

## ABSTRACT BOOK



### 3<sup>rd</sup> Workshop

***Remote Sensing  
of the Coastal Zone***  
**From Inland to Marine Waters**

**June 7 to 9, 2007  
Bolzano/Bozen, Italy**



European Association of Remote Sensing Laboratories

## **3<sup>rd</sup> Workshop**

### ***of the Special Interest Group Remote Sensing of the Coastal Zone***

## **From Inland to Marine Waters**

## **Abstract Book**

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**Operational Water Quality Services and Requirements of EU Directives**

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*Keywords: Water Framework Directive; European Marine Strategy; Water Quality Remote Sensing; Marcoast*

Monitoring of the marine environment has some tradition in Europe. The regional conventions HELCOM (Baltic Sea), OSPAR (North-East Atlantik) and BARCOM (Mediterranean) have been established in the 80s and 90s and requiring a basic monitoring, originally aiming primarily on chemical pollutants as well as nutrients in order to assess the eutrophication status. These conventions have been or are undergoing a change by now including biological parameters and aiming at an ecosystem approach. In 2000 the European Commission put in place the Water Framework Directive, which includes a complete set of requirements for monitoring chemical, physical and biological parameters, and it aims at establishing a good or very good ecological and chemical status of waters bodies. This includes the transitional waters, i.e. the estuaries, and the coastal waters, which extends in the definition of the Water Framework Directive 1nm off the baseline. In the near future the European Marine Strategy will complement the Water Framework Directive into the open ocean. This directive will also be driven by an ecological approach and will require a monitoring of biological, chemical and physical parameters. The monitoring of the eutrophication status of the water body is also required by the European Natura 2000 Directives: the Fauna-Flora Habitat Directive and the Birds Directive. These require a monitoring of habitats including reefs and sandbanks.

The monitoring imposed by these regulations requires information about large areas with partially high temporal frequency. Water quality parameters, such as the chlorophyll-a concentration, the suspended matter concentration and the transparency are important and mandatory parameters of the above mentioned regulations. Remote sensing is considered as an appropriate tool to complement traditional ship measurements in a cost effective way. However, remote sensing data differ from ship measurement in a methodological sense, in spatial integration and vertical resolution. This difference needs to be

understood, and success can only be achieved by combining ship measurements with remote sensing data rather than by competition.

SeaWiFS was the first space borne instrument providing data for this purpose, and today additionally MODIS and MERIS deliver data of better quality. Especially MERIS has been designed for coastal applications. Operational satellites, such as the ESA Sentinel 3 series, will carry follow-on instruments in the future to ensure long data provision. While the 80s and 90s were characterised by methodological research in retrieving quantitative estimates of water constituent concentrations, initiative have been started at national and European level to set-up operational services for providing water quality products derived from remotely sensed data. The EU Marine Core Service and ESA GMES Service Element projects CoastWatch and MarCoast are mentioned here as central European activities to implement operational core services and a net work of service providers delivering tailored data products to monitoring agencies on regional, national and European level.

### **Protection of Marine Parks in the Dutch marine Extended Economic Zone: A scoping study on the potential role of present and future satellites**

Hans J van der Woerd, Marieke A Eleveld, Steef W M Peters & Roy Brouwer  
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*Keywords: EMS; MPA; Ocean Colour; Water Quality Products; Phytoplankton; Patterns; Web Map Server; Metadata*

The European Marine Strategy (EMS) offers an important tool in protecting vulnerable marine areas on a local, regional and global level. Biologically productive areas in the shallow parts of the North Sea require the integral protection of both benthic and pelagic communities and seabirds. The Netherlands has taken up spatial planning at sea and has identified two Marine Protected Areas (MPAs) close to the coast (Foredelta and Holland Coast) and three in the coastal North Sea (Dogger Bank, Frisian Front and Clover Bank). These four areas cover 15% of the Dutch EEZ area, 85 times the surface of the Veluwe, the largest on land man-made park in the Netherlands.

We will present a scoping study on the potential role of satellite information in monitoring and protecting these coastal marine systems. Several examples show information on algal biomass and effect of high sediment load in context of the MPA requirements. Gaps in the current knowledge are identified and remedies are proposed.

First results of IVM's two services that might be a stepping stone towards the new MPA protection services are presented: the MARCOAST near-real time detection of high-biomass blooms linked to a biochemical/hydrodynamic model and the WATeRS portal that provides near-real time satellite derived water quality information as an open Web Map Service.

Our preliminary conclusion is that monitoring of extended and remote areas with complex biological and hydrodynamic behaviour requires more intense exploration of remote sensing products, in seamlessly combination with other data with a geographic component.

### **Remote sensing support to ICZM and Conservation of coastal habitats in Western Crete**

Emil Ivanov & Ioannis Manakos, MAICH, Chania, Greece; Wim van der Knaap, Wageningen University, The Netherlands; Ioannis Vogiatzakis, University of Reading, U.K.

*Keywords: ICZM; coastal habitat conservation; object-oriented analysis; land-use planning*

Coastal areas of Western Crete face the big challenge of integrating biodiversity conservation objectives in land use planning. The lack of adequate operational methods and of sufficient information about human-environment interactions comprise the two major constraints, with which integrated conservation planning confronts.

Based on the ELANEM procedure a new approach was developed by applying indices and indicators, structured according to environmental functions (naturalness, source of resources, sink for waste, service support), human-environment interaction (pressure, state, response) and environmental components (biodiversity, soil, water, land-use). 64 selected indices and indicators are estimated through remote sensing image analysis, existing document and database review, and enquiry of experts.

Remote sensing images from the last three decades are selected to analyze and rapidly assess the multi-temporal and multi-scale dynamics of selected artificialization features, such as urban sprawl, land-use intensification and congestion of infrastructure and activities on the coasts, and of environmental features, such as habitat extent and quality, coastal erosion, and possible risks from natural and human-induced hazards. Object-oriented analysis with eCognition software supported the study of scale-effects of various land cover properties with multi-resolution segmentation.

The outcome is a new approach comprising of historical land-use change assessment and of the development of a planning support tool using multitemporal remote sensing analysis, existing information, and expert knowledge.

**COASTAL WIKI: STATE OF THE ART ON FIELD OBSERVATION TECHNIQUES FOR ICZM IN EUROPE**

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*Keywords: Field observation techniques; ENCORA; Integrated Coastal Zone Management*

The EU FP6 project ENCORA has created a European network structure with new mechanisms for communication on shared problems within and between the communities of coastal science, policy and practice. National Coastal Networks have been established in 13 European countries. Additionally, ten trans-national, cross-disciplinary Thematic Networks, address major issues of concern for implementation of ICZM in Europe. Assessment of field observation techniques is one of these ten themes (Theme 9), together with (1) Multi-functionality and valuation; (2) ICZM Participation and Implementation; (3) Coastal and marine spatial planning; (4) Pollution, prevention and mitigation; (5) Long-term geomorphologic change and climate impacts; (6) Effect of development and use on geomorphology and coastal habitats; (7) Assessment of biodiversity change; (8) New sustainable coastal engineering techniques; and (10) Capacity building, education and training. Together, these themes have developed a Coastal Wiki, providing a survey of existing coastal knowledge and experience in Europe, with references to the most relevant sources published in the literature and on the Internet. Regarding field observation techniques, a broad range of articles is currently incorporated in the Coastal Wiki including: overviews of different remote sensing techniques and sensors, related field methods and samplers; appropriate methods for different parameters; descriptions of specific applications; and integrated information and management systems (including remote sensing and computational models). The Coastal Wiki is primarily intended for use by professionals in coastal science, practice and policy, but is also expected to become an important resource in teaching and educational programmes. The Wiki format allows expert users to continue updating the directory in the future with new knowledge, and allows easy links to related relevant topics. It should become a major tool for keeping coastal professionals informed of recent developments and new major knowledge sources in their field.

Tutorial:

**Remote Sensing of the invisible: What we know about the atmosphere and how we know it.**

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From the 1960s onwards, there has been a growing realization that many far-reaching consequences for the health of the Earth's biosphere could be and in fact were already being affected by atmospheric changes that were poorly understood, but definitely occurring, due to human activities. Explicit concerns about ozone depletion via chlorine released from anthropogenic chlorofluorocarbons spurred a renewed interest in atmospheric chemistry, often involving constituents with concentrations of parts per million to parts per billion and even less. Research required means to make quantitative measurements using remote sensing to reach the relevant high-altitude regions of the atmosphere where changes were taking place. Almost simultaneously with the ozone crisis came a renewed realization that global warming was already standing out above the random short term variations of climate and could present a global threat more serious than ozone depletion. These and other motives over the past 25<sup>+</sup> years have spurred the development of increasingly sophisticated and successful methods of remote sensing to study Earth's atmosphere. In this talk I will discuss a variety of techniques – some old and some new – that have been used for remote sensing of properties such as temperature, pressure, wind speeds, and global-scale transport, and of atmospheric constituents – particularly, chemically active trace species. In brief, how does one see the invisible, and how good are our quantitative measurements in determining present constituents and their vertical distributions through the atmosphere, as well as future trends?

**Towards assimilation of ocean colour satellite observation into coastal ocean biogeochemical models: The tropical Fitzroy River Estuary case study**

Vittorio Brando, CSIRO Land & Water, Canberra, Australia

*Keywords: ocean colour; coastal waters; regional algorithms; data assimilation; biogeochemical models; estimates of material fluxes*

In coastal regions, hydrodynamic and biogeochemical models model-data assimilation requires high temporal resolution satellite data sets due to short time and space scales of coastal ocean processes. Assimilation of ocean colour satellite observation into coastal ocean biogeochemical models is still in an early stage of development; this is partly due to the lack of valid and quantitative (in terms of error analysis) coastal ocean colour products. Coastal waters over the estuary-coast-ocean continuum show a high spatial and temporal variability in optical properties i.e. how they absorb and scatter light as a function of biogeochemical constituents' concentrations.

We present the first results of the assimilation of ocean colour datasets into coastal ocean biogeochemical models for the tropical East Australian Fitzroy Estuary and Keppel Bay system (FE-KB) close to the Great Barrier Reef lagoon. As part of the Great Barrier Reef Monitoring Program, a regional algorithm for operational delivery of valid coastal ocean colour products was recently developed for the Fitzroy River Estuary and Keppel Bay system. A new generation of regional specific algorithm for the FE-KB system had to be developed for large satellite datasets of the MODIS sensors as the global algorithms failed. These new regional algorithms are generic in structure and therefore easily adaptable to SeaWiFs and MERIS.

Concurrently, a biogeochemical model was developed for the system, built upon a three-dimensional hydrodynamic and sediment dynamic model, and simulating nitrogen and phosphorus dynamics including the dynamics of dissolved organic material as well as pelagic and benthic primary production. One of the aims was to provide estimates of material fluxes from Keppel Bay to the Great Barrier Reef Lagoon. The biogeochemical model was run first with fixed boundary conditions based on the limited in situ measurements, then with boundary conditions derived from satellite datasets using the region-specific algorithm.

Several methodologies for matching of remote sensing observations to model variables were evaluated over a period of one year (2004). The biogeochemical model and MODIS satellite imagery derived maps of total suspended matter and chlorophyll were compared. When remote sensing information was used to inform the boundaries, estimates of material fluxes in the model changed substantially in magnitude and direction.

**The Oceans and the Earth climate**

Rainer Reuter, University of Oldenburg, Germany

*Keywords: climate change; seawater temperature increase; sea level rise*

The present knowledge of the role of the oceans in the Earth climate system is reviewed. Compared with land and atmosphere, the oceans play a key factor for the magnitude of climate change due to their higher heat capacity. However, changing thermal conditions in the oceans influence the amount of sea ice and the system of ocean currents, which both affect the climate on land. Increasing seawater temperature causes a sealevel rise with a magnitude similar to the effects from melting continental ice. Increasing atmospheric carbon dioxide is partly damped due to storage in the oceans, but this can lead to seawater acidification causing severe risks for marine ecosystems. The significance of these effects in actually measured oceanographic data is examined, with emphasis on remote sensing as a tool for surveys on global scales. Based on various scenarios of greenhouse gas emissions the future development of the Earth climate and the estimated consequences for the open oceans and coastal zones are discussed.

**GMES and EARSeL: some preliminary thoughts.  
Should/would GMES change EARSeL's mood?**

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*Keywords: remote Sensing, GMES, European Union, ESA, space agencies, services.*

GMES and GALILEO are the two pillars of the European Space Policy.

GMES stands for 'Global Monitoring for Environment and Security'. It ambitions to develop services for users in these domains, which should begin to be operative in 2008.

After having been perceived as pushed by the institutional space lobby, GMES is often perceived now as pushed by the spaceindustrial lobby - sometimes pointed out as having led a too fast conversion towards applications. One year before 2008, it is time to put the right ideas at the right place. Space (and particularly Earth Observation at large) is a unique tool to serve GMES objectives, but by no means it can do it alone. A lot of physical and in situ information as well as relevant models are mandatory. Setting up and maintaining on the long run operational systems is an industrial business. But it is often a long way from Earth Observation and in situ data to operative services requested by GMES. Research - whether academic, institutional or private - remains quite mandatory to make such a giant step. Deontological scientific rules make researchers touchy about their independence. GMES is not a political pressure, but a strong societal demand. Should developing European research about remote sensing applications to serve such a European policy be a driving factor for EARSeL's future?

### Tools and techniques for the analysis of time-series data

Keith McCloy, University of Aarhus, Denmark

The Workshop will focus on the emerging area of analysis in remote sensing to do with changes over time and what sort of information can we get on the land covers and their dynamics from time series image data. The use of time series image data offers real challenges to the researcher as to how to use the data to better understand the problems being investigated and then to subsequently development and test hypotheses concerned with the dynamic processes being studied. There are thus real challenges in the development of tools and techniques as well as in the calibration of the data so as to provide consistent datasets.

The purposes of the workshop are to:

- Discuss the issues and needs in the adequate pre-processing of image data so as to provide a consistent data set for temporal analysis and learn about some of the available time series datasets.
- Learn about the classical methods of time series analysis and consider how it may be adapted to the analysis of image data.
- Learn about the latest techniques in the analysis of seasonality and how to measure its changes in image data.
- Discuss issues of dimensionality (spatial, spectral, informational) in time series of image data and how to reduce this problem yet not remove information from the data.

Provide attendees with the opportunity to display posters of their work during the workshop.

