THE USE OF EARTH OBSERVATION DATA FOR MONITORING BIODIVERSITY IN CENTRAL AMERICA AND THE CARIBBEAN

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Abstract – This contribution summarizes objectives, input data and approaches for products and services to be developed in ESA DUE project "DIVERSITY SUPPORTING THE CBD". The project aims at studying, defining, demonstrating and validating a number of geoinformation products and services based on EO-technology for supporting the user community involved in the implementation of the United Nations Convention on Biological Diversity (CBD). Several products will be generated with a focus on Mesoamerica,:

- **Dry-land biodiversity indicator maps,**
- **regional and local information on land cover, land cover changes and derived indicators in context with biological corridors in Mesoamerica,**
- **coral reef maps and relevant environmental impact maps,**
- **mangrove maps and mangrove change maps,**
- **satellite observations of the Tropical East Pacific Ocean for investigations on correlations between oceanic conditions and migrations of marine animals.**

Maps will be validated using ancillary data, partially generated by intensive ground truth data collection campaigns.

Keywords: Biodiversity, ESA, Mesoamerica, landcover, coral, mangrove, animal, migration

1. INTRODUCTION

In 1992, during Earth Summit in Rio de Janeiro, world leaders agreed on a United Nations Convention on Biological Diversity (CBD). This convention established the goal to conserve biological diversity. In this context European Space Agency (ESA) launched the Data User Element (DUE) project "Diversity supporting the CBD" (DIVERSITY). The project started in December 2006 with a duration of 18 months. It aims at studying, defining, demonstrating and validating a number of geoinformation products and services based on EO-technology for supporting the user community involved in the implementation of the CBD. Several champion users have been identified by ESA to be involved in the project:

- CBD Secretariat,
- Centro American Commission for Environment and Development (CCAD),
- UNESCO,
- MarViva.

These users strongly contribute to the project by setting requirements and providing local ground truth data. The consortium responsible for the generation of products and services consists of an international team with supplementing expertise:

- GeoVille Information Systems GmbH (GeoVille), Austria,
- Nansen Environmental and Remote Sensing Center (NERSC), Norway,
- University of Exeter, Marine Spatial Ecology Lab (MSEL), United Kingdom,
- Collecte Localisation Sataellites (CLS), France.

2. PRODUCTS AND SERVICES

2.1 Overview

The following products and services will be developed:

- Dry-land biodiversity indicator maps,
- Mesoamerican biological corridor maps,
- coral reef maps and relevant environmental impact maps,
- mangrove maps,
- investigation on wildlife migration.

Products are spatially related to Mesoamerica except for dry-land biodiversity indicator maps which will have worldwide coverage.

2.2 Dry-land Biodiversity Indicator Maps

Objective

According to the Convention on Biological Diversity (CBD), 47% of the land surface of the Earth is drylands. Home to a richness of biological diversity, they are also central to the livelihoods of almost 2 billion people. Dryland ecosystems receive very erratic rainfall, and as a result are very fragile. Biodiversity in these ecosystems is under threat from a variety of human activities. The transformation of habitats for human use, mostly agricultural, and increases in overexploitation, including overgrazing, has led to the degradation of up to 20 % of dryland ecosystems – with stark results: desertification and drought, the endangerment of many species and strong economic losses.

As a result, the objective of this service is to support the CBD with an up-to-date map on the extent of drylands (dry and sub-humid lands) at global level and their changes: The product will be a status map of worldwide drylands and their changes over the past 13 years (1993 to 2005).

Data

Input data sources for the product will be existing land cover data:

- International Geosphere Biosphere Programme (IGBP) product from Global Land Cover Characteristics (GLCC) project derived in 1992/93,
- Glob Land Cover (GLC) from 2000,
- GlobCover from 2005.

