“Remote sensing of the coastal zones: present status and priorities for future research”

Ana Cláudia Teodoro
Faculty of Sciences - University of Porto, Portugal
amteodor@fc.up.pt

Workshop “The use of sentinel data for supporting land and marine spatial planning and management specificities of small oceanic islands”

Outline

1. Copernicus program
2. Sentinel data
3. Remote sensing of the coastal zones: Present status
4. Remote sensing of the coastal zones: Future (availability of Sentinel-2 data)
5. What can Sentinels do for Regions?
6. Final Remarks and Recommendations

1. Copernicus Program

Copernicus, headed by the European Commission (EC) in partnership with the European Space Agency (ESA), is an Earth observation programme.

It will provide accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.

Copernicus is the new name for the Global Monitoring for Environment and Security programme (GMES).

The Copernicus Space Component comprises two types of satellite missions, ESA's families of dedicated Sentinels and missions from other space agencies, called Contributing Missions.

http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Services_overview

Copernicus Applications

Copernicus services will provide essential information for six main domains: ocean, land and atmosphere monitoring, emergency response, security and climate change.

- ✓ Marine environment - marine safety and transport; oil-spill detection; water quality; weather forecasting and the polar environment.
- ✓ Land environment - water management; agriculture and food security; land-use change; forest monitoring; soil quality; urban planning and natural protection services.
- ✓ Atmospheric - air quality and ultraviolet radiation forecasts; greenhouse gases and climate forcing.
- ✓ Emergency management – floods; forest fires and earthquakes and contribute to humanitarian aid exercises.
- ✓ Security - peace-keeping efforts, maritime surveillance and border control.
- ✓ Climate change - cross-cut all of the above domains.

2. Sentinel data

ESA is developing a new family of satellites, called Sentinels, specifically for the operational needs of the Copernicus programme.

- ✓ Sentinel-1 provides all-weather, day and night radar imagery for land and ocean services;
- ✓ Sentinel-2 will provide high-resolution optical imagery for land services;
- ✓ Sentinel-3 will provide high-accuracy optical, radar and altimetry data for marine and land services;
- ✓ Sentinel-4 and Sentinel-5 will provide data for atmospheric composition monitoring from geostationary orbit and polar orbit.

Sentinel-2A satellite from 4 the Baltic Sea (4 September 2015) with 10 m of spatial resolution
(http://www.esa.int/spaceinimages/Images/2015/09/Eye_of_an_algal_storm)

http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2

High capabilities of Sentinel-1, -2, and -3 to make a substantial contribution to the current understanding of the Earth System by detecting, monitoring and assessing changes in ocean, cryosphere, and land components.

But...and coastal zones?

Sentinel-2

- Will provide information for agricultural and forestry practices
- Helping manage food security.
- Will be used to determine various plant indices such as leaf area chlorophyll and water content indexes.
- Can be used to map changes in land cover and to monitor the world's forests.
- It will also provide information on pollution in lakes and ***coastal waters***.

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Sentinel-2

- **Launch:** 23 June 2015
- **Orbit**: Polar, Sun-synchronous at altitude of 786 km
- **Revisit time:** Five days from two-satellite constellation (at equator)
- **Coverage:** Systematic coverage of land and coastal areas between 84°N and 56°S
- **Life:** Minimum of seven years

Band number	Central wavelength (nm)	Band width (nm)
1	443	20
2	490	65
3	560	35
4	665	30
5	705	15
6	740	15
7	783	20
8	842	115
8b	865	20
9	945	20
10	1380	30
11	1610	90
12	2190	180

Sentinel-2 spectral bands definition

(Drush et al. (2012). Sentinel-2: ESA's Optical High-Resolution Mission for GMES Operational Services. Remote Sensing of Environment, 120, 25-36.)

- **Instrument:** Multispectral imager (MSI) covering 13 spectral bands (443 nm–2190 nm) with a swath width of 290 km and spatial resolutions of 10 m (4 visible and near-infrared bands), 20 m (6 red-edge/shortwave-infrared bands) and 60 m (3 atmospheric correction bands)

3. Remote sensing of the coastal zones: Present status

- ✓ Optical remote sensing data area a powerful source of information for monitoring the coastal environment.

