Institute of Physics

Sensing and Mapping the Marine Environment 2

Tuesday 5th April 2005
Institute of Physics, London

The one-day symposium will bring together the special interests of the Institute of Physics, Remote Sensing and Photogrammetry Society (RSPSoc) and Challenger Society for Marine Science (CSMS).

Organisers:

Dr Samantha Lavender SEOES, Portland Square A504, University of Plymouth, Plymouth, PL4 8AA Tel: 01752 232460 Fax: 01752 232406 E-mail: s.lavender@plymouth.ac.uk	Dr Alex Cunningham Physics Department University of Strathclyde 107 Rottenrow Glasgow G4 ONG Tel: 0141 548 3474 Fax: 0141 552 2891 E-mail: a.cunningham@strath.ac.uk

Schedule

Time	*Event*	*Comments*
09:30		
09:50	*Welcome*	
10:00	*Paper 1*	*Optical Properties of Tripton: A Review. D.G.Bowers*
10:20	*Paper 2*	*Inherent Optical Properties and Water Quality Parameters of the Irish Sea. David McKee*
10:40	*Paper 3*	*Use of Ferries to monitor water quality in the Irish Sea. Gay Mitchelson-Jacob*
11:00	*Tea/Coffee*	
11:20	*Paper 4*	*Apparent and inherent optical properties of turbid estuarine waters: Measurements, modelling and application to remote sensing. David Doxaran*
11:40	*Paper 5*	*Modelling particulate backscattering probability in coastal waters of Plymouth. R C Nagur Cherukuru*
12:00	*Paper 6*	*Precision of spectral in-situ backscatter coefficient measurements to determine particle backscattering slope. Victor Martinez-Vicente*
12:20	*Lunch*	
13:20	*Paper 7*	*Regional variation in the inherent optical properties of the North Sea: Implications for Ocean Colour Algorithms. Gavin Tilstone*
13:40	*Paper 8*	*Solar induced chlorophyll fluorescence as a tool for detecting phytoplankton populations in oceanic waters. L. Hay*
14:00	*Paper 9*	*Seasonal variability of surface chlorophyll concentrations in the NW African upwelling region. Yaswant Pradhan*
14:20	*Paper 10*	*Evaluating the use of novel remote observations and spatial data analysis to improve the skill of an ocean forecasting system for the central Mediterranean Sea. Charles Galdies*
14.40	*Tea/Coffee*	
15:00	*Paper 11*	*Atmospheric correction of ocean colour imagery: Is it worth using in situ aerosol measurements to improve retrievals? Tim J Smyth*
15:20	*Paper 12*	*MODIS 500m ocean colour data through exploiting spectral and spatial correlation. J. D. Shutler*
15:40	*Paper 13*	*ASAR image handling within the COASTCHART project. Matthew Stuttard*
16:20	*Summary*	
16:30	*End*	

Poster:

- Recent developments at RSDAS. Peter Miller

OPTICAL PROPERTIES OF TRIPTON: A REVIEW

D.G.Bowers

School of Ocean Sciences, Menai Bridge, Anglesey LL59 5AB

In the shallow, tidally-stirred seas of the world, the colour and brightness of the water, viewed from space, often depends on variations in the concentration of mineral suspended sediments (the term “tripton” was suggested for this material by Kirk, 1994). These mineral particles are lifted from the seabed and stirred throughout the water column by the strong tidal currents. The largest ones can be seen at the sea surface with the naked eye, but to view them properly it is necessary to use a microscope. The particles form groups (or flocs): several mineral particles joined together by organic glue. The size of the flocs depends on the concentration of particles and the prevailing level of turbulence. The optical absorption coefficient of tripton can be measured in the laboratory on filters or in suspension. Alternatively, it can be determined *in situ* by applying the results of theoretical models to irradiance meter profiles. The two results agree very well: concentration-specific tripton absorption decreases with increasing wavelength, but is not zero at the red end of the spectrum, as is sometimes assumed (and is probably the case for organic particles, including phytoplankton). Concentration-specific scattering coefficients, b*, are approximately constant across the visible spectrum, but can vary by an order of magnitude from 0.1 to 1 m^2g^{-1}. The mean value in the Irish Sea is 0.4 m^2g^{-1}. There is some evidence that these variations in b* are related to changing levels of tidal stirring, and therefore particle size. Quantitative determination of mineral suspended sediment load from observations of brightness from space can be improved if the effect of varying b* is allowed for. The sediment load can also be determined from a colour ratio, and by combining these two estimates, it is possible to calculate both the sediment concentration and b* from remotely sensed data, and hence to estimate the size of flocs from space.