Approach
Data will first be pre-processed including conversion to same projection, harmonization with regard to classification scheme/ ground resolution and co-registration.
The global land cover data sets will be smoothed to avoid a false precision of the data and the results. Requested maps will be generated for the different dates by reclassification to a common classification scheme. Changes in land cover composition will be mapped by overlaying (intersecting) the smoothed global land cover data sets of the three dates. Validation will be made at specific parts of the global maps using higher resolution national land cover databases.

2.3 Mesoamerican Biological Corridor Maps

Objective
The seven Mesoamerican nations occupy a mere 0.51% of the planet's surface, but around 9% of the world's biological richness is concentrated in this region. For the 1980s, it was estimated that the region was losing 2.1% of its forests annually, one of the highest deforestation rates in the world [FAO 1993]. Accounting for this fact, Mesoamerican countries agreed on the foundation of the "Mesoamerican Biological Corridor (MBC)". The MBC is no fixed protection area or nature reserve with uniform, secured and controlled protection status. Its proposed area is rather comprised of a multitude of land cover and use types, ecoregions, regions with different protection status and unprotected regions, socio-economic and land tenure systems and ongoing land transformation processes. As a solid basis for planning, developing and surveying the MBC and the progress of its implementation, an adequate information base, kept up-to-date, is necessary. The objective of the required information service is therefore a regional information service to support the planning and monitoring of the MBC: Regional and – for five selected areas – local information on land cover, land cover changes, and derived indicators need to be generated.

Data
MERIS data will be used for regional mapping, SPOT data for mapping of local hot spots. In context with the regional maps, data concept needed to be adapted to user requirements and data availability/quality: Three datasets from different time periods will be the base for the products:

- ***"Historic"*** dataset based on MODIS data acquired in 2000,
- ***"Reference"*** dataset based on MERIS FR acquisitions used for ESA's GlobCover2005 product,
- ***"Actual"*** dataset based on future MERIS FR acquisitions to be acquired in 2007 and early 2008.

Each dataset consists of dry- (February – May) and wet-season (September – December) data for mapping vegetation independent of any seasonal changes. With regard to local hot spot mapping, five hot spot areas will be determined on base of the regional products and local knowledge of the users involved in the project.

Approach
All satellite data sets will be orthorectified, radiometrically pre-processed and mosaiced using DEM and state of the art procedures. A pre-classification stratification based on merged MERIS (mosaic) and ancillary GIS data to indicatively five strata will be applied. A pixel-based, hybrid (unsupervised/supervised) classification method will be used for the classification itself with CORINE level-1 classification scheme as a base. As the changes are assumed to be very small, land cover changes will be derived directly from the multispectral/ multitemporal MERIS and MODIS data, as opposed to a thematic approach (pure comparison of land cover maps, i.e. post-classification change detection).

2.4 Coral Reef and related Environmental Impact Maps

The objective of this product group is to design, implement, validate and demonstrate an information system for processing, merging and analysis of EO data products with other information in order to make an inventory, to monitor and to assess the state of Mesoamerican coral reefs in the Caribbean Sea. The product group comprises coral reef maps and ocean water quality maps.

Coral Reef Maps

Objective
The objective is to map Caribbean reefs in the Mesoamerican reef system at two distinct spatial scales and evaluate changes over a one year period. The project will evaluate the efficacy of using MERIS to map reef habitats containing live corals and compare results over two years on regional scale. Should a coral bleaching event take place, an attempt will be made to use MERIS data to identify locations where mass coral bleaching is taking place. At local hot spots, SPOT will be used to make more detailed maps of coral reef habitats.

Data
Coral reef mapping will utilize subsets of MERIS FR data used for Mesoamerican biological corridor maps. Five hotspots have been selected for local precise coral reef maps based on SPOT4 data:

- Glovers Atoll, Belize,
- Southwater Caye and Glovers,
- Banco Chinchorro, Mexico,
- Roatan,
- Bocas Del Toro, Panama.

These five hotspots were chosen because of availability of existing input data, geographic representation and local experience.

