TOWARD PRECISE SHORELINE DETECTION AND EXTRACTION FROM REMOTELY SENSED IMAGES WITH THE USE OF WET AND DRY SAND SPECTRAL SIGNATURES

Panos Drakopoulos[1,]*, George Ghionis[2], Kostas Lazogiannis[2], and Serafim Poulos[2]

[1]Department of Optics and Optometry, Technological Educational Institute of Athens, Ag Spyridonos 12210, Athens, Greece
[2] Department of Geology and Geoenvironment, University of Athens, Zografou, 15784, Athens, Greece

Presented at the 4th International Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE), June 24 to 28, 2013, Mykonos, Greece

ABSTRACT

Shoreline displacements are due to physical, anthropogenic and environmental factors such climate change. Remote sensing has become an essential tool for monitoring shoreline changes and understanding the physical processes in the coastal environment. However, ground truthing is necessary in order to detect the limits of sea-level inundation and /or wave run up. Within the framework of the THALES-DAPHNE project, we have initiated an investigation regarding the reflectance properties and spectral signatures of various samples of dry and wet beach sands. To this end, spectral reflectance characteristics for a collection of sand samples from various Hellenic beaches have been measured in the laboratory under dry and wet conditions. In addition ongoing field measurements are in process along the beach face of the delta of the River Pinios,that debouches at the NW coast of the microtidal Aegean Sea.

KEYWORDS: Environmental monitoring; Remote Sensing, shoreline position

1. INTRODUCTION

Deltaic coasts are amongst the most vulnerable coastal environments either because of human impact (e.g. the construction of dams) and/or because of climate change (e.g. sea level rise, changes in storminess [1]). The study of the seasonal and decadal changes of shoreline position is one of the key processes in understanding the morphodynamic evolution of such sedimentary environments. In particular, for the Pinios delta, recent observations (Thalis-DAPHNE research project) along the deltaic coast revealed seasonal changes in shoreline position in the order of few meters, with the exception of its mouth, where its southern part retreated by more than 10 m after the SE storm of January 2012.

Within this concept, high resolution remote sensing information from already operational satellite sensors (e.g. SPOT-5, IKONOS, Quickbird, Formosat, WorldView-2, Geoeye, TerraSAR-X, TanDEM-X), recently launched or future missions (e.g. SPOT-6/7, Pleiades, TerraSAR-X2, with accuracy down to 0.5 m) could be used in principle to extract information on the morphological characteristics of the beach (e.g. shoreline length/position, beach width and area) and to contribute in a better understanding of the medium-term beach zone dynamics. The procedure includes the collection of in-situ reflectance measurements, the creation of a local database of spectral signatures for the differentiation between the wet part of the lower beach face (swash zone) and the dry upper part, and finally the correlation with corresponding satellite data. This will be a vital step that will lead to an improved determination of the shoreline position through the assessment of the satellite information accuracy and a better image classification of the beach sediment nature.

The selection of the deltaic coast of Pinios river (Figure 1) as a study area, is based on the following facts: *(i)* Pinios is the largest Greek river having its drainage basin (some 10,000 km^2) within Greek geographical boundaries; *(ii)* it is the only river in Greece with very limited flow controls (in less than 10% of its catchment; *(iii)* the Pinios delta is recognized as an environmentally sensitive coastal zone and as such, it is protected by the NATURA 2000 network.

The Pinios River delta has a cuspate shape and is exposed to moderate wave activity (mean wave heights ~1 m); the highest (although rare) offshore waves approach from the SE and because of the long fetches, can locally exceed 4 m in height [2]. The deltaic coast is characterized by sandy beaches with low sand dunes, consisting (mostly) of medium – sized sand abundant in quartz and feldspars.