Modelling particulate backscattering probability in coastal waters of Plymouth.

R C Nagur Cherukuru[1], Samantha Lavender[2], Gerald F Moore[1], and Jim Aiken[1].

NACH@pml.ac.uk

[1] Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth, UK
[2] SEOES, University of Plymouth, Plymouth, UK.

The dynamics of marine optical environment is a reflection of changes occurring in the concentrations and composition of the constituent materials. Suspended particulate material is a major contributor to the backscattered light. Backscattering of light by particulate material is controlled by the composition and their size distribution. Size distribution and composition of particulate material was collected in Plymouth Sound on a weekly basis during 2002-03. Particle size measurements were made using Coulter counter Multisizer-II and composition in terms of mineralogy was analysed using x-ray diffraction techniques. Synthesizing the geochemical and particulate number data with Mie theory, the ratio of particulate backscattering to scattering (b_b/b) was calculated. These calculations reveal the relationship between particulate size distribution (ξ) and the probability of backscattering for a particular bulk relative refractive index. These relationships are in the form of polynomial equations involving ξ and b_b/b. Results are presented to show that this model can produce backscattering values in a realistic way than with a constant value as proposed by Petzold for coastal and turbid waters.

Apparent and inherent optical properties of turbid estuarine waters: Measurements, modelling and application to remote sensing.

David Doxaran, Samantha. J. Lavender and Nagur Cherukuru
School of Earth, Ocean and Environmental Sciences
University of Plymouth
Plymouth
Devon, PL4 6DN , UK
David.doxaran@plymouth.ac.uk

The validation of ocean colour remote sensing and development of algorithms involves apparent and inherent optical property (AOP and IOP) field measurements. In coastal waters, these optical properties are complex and present strong variations, especially in estuaries that are a direct source of terrestrial inputs to the ocean.

In this study, field measurements of remote sensing reflectance (Rrs) and laboratory measurements of absorption (a) coefficients were carried out for two European estuaries: the Tamar (UK) and Gironde (France). The measurement techniques and their adaptation from standard protocols (established for the open ocean or coastal waters) to highly turbid waters are discussed. Typical a and Rrs spectra, and their associated spatio-temporal variations, are then presented together with their respective contributions to the biogeochemical constituents: coloured dissolved organic matter (CDOM), suspended sediments (SS) and phytoplankton (Chl-a). Mean values of the specific absorption coefficients (per unit concentration) are obtained for the two estuaries.

The Rrs signal is reproduced from the measured a coefficients and Mie theory predicted back-scattering coefficients, and its sensitivity to the biogeochemical constituents and their nature/composition is assessed. The detection limits of the different constituents are estimated based on their respective concentrations, of particular interest is the detection and quantification threshold of Chl-a in highly turbid estuarine waters. The Rrs signal is then related to the biogeochemical concentrations with empirical relationships established, reproduced and explained from theoretical calculations. Results show that such relationships can be obtained from AOP or IOP measurements, with their range and limits of applicability discussed. Finally, the relationships are applied to satellite (CHRIS-PROBA) and airborne (CASI) remote sensing data to map the water constituents in the Tamar estuary.

