THE EXTRACTION OF COASTLINE USING OBIA AND GIS

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ABSTRACT:

The aim of the paper was to test the possibility of using object based image analyses of Landsat satellite data for worldwide assessment of sea coast changes over time. The coastline in this project was defined as the seaward margin of dunes or land vegetation. The proposed method uses Red and IRed channels of Landsat images for segmentation. The rule based classification of segmented objects is supported by DEM and wind fetch data modeled in GIS. The coastline extraction from polygons classified as sedimentary beaches are done by designed GIS tool.The results are used to discuss the usefulness of proposed method and to present some coastline changes in the southern Baltic along the polish coast.

1. INTRODUCTION

Coastal erosion is an important contemporary problem in many parts of the world. As a nearly 44 percent of world population lives within 150 km of the ocean and its marginal seas the IPCC prediction of an increase 19 to 50 cm in the global sea level by 2099 create real challenge to cope by managers and local populations. Rising waters strength the rates of coastal erosion intensifying the shift of the land-sea boundary inland. Such tendency has a high level of probability to continue in present century (Cardno, 2009). The changes of coastline over time are most often examined by detecting changes in position of land-water boundary. This boundary can be easily detected using infrared channels of satellite images characterized by a strong absorption in water (White, Asmar, 1999). However this method in opinion of some researches seems to have several disadvantages. First the position of the boundary depends on the short time changes of the sea level. Range of such sea level change for the most of coastlines exceeds two meters, what for some coast may cause changes in position of sea-land boundary up to one hundred meters. In result sea level observations during acquiring images are needed. This unable of using this method in a large scale or in secluded parts of the coast. Second problem is created by lack of stability of many beaches which have tendency for periodic changes of their localization. Summarizing this boundary is easy to detect on satellite images but at the same time many factors makes its position changing over time. In coastal geomorphology the term coastline in contrary to shoreline is used indicating the land margin which is submerged only in exceptional circumstances (Bird, 2008). This means that such defined coastline cannot be detected using remote sensing methods as a simple border between land and water. It can be rather defined as the base of cliffs or the seaward margin of dunes or land vegetation . This can't be easily done using traditional pixel based remote sensing methods. The aim of this project is to test possibility of using OBIA and GIS as a tool for detecting geomorphologic coastline from satellite images and describe its changes using statistics combining dense 100m sampling with length of analyses of several hundreds of kilometers. This approach would give possibility for world wide assessment of coastline changes due to sea level rise caused by global warming. There are several types of coastline of which the sedimentary type usually in form of beaches is most vulnerable to erosion. Types of sedimentary coastlines are defined using angle of incidence of the prevailing waves and wave exposure . There are nearly fifty sectors in the world's coastline that have been subsiding in resent decades creating threats of strong erosion (Bird, 2008). One of such places is the southern Baltic coast from Estonia to Poland for which five areas of investigation were defined (Figure 2).

Figure 1. Erosion of the Southern Baltic coast

2. DATA

In the project the main source of data were Landsat images of the areas of interest obtained for the time step of about 25 years. According to several researches this time step should be long enough to detect changes of about 2-3 meters per year. To improve detection of sedimentary beaches from others form of the coast auxiliary data of DEM and wind fetch were also used. It was also tested how efficient the geomorphologicaly defined coastline can be detected from Landsat images. For the small segment of coastline (the test area) QuickBird and Landsat based classification results were compared to asses the accuracy of proposed method.
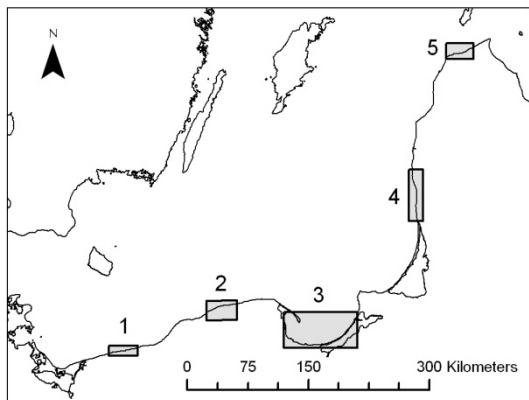
Figure 2. Areas of sea level change examination

2.1 Satellite data

Satellite Landsat data (Figure 3) were obtained from EROS portal (EROS, 2010) and QuickBird data were purchased from Digital Globe. The satellite data used in a project was summarised in Table 1.