### Fluorescence of dissolved and colloidal fractions of natural organic matter

Olga M. Gorshkova, Anton S. Milukov, Svetlana Patsayeva, Elena Prashikova & Viktor I. Yuzhakov, Moscow State University, Russia

*Keywords: fluorescence; natural water; dissolved organic matter (DOM); colloidal organic matter*

Non-living organic matter (NOM) is the largest organic carbon pool in natural waters and plays a central role in biogeochemistry of chemical elements. Colloidal matter makes up a significant portion of the bulk NOM in aquatic environments, but is still poorly characterized. Fluorescence emission spectra excited at several wavelengths chosen in the spectral range of 270...355 nm as well as absorbance values were measured for the following three types of the filtered samples: dissolved organic matter (DOM) received using microfiltration with the 0.2  $\mu\text{m}$  pore size filter; colloidal fraction (CF) with particles size ranging between 5 and 200 nm and low-molecular weight fraction (LMW) with molecules smaller 5 nm prepared using ultrafiltration procedure. Fractionation of DOM samples and fluorescence measurements allowed estimation of percentage of colloidal fraction as  $40\pm 10\%$  on average for unpolluted river water samples. The rest of DOM was in the form of LMW matter with molecules smaller than 5 nm.

Fluorescence spectra of all DOM fractions show blue broadband emission with maximum position depending on the excitation wavelength. Under excitation at 270 and 355 nm maximum position is within 430...440 nm that is typical for humic substances. With excitation at 310 nm the position of maximum undergoes a "blue shift" to shorter wavelength range of 417...427 nm depending on the sample origin. The "blue shift" value is bigger for LMW fraction than for colloidal fraction or DOM. The existence of "blue shift" could be explained by presence of two components in DOM fluorescence emission spectra. The first component with emission maximum in the range 380...410 nm overlaps with another one with maximum positioned at 430...450 nm. First component is prevailing in the emission spectra of LMW fraction while the second one contributes mainly into emission of bigger DOM particles. The proportion LMW material to bigger DOM particles could vary in natural waters as a result of numerous biological and

geochemical processes providing various values of “blue shift” of emission maximum position along rising excitation wavelength.

All river water samples manifested a tendency in the shift of maximum position towards longer wavelengths for colloidal fractions compared to original DOM samples, and for DOM samples compared to LMW fractions. This observation is in agreement with the fact that typically large molecular aggregates have red-shifted emission spectrum compared to monomers and smaller molecular associates. Fluorescence quantum yield estimated for the excitation wavelength of 355 nm is decreasing in 12% for colloidal fraction and increasing in 30% for molecules smaller than 5 nm (LMW fraction) in comparison to DOM samples filtered with 0.2  $\mu\text{m}$ .

The spectral features considered in the work (position of emission maximum, fluorescence quantum yield, absorbance ratio D230/D355) could be used for characterization of NOM properties.

### **First measurement of size, refractive index, depolarization and fluorescence of phytoplankton cells by laser scanning flow cytometry**

Roberta Fantoni, Luca Fiorani, Antonella Lai, Antonio Palucci, Maria Sighicelli & Peter Tarasov, ENEA, Frascati, Italy

*Keywords: Laser scattering, cytometry, phytoplankton cells*

In recent years some attempts have been made to identify algal species in marine waters from the remote measurements of satellite sensors. This difficult task requires an accurate knowledge of the optical properties of phytoplankton cells.

In this framework, the laser scanning flow cytometer CLASS has been developed to characterize marine phytoplankton morphology and composition from the simultaneous measurement of size, refractive index, depolarization and fluorescence (size and refractive index are retrieved by an inversion of Mie theory).

CLASS consists of three main subsystems: hydrodynamics, optics and electronics. Hydrodynamics is quite conventional except that it embeds two closed loop electronic pressure regulators, the first one for the sheath fluid and the second one for the sample fluid. The heart of optics is a cuvette where particles flow in a capillary. The beam delivered by a diode laser emitting at 405 nm is focused in the capillary where it is scattered by particles. The light is reflected by a spherical mirror constituting the bottom wall of the cuvette. Finally, four photomultiplier detects the trigger signal, the scattered light as a function of angle (unpolarized and linearly polarized) and the fluorescent emission. The main parts of electronics are four preamplifiers and a four-channel analog-to-digital converter with 14 bit resolution and 2 MS/s sampling.

Simultaneous measurements of size, refractive index, depolarization and fluorescence of *Chlamydomonas reinhardtii* by CLASS are reported. To our knowledge, they represent the first example of those results by laser flow cytometry.

**Empirical relationships between particulate beam attenuation coefficient, bacteria abundance and production in marine waters**

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*Keywords: bacteria, carbon production, beam attenuation, marine waters*

In this work we explore potential relationships between particulate beam attenuation (cp), chlorophyll a concentration (chl), phytoplankton productivity (PPP), and total (free living + particle-attached) bacteria abundance (BA) and carbon productivity (BCP) in marine waters of different latitudes. The final intention is to investigate the possibility of estimating bacterial parameters in marine waters based on optical (beam attenuation) and environmental (e.g., temperature) measurements. Organic detritus is a substrate for bacteria and contributes significantly to cp magnitude. Also, cp variability is not always related to chl variability. Thus, it might be expected that a higher availability of organic detritus would be related to higher BA, BCP and cp values but not necessarily to higher chl values. Five datasets (three JGOFS cruises, one Palmer-LTER cruise, and the BATS time series) of chl, PPP, BA, BCP and cp at 660 nm were used to test this hypothesis in tropical (Equatorial current, Sargasso Sea), mid-latitude (Arabian Sea), and polar (Ross Sea and the western Shelf of Antarctica Peninsula) surface waters (0-20 m). Preliminary results show positive linear relationships between cp, BA and BCP for all cases. In Sargasso Sea, cp was weakly (PPP) or not (chl) influenced by phytoplankton parameters. As expected based on published literature (higher BCP in particle-attached than free living bacteria), BCP had a stronger relationship with cp than BA.

The effect of other factors (temperature, nutrients, substrate concentration and community composition) on residuals of cp regressions is also discussed.

**Physically based data processing of multi- and hyperspectral remote sensing data: From inland to marine applications**

Thomas Heege, Viacheslav Kiselev & Jörg Heblinski, EOMAP GmbH, Oberpfaffenhofen, Germany; Sabine Miksa, Nicole Pinnel, Peter Hausknecht & Halina Kobryn

*Keywords: Multispectral; Hyperspectral; Airborne; Satellite; Lakes; Coastal Zone; Aquatic; Submerged; Vegetation; Seaweed; Coral Reef; Bathymetry; Chlorophyll; Suspended Matter; data processing; MIP; Multitemporal*

Spectral mapping of aquatic environments using satellite and airborne data has advanced steadily over the last few years as processing time and algorithms become faster and more efficient. In particular, physically based processing methods became robust, sensor independent, and largely independent of the type of aquatic system. Multi-temporal mapping of chlorophyll, suspended matter, bathymetry and submerged vegetation has been carried out in a wide range of lakes and coastal areas using a range of different multi- and hyperspectral satellite- and airborne sensors. Applications presented here were processed in a standardized way using the Modular Inversion and Processing System MIP. The images which have been processed range from inland waters (Lake Constance, Osterseen, Lake Sevan) over Adriatic coastal area mapping and up to the West Australian Ningaloo reef. The potential and the critical limitations of the standardized data processing is demonstrated by means of several processing results and sensor comparisons.

**Diffuse attenuation of light in tropical coastal and estuarine waters  
A semi-analytical approach for Fitzroy Estuary and Keppel Bay,  
Australia**

Nagur RC Cherukuru, Vittorio E Brando, David Blondeau-Patissier,  
Arnold G Dekker, Vittorio E Brando, Land & Water, Canberra, Australia

*Keywords: vertical attenuation; coastal waters; semi-analytical bio-optical  
model; data assimilation*

The spectral diffuse attenuation coefficient ( $K_d$ ) for downwelling irradiance is an important parameter that indicates the ecological and biogeochemical status of the water body. Estimation of  $K_d$  is important for classification of natural waters, heat budget studies, photosynthesis and water quality. Most biogeochemical models use empirical relationships between light and chlorophyll concentration to estimate  $K_d$ . Such an approach contains large uncertainties inherent to empirical algorithms and they are specifically unsuitable to use in coastal waters dominated by non-planktonic material such as Chromophoric Dissolved Organic Matter (CDOM) and non-algal particulate (NAP) matter.

Accurate estimates of  $K_d$  are essential to improve the performance of biogeochemical models. To achieve this objective we developed a semi-analytical bio-optical model. This model contains independent component specific optical models to simulate the behaviour of phytoplankton, NAP matter and CDOM. Subsequently these inherent optical property models are further incorporated into the  $K_d$  model which was developed further using Hydrolight simulations. The result is a comprehensive  $K_d$  model that provides improved underwater light propagation estimation based on detailed light-matter interactions.

Results presented demonstrate the performance of the semi-analytical model and to Model derived  $K_d$  estimates are compared with independent in situ apparent optical property measurements. This work is a part of a wider research with the objective to improve the underwater light climatology in biogeochemical models for assimilating remotely sensed data into ecological models for the tropical Fitzroy Estuary and Keppel Bay waters in Australia.

**Valuation of Shoreline Fluctuations and Vegetation Status in  
Northeast Caspian Coastal Zone Using Terra/MODIS Imagery**

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Tsyhchuyeva

*Keywords: TERRA/MODIS; remote monitoring; shoreline fluctuations;  
vegetation state.*

Natural climate peculiarities of Northeast Caspian lowland cause favorable conditions for forming of positive and negative sea setup at strong wind. Effective height of elevation to several meters ensures onset of coastlines in some directions by 10-15 km. Intensive processes of loose materials transport with sea setup are capable to dynamically change topography and impact on vegetation status within coastal zone. Information on such processes is of high interest due to close proximity to oil production infrastructure. Valuation of vegetation status is of high importance, because vegetation is a basic indicator of the environmental stability of the studied area.

Space Research Institute, Ministry of Education and Science RK, and Tengizchevroil LLP have been conducting monitoring of shoreline and vegetation status studies of Northeast Caspian during 5 years (2002-2006) for a March-November season using Band 1 and 2 of TERRA/MODIS satellite sensor. Near shore territory of Northeast Caspian easily can be divided by 2 classes on space images: sea surface and land surface. Spectral characteristics of these two classes significantly differ in visible and near infrared spectral bands. The gentler the shore, the larger is spatial amplitude of the shore line. In this study,  $\square$ gclose and far $\square$ h locations of the shore line at high and low tides, registered during 2002-2006, were shown as a result of interpretation of weekly TERRA/MODIS imagery.

Long term monitoring of shoreline locations at Caspian setup allows calculating of probability density for the position of water-land border of the coastal area at the regular grid. The cell size of such grid is defined by spatial resolution of MODIS images.

Comparison of time series of the normalized difference vegetation indexes, NDVI, for coastal landscapes and their territorial components, revealed seasonal and annual differences of NDVI values and large

variability of vegetation dynamics of high and low lands vegetation communities. It was demonstrated that high lands vegetation status, those on Mangyshlak and Ustyurt plateaus, remain stable during vegetation period and are not much impacted by Caspian setup and the shore line fluctuations. The opposite situation is being observed at low elevated coastal lands of Caspian depression. The most typical year-to-year differences (time shift of peak values) in vegetation indexes curves is basically caused by temperature conditions in the beginning of the vegetation period and intensive Caspian setup phenomena.

In that way, satellite monitoring and analysis of vegetation dynamics during 2002-2006 allow to acknowledge variations of weather conditions and intensive sea setup as the strongest natural climatic factors considerably impacting on vegetation status in the Northeast Caspian coastal zone.

### **Impact of aerosol physical properties on remote sensing of coastal areas**

Tymon Zielinski & Tomasz Petelski, Institute of Oceanology PAS, Sopot, Poland; Agnieszka Ponczkowska, Krzysztof Markowicz, Joanna Remiszewska, Giorgos Chourdakis, Nikos Mihalopoulos & Bringfried Pflug

*Keywords: Aerosol; coastal area; urban area; remote sensing*

Atmospheric aerosols originate from a wide variety of sources in both the marine and the continental environments. Aerosol content varies significantly depending upon whether the air mass is natural or modified anthropogenically, marine or continental, rural or urban. Therefore, characterizing aerosols not only requires describing their spatial and temporal distributions but their multi-component composition, particle size distribution and physical properties as well.

This is especially evident in coastal areas where aerosols are in the direct interaction zone between the atmosphere and the ocean surface and are characterized by rapid temporal and spatial changes in concentration.

The aim of this work was to determine the variations of aerosol physical properties in the atmosphere over the coastal areas, with a special emphasis on the impact of different particle sources. The studies were carried out in different areas including the coasts of the Baltic, Greece, Crete and Svalbard. The data were collected using lidars, laser particle counters and sunphotometers.

It was confirmed that the aerosol physical properties in the near-water layer in the coastal areas are significantly different from those over the open seas. In cases of coastal areas the aerosol composition can be changed over short periods of time, and the real aerosol concentrations depend on many factors, concerned with different particle origins. The aerosol concentrations change with wind speed and the changes have been described with mathematical formulae. Such information constitutes a very valuable input to atmospheric algorithms in remote sensing studies of marine and especially coastal environments.

**Absorption of natural plankton**

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*Keywords: a\*chl, variability, flowcytometry, spectrophotometry*

Remote sensing of plankton biomass and carbon fixation in oceanic and inland waters requires accurate knowledge of the optical properties of the plankton. The chlorophyll-specific absorption,  $a^*Chl$  [ $m^2$  (mg Chl $^{-1}$ )] is an essential parameter in models used to estimate these quantities because it constitutes the link between biomass and light absorption. For the retrieval of Chl $a$  in eutrophic inland and coastal waters,  $a^*Chl$  at the red absorption peak of Chl $a$  near 675 nm is used. Although often applied as a constant value, the coefficient depends on the plankton size, shape and physiological status, and has been shown to be highly variable in the marine environment and in cultures. Up to date, this variability has not been assessed for eutrophic inland and coastal waters. Variability in the Chl $a$ -specific absorption can be explained by variation in the intracellular pigment composition and pigment packaging, causing absorption to be either altered or reduced, respectively. In the red part of the spectrum most variability appeared to be attributable to the package effect. The current project aims to quantify the impact of this biological variability on satellite mapping of algal and cyanobacterial biomass and productivity.

Current work involves the development of a method that combines flow-cytometric sorting with spectrophotometry. Flow cytometry is used to isolate selected dominant populations from natural waters in order to directly determine their optical properties. The new information on variability in biomass-specific absorption will eventually be used for satellite mapping of biomass and productivity in eutrophic coastal and inland waters, which will be compared to distributions as previously based on a constant, mean value of this coefficient.

**Non-destructive optical characterisation of several pure cultures of microscopic fungi and algae grown in different ecological conditions**

Vera Terekhova, Elena Bandolina, Anna Menshenina, [Svetlana Patsayeva](#), Ekaterina Srebnyak, Tatiana Semenova & Viktor Yuzhakov, Moscow State University, Russia

*Keywords: fluorescence; absorption; algae; fungi; micromycetes; environment*

Luminescence techniques represent a powerful tool for detection of naturally occurring organic substances in water, living photosynthetic organisms, bacterial cells and they are currently applied in remote sensing of large areas using laser-based lidar systems or for in situ water diagnostics using mobile spectrometers. We believe that rapid optical detection and characterization of microorganisms combined with classical bio-indication and bio-testing techniques will improve the methods of environmental monitoring. For instance, biomass, biodiversity and physiological conditions of microscopic algae and micromycetes (microscopic fungi) could characterise the ecological status of fresh-water and coastal zones.

