TECHNOLOGICAL EDUCATIONAL INSTITUTE OF ATHENS

Use of satellite imagery for automated monitoring of the shoreline retreat rate

P.G. Drakopoulos[1], E. Oikonomou[2], G. Skianis[3], S.E. Poulos[3], A.Vaiopoulos[3], K. Lazogiannis[3,4], G. Ghionis[3], A. Velegrakis[4]

1. Department of Optics and Optometry, T.E.I. of Athens
2. Department of Civil Engineering Surveying & Geoinformation, T.E.I. of Athens
3. Department of Geology and Geoenvironment, University of Athens
4. Department of Marine Sciences, University of the Aegean

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ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΕΘΝΙΚΗΣ ΠΑΙΔΕΙΑΣ ΚΑΙ ΘΡΗΣΚΕΥΜΑΤΩΝ
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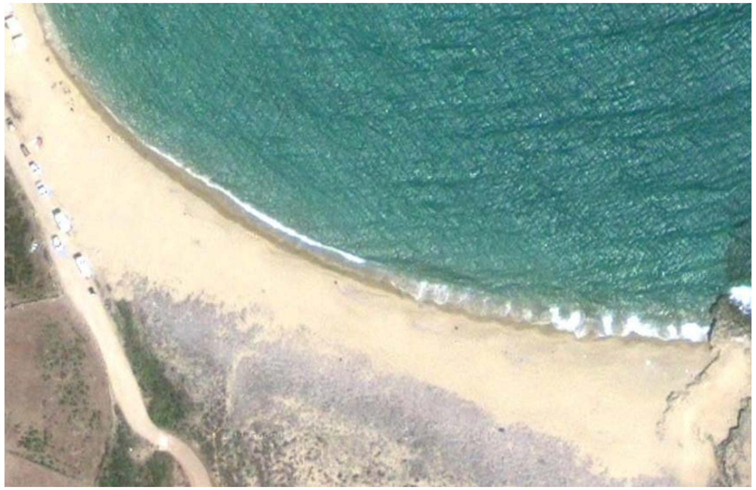
The concept

- Shoreline displacements are due to physical, anthropogenic and environmental factors, including climate change.
- Shoreline mapping and shoreline change detection are critical for coastal resource management, coastal environmental protection, and sustainable coastal development and planning.
- The scope of this work is to develop a cost-effective and reliable tool into identifying the shoreline position with high accuracy



The approach

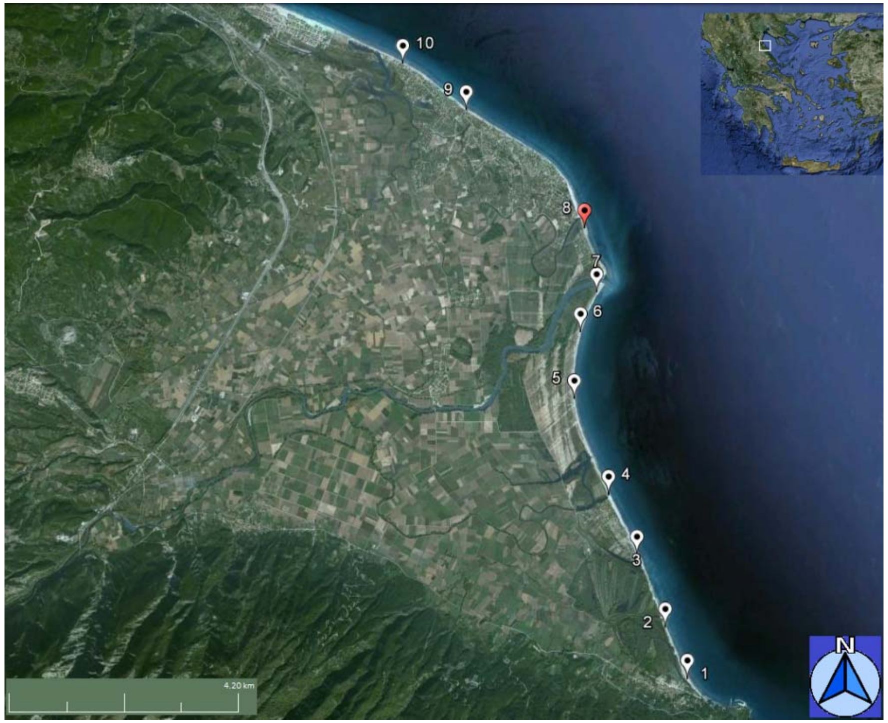
1. Initiate investigation regarding the reflectance properties and spectral signatures of various samples of dry and wet beach sands.
2. Develop a database of the reflectance curves for several types of the sandy beaches around Hellenic coasts as a function of hue, moisture content, grain size
3. Using the spectral signature information, develop a remote sensing technique for the precise shoreline detection and extraction from remotely sensed images (i.e. differentiation between the wet part of the lower beach face and the dry upper part)