Evaluating the use of novel remote observations and spatial data analysis to improve the skill of an ocean forecasting system for the central Mediterranean Sea

Charles Galdies
cgaldies@maltanet.net

A high-resolution (0.042^o by 0.042^o) ocean forecasting system was setup consisting of an atmosphere model (NCEP Eta model) that was coupled to an ocean model (Princeton Ocean Model). This coupling consisted of the provision of surface atmospheric fluxes predicted at 3 hourly intervals to drive forward the ocean model.

The main aspect of this study is to evaluate the potential of remotely-sensed data acquired by an orbiting passive microwave sensor to assess and improve ocean forecasting. Thus, SST derived by the Tropical Microwave Imager onboard the TRMM satellite was evaluated for its potential to define one of the lower boundary conditions of the atmosphere model. The impact was positive, and resulted in an average improvement of the skill of the model to predict lower surface marine winds by approximately 10%. TMI-data proved extremely useful to derive instantaneous turbulent heat fluxes and other surface geophysical fields that were needed to diagnose and fine-tune the skill of the Eta model to forecast these fields. The TMI SST product also proved to be a valuable data source for data assimilation by the ocean model. An optimised data assimilation scheme was derived resulting in a bias of just -0.05^oC after a 15-day model integration run.

This study made use of tailored spatial data analysis to extract detailed information about the high-resolution forecasts and their quality in addition to standard verification tools. Geostatistical analysis was used to model the spatial structure of the residual fields of the predictions and observations, and to translate the degree of spatial correlation in numerical and graphical terms.

Solar induced chlorophyll fluorescence as a tool for detecting phytoplankton populations in oceanic waters.

L. Hay and A. Cunningham,
Environmental Optics Group, Department of Physics, University of Strathclyde, 107 Rottenrow, Glasgow G4 0NG.

Solar stimulated chlorophyll fluorescence from phytoplankton cells can be detected by ship borne radiometer systems and remote sensing platforms such as MODIS (Moderate Imaging Spectroradiometer). Fluorescence line height (FLH) measurements can be used as a tool to map phytoplankton populations and possibly for improving global estimates of primary productivity. This presentation reports field measurements of chlorophyll fluorescence, using hyperspectral radiometer systems, recorded over a range of oceanic water types from turbid Scottish coastal waters to the oligotrophic waters of the tropics and the highly productive North African upwelling. Initial results for Scottish coastal waters indicate that the relationship between FLH and chlorophyll concentration is not straightforward and may depend upon algal physiology and the presence of other optically significant components such as coloured dissolved organic matter (CDOM) and suspended sediment. Radiance transfer simulations have been carried out to illustrate the impact of these optically significant components on the magnitude of the FLH signal. Remote sensing images of chlorophyll concentration and FLH for the North African upwelling retrieved by MODIS will also be discussed.

Precision of spectral in-situ backscatter coefficient measurements to determine particle backscattering slope

Victor Martinez-Vicente (P.M.L.-UK), G. Tilstone (P.M.L.-UK) and P.V.Jørgensen (D.M.I.-DK)
e-mail:vmv@pml.ac.uk

The development of semi-analytical algorithms in optical remote sensing requires the in-situ characterisation of the variability of γ; the spectral slope of particle backscattering coefficient, $b_{bp}(\lambda)$. The most commonly used in-situ backscatter-meter is the Hobilabs Hydroscat, that measures $b_b(\lambda)$ up to six wavelengths to calculate γ. Little is known on the precision of this instrument in estimating γ in-situ.

The precision of measurements from Hydroscat, maybe dependent on the mechanical differences between instruments and on the correction applied to the data in order to take into account the attenuation of the backscattered light (the sigma correction).
In order to quantify differences between instruments, four Hydroscats from different European laboratories took part in an inter-comparison exercise at the Plymouth Marine Laboratory, which consisted of tank experiments and field deployments. The results showed that although it is possible to measure the values of $b_{bp}(\lambda)$ with a precision of 13%, the determination of γ has a higher uncertainty.