- ✓ Due the high complexity of coastal environment, where different natural and anthropogenic phenomenon interact, the selection of the most appropriate sensor(s) is related to the applications required and the different types of resolution available (spatial, spectral, radiometric, and temporal) needs to be considered.

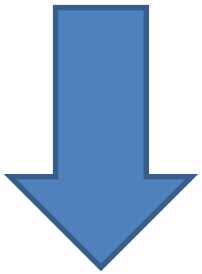
- ✓ A number of sensors have been launched since the Coastal Zone Color Scanner (CZCS) in 1978, as SeaWiFS, MODIS, and MERIS.

- ✓ Traditionally, the Landsat (TM and ETM+), the French Système Pour l'Observation de la Terre (SPOT) and Terra/ASTER have been reliable data sources for coastal zones monitoring.

- ✓ The availability of high-spatial and spectral resolution satellite data has significantly improved the capacity for mapping coastal ecosystems. High-resolution imagery obtained from satellites, such as IKONOS-2, Quick Bird-2, GeoEye-1 and Orbview-3 can be used for different purposes regarding coastal applications.

- ✓ The scientific community can now take advantage of the free availability of images with high temporal resolution and lower spatial resolution (e.g., MODIS) as well multispectral medium resolution Landsat (MSS, TM, ETM+, OLI) images.

- ✓ The assessment to the Sentinel-2 data will improve coastal environment monitoring programs. The design of the Sentinel-2 mission aims complement the Landsat and SPOT data and improves data availability for users.

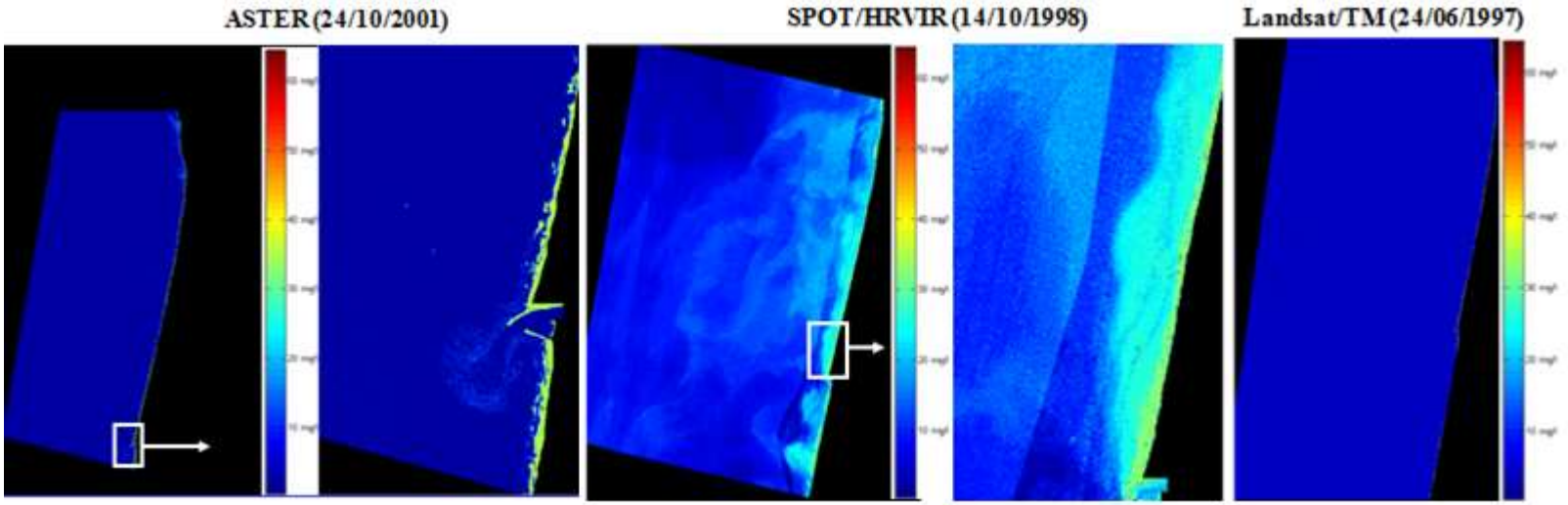


Sentinell-2 will provide increased possibilities to coastal monitoring due the improved spectral, spatial and radiometric resolution and they operational sense.