Approach
With regard to the *mapping of distribution and coverage of live coral* a hierarchical classification of coral reefs in the Caribbean will be applied [Mumby and Harborne, 1999]. Reefs will be mapped at two levels: (1) the locations of coral reefs that harbor live corals and (2) detailed discrimination of individual reef habitats which can be characterized as having quite different coral communities and potential living coral. It is anticipated to being able to map the first level using MERIS, but the second level may have much lower thematic accuracy. SPOT imagery will be processed to map both levels of reef classification.
MERIS data has adequate spectral information to warrant spectral unmixing methods. A method that simultaneously resolves bottom depth and substratum type [Hedley and Mumby, 2003] will be applied. Reef endmembers will be acquired from the imagery itself using existing field data. In addition to this comparatively new technique 'traditional' whole-pixel classification will also be applied to the MERIS data for comparison purposes.
SPOT data will first be subjected to depth compensation processing to generate 3 depth-invariant algorithms [Mumby et al., 1998]. Reef habitats will then be mapped using supervised image classification.
In context with coral reef bleaching, a new MERIS and SPOT scene of Glovers Reef, Belize will be acquired. The spectra of high-coral habitats will be compared between bleached and non-bleached reefs.

However, should no bleaching event take place, a simulation study to predict threshold levels of coral bleaching that can be detected using MERIS and SPOT sensors will be made. Base for this study are existing spectra of bleached and non-bleached corals [Clark et al., 2000; Hedley et al. 2004] combined with a new model of radiative transfer over complex substrates. Additional data required for the simulations (e.g. water optical properties) are available from previous Caribbean fieldwork campaigns.

Water Quality and Conditions

Objective
This service provide the users with regional consistent and validated water quality information products based on the EO ocean color and infrared data to be integrated with other information for studies of the Central American Waters. The service will generate monthly averaged products for sea surface temperature, Chlorophyll-a, total suspended matter, dissolved organic matter and turbidity for the study area.

Data
The products will mainly be based on daily access to MERIS RR Level-2 data from the rolling archives or other available sensor data. MERIS FR data will be used during periods of assessment in order to evaluate the difference in the applicability of the final products. SST information will be derived from MODIS data.

Approach
MERIS RR Level-2 data (atmospherically corrected spectral radiances as well as derived parameters) will be accessed at near daily interval for the study region. Data access will be made in near real-time through the ESA Envisat ftp-rolling archive at ESRIN using data scripts to down-load MERIS data within less than 12 hours after the satellite passing. Subsequent production line is based on daily generation of merged seven days binned products as well as monthly binning of the regional data once per calendar month for all derived parameters. Processed EO data products are generated as image files for web-display (GeoTIFF), in KML format for use in GoogleEarth and as data files for further processing. Finally a web-map server, based on the EU DISMAR project technology (DISPRO-2) will be implemented in order to be able to merge and integrate the environmental information provided by the Project (EO products) as well as by the regional users (field data and other information).

2.5 Mangrove Maps

Objective

Mangrove forest is an integral part of the coastal environment. The root systems as well as the sediment fixed by the roots are important habitats for many organisms. Mangroves are important spawn and growing areas for fish, crab and shrimp which later on contribute to the diversity of coral reefs and other ecosystems. Mangroves are put at risk through the consequent growth of intensively operated shrimp farms and agricultural activity in coastal areas. Other risk factors are water pollution and drainage efforts for widening industrial and residential areas in coastal areas. As a consequence, 25 % of the mangrove forest has been lost during the last 20 years [Wilkie and Fortuna, 2003]. Monitoring of these changes is highly necessary.

For this purpose, mangrove related mapping products will be generated for two different areas in Mesoamerica:

- Yucatan Caribbean Coast (Mexico, Belize, Guatemala),
- Terraba-Sierpe Reserve (Costa Rica).

The products will comprise

- Local precise maps of mangrove forests,
- mangrove forest change maps showing the development of mangrove forests.