The differences due to the sigma correction were evaluated using a sensitivity analysis approach. The ranges of the parameters used were obtained from in-situ data collected in the North West European Shelf between 2002 and 2003. Preliminary results indicate that scattering causes most of the variability on $b_{bp}(\lambda)$, while absorption

Recent developments at RSDAS

Peter Miller, Jamie Shutler, Rory Hutson, Peter Land, Tim Smyth, Steve Groom
Remote Sensing Group, Plymouth Marine Laboratory,
Prospect Place, Plymouth PL1 3DH, UK. E-mail pim@pml.ac.uk.

The NERC Remote Sensing Data Analysis Service (RSDAS) provides value-added remote sensing data to UK environmental scientists. Products include geo-referenced chlorophyll concentration and other ocean colour properties from MODIS, MERIS and SeaWiFS sensors, and sea-surface temperature, land brightness temperature and vegetation index from AVHRR. We process data within 1 hour of acquisition for oceanic and coastal waters around Great Britain and Northern Europe within the receiving range of Dundee Satellite Station and worldwide through collaboration with NASA, NOAA and ESA. Our highly automated software enables us both to guide research vessels at sea and to continuously expand our extensive web-based image archive. A flexible approach to each request allows user-driven products, formats and analyses, including compositing, extraction of positional data, and time-series studies, for example to compare with *in situ* observations or model output.

Recent developments will be demonstrated which include: novel processing of MODIS ocean colour data at higher resolution (500m for chlorophyll and 250m for suspended particulate matter) for coastal and estuarine studies; mapping ocean colour products from Envisat MERIS data provided in near-real time by ESA; atmospheric correction of *casi* data acquired through the NERC Airborne Remote Sensing Facility (ARSF); and delivery of RSDAS data via the NERC DataGrid e-Science portal.

If you are an academic researcher in the UK then you can apply for these data using the application form on the website http://www.npm.ac.uk/rsdas/ or contact Peter Miller at rsdas@mail.pml.ac.uk.

Use of Ferries to monitor water quality in the Irish Sea

Gay Mitchelson-Jacob, David Doxaran, Caren Binding and David Bowers
Centre for Applied Marine Science
Marine Science Laboratories
Menai Bridge
Anglesey, LL59 5AB, UK

Ocean colour remote sensing can be a useful and powerful tool to map the concentrations of optically active water constituents, for example chlorophyll-a (Chla) which relates to the biomass of phytoplankton. Regular observations are needed in coastal waters to assess the seasonal variability of phytoplankton growth and decay, quantify the associated primary production and identify the impact of increasing human activities on bio-geochemical cycles.

However, such observations from satellite can be highly limited in many regions of the world due to the occurrence of clouds which mask the water-leaving signal. One solution may be to consider regular optical measurements carried out onboard ships of opportunity such as ferries, providing long-term observations with a daily temporal resolution. Such an observation system has been installed and used for one year in the Irish Sea using the Irish Ferries' ship, Ulysses, crossing daily between Dublin (Ireland) and Holyhead (North Wales). Onboard measurements have included the remote-sensing reflectance signal (Rrs, in sr^{-1}) obtained from continuous data recorded using several Trios above-water spectroradiometers and weekly water sample collection (notably used to determine the Chla concentration).

Prior to recording regular measurements onboard the ferry, several field experiments were conducted in order to establish a regional algorithm used to quantify Chla concentrations from Rrs data and to assess optimal configuration and processing of the above-water Trios measurements including satisfactory correction for surface reflection effects. The selected set-up for the optical measurements carried out onboard the ferry has been justified on the basis of the initial trials.

A Chla quantification algorithm is being derived from the field trials, applying a surface reflection effect correction. The influence in this on the Chla retrieval is presented along with the first results obtained in terms of Chla mapping in the Irish Sea from the ferry.

