinements of specific instrument parameters for special applications. The CEASAR is in operation now for a number of years while being recalibrated on a yearly basis.
The launch of the MERIS instrument on ENVISAT is planned for 1998. MERIS is utilized for ocean colour monitoring using narrow spectral bands. TNO is participating in this very complex development project for a number of years, specifically on the instrument calibration.
Another TNO activity is the development of sensor systems for environmental monitoring, e.g.:

- Diffraction measurements on natural surface water samples.
- In situ optical particle size distribution measurements.
- Chlorophyll measurements for detection of algae concentrations, using a non-fouling sensor head.
- The MAST II EUROPE project on the development of flow cytometry instrumentation (particle analysis) and associated software for phytoplankton analysis. This equipment will enable water management authorities and environmental agencies to monitor the development of algal blooms on board ship.

From our experience in developing instrumentation for underwater measurements (some sensors are operating underwater for a ten year period) we suggest the following approach:

- Inventory of specifications for the aimed instrumentation and study of the state of the art (starting at this workshop).
- An integrated system design, incl. opto/mechanical aspects, electronics, data-acquisition -processing and -storage, user interface, calibration and combination of in-situ measurement data with remote sensing data.
- Prototyping. In this phase it might be advantageous to built a "work-bench" like instrument first. This can be used by the "oceanographers" to gain more experience in the measuring techniques for refinement of their specific requirements for a final standardized low-cost instrument, and to clarify the feasibility of such an instrument.
- Design and manufacturing of the final instrumentation.

POSTER

THE NERC SIDAL PROJECT AT SOUTHAMPTON UNIVERSITY

K.J. TRUNDLE, J.P. DAKIN, I.S. ROBINSON & A. WEEKS

University of Southampton, UK

An instrument for the measurement of underwater spectral irradiance and transmittance is under development at Southampton University as a joint project involving the Optoelectronics Research Centre and the Department of Oceanography. The instrument uses multimode, step index, optical fibres to transmit collected radiation to a central spectrometer. The main design objective is to provide spectral data at spectral resolutions approaching those of the next generation of remote sensing platforms for ocean colour monitoring such as SeaWiFS and MERIS.

POSTER

OPTICAL FIBRE SENSORS FOR OPTICAL OCEANOGRAPHY

K.J. TRUNDLE & A. WEEKS

University of Southampton, UK

The use of multimode step index optical fibres with bulk optics could provide a range of interchangeable sensors for the measurement of underwater optical properties for use with both single channel and multichannel instruments. This approach to sensor design would have the advantages of making the instruments more versatile and would allow a reduction of sensor size. The key properties of step index multimode fibres relevant to the design of extrinsic fibre sensors for optical oceanography are presented together with possible fibre based sensor designs.

AN OPTICAL PHOTON-COUNTING MULTICHANNEL DETECTOR SYSTEM

H. TÜG

AWI, Bremerhaven, Germany

Multi-element detectors combined with signal processing can be divided into integrating and photon-counting systems. For applications at low light levels just like underwater spectroscopy the photon-counting mode is preferable because of its high sensitivity and accuracy.

The presented detector system has 32 channels all operating as photon-counters and was originally developed for solar UV-B measurements under water. It is based on a modified microchannel plate (MCP) with separate charge-amplifier, discriminator and counter for each channel and can operate at light levels even 10^2 - 10^3 times lower than detectable with a single photomultiplier. The modification concerns the resistance of the MCP and the charge amplification which has a lower limit of 100 electrons per event. While the quantum efficiency depends on the chosen cathode material and wavelength, the dark current is only 0.3 counts per second and channel and independent from the temperature between -20° to +20°C.

In our present version the detector is used together with a double-monochromator and diffusor in the range 280-320 nm with 1.3 nm resolution. In another application it will be part of an underwater prism spectrometer where the range 400-720 nm is measured simultaneously with 10nm resolution.

USE OF A 4-CHANNEL IRRADIANCE METER TO MEASURE CHLOROPHYLL CONCENTRATION

TONY WALNE & RAY WILTON

School of Ocean Sciences, Menai Bridge, Gwynedd, LL59 5EY, UK

The measurement of phytoplankton biomass by in-situ fluorescence is not straightforward. Variation of the chlorophyll fluorescence yield and the relatively small volume observed by flash-stimulated fluorometers make the signal difficult to interpret. Workers at the School of Ocean Sciences have built and deployed a self-contained instrument designed to measure in-situ irradiance at two wavelengths (444 and 521 nm) for up to a month. The blue/green irradiance ratio correlated well with phytoplankton chlorophyll concentration.

Under the NERC SIDAL (Sensor and Instrument Development for Autosub and LOIS) special topics we have developed a new four-channel instrument (wavelengths 440, 490, 570, and 670 nm) to measure sub-surface, PAR irradiance. We have used this instrument to record down-welling irradiance at a mooring in the Western Irish Sea and to measure up-welling irradiance in the Menai Strait. Simultaneous observations were taken of phytoplankton chlorophyll and taxonomic composition, and suspended particulate matter.

The instrument has also been used on ARGOS-tracked drifters to record up welling irradiance in the vicinity of the Canary Islands.

We are currently calibrating the observed colour ratios with respect to chlorophyll concentration.

TRANSMITTANCE & REFLECTANCE SPECTRA OF NORTH SEA PARTICULATES

RODERICK E. WARNOCK & WINFRIED W.C. GIESKES

University of Groningen, Department of Marine Biology, P.O. Box 14, 9750 AA haren, The Netherlands

Multispectral measurements of the diffuse reflectrance ($R^*(\lambda)$) and transmittance ($T^*(\lambda)$) of marine particulate material collected on GF/F glass-fibre flters are presented to illustrate the spectral variability of particulate absorption. The examples were collected from Dutch coastal waters along three coast-to-offshore transects in the Southern Bight of the North Sea. Water samples from all three transects display in particle load and an increase in the contribution of the phytoplankton to the ensemble with increasing distance from the caost. Example spectra include samples collected during a spring *Phaeocystis* bloom, from a station rich in diatoms (mainly *Rhizosolenia* spp.) and from a station where the particulate material was dominated by inorganic silt and detritus (tripton). The diffuse attenuation coefficient of particles, $a^*_p(\lambda)$, may be calculated from $R^*(\lambda)$ and $T^*(\lambda)$ however the resultant magnitude of $a^*_p(\lambda)$ is dependent upon the algorithm chosen. The quantitative differences arising from the choice of available algorithms are illustrated. The use of second derivative spectra to highlight subtle differences in the spectral shape of particulate absorption is also presented. In all samples a peak at 675 nm is discernible and may be attributed to chlorophyll *a*. The shape of the absorption spectrum at blue wavelengths is similar in samples dominated by *Phaeocystis* and *Rhizosolenia* with a principal peak at 440 nm and shoulders at 430 nm and 475 nm. Minor peaks are also found at 580 nm and 630 nm. These peaks are greatly diminished in samples dominated by tripton such that the second derivative spectra of phytoplankton-dominated and tripton-dominated samples are quite distinct in this wavelength region. The utility of multispectral measurements in the blue for discriminating between phytoplankton and tripton is outlined.

A TOWED NEAR-SURFACE OPTICAL REFLECTANCE METER FOR MEASURING OCEAN COLOUR IN SUPPORT OF SEAWIFS

A.R. WEEKS, I.S. ROBINSON & B. BOOTY

Department of Oceanography, University of Southampton, Southampton, S09 5NH, UK

The measurement of optical reflectance, the ratio between upward and downward irradiance, is required to support the calibration and analysis of remotely sensed ocean colour data. The spectral ratio between reflectance at different wavebands, a measure of ocean colour, can provide information about the concentration of optically active water constituents such as chlorophyll. An instrument is described which has been designed especially for the accurate measurement of spectral reflectance when towed just below the surface. Particular attention is given to the minimising of potential errors due to natural variability of the light field and due to the shadow cast by the instrument itself. The instrument, called Lightfish, is able to considerably reduce the variance of in-water reflectance measurements whilst sampling frequently along transects. Its potential for applications to the development of ocean colour calibration algorithms, and for other oceanographic purposes, is discussed and its ability to detect the spatial variability of ocean colour at high resolutions is demonstrated.

MULTI-BAND (IR)RADIANCE AND TRANSMISSION MEASUREMENTS

MARCEL R. WERNAND & SUSAN SHIMWELL

Netherlands Institute For Sea Research, Texel, The Netherlands

Determination of the optical properties of natural media is essential for the investigation of the composition of the different media. To accomplish these investigations an optical oceanography group started in 1977 at the Netherlands Institute for Sea Research. The lack of commercially available instruments at this time made us decide to design and construct our own optical instruments. A start was made with the construction of a Photon Scalar Irradiance Meter (TIR) for the evaluation of the energy available for photosynthesis. In 1978 an 11-band Spectral IRradiance meter (SIR) was constructed and was followed by the design of a 22-band Advanced Spectral IRradiance meter (ASIR) in 1983, which is still in use.

The incident and scattered solar radiation is collected by cosine collectors. The light leaving the collectors is transmitted via a wide-angle lens through one of the interference filters, mounted in 2 rings for up- and down welling irradiance (resp. Eu, Ed), and collected by a silicon photo diode.

The dynamical range of ASIR for Ed in the blue and red is 0.4 mW/m^2/nm - 4 W/m^2/nm, in the green 1 mW/m^2/nm - 10 W/m^2/nm and for Eu 10µW/m^2/nm - 1 W/m^2/nm and 180 µW/m^2/nm - 1.8 W/m2/nm respectively.

In 1990 a start was made with the development of a multi-band transmissometer (TRASIR). Most of its design was derived from the ASIR. The main filter housing stayed the same and we chose a design where one could measure both the beam attenuation (c) and simultaneously up welling- or down welling irradiance depending on how the instrument would be deployed. For the transmission side a path length of 40 cm was chosen so that the instrument could be used both in coastal and open ocean waters. As a light source a flashtube is used together with a sample / hold detection system. The dynamical range for the beam attenuation coefficient c* = c total - c pure is 0.025 1/m - 15.0 1/m. For the irradiance side the specifications are similar to the Eu side of ASIR.

In 1983 a non-imaging aircraft radiometer was built. This COastal Remote Sensing AIrborne Radiometer (CORSAIR) is used to validate ocean colour algorithms. The system consists of a sky horn and a objective lens for the measurement of down welling irradiance and up welling radiance (Lu) respectively. The dynamical range for Ed is .002 - .7 (max of 20 is optional) W/m^2/nm and for the Lu side 4E-5 to .7 W/m^2/nm/sr,

The system was updated in 1992 to access on board calibrated data storage complete with GPS. 122 channels are scanned between 390 and 720 nm with a scan-time of 36 msec. The total viewing angle is 12 degrees and the sensor head can be tilted 20 degrees.

To achieve high resolution spot measurements during ship cruises a commercially available radiometer (PR650) was bought. The spectral range is 380 - 780 nm with a bandwidth of 8 nm and a accuracy of 2 nm. The viewing angle is 1 degree.

With the 22 band (of ASIR and TRASIR) spread over the visible spectrum underwater wave band simulation of forthcoming satellite sensors is possible. To validate ocean colour algorithms a comparison is made between the remote sensed data collected with CORSAIR and PR650, and the underwater data.

INHERENT OPTICAL PROPERTIES

RON ZANEVELD

Oregon State University, Oregon, USA

The inherent optical properties that determine the remote sensing reflectance are primarily the backscattering coefficient and the absorption coefficient, with a weak dependence on the single scattering albedo. These then are the inherent optical properties that must be measured for ground truthing of remotely sensed radiance.

We have developed a device that simultaneously measures the spectral absorption and attenuation coefficients in situ. The device measures 6 spectra per second at nine wavelengths. The absorption measurement is based on the reflection tube principle. The instruments will be described. Results from both turbid coastal and clear oceanic regimes will be presented. Calibration of the device is based on optically pure water in combination with a variable pathlength attenuation meter. Accuracies are approximately $0.005 m^{-1}$ and precision is $0.002\ m^{-1}$.

Further development of this device will include a measurement of spectral backscattering. This is necessary as the reflectance depends strongly on this parameter and it can also be used to correct the absorption measurement.

CURRENT PROBLEMS IN OCEANIC AND ATMOSPHERIC IN-SITU OPTICAL MEASUREMENTS

GIUSEPPE ZIBORDI & PETER SCHLITTENHARDT

Institute for Remote Sensing Applications, Joint Research Centre-CEC, 21020 Ispra, Italy

Visible and near infrared radiometers installed on satellites have been shown capable of providing information on optical properties of sea water. Most of this information is derived from satellite radiances using radiative transfer models of the ocean-atmosphere system. Forthcoming ocean colour radiometers (i.e. SeaWiFS, MERIS, MODIS), characterized by improved sensitivity and a higher number of spectral channels compared to the former radiometers (i.e. CZCS, TM) will provide more accurate measurements. The retrieval of quantitative information from these remotely sensed data will require advanced radiative transfer models whose validation could only be carried out with very accurate in-situ oceanic and atmospheric radiance and irradiance measurements. Thus non accurate calibration of in-situ radiometers and inherent measurements errors could induce relevant non accuracy in satellite derived products. The aim of this work is to introduce elements on calibration of optical radiometers and review some inherent errors in marine measurements, which are *current problems* in oceanic and atmospheric in-situ optical measurements.

