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Applicability of Remote Sensing in Monitoring Coastal Zones

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Abstract

The coastal zone is a very dynamic and resource rich system, which is reflected by the numerous policy-driven monitoring programs. Their goal is to detect and assess natural and anthropogenic influences and effects. The monitoring of intertidal flats and of coastal water quality is time and cost intensive. In order to reduce these costs, the use of remote sensing techniques in different fields of application has been investigated during the last few years in the scope of EU co-funded and user driven projects. Different sensors and methods are required for the different demands and questions of specific monitoring programs. Examples of remote sensing applications are sediment and surface type classification of intertidal flats using Landsat ETM data or the interpretation of high spatial resolution data in order to detect changes in coastal morphology and density of dune vegetation. Visual interpretation and classification methods such as Maximum-Likelihood classification and linear spectral unmixing are used for these purposes. Regarding coastal water quality, MERIS data have been used to produce maps showing the distributions of chlorophyll-a, total suspended matter and yellow substance concentrations. These investigations have demonstrated, that remote sensing techniques can deliver information on quite a number of parameters, however their combination with conventional in-situ measurements is necessary to provide the best possible result.

1 Introduction

Investigations have shown how remote sensing techniques can provide valuable information on different aspects of the coastal zones. The requirements on data for observing the coastal zone are very different and knowing what kind of data is suitable for which application is important if a reliable and accurate monitoring is to be achieved. The present contribution will focus on three concrete examples of how remote sensing data can be used in combination with in situ data to produce accurate quantitative maps of parameters viewed as being very important in coastal monitoring programmes, such as the Trilateral Monitoring and Assessment Programme (TMAP). These parameters include coastal morphology, sediment type and water quality. The studies outlined presently were driven mainly by End User requirements. These End Users were distributed mostly around the North Sea coast and each dealt with different aspects of the coastal zone.

The clear advantage of using remote sensing data is that they provide a synoptic overview of large area, whose measurement would not normally be possible using only ground-based techniques. There is, however, a limit to the number of optical remote sensors which are appropriate for monitoring the coastal zone, therefore knowing which sensor is best suited for which parameter and budget is a very important initial criteria. Table 1 lists typical representatives of the available satellites, with their respective characteristics.

Sensor	IKONOS	QUICK-BIRD	SPOT	IRS	LANDSAT ETM	MERIS FR	NOAA AVHRR	SeaWifs	MERIS RR
Spatial Resolution	1m (pan) 4m (ms)	0.7 m (pan) 2.6 m (ms)	20m	23m	30m	300m	1000m	1100m	1200m
Swath Width	11 km	22 km	60x60km	140x140km	183x 172km		3000x 6000km	2800km	1150 km
Spectral Resolution	1 pan 4 (vis, NIR)	1pan 4 (vis, NIR)	4 (vis, NIR)	3 Vis, NIR, thIR	8 (pan, vis, NIR, MIR, thIR	15 (vis, NIR)	5 Vis, NIR, MIR, thIR	8 (vis, NIR)	15 (vis, NIR)
Temporal Resolution	3 days	1-3days	26 days	24 days	16 days	3 days	2-4 days	1 day	3 days
Price*	US$29/km2	US$30/km2	1250-2600€	1800€	US$500	200€	100€	US$50	200€

Tab. 1: Spatial and spectral characteristics of sensors used in the optical remote sensing of water constituents and land characteristics. *Prices are only a rough guide for the present purposes and were mostly obtained from the recent Price Catalogue from Eurimage and Infoterra (2003) and refer to the price per km^2 and/or minimum request allowed for standard products (radiometric and geometric corrected).

For the present study data from the high resolution IKONOS were used to investigate coastal morphology, data from Landsat 7 ETM to map sediment type and data from the medium resolution MERIS instrument was employed for water quality mapping. Aside from the cost factor, the choice of these instruments was based on the requirement guidelines for monitoring these parameters, as outlined for example in the TMAP (1997) following from OSPAR (1997) and HELCOM (1988) (see Table 2).

Parameter	TMAP Guideline Measurement	Instrument
Coastal Morphology	Extent/Change Every 5-10 yrs	IKONOS
Sediment Type	Extent of mud sand and mixed sediment Every 5-10 yrs	LANDSAT
Water Quality (Chlorophyll_a concentration)	Biomass and extent Whole year: weekly or every 2 weeks (except in winter). Increase during bloom.	MERIS

Tab. 2: The choice of sensor depends on the parameter to be measured and the frequency of measurement required to accurately monitor changes.