The current research was targeted to develop a basis for further optical characterisation of living cultures of microscopic fungi and aquatic algae grown in different conditions, including those grown in heavily polluted water. The optical characterization of typical microorganisms used as bio-indicators and test-systems in environmental monitoring was performed in laboratory conditions using spectrophotometer Perkin Elmer Lambda 35 and luminescence spectrometer Perkin Elmer LS55. Absorption and fluorescence spectra with different excitation wavelength were measured for several species of aquatic algae and differently pigmented fungi at various stage of their growing in polluted and unpolluted media.

Scattering by cells (in case of algae), spores and parts of hyphae (in case of fungi) is prevailing in absorption spectra of living cultures in water suspensions. Some specific pigments as carotenoids, flavonoids, chlorophylls (for algae), melanin-type brown pigments (for some fungi) are noticeable in absorption spectra. Fluorescence spectra of living cells showed correlation with cell numbers or total biomass of the sample. For algae correlation of chlorophyll fluorescence and cell

numbers was 0.6...0.9 depending on physiological status of culture and degree of water polluting. Fluorescence spectra of fungi were diverse depending on culture species, culture age and physiological status. However several typical emission bands were specified for different types of fungi coloration.

While absorption and fluorescence spectra of aquatic algae were reported previously by many scientists there is not yet published much information about spectral properties of fungi in spite of their importance in the environmental processes. Microscopic fungi take part in the major processes in terrestrial, soil and aquatic ecosystems, primarily in the destruction of organic compounds, and they also participate in various processes of biogeochemical transformation of mineral elements in water and soil. Transformations in fungi communities, especially increase of the amount of dark-coloured (melanin containing) fungi, serves as an important signal of disturbing processes in soil and aquatic eco-systems. For instance the ratio of dark-coloured to non-pigmented fungi could be used for determination of the ecological status of water and soil polluted by heavy metals and mineral oil. Therefore rapid characterisation of transformations in fungal communities using spectral techniques constitutes a basis for express and sensitive in situ monitoring.

## **THE USE OF ASTER IMAGES TO MAP FLUVIAL SEDIMENT DISCHARGE INTO NORTHERN ADRIATIC SEA**

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*Keywords: suspended matter; river plume; North Adriatic*

The most important Italian rivers (Po, Adige, Brenta, Piave, Tagliamento, and Isonzo) flow into the Northern Adriatic Sea generating a fundamental supply of freshwater with its suspended material which generally tends to disperse depositing prevalent sandy material along the coastal areas.

Suspended sediment concentration is one of the most important water quality parameters. Furthermore, its distribution is a key issue for analyzing the deposition and erosion of the coasts and estuaries, evaluating the material fluxes from river to sea and then along the shore.

Remote sensing techniques can provide spatially distributed information for estimating and mapping the concentrations of total suspended matter (TSM), with a high temporal frequency. However, it cannot completely replace conventional methods, as the results are not as accurate as from conventional methods.

A continuous record of freshwater discharge and suspended sediment transport was carried out in Piave river mouth during November 2003, for the research programme with the Autorità di Bacino dei fiumi dell'Alto Adriatico. During an important flood event on 29th of November 2003, three ASTER images of the North Adriatic Sea are being acquired with the objective of providing information on the spatial distribution of suspended sediment concentration from spectral profiles of water reflectance using a semi-empirical algorithm suitable for highly turbid waters.

The selection of the map construction algorithms is based on the analysis of the reflectance spectral signatures of increasing gradient transect samples. It was found that a good algorithm can be compiled on the ratio of angles of the reflectance values of the VIS/NIR channels. The ratio reduced the effects of changes in illumination conditions and sediment type.

Calibrating the algorithm on in situ samples, it was possible to estimate and map suspended sediments discharged from Piave river. This obtained function, which appeared to be successfully applied to the plumes of the other rivers of North Adriatic Sea with similar sediment size and composition, may be used with highly turbid waters, even if in situ data are not available.

### **Seawater dual fluorescence analysis during the Arctic transect of the Summer 2006 Polish oceanographic campaign**

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*Keywords: Laser fluorescence, chlorophyll, CDOM, Arctic*

The Arctic Ocean, despite to its economic and environmental importance, it is the smallest and shallowest of the world's five oceans. The greatest inflow of water comes from the Atlantic Ocean by way of the Norwegian Current, which then flows along the Eurasian coast. Water also enters from the Pacific Ocean via the Bering Strait. The East Greenland Current carries the major outflow. The Spitsbergen Current, with cool and fresh glacial water, strongly affects the mixing area of salty and warm water in the Norwegian Seas region up to Svalbard Islands.

The Institute of Oceanology of the Polish Academy of Sciences (IO-PAS) conducts regular scientific researches in the shelf seas and coastal regions including the Baltic and European Arctic Seas with its research vessel S/Y Oceania. The ENEA remote sensing laboratory has joined the Summer 2006 Polish Arctic campaign (from June 19th to July 20th) with the recently developed dual laser spectrofluorometer CASPER.

That compact instrument allows a dual laser excitation of sea water samples in the UV (266 nm) and visible (405 nm) spectral regions, in order to match the fluorescence analysis of dissolved (protein like compounds, humic acids) and particulate (phytoplankton) organic matter. Furthermore, a double filtration is included in the hydraulic feeding circuit, in order to better discriminate between fluorescence contribution of dissolved components from overlapping phytoplanktonic pigments.

More than 300 samples were analysed at different depths along the cruise in the campaign transects. Fluorescence data, after proper spectral deconvolution, were calibrated with simultaneous on board measurement and released in absolute concentrations. That information will be used as database for the development of regional bio-optical algorithms for radiance measurements obtained from satellite radiometers.

**Groundwater fluorescence analysis in Southern Italian regions affected by desertification processes**

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*Keywords: Laser fluorescence, chlorophyll, CDOM, desertification*

Desertification is the degradation of land in arid, semi-arid, and dry sub-humid areas and it is primarily due to human activities and climatic variations. Nowadays, this matter does not refer only to the expansion of existing deserts but it occurs because dryland ecosystems are extremely vulnerable to climate changes, over-exploitation and inappropriate land use.

In the Italian scenario, the impact of desertification is restricted to the southern regions where the risk is linked to water erosion, strong human aggressiveness, intense precipitations and to water and soil salinization. To this respect, the Italian project RIADE (Integrated Research for Applying new technologies and processes for combating DEsertification), has selected the area of Syracuse and the alluvial plain of the Licata town for an integrated application of the hydrogeochemical and spectroscopical methods in order to settle on qualitative characteristics of the water resources.

Laser Induced Fluorescence (LIF) spectroscopy has been chosen for its intrinsic skills to be employed in real time water quality parameter determinations, with portable instruments during intensive monitoring campaigns. This technique allows to perform qualitative and quantitative in situ determination of dissolved (humic and fulvic acids, pollutants) or particulate (phytoplankton) organic matter. The ENEA laser remote sensing laboratory has designed and developed a new portable instrument, in order to match the requests of monitoring skills on relevance sites for RIADE.

In the late Spring 2005 (May 22 – 25), a joint campaign has been performed in the Licata area (Sicily, Agrigento province), along the Salso river and in different wells in the neighbourhood territory. Distribution maps of the measured parameters as: a) dissolved matter, i.e. CDOM (Chromophoric Dissolved Organic Matter), tyrosine and tryptophan; b) particulate matter (algae); c) groundwater depth; d) electrical conductivity; e) pH; f) temperature; will be presented and discussed in term of emerging information on ongoing desertification processes.

**Comparison of different methods to estimate suspended particles in turbid coastal waters**

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*Keywords: multi-spectral transmissometer (MST), LISST, in situ photography, particle, SPM*

The dynamics of sediment transport in the East Frisian Wadden Sea are important for the coastal zone and for ecosystem functioning. In order to estimate the quality and quantity of the sediment transport, in situ measurements and satellite data are equally essential. This work compares three different methods to determine the temporal variability of suspended particle matter (SPM) in situ: By use of a multi-spectral transmissometer (MST), particle concentrations are calculated via measuring the spectral attenuation coefficient in the water. In addition, SPM was measured by a laser diffraction method ( LISST) and by image analysis of in situ photography. The MST is permanently deployed at a time series station located at a tidal inlet between two East Frisian Islands in the Wadden Sea. Comparisons between all three instruments were conducted in the inner Jade estuary. The paper will describe and discuss the suitability of the different methods to validate satellite data in highly turbid coastal waters.

**Laser remote sensing for Danube River pollution analysis**

Gabriela Pavelescu, Georgeta-Jeni N Vasilescu, Dan Savastru, Livio Belegante, Emil Carstea, Camelia Talianu, Doina Nicolae, Claudia Strehie, Laura Jugaru, Sergey Shchemelyov, National Institute of Research and Development for Optoelectronics (INOE), Magurele, Romania; Sergey Babichenko & Alexey Lisin, LDI Ltd., Tallinn, Estonia

*Keywords: fluorescence lidar, Chlorophyll, DOM, water pollution*

The paper presents preliminary results of fluorescence measurements performed in the Murighiol area of the Danube River. FLS-S lidar with 308 and 460 nm excitation wavelength was used to estimate the dissolved organic matter and chlorophyll a levels. Measurements on an anthropic channel designed to shorten the Danube course were compared with those on the ancient course of the River. The data were combined with Acoustic Doppler Profiler System (ADP) measurements of the water velocity. The fluorescence intensity indicates a high pollution with DOM and high value of chlorophyll a. On the shortcut channel the water speed and the turbulence is high and the deposition rate is low. On the ancient course of the river, the water flows slowly and the deposition rate of the sediments is high leading to an increase in DOM pollution.

**Dissolved Organic Matter and Chlorophyll measurements on Black Sea Romanian coastal zone**

Gabriela Pavelescu, Georgeta-Jeni N Vasilescu, E Pfeiffer, L Belegante, E Carstea & C Strehie, National Institute of Research and Development for Optoelectronics (INOE), Magurele, Romania; Sergey Babichenko & Alexey Lisin, LDI Ltd., Tallinn, Estonia

*Keywords: fluorescence lidar, DOM, chlorophyll*

The aim of the paper was to analyze the fluorescence signal of the polluted water in the south area of the Romanian Black Sea coast. A Fluorescence Lidar system, based on a XeCl and Dye laser, was used for remote investigations. The characteristics of the spectral fluorescence of water were analysed in connection with the sounding area characteristics, pollutants type (dissolved organic matter, chlorophyll) and seawater physico-chemical parameters. In order to eliminate the influence of the system characteristics, the adjacent scattering and volume of water investigated the fluorescence spectra were characterized in correlation with the band of the water Raman scattering.

**The existing Lidar Data Formats and Standards**

Andre Samberg, AVAPROedu, Helsinki, Finland

*Keywords: Lidar; Data format; Standards*

In this paper we shall introduce the existing formats of various commercial lidar data. Their present structures and foreseeing changes will be reviewed and discussed with respect to topographic, terrestrial, and LIF-based airborne laser sensors. An ongoing standardization work will be revealed.

**A Feasibility Study of Commercial SW Tools for Processing Airborne Fluorosensor Data**

Andre Samberg, AVAPROedu, Helsinki, Finland

*Keywords: Airborne; fluorosensor; data processing*

A recent development in the field of airborne LIF-based laser remote sensing has demonstrated that a wider commercial use of such remote sensing means is limited because of the two major factors. Firstly, a hardware must be more compact, and less power consumable. Secondly, data processing is a complicated process. It is still in-house what requires a skilled and properly trained personal. In our feasibility study, we looked at the market in order to see the suitable commercial software packages. The main digital image processing tools were reviewed, and their features studied. An example data set of FLS-AM has been used. As a result, we found that IDL is the most flexible and potential tool. IDL does not require the expensive core modules as compared to the other SW candidates. A customer application can be easily delivered as an IDL run-time application, which is not available from the other digital image processing tools studied.

**Ocean colour data in case II waters: a different approach in support of ecosystem models**

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*Keywords: ocean colour, reflectance, bio-optical model, ecosystem model*

Satellite ocean colour data products are expected to provide an opportunity to constrain ocean biogeochemical or ecosystem models through assimilation and comparison. However, such an approach is challenged by the uncertainties associated with inverting satellite ocean colour data to retrieve optically-related water constituents such as chlorophyll, especially in case II waters. We present an alternative way for using ocean colour data in support of ecosystem models which makes use of the complete visible reflectance spectrum measured by satellite sensors and should, in principle, maximise the bio-optical information that is retrieved.

In this approach we propose the use of satellite-retrieved remote sensing reflectance as the parameter to be used in the comparison interface between an ecosystem model and satellite observations, instead of using products such as chlorophyll, coloured dissolved organic matter or suspended particulate matter, which contain a high degree of uncertainty.

For this approach, we explore the feasibility of generating inherent optical properties inside the ecosystem model from its state variables, (chlorophyll, cdom and spm), and thence calculating the remote sensing reflectance for the particular sun-sensor geometry at each pixel. Different forward bio-optical models from literature are tested for a case study in the Irish Sea. Modelled remote sensing reflectance is compared and evaluated against satellite remote sensing reflectance. Uncertainty inherent to the bio-optical modelling is compared with the uncertainty of standard satellite-derived products

**Image processing of MODIS data on Mediterranean sea for a comparison with in situ measurements of bio-physical parameters**

Angelo Cau, Francesco Dessi, Alberto Marini, Maria Theresa Melis, Matteo Murenu & Andrea Ortu, University of Cagliari, Italy

*Keywords: MODIS, MEDITS, Mediterranean sea*

The aim of this work is the testing of MODIS standard products for chlorophyll a and Sea Surface Temperature (SST) mapping on Mediterranean sea around Sardinia.

The collaboration between TeleGis Laboratory and Biology and Ecology Department of University of Cagliari is carrying out an interdisciplinary research. From 2004 TeleGis laboratory acquire MODIS data by a direct antenna system daytime and nighttime and these data are stored in the original EOS hdf format. The Biology and Ecology Department is involved in the Project MEDITS which contributes to the characterization of bottom fisheries resources in the Mediterranean in term of population distribution (relative abundance indices) as well as demographic structures (length distributions), and provide data for modelling the dynamic of the studied species. In this scope, estimation of total mortality of the exploited species constitutes an important aim. From June 14 to July 7th 2006 an oceanographic cruise around Sardinia was organized to acquire data about biological and biophysical parameters, with water samples to determine pH, Salinity, Conductibility, chlorophyll a concentration.

In this work the first step of this research is presented, focused on comparison of these direct information with the data model from MODIS images.