Satellite	Date	Area
QuickBird	24.05.2006	test area
Landsat 7	17.07.2006	test area
Landsat 7	01.09.2009	aoi 1 present
Landsat 5	02.09.1984	aoi 1 past
Landsat 7	25.08.2009	aoi 2 present
Landsat 5	31.10.1984	aoi 2 past
Landsat 7	27.09.2009	aoi 3 present
Landsat 5	07.05.1986	aoi 3 past
Landsat 7	07.05.2009	aoi 4 present
Landsat 5	27.04.1985	aoi 4 past
Landsat 7	12.09.2009	aoi 5 present
Landsat 5	03.07.1986	aoi 5 past

Table 1. Satellite images used in a project

For QuickBird and Landsat data only Red and IRed channels were used. In case of Landsat data it was channels 3 and 4. It was decided not to use Panchromatic channel of Landsat 7 to make procedure working for both Landsat satellites (5 and 7).
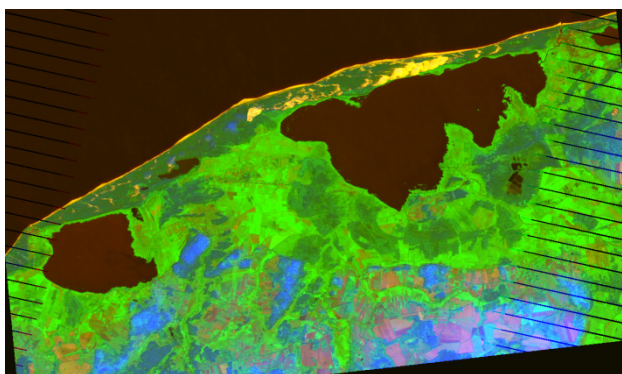

Figure 3. Landsat mosaic of AOI 2 (RGB = Red, IRed, DEM)

All DN data were transformed to irradiance. Also some geometrical correction has been done if needed.

2.2 Auxiliary data

2.2.1 SRTM

As the DEM model for test area and all areas of interest SRTM elevation model was chosen. In the project SRTM version 4 was used (Jervis at all., 2008). Its 90 meters spatial resolution and low level of errors are enough to detect cliff coast and what important the data are available for the whole world in range of latitude 56S to 60N.
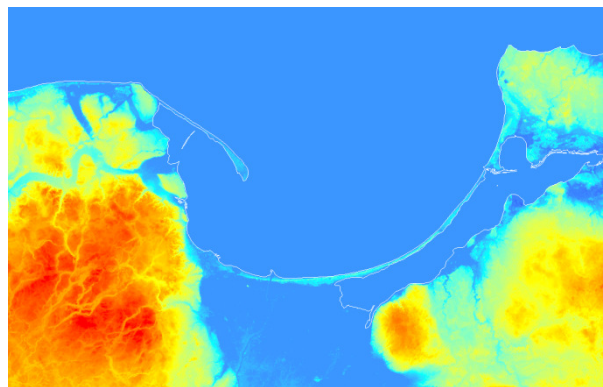

Figure 4. SRTM data for AOI 3 region

2.2.2 Fetch model

As a wind and waves are major forces shaping the coast fetch length is an important parameter in coastline classification. In this project its value were used to eliminate fetch-limited coast-lines. For modelling fetch a GIS model was created based on narrow spread of energy in the wave spectrum method which takes the average of fetch lengths measured at 3° intervals over a range of 12° to either side of wind direction (Sorrensen, 1993). The map created by interpolation from grid of points was extended for coastal zone by allocation to unable using fetch value for coastal pixels.
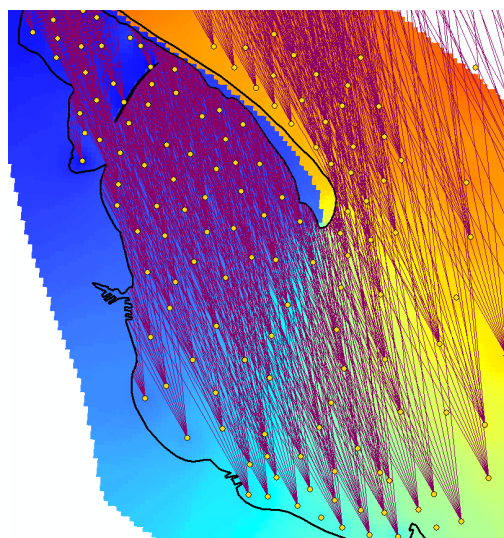

Figure 4. Fetch GIS model for part of AOI 3 region

3. METHODS

The method of extraction of coastline as a line shapfile consists of two separate stages. The first one uses OBIA process and ends with export of thematic map of polygons with assigning classes of water and beach. This part of work is done in Definiens Developer 7 software. The next stage is done in ArcGIS and its aim is to extract line of coastline from the polygons layer exported by Definiens Developer.