Acquired on 27 June 2015 at 10:25 UTC (12:25 CEST), just four days after launch, this first image from Sentinel-2A covers the Po Valley (Northwest Italy and southern France)

TSM concentration estimation

Estimate the total suspended matter (TSM) concentration, from remotely sensed multispectral data (ASTER, SPOT, Landsat TM), based on single-band models, multiple regression, and artificial neural networks (ANNs).

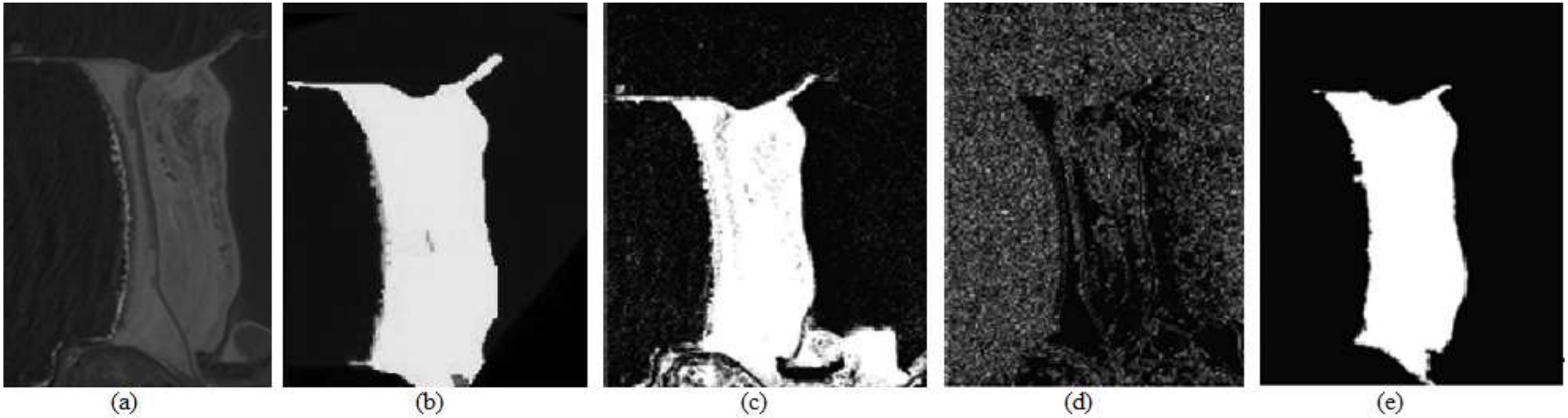


TSM concentration estimation based on a ANN, obtained from ASTER, SPOT and Landsat data

- Teodoro, A. C., Veloso-Gomes, F. and Gonçalves H., (2008). "Statistical techniques for correlating TSM concentration with seawater reflectance using multispectral satellite data". Journal of Coastal Research, Vol. 24, sp3, 40-49.
- Teodoro, A. C., Veloso-Gomes, F. and Gonçalves H., (2007). "Retrieving TSM concentration from multispectral satellite data by multiple regression and artificial neural networks". IEEE Transactions on Geoscience and Remote Sensing, 45, 5, 1342-1350.
- Teodoro, A. C. and Veloso-Gomes, F., (2007). "Quantification of the Total Suspended Matter concentration around the sea breaking zone from in situ measurements and TERRA/ASTER data". Marine Georesources and Geotechnology, 25, 2, 67-80.
- Teodoro, A. C., Marçal, A. R. S., Veloso-Gomes, F., (2007). "Correlation analysis of water wave reflectance and local TSM concentrations in the breaking zone, using remote sensing techniques". Journal of Coastal Research, 23, 6, 1491-1497.

Shoreline extraction and sand spits behaviour

Cabedelo SANd Spit MorphoDYnamic Evolution and Modelling using IKONOS data- Douro River, Portugal (ESA,EOP,Category-1- ID#6495)