**Multi-spectral IR and Visible Imaging Spectrometer (MIVIS) data to assess optical properties in shallow waters**

Claudia Giardino, Gabriele Candiani & Mariano Bresciani, CNR-IREA, Milano, Italy; Marco Bartoli & Luca Pellegrini, University of Parma, Italy

*Keywords: lake, shallow waters, bio-optical models*

Macrophytes are variables of primary importance for the evaluation of the quality of a lake ecosystem. In fact macrophytes in the littoral zone react slowly but progressively to changes in nutrient conditions and thus they can be used as long-term limnological indicators. Therefore, information about macrophytes abundance and distribution as well as their species composition have to be collected for a comprehensive monitoring of the water quality status. For the assessment of such information, remote sensing can be employed with a reasonable accuracy. In this study the properties of the substrate along the littoral zone of Sirmione Peninsula, in the southern part of Lake Garda (Italy), were investigated from imaging spectrometry. Two images with a ground resolution of 5 m were acquired by the Multispectral Infrared and Visible Imaging Spectrometer (MIVIS) onboard of a Casa aircraft during summer 1997 and 2005. Image data were geo-coded and then atmospherically corrected to remote sensing reflectance units (Rrs). The Rrs value of each image pixel was inverted using a bio-optical model, ad hoc parameterised with inherent optical properties of Lake Garda. The inversion was performed through an optimisation technique which allowed the estimation of bottom depth and of three different bottom albedo types: "Sand", "High-albedo macrophytes" (i.e., Ceratophyllum, Potamogeton and Lagarosiphon) and "Low-albedo macrophytes" (i.e., Chara and Vallisneria). This inversion technique allowed to retrieve concentrations of chlorophyll and suspended particulate matter and coloured dissolved organic matter absorption at 440 nm, as well.

Comparison of the bottom-related products for the two years shows an overall decrement of both classes of macrophytes (high and low albedo) and a consequent increment of the sandy substrate, whose extension was almost doubled from 1997 to 2005 (33.5 % in 1997 to 61.7 % in 2005). This macrophytes disappearing could be an indicator of the worsening of water status nearby the Sirmione Peninsula, and can indicate an increase of the antropic pressure acting in the southern portion of the lake.

**Suspended matter measured with airborne remote sensing and satellite images in the East Frisian Wadden Sea, Germany**

Christina Mehrtens, Thomas Badewien & Rainer Reuter, Institute of Physics, University of Oldenburg, Germany

*Keywords: suspended particulate matter; tidal flats; airborne multispectral imagery*

Satellite image analysis is a common method for detecting suspended particulate matter in coastal waters. The geometric resolution of these optical images is often not appropriate for the identification of complex hydrodynamic features as they often occur in tidal flat regions. This limitation can be overcome with airborne digital imagery, where a pixel size of less than 20 cm can be easily achieved. Moreover, airborne suspended matter detection can be coordinated to the tides while satellite imagery follows strict time schedules. In this paper, we explore airborne digital imagery for suspended matter detection. Four digital consumer cameras with different optical filters attached to an airplane are used to take images of the East Frisian Wadden Sea, which are compared with satellite images from MERIS. Spectral reflectances in the airborne images are calibrated in suspended matter concentration with filtered water samples taken onboard ship during overflight. The data are also used to validate MERIS data on suspended matter also in regions where the MERIS algorithm does not produce reliable data because of too high concentrations or insufficient atmospheric correction.

**Comparison of sediment transport modelling with hyperspectral airborne data analysis for the retrieval of sediment concentration**

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*Keywords: Suspended sediments, Scheldt, hyperspectral, AHS, sediment transport models*

On June 15th 2005 hyperspectral airborne data were collected from the Lower Sea Scheldt at different stages during the tidal cycle with the AHS Advanced Hyperspectral Sensor (SenSytech Inc). An airborne hyperspectral sensor offers both a high spectral and spatial resolution and therefore has a high potential for mapping the sediment concentrations in rivers or coastal waters. Simultaneously with the airborne campaign a field survey took place. The goal was to collect ground truth data while the hyperspectral sensor was imaging the study area. This ground truth is essential for calibration and validation of the airborne remote sensing data. Three survey vessels were used at different stretches of the Lower Sea Scheldt to include some spatial variability. Several measurements were done on board of each vessel on predetermined locations at the time of airplane crossing over the study area. Surface water samples were collected for analyzing total suspended matter concentration, optical reflectance measurements were carried out and a turbidity sensor continuously measured turbidity in the surface water layer. Using these field data and the high resolution airborne data, a reliable empirical algorithm has been developed to derive near-surface suspended matter maps in an operational way. The produced TSM maps showed good agreement with known variations of the suspended sediment content over the tidal cycle: maximum turbidity around high water and gradual settling of the sediment in the succeeding slack water. A resuspension of sediment takes place at the onset of the ebb flow stage, especially at the bend-related shoals. The suspended sediment maps were validated against sediment transport model simulations. These simulations were performed using the Delft 3D modeling system for three specific locations in the Scheldt. The model returns TSM concentrations maps every thirty minutes starting at high tide. The succeeding spatial patterns of suspended sediment agreed very well with the patterns derived from the remote sensing data.

**Remote Sensing and data model integration for assessing SPM transport in the Dutch coastal zone**

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*Keywords: Suspended Particulate Matter (SPM); Ocean Color; Data Assimilation; Transport Modeling; Coastal Zone*

In the Netherlands, there is great concern about the potential impact of several proposed large-scale coastal infrastructural works with respect to the concentrations and fluxes of Suspended Particulate Matter (SPM) in the Dutch coastal area including the Wadden Sea, a protected natural area. SPM has several direct and indirect effects on the environment including influencing the light conditions in the water (relevant for primary production). The quantification of SPM conditions within the coastal zone is difficult due to high spatial and temporal variability and the limited number of in-situ monitoring data. SPM surface concentrations can also be measured by ocean colour remote sensing which extends spatial and temporal coverage. Additionally, the application of SPM transport models can provide information and mass balances for continuous and synoptic assessment of SPM concentrations and transports in all three dimensions. Each of these methods has certain advantages and disadvantages with respect to quantifying SPM conditions. To help overcome challenges related to both observations and models, Data-Model Integration (DMI) has been carried out by means of data assimilation, applied to the Delft3D-WAQ transport model on a Southern North Sea grid of intermediate resolution (down to about 2 km) using Reduced and Full Resolution MERIS and MODIS data. Uncertainties in both observations and model are exploited to reach an optimal solution of the state of the SPM transport at any given time and location during the year considered (2003). Additional insight is gained with respect to the joint application of different sensors and RS products, evaluation of relevant observational and model uncertainties, as well as assessment of fluxes of SPM in the coastal zone.

**Remote sensing techniques for macrophytes and water compound concentrations mapping: Benefit of remote sensing techniques applications in environmental management of inland water**

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*Keywords: environmental management; water compound concentrations; macrophytes bloom; water quality; radiative transfer method*

The present research aims to test the benefit of remote sensing techniques applications in environmental management of inland water. The study, proposed in the framework of a cooperation between Italian Foreign Affairs Ministry (through the University of Rome) and Kenyan authorities, has been carried out on the Kenyan part of the Victoria Lake (Kisumu bay). This lake is one of the largest freshwater bodies of the world, where, in the recent years environmental challenges and human impact have perturbed the ecological balance affecting the biodiversity.

Water compound concentrations and floating vegetation maps have been provided by the applications of different techniques to remote sensed data to support a farsighted environment and resources management of the territory. A method (based on the radiative transfer theory) for phytoplankton, coloured dissolved organic matter (CDOM) and total suspended sediment (TSS) assessment has been applied to a MERIS image acquired on 27 January 2004. Few days after the image acquisition a field campaign was accomplished for retrieving water optical properties.

During the same field campaign the reflectance spectra of the aquatic species available in the lake have been collected. These spectra have been used, applying classification techniques to historical series of ETM images, in the estimate of the water hyacinth spread. This procedure allowed the separation of the different weed species and the estimate of hyacinths concentration in the pixels covered by this plant.

The comparison between vegetation and water compound concentrations maps has confirmed that hyacinth proliferation is connected to rivers water inflow with a high concentration of sediments and has allowed to individuate areas at risk of anomalous growing of new macrophytes populations.

**Ocean Colour (SeaWiFS) investigations of Lake Baikal's surface waters (Siberia) within a paleoclimate research network**

Birgit Heim, Martin-Luther University Halle-Wittenberg; Susanne Fietz, University of Essex, Colchester, UK; Vera Straskrabova, Hydrobiological Institute, Ceske Budejovice, Czech Republic; Hedi Oberhaensli, GeoForschungsZentrum Potsdam, Germany

*Keywords: Lake Baikal (Siberia); SeaWiFS; OC2 Chl-a; terrigenous input*

Within the research frame of the European paleoclimate project CONTINENT at Lake Baikal, Siberia, present-day information was essential for the comprehensive interpretation of autochthonous and allochthonous paleoclimate proxies in the lake sediment cores. Ocean Colour provided valuable information to decipher the pathways of allochthonous matter (i.e., foreign matter, in this case the terrigenous input), and monitor the dynamics of autochthonous matter (i.e., produced within the system, in this case the phytoplankton productivity). CONTINENT ground truth data (pigments, phytoplankton functional groups, SPM, DOC, field spectrometer measurements) were evaluated in respect to processed SeaWiFS OC2 Chl-a data of summer seasons in 2001, 2002 and 2003. The deepest and oldest lake of the world is oligotrophic ocean-like and by this, the spectral water-leaving reflectance maximum of Lake Baikal's pelagic and deep coastal waters is restricted to the blue spectral domain. Coastal field investigations at places of terrigenous input locally showed the spectral shift of the reflectance maximum towards the green spectral domain. On one hand, this optical behaviour lead in consequence towards local overestimation in calculated OC2 Chl-a concentrations. On the other hand, the organic-rich terrigenous input optimally served as tracer for the spatial extent of the short-termed input events.

SeaWiFS time series showed the phytoplankton dynamics of the various bio-optical provinces in Lake Baikal for early to late summer months in 2001, 2002, and 2003. This assisted with analyzing the relationships between the CONTINENT project sites.

**Oil spill remote sensing from airborne maritime surveillance platforms: A new generation of known sensors and new approaches to data processing**

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*Keywords: remote sensing; marine pollution; airborne; oil spills; multisensor systems; data acquisition; MEDUSA; data fusion; laser fluorosensing; lidar; infrared sensors; ultraviolet sensors; microwave sensors; GIS*

Remote sensing of oil spills in conjunction with their prevention and combat has long become a global objective and represents a key element for the protection of the coastal zone. Airborne remote sensing is preferred by response crews to satellite remote sensing with regard to quick situation assessment and decision-making at the oil spill scene because it allows a spatio-temporally flexible analysis of local characteristics of oil spills. Currently there is a variety of specialized airborne remote sensing systems all over the world which are based on well-established oil spill remote sensors like infrared/ultraviolet line scanners, visible line scanners, camera systems, microwave radiometers, laser fluorosensors, and X-band radar systems. Besides optimization of existing sensor technology there have been new approaches to handling of remotely sensed multisensor oil spill data, especially in terms of acquisition, visualization, analysis, fusion, and GIS integration. In this paper we present a new generation of known oil spill remote sensors in conjunction with the latest configuration of the network-based data acquisition and processing system MEDUSA. We focus on data processing and present ways of improving the usability of airborne multisensor oil spill remote sensing systems with regard to on-board and ground-based data processing as well as the integration of pollution data and related products into (web-based) geospatial information systems.

**Use of Ferrybox and above-water radiometric measurements for coastal water monitoring and remote sensing product validation**

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*Keywords: radiometer; chlorophyll a; Baltic Sea; ocean colour*

Autonomous above-water radiometer SeaPrims was installed in spring 2006 on Helsinki Light House Tower (HLT) in the Gulf of Finland. Normalized water leaving radiances observed by Seaprim system at various wavelength from 412 to 675 nm were analysed for summer 2006. To collect a relevant in situ dataset for comparison and validation, a ferrybox monitoring system on board Finnpartner, as a part of Alg@line project, passed the HLT at the distance of 0.5-1 km weekly. Ferrybox includes flow through system measuring chlorophyll a and phycocyanin fluorescence and turbidity, and also collects water samples for laboratory analysis of absorption properties of coloured dissolved organic matter and particulate matter including phytoplankton. Remote sensing products for the HLT area were obtained from MODIS.

Here we compare the optical data from these three sources, show their success and failure in the optically complex waters of the Baltic Sea, and discuss on the potential of their combined use in water quality monitoring and satellite ocean colour validation activities.

**Application of NASA Giovanni to coastal zone remote sensing research: Web-based use of NASA remote-sensing data**

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*Keywords: NASA, precipitation, chlorophyll, events*

The Goddard Earth Sciences Data and Information Services Center (GES DISC) Interactive Online Visualization ANd aNalysis Infrastructure (Giovanni) provides rapid access to and enables effective utilization of remotely-sensed data that are applicable to investigations of coastal environmental processes. Data sets in Giovanni include precipitation data from the Tropical Rainfall Measuring Mission (TRMM), particularly useful for coastal storm investigations; ocean color radiometry data from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Moderate Resolution Imaging Spectroradiometer (MODIS), useful for water quality evaluation, phytoplankton blooms, and terrestrial-marine interactions; and atmospheric data from MODIS and the Advanced Infrared Sounder (AIRS), providing the capability to characterize atmospheric variables. Giovanni provides a simple interface allowing discovery and analysis of environmental data sets with accompanying graphic visualizations. Examples of Giovanni investigations of the coastal zone including hurricane and storm impacts, hydrologically-induced phytoplankton blooms, chlorophyll trend analysis, and dust storm characterization. New and near-future capabilities of Giovanni will be described.

## Open source web GIS: Intelligent and Dynamic Router Based in Traffic Classification in Three Levels

Daniel Gorni, UPSAM, Madrid, Spain

*Keywords: geographic information system; route system; web system; spatial database; ordbms; postgresql; postgis; maps server; web server; java, jsp; apache/tomcat; wms*

### 1- Definitions

#### 1.1- Information System

An Information System (IS) is a computer program where (generally) there are input data, processing of these data and an exit data. It is common that one IS stores data. One IS can be composed by just one, or several computers. A programming language is necessary to implement a program (for example: Java, ASP, etc.).

#### 1.2- Client-Server Information System

A Client-Server Information System is a computational model where there are two (or more) entities changing information. Generally, these entities are in distinct places, and consequently in distinct computers, being that one of the computers is nominated Client, and the other, Server. The server has the responsibility "to serve" the customer with information. The basic sequence of actions is: the customer sends a service request to the server, who carries through a processing previous (if necessary) of the information and sends back the data to the Client.