EXHIBITION, POSTERS AND DEMONSTRATIONS

Participants had been given the opportunity to present a poster. Annex C provides a list of the posters presented during the workshop. From this list it appeared that through these posters valuable material had been made available as background information for the discussions. The posters were displayed in the room where the coffee breaks were held. This allowed for a close interaction between the participants and the authors of the posters.

A number of companies active in the field of optics had been invited to provide documentation, posters or demonstrations. Positive responses were obtained from the following companies: KIPP & ZONEN, Leica, InterSurface (Analytical Spectral devices), Fairlight (Oriel), Notra BV, Chelsea Instruments Ltd, Koninklijke Landre en Glinderman (Macam and Photo Research). These demonstrations and posters by industry were held in the same room as the scientific posters, after the afternoon coffee break of the second day. This element of the programme proved to be highly successful. Relevant documentation was also displayed in this room.

OVERVIEW OF DISCUSSION ON THE RELEVANT ITEMS

The main discussions took place in the three subgroups: Instrument Development chaired by HUNDAHL, Optical Data Bank chaired by WEEKS, (Inter)Calibration chaired by MOORE. A summary of the discussions in these subgroups is presented below.

INSTRUMENT DEVELOPMENT SUBGROUP

The aims of the instrument development group were: i) to set a ground truth ocean colour instrument standard for case 2 waters and ii) to define with such a standard a low-cost multi-band radiometer design.

A new low-cost device could be distributed amongst a wide community dealing with validating remote sensing data. The most important aspect of an inter-instrumental agreement is the opportunity for direct comparison of optical data when calibrated with the same spectral standard.

By the end of the first day a straw man design (by WERNAND) of a 5-channel radiometer was presented to the whole group. The design was based upon a throw-overboard system that collected the down welling or up welling light through cosine diffusers. The channels coincide with the design of the SeaWiFS sensor.
The group agreed upon the necessity of such a new device to be build and used as a ground truth reference within ocean colour remote sensing research.

The straw man design was further developed during the second day. Relevant optical parameters to be measured and the actual technical radiometer design were then discussed.

The group decided that the parameters to be measured with the instrument should be **down/(up) welling irradiance (E(λ))** and **up welling radiance (Lu(λ)**) and, possibly, the **scalar** or **vector** irradiance. The actual characteristics of the instrument to be build were defined as follows. The wavelength range should be between 400 and 720 nm with a minimum number of 5 (SeaWiFS) bands and a FWHM of 10 nm. The minimal sampling speed was set to 0.1 second. As this new ocean colour ground truth radiometer should have the possibility to measure Lu(λ) or E(λ) vector or E(λ) scalar it was decided to design the instrument as a modular system. To avoid shadowing effects the size of the instrument was limited to an overall length of 25 cm with a maximum diameter of 10 cm. Furthermore it should be used as a floating device i.e. throw overboard, no winch needed. The data interface will be of the RS232 type and the unit will be battery powered. The cost factor of such a device was limited to $ 5000.- US dollars. The characteristics of this newly to develop European ocean colour ground truth instrument are shown on the following page.

THE EUROPEAN MARINE OPTICS FIELD INSTRUMENT (proposed specifications)

Radiometer specifications:

Collector types: scalar, vector, radiance
Radiance acc. ½ angle: 10° in H_2O
Wavelength range: 400-720 nm
Resolution: FWHM 10 nm
Centre wave acc.: 2 nm
Blocking: 10E6
Number of bands: min. 5 SeaWiFS
Maximal signal level: 4 W/m^2/nm
Dynamic range: 6 decades (S/N at lowest=1)
Output data format: 12 bits auto ranging
Sample speed: min. 0.1 sec. (programmable)
Depth sensor: 0-200 m, resolution: 5 cm

Boundary conditions:

Modular system
Floating device type
Housing size: max. 10 cm diameter, length = 25 cm
Thermal stabilising: vacuum or T sensor
Operating temperature: 0-70°C
Start time synchronisation: (deck sensor) < 0.1 sec.
Power: rechargeable battery
Data interface standard: RS 232
Manual and software

- The characteristics of the instrument enables it to be employed from ships, buoys and aircraft.

During the discussions at the end of the second day **three designs** for the multi-channel radiometer came forward and it was recommended that within a month after the WOIRS workshop a feasibility study of the 3 designs will be completed. **The result of this study was completed before publication of this report and therefor already presented at the end of this chapter.**

Furthermore it was suggested that a bread board design will be completed 3 months after the workshop and a prototype after 6 months, where funds allow this. The designers will test and compare the performance of the instruments. After this period the final recommended design will be presented to the participants of this workshop.

DESIGN ALTERNATIVES

- **Design 1** (Dr. HELMUT TÜG, Alfred Wegener Institute, Bremerhaven, Germany):
  This design is based upon a prism spectrometer with a linear diode array as a detector with an optical resolution of 2.5 nm. The number of channels is programmable up to 32. It is explained below as alternative 1.

- **Design 2** (KEITH TRUNDLE, Southampton University, UK):
  The design is based upon a grating spectrograph with a discrete linear photo diode array and gives an output through 16 channels. It is explained below as alternative 2.

- **Design 3** (MARCEL R. WERNAND, Netherlands Institute for Sea Research, NL):
  The design is based upon a silicon UV-Enhanced photodiode and will have a rotating filter wheel containing interference filters with a FWHM of 10 nm. It is explained below as alternative 3.

Alternative 1

A SIMPLE MULTICHANNEL RADIOMETER TO MEASURE OCEAN COLOUR

H. TÜG

AWI, Bremerhaven, Germany

This small report is based on a proposal made in the Instrument Design Group during WOIRS (Nov. 23-25, 1993, NIOZ, Texel). It describes the design of a simple instrument to measure ocean colour in the wavelength range 400 - 720 nm.

The proposed instrument is based on a prism spectrometer with a linear diode array as a detector. These main components are rather inexpensive and fit quite well to the required specifications. The prism spectrometer has only low light loss and needs no suppression of second order. The diode array has 256 pixels and allows to correct the dispersion of the prism as well as to combine the diodes to a desired number of channels with specified resolution. For example, the SeaWiFS bands are programmable with about one nm accuracy. Wavelength bands and integration time can be selected via a PC link.

Optical Design

As shown in the Fig. 1 light passes an exchangeable diffusor and a set of diaphragms which define an aperture f/2.6. The spectrometer itself consists of an entrance slit (0.05 x 2.5 mm), two achromatic lenses (f/2.6; f/4.6) and an equilateral dispersion prism of flint glass (40 mm). The hole spectrum from 400 to 720 nm covers the detector area with an optical resolution of 1.25 nm. The light loss factor due to the optical elements including diffusor, achromates prism and detector (Q.E. 0.3-0.7) is calculated to be about 0.1 to 0.2 depending on wavelength.

Detector

The detector is a linear array of type S3901-256Q from Hamamatsu with a pixel size of 50 um x 2500 um. In the proposed optical design under bright sunshine conditions (at sea level) the detector is saturated in 50 - 70 msec depending on wavelength. This corresponds to about 10^{10} photons per pixel and second and is assumed to be the upper detection level. With a typical dark current of 0.2 pA the dynamic range is about 3500 down to a signal to noise ratio of S/N = 1 (uncooled, 25°C). Assuming a light loss factor of 0.1 by clouds and an attenuation down to 1% in the water the detector could operate in a fixed mode. The whole spectrum is imaged on the array in 1.25 nm steps with 2.5 nm optical resolution. Note, that the programmable processor makes an on-line reduction of the 256 values and reduces these "raw data" to the selectable channels. Only the channel information will be stored in the memory.

Specifications multy channel radiometer design (AWI)

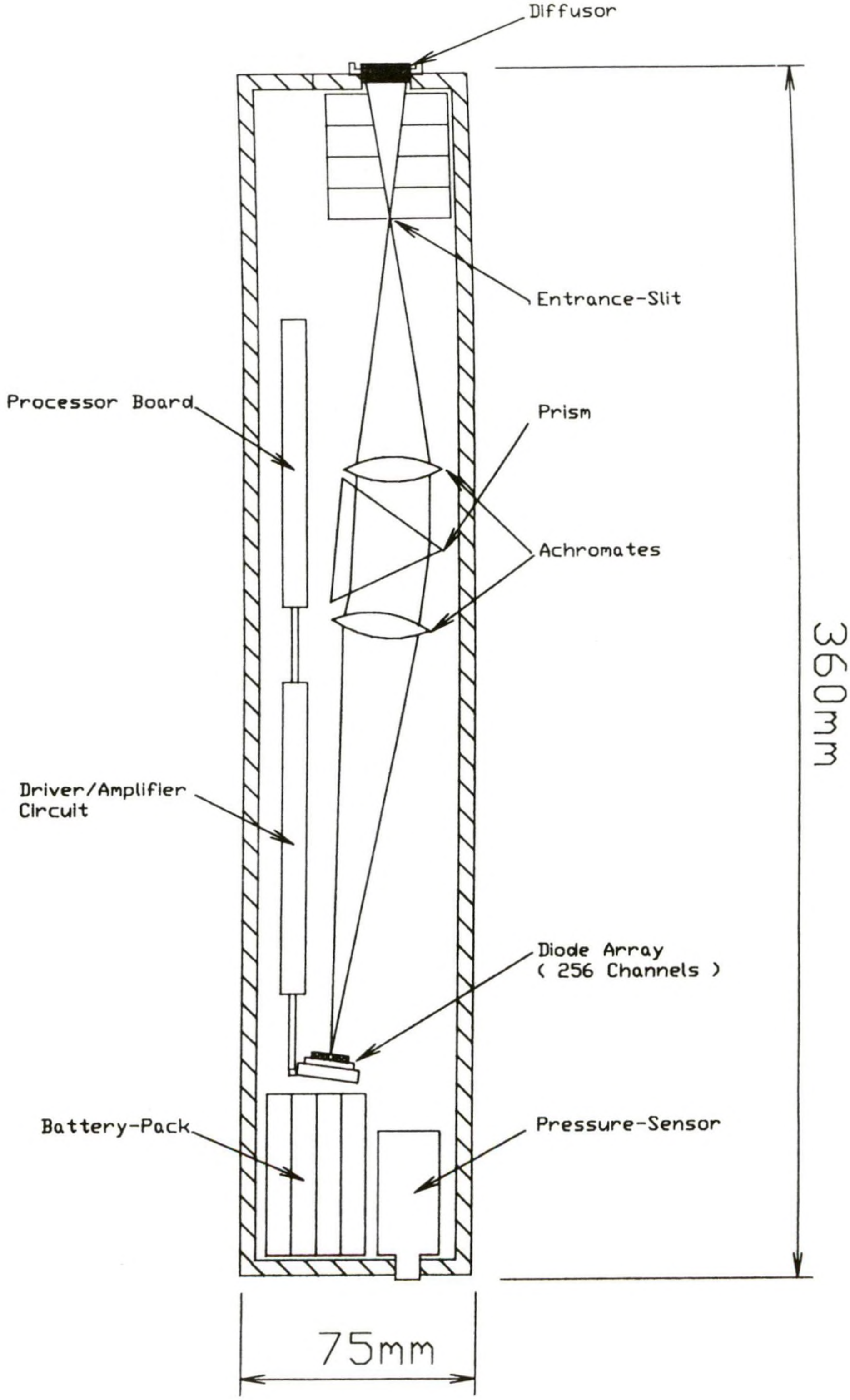
Optical Data
Wavelength range: 400 - 720 nm (measured simultaneously)
Optical resolution: 2.5 nm
Spectral accuracy: ~1 nm
Number of channels: Max. 32, programmable
Integration time: 0.1 - 1.0 sec, selectable by the electronics
Dynamic range: 3500 (uncooled, 25 °C)
Stray light suppression: Still unknown (must be measured)
Prism: Equilateral, flint glass, 40 mm
Lenses: Achromates, 30 mm Ø

Electronics
Amplifier: C4070 driver/amplifier circuit (Hamamatsu)
Processor: SAB 80535, A/D: 12 bit
Channels: Max. 32; 2 bytes per value
Memory: 128 Kbyte standard (expandable to 1 Mbyte)
Operation Mode: Direct on-line or data storage
Supply Voltage: +5V, +15V, -15V
Interface: Seriell, RS 232

Housing
Size: 7.5 cm diameter, 36 cm length
Max. depth: 300 m
Rechargeable battery (NiCd)
RS 232 connector
Sensors for pressure (resolution: 5 cm water column) and temperature (for operation control)

Costs
The total material costs for the system come up to **2.740 US $** inclusive 15% tax (on-board PC not included).

Fig. 1: layout for prism-spectrometer



Alternative 2

A SIMPLE INSTRUMENT FOR THE MEASUREMENT OF OCEAN COLOUR

KEITH J. TRUNDLE

ORC Southampton University, UK

1. INTRODUCTION

The requirement for an inexpensive instrument for the measurement of underwater irradiance and radiance was discussed by the WOIRS Instrument Design Group. It was considered important to have a low cost design measuring at a number of discrete spectral bands in the visible region of the spectrum. An initial requirements specification and a component cost target of $5000 US were set at this meeting.