Inherent Optical Properties and Water Quality Parameters of the Irish Sea

David McKee and Alex Cunningham

An investigation into the inherent optical properties (IOPs) of the Irish Sea reveals two optically distinct water types which can be classified into High and Low Reflectance subsets using the ratio of particulate backscattering to non-water absorption (b_{bp}/a_n) at 676 nm. Blue to red absorption ratios and absorption to scattering ratios are also different for High and Low Reflectance stations. The composition of seawater constituents is shown to be different in the two water types, with High Reflectances associated with low ratios of chlorophyll to minerals (*Chla / MSS* < 0.4 mg/g) and Low Reflectances associated with high values of *Chla* / *MSS* (> 0.4 mg/g). Regression analysis is used to derive relationships between IOPs and water quality parameters for the two water types. The pseudo mass-specific IOPs which are obtained from this analysis form the basis for a model which can be used to successfully reconstruct absorption, scattering and backscattering coefficients from measurements of *Chla*, *MSS* and *CDOM* for Irish Sea stations.

Seasonal variability of surface chlorophyll concentrations in the NW African upwelling region

Yaswant Pradhan, Samantha Lavender

School of Earth, Ocean and Environmental Sciences, University of Plymouth, Plymouth PL4 8AA, UK

E-mail: yaswant.pradhan@plymouth.ac.uk

Seven years of SeaWiFS data in conjunction with other environmental parameters are being analysed to evaluate the seasonal cycle of surface chlorophyll (chl) concentration in the tropical waters off northwest African upwelling system. We examine the seasonal cycle and anomaly fields through Empirical Orthogonal Function analysis of monthly composites of surface chl data from Sep 1997 to Sep 2004. The observation reveals an unusual episode of high surface chl concentration, during autumn 1998, of magnitude 2-3 times higher than the normal spring event. Surface chl and sea surface height (SSH) are weakly correlated; however the local wind seems to play a major role, alongside other environmental parameters, on the evolution of the chl cycle. It is also realised that the seasonal cloud covers in summer are often impede the construction of the spatially averaged time-series. So the usefulness of effective pixels and combination of multiple data sources to reconstruct and interpret the time-series are discussed briefly.

MODIS 500m ocean colour data through exploiting spectral and spatial correlation.

J. D. Shutler, P. E. Land and S. B. Groom

Plymouth Marine Laboratory,
Prospect Place, The Hoe,
Plymouth,
PL1 3DH U.K.
{jams, peland, sbg}@pml.ac.uk

Abstract witheld

Atmospheric correction of ocean colour imagery: Is it worth using in situ aerosol measurements to improve retrievals?

Tim J Smyth and R C Nagur Cherukuru
[1] Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth, UK

The remotely sensed signal measured by satellite or airborne sensors in the visible and near infra-red is strongly affected by the Earth's atmosphere along the path from the sun to the target surface, and back to the sensor. In the marine environment the atmosphere may account for >90% of the total signal and therefore if accurate retrievals of water leaving radiance are to be obtained the imagery requires atmospheric correction.
A four year time series of aerosol optical properties has been collected at the Plymouth Marine Laboratory (PML) using a POM01-L sky radiometer with wavelengths of 315, 400, 500, 675, 870 and 1020 nm. These data can be used to check for the internal consistency of (e.g.) the SeaWiFS atmospheric correction by comparing the aerosol optical depth (AOD) calculated at 870 nm by SeaWiFS and measured by the POM. The in situ data can also be used to derive the spectral distribution of AOD, known as the Angstrom exponent (α). This paper describes different approaches to calculate α using in situ data and a comparison is made with the SeaWiFS derived values: the impact upon the retrieved ocean colour parameters is shown and modelling approaches are investigated.