#### 1.3- Web Information System (World Wide Web) - Based in HTTP and HTML

A Web Information System (WWW) follows the model Client-Server in nets TCP-IP using protocol of communication HTTP and programming language HTML (Hypertext Mark-up Language). An application client (generally one browser as FireFox or Internet Explorer) sends a request to the server to get a "web page". Example: if we desire to visit the Google web page, we can open a browser and type a solicitation like `HTTP://www.google.com`. The responsible server will send back for us the requested data. Then the browser interprets these data and shows us the result. In this in case, as the server to provide web pages, we call it web server. Examples of web servers: Apache, JBoss, IIS, etc.

### 1.4- Geographic Information System

A Geographic Information System (GIS) is, in few words, a system information that manipulates geographic data (or special data). Ray Júnior (2000) call a SIG as being terminology frequently applied to the geographically guided computational technology. Other definitions: (1) Automatized systems used to store, analyze and manipulate geographic data; (2) System based on computer, that allows the user to collect, handle and analyze georeferenced data; (3) Set of informatics tools for the acquisition, storage, analysis and representation of spatial data.

Geographic information: Land Sciences (Geology, Geography, Geodesy, Oceanography, etc.), manipulate a great volume of data about diverse origin and nature. These data form are called geographic information (or spatial). When these spatial data are located, say that the data are georeferenced.

Classification: Romero (2006) classifies the GIS's according the model of the geographic data in:

- Raster Data Model: GIS with spatial information continuous as images of satellite or gotten by aero-photogrametry.

- Vector Data Model: GIS with spatial information as points, straight lines and polygons.

GIS Structure: A GIS is composed for the same basic components of a conventional information system: input data, processing, output data, a data base (for storage) and a programming language. The great difference of a GIS is its data base (DB). The DB for a GIS also must be capable to store spatial information and to carry through spatial operations on this information, such as: proximity, distance, area, etc. Thus, a GIS DB is composed basically for two components:

- Spatial component: that includes the spatial localization (coordinates system), and geographic spatial relationships between distinct entities.

- Thematic component: the information of the represented objects properties.

GIS in the Web: A GIS can be structuralized to be available in the Internet. We can call this GIS type like Web Geographic Information System (WebGIS). A good example of a WebGIS is GoogleEarth: one computer program where it is possible to view practically all Earth

surface. There are who say that GoogleEarth is not a GIS because it does not carry through some types of spatial operations. But as it carries through input e output spatial data, it can be considered a GIS.

### 1.5- Web Geographic Information System (WebGIS)

A WebGIS is composed basically of five elements:

- A Client (browser of Internet as InternetExplorer, FireFox, others).
- A Web Server (IIS, Apache, JBoss, others).
- A Programming Language compatible with web information system.
- A Spatial database (able to store spatial information).
- A Maps Server (MS): An excellent characteristic of a WebGIS is the capacity to generate maps dynamically according the user necessities. For this, a map server is required. Mapserver is the element of the WebGIS that generates maps based in a Webserver request, that in turn, received a request from the client (a browser). Map servers examples: ArcIMS (ESRI), GeoMediaWebMap (InterGraph), MapExtreme (MapInfo) and MapServer (UMN - USA).

### 2- Open Source Web GIS

Now that we already know the five base components of a WebGIS of high quality, we go to describe a little each one of them, remembering that all are free and in its majority, follow the line of development standard open source (source code "is opened", public access).

#### 2.1- A Client – Web Browser - FireFox

FireFox is a free Internet browser that respects the World Wide Web Consortium (W3C) and it has diverse and original functionalities (that they will not be cited here).

W3C is an Internet international organization responsible for the standards of development of systems for Internet as how much to the use of languages HTML and XML. For following the norms of the W3C and being free, the use of the FireFox grows up day by day.

#### 2.2- A Web/Application Server - Apache/TomCat

Apache/TomCat is a free and opensource system. It is resulted of a corporative project of the Apache Group and can be used in distinct operational systems platforms (Linux/Unix, Windows, Solaris, AIX, etc).

Apache is a web server and can work isolated, without the TomCat (who is an application server). But it is not qualified to interpret Java servlets for example. TomCat is an application server, one contenedor of servlets. It is very used together with Java.

### 2.3- A Programming Web Language - Java (JSP)

Java is an object oriented programming language that does not need license use. Programs written in Java need a structure to be able to be executed. This structure is called Java Virtual Machine (JVM), and it is also free. Java programs are of high portability because the JVM can be installed in different operative systems.

### 2.4- A Spatial Data Base - PostgreSQL/PostGIS

A database for a GIS needs to manipulate spatial information and, to carry through spatial operations with these data. PostgreSQL/PostGIS is a data base with these characteristics, beyond to be free and opensource.

PostgreSQL is one Object Relational Data Base Management System (ORDBMS). It works with objects as points, lines and polygons.

PostGIS is an extension of the PostgreSQL that becomes it able to manipulate spatial data.

### 2.5- A Maps Server - MapServer (UMN)

MapServer is a free and opensource maps server developed by the Minnesota University (USA) that today it is part of the NASA projects.

It can be installed in operational systems Linux/Unix, Windows y Mac the X. MapServer can connect to different data structures for example: PostgreSQL/PostGIS, ORACLE, ArcSDE, Shapefiles, Erdas, ECW, GeoTIFF, etc. The image types that MapServer can generate are: GIF, PNG, JPEG, TIFF, BMP and SVG. The MapServer configuration is based on just one file (MapFile). In this file there are the map characteristics and the connections that will have to be made to get the data directly ( shape files, the data bases or WCS/WMS/WFS - services of information web of Coverage's, Map's e Feature's, respectively).

### 3- The Application

The WebGIS of this project was developed using the technology presented above.

**Objective:** This WebGIS has the target to help people in traffic. There are two modules. The first is a simple streets classification system based in traffic conditions in three levels (hard, medium and light traffic). The second one is a system that permits to choose two addresses (start point and final point). A best way algorithm is used to track a way between these two points. This algorithm has been developed in this project and it respects special rules like to avoid worst ways (classified like hard traffic condition). Thus, this router is called by us as Intelligent. The second main compartment is to update the route while the user is going to your final point. This is very useful because is very common the user to go out from the original rout due several reasons. And the traffic is always having their conditions changed by the operator responsible for this job. Thus, in real time, the system is re-building the route. Because this we can called this system as Dynamic.

**Scope:** This Geographic Information System is a web information system applied to Sao Paulo City – Brasil. The study area has 70 km<sup>2</sup>, since -46° 41' 00" until -46° 36' 00" of longitude and since -23° 37' 00" until -23° 32' 00" of Latitude. The data are vector type with the possibility to apply a raster layer of the world mosaic provided by NASA in WMS format.

**Data:** The way streets net used in this project was a heavy shapefile. We have used tools to get the shapefile information and put it in a spatial data base conforming to be utilized by best way algorithm. After this we needed to change the database structure to design it like a relational database.

**Technology:** The technology used in this web geographic information system is totally free and almost all open source. They are:

- Spatial database PostgreSQL / PostGIS
- Maps server MapServer (UMN - USA)
- Development Language: Java – JSP + HTML + JavaScript
- Web Server Apache/TomCat

**Topology:** After preparing of the data to work, the system was using 3.023 streets, composed by 18.787 arcs and 14.704 nodes. The topology implemented for this project was arc-node. If two arc's share the same point, this arc's have connectivity.

**GPS Users:** For users that have a GPS, it is not necessary to input in system the start point. This user type enter in the system (using a user and password), the system already knows who is. If this user does not choose the start point, the system gets this point from your GPS. And always to get new positions using this way.

**Updating user's positions not automatically:** For users without a GPS, the system has one feature where the user can click on map to update the start position. This is a way, but the main idea of this system is work with a GPS. In Europe, for example, is very common that people have a GPS in their cars.

#### 4- Best Way Algorithm

The algorithm to generate routes between two points used in this project has been developed based in an original idea to use one of the 16 possible directions. This is done observing which directions are possible since each point possess its connectivity's.

#### 5- Conclusion

In this analysis of case, we implement a WebGIS of intelligent and dynamic router. An application as this, but without the analysis of the traffic conditions, wide is used for navigation in vehicles of developed countries more as England and Spain.

We see that is possible, using opensource and free technology, to get structure for a Web Geographic Information System of high quality, performance and portability. Examples of use of the structure PostgreSQL/PostGIS and MapServer in Brazil are: Ministry of the Environment, Social Ministry of Public Works and the Economy and Bank of Brazil.

**An Integrated GPS Receiver for remote sensing Sea state & land cover: New Application of Integrated Reflected GPS Signals L1 & L2 observation and Ground Object Reflectivity with an Integrated GPS Receiver for remote sensing Sea state & land cover**

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*Keywords: Reflection coefficient, Object detection, Sea surface, Terrain mapping*

In the paper, a new application and development of a highly integrated GPS receiver with reflected GPS signals for Ground Object Detection and Digital Terrain Elevation Mapping will be described. Several application considerations have been analyzed in order to successfully acquire and track weak, reflected GPS signals from ground surface. First of all, both RHCP and LHCP antennas are employed so that direct and reflected signals can be acquired simultaneously. The direction of arrival of the signals may be along the reflected signal path or even along the line-of-sight of a particular satellite. Unlike most existing GPS reflection experiment, the goal of the study is to exploit the carrier phase, reflectivity of L1 & L2 SNR components of the reflected signals and direct signals for sea clam water, disturbed water and rough bare soil ground object detection with coastal zone land surface. The sea state is predicted by using Doppler shifts due to surface reflection as a moving surface. The terrain moisture classes are defined by using two GPS-derived reflectivity classification features and visual element terrain with land-cover classes containing a surface/soil moisture component. An integer ambiguity resolution algorithm has also been implemented. During the development and test stage, the digital terrain elevation data and satellite's images has been used and mapped with the integrated software.

**Oil spill detection solution based on SAR data**

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*Keywords: Oil spill detection; oil slicks; remote sensing; radar; monitoring*

Fast oil spill monitoring on sea surface is a very difficult and urgent task.

Oil and oil products spills may occur at any stage of the offshore oil production and transportation cycle. Therefore taking into account the current trends of oil production, it is important to create an optimal for consumer oil spill monitoring technology based on satellite data.

The ScanEx R&D Center has developed specific solution for oil spill monitoring based on SAR data, which consists of the SAR data fast acquisition, processing and oil spill detection. This solution has combined the UniScan multimission station receiving, the ScanEx SAR Processor and ScanEx Image Processor software processing. The UniScan station is capable to receive data from the 12 operating Earth observation satellites including the Radarsat-1 and Envisat-1. This SAR images were processed using the ScanEx SAR Processor software. The new version of the ScanEx Image Processor supports automatic and manual oil spill detection.

The ScanEx oil spill detection solution is successfully used for oil spill operating monitoring in the North Caspian Sea since 2005. Obtained results show high importance in oil spill monitoring of offshore and shoaling waters based on satellite data.

**Oil spill monitoring in the Black Sea using remote sensing**

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*Keywords: SAR images, oil spills, image operation*

One of the problems in order to create an operational integrated space-based monitoring and emergency system is an absence of various pilot researches to develop methodological principles for the unified algorithm of monitoring on international level. To contribute to this need a pilot research on Oil Spills Monitoring in the Black and Azov Seas was conducted by SSPC Pryroda and GIS Analyst Center with a support of European Space Agency under the ERUNET project within the framework of collaboration of GMES. The objectives of the research were to: appropiate SAR images for oil spills detecting; specify of the remote sensing needs for space-based monitoring of oil spills; create databases and schemes of oil spills dissemination in the Black and Azov Sea (in 2002 – 2004); provide the recommendations for the development of oil pollution modeling complex for the Ministry of Ukraine of Emergencies.

On the first stage of the research the physical-chemical characteristics of oil pollution and etalon characteristics of the oil spill were studied. The average size of an oil spill is about 0.5 km<sup>2</sup>. Satellite images should have a proper resolution to detect it, so ENVISAT and ERS-2 images with resolution 25 – 12 m were selected as a basis. The satellites SAR (Synthetic Aperture Radar) images do not depend on cloud coverage, season and daytime. Oil, discharged in the water, damps gravity-capillary waves and changes the slope angle. Thus, oil spills could be viewed on the SAR images as black spots on an unpolluted sea surface.

On the second stage every dark spot on the image was analyzed in detail. In particular, the following information was taken to the account: year period (probability of formation of ice); wind speed (required wind speed – 2-14 m/c ); spot form and size (large areas are either areas with low wind or natural oil); geographical location; ship presence nearby; etc. However, the similar effect of dark spots on the SAR images can cause the row of other ocean and marine phenomena, such as atmospheric front, wind shadow, currents, calm zones, rain, topography, sewerage flowing, ice, internal waves and other. Therefore, the synergetic analysis with visible and infrared images consideration

was conducted as a second stage of the project to confirm the results of the research. AVHRR (NOAA) images and SeaWiFS data were selected as reference data. The complex information was studied, such as, temperature of water of marine surface, concentration of chlorophyll, marine flows and meteorological parameters. The features of oil spill presence were the following: temperature and vapor minimum; absence of chlorophyll concentration maximum; sea surface albedo minimum; etc.

The scheme of oil spills dissemination was designed. It shows high correlating with the scheme of transportation roads.

As a result the recommendations for the development of oil pollution modeling complex for the Ministry of Ukraine of Emergencies was conducted.

**Revisiting fifteen years of satellite altimetry near the European coasts: the ALTICORE project**

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*Keywords: Satellite altimetry, European seas, coastal zones*

The past and present satellite altimetry missions were conceived to investigate several fundamental aspects of the dynamics of the global ocean, as well as its changes. These missions were not designed to be used in the context of coastal oceanography, however, their data would represent an extra valuable source of information for use in coastal monitoring and modelling. Forthcoming altimetric missions such as AltiKa and CryoSat-2 promise much improved capabilities close to the coast, therefore a current priority is to analyze the existing, under-exploited, 15-year global archive of coastal altimeter data and formulate recommendations and solutions for future missions. There are intrinsic difficulties in processing and interpretation of the data (e.g.: proximity of land, control of seabed, rapid variations due to tides and atmospheric effects); however there are also unexploited possibilities (e.g.: higher along track data rates, multi-altimetry scenarios). Therefore, it is difficult to get data in a ready to use format, which has undergone a treatment strategy optimized for coastal targets. This problem has been common to other remote sensing techniques (e.g., ocean colour), however, research in coastal altimetry is still at an early stage when compared to those techniques. Moreover, satellite altimetry in the context of coastal ocean requires access to and manipulation of data from multiple sources, many of which undergo regular revision and enhancement; at the moment this is only within reach of a small number of specialists, while many potential users would not be able to take full advantage of improved coastal altimetry. It is therefore also necessary to move from the present collection of unstructured data sets to a fully accessible network of linked data and software. In response to these needs, the ALTICORE (ALTimetry for COastal REgions - [www.alticore.eu](http://www.alticore.eu)) project started in December 2006, funded for two-years by the European

INTAS scheme ([www.intas.be](http://www.intas.be)). The overall aim of ALTICORE is to build up capacity for provision of altimeter-based information in support of coastal ocean studies in some European Seas (Mediterranean, Black, Caspian, White and Barents). ALTICORE will also experiment with more effective and reliable methods of data exchange, through the development of Web services- and Grid-compliant data management infrastructures that ensure long-term continuity and interoperability. This presentation discusses the project, summarizes the planned work and shows how the coastal community should eventually benefit from better access to improved altimeter-derived information.