An alternative design approach is to use a spectrograph to form an image spectrum on a linear photodiode array, providing the advantages of measurement at a greater number of spectral bands with only a single optical input channel. However, compared to the discrete channel approach, the radiation transfer between the input optics and detector plane is less favourable due to losses in the spectrograph. In particular, typical active areas of commercially available linear photodiode arrays are in the range from 0.1 to 1.0 mm^2. Furthermore the numerical aperture of the spectrograph restricts the light throughput. Hence, greater signal gain is required between the detectors and data acquisition subsystem. Two diode array based designs were proposed at WOIRS as possible candidates for further investigation subject to the availability of funding.

This report describes a design based upon a grating spectrograph with a discrete linear photodiode array capable of being polled by an instrument controller providing measurement of 16 spectral bands. Section (2) summarizes the optical design of the spectrograph. An outline of the required electronics is given in section (3) and section (4) gives an estimation of optical losses and the available radiation at the detector plane.

2. INITIAL OPTICAL DESIGN (SOTON)

The design presented WOIRS was based upon a commercially available sixteen element linear discrete photodiode array. This array has detector elements with a 0.81 x 0.81 mm (0.66 mm^2) active area and a centre to centre pitch of 1.02 mm giving an overall array length of 16.14 mm. This array format is assumed for the calculations presented in this report although other choices of sixteen element discrete photodiode arrays with larger active areas are available.

The layout of a simple spectrograph design is shown in Fig. 1. It is comprised of two aplanatic achromatic doublet lenses and a linear reflective diffraction grating. The first lens collimates the diffuse light from the entrance slit. A high order rejection filter for the removal of radiation below 400 nm is included after the first lens. The filtered radiation is then incident upon a reflective, linear diffraction grating. The image spectrum of the light from the grating is then formed on the detector plane by the second lens.

The optical layout shown in Fig. 1 is for a spectrograph using the first order of diffraction from a grating with 600 grooves per mm. The collimating and decollimating lenses are off-the-shelf corrected doublets with a nominal focal length of 44 mm. It is possible to estimate the wavelength measurement bands for each of the photodiode detectors using the grating formula. The results of this calculation for the example layout are shown in Table 1 below. The non-linearity of the band central wavelength location should be noted. Locating the physical aperture stop for the spectrograph at the grating has the advantage of minimizing the size of grating required. It also makes the optical design symmetrical about the aperture stop leading to an automatic correction of odd aberration terms. For the design shown in Fig 1, the aperture stop mask should be designed such that the second lens operates at about F#4.5 to ensure that radiation at the edges of the spectrum is not vignetted by the lens clear aperture.

The doublet lens is well corrected for spherical aberration, chromatic aberration and coma. Freedom from distortion is obtained by using a symmetrical design about the aperture stop. The main uncorrected aberrations are field curvature and astigmatism. Initial raytracing studies of the doublet show that the effects of these are only significant at the edges of the spectrum when the detector array is placed at the optimum focus of the axial beam from the lens. This will affect the wavelength ranges in Table 1, resulting in a partial overlap in the wavelength bands at the extremes of the spectrum due to aberration blur. However, it might still be possible to produce a spectrograph design using off-the-shelf lenses by positioning field flattening negative singlet lenses adjacent to the entrance slit and detector plane such that correction of field curvature and astigmatism off axis is balanced against increased spherical and chromatic aberration on-axis. Such design considerations would need to be investigated during the next stage of instrument design.

Estimates of optical component costs for spectrograph construction are given below in pounds sterling:

2 x Achromat, aplanat doublet lenses @ £82.00 ea:	£ 164.00
1 x Schott GG395 filter for order selection:	£ 15.00
1 x 25 by 12.5 mm 600 l/mm diffraction grating:	£ 70.00
1 x Path folding mirror:	£ 100.00
TOTAL:	£ 349.00

Additional costs would be incurred for providing multilayer antireflection coatings for the components and in the construction of the spectrograph metalwork. However, based upon the above, it should be possible to construct such an optical system for a total **component** cost of around £1000. Further work on the likely costs of the optics would be carried out at the next stage of development.

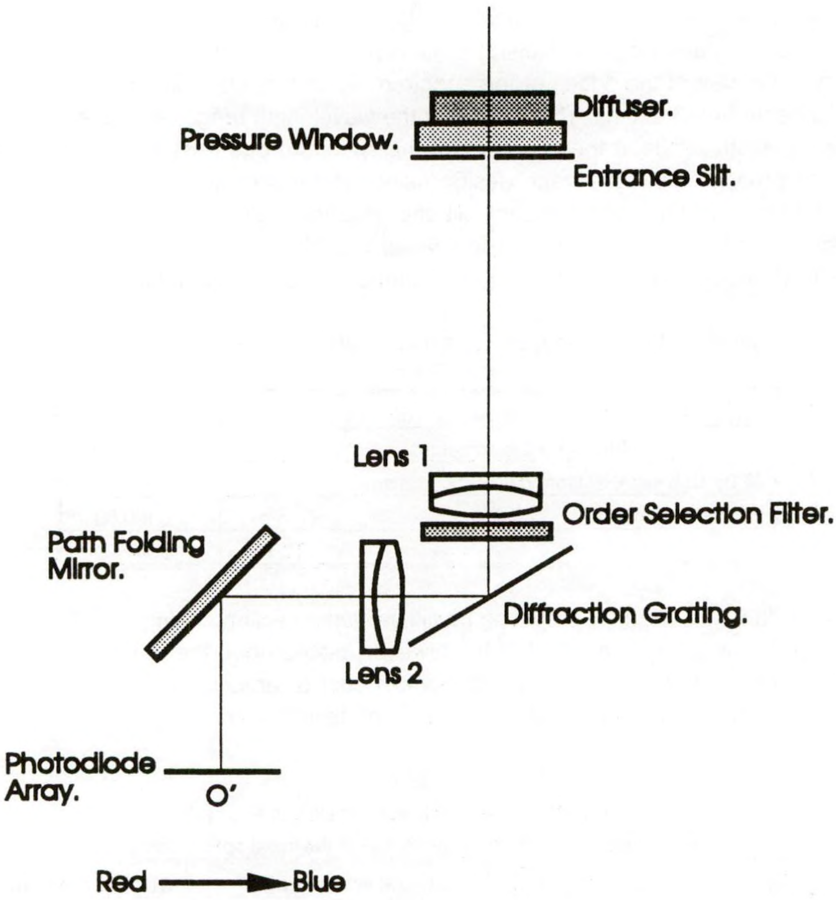
TABLE 1

Spectral Measurement Bands for Design Example.

For the linear photodiode array format of the initial optical design.

Element No.	Element X Position	Central Wave- length	Wavelength Range
1	-7.65	423.9	19.3
2	-6.63	447.9	18.9
3	-5.61	471.5	18.5
4	-4.59	494.5	18.0
5	-3.57	516.9	17.5
6	-2.55	538.6	17.0
7	-1.53	559.7	16.5
8	-0.51	580.1	15.9
9	0.51	599.7	15.3
10	1.53	618.5	14.6
11	2.55	636.5	14.0
12	3.57	653.7	13.3
13	4.59	670.0	12.6
14	5.61	685.5	11.9
15	6.63	700.0	11.2
16	7.65	713.7	10.5
[-]	[mm]	[nm]	[nm]

Fig. 1. Optical Layout for Spectrograph



Scale 1:1 Approx.

Lenses 1 and 2	:	Aplanat, achromat doublets.
Order selection filter	:	Schott GG395, 2mm thick.
Diffraction Grating	:	600 l/mm, reflective.
Photodiode Array	:	16 element.

INITIAL ELECTRONICS DESIGN

A schematic of a possible implementation of the commutation and signal conditioning electronics for the instrument is shown in Fig. 2. The use of a sixteen element photodiode array results in a simple and hence inexpensive design. The first stage of amplification would be provided by four quad-package, low noise, jfet input transimpedence amplifiers. The outputs from these amplifiers are connected to a sixteen to one analogue multiplexer. The channel for measurement can then be selected by the instrument controller/logger. The output from the analogue switch is passed to a further amplification stage and is filtered to reduce noise before digitization in the controller/logger. The gain of the amplification stage after the multiplexer would be selected by the controller/logger with values of 1, 10, 100 and 1000. The value of the feedback resistance R on the detector transimpedence amplifiers would be selected to give a sufficient output level at the input to the controller at the lowest variable gain setting for the maximum expected input light level. An estimate of this value is given in the last section on the basis of a simple radiometric model of the instrument optics. Detailed design of the instrument electronics, taking the required dynamic range and sampling rate into account, will be deferred until the next stage of development.

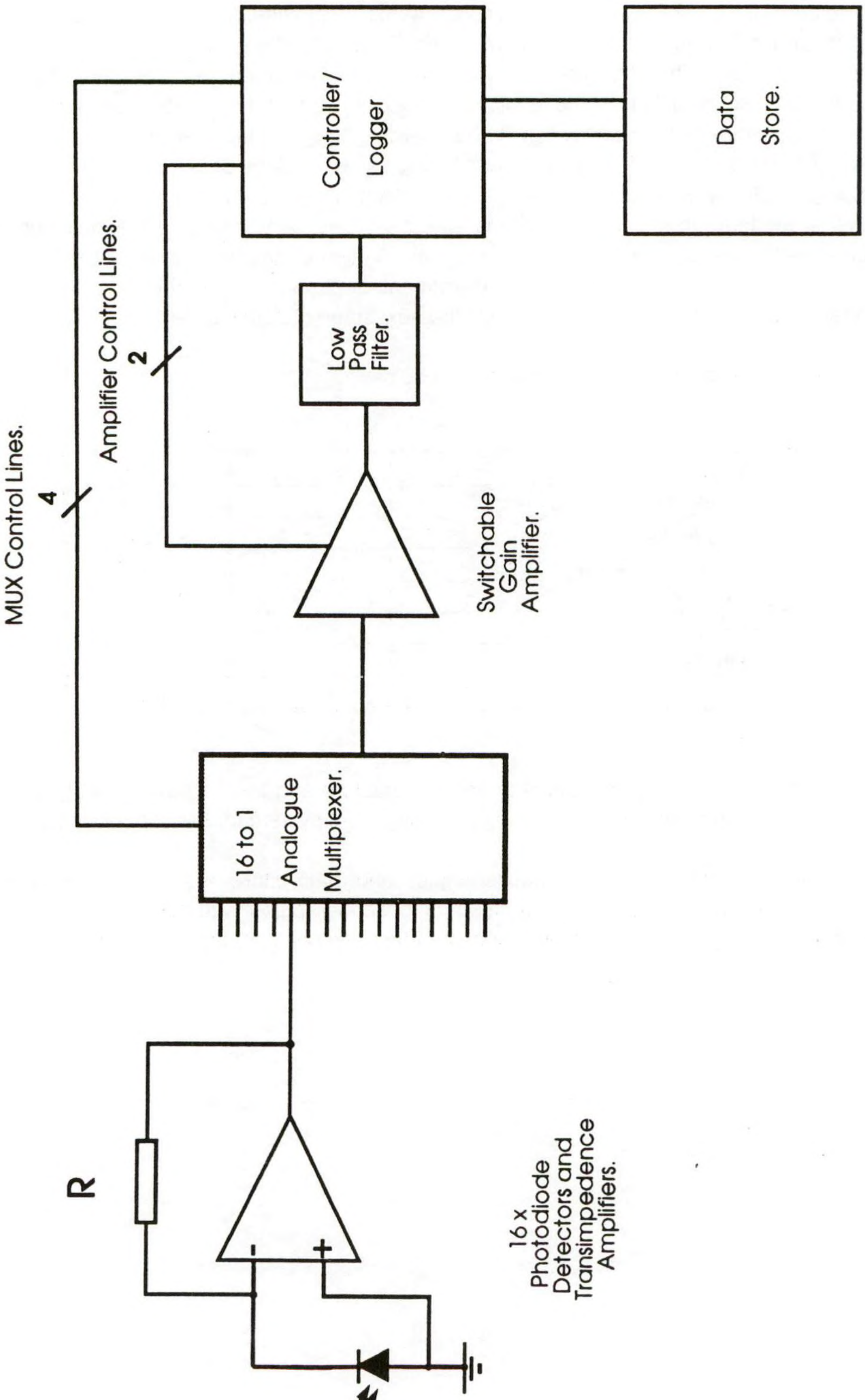
An estimate of the basic component costs is shown below.

Description	**Quantity**	**Cost**
Quad, JFET input op amps.	4	£ 60.00
16 Way Analogue Multiplexer.	1	£ 5.00
Switchable Gain Amplifier. (2 ICs).	1	£ 10.00
Low Pass Filter. (2 ICs).	1	£ 10.00
Controller/Logger.	1	£ 500.00
40 MB Hard Disk Module.	1	£ 300.00
TOTAL:		**£ 885.00**

Additional costs will be incurred for circuit board manufacture and for the power supply electronics. A non-recurring cost would be incurred in purchasing a development system for the controller/logger.

