



## **Opération Cadre Régional Beachmed-e**

# Projet OpTIMAL Optimisation des Techniques Intégrées de Monitorage Appliquées aux Littoraux

## OANAK

Cahier Technique de Phase A

## Shoreline extraction using satellite imagery

### a. Introduction

The coastal area is a highly dynamic environment with many physical processes, such as tidal inundation, sea level rise, land subsidence, and erosion-sedimentation. Those processes play an important role for the shoreline change and coastal landscape development. Multiyears shoreline mapping is considered a valuable task for coastal monitoring and assessment. A shoreline is defined as the line of contact between land and a body of water. It is easy to define but difficult to capture, since the water level is always changing. Therefore, a problem exists in the mapping community because different public or private entities have compiled and published shoreline delineations that are based on different shoreline definitions. This has created confusion and uncertainty for those who use shoreline information daily for decision making, resource planning emergency preparedness etc. In USA for example, NOAA use the tide-coordinated shoreline, which is the shoreline extracted from a specific tide water level. The MLLW (Mean Lower Low Water) and MHW (Mean High Water) are used in this way to map shorelines that can be georeferenced. Both the MLLW and MHW are calculated from averages over a period of 18.6 lunar years (Li et al., 2001). In contrast, the U.S. Geological Survey (USGS) compiles shoreline data for the 1:24.000-scale topographic base map series from digital orthophoto quadrangles created from photographs that are not tide coordinated, thereby making the shoreline a snapshot in time (Scott et al., 2003). It is therefore obvious that since shoreline has a dynamic nature, its definition, mapping and monitoring are complicated tasks.

### b. Background

Different approaches to shoreline mapping and change detection have been used in the past. Traditional shoreline mapping in small areas is carried out using conventional field surveying methods. The method used today by the American National Geodetic Survey to delineate the shoreline is analytical stereo photogrammetry using tide-coordinated aerial photography controlled by kinematic GPS techniques (Di et al., 2003). Land vehicle-based mobile mapping technology has been proposed to trace water marks along a shoreline using GPS receivers and a beach vehicle. Lidar depth data have also been used to map shorelines (Shaw and Allen, 1995; Li, 1997).

Automatic extraction of shoreline features from aerial photos has been investigated using neural networks and image processing techniques (Ryan et al., 1991). Photogrammetric techniques have been employed to map the tide-coordinated shoreline from the aerial images that are taken when the water level reaches the desired level. Aerial photographs taken at these water levels are more expensive to obtain than satellite imagery.

Besides aerial imagery, spaceborn radar and especially Synthetic Aperture Radar (SAR) has proven a valuable tool for coastal monitoring. SAR imagery has also been used to extract shorelines at various geographic locations (Erteza, 1998; Chen and Shyu, 1998; Trebossen et al., 2005; Wu and Lee, 2007). SAR is a very promised technology, especially for Europe since the European Space Agency (ESA) is recognized as a world leader in SAR missions (ERS1, ERS2, Envisat, GMES-Sentinel-1).

In recent years, optical satellite remote sensing data has been used in automatic or semiautomatic shoreline extraction and mapping. Braud and Feng (1998) evaluated threshold level slicing and multi-spectral image classification techniques for detection and delineation of the Louisiana shoreline from 30-meter resolution Landsat Thematic Mapper (TM) imagery. They found that thresholding TM Band 5 was the most reliable methodology. Frazier and Page (2000) quantitatively analyzed the classification accuracy of water body detection and delineation from Landsat TM data in the Wagga region in Australia. Their experiments indicated that the density slicing of TM Band 5 achieved an overall accuracy of 96.9 percent, which is as successful as the 6-band maximum likelihood classification. Scott et al. (2003) proposed a semi-automated method for objectively interpreting and extracting the land-water interface has been devised and used successfully to generate multiple shoreline data for the test States of Louisiana and Delaware. This method was based on the application of Tasseled Cap transformation coefficients derived by the EROS Data Center for ETM+ data as described by Huang et al. (2002). The Tasseled Cap transformation was chosen over other methods primarily because of the objective and consistent manner in which it classifies pixels and because its use allowed the creation of other useful raster byproduct files. In operation, the Tasseled Cap transformation recombined spectral information of the 6 ETM+ bands into 3 principal view components through the use of coefficients derived by sampling known land cover spectral characteristics. Of the three principal view components created, i.e., Brightness, Greenness, and Wetness, the Wetness component is exploited to differentiate land from water. Zakariya et al. (2006) tried to detect shoreline changes for the Terengganu river mouth and related coastal area. Landsat data were used together with GIS capability to determine shoreline, sandy area and the changes occur specially on sediment movement from 1996 to 2002. RGB to IHS imagery conversion analysis ISODATA (Iterative Self-Organizing Data Analysis) classification were employed. Liu and Jezek (2004), as well as Karantzalos and Argialas (2007) automated extraction of coastline from satellite imagery by canny edge detection using digital number (DN) threshold.