**Investigation of water masses distribution and zooplankton assemblage off Northwest African coast using satellite altimetry data and in-situ observations**

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*Keywords: Water masses; satellite altimetry; zooplankton; Northwest African coast*

One of the main oceanographic features of waters off the Northwest African coast is boundary between North Atlantic Central Waters (NACW) and South Atlantic Central Waters (SACW), which occurs near Cab Blanc. Location of this boundary can be well defined on the basis of oceanographic survey. Multivariate statistical analysis of temperature and salinity data, which had been obtained in eight cruises in the Moroccan and Mauritanian EEZs in 1994-2005, was applied to reveal spatial variation of the boundary in the upper layer. The main reason of the boundary shifts is dynamic factor, such as intensity of the North Branch of Equator Counter Current (NECC) and Canary Current (CC). It was revealed from TOPEX/POSEIDON satellite altimetry data. Variations of sea level anomaly (SLA) in the coastal region and location of the boundary between NACW and SACW are coherent. Investigations on zooplankton in the coastal waters off Mauritania, which had been conducted in the summer periods of 1998-2004, have showed significant variability of zooplankton biomass, distribution and species diversity. Despite the fact that upwelling intensity had been decreasing, abundance and biomass of zooplankton had been increasing in the summer periods of 1998-2004. Analysis of zooplankton assemblage reveals pronounced increase of percentage of the species, which are usually prevailing in the Senegal and Guinea waters. At the same time the boundary between NACW and SACW had been shifting to the north. It indicates on NECC intensification. Thus the south species abundance on Mauritania shelf can be attributing to the northward advection of SACW.

**Mapping the shallow marine benthic habitats of Rottnest Island, Western Australia**

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*Keywords: Western Australia; hyperspectral imagery; coastal habitat mapping; Rottnest Island; imaging spectroscopy*

The introduction of new, high resolution hyperspectral sensors has led to growing interest in the development of techniques to utilise data from these instruments for mapping the shallow marine environment. The increased spectral resolution of the hyperspectral sensors allows the use of the unique spectral signatures of the individual habitat components to identify these components within the image. Hyperspectral data also allows for the mapping of habitats in shallow areas that are inaccessible to other methods such as hydro-acoustic mapping. The coastal waters surrounding Rottnest Island, Western Australia, provide a unique opportunity to apply hyperspectral imaging techniques in a temperate environment because of the oligotrophic conditions maintained by the Leeuwin Current. The shallow marine benthic habitats of Rottnest Island Reserve have been mapped to a depth of ~15 m, using spectral signatures contained in a library created from in-situ measurements of the dominant habitat components. Three lines of HyMap hyperspectral data flown for the Rottnest Island Reserve in April 2004 were corrected for sunglint, atmospheric effects and the influence of the water column using the Modular Inversion and Processing System which requires no inputs from parameters measured in the field. A decision tree based classification scheme which utilises a range of spectral similarity measures was used to map the different habitat components identified in the bottom reflectance image and the results were validated in the field using SCUBA divers. The shallow subtidal habitats found around Rottnest Island are generally dominated by either bare sand, reef with large macroalgae, such as *Ecklonia radiata* and *Sargassum* spp., or a number of different seagrass species. These new hyperspectral imaging techniques provide a platform for the mapping of shallow marine benthic habitats over a broad area, at a scale that is relevant to marine planners and managers.

**High resolution optical remote sensing for habitat mapping of the Amirantes Ridge, Seychelles: a Reefscape Ecology perspective**

Sarah Hamylton, Cambridge Coastal Research Unit, Cambridge University, UK

*Keywords: Habitat mapping; Reefscape ecology; CASI sensor*

Remote sensing data provide a synoptic picture of reefscales in a format conducive to statistical manipulation in a GIS environment. Despite the wide adoption of remote sensing by coral reef managers for habitat mapping, the value of these data formats for applying landscape ecology theories to the marine realm has not been recognised. This study takes advantage of the benefits that imagery acquired using a Compact Airborne Spectrographic Imager can offer reefscape ecology studies. Vector data formats are a useful tool for aligning image classification units with the concept of patches conventionally adopted by landscape ecologists. Typical landscape ecology metrics are analysed for community patches with regard to predictable ambient environmental gradients across the reef shelf. Habitat maps are used to generate spatial variability models to test hypotheses commonly cited in reef science literature, based primarily on the geography of the data; a key property of remotely sensed imagery.

**Saltmarsh habitat classification from satellite imagery**

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*Keywords: saltmarsh; habitat mapping*

Saltmarsh habitats provide a good indicator of the condition of the coastal margin environment with respect to changing sea levels, saltwater inundation, air and water temperature, and land management practices. Fragmented saltmarsh vegetation is often mapped by field techniques, however these are both labour and time intensive and not amenable to the objective monitoring of continuous change. Airborne remote sensing requires extensive logistical preparation, and commissioning of overflights for small areas is expensive. Satellite imagery however is relatively easy to acquire, and once the processing chain has been established can be repeated on a regular basis and at varied sites allowing interannual variations in extent and dynamics to be identified. This research seeks to identify the optimum spatial, temporal and spectral resolutions required to discriminate key indicator habitats from satellite imagery, at sites in northern England and Wales. Pixel-based and object-based methods of distinguishing vegetation classes are compared for imagery products from a range of sensors and platforms. The potential benefits of integrating LiDAR data with the multispectral imagery are investigated, as are results obtained through both hard and fuzzy classification methods. These investigations are used to frame guidelines and recommendations for the analysis of saltmarsh habitats from space.

**On the processing of field spectroradiometric data for remote sensing mapping of submerged vegetation in coastal zones and lagoon environments**

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*Keywords: submerged vegetation mapping, spectroradiometric measurements*

Remote sensing techniques are currently applied in order to map the submerged vegetation in coastal zones and lagoon environments. The lack of spectral signatures of submerged vegetation often restricts the use of some classification algorithms.

In this paper, data processing techniques of field spectroradiometric measurements of spectral radiance on both submerged vegetation and on calibration targets are discussed and applied in order to show the usefulness and limits of this method for coastal zone submerged vegetation mapping.

A field campaign was carried out to quantify the transparency of the water, measuring underwater downwelling irradiance at different depths, and to acquire spectral signatures with a spectroradiometric sensor. The use of multibeam bathymetric data seems to be particularly appropriate for water column correction, since their accuracy allows the user to process the images without incurring under or over correction due to the exponential influence of the bathymetric term. The retrieval of an accurate diffuse attenuation coefficient is therefore equally important; this study has shown that these are readily obtainable using in situ measurements of spectral irradiance. Although the spectral signature of the submerged vegetation is expected to vary with phenological period, a result of this research was the determination of spectral signatures of some of the most important Mediterranean submerged vegetation, during the most favourable period for optical remote sensing acquisitions.

**Recurrent vs anomalous blooming patterns in the coastal and pelagic regions of the Black Sea**

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*Keywords: algal blooms; chlorophyll concentration anomalies; Black Sea*

Systematic observations in the visible spectral range allow the determination of algal bloom markers such as the concentration of chlorophyll-like pigments (chl). In near-coastal waters, uncertainties can arise in the computation of chl absolute values, due to the presence of other optically active materials (i.e. dissolved organic matter and suspended inorganic particles). Nevertheless, the analysis of historical time series of satellite data can provide rather accurate information on recurring and/or anomalous algal blooming in enclosed seas. A SeaWiFS-derived (1998-2005) chl data set was used to monitor phytoplankton growth patterns in the Black Sea (and, to a lesser extent, in the Marmara Sea and the Azov Sea as well). Yearly and monthly mean concentrations were computed for the eight years available, and climatological mean images derived. Interannual and seasonal variabilities were assessed, computing yearly and monthly anomalies as the difference between each individual year/month and the corresponding climatological year/month. The analysis of these anomalies provides a novel insight into the Black Sea algal blooms dynamics and sea-sonality, and related environmental boundary conditions. Differences between the inner (< 50 m depth) and outer (50-200 m depth) shelf emerge, as well as between these areas and the pelagic part of the basin. High-chl patterns, and higher anomalies, recur in the northwestern coastal zone (under the direct influence of runoff from major European rivers) throughout the year, with maxima in the warm season. More variable conditions are observed in the pelagic zone, where maxima tend to occur in the cold season. Mesoscale eddies are thought to provide a viable mixing mechanism between these two regimes. Interannual variability is large, with lower chl values (and anomalies) in 2000 and 2001, and then even more so in 2002 and 2003.

**MERIS satellite chlorophyll mapping in the Great Lakes USA**

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*Keywords: MERIS; Chlorophyll; Great Lakes; reflectance; fluorescence*

Chlorophyll-a (Chla) and 'water-leaving' reflectance were assessed in oligotrophic Keweenaw Bay, Lake Superior, and in eutrophic Green Bay, Lake Michigan. A red-to-NIR band Chla algorithm (RNIR) proved to be applicable to Green Bay, but gave negative values for Keweenaw Bay. An alternative algorithm could be based on Chla fluorescence. Bands of the Medium Resolution Imaging Spectrometer (MERIS) have been specifically assigned to detection of algal fluorescence in coastal waters. A linear relationship was found between Chla concentration and the fluorescence line height (FLH) computed for the MERIS bands. The same relationship held for observations on oligotrophic waters elsewhere, but not for Green Bay, where the FLH diminished to become negative as Chla increased. A MERIS scene was acquired for the day of the field observations on Keweenaw Bay, one day after those on Green Bay. For Green Bay the pixel values from the RNIR algorithm compared very well to Chla in situ. This result is very positive from the perspective of satellite monitoring of eutrophic waters in many parts of the world. Implementation of the FLH relationship in the scene of Keweenaw Bay produced highly variable pixel values. The FLH in waters like Keweenaw Bay appears to be too close to the MERIS detection limit, hence Chla mapping in vast areas of the Great Lakes remains problematic for the current satellite sensors.

**Intercomparison of regional products of water quality processed from MERIS data**

Kerstin Stelzer & Carsten Brockmann, Brockmann Consult, Geesthacht, Germany; Holger Klein, Kai Sørensen, Roland Doerffer & Michael Schaale

*Keywords: water quality; MERIS; case2 waters; validation*

Optically complex waters, so called case-2 waters, are a challenge for retrieving water constituents from remotely sensed spectral data. The mixture of phytoplankton, suspended matter (TSM) and yellow substance requires well selected spectral bands of the instrument to allow a differentiation of the components. Furthermore, case-2 waters are typically located in coastal areas, where the masking effect of the atmosphere is also stronger varying as compared to the open ocean. With the imaging spectrometer MERIS onboard of the ENVISAT satellite an instrument has been build which is specifically addressing these problems in addition to measuring the chlorophyll-a concentration with high accuracy in case-1 waters.

The standard MERIS processing is performed using a global algorithm which fulfils the basic requirements of the users. However, for some regions, with specific environmental conditions and events, additional algorithms have been developed in order to retrieve regionally adopted products. This is especially important for areas which are characterized by water bodies with generally high concentrations of chlorophyll and suspended matter with high dynamic changes. In the spectral reflectance signal, high concentrations of TSM, e.g. in estuaries, mask the influence of chlorophyll and vice versa.

The investigation described here compares three different algorithms for retrieving water constituents in case-2 waters, namely the standard L2 product, the Case2Regional algorithm (C2R) and the FUB-WeW water processor. The first one is a global case-2 waters algorithm, based on the approximation of inverse modelling of the measured signal by an artificial neural network (ANN). The ANN has been trained with input data from the Meditterrean Sea, North Atlantic and North Sea. It derives simultaneously pigment absorption, total suspended matter scattering and yellow substance absorption which are further converted into concentrations of chlorophyll-a and TSM by (global) conversions factors. The C2R algorithm is an evolution of the standard L2 case-2

algorithm. ANNs trained with optical properties from different regions can be used. Currently, a net for the North Sea is available. Several optimizations for an improved retrieval of the water constituents have been implemented. The C2R algorithm is applying an own atmospheric correction which treats besides the standard atmospheric parameters also the sun-glint. The third algorithm investigated here has been developed by the Freie Universität Berlin. It uses two separate chains for the retrieval of surface reflectances and water constituents. The water constituents are derived through three different neural networks trained for North Sea and Baltic Sea.

In this study, the water constituents derived by the different processing chains are investigated and inter-compared. Special emphasis is given to the quality flags. The retrieved products are compared with in-situ measurements in the North Sea (BSH Marnet measurement net) and in the Skagerak, where Ferry Box data are used. Conclusions are drawn and recommendations for the application of the different algorithms will be given.

### **MERIS timeseries data to detect water quality in Subalpine lakes**

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*Keywords: multi-temporal, water quality, lakes*

Lakes are important resources for economic and recreational purposes. Sustainable use of water resources requires the coupling of surface waters assessment monitoring programs, and decision making and management tools. The Water Framework Directive (WFD) of the European Commission is the major reference in Europe to guide efforts for attaining a sustainable aquatic environment in the years to come. The WFD includes guidelines which define the categories of quality and the required components and parameters. As some of these parameters can be determined by Remote Sensing (RS) with a reasonable accuracy, RS-related technologies may be integrated in the monitoring programs defined by the WFD, provided they can be demonstrated to independently assess Water Quality Parameters (WQPs). To this aim the MERIS sensor onboard ENVISAT with its 300 m resolution in the full resolution mode and its high spectral and radiometric sensitivity offers an excellent choice for the assessment and monitoring of lake water quality parameters. Unfortunately, MERIS Level 2 water products available for the Subalpine lake district, which represents more than 80% of the total Italian fresh water volume, partially fail in describing the concentrations of WQPs. This is probably due to two different issues: (1) the use of an atmospheric correction procedure not suitable for lakes where adjacency effects induced by steep vegetated sides surrounding the Subalpine Italian lakes may play an important part in the water reflectance spectra; (2) the use of a bio-optical model parameterised for different water types. Therefore MERIS Level 1 data were used in this study to overcome these limitations. MERIS Level 1 at-sensor radiances were converted into subsurface irradiance reflectance values using a MODTRAN-based atmospheric correction code complemented with a correction for the air/water interface. The atmospheric correction algorithm also includes a component for the adjacency effects correction. Subsurface irradiance reflectance were the input of the inversion of a bio-optical model parameterised using the specific inherent optical properties of some of Subalpine lakes. Derived products from image data from 2003 to 2005

were then compared to in situ measurements and to Level 2 water products. This study is part of ongoing research efforts aimed at developing RS strategies towards the implementation of the WFD, ensuring systematic monitoring of water quality in Lake Garda, the largest lake of the Subalpine ecoregion. Preliminary results obtained from MERIS Level 1 data appeared promising to implement a scene-independent method to assess water quality in this lake. Qualitative conclusions were also derived for other lakes (i.e., Maggiore, Como and Iseo) belonging to the same Subalpine lake district in the northern Italy.