2 Results

The following section shows how a good choice of sensors can be used to help in supporting monitoring activities in the coastal zone.

2.1 Coastal Morphology

The sometimes very small spatial-scale heterogeneous nature of coastal zones requires an instrument with a resolution of 1 metre or less. However, it is generally the case that the areas of interest extend over very large areas which even with airborne techniques is sometimes very difficult to achieve synoptically. This is where the IKONOS satellite which has a spatial resolution of 1 m in a panchromatic band and a 4 m resolution in the multispectral bands can be of great advantage. This combination of both panchromatic and several multispectral bands offers, on the one hand, the better spatial resolution of the panchromatic band and on the other hand the possibility of using the information contained in each of the four spectral bands. This combination is achieved by image sharpening techniques.

A prerequisite for change detection is the differentiation of surface types in the data. For the present example, an IKONOS image has been compared with vector data of morphological structures obtained from field mapping. The result shows lines of dune edges and waterlines compared with the IKONOS image. Changes can be detected at the extend of dune vegetation and slight shifting of water outlets.

Using a simple ratio of reflectances values in two spectral channels of IKONOS, a normalised difference vegetation index (so-called NDVI index, Weir and Herring, 2001) can be obtained of the vegetation density on dunes, with very little effort. This parameter is important for assessing the stability of the dunes. Another method for detecting vegetation density is the linear spectral unmixing (Hill 1998), using a sand and a vegetation endmember, which delivers comparable results.

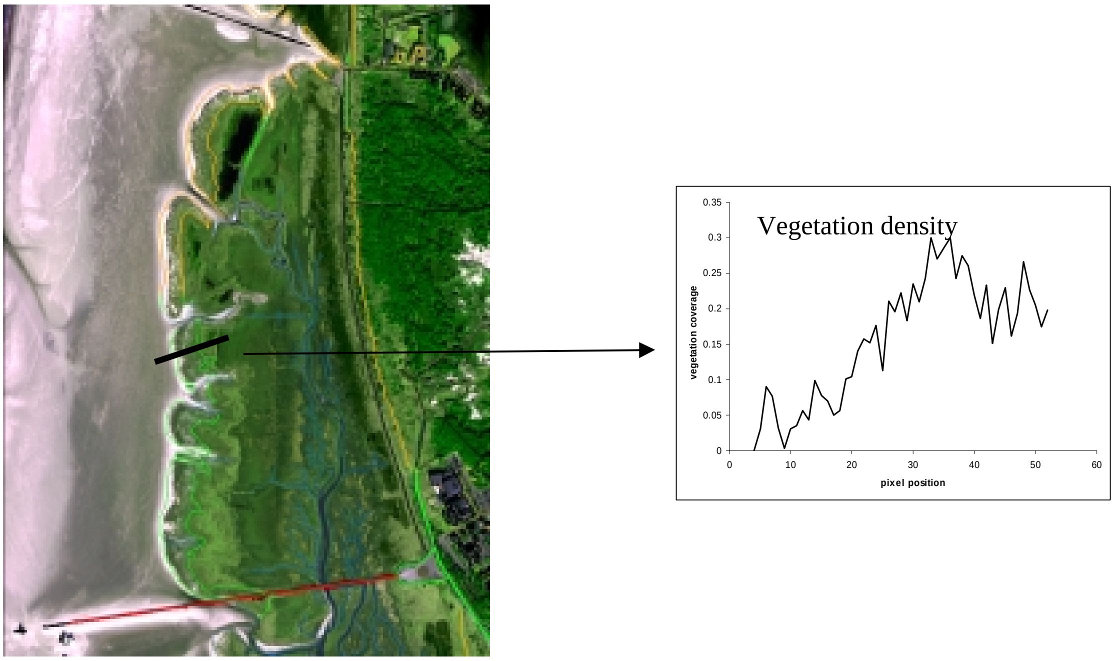

Fig. 1: Panchromatic IKONOS image with vector data set showing morphological borders and profile of vegetation density on dunes (derived from NDVI). NDVI values are dimensionless. The vector data set has been provided by ALR Husum.