TOWARDS BUILDING UP A SPECTRAL SIGNATURE DATABASE

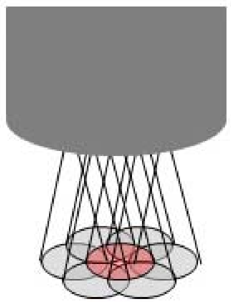
Spectral reflectance characteristics for a collection of sand samples from various Hellenic beaches have been measured in the laboratory under dry and wet conditions.

pilot project area

- We test the approach using 2m resolution Worldview images in a pilot project area along the beach face of the delta of the River Pinios, that debouches at the NW coast of the microtidal Aegean Sea.
- Pinios is the only river in Greece with very limited flow controls
- The deltaic coast is characterised by sandy beaches with low sand dunes
- Pinios delta is recognized as an environmentally sensitive coastal zone and as such, it is protected by the NATURA 2000 network



Lab instrumentation



- **HR4000 spectrometer resolution: 0.75 nm range: 200-1050 nm**
- **fiber optic diffuse reflectance probe**
- **tungsten-halogen light source (360-2500 nm), 3100 K**
- **diffuse reflectance standard (spectralon plate)**

Field instrumentation

- **Jaz (Ocean Optics) spectrometer resolution: 1.3 nm range: 250-800 nm**
- **Optical fiber equipped with a 6^{o} FOV Gershun tube**
- **Daylight conditions (small sun zenith angle)**
- **spectralon reflectance plate.**

From hyperspectral reflectance to Classification indices

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

$L_{sand}(\lambda)$ is the radiance from the sand sample
$L_{spec}(\lambda)$ the radiance from the spectralon
R_g the known reflectance of the plate.

$$BI = \left[\frac{CH5^2 + CH3^2 + CH2^2}{3}\right]^{1/2}, \quad HI = \frac{(2CH5 - CH3 - CH2)}{(CH3 - CH2)}, \quad MRI = \frac{CH7^2}{CH2 \times CH3^3}$$

BI, the brightness index, is indicative of the average reflectance magnitude
HI, hue index, accounts for the relative proportions of three primary colors
MRI, modified redness index, is indicative of the (infra)redness of the signature
SI, slope index, proportional to the finite element first derivative (slope from red to blue) and it is closely tied to the water content of the sample $SI=(CH5-CH2)$

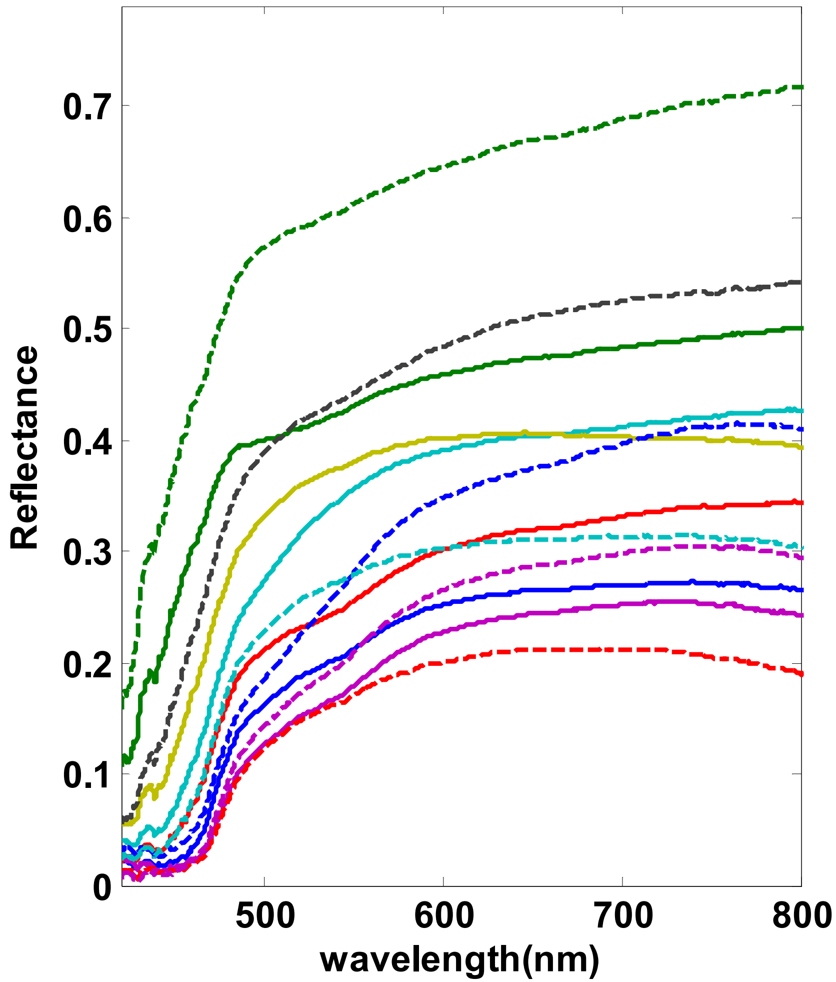
The indices were evaluated at the center of the corresponding band of the WorldView-2 satellite (**CH2=479 nm, CH3 =548nm**, **CH5=659 nm**, **CH7=825nm**)

Why choose these indices?