The scope of this contribution is to develop a tool that will be used to identify the shoreline position with high accuracy. The results will be verified using satellite images calibrated through ground truthing on both the wet lower shoreface and the adjacent dry (beyond the wave reach) part of the upper beach face. This work also con-

* Corresponding author

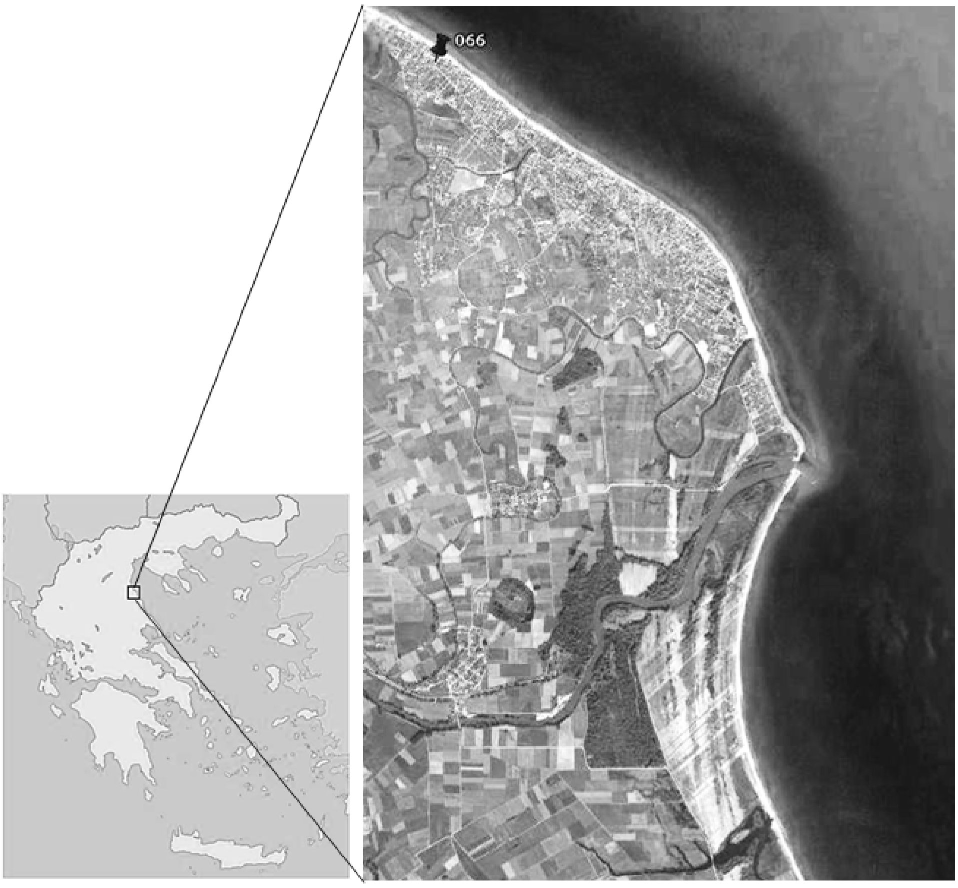

FIGURE 1 - Map of the study area and sampling site (image source: Google Earth).

tributes to an effective coastal zone management facilitating a rapid and cost-effective assessment of shoreline retreat induced by changes in mean sea level and storm surges, in order to identify hot-spots of beach erosion.

2. MATERIALS AND METHODS

For the development of the procedure, reflectance spectra were initially acquired in the laboratory. For this reason the sand samples were placed in ~7 cm diameter, 1.5 cm deep tin plates. The measurements were performed by means of a reflectance probe placed at a 45° monitoring and illumination angle thus avoiding possible specular components. The sensing output of the probe was fed to an HR4000 miniature spectrometer while the illumination input was coupled to a tungsten-halogen light source operating at 3100 K (all components supplied by Ocean Optics). Reference reflectance was provided by a 99% diffuse reflectance standard spectralon™ plate. For the field measurements, the various radiances were probed under daylight conditions normal to the surface through a 6° FOV Gershun tube attached via an optical fiber to a portable Jaz (Ocean Optics) field spectrometer. Spectral data were collected throughout the 350 -850 nm range with 1 nm resolution.

