



**Sensing and
Mapping the
Marine
Environment from
near and far**



**Wednesday 16 July 2003
The Geological Society, London**

The one-day symposium brings together the special interests for
The Challenger Society for Marine Science (CSMS)
and
Remote Sensing and Photogrammetry Society (RSPSoc)
through the jointly affiliated
Ocean Colour Special Interest Group

Organisers:

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Schedule

Time	Event	Comments
09:30	Tea/Coffee	
10:00	Welcome	
10:10	Paper 1	<i>Hyperspectral sensor technologies for marine applications. Ruediger Heuermann, TriOS Mess- und Datentechnik GmbH</i>
10:30	Paper 2	<i>Radiance Transfer in Coastal Waters : Measurements and Modelling. David McKee, Alex Cunningham and Agnes Dudek, University of Strathclyde</i>
10:50	Tea/Coffee	<i>View posters and stands</i>
11:20	Paper 3	<i>Hyper-spectral ocean colour and water quality monitoring in the Irish Sea. C. E. Binding & E. G. Mitchelson-Jacob, University of Wales, Bangor</i>
11:40	Paper 4	<i>Correlating In-situ and SeaWiFS measurements of normalised water leaving radiance and remote sensing reflectance in UK shelf seas. Agnès DUDEK, University of Strathclyde</i>
12:00	Paper 5	<i>Pattern Recognition Techniques for atmosphere and water type classification using SeaWiFS data. A. Lyaskovskiy and D. Cornford, Aston University</i>
12:20	Lunch	<i>View posters and stands</i>
13:10	Paper 6	<i>Phytoplankton community structure and pigment characteristics across the Atlantic Ocean. Claudia Omachi^{1,2}, Ray Barlow³, Jim Aiken² and Derek Pilgrim¹ 1. University of Plymouth, 2. Plymouth Marine Laboratory and 3. Marine and Coastal Management Cape Town</i>
13:30	Paper 7	<i>Towards more complex modelling of primary productivity using remote sensing data as input. Tim Smyth, Steve Groom and Gavin Tilstone, Plymouth Marine Laboratory</i>
13:50	Paper 8	<i>Potential of Current and Future SAR Satellites for Ocean Imaging from Space. Gordon Staples¹, Melanie Dutkiewicz¹, Vince Mantle¹, Bernd Scheuchl¹, Stephen Lilley¹, Geoff Twentyman², Lt. Cdr. Colin Manson³ 1. MacDonald Dettwiler, 2. Dstl and 3. RN, DNSOM/AW</i>
14:10	Tea/Coffee	<i>View posters and stands</i>
14:45	Paper 9	<i>The Use of Remote Sensing Imagery for Admiralty Charting. Ruth Adams, UK Hydrographic Office</i>
15:05	Paper 10	<i>Sensing, Managing ... and then Mapping the Marine Environment. Gert Riemersma, MAPIX technologies Ltd.</i>
15:25	Summary	
15:45	End	

List of Attendees

Dr V Abbott (University of Plymouth)
Mrs R Adams (UK Hydrographic Office, Taunton)
Miss C Binding (University of Wales, Bangor)
M de Farago Botella (NPA Group)

Mr A Callaghan (National University of Ireland)
Miss H Cherry (UK Hydrographic Office)
Ms S Chesworth (RADARSAT International)
Dr D Cornford (Aston University)

Miss C Deeley (R.S. Aqua Ltd)
Dr D Doxaran (University of Plymouth, PhD student)
Miss A Dudek (Strathclyde University)
Dr M Dutkiewicz (MacDonald Dettwiler, Canada)

Dr N Dwyer (University College, Ireland)
Mr R Goodman (Z/I Imaging (UK) Ltd)
Dr R Heuermann (TriOS Optical Sensors, Germany)
Lt Cdr J Kraft (Dept. of National Defence, Canada)

Dr S Lavender (University of Plymouth)
Dr C Lavers (Britannia Royal Naval College)
Dr A Lyaskovskiy (Aston University)
Dr B Maughan (UK Hydrographic Office, Taunton)