### **A Noctiluca scintillans detection algorithm for MERIS imagery**

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*Keywords: Noctiluca scintillans ; MERIS ; detection algorithm*

Noctiluca scintillans is a heterotrophic, bloom forming dinoflagellate. Although the cell is mainly colourless and non-photosynthetic on its own, it appears pink, red or green in colour by the presence of symbionts and ingested material. In the Belgian continental zone Noctiluca scintillans blooms are characterized by reddish, tomato soup like coloured patches appearing yearly in June-July. Thanks to the strong optical signature of these blooms, they can be detected by ocean colour satellite sensors, with high spatial resolution (< 1 km).

Seaborne measurements show that the reflectance spectrum of Noctiluca scintillans patches is distinct from that of other high reflecting components like normal suspended material. This difference might cause the standard atmospheric correction to fail where a Noctiluca scintillans bloom occurs. Therefore, an algorithm is developed to detect the blooms from the top-of-atmosphere radiances. This algorithm is tested on MERIS imagery of June – July 2005, when visual observations, airborne and in-situ spectral measurements of Noctiluca scintillans were made near the Belgian coast.

**The use of ASTER images to map fluvial sediment discharge into northern Adriatic Sea**

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*Keywords: suspended matter; river plume; North Adriatic*

The most important Italian rivers (Po, Adige, Brenta, Piave, Tagliamento, and Isonzo) flow into the Northern Adriatic Sea generating a fundamental supply of freshwater with its suspended material which generally tends to disperse depositing prevalent sandy material along the coastal areas.

Suspended sediment concentration is one of the most important water quality parameters. Furthermore, its distribution is a key issue for analyzing the deposition and erosion of the coasts and estuaries, evaluating the material fluxes from river to sea and then along the shore.

Remote sensing techniques can provide spatially distributed information for estimating and mapping the concentrations of total suspended matter (TSM), with a high temporal frequency. However, it cannot completely replace conventional methods, as the results are not as accurate as from conventional methods.

A continuous record of freshwater discharge and suspended sediment transport was carried out in Piave river mouth during November 2003, for the research programme with the Autorità di Bacino dei fiumi dell'Alto Adriatico. During an important flood event on 29th of November 2003, three ASTER images of the North Adriatic Sea are being acquired with the objective of providing information on the spatial distribution of suspended sediment concentration from spectral profiles of water reflectance using a semi-empirical algorithm suitable for highly turbid waters.

The selection of the map construction algorithms is based on the analysis of the reflectance spectral signatures of increasing gradient transect samples. It was found that a good algorithm can be compiled on the ratio of angles of the reflectance values of the VIS/NIR channels. The ratio reduced the effects of changes in illumination conditions and sediment type.

Calibrating the algorithm on in situ samples, it was possible to estimate and map suspended sediments discharged from Piave river. This obtained function, which appeared to be successfully applied to the plumes of the other rivers of North Adriatic Sea with similar sediment size and composition, may be used with highly turbid waters, even if in situ data are not available.

## **ANALYSIS OF SATELLITE DATA FOR THE PRODUCTION OF THEMATIC MAPS OF MARINE POLLUTION**

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*Keywords: Marine pollution, monitoring, ocean colour, MODIS*

In this paper we discuss the techniques and the procedures used for the production of thematic maps useful for monitoring the status of the sea. We have used the data coming from MODIS sensor, assembled on satellite platforms Terra and Aqua, which are downloaded in real time from antennas of Salerno University ReSLEHM, the Remote Sensing Laboratory for Environmental Hazard Monitoring, to obtain daily information regarding the state and the development of the biological activities in the Mediterranean Basin.

We have analysed the multi-spectral bands in order to obtain both physical and biological information such as the chlorophyll level, the organic matter concentration, the possible presence of solid particles and the sea surface temperature by using the Ocean Colour technique.

These measures, if analyzed with appropriate care, can provide useful information about the spatial diffusion and the temporal evolution of the algal assemblages and of the plankton concentration: this gives important information about the pollution level of the coastal areas and their productive potential. We have evaluated the procedures commonly used in order to manage and elaborate MODIS data. We have implemented a semi-automatic procedure able to elaborate in a very short time the data coming by the sensor during its daily communications.

Finally we have made a number of tests by comparing the results obtained using both remote sensing images, coming from archives or of new acquisition, and the measurements carried out in situ in order to calibrate our procedure and to verify the goodness of the results.

## **Combined use of SAR and Vis/NIR imagery in sunglint condition for detecting and tracking oil slicks**

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*Keywords: sunglint, Modis, Meris, Sar, oil spill*

Large spills of oil in the marine environment can have serious biological and economic impacts.

The knowledge of the present position of spilled oil and the ability to predict its motion are essential components of any oil spill response. These functions are known as surveillance and tracking. Remote sensing is playing an increasingly important role in oil spill response efforts. Satellite instruments are well adapted to monitor, and therefore to detect, oil pollution. Space-borne Synthetic Aperture Radar (SAR) seems to be one of the most suitable instruments to the detection of slicks, since slicks damp strongly short waves measured by SAR and oil spills appear as a dark patch on the SAR image. However, SAR systems do not offer the required temporal acquisition rate of the same area, to guarantee the possibility to monitoring large oil spill movement on the sea. Actually the revisiting time of a SAR sensor on the same area is about 30 days, so that it is desirable to use additional satellite information gathered at higher temporal rates. For this reason it is necessary to investigate about the possible application of optical/NIR imaging which have a high repetitive coverage (about two times a day). We propose the use the Modis (MODerate resolution Imaging Spectroradiometer) and Meris (MEDIUM Resolution Imaging Spectrometer) images acquired in sunglint conditions to reveal smoothed regions such as those affected by oil pollution.

The underlying physical mechanism of the oil spill detection using an optical/NIR sensor is based on the modification of the surface slopes distribution composing the roughened sea due to the action of mineral oils. In the sun glint condition, the sea surface has a high reflectance, but the presence of the oil, reducing the roughness of the sea surface, modify the geometric condition of the sun, sea and sensor system. This modification change dramatically the reflectivity of the sea surface, so that the area in which is present a oil spill appears as black patch on the Vis/NIR images.

The detection method is based on the comparison between the simulated images using the Cox and Munk distribution and the real Modis and Meris acquisitions. Wind speed and direction are input parameters of the sunglint simulation and they has also been used to track the movement of oil spill. The wind field has been retrieved using the semi-empirical backscatter model CMOD4 on the SAR image. Surface wind vectors predicted by the meteorological ECMWF model were exploited as guess input to SAR wind inversion procedure.

To improve this comparison, the atmospheric effects are taken in account using 6S Vectorial radiative transfer model. The most important input for the radiative transfer code is the description of the aerosol present in the atmosphere. Where possible, these information has been taken from the public domain database of the AERONET program, otherwise a procedure for the retrieval of them from MODIS data were used.

In this work we present a dataset of cases, interesting the Mediterranean Sea area, in which this methodology has been applied to oil spills detected on ERS2 Sar or ASAR (Advanced Synthetic Aperture Radar) images.

The obtained results show that the capability to detect oil slicks on Vis/NIR images is improved considering the ratio between the TOA reflectance measured on the image and the one simulated with the Cox and Munk model. Moreover the oil slick tracking results are consistent to that reported in literature.

### **An investigation of industrial solid waste pollution in marine environment using remote sensing in Zonguldak Coasts, Turkey**

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*Keywords: Zonguldak Coast, power plant waste, industrial pollution, classification and Landsat-7 ETM+*

In a coal fired power plant, the slag and ash (bottom and fly) management is one of the main environmental problems. Since there is no solid waste (slag, bottom ash and fly-ash ) control systems in the Çatalagzi power plant, Zonguldak, Turkey, the ashes and slugs are collected from filters (electrostatic filters) and burners and mixed with marine water in a 1/10 ratio, and discharge directly into the marine environment (Black Sea) using 1105 meter long small size canals. This process cause pollution in the West Black Sea region, and its dimensions and effects on coastal regions are urgent task to take action.

The ability of space borne instruments to measure the amount of electromagnetic radiation reflected and emitted by the Earth's surface has proved to be valuable for the understanding of our environment. In the interpretation such data, since it is not easy or feasible to survey over the sea by geodetic or other ground methods, remotely sensed data were employed for quantifying and classifying the pollution effects in such environment. In this case, computer-assisted classification which is useful for extracting information that can be exploited for cartographic purposes, such as in the generation of thematic maps of land cover types.

In this study, spatial and temporal variation and classification of power plant's pollution and its interaction with marine environment were evaluated using two satellite imageries. For this purpose, Landsat 5 TM (Thematic Mapper) satellite imagery, dated 06 of July 1993, and Landsat-7 ETM+ (Enhanced Thematic Mapper) satellite imagery, dated 04 of July 2000 were processed to find out a power plant's solid waste effect area on the marine environment and its dispersion in the coastal region. To this aim, e-Cognition v.4.0.6 software was utilized to perform classification and comparison of the polluted area in the aquatic marine environment. Polluted area obtained from Landsat 5 TM satellite imagery, can be classified into two regions: polluted and less polluted

region and their field dimensions were evaluated to be 2.5 km<sup>2</sup> and 18 km<sup>2</sup> respectively. On the other hand, polluted area obtained from Landsat-7 ETM+ satellite imagery can be grouped into three regions: highly polluted, moderate polluted and less polluted region. It was evaluated that highly polluted region covers 3.5 km<sup>2</sup>, moderate and less polluted region cover 4.0 and 30 km<sup>2</sup> respectively.

This study shows that remote sensing methods are not only used in land applications but also in marine environment application. Using remote sensing, one can classify, observe and track pollution itself, its route, dimension and effects in the marine environment.

### **Diagnostics of oil pollution in iced water with airborne LIF lidar**

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*Keywords: Lidar, fluorescence, oil pollution*

This work is addressed at the application of airborne LIF lidar for detection and mapping of oil spills in sea water in specific winter conditions. In this season, the water in coastal zones of freezing seas is covered either by solid or melted ice, and typically contains chipped ice along the transport routes. Oil pollution can be observed on water surface and in depth, on or under solid ice, and as a film covered ice pieces. Such diversity of oil in water conditions complicates the analysis of LIF spectra. High variable underlying surface creates additional challenges in lidar data interpretation.

Hyper-spectral FLS-AM lidar was used in winter 2006 in several experimental and operational missions related to detection of spilled oil in the Gulf of Finland and on the shore. Besides the expected outcomes of the flights – detection of oil pollution due to shipwreck and illegal spills, the results demonstrated additional needs for LIF data analysis improvements. As an outcome of the flights, the library of the reference LIF spectra was re-organized to include LIF spectra of oils at various aggregative states (water emulsion, film on water surface, thin film or inleakage on solid background). Laboratory calibration of remote LIF spectra with front-surface fluorescence measurements of various oil products was used for in-flight pollution quantification.

### **Intercomparison and lidar-calibration of ocean color satellite radiometers in the Southern Ocean**

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MERIS, MODIS and SeaWiFS are the more relevant ocean color satellite radiometers and determine the chlorophyll-a concentration from the blue-to-green ratio of the sunlight backscattered by the sea surface.

The ENEA lidar fluorosensor (ELF) operates aboard the research vessel *Italica* and is based on laser induced fluorescence (LIF): chlorophyll-a is detected measuring its emission at 680 nm after excitation by a frequency-tripled Nd:YAG laser at 355 nm. Thanks to narrowband filtering and electronic gating, LIF signals do not need corrections for radiometric and spectral characteristics of solar irradiance and surface reflectance. Furthermore, due to the short distance from the target, atmospheric effects are negligible. This explains why ELF data can be regarded as sea truth and have been used for the satellite calibration.

The simultaneous measurements of chlorophyll-a by MERIS, MODIS, SeaWiFS and ELF have been compared during the 18th Italian expedition in Antarctica, carried out from January 5th to March 4th, 2003. The region under study has been named Ross Sea Sector (RSS) and has been defined as the zone of Southern Ocean from the coast of Antarctica north to 50 S latitude in the 160 E – 130 W interval.

A general consensus between ELF, MODIS and SeaWiFS has been observed, while MERIS values are generally higher. For this reason, the MERIS bio-optical algorithm has been calibrated, following a procedure already used for SeaWiFS and MODIS i.e. the ELF-calibrated MERIS bio-optical algorithm has been based on the linear fit of the log-log plot of the ELF chlorophyll-a concentration versus the MERIS 490-560 band ratio. The results reported here suggest that MERIS, if properly calibrated, has a high potential, especially in coastal zones.

### **Key Developments for a Brillouin-LIDAR for Remote Sensing of Oceanic Temperature Profiles**

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*Keywords: LIDAR; Brillouin-scattering; remote sensing; oceanic temperature profile; fiber amplifier; narrow bandwidth filter; edge filter*

The knowledge of the temperature profile of the upper-ocean mixed layer is relevant in oceanography, weather forecasts and climate studies. Currently, only in situ techniques such as fixed buoys or bathythermographs which are deployed by aircrafts or vessels, are accessible to the measurement of oceanic temperature profiles [1]. As these techniques are not able to deliver cost-effective on-line data from an extended region of the ocean, a more efficient measurement technique is highly desirable. Guagliardo et al. proposed Brillouin-scattering as a possible temperature tracer [2]. The working principle can be understood as an expansion to commonly used airborne lidar bathymetry [3], exploring the Brillouin-scattering for the temperature information. However, only recent progress in laser and receiver technology made an exploitation feasible [4-7].

Specifically, the injected laser pulses are scattered off of moving density fluctuations in the water; due to the Doppler shift, the spectrum of the backscattered light is shifted to the red and blue of the original light frequency. Typical frequency shifts to be expected are in the order of 7-8 GHz located symmetrically around the wavelength of the injected laser pulses. Thus, the method is sensitive to the local velocity of sound which itself has a well known temperature dependency [8,9]. Together with theoretical investigations on the accuracy limitations [9] and by recent laboratory based measurements Fry and coworkers have shown the feasibility of the approach [10-12].

The requirements on the complete sensor system are rather stringent: (1) Since operation from a mobile platform is intended, the sensor has to be compact, light-weight, insensitive to vibrations and exhibit relatively low power consumption. (2) In order to resolve the Brillouin-shift the laser source has to produce relatively high energy ns-pulses, preferentially near-Fourier bandwidth limited. (3) The laser radiation

should be close to the absorption minimum of water, e.g. between 380 and 550 nm [13]. (4) The receiver unit must exhibit a high light gathering power, and be able to resolve the Brillouin shift.