The wavelength dependent reflectance measured is defined as:

$$R(\lambda) = R_g \frac{L_{\text{sand}}(\lambda) - L_{\text{dark}}(\lambda)}{L_{\text{spec}}(\lambda) - L_{\text{dark}}(\lambda)} \quad (1)$$

Where $L_{sand}(\lambda)$ is the radiance from the sand sample, $L_{spec}(\lambda)$ the radiance from the spectralon™ plate and R_g its known reflectance.

For classification purposes, the following indices were estimated [3,4]:

$$BI = \left[\frac{R^2 + G^2 + B^2}{3}\right]^{1/2}, \; HI = \frac{(2R - G - B)}{(G - B)} \quad (2)$$

where *BI*, the brightness index, is indicative of the average reflectance magnitude and *HI* the hue index related to the dominant colour of the sample. We have also introduced the simple slope index:

$$SI = (R - B) \quad (3)$$

This index is proportional to the finite element first derivative (slope from red to blue) and is closely tied to the water content of the sample. The parameters *R*, *G*, and *B* denote the reflectances at red, green and blue wavelengths respectively. The indices were evaluated at the center of the corresponding band of the IKONOS satellite (*R*=665 nm, *G*=551 nm, *B*=480 nm) using the appropriate boxcar bandwidth.

In addition we evaluated the *Y* – luminance component of the sampled spectra which corresponds to the pixel value of the panchromatic images:

$$Y = \int_{380}^{780} R(\lambda)\overline{y}(\lambda)d\lambda \quad (4)$$

The laboratory measurements were carried on samples from 11 beaches all around Greece. The samples were initially dry and gradually the moisture content was increased while the reflectance was monitored. Pinios beach in situ reflectance spectra were also collected at station 66, located 5 km north of river's outfall. In addition, beach sediment samples were analysed granulometrically by dry-sieving (for material coarser than 0.0625 mm) and characterised according to Folk's (1980) nomenclature [4].

3. RESULTS AND DISCUSSION

The measured reflectance spectra showed that different kinds of sand have dissimilar optical properties and spectral signatures, as expected. Whitish sands have high reflectance (~70% in the visible part of the spectrum), while dark grey sands low (~20%), with an overall ascending slope of the spectrum towards longer wavelengths. Colored sand samples generally have spectral curvatures associated to the dominant color (Figure 2). Grain size seems to contribute to the overall albedo which increases with decreasing grain size.

Experiments including dry and wet samples showed that increased wetness lowers, proportionally, the albedo of the samples across the whole spectrum (Figure 3a). Field measurements of the spectral reflectance of the wet and dry sediments of the foreshore zone along the deltaic coast of the River Pinios produced similar results (Figure 4a).

Two spectral indices were found to be highly efficient in differentiating between wet and dry spectra: dry samples have high Brightness Index (average reflectance magnitude) and Slope Index; increased water content in the samples results in proportionally lower Brightness Index and Slope Index (3b, 4b). Moreover the presence of water shifts significantly the dominant colour (3c, 4c). Therefore, depending on the water content, two separate classes of signatures exist in the three dimensional space of *BI*, *SI* and *HI* and can be used to classify beach sand samples as dry or wet (Figure 4d). Evaluation of a similar set of classification indices proposed by Ouillion et al. [6] but for dry samples only, did not exhibit as high sensitivity for different moisture contents.

In Table 1 the granulometric results for the location where in-situ measurements were performed are shown. The mean grain size is similar significantly throughout the sampling region and therefore no variation in the albedo is expected due to this factor.