- Sand samples can be classified in terms of their colour (hue)
- the reflectance of pure water is quite completely absorbed in the near-infrared (NIR) wavelengths with a rapid decrease from red to NIR bands
- The spectral signature of land has higher value at all wavelengths, especially at NIR range

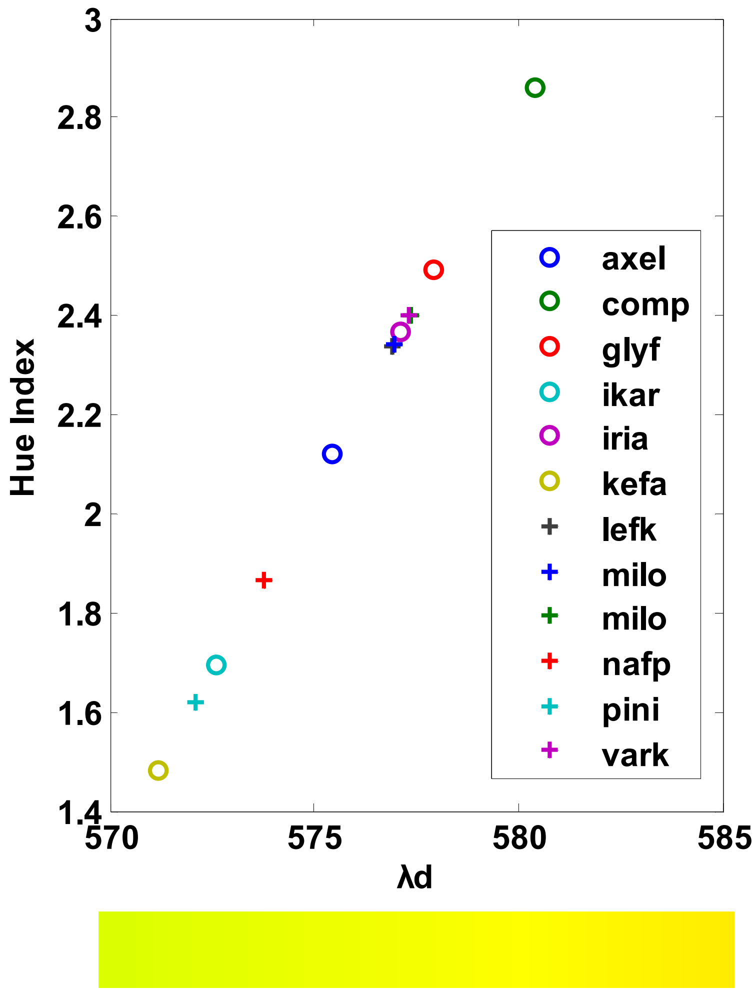
Results: dry sand reflectances

- Whitish sands have high reflectance (~70% in the visible part of the spectrum)
- dark grey sands have low reflectance (~20%), with an overall ascending slope of the spectrum towards longer wavelengths
- Colored sand samples generally have spectral curvatures associated to the dominant color
- Grain size seems to contribute to the overall albedo which increases with decreasing grain size (more mirrors).