Dr D McKee (Strathclyde University)
Dr P Miller (Plymouth Marine Laboratory)
Dr G Mitchelson-Jacob (University of Wales, Bangor)
Mr D Mortell (UK Hydrographic Office, Taunton)

Miss C Omachi (University of Plymouth, PhD student)
Mr CRC Nagur (University of Plymouth, PhD student)
Mr G Riemersma (MAPIX Technologies Ltd)
Dr G Savidge (Queen's University Marine Laboratory, Northern Ireland)

Mr R Scrivens (R.S. Aqua Ltd)
Miss A Singh (University of Plymouth, PhD student)
Dr T Sephton (EADS Astrium)
Dr T Smyth (Plymouth Marine Laboratory)

Mr G Staples (RADARSAT International, Canada)
Mr H Thomas (Southampton Oceanography Centre, MSc Student)
Mr J Tunaley (Dept. of National Defence, Canada)

Mr G Twentyman (DTSL)
M A Williams (NPA Group)
Prof J Yu (University of Vermont, USA)

Hyperspectral sensor technologies for marine applications

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Within the past ten years optical sensor technology has made great progresses due to the availability of highly miniaturized spectrometer modules. These modules covers wavelength ranges from the UV to the NIR. Principles of these modules are discussed as well as dark current handling and sensitivity. Different set ups for measuring apparent optical properties are shown by the principles of the RAMSES sensors. Examples of the different applications in-water and above-water were given, with special respect to autonomous operation on stations, buoys and ships. In addition to passive sensors, instruments for transmission measurements in the UV and the UV/VIS using spectrometer modules were discussed, including possibilities for discriminating fouling effects from the measurement. Principles and results of spectral analysis methods were presented to derive single substance concentrations out of a natural sample (e.g. nitrate, yellow substance and suspended matter).

Radiance Transfer in Coastal Waters : Measurements and Modelling

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The standard scattering correction algorithm for AC-9 absorption measurements is based upon the assumption of a wavelength-independent scattering phase function. There is little evidence to support this assumption and radiance transfer simulations based upon standard measurements of inherent optical properties (IOPs) do not provide closure with *in situ* radiometric measurements for a variety of UK coastal waters. A modified, semi-empirical scattering correction algorithm is proposed, which is shown to provide significantly improved radiance transfer simulation results. Comparison of backscattering ratios in the blue and the red indicate that scattering phase functions in coastal waters may indeed be wavelength-dependent.

Hyper-spectral ocean colour and water quality monitoring in the Irish Sea

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RAMSES hyper-spectral radiance and irradiance sensors (TriOS GmbH) were used to measure remote-sensing reflectance from 300 to 950 nm along a transect between Holyhead and Dublin in April 2003. The transect extended from the turbid waters around Anglesey, where bottom re-suspension of suspended sediment dominated the optical properties, through clearer waters associated with the deep trench in the central Irish Sea, to a region of weakly stratified water in the western Irish Sea experiencing an early phytoplankton bloom. Results will be presented that describe the changes in the measured optical properties along this transect with the view to developing regional algorithms that may be applicable to a long term water quality monitoring scheme linking the University of Wales Bangor, the National university of Ireland Galway and Irish Ferries. TriOS sensors are to be mounted on board the Irish Ferry Ulysses to measure above-water reflectance which, it is hoped, will enable the daily measurement of the key constituents determining ocean colour at the sea surface.

Correlating In-situ and SeaWiFS measurements of normalised water leaving radiance and remote sensing reflectance in UK shelf seas

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The results of SeaWiFS normalised water leaving radiance, n/w , and remote sensing reflectance, R_{rs} , compared with those measured in-situ, are presented. The data were collected at 22 locations identified as cloud free stations in the Irish and Celtic seas. The measurements were made from ship using the free falling SeaWiFS Profiling Multichannel Radiometer (SPMR) for measurements of downwelling irradiance and upwelling radiance just below the surface. Spectral values of n/w and R_{rs} were computed from the SPMR data. The radiometer profiles were made the same day within 3 hours of the satellite overpass. The in-situ measurement of R_{rs} and n/w were compared with data obtained from SeaWiFS (the Sea-viewing Wide Field-of-View Sensor) and processed with the latest version (at the time of analysis) of SeaDAS, 4.3, using the default settings. The comparisons show encouraging fits between satellite and in-situ measurement. RMS difference between in-situ and SeaWiFS values for R_{rs} is 0.002sr^{-1} , about 10% of the full range. RMS difference for n/w is $0.35\text{mW}\cdot\text{cm}^{-2}\cdot\mu\text{m}^{-1}\cdot\text{sr}^{-1}$, again about 10% of the full range. The implication is that the default atmospheric correction of SeaWiFS is reasonably correct and that the ocean-colour sensor data can be used with some confidence for quantitative measurements.

