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COASTWATCH – a coastal and marine indicator and water quality service

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Abstract

Integrated with other tools, remote sensing can provide crucial data for monitoring and management of the coastal environment. The COASTWATCH initiative aims at making best use of processed satellite data to provide innovative information services to the coastal management community in support of European policies regulating this sector, in particular the Integrated Coastal Zone Management (ICZM) Strategy of the European Commission, the Water Framework Directive, and the Marine Strategy. This paper gives an introduction to the COASTWATCH services, in particular: a) The ICZM Indicator Service covers for the moment "land take by built-up in the coastal area", "urban sprawl", and "dominant landscape type". COASTWATCH can process satellite-derived data for these indicators at European and national level. b) The Water Quality of Marine Waters Service, providing information products required by the Water Framework Directive, such as Chlorophyll-a maps, suspended particulate matter maps, or primary production maps. Case studies highlight the potential of COASTWATCH services. The discussion refers to improvements and extension of COASTWATCH Services in the near future.

1 Introduction

1.1 COASTWATCH, part of the GMES programme

COASTWATCH is an information service for the coastal management community that makes best use of processed satellite data. It started early 2003 and supports European policies regulating this sector, in particular the Integrated Coastal Zone Management (ICZM) Strategy of the European Commission, the Water Framework Directive, and the Marine Strategy. The European Space Agency (ESA) provides financial support in the framework of GMES, a coordinated effort of the European Commission and ESA to establish an autonomous European Global Monitoring capability for Environment and Security. The COASTWATCH partnership is being led by ACRI-ST (France) and includes a network of experienced service providers delivering high-level earth observation based information on the coastal and marine environment as well as representatives of the user community, including EUCC – The Coastal Union.

The role of Earth Observation and satellite remote sensing is well established as a method of environmental monitoring and mapping. However, its place as a tool for coastal monitoring is less well developed. A possible reason for this is that although many different satellite sensors can be used for coastal monitoring, very few were specifically designed for this application. For example, most satellite sensors are designed to monitor either the land (e.g. Landsat, SPOT, IKONOS) or the marine environment (e.g. SeaWIFS, Coastal Zone Color Scanner (CZCS), MERIS), although land sensors are sometimes used for marine applications and marine sensors for land applications.

Nevertheless, satellite remote sensing does have the potential to contribute to coastal management in a number of ways. Some benefits include:

- Up-to-date data provision, or data (almost) on demand
- Data acquisition without field visits

- Early identification of environmental problems
- The ability of satellites to image large tracts of the Earth. At a broad scale, coastal managers can view whole coastal systems (sediment cells for example)
- Detailed monitoring of coastal landscapes, habitats and processes using higher resolution imagery.

Satellite remote sensing also has a number of limitations, including:

- The spatial resolution of some sensors is too low for detailed coastal monitoring and mapping
- Data for a specific date and time is not always available, e.g. because cloud cover prevents an image from being taken.

Consequently, remote sensing is best used in combination with other methods, in particular in-situ data collection and modelling.

1.2 Objectives of COASTWATCH

COASTWATCH responds to the growing need for cost-effective monitoring information on the coastal environment. COASTWATCH services are established by consolidating, aggregating, and improving existing services with the aim to:

- support organisations in the policy-driven coastal monitoring and compliance process, including routine monitoring, emergency response, and planning
- supply information integrating land and sea, earth observation & non-earth observation data, and models
- provide scientifically sound and validated services,
- ensure seamless access to the service wherever required in Europe.

COASTWATCH services provide basic geo-physical information, such as water quality parameters, integrated information such as indicators, and "decision support"-oriented information.

The initial service portfolio supports policy measures defined at the European level including the Strategy for Integrated Coastal Zone Management (ICZM), the Water Framework Directive (WFD), and the Marine Strategy. The COASTWATCH portfolio is gradually being extended in an open and coordinated fashion incorporating new service providers and new information services to satisfy new users. The long-term objective of COASTWATCH is to establish an operational service for the provision of effective information supporting decision-making in coastal management.

2 Results

In 2003, COASTWATCH developed two services, the Integrated Coastal Zone Management Indicator Service and the Water Quality of Marine Waters Service.

2.1 The ICZM Service

The ICZM Service provides information to support the implementation of the European ICZM Strategy and Recommendations at national, regional, and European level. A set of indicators and maps are delivered according to the standard of the European Environment Agency (EEA). The ICZM Indicator Service contributes to monitoring coastal environment status and land use changes in Europe.