ASAR image handling within the COASTCHART project

Fergus Taylor[1], Matthew Stuttard[1], Samantha Lavender[2], Mike Wooding[3], Nicole Lenotre[4]

1 LogicaCMG UK Limited, 2 University of Plymouth School of Ocean and Earth Science, 3 Remote Sensing Applications Consultants Limited, 4 BRGM

Accurate and up-to-date coastal information is essential to ensure the safety of navigation, to prevent ecological impacts, to plan economic activities (e.g. harbour infrastructures, tourism, fisheries) and to define sovereign limits. Navigational charts are created to allow vessels to plan safe passage so charts must be kept up to date, particularly on shipping routes. Depending on the coastal geomorphology, coastlines can change significantly over a period of weeks or months (and occasionally – as we have seen recently - in a matter of minutes). This is faster than the current update cycles of most charts – particularly those of developing countries. Lack of geographical coastal information is a particular issue in West African countries. For the French, British, Portuguese and Spanish hydrographic offices that have primary charting responsibility in West Africa, this typically implies an update cycle of around 5 to 10 years to provide a complete coverage.

COASTCHART is an ESA funded project aiming to develop and qualify an Earth Observation (EO) information system for the production of validated "Coastline Restitution" products. The aim is to support hydrographic organisations in their marine charting activities, in particular allowing more timely and cost effective updating of the coastline. The Coastline Vector Restitution will be derived from optical and radar satellite images with a recent acquisition date.

This presentation will provide a brief overview of the project, followed by a description of the methods being developed for using VHR optical and SAR imagery.
Specific issues that will be described are

a) the specification of satellite image data required for coastline delineation at 1:50 000 scale and 1:15 000 scale. The acquisition plan includes images at different look angles, polarisations and from ascending and descending track acquisitions.
b) the method being developed for interpreting the coastline from multiple images.

Regional variation in the inherent optical properties of the North Sea: Implications for Ocean Colour Algorithms.

Gavin Tilstone[1], Hajo Krasemann[2], Victor Martinez-Vicente[1], Gerald Moore[1], Wolfgang Schoenfeld[2], Eyvind Aas[3], David Blondeau-Patissier[1], Roland Doerffer[2], Jo Hokedal[4], Peter Jorgensen[5], Marieke Eleveld[6], Reinold Pasterkamp[6], Steef Peters[6], Rudiger Rottgers[2], Kai Sorensen[4], Hans van der Woerd[6].

[1]*Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth, PL1 3DH, UK.* [2]*GKSS, Geestacht, GERMANY.* [3]*University of Oslo, Oslo, NORWAY.* [4]*Norwegian Institute for Water Research (NIVA), Oslo, NORWAY.* [5]*Danish Meteorological Institute, Copenhagen, DENMARK.* [6]*Institute for Environmental Studies, Vrije Universiteit, De Boelelaan 1087, 1081 HV Amsterdam, THE NETHERLANDS.*

The absorption properties of phytoplankton, non algal particles and coloured dissolved organic material were measured at 466 stations at coastal sites in the North Sea, Western English Channel and Celtic Sea from April 2002 to September 2003. Chlorophyll-a (Chla) and chlorophyll specific absorption coefficient of phytoplankton (aph* 442) were significantly higher and lower along the Dutch coast, total suspended material (TSM) was significantly lower in the Western English Channel (WEC) and the absorption coefficient of Coloured Dissolved Organic Material (CDOM) was significantly lower on the eastern UK coast. There was no difference in the TSM specific absorption of detrital material (aNAP* 442) between regions.

A significant difference was observed between different methods of fitting SCDOM & SNAP curves and these are discussed in relation to remote sensing (RS) algorithms. We also found a significant difference in the relationship between aph (442) & Chla for coastal waters of the North Sea compared to other models commonly used in RS algorithms. Based on absorption properties observed, three distinct optical regions were classified in the North Sea and surrounding environs. A bio-optical remote sensing model was parameterised using mean specific inherent optical properties for each optical region and over the whole dataset. The results are discussed into regional parameterisation of remote sensing algorithms for coastal areas.