Data

Synthetic Aperture Radar (SAR) data from ERS-2 sensor will be used for mangrove mapping, because these are independent of cloud cover and acquisition time (day/night) and consequently assuring high data availability. Following the selected approach, for each area of interest a set of SAR scenes has been selected, which ensures at least a three-times coverage of the areas under investigation. Two phases of data acquisitions are foreseen:

- Historic Phase (SAR acquisitions from 1992 to 1996),
- actual Phase (SAR acquisitions from 2007).

Approach

The approach of Häme et al. [2004] and Wegmüller and Strozzi [2002] will be implemented for product generation: First, speckle will be reduced and images will be co-registered. Radar brightness and backscatter will be derived. Classification will generally be based on three layers that will be derived from brightness and backscatter of multitemporal SAR images:

- Average texture,
- average backscattering,
- temporal variability.

All layers will be integrated into multi-channel images and mosaiced for each period covering both areas of interest. The multi-channel image mosaics will be classified using a combined unsupervised-supervised approach using a pixel based classification approach. This will yield classification maps (Mangrove / Non Mangrove) for each phase (historic/actual) and each mapping area. Mangrove forest change maps will be produced using GIS functionality.

2.6 Study on Wildlife Migration

Objective

This information service will support investigations on wildlife migrations from Galapagos Islands to Isla de Cocos. It concerns the Tropical East Pacific Corridor (TEPC), a large marine protected area including the Galapagos (Ecuador) and Isla de Cocos (Costa Rica). The service will have both, a scientific and an operational component: The operational service will be to provide near-real-time satellite-derived maps of oceanographic conditions (sea surface temperature, water quality, surface current) in the TEPC area to support user's operational activities such as monitoring the oceanic conditions along the trajectories of satellite-tracked animals or supporting scientific campaigns at sea. The scientific component of the service will be to perform a study of oceanic conditions inducing, or at least facilitating, marine migrations from Galapagos to Isla de Cocos.

Data

Most of the data for the operational service will be obtained from on-going ESA-funded projects.

SST maps will be provided by the MEDSPIRATION project. The GLOBCOLOUR project will provide Chl-a data.

The surface currents will directly be produced by CLS using merged altimeter data from the JASON-1 and ENVISAT missions. SST and Chl-a maps will be provided on a daily basis, currents will be provided twice per week.

A number of individuals of both species are presently satellite-tracked (or about to be tracked) in the TEPC area. These data will be provided for the scientific component of the service by the involved user organizations.

Approach

The study of oceanic conditions inducing marine migrations from Galapagos to Isla de Cocos, focus will be on hammerhead sharks and leatherback turtles. It will be investigated, how water temperature, the presence of forage (derived from Chl-a product of ocean color maps) and favorable ocean currents influence their migration paths in the TEPC.

Different types of analyses regarding correlations between observed trajectories and satellite –derived oceanographic conditions along these trajectories [Polovina et al., 2001; Gaspar et al., 2006] are foreseen depending on quality and quantity of tracking data available.

3. GROUND TRUTH

Collection of ground truth data is needed for different reasons:

- Training for supervised classification of EO data in regional (e.g. MERIS) and local (SPOT, ERS) scale,
- validation of classification results (e.g. mangrove maps, biological corridor maps).

The collection of ground truth data is foreseen for the following products and services

- Mesoamerican biological corridor maps,
- coral reef maps,
- mangrove maps.

An initial training on ground truth has been done during DIVERSITY's 2nd User Meeting in Costa Rica in April 2007. During this meeting, different – product related - sites in the field have been visited from San José in order to test, to review and finally improve the foreseen ground truth data concept on-site. The training will be followed by other country specific trainings involving all people responsible for ground truth data collection in the project.

4. CONCLUSION

The project "DIVERSITY" is currently in the design engineering phase: User Requirements Engineering phase has been finalized, resulting in technical specifications of products. Based on these specifications, prototype products are under preparation. They will be evaluated by the users. During User Requirements Engineering, a goal-orientated collaboration between partners and users can be reported serving as a good base for future activities.

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