The prices quoted above for the controller/logger and data store are typical for small, low power, microprocessor based systems commonly used for oceanographic instrumentation. It is apparent that the costs of these items will constitute a high proportion of the overall component cost of the instrument.

Fig. 2. Initial Electronics Schematic



ESTIMATION OF OPTICAL LOSSES AND AVAILABLE RADIATION

The amount of radiation transmitted through the spectrograph from the diffuser to the detector plane can be estimated using the following equation:

$$E'' = T_1.T_2.(NA')^2.E \qquad (1)$$

Where E" is the irradiance at the detector plane,
E is the irradiance at the entrance to the diffuser,
T_1 is the irradiance transmittance of the diffuser,
T_2 is the transmittance of the spectrograph
and NA' is the numerical aperture of the image forming beam at the detector plane.

The spectrograph transmittance can be estimated using the following equation:

$$T_2 = (T_s)^n.(R)^m.G \qquad (2)$$

Where T_s is the transmittance per glass/air interface due to fresnel losses,
R is the reflectance per mirror surface,
n is the number of glass/air interfaces (including detector window),
m is the number of mirror surfaces (including the grating)
and G is the grating efficiency.

The grating efficiency is a function of wavelength. The locations of the peak efficiencies for s and p polarization planes separate on increasing the grating blaze angle. In general, the peak s-plane efficiency (light with E-field in a plane perpendicular to the grating grooves) remains at the wavelength at which specular reflection occurs from the grating facets while the p-plane efficiency peak moves towards shorter wavelengths [1]. If a 600 l/mm reflective diffraction grating with a Littrow blaze wavelength of 500 nm (blaze angle 8.63^{o}) is considered then the peak s-plane efficiency will occur at about 388 nm for the grating orientation in the spectrograph design. Then, the overall efficiency will roll off towards the red, partially compensating the roll off in silicon detector responsivity towards the blue. The grating efficiency will be taken as 1.0 and the detector responsivity as 0.2 A/W for the purposes of giving an initial estimation.

If the effects of aberration and diffraction on the instrument transfer function are neglected, then for the case when the entrance slit width is less than the detector width, the available flux for the formation of a photocurrent can be estimated by:

$$P = k.A_d.E''_\lambda.\Delta\lambda \qquad (3)$$

Where k is the ratio of the entrance slit image width to the detector width,
A_d is the active area of the detector element (m^2),
E''_λ is the spectral irradiance from equation (1) ($W/m^2/nm$)
and $\Delta\lambda$ is the wavelength bandwidth for the detector element from Table (1).

The values used in the estimation of the available flux based upon this simple model are tabulated below. The first column on the right of the first table gives the values substituted into the transmittance model (Equations (1) and (2). The last column gives te various contributions to the overall transmittance. The irradiance transfer (E''/E) is the product of the terms in this column. The second table gives the values used in the estimation of available flux using equation (3).

Diffuser irradiance transmittance T1	[-]	0.1
Air/Glass interface transmittance Ts	0.98	[-]
Number of air/glass interfaces n	9	0.83
Mirror surface reflectance R	0.92	[-]
Number of mirror surfaces m	2	0.85
Grating efficiency G	[-]	1.00
Image numerical aperture NA	0.11	0.012
Irradiance transfer (E''/E)	[-]	0.00085

Maximum spectral irradiance, E''_λ (WOIRS Specification).	4.0	[W/m^2/nm]
Irradiance transfer, (E''/E)	8.5e-4	[-]
Detector area, Ad	6.6e-7	[m^2]
Mean spectral bandwidth, $\Delta\lambda$ (From Table (1)).	16	[nm]
Instrument Factor, k.	0.1	[-]
Available flux, P.	3.6	[nW]

Taking a detector responsivity of 0.2 A/W, the available flux P will generate a photocurrent of about 0.72 nA. Hence a transimpedence resistance R of 1.4 GOhms (1.4e9 Ohms) would be required to give a signal of 1.0 volt at the output of the first amplification stage in figure (2).

5. CONCLUSIONS

On the basis of the initial design outlined in this report, a multi-band instrument based upon a discrete linear photodiode array is likely to meet both the WOIRS requirement specification and the component cost target. The combined component costs for the optical and electronics subsystems would be in the order of £2000 ($3000 US). This would leave a balance of $2000 US for the provision of additional components such sensors for temperature, depth and tilt monitoring and for encapsulation of the instrument for subsurface deployment.

It is suggested that the next phase of development should be to produce a detailed paper design before making any decision to proceed with the construction of a prototype instrument. This exercise will give a better idea of the likely costs and performance of the instrument. It will be executed subject to the availability of funding.

REFERENCES

LOEWEN, E.G., M. NEVIERE & D. MAYSTRE, 1977. Grating Efficiency Theory as it applies to Blazed and Holographic Gratings. APPLIED OPTICS V16: 2711-2722.

Alternative 3

A SIMPLE DESIGN FOR A 5-CHANNEL RADIOMETER

MARCEL R. WERNAND

Netherlands Institute for Sea Research, The Netherlands

During the WOIRS workshop a straw man design of a radiometer was presented at the end of the first day. This design together with two others was chosen by the Instrument Development subgroup to be part of a feasibility study, with its' breadboard design phase and its prototype phase, for the construction of a European standard ground truth radiometer for the validation of remote sensing data. The general specifications given for such an instrument imply that it should be designed as a modular system that enables to measure vector and scalar irradiance and up welling radiance

This report describes the straight forward design of radiometer with 5 discrete bands in the wavelength range 400 - 720 nm. The design presented here differs from the initial strawman design presented at the WOIRS meeting. Instead of 5 collectors a design is presented where one collector is used.

A 5-band instrument was chosen considering that 5 bands are sufficient to reconstruct a full spectrum between 400 and 700 nm (100 bands). In this case when the central wavelengths of the satellite sensor change a reconstruction of these channels can be performed without changing the instrument wavebands; 4 of the 5 bands are chosen to be SeaWiFS bands.

DESIGN

The instrument, schematically shown in Fig. 1, detects incoming light through a special designed PMMA cosine head or through a PMMA clear window in case of radiance measurements. The design of the scalar head is shown but the precize construction will be decided in a later stage.

Two broadband filters are placed under the light collector. One is a KG3 heat absorbing filter to supress second order transmissions of the near infra-red and the second filter is a BG24 to flatten the incoming spectrum. Between these filters and the detector an achromatis lens is placed for maximum signal output.

As detector one Silicon UV-Enhanced Photodiode, with an active area of 23.4 or 100 sq.mm, will be used. A filterwheel containing 5 interference filters and a dark filter, to compensate for electronic noise and temperature effects, is rotated under the collector head with a rotation speed of 300 rpm. The discrete wavelengths are 412, 490, 555, 620, 670 nm. The interference filter has a FWHM of 10 nm. The light Transmittance factor T of respectively the diffuser, BG24, KG3 is shown in Table 1.

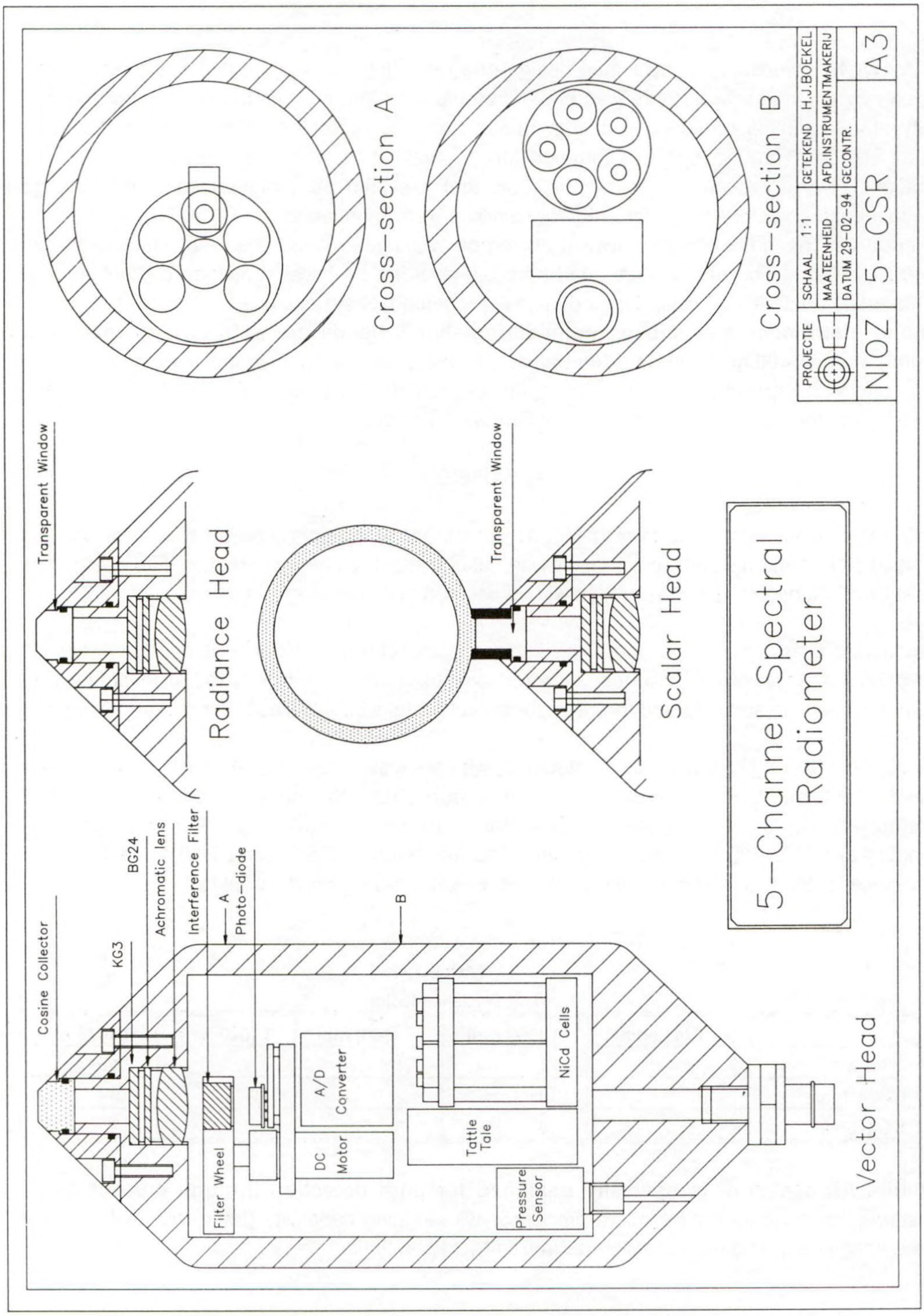
TABLE 1

Transmittance factors

	T (412 nm)	T (590 nm)	T (560) nm	T (620 nm)	T (670 nm)
Diffuser	.07	.1	.1	.1	.1
BG24-1mm	.97	.4	.2	.2	.9
KG3- 5mm	.8	.8	.8	.7	.3

The 20-bits AD-converter is specially designed for ligth detection through current measurement. Signal storage is performed by a micro-processor with logging capability (tattle tail). A DC-motor (10 mA) drives the filter wheel. The unit is powered through NiCd pen-lights.

Fig. 1. Schematic view of the 5-channel radiometer (scale 1:2.2)



Specifications 5-band radiometer (NIOZ)

Optical:

PMMA cosine collector (perspex)

1 Optical filter BG 24 - 1 mm -
flattening of incoming spectra
1 Optical filter KG 3 - 5 mm -
blocking of IR (> 720nm)

1 Achromatic lens f= 20 mm , diam.= 25 mm

Silicon UV-Enhanced Photodiode
(active area: 23.4 or 100 sq.mm)

Filterwheel containing:
a) 412 nm, FWHM of 10 nm.
b) 490 nm, FWHM of 10 nm.
c) 555 nm, FWHM of 10 nm.
d) 620 nm, FWHM of 10 nm.
e) 670 nm, FWHM of 10 nm.
f) dark

Maximal Signal level:	Maximum = 4 W/m2/nm
Dynamical Range:	5 decades

Electronics:

Resolution:	20 bits AD converter, range adjustable
Data storage:	Micro-processor with logging capability RS-232 data I/O port ASCII character set 8000 data sets of 6 sensor values (incl. depth)

Mechanical:

Housing:	Polyoximethyleen (Delrin)
	throw-overboard deployment pre-determined sinking speed strong up righting force
Power:	NiCd battery
Depth sensor:	0-200 m, resolution 5 cm
Temperature sensor:	NTC or semi-conductor
Accuracy:	.5 °C
Connector:	RS-232

5-band radiometer

Costs (US dollars):

Silicon p-i-n Photo diode	125.-
Interference filters (5)	500.-
Attenuation filters (BG 24 and KG 3)	60.-
Achromatic lens	80.-
Pressure sensor	150.-
20-bits AD converter, range adjustable	70.-
Micro-processor with logging capability	700.-
Housing and connector	150.-
Floating aid, weight, saveline	20.-
TOTAL COSTS	**1855.-**

OPTICAL DATA BANK SUBGROUP

The aims of ODB relate to i) provide a reference for sensor calibration, ii) support algorithm development and iii) act as a climatological record.