3.1 OBIA process

The OBIA process presented on Figure 5 uses RED and IRED channels of QuickBird or Landsat and DEM and fetch raster data. In pre-processing stage NDVI image is created by customised feature in form:

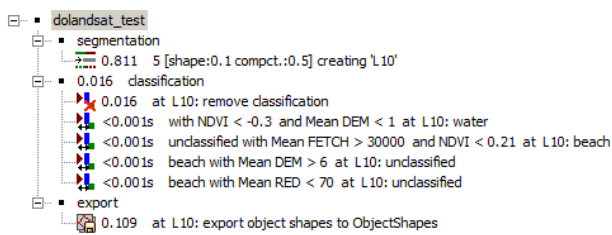$$NDVI = (RED - IRED) / (RED + IRED)$$

Figure 5. Definiens Developer process

The process consist of three steps. In the first step the multiresolution segmentation is done using Red and Ired images with equal weights. The shape 0.1 and compactness 0.5 is used. In the second step the rule based classification is carried out. In the begining all objects with Mean NDVI < -0.3 and DEM < 1 are classified as water. Next class beach is assigned to unclassified pixels with Mean Fetch > 30 km and NDVI < 0.21. Classification process ends with reclassification of pixels previously classified as beaches to unclassified where DEM is > 6m or RED is less than some threshold value depending on radiation condition (Figure 6).
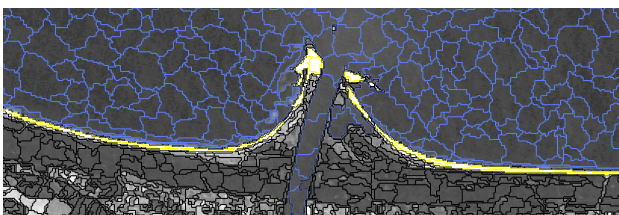

Figure 6. Definiens Developer results of classification (yellow = beaches, blue = water)

The third step consists of exporting all segmented polygons with assigned classes as polygon shapefile.

3.2 GIS tool of coastline delineation from beach polygons

The GIS tool of coastline delineation build in ArcGIS Model Builder is presented on Figure 7.
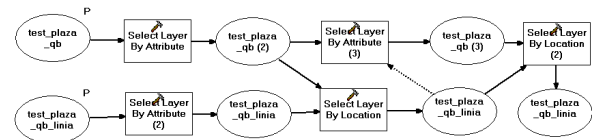

Figure 7. ArcGIS Builder model (Line Delineation Tool)

Before running the model the copies of both polygon shapfiles are made. Then intersect of polygons and its copies to line layers is done for both pairs of shapefiles. The Line Delineation Tool has two parameters in form of polygon and line prepared before. First records classified as beach in line layer are selected. Then records which share border with polygons classified as water are removed from selection. The new selection selects all records in polygon layer which are unclassified. Then the subset from selected lines is selected which share lines with unclassified polygons. After running a tool selected lines forming coastline are exported to new line shapefile.

3.3 Determination statistics of coastline change in GIS

The statistics of coastline change is calculated by comparing change of coastline localisation using sampling with interval of 100m (Figure 8). First the old coastline is converted to points with constant interval then the distance from these points is calculated to present coastline using an ArcGIS tool that join attributes to points from present coastline based on their spatial location. This function adds field with a distance of each point to a present coastline. The sign of change is defined by selecting points which are inside of polygon classified as a present beach and multiply their distance by minus one. In result a set of distances between a new and old coastline is obtained which allow for their statistical analyses.
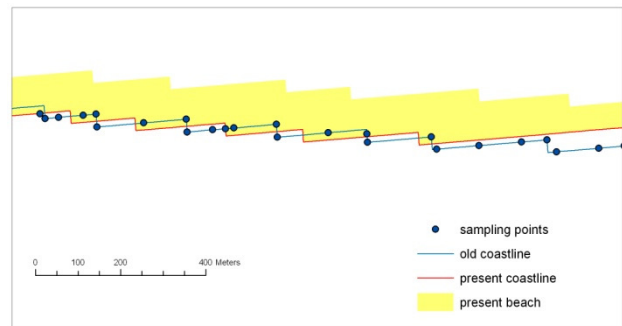