Li et al. (2001) compared shorelines of the same area extracted using different techniques, evaluated their differences and discussed the causes of possible shoreline changes. The different shoreline products had been generated using different techniques: by digitizing from

aerial orthophotos, intersecting a digital water surface with a coastal terrain model and extraction from stereo satellite images. In addition, existing shorelines digitized from USGS maps and NOAA T-Sheets were included in their analysis.

With the development of remote sensing technology, satellites can capture high resolution imagery with the capability of producing stereo imagery. The new generation of very high spatial resolution satellite imaging systems, such as IKONOS and QuickBird, opens a new era of earth observation and digital mapping. They provide not only high-resolution and multispectral data, but also the capability for stereo mapping. Because of their high resolution and their short revisit rate (~3 days), IKONOS and QuickBird satellite images are very valuable for shoreline mapping and change detection, therefore their data have been used in several past studies. Wang et al. (2003) investigated a novel approach for automatic extraction of shoreline from IKONOS images using a mean shift segmentation algorithm. Di et al. (2003) investigated a novel approach for automatic extraction of shorelines from IKONOS imagery. 4 m and 1 m resolution IKONOS images along the Lake Erie shore were used. In the first step the images were segmented into homogeneous regions by mean shift segmentation. Then, the major water body was identified and an initial shoreline was generated. The final shoreline was obtained by local refinement within the boundaries of the candidate regions adjacent to the initial shoreline. Li et al (2003) used IKONOS stereo imagery in shoreline extraction. They presented the results of an experiment in which they attempted to improve IKONOS Rational Functions (RF) for a better ground accuracy and to employ the improved RF for 3-D shoreline extraction using 1-meter panchromatic stereo images in a Lake Erie coastal area. In this method, a 2D shoreline is extracted by manual digitizing on one IKONOS image; then corresponding shoreline points on the other image of the stereo pair are automatically extracted by image matching. The 3D shoreline is computed using photogrammetric triangulation. Chalabi et al. (2006) had used pixel-based segmentation on IKONOS image using DN threshold. The partition of the land and sea boundary was done using pseudo color which exhibits a strong contrast between land and water features.

Shoreline change is considered one of the most dynamic processes in coastal area. It has become important to map the shoreline change as an input data for coastal hazard assessment. There are many change detection techniques currently in use including visual interpretation, spectral-value-based technique (differencing, image regression, DN value analysis), multi-data composites, and change vector analysis. Visual interpretation of multi-temporal images for coastal monitoring was presented by Mazian et al. (1989) and Elkoushy and Tolba (2004). Bagli and Soille (2003) analyzed DN value using slicing operation for change monitoring. In addition, Whithe and El Asmar (1999) introduced an algorithm function and DN analysis to deviate the water from the land. The DN value analysis has also been applied on Landsat images, e.g. by Frazier and Page (2000) and Marfai (2003). Fromard et al. (2004) identified coastal changes that took place over the last 50 years, and related them

to natural processes of turnover and replenishment of mangrove forests. They used a combination of remote sensing techniques (aerial photographs and SPOT satellite images) and field surveys in the area of the Sinnamary Estuary, French Guiana. Mills et al. (2005) introduced the integration of the geomatics techniques to form accurate representations of the coastline. A highly accurate Digital Elevation Model (DEM), created using kinematics GPS, was used as control to orientate surfaces derived from the relative orientation stage of photogrammetry processing. Mostafa and Soussa (2006) have applied GIS and remote sensing technique to monitor the lake of Nasser including the shoreline dynamic. Three satellite Landsat images for Nasser Lake was available in a time series (1984, 1996, and 2001). Topography map of scale 1:50,000 that is suitable to the resolution of Landsat images, was used for developing DEM. Chalabi et al. (2006) assessed multi-data sources for monitoring shoreline in Kuala Terengganu, Malaysia using IKONOS and aerial photographs. Results of time series data were combined each other showing spatial change of shoreline. Marfai et al. (2007) illustrated the shoreline dynamic in a coastal area of Semarang-Indonesia using multisources spatial data. In spite of the technique and approach to shoreline monitoring and delineation, no single method has been implemented that is free from major disadvantages.