The subgroup agreed that ODB should contain three levels of marine optical data: i) the original 'raw' data, ii) calibrated data, iii) derived parameters such as the concentrations of chlorophyll and other pigments, yellow substances, particles, and rates of primary production.

The subgroup then considered the different types of data that should be measured and archived along with the optical data. The parameters considered to be essential included: time, position, C, T, D, as well as E, L (above and below water), a, b, c + related biological and geophysical parameters where available. Furthermore, it was essential to include information on: the instrument and sensor, the method of observation and calibration and the type of processing applied. In this context, it was realised that there was a lack of standardisation with regard to the 'conventional' ocean data which could severely influence the accuracy of derived data products.

Discussing the various aspects of a distributed multi-centre as opposed to a unique-centre, the group agreed with the principle that one centre would provide an optimum access to ODB through digital data communications. ODB should have a highly operational character to be able to satisfy the requirements of its users. For the physical location of ODB the Joint Research Centre, Ispra, was considered but, in view of the excellent level of data communications across Europe, other locations could be perfectly feasible provided the required level of experience and operational performance was available. For access to ODB, systems such as Internet, EARN and SCIENCEnet were mentioned as options.

In order to minimize the efforts required to submit data to ODB or retrieve data from it, an appropriate set of user-friendly standard software tools and standard formats should be developed and made available to the relevant scientists and technicians. This would strongly facilitate merging marine optics data with conventional oceanographic data. These tools and formats could perhaps be derived from existing oceanographic standard data processing software such as OCEAN-PC and formats such as GF3, both developed by IOC. It should be realized that a permanent mechanism on a European level would be required to manage such an undertaking.
It was deemed by the subgroup to be of great importance to establish close links with similar and related databases and systems operated or planned by NASA (SeaWiFS), ICES, IOC (IODE network), ESA (GENIUS), EC (CEO), BODC (UK) and JRC-OCTOPUS. Furthermore, it was recognized that apart from this European ODB centre, **specialized national marine optics data centres will continue to exist**. In order to maintain close co-ordination and standardization between all relevant centres a permanent mechanism at the European level will be required.

Another important element of the discussion focussed on the requirement of **data protection for individual scientists**; it was important to cover this element satifactorily in order that valuable marine optical data reached ODB, thus avoiding problems priviously experienced with other types of marine data.
A number of different timelags were considered for the several levels of data: raw data, first level processed data and dataproducts of biological parameters in geophysical units. It was recommended to adhere to existing procedures for other types of marine data, e.g. at ICES and IOC.

The subgroup emphasised that all aspects of marine optics measurement activity from acquisition to final archival should be closely coordinated and strictly standardized, including the related 'conventional' oceanographic data. From this it became apparent that there was a need for a manual for marine optical measurement protocols and techniques aimed at relevant European scientists and technicians. However, as such a manual could also be of wider geographical value, it was suggested that it would be of benefit to produce this manual in the IOC Series "Manual and Guides" with co-funding from the EC. In order to further improve co-ordination and standardization, specialized training courses on marine optics could be considered and possibly also funded by the EC. Our intention is to continue to collaborate with our US colleagues so that our protocols are comparable.

The subgroup considered ways of raising funds for the various follow-up activities including: establishment of the marine optical database; a European training course in marine optics; the production of a manual for marine optical measurement protocols and techniques; and for regular meetings of marine optical experts in Europe. In this context specific reference was made to EC-COST, EC-MAST and IOC.

Annex I presents the proposed performances of a European marine ODB.

(INTER)CALIBRATION SUBGROUP

The subgroup discussions confirmed the **lack of European standardization in the marine optical field** and recommended three lines of approach in order to adress this.

- establishment of a central European marine optics calibration facility;
- development of a set of protocols and guidelines for marine optical measurements;
- development and implementation of specific training courses in marine optics.

With regard to the central European marine optics calibration facility the subgroup noted the kind offer of GKSS Geesthacht, Germany to provide its facilities to the European marine optics community. The subgroup highly welcomed this offer in view of GKSS's long standing experience in marine optics mainly related to applications in marine biology. And also because GKSS was already appointed to act as a European coordinator of a calibration facility in relation with SeaWiFS.

Two types of calibration were considered necessary: **periodical** (1-2 years) -perhaps in the form of an intercalibration - by the central facility; and **regular** (every cruise), by each individual centre or on a national level using references provided by the central facility.

Concerning the protocols and guidelines for marine optical measurements, it was stated that these should be based upon the protocols and guidelines issued by NASA in relation to the SeaWiFS programme, but should be adapted to European needs and to the facilities available in the relevant European centres; specifically the NASA protocols give no guidence for the testing and validation of inherent optical property (IOP) instruments such as transissometers, which can provide valuable water colour information in turbid waters. Furthermore, close contact was recommended with the science teams of MERIS, MODIS, OCTS and POLDER. The subgroup considered it essential that the EC acted as the European authority responsible for issuing and maintaining these protocols and standards.

The group also felt it was necessary to specify a number of levels of calibration. The levels of calibration suggested ranged from simple verification of wavelength and linearity of an instrument intended to measure the diffuse attenuation coefficient (Kd), to full absolute radiometric calibration of an instrument deployed in remote sensing validation. Such a hierarchy of calibration would enable data such as Kd to be used by modellers, and provide a suitable framework for the ODB group to incorporated historical data.

As a first step towards the necessary protocols and guidelines, see **Annex H, K and L**. **Annex E** presents a **simple method for radiance calibration by Eyvind Aas.**

ANNEX A

WORKSHOP PROGRAMME

MONDAY 22 NOVEMBER 1993

Arrival of participants

18.00 - 19.00	Registration + welcome drink at hotel
19.30	Dinner at hotel

TUESDAY 23 NOVEMBER 1993 MORNING

08.15	Opening and welcome *Prof. Dr. Wim G. Mook* (director NIOZ)
08.30	Introduction *Marcel Wernand* (NIOZ, NL)
08.45	The OCTOPUS programme *Dr. Peter Schlittenhardt* (JRC, I)
09.05	Marine applications of Remote Sensing and in situ optical measurements in European waters *Dr. Dave Mills* (MAFF, UK)
09.25	Use of a towed undulating sensor to develop SeaWiFS algorithms *Dr. Gerald Moore* (PML, UK)
09.45	Optical measurements in the institute of Baltic Sea Research *Dr. Herbert Siegel* (Inst. für Ostseeforschung, FRG)
10.05	Coffee break
10.35	A device to measure in situ visible light absorption in natural waters *Hans Hakvoort* (Delft University, NL)
10.55	Apparent optical property measurements and inherent optical property estimation with the MARAS system *Dr. Eon O'Mongain* (Dublin University College, IRE)
11.15	Multi-band (ir)radiance and transmission measurement *Marcel Wernand* (NIOZ, NL)
11.35	A towed near-surface optical reflectance meter for measuring ocean colour in support of SeaWiFS *Dr. Alison Weeks* (SOTON, UK)
11.55	Inherent optical properties *Dr. Ron Zaneveld* (OSU, USA)
12.15	Use of a 4-channel irradiance meter to measure chlorophyll concentration *Dr. Anthony Walne* (UCNW, UK)
12.35	Lunch

TUESDAY 23 NOVEMBER 1993 AFTERNOON

13.35	Overview of TPD-activities in remote sensing and optical measuring systems *Ir. Bert Snijders* (TPD-TNO, Delft, NL)
13.55	Current problems in oceanic and atmospheric in situ optical measurements *Dr. Giuseppe Zibordi* (JRC, I)
14.15	A simple method for radiance calibration *Dr. Eyvind Aas* (University of Oslo, N)
14.35	On the origin of the Kattegat deep water *Dr. Niels Højerslev* (University of Copenhagen, DK)
14.55	Tea break
15.25	An optical Photon-Counting Multi-channel Detector System *Dr. Helmut Tüg* (AWI, FRG)
15.45	Transmittance & Reflectance spectra of North Sea particulates *Roderic Warnock* (University of Groningen, NL)
16.05	Inherent optical properties of Eutrophic waters *Dr. Arnold Dekker* (IVM/VU, NL)
16.25	Intro to tomorrow's discussion: - Full spectrum reconstruction by a 5 band approach - Strawman design for a 5-band irradiance meter - Optical parameters to be detected? *Marcel Wernand* (NIOZ, NL)
18.00	Bus leaves for hotel
19.30	Workshop dinner - Den Burg

WEDNESDAY 24 NOVEMBER 1993

08.15	Discussion on Strawman design
10.05	Coffee break
10.35	Separate subgroups discussion
12.30	Lunch
13.30	Discussion ctd.
15.30	Posters, exhibition, presentation compagnies
19.30	Dinner at hotel

THURSDAY 25 NOVEMBER 1993

09.00	Plenary session subgroups, reports on outcome of previous discussions
10.05	Coffee break
10.35	Plenary session subgroups ctd.
12.00	WOIRS group: Drafting of conclusions and recommendations
12.45	Closure session
13.00	Lunch
14.30	End of workshop

ANNEX B

LIST OF PARTICIPANTS

AAS, Dr. Eyvind
Institute of Geophysics
University of Oslo
P.O. Box 1022 Blindern
0315 Oslo
Norway
Tel. +47 22855808
Fax. +47 22855269

BEEKER, Ir. Arnoud E.R.
Kantakun Instruments and Research
Gasthuisplaats 1
2611 BN Delft
The Netherlands
Tel. +31 (0)15136618
Fax. +31 (0)15130713

BOXALL, Dr. Simon
Southampton University
Dept. of Oceanography
Highfield
Southampton 509 5NH
England
Tel. +44 703592744
Fax. +44 7035930059

BRICAUD-WEHRLIN, Annick
Lab. de Physique et Chimie Marines
P.O. Box 8
06230 Villefranche S/M
France
Tel. +33 93763712
Fax. +33 93763739

BRUNSSEN, Jutta
Alfred Wegener-Institut für
Polar- and Meeresforschung
27515 Bremerhafen
Germany
Tel. +49 (0)4714831190
Fax. +49 (0)4714831149

DEKKER, Dr. Arnold G.
Vrije Universiteit/IVM
De Boelelaan 1115
1081 HV Amsterdam
The Netherlands
Tel. +31 (0)205482432
Fax. +31 (0)206462457

DUBELAAR, George
Dubelaar Research Instr. Engineering
Zeelt 2
2411 DE Bodegraven
The Netherlands
Tel. +31 (0)172616841
Fax. +31(0)172615219

HAKVOORT, Hans H.M.
Delft University of Technology
Fac. Civil Engineering
P.O. Box 5048
2600 GA Delft
The Netherlands
Tel. +31 (0)15783714
Fax. +31 (0)15786993

HAYS, Dr. Graeme
Sir Alistar Hardy Foundation
for Ocean Science
The Laboratory-Citadel Hill
Plymouth PL1 2PB
England
Tel. +44 752222772
Fax. +44 752226865

HØJERSLEV, Dr. Niels
University of Copenhagen
P.O. Box 2177
1017 Copenhagen
Denmark
Tel. +45 35320606
Fax. +45 35822565

HUNDAHL, Dr. Henning
University of Copenhagen
P.O. Box 2177
1017 Copenhagen
Denmark
Tel. +45 35320607
Fax. +45 35822565

MILLS, Dr. Dave
MAFF
Fisheries Laboratory
Lowestoft Suffolk NR33 0HT
England
Tel. +44 (0)502562244/4253
Fax. +44 (0)502524511

O'MONGAIN, Dr. Eon
Physics Dept.
University College Dublin
Belfield
Dublin 4
Ireland
Tel. +353 17062233/2200
Fax. +353 12832275

MOORE, Dr. Gerald
Plymouth Marine Lab.
Prospect Place, West Hoe
Plymouth PL1 3DH
England
Tel. +44 (0)752222772
Fax. +44 (0)752670637

OHM, Klaus
Alfred Wegener-Institut für
Polar- and Meeresforschung
27515 Bremerhafen
Germany
Tel. +49 (0)4714831190
Fax. +49 (0)4714831149

PEARSON, Nick
MAFF
Fisheries Laboratory
Lowestoft Suffolk NR33 0HT
England
Tel. +44 (0)502524319
Fax. +44 (0)502524318

PINKERTON, Matthew
Plymouth Marine Lab.
Prospect Place, West Hoe
Plymouth PL1 3DH
England
Tel. +44 (0)752222772
Fax. +44 (0)752670637

REID, Andy
Hydrosphere Systems and Services
1 The Lodge, Beavers Close
Farnham
Surrey GU9 7BE
England
Tel. +44 (0)252713627
Fax.+44 (0)252718319

ROBINSON, Dr. Ian S.
Southampton University
Dept. of Oceanography
S09 5NH Southampton
England
Tel. +44 (0)703593038
Fax. +44 (0)703593058

SCHLITTENHARDT, Dr. Peter
JRC-IRSA-ME, CEC
21020 Ispra (VA)
Italy
Tel. +39 332789415
Fax. +39 332789034

SHIMWELL, Susan
NIOZ
P.O. Box 59
1790 AB Den Burg
The Netherlands
Tel. +31 (0)222069505
Fax. +31 (0)222019674

SIEGEL, Dr. Herbert
Institut fur Ostseeforschung
Seestr. 15
P.O. Box 301038
18119 Rostock
Germany
Tel. +49 38158286
Fax. +49 38158336