Figure 8. Method of determination of coastline change

4. RESULTS

4.1 Testing of accuracy using Landsat images

To test accuracy of using Landsat in coastline delineation the presented above method was used for QuickBird and Landsat images of the same test area (Figure 9). The images were made in May and July of the same year. The histogram of delineated coastlines difference is shown on Figure 10.
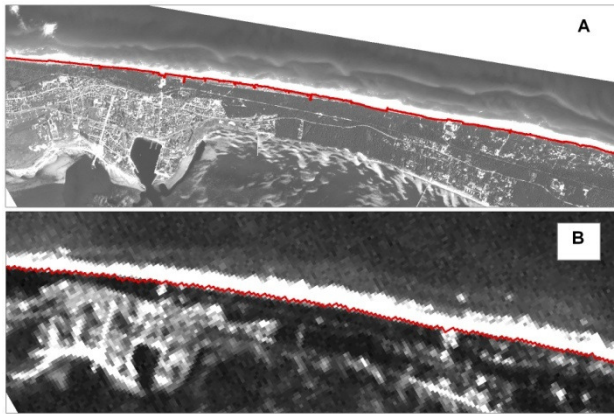
Figure 9. QuickBird (A) and Landsat (B) images of test area with overlaid extracted coastlines
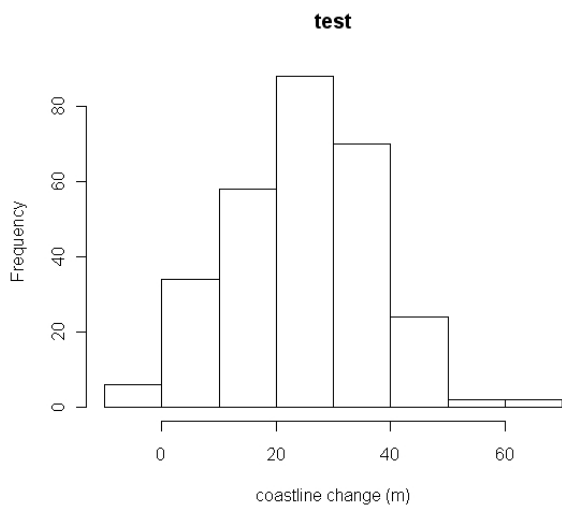

Figure 9. The histogram of delineated coastlines difference for test area

Figure 10. The histogram of delineated coastlines difference for test area

The observed shift in position of 20-30 may be caused by difference in scales of coastline objects and recognition possibilities on both images. It is possible that the coastline position is scale dependent due to of the scale of vegetation patches. In the test area some artificial protection systems were build on the beach which because of its size were detected on Quickbird images only.

4.2 Detection coastline changes in Southern Baltic

The results of analyses of coastline change in time for four selected areas of interest on Baltic coast are presented on Figure 10 as histograms. Only area of interest number 3 shows no signs of erosion. The histogram is symmetrical with the most frequent values occur at zero on axis of changes. On remaining histograms the most frequent values are about minus twenty meters. This means the existence of small erosion about 1 m per year. The strongest and the most evident erosion is observed on area of interest number 2.
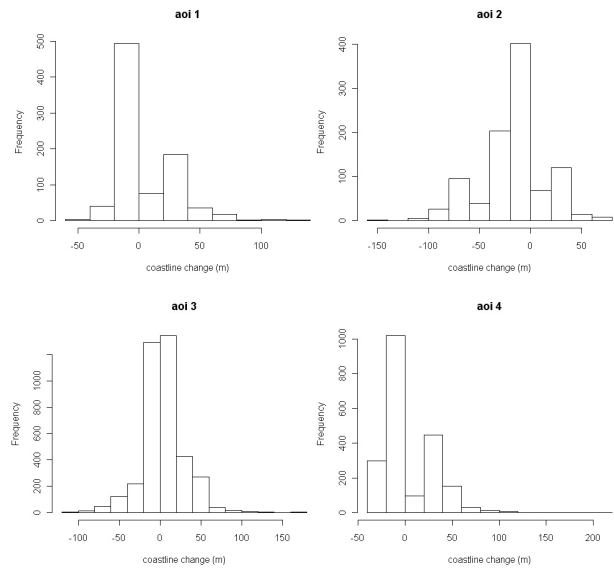
5. CONCLUSION

The presented method shows its ability to detect coastline changes in a broad scale using Landsat images. Using statistics allows quantitative analyses of small changes even of about 1 m per year. The bigger changes of few meters per year may be efficiently detected using this method along long segments of coast.

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