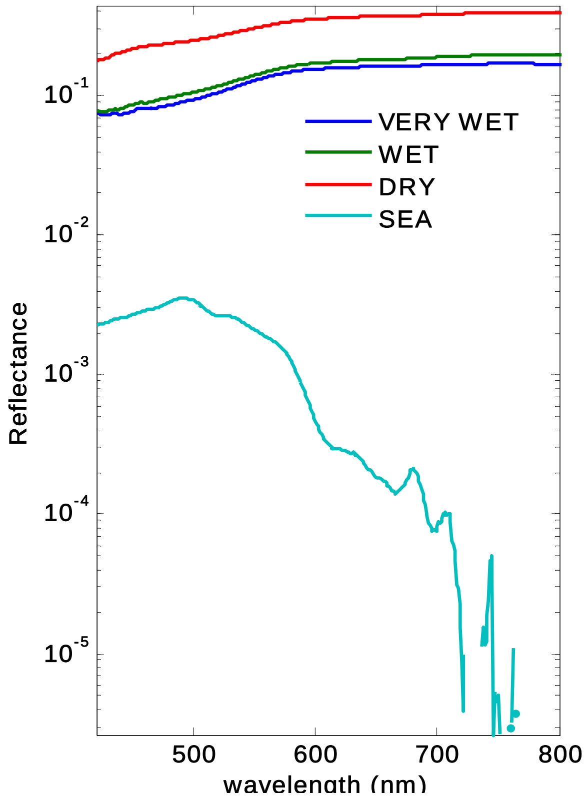


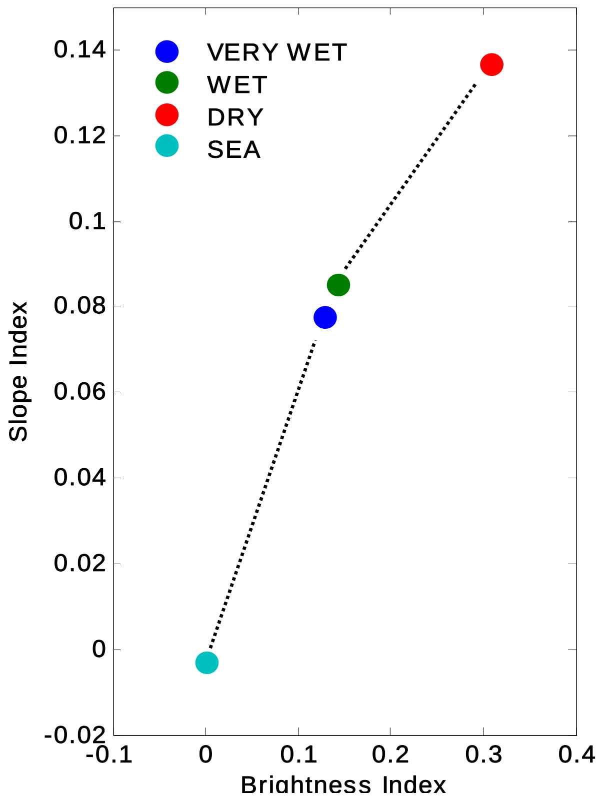
Dry sand reflectances

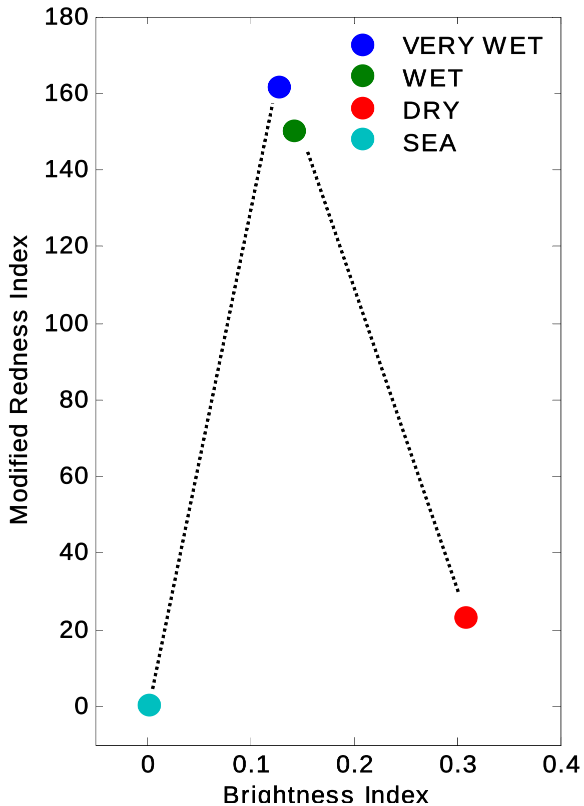
- Use hue index to classify different sand samples as a function of the dominant color of the sand (usually from Y to R)
- Use brightness index to classify the overall reflectance magnitude of the sample



Dry vs wet reflectance







WORLD VIEW-2

- For the scope of the present study, a satellite image has been purchased from WorldView-2 sensor over the study area of Pinios delta acquired on June 27, 2013 at 09:35:16 UT
- The satellite is in a nearly circular, Sun-synchronous orbit with a period of 100.2 minutes and an approximate altitude of 770km
- **one panchromatic band (450-800nm) at 0.5m**
- **eight multispectral channels at 2m spatial accuracy namely**

1. **Coastal (400-450nm)**
2. **Blue (450-510nm)**
3. **Green (510-580nm)**
4. **Yellow (585-625nm)**
5. **Red (630-690nm)**
6. **Red Edge (705-745nm)**
7. **Near-IR1 (770-895nm)**
8. **Near-IR2 (860-1040nm)**