Therefore, shorelines of the same area may be extracted at different times using satellite data and represent changes appeared in difference periods illustrated as differences among them. There are two possible interpretations of the shoreline differences. One is that the shoreline in deed changed in the real world. The other possibility is that the differences are introduced by shoreline mapping errors. The accuracy of the shoreline derived from 1 meter IKONOS imagery should be about 2 - 4m (Zhou and Li 2000; Li et al., 2001, Grodecki and Dial, 2003), considering the fact that the accuracy of 3D ground control points (GCPs) reaches 2 - 3 m, with GCPs and the accuracy of identifying and locating conjugate shoreline points is about 1.5 pixels (1-2m). An optimistic estimation of the shoreline accuracy derived from the 4-meter IKONOS images in this specific case is about 8.5m (Li et al., 2001).

In most of the aforementioned methods, the shoreline extraction using IKONOS orthoimagery is based on land cover classification to discriminate the pixels corresponding to water bodies from those corresponding to land. Following, the resulted thematic image is converted to vector coverage, usually a polygon shapefile (ESRI, 2005) containing the polygons corresponding to each class. The shoreline is finally extracted from the polygon that corresponds to water by employing automatic or semi-automatic GIS procedures. Thus, the accuracy of the image orthorectification, as well as the accuracy of the image classification are the most important factors affecting the accuracy of the extracted shoreline. The orthorectification accuracy has discussed above. Concerning classification accuracy, it depends on the spatial, spectral and radiometric resolution of the image, as well as on the classification method. Numerous studies have been carried out using satellite images to

extract land cover types (Congalton, 1991; Ridd and Liu, 1998; Martin et al., 1988; Gong and Howarth, 1990; Chrysoulakis 2003; Gallego, 2004). The majority of the past studies rely on remote sensing data to classify land cover types using either raw DN or calibrated radiance values. However, if very high spatial resolution data such as IKONOS images are used, the land cover classification of coastal areas may be problematic because of the heterogeneity and small spatial size of the surface materials, which leads to significant sub-pixel mixing (Foody, 2000; Kontoes et al., 2000). Therefore, the spatial context should be taken into account in image classification and object oriented algorithms should be used. Improvements in the accuracy of classification have been achieved using a variety of sophisticated approaches including the use of neural networks (Berberoglu et al., 2000), fuzzy logic (Bastin, 1997; Zang and Foody 1998;), texture analysis (Stuckens et al., 2000), machine learning (VLS, 2007) and incorporation of ancillary spatial data in the classification scheme (Harris and Ventura, 1995; Vogelmann et al, 1998, Stefanov et al., 2001).

#### References

- Bagli S and Soille, P. (2003) Morhological automatic extraction of Pan-European coastline from Landsat ETM+ images. International Symposium on GIS and Computer Cartography for Coastal Zone Management, Genova, Italy.
- Bastin L (1997) Comparison of fuzzy c-means classification, linear mixture modeling and MLC probabilities as tools for unmixing coarse pixels. *International Journal of Remote Sensing*, 18: 3629 3648.
- Berberoglu S Lloyd CD Atkinson PM and Curran, PJ (2000) The integration of spectral and textural information using neural networks for land cover mapping in the Mediterranean. *Computers & Geosciences*, 26: 385 396.
- Braud, D. H. and W. Feng (1998). Semi-automated construction of the Louisiana coastline digital land/water boundary using Landsat Thematic Mapper satellite imagery. Department of Geography & Anthropology, Louisiana State University. Louisiana Applied Oil Spill Research and Development Program, OSRAPD Technical Report Series 97-002.
- Chalabi A Mohd-Lokman H Mohd-Suffian I Karamali K Karthigeyan V and Masita M (2006) Monitoring shoreline change using Ikonos image and aerial photographs: a case study of Kuala Terengganu area, Malaysia. In: Proceedings of the ISPRS Mid-term Symposium Proceeding, Enschede, The Netherlands.
- Chen LC and Shyu CC (1998) Automated Extraction of Shorelines from Optical and SAR Image. In: Proceeding of Asian Conference on Remote Sensing (http://www.gisdevelopment.net/ aars/acrs/1998/ps3/ps3013a.asp)
- Chrysoulakis N (2003) Estimation of the all-wave urban surface radiation balance by use of ASTER multispectral imagery and in situ spatial data. *Journal of Geophysical Research*, 108: 4582 (DOI:10.1029/2003JD003396).
- Congalton RG (1991) A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data. *Remote Sensing of Environment*, 37: 35-46.
- Di K Wang J Ma R and Li R (2003) Automatic shoreline extraction from high-resolution IKONOS satellite imagery. In proceeding of the Annual ASPRS Conference, Anchorage, Alaska.
- Elkoushy AA and Tolba RA (2004) Prediction of shoreline change by using satellite aerial imagery. In: Proceeding of the XX ISPRS Congress, Istanbul, Turkey.
- Erteza IA (1998) An automatic coastline detector for use with SAR images. SANDIA Report SAND98-2102. Sandia National Laboratories, California.
- ESRI (2005) ArcGIS 9. What is ArcGIS 9.1? Environmental Systems Research Institute, Redlands, California.
- Foody GM (2000) Estimation of sub-pixel land cover composition in the presence of untrained classes. *Computers & Geosciences*, 26: 469 – 478.
- Fraser CS and Hanley HB (2003) Bias compensation in rational functions for IKONOS satellite imagery. *Photogrammetric Engineering and Remote Sensing*, 69: 53-57.
- Fraser CS Hanley HB and Yamakawa T (2002a) Three-dimensional geopositioning accuracy of IKONOS imagery. *Photogrammetric Record*, 17: 465–479.
- Fraser CS Baltsavias E and Gruen A (2002b) Processing of IKONOS imagery for sub-metre 3D positioning and building extraction. *ISPRS Journal of Photogrammetry and Remote Sensing*, 56, 177–194.