SNIJDERS, Ir. Bert
TPD-TNO
P.O. Box 155
2600 AD Delft
The Netherlands
Tel. +31 (0)15692000
Fax. +31 (0)15692111

SØRENSEN, Dr. Kai
Norwegian Institute for Water Research
P.O. Box 69
Korsvoll
N-0808 Oslo
Norway
Tel. +47 22185100/22185275
Fax. +47 22186200

STOCKDREHER, Dr. Eike
GKSS Forschungszentrum
Max-Planck Strasse
Geesthacht, D-2054
Germany
Tel. +49 (0)4152872480
Fax. +49 (0)4152872486

TRUNDLE, Mr. Keith J.
Optoelectronics Research Centre (ORC)
University of Southampton, Mountbatten
Bldg, Highfields, Southampton, S09 5NH
England
Tel. +44 (0)703592825
Fax. +44 (0)703593149

TÜG, Prof. Dr. Helmut
Alfred Wegener-Institut für Polar- und
Meeresforschung
27515 Bremerhaven
Germany
Tel. +49 (0)4714831190
Fax. +49 (0)4714831149

WALNE, Anthony
UCNW
School of Ocean Sciences
Menai Bridge, Gwynedd LL59 5EY
England
Tel. +44 (0)248351151
Fax. +44 (0)248716367

WARNOCK, Dr. Roderick
University of Groningen
Dept of Marine Biology
P.O. Box 14
9750 AA Haren
The Netherlands
Tel. +31 (0)50632268
Fax. +31 (0)50635205

WEEKS, Dr. Alison R.
Southampton University
Dept. of Oceanography
S09 5NH Southampton
England
Tel. +44 (0)203593038
Fax. +44 (0)203593058

WERNAND, Marcel R.
Netherlands Institute for Sea Research
P.O. Box 59
1790 AB Den Burg, Texel
The Netherlands
Tel. +31 (0)222069417
Fax. +31-(0)222019674

WILTON, Raymond
UCNW
School of Ocean Sciences
Menai Bridge, Gwynedd LL59 5EY
England
Tel. +44 (0)248351151
Fax. +44 (0)248716367

ZANEVELD, Prof. Ron
Oregon State University
Ocean Admin. Building 104
Corvallis, Oregon 97331 5503
USA
Tel. +1 (503)7373571
Fax. +1 (503)7372064

ZIBORDI, Giuseppe
JRC-IRSA-ME, CEC
21020 Ispra (VA)
Italy
Tel. +39 332785902
Fax. +39 332789034

ANNEX C

LIST OF POSTERS

HAYS, G.	: Extending the role of the CPR on ocean monitoring.
SHIMWELL, S.	: Ocean colour algorithm development in Dutch coastal waters.
TRUNDLE, K.J.	: 1. The NERC sidal project at Southampton university. : 2. Optical fibre sensors for optical oceanography.
TÜG, H.	: Demonstration optical multichannel detector.
WALNE, A.	: Use of a 4-channel irradiance meter to measure chlorophyll concentration.
WEEKS, A.R.	: A towed near-surface optical reflectance meter for measuring ocean colour in support of SeaWiFS.
WERNAND, M.R.	: Determination of spectral signatures of natural water by optical airborne and shipborne instruments.
ZANEVELD, R.	: A theoretical derivation of the dependence of the remote sensing reflectance on the inherent optical properties.

ANNEX D: THE EUROPEAN MARINE OPTICS FIELD INSTRUMENT
(by the WOIRS group proposed and adapted specifications)

Radiometer specifications:

Collector types: scalar, vector, radiance
Radiance acc. ½ angle: 10° in H_2O
Wavelength range: 400-720 nm
Resolution: FWHM 10 nm
Centre wave acc.: 2 nm
Blocking: 10E6
Number of bands: min. 5 SeaWiFS
Maximal signal level: 4 $W/m^2/nm$
Dynamic range: 6 decades (S/N at lowest=1)
Output data format: 12 bits auto ranging
Sample speed: min. 0.1 sec. (programmable)
Depth sensor: 0-200 m, resolution: 5 cm

Boundary conditions:

Modular system
Floating device type
Housing size: max. 10 cm diameter, length = 25 cm
Thermal stabilising: vacuum or T sensor
Operating temperature: 0-70°C
Start time synchronisation: (deck sensor) < 0.1 sec.
Power: rechargeable battery
Data interface standard: RS 232
Manual and software

- The characteristics of the instrument enables it to be employed from ships, buoys and aircraft's.

ANNEX E

A SIMPLE METHOD FOR RADIANCE CALIBRATION

EYVIND AAS

University of Oslo, Department of Geophysics

ABSTRACT

It is demonstrated how the effective solid angle of a marine radiance meter's field of view may be determined by means of an ordinary halogen lamp. If the spectrum of the lamp is known, the instrument will be spectrally calibrated in the same process. No diffusing surfaces are needed.

INTRODUCTION

If we want to calibrate an instrument which is designed to measure the radiance from nadir in the sea, one of the first problems that we meet is that most of the available standard lamps will produce light intensities that at a distance of 0.5 - 1 m are more comparable with atmospheric conditions than with the sea. On a clear day at noon the radiance from the sun at 450 nm may be as high as $2 \cdot 10^4$ W m^{-2} nm^{-1} sr^{-1}, while the radiance from the sky may vary in the range 0.05 - 1.0 W m^{-2} nm^{-1} sr^{-1}. But just beneath the surface of the Oslofjord, the radiance from nadir at 450 nm will be of order 10^{-3} - 10^{-2} on a clear summer's day, in the same units as above, while on a cloudy day in December it may be as low as 10^{-5}. This means that we will usually have to reduce the radiation from a standard lamp at the conventional distance by a factor of 10^2 - 10^3 in order to get signals in the appropriate range.

It is my experience that the most reliable method to decrease the radiation from a lamp in a known way, is to increase the distance between lamp and instrument. Provided that the lamp is contained within the instrument's field of view, this also seems to be the best method to test the linearity of the instrument. The inverse square law of the distance may then be applied. In such experiments it is important to measure and subtract the background signal from the total signal.

When the linearity has been calibrated, the instrument's response to radiance may be investigated. The conventional method is to apply a disk covered with a diffusing material like magnesium oxide or special optical paints, and to irradiate it with the light from a standard lamp. The radiance of the reflected diffuse light from the disk may then be calculated and used as the calibration reference. However, this method involves several problems, such as possible stray light from the environments to the diffusing disk, the reliability of the diffusing properties of the disk, and the magnitude of the resulting signal. The simple method described below, which is independent of diffusing disks and which allowes any distance between lamp and instrument, is probably to be preferred.

METHOD OF CALIBRATION

The method is based upon the fact that when a light source is so small that it is contained within the field of view of a radiance meter, the instrument acts as an irradiance meter. In the ideal instrument the lamp would produce a constant signal within the instrument's field of view (position *a* in Fig. 1), and no signal at the outside (position *c*). At the border (position *b*) there should be a sharp transition. The response curve of such an idealized instrument is shown in Fig. 2. If we knew the irradiance E and the solid angle Ω. observed by the instrument, the corresponding radiance would be $L=E/\Omega$. The calibration factor F, defined as the ratio between the radiance L and the response R, would then become

$$F = \frac{L}{R} = \frac{E}{\Omega R}$$

Radiance meters designed for atmospheric measurements, may have simple geometric constructions where the solid angle is easy to estimate. In more advanced instruments with a lens and pinhole system, the effective solid angle should be measured.

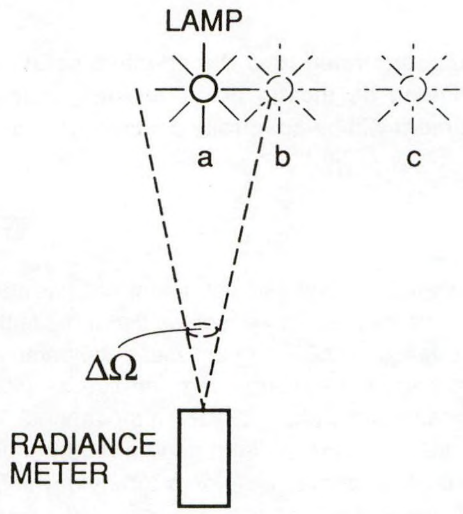


Fig. 1. The instrument functioning as an irradiance meter. Position *a* of the lamp is inside the instrument's field of view, while position *b* is on the border and *c* is at the outside.

We record the signal from the radiance meter with the simple set-up in Fig. 3, which is seen from above. The instrument, which is at the same horizontal level as the lamp, looks toward an optical bench (or a table) where the lamp can be moved sideways. At all positions of the lamp the background signal should be subtracted from the total signal. In order to measure the background signal, a shading device, for instance a ruler or simply just the hand, is put between the lamp and the instrument, and the resulting response is recorded.

If the device is kept close to the lamp, very little of the instrument's field of view is occupied, but a large part of the environments may become shaded, so that the background light conditions are altered. If, on the other hand, the shading device is kept close to the instrument, the background light may be unchanged, but too little of it will be received by the instrument since the device occupies too large a part of the field of view. As a compromise I have usually made the shading about halfway between lamp and instrument. The signal, corrected for background contributions, is the response *R* of the instrument to the direct irradiance from the lamp.

If the lamp is moved a distance *x* from its central position, as in the figure, the distance *r* between lamp and instrument increases, and in order to compensate for this decrease in irradiance, the response *R(x)* should be multiplied by the squared ratio between the distances. The corrected response *R(θ)* then becomes

$$R(\theta) = R(\chi)\frac{\chi 2 + y2}{y2}$$

where y is the distance from the instrument to the lamp when x=0.
The effective solid angle Ω_{eff} will be defined by

$$\Omega_{eff} = \frac{1}{R(0)} \int_{2\pi} R(\theta) d\Omega = \frac{2\pi}{R(0)} \int_{0}^{\pi/2} R(\theta) \sin\theta \ d\theta$$

where the angular distance θ from the central position is given by

$$\tan\theta = \frac{x}{y}$$

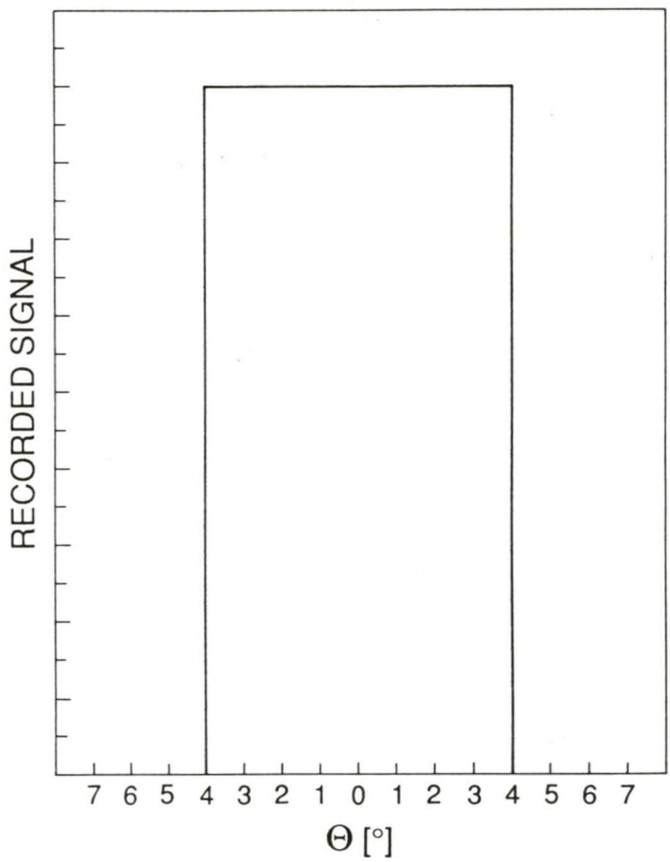


Fig. 2. The response curve $R(\theta)$ of an ideal radiance meter as a function of the angular distance θ from the center of the field of view.

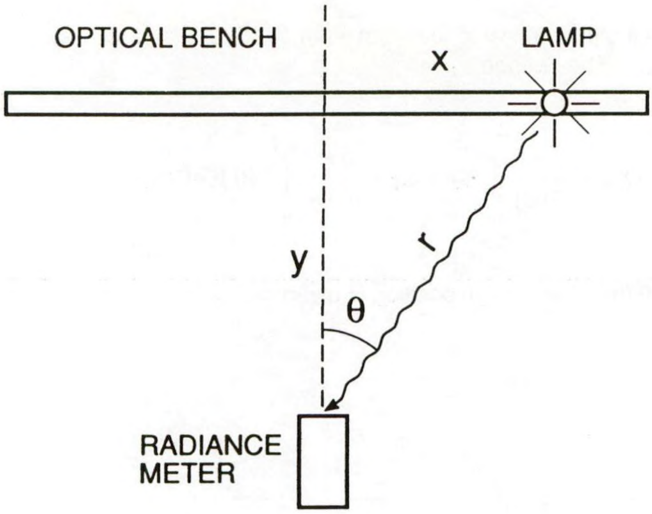


Fig. 3. Set-up for the mapping of the radiance meter's field of view.