2.2 Sediment classification

Sediment classification has been performed using Landsat ETM data (original Landsat ETM data provided by Eurimage © 2002). With a spatial resolution of 30 m and 7 spectral bands, this instrument fits well into the requirements for providing a good overview of a very large area while simultaneously providing a wide range of spectral information. In tidal flat areas, water remaining on the sediment during low tide can sometimes cause difficulties. Water strongly influences the spectral signal and leads to a misclassification of the sediment towards a more muddier class. The method applied here puts special emphasis on the water problem. Using a linear spectral unmixing technique, the percentage of sediment and water within each pixel of the image can be derived. As part the EU-FP5 HIMOM project this method has been successfully applied to different estuaries and intertidal flats around Europe, namely in the Westerschelde, The Netherlands, the German Wadden Sea, Barrow Estuary, Ireland and the Tagus Estuary in Portugal.

In addition to the spectral unmixing, an unsupervised classification gave similar results, however, as this method is based purely on image statistics, the results cannot easily be transferred to other scenes. Expert knowledge of the local area is necessary for interpretation, and the derived classes depend on the image statistics and may differ from scene to scene.

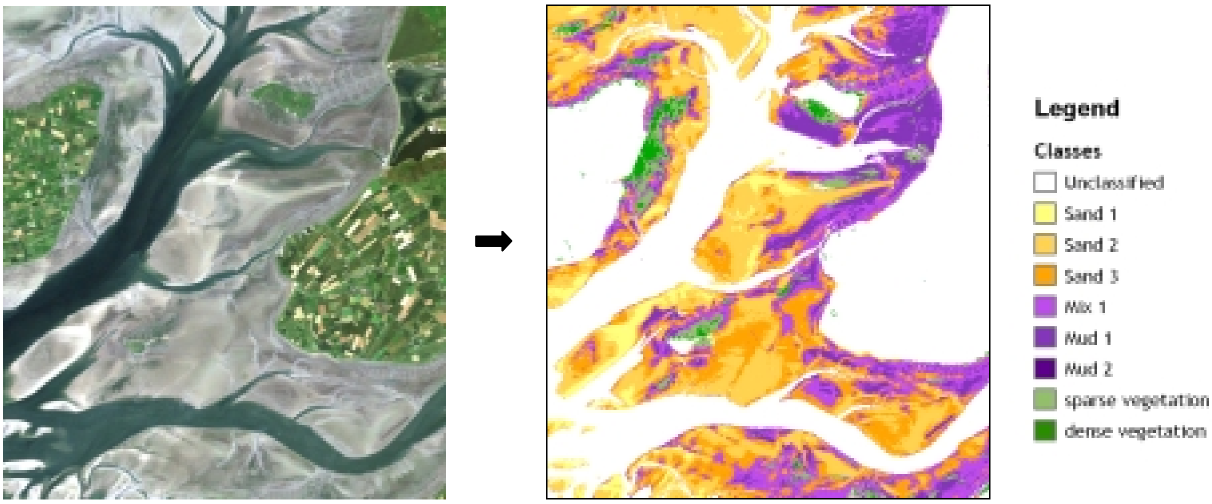

Fig. 2: Map of the distribution sediment type using linear spectral unmixing.

2.3 Water Quality

MERIS is a medium resolution imaging spectrometer developed specifically to retrieve the distribution and concentration of water quality parameters, namely chlorophyll-a, total suspended matter and yellow substance for both Case-1 and Case-2 waters. These parameters are derived from the multi-spectral information by inverting a radiative transfer model. This method differs significantly from the previously described since the physics of the imaging is modelled and inverted. As a result quantitative values of the water constituents can be derived, as well as quality information accompanying the concentration values (Brockmann, 2003). This is important since all national and international regulations include clear specifications of such concentrations.

Figure 3 shows a classified chlorophyll concentration map of the north-eastern of the North Sea for the period April – August 2003. The classification matched the requirements of the Norwegian monitoring programme and is a simple mapping of the continuous chlorophyll concentrations derived by MERIS. The averaging, binning, mapping and classification has been performed with the BEAM software, which has been specifically developed in order to support the post processing of MERIS data (Brockmann, 2003).