SATELLITE DATA PROCESSING

$$L_{\lambda(\text{pixel,band})} = \frac{K_{band}\, q_{pixel,band}}{\Delta\lambda_{\text{band}}}$$

Raw pixels

ToA Radiance

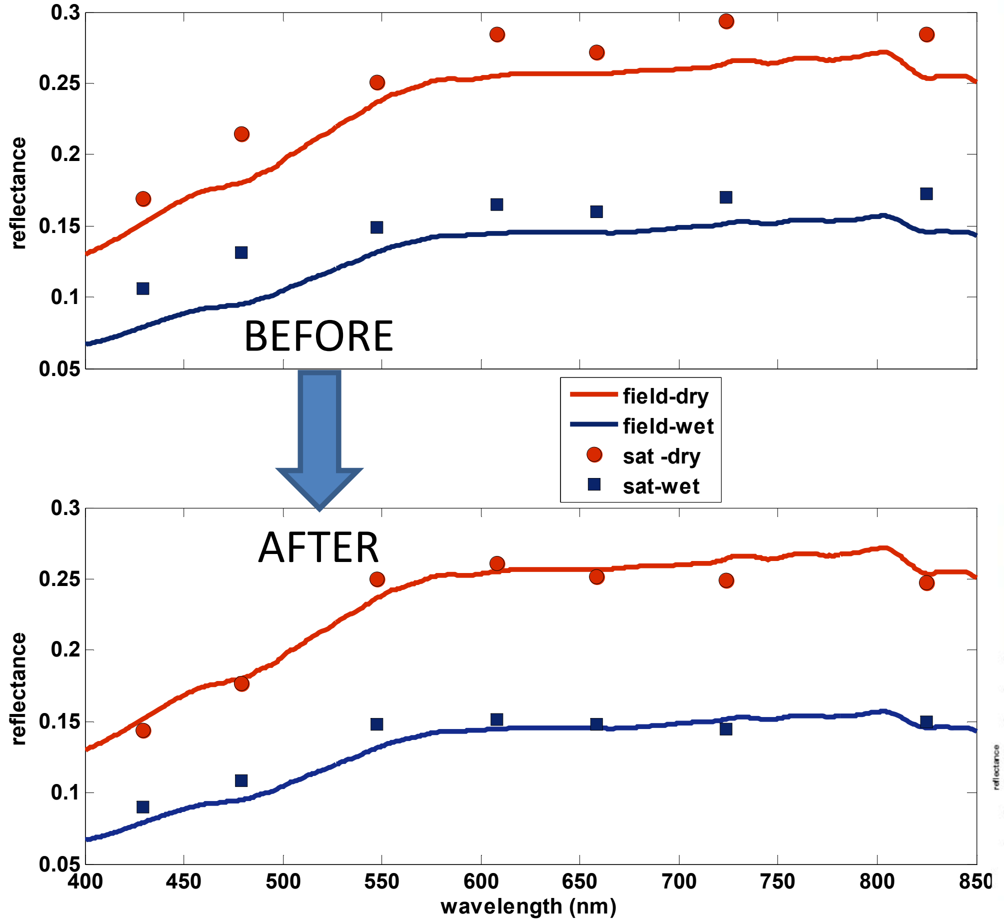
ToA Reflectance

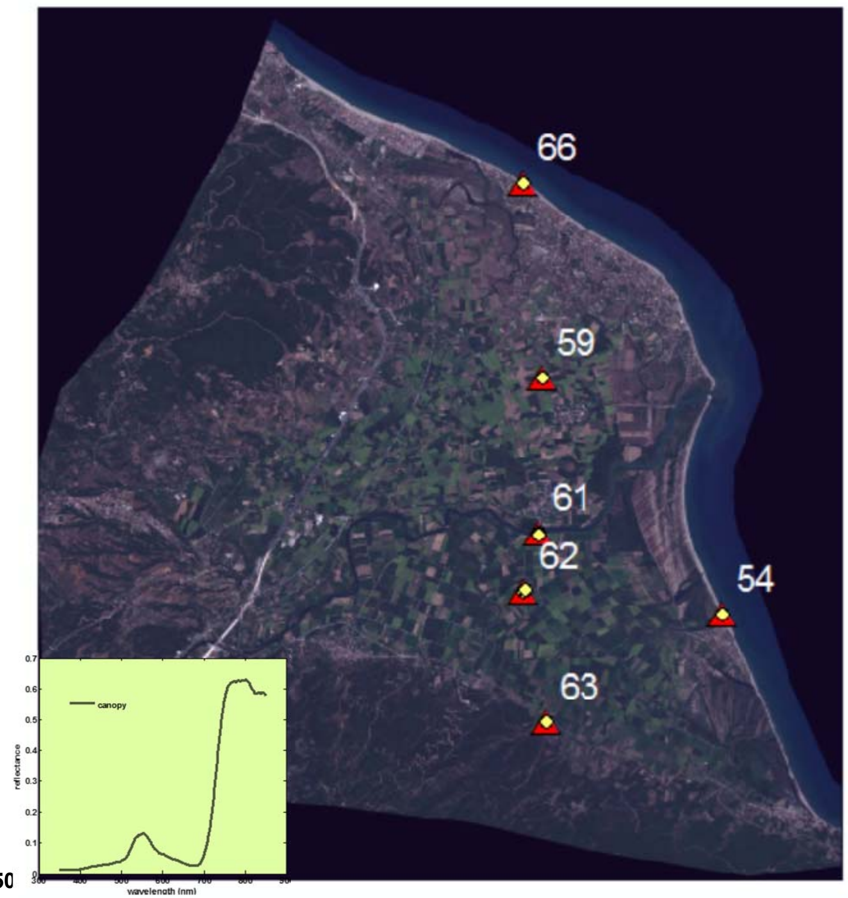
$$\rho_{\lambda(\text{pixel,band})} = \frac{L_{\lambda(\text{pixel,band})}\, d_{es}^{\;2}\, \pi}{E_{\text{sun, }\lambda(\text{band})} \cos(\theta_s)}$$