Pattern Recognition Techniques for atmosphere and water type classification using SeaWiFS data

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Neural network based techniques have been applied to identify the cloud contaminated pixels in the SeaWiFS images and to perform a cloud and water type pixel classification. Two separate datasets were generated, representing boxes of 9 by 9 pixels with the Top-of-Atmosphere (TOA) reflectances corrected for the Rayleigh scattering, white caps, sun glint reflectance, oxygen and ozone absorption. Boxes from the first dataset were further manually labelled by an expert according to their cloud type and whether the ocean surface was visible or covered. We distinguished 3 open ocean classes, 8 cloud type classes and 1 atmospheric aerosol class. The second dataset consists of 20,000 unlabeled boxes randomly chosen from the SeaWiFS images of different marine regions. A multi-layer perceptron (MLP) network with forward propagation of the 8 reflectance values as input data was used for probabilistic cloud/no-cloud pixel classification. In order to make cloud and water type classification it is necessary to use a spatial context or neighbourhood for each pixel which dramatically increases the number of input variables. To reduce the dimension of the labelled and unlabeled input data, feature extraction was applied to the windows of 9 by 9 pixels to obtain a set of 47 summary statistics such as entropy, spatial structure, etc.

The dimension of these statistical parameters was further reduced using linear (principal component analysis) and non-linear (generative topographic mapping and neuroscale) algorithms. We contrast the linear and non-linear methods and show that they produce some clustering in the data according to class labels. We use the projection defined by the unlabeled dataset to learn a good manifold for the subsequent classification using the projected labelled data. An MLP network was then constructed to assess the probability of pixels belonging to a certain class. We show how the cloud mask we have developed enables an estimate of cloud type and is more conservative than the SeaDAS cloud mask, especially in the presence of thin cirrus. We illustrate our methods on several images and show how the unlabeled data have been used to improve classification accuracy.

Phytoplankton community structure and pigment characteristics across the Atlantic Ocean

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In this study phytoplankton community structure and pigment characteristics were assessed across the Atlantic Ocean. The increased amount of information that the HPLC supplies makes necessary an analytical method to seek for a pattern in the pigment distribution. A data set with 167 samples collected in oligotrophic gyres, Equatorial and coastal upwelling regions in the Atlantic Ocean was analysed with Cluster analysis. The Chl a concentration ranged from 0.07 to 50 mg m⁻³. The 27 pigments per sample were summarised with 9 ratios: 5 Chl a ratios to represent the phytoplankton taxa and 4 optical ratios to represent groups of functional pigments. The cluster analysis produced 8 clusters, smoothly distributed reflecting the Chl a distribution, with succession in the phytoplankton taxa composition and change in the functional pigment composition. Although Chl a concentration was not included in the analysis, it was well represented by the 9 ratios. The clusters were also distributed reflecting the environmental condition across the Atlantic Ocean. Clusters of lower Chl a concentration with prochlorophytes and nanoflagellates dominance were from oligotrophic gyres. In this region, the level of photoprotection was an indicator of the depth of sampling. Clusters of higher concentrations with lower photoprotectant pigments were from coastal upwelling regions and dominated by diatoms and dinoflagellates. Nanoflagellates were ubiquitous in all the clusters. The increase in Chl a concentration across the clusters was followed by the increase in proportion of Chl a to the total pigments. The only cluster that did not follow this pattern was composed by samples with high proportion of chlorophyllide, indicating a likely senescence. These results suggest a relationship between the phytoplankton community structure, the biomass and the proportion of Chl a to the total pigments. Deviations from this relationship may be related to senescent phytoplankton.