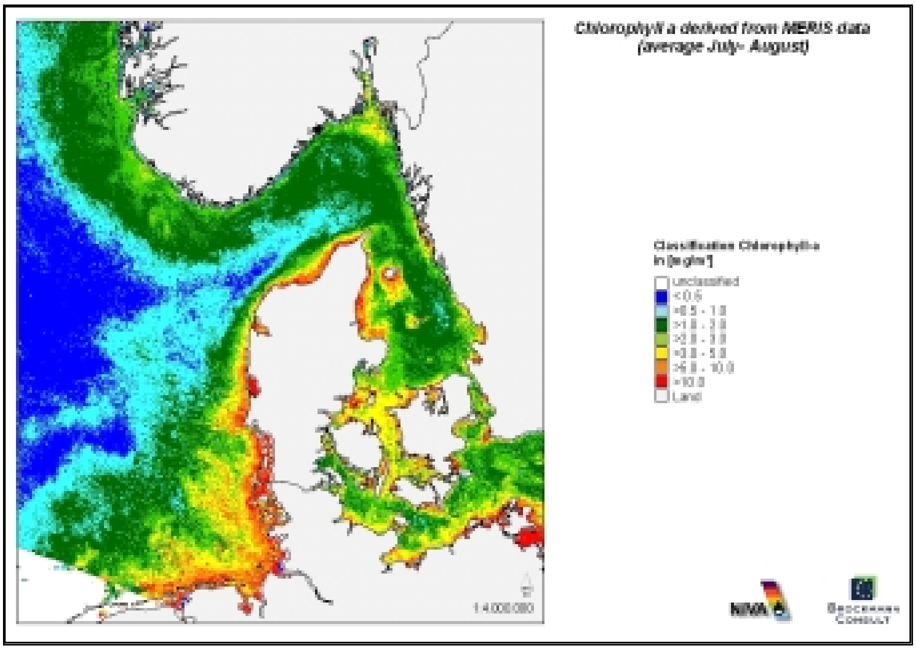

Fig. 3: Chlorophyll_a concentration derived from MERIS full resolution products.

3 Discussion

That remote sensing data can contribute to our understanding of coastal systems in a quantitatively accurate and visually compelling way, reflects the development which has taken place both in the algorithms necessary to properly process these data and also the realization by scientists and policy makers alike that without such data a global assessment of ecosystems is next to impossible. Different sensors can be used for different monitoring applications and the present examples illustrate the potential these data have to contribute to operational monitoring programmes. In order to serve End Users with products which can be integrated into their monitoring programs, it is important to know what End Users require but it is similarly important for the End Users to know what is available and realistically possible. Communication between service providers, i.e. those providing the maps, and those people involved in policy and management decisions concerning the coastal zone is improving. Efforts such as the Global Monitoring for Environment and Security (GMES) programme, jointly initiated by the European Space Agency and European Commission, will certainly provide impetus to the dialogue between both parties. However, it should not be forgotten that the best way forward is to combine conventional methods with remote sensing techniques. This will ensure a consistent time series is obtained and may even offer a more cost effective alternative to only using expensive and time consuming field data collection methods.

4 References

Trilateral Monitoring and Assessment Group, 1997: TMAP Manual. The Trilateral Monitoring and Assessment Program (TMAP). Common Wadden Sea Secretariat, Wilhelmshaven.

HELCOM, 1988: Guidelines for the Baltic Monitoring Program for the Third Stage, Baltic Sea Environment Proceedings No. 27 A, Helsinki Commission, December 1988

OSPAR, 1997: Common procedure for the identification of the eutrophication status of the maritime area of the Oslo and Paris Conventions. OSPAR 97/15/1, Annex 24.

Weier, J. and David Herring, D.: 2001, Measuring Vegetation (NDVI and EVI). Earth Observatory Reference, NASA online Library, http://earthobservatory.nasa.gov/Library/MeasuringVegetation/

Hill, J., 1998: Neue Wege zur geowissenschaftlichen Auswertung multispektraler Fernerkundungsdaten. Geographische Rundschau, Bnd. 50, S. 113-119

Brockmann, C. et al, 2003: BEAM – Basic MERIS and AATSR Toolbox (http://www.brockmann-consult.de → projects → BEAM)

Brockmann, C., 2003: Scope of Water Products - The Quality and Science Flags. MERIS User Workshop 2003. Proceeding (in press). ESRIN, Frascati, Italy.

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