- Frazier PS and Page KJ (2000) Water body detection and delineation with Landsat TM data. *Photogrammetric Engineering and Remote Sensing*, 66: 147–167.
- Fromarda F Vegaa C and Proisy C (2004) Half a century of dynamic coastal change affecting mangrove shorelines of French Guiana. A case study based on remote sensing data analyses and field surveys. *Marine Geology*, 208: 265–280.
- Gallego FJ (2004) Remote sensing and land cover area estimation. *International Journal of Remote Sensing*, 25: 3019-3047.
- Gong P and Howarth PJ (1990) The use of structural information for improving land-cover classification accuracies at the rural urban fringe. *Photogrammetric Engineering and Remote Sensing*, 56: 67 73..
- Grodecki J and Dial G (2003) Block adjustment of highresolution satellite images described by rational polynomials. *Photogrammetric Engineering and Remote Sensing*, 69: 59-68.
- Harris PM and Ventura SJ (1995) The integration of geographic data with remotely sensed imagery to improve classification in an urban area. *Photogrammetric Engineering and Remote Sensing*, 61: 993 998.
- Huang C Wylie B Homer C Yang L and Zylstra G (2002) Derivation of a tasseled cap transformation based on Landsat 7 ETM at-satellite reflectance. *International Journal of Remote Sensing*, 23: 1741-1748.
- Karantzalos K and Argialas D (2007) Automatic shoreline mapping from panchromatic satellite images. In: Proceedings of 8<sup>th</sup> Pan-Hellenic Geographic Conference. Greek Geographical Society (in Greek).
- Kontoes CC Raptis V Lautner M and Oberstadler R (2000) The potential of kernel classification techniques for land use mapping in urban areas using 5 m-spatial resolution IRS-1C imagery. *International Journal of Remote Sensing*, 21: 3145–3151.
- Leica (2005) ERDAS Field Guide. Leica Geosystems. Atlanta, Georgia, USA.
- Li R Di K and Ma R (2001) A Comparative Study of Shoreline Mapping Techniques. In: Proceeding of the 4<sup>th</sup> International Symposium on Computer Mapping and GIS for Coastal Zone Management, Halifax, Nova Scotia, Canada.
- Li R Di K and Ma R (2003) 3-D Shoreline Extraction from IKONOS Satellite Imagery. *Marine Geodesy*, 26:107–115.
- Li R (1997) Mobile mapping: An emerging technology for spatial data acquisition. *Photogrammetric Engineering and Remote Sensing*, 63: 1165-1169.
- Liu H and Jezek KC (2004) Automated extraction of coastline from satellite imagery by integrating canny edge detection and locally adaptive thresholding methods. *International Journal of Remote Sensing*, 25: 937–958.
- Marfai MA Almohammad H Dey S Susanto B King L (2007) Coastal dynamic and shoreline mapping: multi-sourcesspatial data analysis in Semarang Indonesia. *Environ Monitoring and Assessment*, DOI 10.1007/s10661-007-9929-2.
- Marfai MA (2003) Monitoring of the coastal zone dynamics by means of multi-temporal Landsat TM. In: Proceedings of the annual scientific meeting XII, Indonesian remote sensing society, Bandung.
- Martin LRG Howarth PJ and Holder G (1988) Multispectral classification of land use at the rural-urban fringe using SPOT data. *Canadian Journal of Remote Sensing*, 14: 72 79.
- Mazian HI Aziz I and Abdullah A (1989) Preliminary evaluation of photogrammetric-remote sensing approach in monitoring shoreline erosion. In: Proccedings of the 10<sup>th</sup> Asian Conference on Remote Sensing Proceeding. Kuala Lumpur.