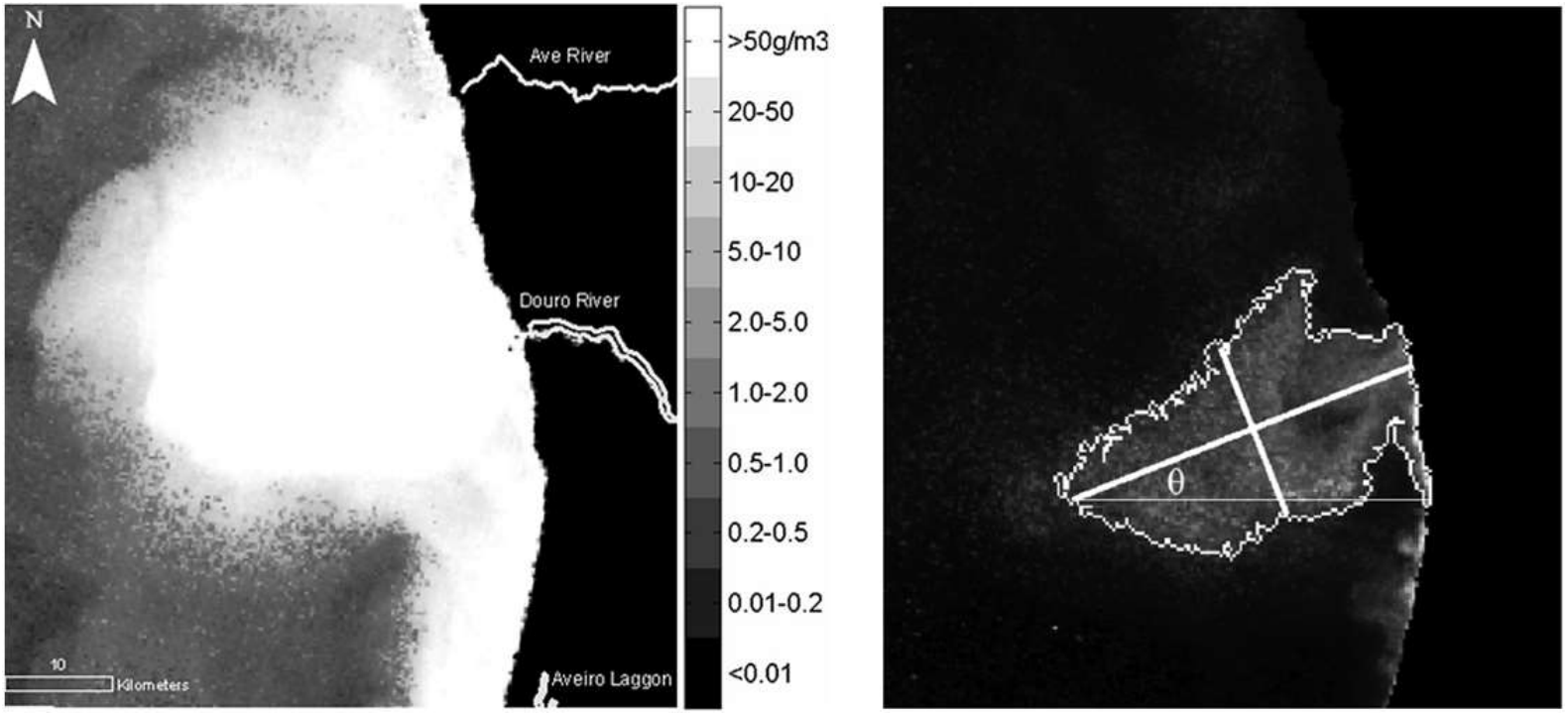


Panchromatic band of the IKONOS-2 image from Jun. 2005; (b) the sand spit extraction with object-based approach; (c) Global thresholding of the image in Fig. 1(a) through the Otsu's method; (d) Edges of the image in Fig. 1(a) obtained through the Canny edge detector; (e) Final extraction of the sand spit in Fig. 1(a), through the refinement of the global thresholding in (c) through the edges represented in (d)

- Teodoro A C, Gonçalves H 2012 "A semi-automatic approach for the extraction of sandy bodies (sand spits) from IKONOS-2 data" IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 5(2) 634-642.