In our approach, the intended light source is comprised of a multi-stage pulsed Yb-doped fiber amplifier. Yb-doped fiber amplifiers can be operated in a wide spectral range between 1015 nm - 1100 nm [14,15], which makes it easier to match the laser with a receiver based on a molecular or atomic edge filter [16]. Using a seeding technique near Fourier transform limited pulses can be generated [17]. Recently, we have achieved laser pulses with a duration of 15-50 ns and a repetition rate between 1-2 kHz at a mJ-energy per pulse level [7]. Frequency doubling is employed to reach the desired green spectral region.

The detector will be based on the edge filter technique: Steep transmission edges of the filter in the regions of interest convert frequency shifts in the Brillouin lines to a change of transmission. Such an edge filter can be realized using an excited state Faraday anomalous dispersion optical filter (ESFADOF) [18,19,6]. They exploit the anomalous dispersion in the vicinity of an atomic transition. As the filter characteristics can be tuned over a wide range, it can be tailored to meet the required frequency shift of 7-8 GHz. In addition the filter shows excellent suppression of daylight.

We will discuss current details of the transmitter and the receiver unit.

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**Mapping water quality at the lake Buyukcekmece, Istanbul, by using IKONOS multispectral imagery**

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*Keywords: Water quality, IKONOS multispectral imagery, multiple regression*

The main purpose of this study is to present water quality conditions at the Lake Buyukcekmece, southwest Istanbul and investigate the feasibility of IKONOS multispectral imagery for water quality mapping in this fresh water reservoir for water quality parameters (WQPs) which are NO<sub>3</sub>-N and suspended sediment (SS) concentration. Field work including water sampling and ground truth is simultaneously performed with the IKONOS satellite overpass of the March 2004. High resolution IKONOS multispectral imagery collected on March 25, 2004 is selected as remotely sensed data source for water quality mapping. Water quality models are developed by using multiple regression (MR) technique that is mostly used in many water quality studies. In the image processing step, radiometric correction procedure including conversion from DN (digital number) to spectral radiance is applied to already geometrically corrected IKONOS data. The results show that the measured and estimated values for WQPs are in good agreement with R<sup>2</sup> values of higher than 0.95. Additionally, the resulting water quality maps show spatial distribution of WQPs for the surface water of Lake Buyukcekmece for year 2004. As a result of this study, it is suggested that future water quality measurements should be supported by current satellite images.

**Comparative methods for the extraction of coastal areas from VHR images.**

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*Keywords: Quickbird; Italy; object-oriented*

This contribution presents the results of a study conducted by the Università degli Studi di L'Aquila, Dipartimento di Architettura ed Urbanistica, and the Università degli studi "La Sapienza", Dipartimento Idraulica Trasporti e Strade, dealing with comparative semi-automatic methods for extracting information about coastal lines from very high resolution optical satellite images. A recent standard Quickbird image of the coastal area of Pescara has been utilised for the analysis.

When dealing with very high resolution satellite images, object-oriented classification methods are often used to extract information. This classification method represents a conceptual evolution with respect to the traditional pixel oriented method, implying a preventive subdivision of the image in meaningful objects through a procedure called segmentation.

The correct selection of the segmentation parameters, strongly related to the objective of the study, is the key for a satisfying classification result. Scale, shape and compactness parameters have been carefully selected to avoid over or under-segmentation. Further on, mathematic and logical operators have been developed to extract elements characterized by elongated shape, characteristic of the coastal areas.

In parallel, traditional classification pixel-oriented methods have been carried on in order to obtain a cost-effect analysis of the results.

**The expected potential of TerraSAR-X high resolution spotlight mode data for shallow sea bottom topography imaging**

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*Keywords: TerraSAR-X, normalized radar cross section modulation, marine sand waves*

The proposed project for studying sea bottom topography signatures at the water surface is based on normalized radar cross section (NRCS) modulations measured by the new German TerraSAR-X satellite. The investigation area is the tidal channel of the Lister Tief in the German Bight of the North Sea characterized by large morphological changes of four-dimensional submarine bedforms in time and space. Due to the high spatial resolution of the radar data acquired by TerraSAR-X it will be possible to identify sea surface roughness variations caused by meso-scale sand waves at water depths < 40 m and associated unique oceanographic phenomena such as up- and downwelling events, turbulence, and eddies. Shipborne radar data and in situ bathymetric measurements as well as meteorological and current velocity data are needed for the interpretation of the TerraSAR-X data. Comparisons of the different data sets will show the advantages and limitations of TerraSAR-X data. Analyses of TerraSAR-X NRCS modulation data in dependence on radar parameters, tidal current speed and -direction as well as wind speed and -direction, respectively, during different flood and ebb tidal phases will lead to corrected parametrisations of the imaging theory. TerraSAR-X and shipborne radar data will be also validated by carrying out simulations of the NRCS modulation based on the improved theory. Therefore, detailed TerraSAR-X data with a spatial resolution of up to 1 m and up to 1.5 dB radiometric resolution will be used with the advantage to be nearly weather independent. The advanced knowledge of transport characteristics of marine sand waves is very important for ship navigation and coastal zone management.

**Wind field, sea state and currents in the coastal zone by TerraSAR X**

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*Keywords: SAR, TerraSARX, Wind Farm*

It is well known that space borne radar systems are capable of providing wind field sea state information over the ocean. Radar instruments are of high value for operational applications because of their all weather and daylight capabilities. Synthetic aperture radar (SAR) instruments as flown on the European satellites ERS-2, ENVISAT or the Canadian platform RADARSAT are of particular interest for applications where high resolution two-dimensional information on the near surface wind field is needed.

In this presentation an overview is given of the present status of SAR wind field and sea state retrieval techniques with a special focus on the requirements of the offshore wind farm community. Wind fields computed from SAR images of the offshore wind park sites Borkum West, Horns Rev, Kriegers Flag and Butendiek are presented and compared to in situ measurements. Spatial wind speed measurements from the SAR images are compared to time series measured at the FINO 1 platform thus evaluating the possibility to use the 400 km x 400km SAR images for short term wind forecast. Measurements of wind field and sea state for the storms Anatol, Lothar and Kyrill at landfall are shown.

The resolution of existing SAR sensors on ERS and ENVISAT for ocean wave measurements is rather coarse, as only ocean waves longer than 100 meters are imaged. Higher resolution, up to one meter is available from the new X band satellite Terra-SAR X, to be launched in March 2007.

Oceanographic applications of the new TerraSAR-X mission will be discussed. The TerraSAR-X instrument has a spatial resolution of up to 1 m and additional features like multi polarisation, which make it a very interesting tool for oceanographic applications. The platform FINO 1 was chosen as a primary test site to calibrate and validate wind fields for X-band satellite images. For the development, optimisation and validation of the retrieval algorithms comparisons with in situ data, e.g., acquired at the FINO platform will be carried out. The respective calibration and validations strategies will be summarised.

**Application of satellite altimetry for study of the Euphrates-Tigris river system**

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*Keywords: Euphrates-Tigris river system, reservoirs, water level, flooded zones, radar altimetry*

Water resources of the extensive Euphrates-Tigris (ET) river basin have vital importance for people living on its watershed, and for its ecosystems. It also provides freshwater input into the Arabian Gulf, affecting fishery, marine biology and biogeochemistry. ET basin is shared between several countries and a series of large reservoirs are constructed in each of these countries. As a result, water availability and water management in the ET basin are always a hot issue. Information on hydrological regime of the ET basin (water level in the reservoirs, amount of diverted water, river level and discharge) has paramount importance for studies of natural and anthropogenic influence on ET river system, and freshwater input into the Arabian Gulf. For several last decades such information, commonly obtained using in situ observations, has become very scarce and not available for scientific research.

Satellite Earth Observation is a useful tool to complement in situ observations or to replace them when no data is available. We demonstrate how the use of satellite radar altimetry could benefit ET studies. Although the primary mission of satellite altimetry was the study of water level of the open ocean, this technique has been successfully applied to monitor water level of inland seas, lakes and reservoirs, as well as large rivers, wetlands and floodplains. Recently, satellite altimetry has been applied not only to derive river level, but also to reconstruct river discharge (Ob' and Amazon rivers).

We use data from several radar altimetry missions. The earliest data are available from the TOPEX/Poseidon (T/P) satellite, operating since 1992 up to 2002. We complement the T/P data by observations from recent radar altimeters onboard Geosat Follow-On (GFO) (since January 2000) and ENVISAT (since November 2002) satellites. The repeat period is 10 days for T/P, 17 for GFO and 35 days for ENVISAT.

We show how satellite altimetry enable us to analyse variability of water level for more than ten large reservoirs for ET, and to estimate temporal variability of flooded areas in ET marches using radar waveform parameters. We discuss how these data could be used to assess temporal variability of hydrological regime (affected by natural changes in precipitation and anthropogenic water management) and, ultimately, to estimate the amount of water coming to the Arabian Gulf, and its relation to the fishery, marine biology and biogeochemistry.

### **Calculating Sea Surface Current Fields Using Multi-Sensor Satellite Data**

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*Keywords: Multi-sensor remote sensing; Baltic Sea; sea surface currents; algae blooms*

A new approach is presented for the calculation of sea surface current fields using multi-sensor satellite data. We used two sets of satellite remote sensing data acquired in July, 1997, over the Northern Baltic Proper and in July/August, 1999, over the Southern Baltic Proper by various satellite-borne sensors working at optical, infrared, and microwave bands. During both time periods, calm and cloud-free weather conditions allowed for the acquisition of multiple satellite images of the same area. The used data set comprises images acquired by Landsat TM, WIFS, ERS SAR, and SeaWiFS.

We took advantage of the fact that intense algae blooms occur frequently in the Baltic Sea during the summer months. Manifestations of such algae blooms are often visible on satellite imagery from sensors working at different electromagnetic bands and are driven by the local currents. Therefore, the analysis of series of satellite data may allow for the calculation of mesoscale surface current fields. We have applied two different algorithms for our analyses: (1) a cross-correlation analysis was performed with data from sensors working at different electromagnetic frequencies; (2) a differential method based on the Gradient Constraint Equation was used for series of data acquired by similar sensors within a short time period. The resulting surface current fields are in good agreement with results from a numerical model run by the German Hydrographic Office (BSH). We demonstrate the main consistencies and show in which way our results can complement those from existing models. However, we also demonstrate limitations of the applied methods due to, e.g., a limited amount of data or limited visibility of the surface features.

**Morphodynamics of the Belgian shoreline studied with airborne Lidar and hyperspectral remote sensing**

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*Keywords: Airborne hyperspectral remote sensing, Lidar, beach morphodynamics, sediment transport, sandy shoreline, Belgium*

Airborne hyperspectral data and airborne laserscan or LiDAR data were applied to analyse the beach morphodynamics along the Belgian shoreline. Between 2000 and 2004 four airborne acquisitions were performed with both sensors. The hyperspectral data were classified in seven sand type classes following a multiple-binary classification approach based on Linear Discriminant Analysis. The seven classes allow to analyse the spatial distribution and dynamics of specific sediment volumes. The technique made it possible to distinguish the sand used for berm replenishment works or for beach nourishments from the sand naturally found on the backshore and the foreshore. Subtracting sequential DTMs (Digital Terrain Models) resulted in height difference maps indicating the erosion and accretion zones. The combination of both data types, hyperspectral data and LiDAR data, resulted in a powerful tool, suited to analyse the morphodynamics of sandy shorelines. The technique was demonstrated on three sites along the Belgian shoreline: Koksijde, located at the West Coast and characterised by wide accretional beaches, influenced by dry berm replenishment works and the construction of groins. Zeebrugge, at the Middle Coast, where the dams of the harbour of Zeebrugge are responsible for the formation of a large accretional beach. The third site, Knokke-Heist, is located at the East Coast and is characterised by narrow, locally reflective beaches. This last site is also heavily influenced by nourishment activities. The methodology applied allowed to retrieve the main sediment transport directions as well as the amount of sediment transported. It proved to be specifically suited to follow up the redistribution and re-sorting of the fill in beach nourishment areas.

**Lake Baikal ice regime: application of radar altimetry and radiometry**

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*Keywords: Lake Baikal, lake ice and snow cover, ice regime, radar altimetry, radiometry*

The state of ice cover, and the freeze-up and break-up dynamics of lakes are good indicators of large-scale climate changes. We demonstrate the potential of combination of satellite altimetry and radiometry for studies of lake ice and snow cover on the example of lake Baikal in Siberia. We show the synergy of the combined use of passive and active microwave satellite data - simultaneous active and passive observations available from the recent satellite altimetry missions (TOPEX/Poseidon, Jason-1, ENVISAT and Geosat Follow-On), complemented by the SSM/I passive data. We propose an methods for ice discrimination and snow height estimation based on a combined use of the data from the four altimetric missions and SSM/I and validate it using available in situ observations. We have applied this approach to the entire satellite dataset and have defined specific dates of ice formation and associated uncertainties. Using these satellite-derived estimates we have reliably extended up to the 2004 the existing time series of ice events in the Southern Baikal and provided new information on Middle and Northern Baikal, where no recent ice cover observations are available.

These data show recent (since the 1990ies) tendency for colder winters, manifesting in earlier ice formation, later ice break-up and increase of ice duration. Complementing the ice cover dataset by ERA40 air temperature data we further analyse how ice regime is influenced by air temperature, dynamic (wind field, currents) and other (bathymetry, precipitation etc) factors. We estimate the relation between air temperature parameters and the timing of ice events. Dynamic and other factors interfere with the thermal influence, resulting in a further increase or decrease of ice formation dates. Finally, we stress the necessity to have lake-wide assessment of ice regime for climate research and summarise the potential influence of various environmental factors on ice conditions of lake Baikal.

**Cross-frontal water exchange produced by upwelling filaments**

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*Keywords: Upwelling filaments, Water exchange, Canary and Benguela upwelling regions*

Satellite data (thermal and color imagery) show that offshore flowing filaments off the west coasts of North America, North and South Africa can influence significantly the cross-frontal mixing in the coastal upwelling zones. To evaluate this role, we investigated structure, dynamics and behavior of surface filaments in the Canary and Benguela upwelling regions on the base of daily satellite IR and VIS imagery (AVHRR NOAA, MODIS-Terra and Aqua). A geographic distribution of filaments was analyzed with relation to bottom topography in order to explain their concentration in definite places. It was found that seasonal variability of the filaments location depends on the annual shift of general upwelling intensity along the coast. The main statistical characteristics of filaments - length, width, temperature anomaly and estimates of velocity were obtained. Three-dimensional velocity structure of a filament was registered by ADCP in the Canary upwelling region. The most striking was an observation of a very high vertical velocity in filaments. Peculiar features of their dynamics are discussed. Estimates of cross-frontal water exchange due to filamentation based on the statistical data show that these coherent structures play a major role in the water and particle exchange between coastal zone and the open ocean in both upwelling regions.