An example of a real angular response curve is shown in Fig. 4. In this case the radiance (and colour index) meter was a construction by Henning Hundahl and Niels K. Højerslev at the University of Copenhagen, manufactured by Dansk Havteknik. The applied lamp was an ordinary 100 W, 12 V DC halogen lamp. The background signal from the grey walls of the laboratory was typically about 3-4% of the total signal with the lamp at the center.

Figure 4 illustrates that the response is far from constant within the half opening angle of 6°. The effective solid angel becomes 0.0206 steradians, which corresponds to an effective half opening angle of 4.64°. The last angle is obtained from the relation

$$\Omega_{eff} = 2\pi \int_0^{\theta_{eff}} \sin\theta \; d\theta = 2\pi\left[1-\cos\theta_{eff}\right]$$

Provided that the instrument has a known spectral response centered at the wavelength λ, the calibration factor of the instrument in air becomes

$$F_a = \frac{L_\lambda(\lambda,0)}{R(0)} = \frac{E_\lambda(\lambda,0)}{\Omega_{eff} R(0)}$$

At this workshop dr. Helmut Tüg pointed out that when the lamp is moved sideways it should also be turned so that it always presents the same length of filament to the instrument, and consequently gives the same irradiance. For the example in Fig. 4, however, the error is likely to be less than 1%.

While the effective solid angle of the instrument probably remains constant, the sensitivity of the photo detector is more likely to change with time. A routine check is then easily made by just directing the instrument towards the standard lamp, and reading off the maximum and background signals to obtain *R(0)*.

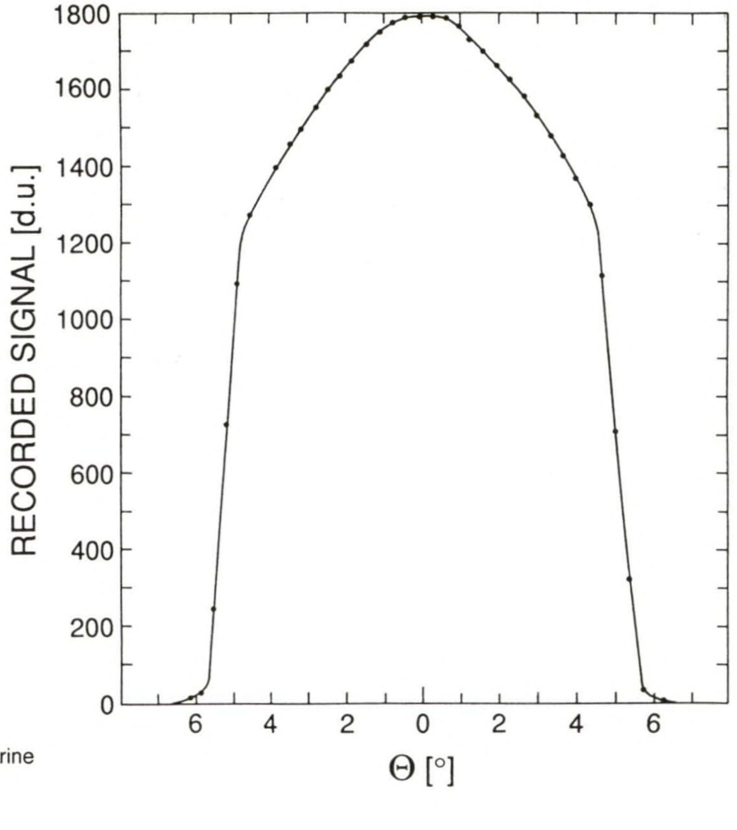


Fig. 4. The response curve of a real marine radiance meter.

CALIBRATION FACTOR IN WATER

If the instrument receives the radiance through a flat glass window, a fraction of the light, given by

$$\rho_a = \left(\frac{n_g - 1}{n_g + 1} \right)^2 \approx 4.0\%$$

where $n_g \approx 1.50$ is the refractive index of glass, will be reflected at the glass/air interface. In water, however, the reflection at the glass/water interface will be reduced to

$$\rho_w = \left(\frac{n_g - n_w}{n_g + n_w} \right)^2 \approx 0.3\%$$

where $n_w \approx 1.34$ is the refractive index of sea water. At the same time the radiance which passes from water through the glass window to the internal air of the instrument, will be spread out into a larger solid angle and be reduced by the factor $1/n_w^2$. The calibration factor of the instrument in water is then

$$F_w = F_a \frac{1-\rho_a}{1-\rho_w} n_w^2 = F_a \left(\frac{n_g + n_w}{n_g + 1} \right)^2 n_w \approx F_a 1.73$$

If the nadir radiance is measured just beneath the surface, we are often more interested in the value that the radiance will obtain after having passed from water to air through the water/air interface. It will then suffer a reflection loss of about 2% (GORDON, 1969, as quoted by AUSTIN, 1974) and be reduced by the factor $1/n_w^2$. We may then apply directly the calibration factor

$$F_{wa} \approx F_w \frac{0.98}{n_w^2} \approx F_a 0.94$$

A more detailed description of the different sorts of calibration of a marine radiance meter has been given elsewhere (AAS, 1993).

REFERENCES

AAS, E., 1993. Calibration of a marine radiance and colour index meter. Rep. Univ. Oslo, Dep. geophys. **87.**

AUSTIN, R.W., 1974. The remote sensing of spectral radiance from below the ocean surface. In: N.G. JERLOV & E. STEEMANN NIELSEN. Optical aspects of oceanography, Academic Press, London: 317-344.

GORDON, J.I., 1969. SIO Ref. 69-20, Univ. Cal., Scripps Inst. Oceanogr., San Diego, California, U.S.A.

ANNEX F

LIST OF ABBREVIATIONS AND ACRONYMS

a	-	Absorption coefficient
ABS	-	Automatic on Board logging System
ASIR	-	Advanced Spectral IRradiance meter (NIOZ, The Netherlands)
ATC	-	Athens Technology Centre Ltd (Greece)
AWI	-	Alfred Wegener Institute (Germany)
b	-	Scattering coefficient
BODC	-	British Oceanographic Data Center
c	-	Beam attenuation coefficient
CTD	-	Conductivity, Temperature and Depth sensor
CAPTEC	-	Computer Applied Techniques (Ireland)
CCD	-	Charged Coupled Device
CAESAR	-	CCD Airborne Experimental Scanner for Applications in Remote Sensing (TNO, The Netherlands)
CEC	-	Commision of the European Communities
CNES	-	Centre National d'Etudes Spatiales
CORSAIR	-	COastal Remote Sensing AIrborn Radiometer (NIOZ, The Netherlands)
CPR	-	Continuous Plankton Recorder
CZCS	-	Coastal Zone Colour Scanner
EARN	-	European Academic Research Network
Ed	-	Down welling irradiance
ENVISAT	-	ENVIronmental SATellite
Es	-	Above water irradiance (measured by deck unit)
ESA	-	European Space Agency
Eu	-	Up welling irradiance
FWHM	-	Full Width Half Maximum
GKSS	-	Forschungszentrum Geesthacht (Germany)
GPS	-	Global Positioning System
ICES	-	International Council for the Exploration of the Seas
IOC	-	Intergovernmental Oceanographic Commission (UNESCO)
IS	-	in-situ
JRC	-	Joint Research Centre (Italy)
k	-	Diffuse attenuation coefficient
Ld	-	Down welling radiance
LOIS	-	Land-Ocean Interaction Study (United Kingdom)
Lu	-	Up welling radiance
Lwn	-	Normalised Water Leaving Radiance
MAFF	-	Ministry of Agriculture, Fisheries and Food (United Kingdom)
MARAS	-	MArine RAdiometric Spectrometer (Univ. coll. of Dublin, GKSS, CAPTEC, ATC)
MAST	-	MArine Science & Tecnology (R&D development programme European Union)
MCP	-	MicroChannel Plate
MERIS	-	MEdium Resolution Imaging Spectrometer (ESA)
MODIS	-	MOderate Resolution Imaging Spectrometer (USA)
NASA	-	National Aeronautics and Space Administration (USA)
NASDA	-	NAtional Space Development Agency of Japan
NERC	-	National Environmental Research Council (United Kingdom)

(NERC)SIDAL	-	Sensor and Instrument Development for Autosub and LOIS
NIOZ	-	Netherlands Institute for Sea Research (The Netherlands)
NOAA	-	National Oceanic and Atmospheric Administration (United States of America)
OCEAN	-	Ocean Colour European Archiving Network
OCTOPUS	-	Ocean Colour Techniques for Observation, Processing and Utilization Systems
OCTS	-	Ocean Colour and Thermal Scanner (Japan)
ODB	-	Optical Data Bank
ORC	-	Optoelectronics Research Centre (Southampton, United Kingdom)
OSU		Oregon State University (United States of America)
PML	-	Plymouth Marine Laboratory (United Kingdom)
POLDER	-	POlarization and Directonality of Earth Reflectances (CNES, NASDA)
PR650	-	Spectral Radiometer (Photo Research, United States of America)
R	-	Reflectance
RS	-	Remote Sensing
S/N	-	Signal to Noise ratio
SeaWiFS	-	Seaviewing Wide Field of view Sensor
SIR	-	Spectral IRradiance meter (NIOZ, The Netherlands)
SOTON	-	Southampton University (United Kingdom)
T	-	Temperature
TIR	-	Total (Photon Scalar) IRradiance meter (NIOZ, The Netherlands)
TM	-	Thematic Mapper (LANDSAT)
TNO	-	Netherlands Organization of Applied Scientific Research
TRASIR	-	Transmissiometer and Advanced Spectral IRradiance meter (NIOZ, The Netherlands)
UCNW	-	University College of North Wales (United Kingdom)
UOR	-	Undulating Oceanographic Recorder (United Kingdom)
VU	-	Free University (The Netherlands)
WOIRS	-	Workshop on Optical ground truth Instrumentation and Remote Sensing

ANNEX G

EUROPEAN MANUAL ON MARINE OPTICS MEASUREMENTS
(proposed contents)

GENERAL INTRODUCTION

ACQUISITION: ....general, instruments, deployment, supporting measurements

CALIBRATION AND INTERCALIBRATION:......methods, references, European facility

PROCESSING: ....general, quality control and assessment, methods

ARCHIVAL: ....general, ODB, annotation/documentation, format

EXCHANGE: .... general, networks, formats

ANNEX H

EUROPEAN MARINE OPTICS CALIBRATION FACILITY

GERALD MOORE

Plymouth Marine Laboratory, University of Southampton, UK

In describing this facility it is only reasonable outline the facilities and nature of operations to be carried out. It would be envisaged that any such facility would need to employ a full time scientist and technician, and these staff would specify the equipment and procedures needed to fulfil the aims of calibration for marine optics. Calibration of optical equipment is an exacting rather than exact science; the best calibrations for remote sensing will be achieved when the methodology and equipment is closely tied to that used for the calibration of the space segment of the mission. For example for the SeaWiFS mission the standards have been interrelated by "round-robin" calibrations of 1000W FEL lamps; however other science teams may opt to use other methods such as transfer by calibrated radiometer.

As well as providing calibration, possibly as a service for the European Instrument, the facility should take on a role of training so that expertise can be disseminated to optical laboratories within the EEC. It is envisaged that such training should involve "hands-on" cross calibrations with scientists setting opt their own regional facility for marine optics, input to European advanced training courses (outlined in appendix J), and the preparation of handbooks to enhance the protocols handbook suggested by the database group.

OUTLINE OF FACILITIES AND SERVICES

Provision of apparatus to determine the following:
Radiometric calibration of radiance and irradiance to +/- 1%.
Spectral response of instruments to +- 0.2 nm.
Linearity of instruments using solar simulators to +/- 1%.
Angular response of radiance detectors to +/- 0.2 degree.
Cosine response of irradiance sensors to +/-1%
Immersion effects on such measures.
Temperature effects on sensors.
Pressure effects on sensors

A system to provide optically pure water to calibrate inherent optical property instruments.

In additions to these a database of the status of the instruments that have passed through the facility should be established. Such a database should be made available to the proposed marine optics database.

Periodic (inter) calibration at the facility

Scientists from EEC laboratories should be able to access the facility with their own instruments (not necessarily the instrument specified in the workshop). Experience shows that setting up a calibration for a non standard instrument takes time and requires input from the originator of the instrument e.g. setting up computer interface protocols. It is suggested that funding be found for scientists from regional laboratories to visit and cross calibrate their instruments at the European Facility.

Procedures for local (inter) calibrations

The calibration facility should be able to provide to regional laboratories materials such as standard lamps, and reflectance standards (at materials cost) that have been cross calibrated with reference materials in the calibration facility. This would be analogous with the NASA SeaWiFS team passing on their FEL lamps to foreign laboratories. Encouragement should be given to regional laboratories to pass on their results to the optics database.

Reference materials

The nature of reference materials will depend on the standards adopted for future space missions. The calibrations facility should be able to reference their measurements of optical instruments to a number of sensors i.e. SeaWiFS, OCTS, MERIS, MODIS. Its specific role should be to establish links with the science teams and or instrument designers, to both provide a calibration facility for ground truth experiments so that in-situ optics can be used for sensor calibration and validation.