Towards more complex modelling of primary productivity using remote sensing data as input

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The determination of primary productivity from space has long been a goal of several generations of ocean colour sensors. This is because it represents a useful measure of the uptake of carbon into the oceans. In situ ship-borne data suffers from the limitation of data sparsity in both time and space. Satellite sensors suffer from no such limitations and can provide global imagery on a timescale of days, weeks, months and years. The first algorithms to determine productivity from satellite involved a simple log regression of production against chlorophyll. Here we present results of the mechanistic Morel (1991) model adapted for use on global ocean colour imagery. The inputs to the model are Photosynthetically Active Radiation (PAR), Sea Surface Temperature (SST), daylength and chlorophyll. The light within the model is propagated spectrally through the water column and includes a parameterisation to extract this from the satellite measurable of PAR. The results show that, in comparison with other (25) models, the global estimates of primary productivity using the Morel model are within 20% of the mean of all the models.

Potential of Current and Future SAR Satellites for Ocean Imaging from Space

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Oceans comprise ~72% of the surface area of the world and are inherently changeable and difficult to access. Mapping and monitoring the marine environment is therefore an onerous task. Spaceborne SAR sensors can greatly aid with these missions. Such sensors are constantly circling the globe and are capable of imaging day and night in almost all weather conditions. . This paper will review the current capabilities in ocean feature detection from SAR imagery, including characterisation of wind fields, currents, internal waves, shallow water bathymetry, and ice mapping and classification. The next generation of SAR satellites will offer added capabilities, such as multi-polarimetry and along-track interferometry. We will discuss the potential of such sensors to improve on existing capabilities, for example in enhanced mapping of currents, fronts, and eddies, and improved ice classification. To conclude, we will discuss how applications such as coastal zone monitoring, maritime pollution detection, and regional meteorology can benefit from the inclusion of SAR-derived information.

The Use of Remote Sensing Imagery for Admiralty Charting

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The use of high resolution (pixel size smaller than 30m) imagery has long been used in support of Admiralty chart production. Coastlines can be mapped, offshore rocks located, reefs plotted and, depending on water clarity, sub-surface features can be charted. The United Kingdom Hydrographic Office (UKHO) uses a variety of imagery – both aerial photography and satellite imagery such as Landsat, SPOT and IKONOS. Examples will be provided to illustrate how the imagery has been used to enhance the Admiralty chart as well as other non-chart products which have been produced from Photogrammetry and Remote Sensing work.

Sensing, Managing ... and then Mapping the Marine Environment

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The volume and types of datasets collected from our oceans has dramatically increased over the past decade, as sensor technology has improved, new sensors developed and the output from the sensors has gone digital. The latest, and perhaps the last, sensor to go digital is the underwater camera with its associated data volume doubling anything that has gone before it. The volumes and disparate types of oceanographic data have brought with it its own set of problems, including data storage, data management and presentation. It requires a totally new approach to managing the data to ensure that the maximum is extracted from it, especially considering the high cost of a typical oceanographic survey. A common denominator for all the datasets is geographical position, and hence a system that can manage these datasets in relation to its position would be the ideal solution. Geographical Information System (GIS) technology is such a tool as it can manage, analyse and then map the data using the spatial element of the information as the common key.

The majority of the popular and commercial GIS on the market today are geographer's tools and are not particularly well suited for handling the data volumes, 3-dimensional or temporal datasets collected by the oceanographic industry. A thorough understanding of how a Desktop GIS is constructed and then leveraging the maximum out of the system will however enable it to become an effective tool for interpretation, analysis and mapping oceanographic data.

This paper describes two datasets that require particular attention when managed via a commercial Desktop GIS: swathe bathymetry and digital video. Explained are the issues associated with these datasets, from acquisition to data delivery. The paper details how these issues can be resolved and how by using ESRI's Desktop GIS product "ArcGIS" the maximum value can be realized from the data.