River plumes

Estimation of the Douro river plume size based on image segmentation of MERIS scenes (ESA, EOP, Category-1- ID#6495)

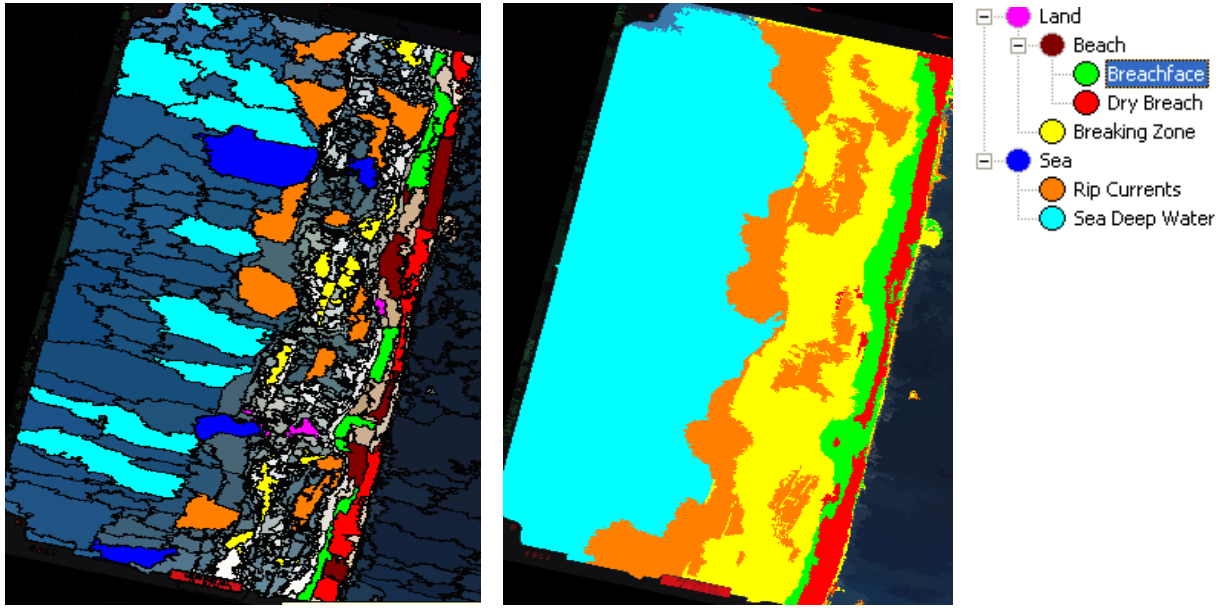


Douro River plume idntification thought TSM concentration
retrieved from a MERIS scene (left) and Douro River plume attributes achieved (right)

- Gonçalves H, Teodoro A C, Almeida H 2012 "Identification, characterization and analysis of the Douro river plume from MERIS data" IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 5(5) 1553-1563.

Beach classification

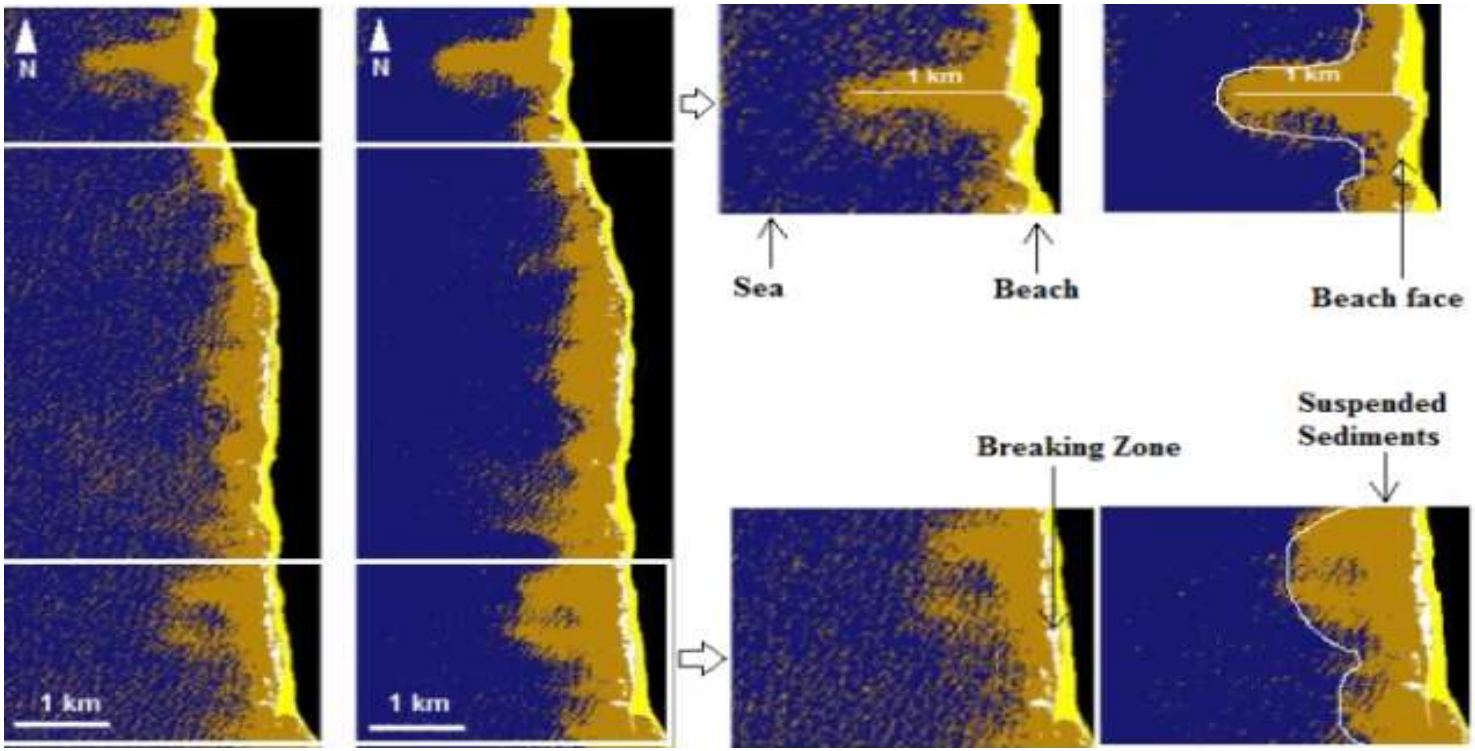
The main objective of this work is to improve, develop and implement new methodologies to identify coastal features/patterns. In order to achieve that, pixel-based classification algorithms, object-oriented classification algorithms, a new method based on PCA and a pattern recognition approach were employed. IKONOS-2 images were used.