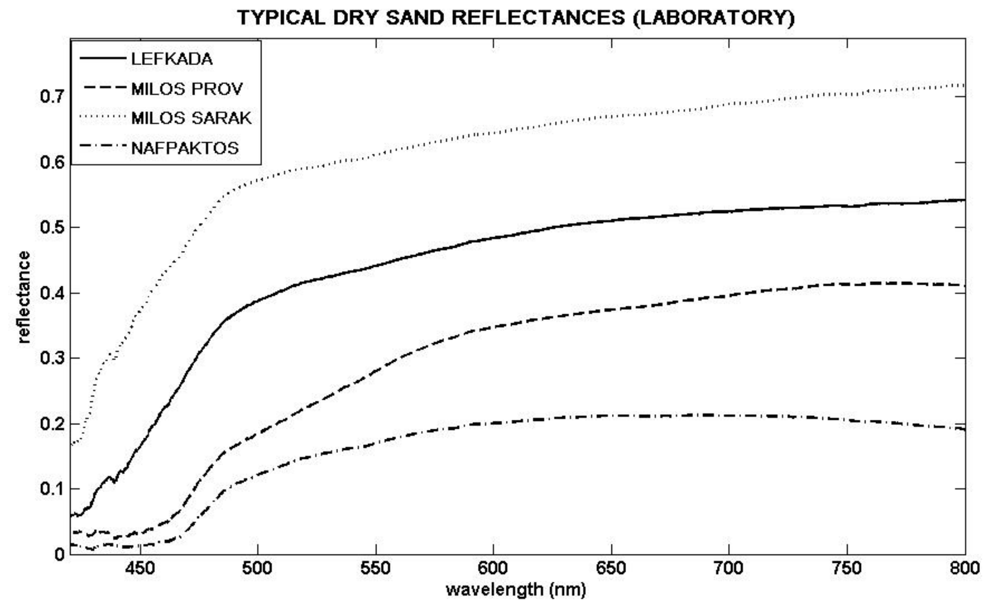

FIGURE 2 - Reflectance spectra of different sand types as measured in the laboratory. To avoid congestion only four representative spectra are displayed.

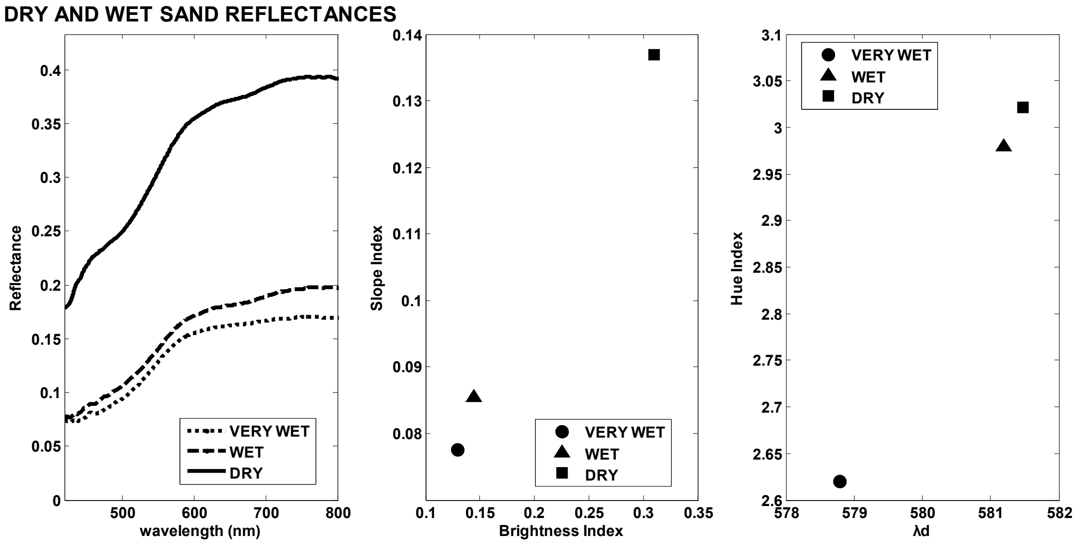

FIGURE 3 - (a) Sand reflectance spectra in the visible for variable moisture content. (b) Variation of slope index and brightness index with moisture content. (c) Variation of hue index with water content – here plotted as a function of the dominant colour. The sample is from the Glyfada beach (Near Athens).