ENVI and via its FLAASH

Surface Reflectance

GROUND TRUTHING





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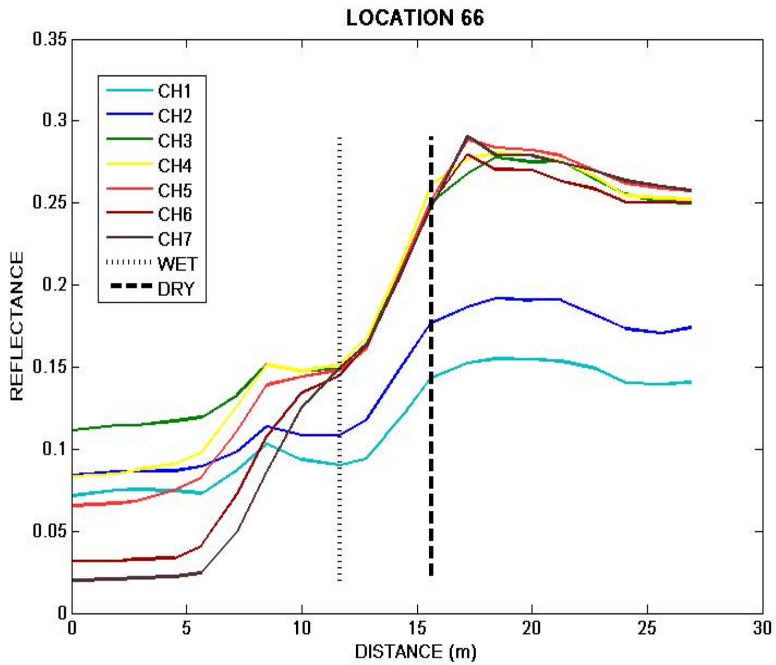
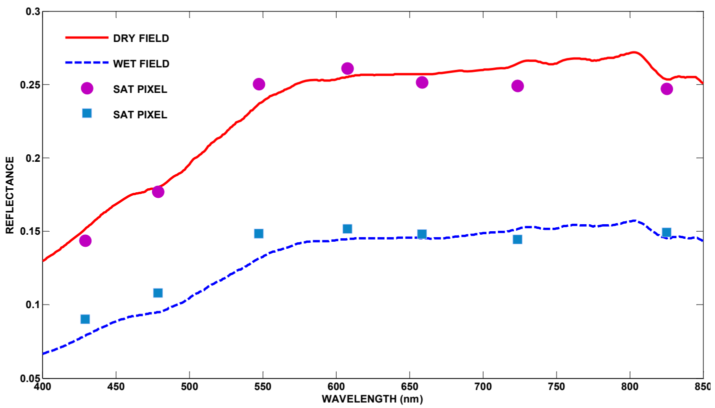
WORLD VIEW CHANNELS ALONG TRANSECT