- Mills JP Buckley SJ Mitchell HL Clarke PJ and Edwards SJ (2005) A geomatics data integration technique for coastal change monitoring. *Earth Surface Processes and Landforms*, 30: 651–664.
- Mostafa MM and Soussa HK (2006) Monitoring of Lake Nasser using remote sensing and GIS techniques. In: Proceedings of the ISPRS Mid-term Symposium, Enschede, The Netherlands.

PCI (2003) OrthoEngine User Guide, PCI Geomatics, Ontario, Canada.

- Ridd MK and Liu J (1998) A comparison of four algorithms for change detection in an urban environment. *Remote Sensing of Environment*, 63: 95 100.
- Ryan TW Sementilli PJ Yuen P and Hunt BR (1991) Extraction of shoreline features by neural nets and image processing. *Photogrammetric Engineering and Remote Sensing*, 57: 947-955.
- Scott JW Moore LR Harris WM Reed MD (2003) Using the Landsat 7 Enhanced Thematic Mapper Tasseled Cap Transformation to Extract Shoreline. Open-File Report OF 03-272 U.S. Geological Survey.
- Shaw B and Allen JR (1995) Analysis of a dynamic shoreline at Sandy Hook, New Jersey, using a geographic information system. In: Proceedings of ASPRS/ACSM, pp. 382-391.
- Stefanov W L, Ramseyc MS and Christensen PR (2001) Monitoring urban land cover change: An expert system approach to land cover classification of semiarid to arid urban centers. *Remote Sensing of Environment*, 77: 173 – 185.
- Stuckens J, Coppin PR and Bauer, ME (2000) Integrating contextual information with per-pixel classification for improved land cover classification. *Remote Sensing of Environment*, 71: 282 296.
- Toutin Th (2004) Review article: Geometric processing of remote sensing images: models, algorithms and methods. *International Journal of Remote Sensing*, 25,1893–1924
- Toutin Th (2003a) Block bundle adjustment of Ikonos in-track images. *International Journal of Remote* Sensing, 24: 851–857.
- Toutin Th (2003b) Error tracking in IKONOS geometric processing using a 3D parametric modelling. *Photogrammetric Engineering and Remote Sensing*, 69: 43–51.
- Trebossen H Deffontaines B Classeau N Kouame J and Rudant J-P (2005) Monitoring coastal evolution and associated littoral hazards of French Guiana shoreline with radar images. *Comptes Rendus Geosciences*, 337: 1140-1153.
- Vogelmann JE Sohl T and Howard SM (1998) Regional characterization of land cover using multiple sources of data. *Photogrammetric Engineering and Remote Sensing*, 64: 45 57.
- VLS (2007) Feature Analyst Version 4.1 for Imagine. Reference Manual. Visual Learning Systems Inc. Missoula, USA.
- Wang KDJ Ma R and Li R (2003) Automatic shoreline extraction from high resolution Ikonos satellite imagery. In: Proceedings of the ASPRS Annual Conference, Anchorage, Alaska.
- Whithe K and El Asmar HM (1999) Monitoring changing position of coastline using thematic mapper imagery, an example from the Nile Delta. *Geomorphology*, 29: 93–105.
- Wu TD and Lee MT (2007) Geological Lineament and Shoreline Detection in SAR Images In Proceeding of IEEE Geosciences and Remote Sensing Symposium (IGARSS 2007), Barcelona, Spain.
- Zang J and Foody GM (1998) A fuzzy classification of sub-urban land cover from remotely sensed imagery. *International Journal of Remote Sensing*, 19: 2721 2738.

Zhou G and Li R (2000) Accuracy Evaluation of Ground Points from IKONOS High-Resolution Satellite Imagery. *Photogrammetric Engineering and Remote Sensing*, 66: 1103-1