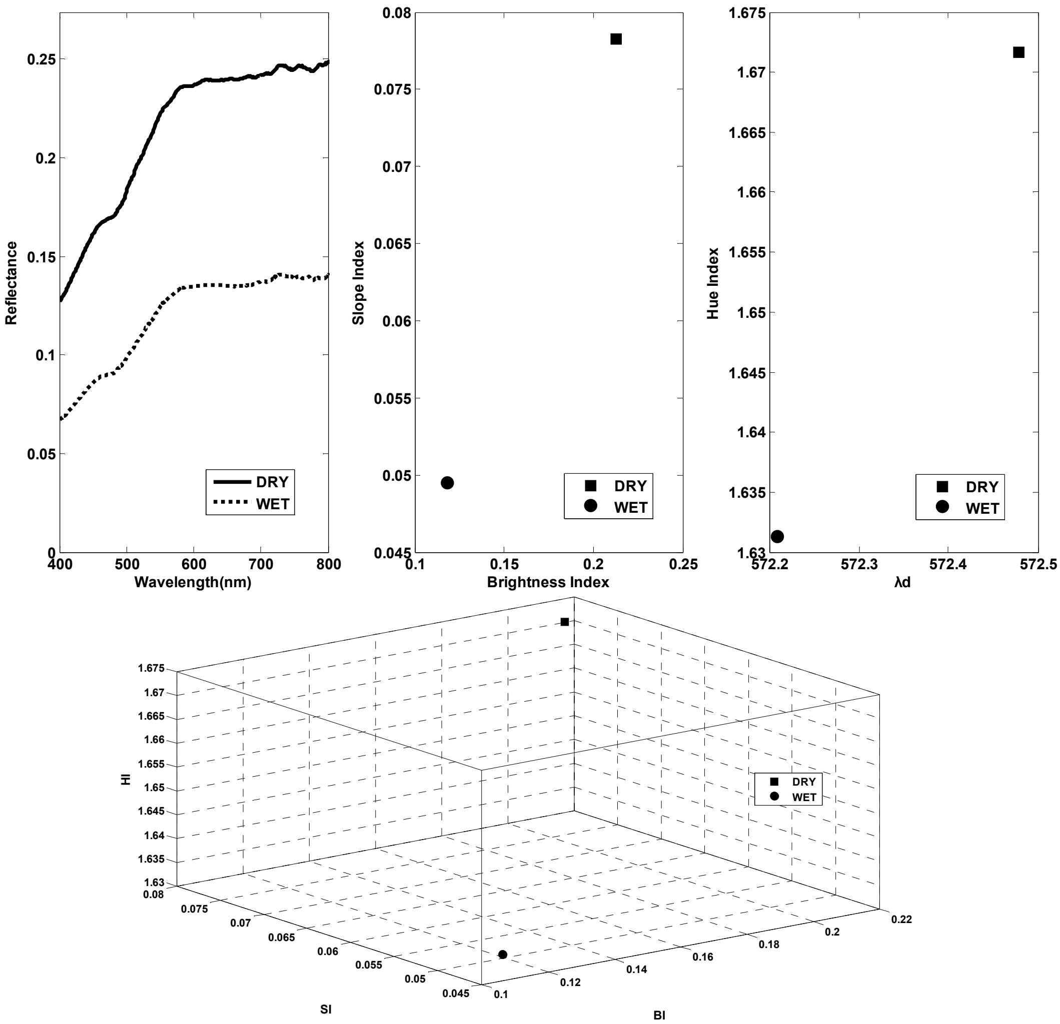

FIGURE 4 - (a-c) Similar to Figure 3 but for field measured spectral reflectance under daylight conditions (Delta of Pinios). (d) Wet and dry properties in 3D index space.

TABLE 1 - Granulometric results for the beach sediments at Station 8 (Pinios river delta).

Sample	Mean grain size (Mz)	Characterization (Folk Class)
66S (Swash zone)	1.45	slightly gravelly sand
66B (Beach face)	1.55	slightly gravelly sand