Posters

Quantification of suspended sediments in estuarine waters from remotely sensed (SPOT, Landsat) data - a semi-empirical approach

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The study concerns the quantification of suspended sediments in highly turbid estuarine waters from high spatial resolution remotely sensed data (SPOT-HRV, Landsat-ETM+). It is applied to the following areas: the Gironde and the Loire estuaries (France), where suspended sediment concentrations (SSC) in surface waters vary in the range (20 – 1000 mg.l⁻¹).

The methodology is essentially empirical. Based on in situ optical measurements, calibration relationships are established between the remote sensing reflectance (R_{rs}) signal and SSC. These relationships, obtained using reflectance ratios between near-infrared (NIR) and visible (VIS) wavebands, are few dependent on the sediment grain-size and mineralogy, and also few dependent on the illumination conditions (e.g. the cloud cover). Consequently, they can be applied to satellite images, even if no simultaneous in situ measurements were carried out at the moment of the satellite overpass. They allow an accurate estimation of concentrations, once satellite data are corrected from atmospheric effects. Resulting SSC maps are presented.

A bio-optical model is used to explain the obtained empirical results. It relates the inherent and apparent optical properties of the considered estuarine waters. Scattering by sediments is modelled using the Mie theory. Absorption by sediments is modelled according to the existing knowledge in the domain. The modelled optical properties are validated by comparison with in situ (AC9) measurements.

Finally, experiments are done in order to study the bi-directional aspects of reflectance for such turbid waters. Coincident in situ measurements of the R_{rs} signal, just above the water surface, and irradiance reflectance, just below the surface, are carried out. The obtained results are discussed, notably concerning the correction of surface effects (sun glint, sky glint) related to above water optical measurements.

SeaWiFS discrimination of harmful algal blooms

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This paper describes the use of NASA's Sea-viewing Wide Field-of-view (SeaWiFS) ocean colour data, bio-optical absorption and backscatter models, and multivariate classifiers for detection and monitoring of monospecific harmful algal blooms (HABs). The EU HABLE project aims to assess and quantify the environmental conditions required for the formation of identified HABs in the North Sea, Baltic Sea and Galician Sea. Part of this project concerns the ability of current and future Earth observation sensors to discriminate HABs from harmless species. Focussing on the SeaWiFS instrument that has the best spatial and temporal coverage of known HAB events, we explore multivariate classification of several important species that have previously caused great damage to aquaculture and fisheries in the study regions. A recent bio-optical model is exploited to derive inherent water absorption and backscatter properties, which are examined objectively for inclusion in a classifier. We present preliminary results for several HAB events, and discuss the potential of such techniques for operational monitoring of fisheries and future extension to NASA MODIS and ESA MERIS ocean colour sensors.

Also, a recent oceanic front visualisation technique is applied to the problem of detecting and tracing the spatio-temporal development of algal blooms. The composite front map approach is to combine the location of all ocean colour 'fronts' observed over just a few days into a single map. Information on both the strength and persistence of those fronts is integrated in a form that allows intuitive interpretation and animation of dynamic processes.

Automated Sea Ice Texture Classifications and Motion Analysis for SAR Imagery

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In the marginal ice zone, sea ice features include thickness, type and motion have been studied using the high resolution synthetic aperture radar (SAR) imagery. First, a segmentation technique with dynamic local thresholding is used to analyze and segment unstructured sea ice data. The dynamic local thresholding method allows separation of the ice into thickness classes based on local intensity distributions. The initial classification is supplemented using statistical attributes and heuristic geophysical knowledge organized in expert systems. A comparison with results from a tree-structured wavelet packet based classifier has also been carried out. Finally, a statistical method is used to derive ice motion map from the classified images. Also, imaging processing results and techniques for sea-ice study will be discussed and summarized.

Comparative analysis of Thermal images with Visible and Near Infra Red photography of the Dartmouth Castle archaeological site

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This work validates the ability of thermal imaging and Near Infra Red (NIR) photography to complement conventional visible photography to reveal environmental scene details invisible to the unaided eye. Thermal imagery, Visible and NIR photographic data was collected from the Dartmouth Castle environmental site throughout a 9 month period. We took maximum opportunity to examine the site under varied illumination levels in unpredictable weather conditions and through seasonal variations.

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