Results of the object-based classification for an IKONOS-2 image

- Teodoro, A.C., Pais-Barbosa, J., Gonçalves, H., Veloso-Gomes, F., Taveira-Pinto, F., 2011. Beach Hydromorphological Analysis through Remote Sensing. Journal of Coastal Research, Sp. Iss. 61, 44-51.
- Teodoro, A.C., Pais-Barbosa, J., Gonçalves, H., Veloso-Gomes, F., Taveira-Pinto, F., 2011. Identification of beach features/patterns through image classification techniques applied to remotely sensed data, International Journal of Remote Sensing, Vol. 32, No. 22, 7399-7422.

Beach classification- rip currents identification and estimation

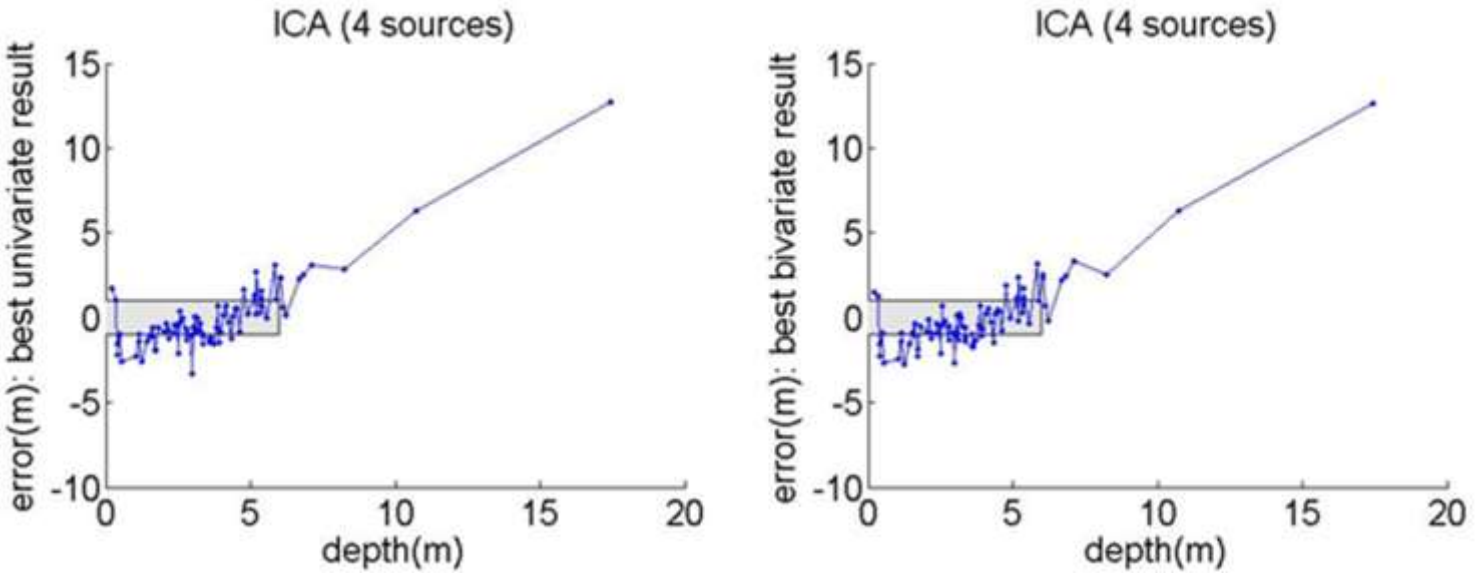


Rip currents patterns/forms identification and two zoomed areas obtained through (a) DT with pruning and (b) ANN – IKONOS – 2 image

- Teodoro AC, Pais-Barbosa J, Veloso-Gomes F, Taveira-Pinto F: Evaluation of Beach Hydromorphological Behaviour and Classification Using Image Classification Techniques. Journal of Coastal Research. 2009;2(56):1607-1611.
- Teodoro AC, Pais-Barbosa J, Gonçalves H, Veloso-Gomes F, Taveira-Pinto F: Identification of beach features/patterns through image classification techniques applied to remotely sensed data. International Journal of Remote Sensing. 2011;32(22):7399-7422.
- Teodoro AC: Applicability of data mining algorithms in the identification of beach features/patterns on high-resolution satellite data. Journal of Applied Remote Sensing. 2015;9(1):095095.

Bathymetric Estimation

The use of satellite data is a valid alternative to the classical survey bathymetric methods for bathymetric estimation in shallow waters. In this work, alternative univariate and bivariate models are proposed for the same IKONOS-2 image based on PCA and ICA.



Errors as function of the depth: ICA based best univariate and bivariate models with 4 predictors (for reference the interval]-1m, 1m[is plotted in grey) for the 81 points

- A. C. Teodoro, Rute Almeida, M. Gonçalves, "Independent Component Analysis (ICA) performance to bathymetric estimation using high resolution satellite data in an estuarine environment", in Remote Sensing for Agriculture, Ecosystems, and Hydrology XVI, C. Neale; A. Maltese, Editors, Proceedings of SPIE Vol. 9239 (SPIE, Bellingham, WA 2014), 923915.