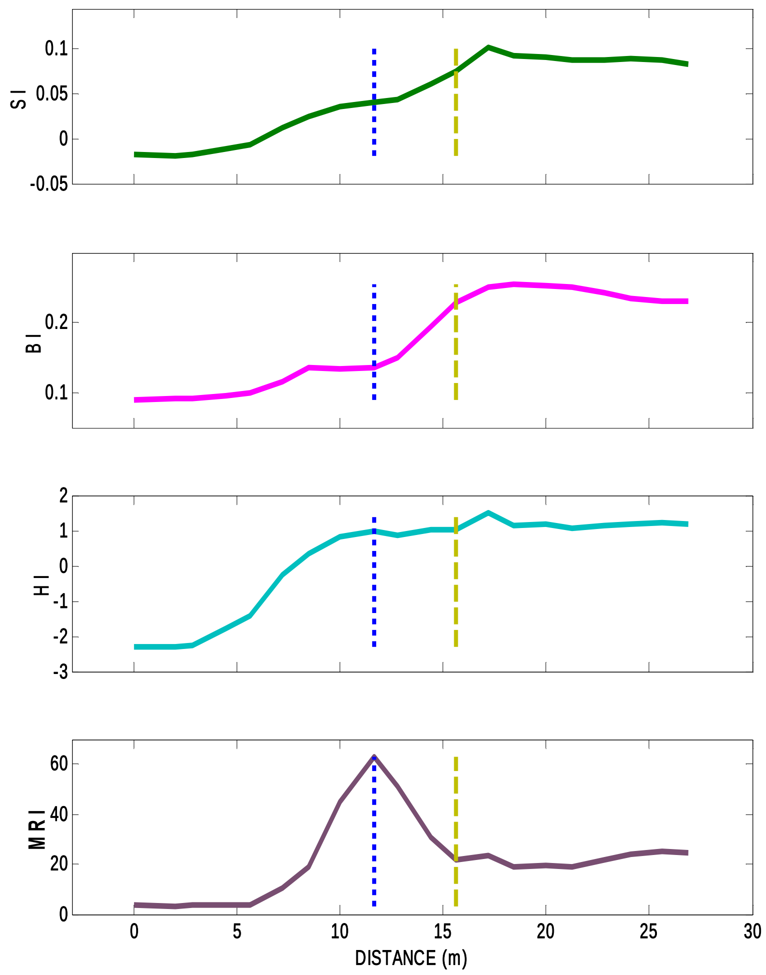
- The distinction between wet and dry shoreface is characterized by a reflectance increase of 0.10-0.15 (going shoreward) at the Green (510-580nm) wavelength and above.
- At the shorter Coastal blue and Blue wavelengths (400-510nm), the distinction between wet and dry shoreface is characterized by a more restricted reflectance increase of 0.05 .



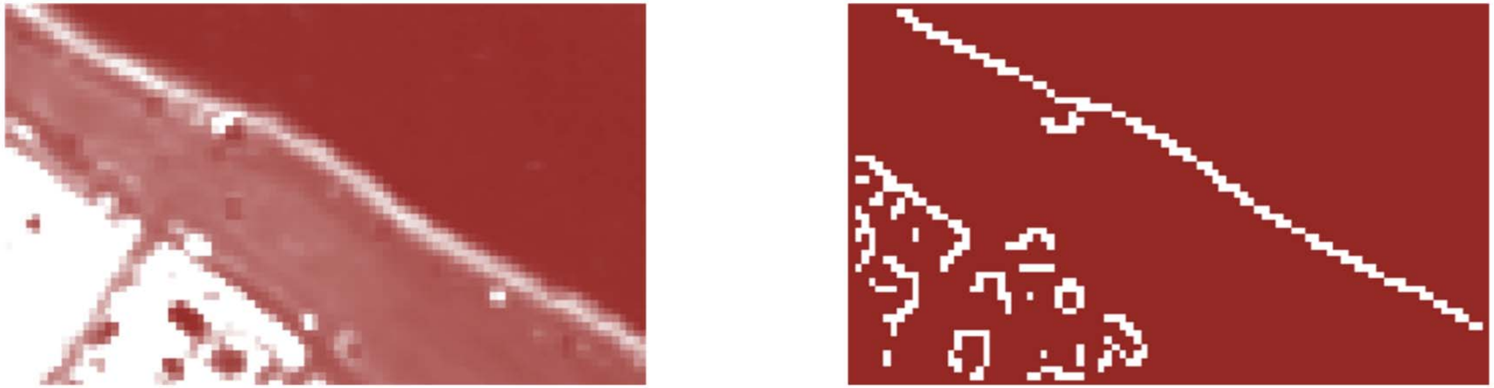


INDICES ALONG TRANSECT

- The evaluation of the indices clearly shows that within the transition zone from wet to dry sand, there exists a continuous increase
- of the slope index,
- brightness index and
- hue index.
- The MRI (Modified Redness Index), which increases as the bottom depth drops, abruptly starts a reduction trend at the location of wet sand up to the point where the dry shore face begins. Therefore, the first and second spatial derivatives of this index set the limits of the transition zones.