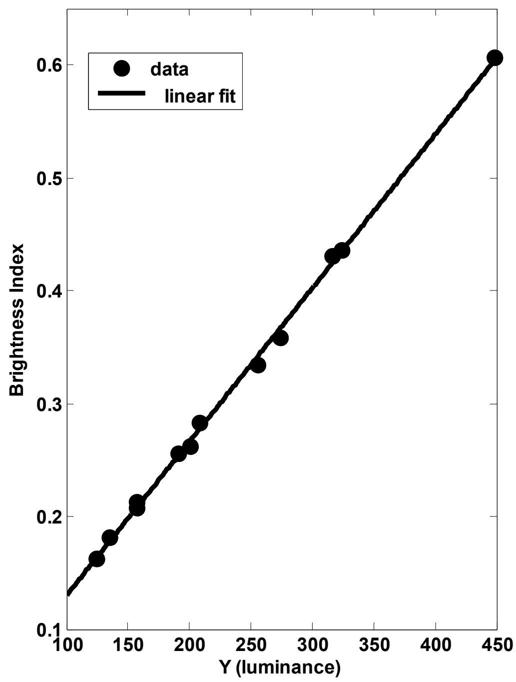

FIGURE 5 - Brightness index of the eleven sand samples plotted against their panchromatic luminance.

An interesting correlation is that arising between CIE panchromatic luminance (Y) and brightness index –BI (Figure 5). As is indicated, higher spatial resolution panchromatic data can be used to support lower resolution sand brightness index data and thus increase the accuracy in the identification of the shoreline position.

4. CONCLUSIONS

This paper presents some of the preliminary results of an investigation on the reflectance properties and spectral signatures of various samples of dry and wet beach sand. Future work may include monitoring of the in-situ sediment moisture [7] as well as an identification of the mineralogical composition of each sample. Additional indices comprising the water- sensitive near infrared band will be investigated. Nevertheless, initial laboratory and field results seem encouraging enough that a database with distinct spectral signatures for various sand types and conditions of sand can be built. Having established typical ranges of spectral indices for dry -wet state of a particular beach from in-situ measurements, remotely sensed images can be potentially used for the automated identification and extraction of the shoreline position by engaging neural network models. The next major step to undertake will be the association and comparison of the above indices with indices estimated from satellite images acquired concurrently with the in-situ measurements.

ACKNOWLEDGEMENTS

This work is supported by the research program THALES - DAPHNE (MIS: 375908) that is funded by the Operational Programme "Education and lifelong learning, 2007-2013" of the Ministry of Education and Religious Affairs, Culture and Sports

The authors have declared no conflict of interest.

REFERENCES

[1] Vörösmarty C.V., Meybeck M., Fekete B., Sharma K., Green P. and Syvitski J. (2003). Anthropogenic sediment retention: major global impact from registered river impoundments, Global and Planetary Change, (39), 169–190.

[2] Soukissian, T., Hatzinaki, M., Korres, G., Papadopoulos, A., Kallos, G. and Anadranistakis, E. (2007). Wind and Wave Atlas of the Hellenic Seas, Hellenic Centre for Marine Research Publ., 300 pp., ISBN-987 960 86651 9-4.

[3] Mathieu R., Pouget M., Cervelle B. and Escadafal R. (1998). Relationships between Satellite-Based Radiometric Indices Simulated Using Laboratory Reflectance Data and Typic Soil Color of an Arid Environment, Remote Sens. Environ., (66), 17-28.

[4] Ray S.S., J.P. Singh, G. Das and S. Panigrahy, (2004). Use of High Resolution Remote Sensing Data for Generating Site-specific Soil Mangement Plan, in ISPRS Archives Vol XXXV (B7), 132-137.

[5] Folk, R.L. (1974). The petrology of sedimentary rocks: Austin, Tex., Hemphill Publishing Co.

[6] Ouillion S., Lucs Y. and Gaggelli J. (2002) Hyperspectral detection of sand, Proceedings, 7th International Conference on Remote Sensing for Marine and Coastal Environments, Miami Florida

[7] Kaya S., Seker D., Yasa N., Kabdasli S. and Tanik A. (2007). Utility of remote sensing technology for determining characteristics of sandy beaches, Clean 2007, 35(6), 654 – 659

Received: March 19, 2014
Accepted: April 02, 2014

CORRESPONDING AUTHOR

Panos Drakopoulos
Department of Optics and Optometry
Technological Educational Institute of Athens
Ag Spyridonos
12210 Athens
GREECE

Phone: +30 2105385747
E-mail: pdrak@teiath.gr