ANNEX I

EUROPEAN MARINE OPTICAL DATA BANK (proposed performance)

GENERAL SECTION

LOCATION .... one European

MANAGEMENT .... responsibility, costs

TYPES OF MARINE OPTICAL DATA................. R, Ed, Lu, L normalized

TYPES OF SUPPORTING DATA .... chlorophyll, suspended matter, yellow substance, pigments

ANNOTATING AND DOCUMENTING DATA

FORMATS .... HDF, compressed

ACCESS.. internet

DATA PROTECTION

ODB MANUAL .... describes procedures

ANNEX J

EUROPEAN ADVANCED TRAINING COURSE ON MARINE OPTICS (draft setup)

Aim of course:	to introduce the participants to the theoretical and practical aspects of marine optics observations, data processing and related procedures;
Participants:	up to twenty individuals with a background in oceanography and physics, desiring to acquire training in the field of marine optics; postgraduates, also others with an adequate background could be elected to participate;
Lecturers:	three experts active in the marine optics field and working at various relevant European institutions and organizations;
Presentations:	the presentations will cover the full field with subjects such as: behaviour of radiation, optics, interrelation with physical, chemical and biological phenomena, instrument designs, measurement and processing procedures, systems and formats for exchange and archival; the total duration of the course will be two weeks.
Practical work:	ample opportunity will be given to the participants to practise with a variety of techniques and systems in a real world situation; facilities will be provided for acquisition and processing of marine optical data.
Location:	the course will be organized at an institute with a background in advanced courses and with the required infrastructure; in this context the Ecole des Mines, Sophia Antipolis is being considered.
Cost:	the total cost (ECU) of the course can be subdivided into:

Preparation/organization:	30K
Travel/subsistence three lecturers:	10K
Local technical infrastructure:	20K
Course materials/documentation:	10K
Total cost (ECU)	70K

ANNEX K

PROPOSED STANDARDS FOR DEPLOYMENT OF IN SITU RADIOMETERS

GERALD MOORE

Plymouth Marine Laboratory, University of Southampton, UK

Below is a brief outline of the considerations required for the characterisation, deployment and processing for an instrument rig intended to measure remote sensed reflectance. The rig consists of three radiometers: a deck cell measuring above water irradiance (Es), and downward irradiance sensor (Ed) and an up welling radiance sensor (Lu). It is assumed that the intention is to measure irradiance at the SeaWiFS, OCTS or similar wavelengths. It is assumed that depth is measured to an accuracy of +/- 0.2 m within the euphotic zone. In addition to the radiometer measurements it is desirable to measure temperature, conductivity, chlorophyll fluorescence and beam attenuation. These proposals have been adapted from the SeaWiFS optical protocols (MUELLER & AUSTIN, 1992); this document is freely available from NASA and in the absence of a suitable European Manual can serve as a working set of protocols.

1. INSTRUMENT CHARACTERISATION

Radiometric Performance

The down welling irradadiance sensor (Ed) should have a dynamic range from E0 (extraterrestrial irradiance - approx. 200μW/cm^2/nm) to at least .5% of E0. In addition it should recover from exposure to 2⋆E0 and flag saturation. Tables of extraterrestrial radiation are to be found in NECKEL & LABS (1984).

The up welling radiance sensor (Lu) should be capable of measuring a reflectance of measuring a maximum reflectance of 0.25, which gives a saturation radiance of 0.08⋆Es (approx. 16μW/cm^2/nm/sr). As with Ed saturation should be flagged and the sensor should recover from it. The minimum detectable irradiance should be numerically 1x10^{-5}⋆E0.

The deck cell (Es) should have a similar specification the Ed sensor, but the problem of saturation will not occur. Ideally the deck cell should match the Ed sensor spectrally, but where care is taken to measure profiles under uniform conditions a single wavelength may suffice.

Data logging

Data should be logged to at least 16 bit resolution. The data rate should be sufficient determine at least 5 samples per meter or 100 samples per optical depth. It is strongly suggested that oversampling and averaging should be carried out to reduce the signal to noise ratio.

Spectral resolution

The exact spectral bands will depend on the properties and wavelengths of the sensor to be validated an the nature of the marine optical research. The requirements for SeaWiFS are for sensors of an 8nm width to cover the SeaWiFS bands, either singly or in pairs depending on the spectral variation of the expected reflectance spectrum. It is necessary to verify the spectral response of the sensor on a regular basis to a resolution of about 0.2nm, since both grating and interference filter instruments will show degradation over time. The results of these spectral measurements should be made available for the marine optics database to enable the interpretation of data.

Radiometric calibration

The calibration of both radiance and irradiance sensors should be carried out with sources whose calibrations are traceable to either national laboratories, or instrument science teams. It is important that the sources should be of sufficient intensity to provide a calibration point within the normal working range of the instrument. Radiometric calibration should be carried out on a cruise by cruise basis.

Angular response

The cosine response and the angle of acceptance of the radiance sensor should be verified. The angular response of the radiance sensor is of particular importance, since any change due to degradation of the sensor may invalidate the radiance calibration procedure.

Immersion effects

The transmittance through the instrument window will change in water, and readings of the instrument with a stable source should be taken in air and water to estimate this effect on calibration.

Temperature Effects

Verification of the effects of temperature on the instruments response should be made. Such verification is of special importance when the instrument is to be deployed in polar and tropical waters.

Calibration equipment

In the absence of a European protocols manual, it is difficult to specify an exact list of equipment; however when any major marine optical project is specified funding should allow for calibration equipment. The cost of setting up a local calibrations facility will vary depending on what optical equipment is already available on site. A minimum list would be: a calibrated lamp (irradiance source); either a calibrated reflectance plaque or a integrating sphere (radiance source); and a monochromator with stable light source, and calibrated photodiode. Such a set of equipment will enable the basic pre- and post-cruise checks to be made. Other measurements such as the immersion effect can normally be made by adapting equipment already available in house.

2. INSTRUMENT DEPLOYMENT

The possibility of instrument shading by the ship should noted and data should be rejected as appropriate (for a full discussion see Gordon, 1992). Although instrument self shading in oceanic waters is only a problem in the near infrared, the high turbidities experienced in European Waters may cause problems at lower wavelengths and due note should be taken of this possibility (see Gordon & Ding, 1992 for a full discussion).

Full details of the illumination conditions should be logged, and if possible measure of the sea-state and sky radiance distribution should be made. The attitude of the instrument should be measured, and suspect data rejected. Such attitude measurements are especially important in areas high tidal flows, where even a well balanced instrument can be tilted by more than 20 degrees. At present there are no published limits or error bounds for tilt.

3. ANCILLARY MEASURES

It would be expected that the normal suite of oceanographic measures be made at the time of optical deployment. Hitherto pigments have been determined by the fluorometric method (Holm-Hansen *et al.*, 1965); however as spectral resolution has improved such measures are no longer sufficient to determine the absorption properties at other wavebands. Further doubt has been cast on the validity of fluorometric measures of phaeopigment (Trees *et al.*, 1985), and hence total pigment algorithms; thus it is suggested the HPLC (Mantuora & LLewellyn, 1985; JGOFS, 1991) should be the standard measure for pigments, and as a minimum fluorometric measures of chlorophyll-a should be validated against HPLC.

The absorption of dissolved organics or gelbstoff have been shown to substantially influence algorithms, especially in case 2 waters (Carder *et al.*, 1989). For shelf sea and coastal work measures of optically active dissolved organics matter should be made following the method of Bricaud *et al.*, 1991.

ANNEX L

RELEVANT REFERENCES FOR OPTICAL MEASUREMENTS

BRICAUD, A., MOREL, A. & PRIEUR, L., 1981. Absorption by dissolved organic matter of the sea (yellow substance) in the UV and visible domains, Limnol. Oceanogr. **26**: 43-53.

CARDER, K.L., HARVEY, G.R. STEWARD, R.G. & ORTNER, P.B., 1989. Marine humic and fulvic acids: their effect on remote sensing of ocean chlorophyll. Limnol. Oceanogr. **34**: 68-81.

GORDON, H.R., 1992. Ship perturbations of irradiance measurements at sea, 1: Monte Carlo simulations. Appl. Opt. **24**: 4172-4182.

GORDON, H.R. & DING, K., 1992. Self Shading of in-water optical instruments. Limnol. Oceanogr. **37**: 491-500.

GORDON, H.R., DING, K. & GONG, W., 1993. Radiative transfer in the ocean: computations relations to the asymptotic and near asymptotic daylight field. Appl. Opt. **32**: 1606-1619.

HOLM-HANSEN, O., LORENZEN, C.J., HOLMES, R.W. & STRICKLAND, J.D.H., 1965. Fluorometric determination of chlorophyll. J. Cons. Int. Explor. Mer. **30**: 3-15.

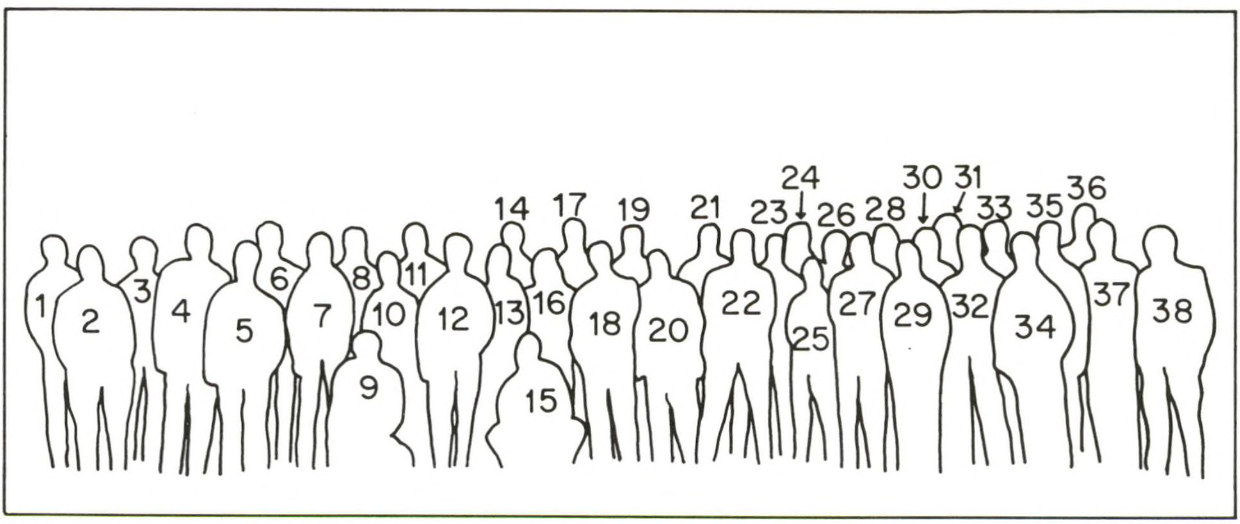
JGOFS, 1991. Joint Global Ocean Flux Study Core Measurement Protocols, JGOFS Report 6, Scientific Committee on Oceanographic Research: 40 pp.

MANTUORA, R.F.C., & LLEWELLYN, C.A., 1983. The rapid determination of algal chlorophyll and carotenoid pigments and their breakdown products in natural waters by reverse phase high-performance liquid chromatography. Analytical Chim. Acta **151**, 297-314.

MUELLER, J.L. & AUSTIN, R.W., 1992. Ocean Optics Protocols for SeaWiFS validation. SeaWiFS Technical Report Series, Volume 5. NASA Technical Memorandum 104566. NASA, USA: 43 pp. (Copies available from: The SeaWiFS Office, Goddard Space Flight Centre, Greenbelt, Maryland 20771, USA).

NECKEL, H. & LABS, D., 1984. The solar radiation between 3300 and 12500 Angstrom. Solar Physics **90**: 205-258.

TREES, C.C., KENNICUTT, M.C. & BROOKS, J.M., 1985. Errors associated with the standard fluorometric determination of chlorophylls and phaeopigments, Marine Chemistry **17**: 1-12.



1 Eon O'Mongain, **2** Eyvind Aas, **3** Graeme Hays, **4** F.W. van der Meij, **5** Chris MacLellan, **6** Dave Mills, **7** Andy Reid, **8** Arnoud E.R. Beeker, **9** Marcel Wernand, **10** Jutta Brunssen, **11** Ron Zaneveld, **12** Gerald Moore, **13** Alison R. Weeks, **14** Ian S. Robinson, **15** Bert Snijders, **16** Susan Shimwell,**17** Matthew Pinkerton, **18** Simon Boxall, **19** Helmut Tüg, **20** Keith J. Trundle, **21** Niels Højerslev, **22** Kai Sørensen, **23** Raymond Wilton, **24** Henning Hundahl, **25** Annick Bricaud-Wehrlin, **26** Anthony Walne, **27** Peter Schlittenhardt, **28** George Dubelaar, **29** Giuseppe Zibordi, **30** Roderick Warnock, **31** Bruce Swale, **32** Hans H.M. Hakvoort, **33** Herbert Siegel, **34** Eike Stockdreher, **35** Nick Pearson, **36** Maarten van Arkel, **37** Klaus Ohm, **38** Paul Geerders

CONTENTS