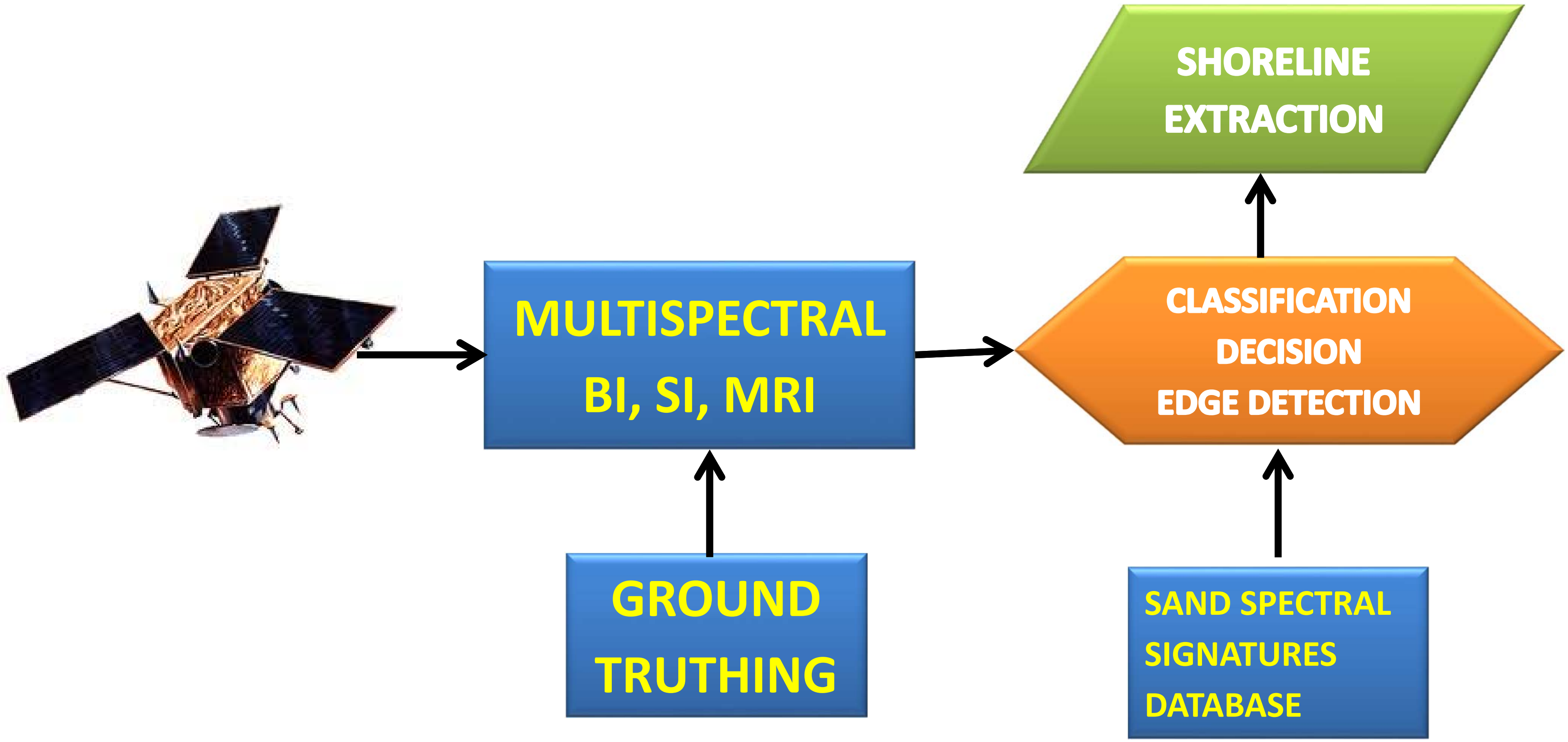


MRI APPLIED TO TEST AREA



- A better understanding of the MRI significance can be obtained if all the pixels of the map section are evaluated in terms of this index.
- Width of two consecutive pixels defines the shoreline position while by applying a simple Canny edge detection function on MRI, the shoreline is revealed with one pixel (2m) resolution

DATA PROCESSING FLOW



STEPS TO FOLLOW

- The work here presents preliminary findings of comparing in situ reflectance measurements with co-located satellite data from the multi-spectral WorldView-2 sensor collected near the Pinios river delta, in central Greece, a both environmentally vulnerable and highly touristic region.
- Next, a neural computational algorithm should be built for automatic coastal changes monitoring. Inputs will include image layers evaluated in terms of the above mentioned indices and ground truthing (training dataset) for aiding the supervised model learning procedure. The output will simply provide shoreline position with minimal human interaction.
- Future work shall include the above implementation at several locations, where in situ measurements may exist, as well as expanding the methodology possibly onto other sites and high resolution multi-spectral satellite sensors. Use of satellite fusion products (spectral channels merged with high resolution panchromatic) could improve the accuracy of the shoreline extraction.