Target groups are the, EEA and European Topic Centres, institutions of EU Member States and acceding countries in charge of the implementation of the ICZM Recommendations (in particular, the EU ICZM Expert Group, WG-ID), and regional sea conventions. In 2003, the EEA, the regional government of Catalonia (Generalitat de Catalunya) in Spain, as well as the INC- Institute for Nature Conservation and the Flemish Coordination Centre for ICZM, both located in Belgium, were the main users.

Coastal Indicator service line

The Coastal Indicator service line is mainly dedicated to the production of regional, national, and Europe-wide indicators as defined by the ICZM National Strategies, the EU Working Group on Indicators and Data set up by the EU Expert Group on ICZM (DG Environment), and the EEA. In this frame, a set of environmental stress indicators has been developed. Coastal indicators delivered by COASTWATCH belong to the "core set of indicators" as specified by the Working Group. The Coastal Indicator service line delivers the following products:

Indicator "Built-up in distance to the coast"

This environmental indicator delivers a percentage of land taken by build-up in coastal areas depending on the distance from the coast. European coverage is delivered in a coastal strip of 10 km.

Indicator "Dominant landscape type in the coastal areas"

The dominant landscape type indicator gives the dominance of major land cover types from CORINE in the European coastal area. This indicator delivers a percentage of dominant landscape in the coastal areas depending on coastal units. The aim of this indicator is to make a current typology of the low coast and high coast in function of 7 aggregated CORINE classes: Urban dense areas, dispersed urban areas, broad pattern intensive agriculture, composite rural landscape, forested landscape, open-semi natural and natural landscape, areas without dominance.

Indicator "Land take by built-up area in the coastal areas"

This indicator delivers a percentage of land take by build-up areas in the coastal zone 10 km from the waterline. It allows comparison on the growing of build-up area among different countries and regions in Europe. Its potential environmental impacts depend on the type of land affected, on the built-up characteristics and on its extension.

Indicator "Land take by diffuse and compact sprawl"

The land take by diffuse and compact sprawl indicator identifies sealing of the land by urban development in coastal areas. It is reflected by land take by urban sprawl in coastal areas, identifying:

- the intensive/compact urban development attached to the core of the city, and
- the extensive development forming disperse urban area.

The indicator shows the expansion trends of urban growth as well as the intensity pattern of the urban development.

Supply features

For the first three indicators, the Coastal Land Cover (CLC) accuracy is that of CORINE Land Cover. All features are digitised from an interpretation of satellite image printouts of the scale 1:100.000 with 150 m positional accuracy, and 25 ha minimum mapping unit. The best resolution is 100 m. Products can be delivered from an archive, starting from 1986 and ending in 1995. The special coverage is from the Faeroes to the Canary Islands and from the Canary Islands to Kastellorizon. The on-earth resolution is 100 x 100 m. Products can be delivered as jpg, xls, or dbf files.

Indicator 4 is being projected as specified by the user. Time coverage is by single year or multiple years. The indicator is calculated based on several cities located at the Belgian coast (Knokke-Heist, Oostende, De Panne). Additional cities can be covered on request. The product is always delivered as shapefile.

Validation

The validation process has been done in strong co-operation with EEA.

Coastal land cover and land use change mapping service line

Regular delivery of coastal land cover and land use change (CLC/LUC) maps is an asset for the monitoring of coastal zones. They present a standardised product for the continuous monitoring of land cover / land use changes in coastal zones and establishing a reporting system on land cover / land use changes based on long term spatial survey (e.g. CORINE Land Cover, LACOAST) and extensive use of high resolution earth observation data.

This service line aims to:

- deliver standardised products for the continuous monitoring of land cover / land use changes in the coastal zone in form of 1:15.000 up to 1:100.000 uni-temporal or multi-temporal maps / difference maps,
- report on land cover / land use changes based on long term spatial surveys, statistical assessment for specified areas (part of the coastal strip) in form of uni-temporal and/or multi-temporal, 1:15.000 up to 1:100.000 maps.

The coastal land cover and land use change maps can be produced for any part of the European coastal strip (EU member states and CEEC countries).

The following products are presently available:

Coastal land cover 100 product

These are small-scale land cover maps for coastal areas derived from high-resolution satellite imagery (e.g. Landsat, Aster, Spot-4 HRV, etc.). The accuracy is 90%.