4. Remote sensing of the coastal zones: Future (availability of Sentinel-2 data)

The Sentinel-2 data will be really useful?

Yes!

How can Sentinel-2 data improve the coastal zone environment monitoring?

Providing free, continuous and high-resolution data.

What are the main applications?

- Water quality parameters such as the surface concentration of chlorophyll, turbidity, TSM;
- Detect harmful algal blooms;
- Coastal hazards and vulnerability studies.

What is the main limitation?

The 10 m of spatial resolution limits some applications, where the use of high resolution spatial data is required.

5. What can Sentinels do for Regions?

Sentinel satellites can significantly contribute to regions development providing regular, timely, reliable observations.

- ✓ Provide access to a set of free data that can be transformed into useful information.
- ✓ Making available a set of information that otherwise would not be accessible.
- ✓ Reduce the costs of some work related to systematic *in situ* data collection.
- ✓ Contribute to scientific and technological development of these regions, attracting investment.
- ✓ Sentinel-2 can support the sustainable management of water/coastal resources.
- ✓ Are an effective tool for environmental management.

6. Final Remarks and Recommendations

- ✓ Sentinel-2 data will be a source of valuable data for the study of coastal areas.
- ✓ The LRAs need to be prepared to deal with this information.
- ✓ It is necessary to invest in advanced training.
- ✓ It is a priority to create institutional partnerships in order to identify which problems need be addressed and the best partners to contact.
- ✓ The major challenge still is to have remote sensing techniques adopted as a routine tool in assessment of change in the coastal zone.
- ✓ Continuing research is required into the techniques employed for assessing change in the coastal environment.

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