Coastal land cover 15 product

Large-scale land cover map for coastal areas derived from very high-resolution satellite imagery (e.g. IKONOS, QuickBird, etc.). Accuracy depends on the specific case, but is estimated at 75 %.

Coastal land use change product

Land cover change map for one or several coastal areas (scale 1:100.000 or 1:15.000). Accuracy is typically several times the initial land cover accuracy. The product can be ordered by e-mail or fax.

Examples of service application

COASTWATCH provided the Co-ordination Centre for Integrated Coastal Zone Management of the Flemish region in Belgium with indicators and land cover maps to help them keep track of the current evolution in coastal areas and consequently adjust coastal management plans. COASTWATCH delivered an up to date land cover map of the year 2002 as a reference base for the future.

The European Environment Agency's core task is to provide decision-makers with the information needed for making sound and effective policies to protect the environment and support sustainable development. In this framework, COASTWATCH services support the development of some coastal environmental indicators to be used for improving spatial analysis and assessment at EU and Member States level, and to facilitate the production of reports by the Agency. The main benefits identified by the EEA regarding the COASTWATCH service portfolio are free access to updated data on land and sea, and the ability to obtain homogenous information on the coastal environment at a national level, which will allow them to follow up on the implementation of the ICZM Strategy.

2.2 The Water Quality for Marine Waters Service

The Water Quality for Marine Waters Service provides supplies data and expertise to users for monitoring activities as defined by the Water Framework Directive and marine conventions: surveillance, operational, investigative and protected areas monitoring. It delivers environmental indicators, water quality bulletins and early warning alerts derived from Earth Observation, and particularly ocean colour sensors for environmental monitoring, statistical and operational survey.

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Water Quality Monitoring

Water Quality Monitoring offers an on-line support for e.g. oceanographic cruises, pollution monitoring and survey of anthropogenic discharge, natural resources monitoring, or algal blooms surveys through the supply of maps, water quality bulletins and early warning alerts.

This service line delivers a wide number of qualified and validated geo-physical products over coastal seas (as well as over open seas):

- Sea surface temperature
- Chlorophyll-a concentration
- Suspended particulate matters
- Water transparency
- Photo-synthetically available radiation.

Key users of the Water Quality for Marine Waters Service are national and regional operational organisations in charge of marine, coastal and transitional waters monitoring.

Wave Exposure Monitoring

The Wave Exposure Monitoring service line delivers near real-time sea state information, significant wave height and wind speed, as well as climatologic statistics of waves, namely wave height, mean period and zero-crossing period, and mean direction.

Supply features of the Water Quality for Marine Waters Service

product	level	unit	range	accuracy	sources
water transparency	4	m	[0,100]	15%	MERIS/SeaWIFS/MODIS
Suspended particulate matter	3	$g.m^{-3}$	[0.01, 100]	15%	MERIS
Photo-synthetically available radiation	3	Einstein $g.m^{-3}$ day-1	[0, 75]	15%	MERIS/SeaWIFS
Chlorophyll a	3	$mg.m^{-3}$	[0.01, 64]		MERIS/SeaWIFS
Chlorophyll Case 1	3	$mg.m^{-3}$	0.03, 300]	13%	MERIS/SeaWIFS
Sea surface temperature	3	^0C	[-5, 35]	0.2	AVHRR
Wave fields in real-time		m	[0, 25]	0.5 m 10%	ERS-2, Envisat, Jason-1, NOAA

Table 1: A free toolkit for data handling, display and editing is supplied with the products.

Validation

Three types of validation are routinely performed :

- Running validation: L3 outputs are compared to available in situ data. For instance, Sea Surface Temperature data are routinely compared with buoys data. Any discrepancy is registered and reported to the expert in charge of this chain.
- Case by case validation: Inter-comparison with other similar results. Each product delivered to a user is systematically checked before sending.
- Scientific validation: Keeping track of latest scientific results in order to maintain quality on highest possible level.

Examples of service application

Fin whale populations are an indicator for good ecological status of coastal and marine waters, as defined by the Water Framework Directive. The relationship between primary production (measured by earth observation techniques) and the summer distribution of Fin whales (observed by boat survey) in the north-western Mediterranean Sea has led to a predictive model that integrates primary production data over different temporal scales from the beginning of March to the start of whale surveys by ship. In order to take into account the environmental changes and the likely whale movement, the model is being adjusted every eight days. COASTWATCH has provided primary production data and an adjusted model to GREC, a cetacean study group, thereby contributing to a more efficient monitoring of Fin whale populations. Results of a field campaign by GREC have confirmed the relevance of the model and COASTWATCH data.

Another COASTWATCH application example is the support of the GAUSS campaign, the research vessel of the German maritime institute BSH, for surveillance monitoring for Water Framework Directive compliance. The Coastwatch Water Quality Service delivered in near-real time ocean colour derived products (Chlorophyll-a, Total Suspended Matter, Transparency) and Sea Surface Temperature. The results obtained on board showed a very good agreement between measured in situ Secchi depth and the transparency derived from COASTWATCH with the help of MERIS, and consequently helped to validate results obtained in the conventional way.

On Saturday 31st May, 2003, the Chinese freighter “Fu Shan Hai” sank to a depth of 68 m in the Bornholms-gat, Baltic Sea, and caused an oil spill. Although optical remote sensing of ocean colour is generally not used to detect oil spills, the extraction of spatio-temporal information from MERIS imagery was successfully done as a preliminary attempt to demonstrate the use of MERIS as a potential complementary tool to other means of investigation (e.g. SAR). It could be concluded that the detection of small scales structures is definitely possible using MERIS Full Resolution products, and that this technique is certainly of interest to monitor coastal pollution.

3 Discussion

The two thematic COASTWATCH services have been successfully operating during 2003, the first year of the initiative. The quality of the products generated by the ICZM Service is related to the quality of the input databases, which is ensured by the EEA and the ETC-TE (Terrestrial Environment), among others. The robustness of the service has been successfully demonstrated since few anomalies occurred. However, users noted that the resolution of delivered information, especially when addressing local products, is sometimes too coarse (100m) and the updating frequency for some delivered information could be higher (at least every five years). In both cases, the topic is related to CORINE Land cover, which is one of the main input data sets.

3.1 Future of the ICZM Service

With the future EU enlargement, new efforts are needed to achieve a seamless coverage and comparable information to build the indicators. Indicators are mainly based on CORINE, which has a seamless coverage, but the scale and resolution is not sufficient to work on the local and regional level and the updating frequency is around 10 years only. Consequently, a new product is needed, based on CORINE but with better resolution and updated more frequently.

The dominant landscape type indicator will need to be completed by COASTWATCH with statistical data on tourism, population, agriculture, and environment, among others. To this aim, the EEA proposes, that for analysis at regional level, indicators will be elaborated using satellite imagery with a higher resolution (e.g SPOT 5, Quick Bird, IKONOS).

Moreover, COASTWATCH aims to cover more indicators in the near future:

- Rate of development of previously undeveloped land
- Proportion of coastal zone (land and sea) protected by Natura 2000
- Pressure on the coastal ecosystems, both from land and the sea
- Coastal erosion patterns within dominant landscape types (percent of km of eroding and accreting coast, trend in relation to Natura 2000 and landscape types)
- Coastal habitat loss indicator (derived from Coastal Land Cover maps at 1:15.000 scale).

3.2 Coastal Engineering Service

A new COASTWATCH Service will be developed in 2004, the Coastal Engineering Service. It aims to provide COASTWATCH with the ability to deliver information on coastal processes that underpin decision making, such as safety issues or environmental management and planning in coastal zones. The physical parameters required for understanding coastal processes are wind and waves, currents, and sea level. A key focus of this new service element is the ability to deliver this information at the range of scales required by the users from regional to local level by coupling data sources with numerical models. Combining this service with the Water Quality Service can help identify pollutants dispersal and pollutants sources. Combining the service with the ICZM Indicator Service can provide indicators of coastal vulnerability or coastal hazard. Potential users are national and local organisations involved in coastal development, planning, defence, or conservation, or consultants who supply those organisations.

3.3 Validation Bureau

The COASTWATCH Validation Bureau, established in 2003, will be strengthened in 2004 and beyond. It establishes rules to ensure unbiased and independent validation and includes representatives of the service providers and the end user community. Validation of the Water Quality Service will be conducted using in situ data and cruise data.

3.4 Cooperation

Cooperation with related initiative such as the REVAMP project on data harmonisation and the GMES project ROSES - Real time Ocean Surveillance for Environment and Security covering oil pollution and water quality - will be strengthened in order to maximise synergies and use resources more efficiently. Moreover, cooperation with SAGE (Service for the Provision of Advanced Geo-Information on Environmental Pressure and State) is under positive discussion. Furthermore, COASTWATCH will also aim at providing follow-up to information related aspects of EUROSION, a European initiative on coastal erosion management.

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