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# Monitoring the Mean High Water Shoreline Along the Meso-Macrotidal Cap Ferret Sand Spit, SW France, Using the Satellite-Derived Wet/Dry Sand Line

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**Abstract.** Building long shoreline position databases is critical to improve knowledge on past coastal dynamics and predict future changes. Several satellites acquiring recurrent optical images over land and coastal areas have been commissioned since the 1980s. This has allowed the implementation of various satellite-imagery-based shoreline detection algorithms for sandy coasts, which rely on the waterline delineation. However, the detection accuracy decreases with increasing tidal range at sites exhibiting a non-uniform intertidal profile slope. This generally forces to exclude satellite images acquired near low tide at meso and macrotidal coasts. This communication explores the ability of the wet sand/dry sand line extracted from satellite images to reproduce the mean high water shoreline along the km-scale meso-macrotidal Cap Ferret sand spit, SW France. The results show that satellite-derived wet/dry line provides a consistent proxy of the mean high water shoreline, with almost no influence of low water levels at image acquisition time. However, the use of satellite-derived waterline to retrieve the MHW shoreline should still be preferred for images acquired at high water levels.

**Keywords:** sandy coasts · mesotidal · macrotidal · satellite-derived shoreline · wet/dry line

## 1 Introduction

With the commissioning of satellite constellations providing free-access high-resolution images in the recent years (e.g. Landsat 8/9, Sentinel-2), there have been a growing effort within the coastal science community to implement robust and accurate methods to monitor shoreline changes from earth observation products (e.g. [1–3]). Most of these methods rely on delineating the interface between water and land surfaces, usually referred to as the instantaneous waterline.

In microtidal environments, this satellite-derived instantaneous waterline matches well with shoreline proxies (e.g. mean sea level, upper swash limit) used to study shoreline changes on timescales from days to decades (e.g. [3]). In meso and macrotidal environments, between low and high tides, the cross-shore position of the waterline can

easily vary by tens to hundreds of meters, depending on the tide range and intertidal beach morphology and slope. Because the satellite images are taken at different tide states from one image to another, the satellite-derived instantaneous waterline cannot be used as a consistent proxy of the shoreline to address coastal changes in such tidal environments. To face this limitation, tidal-correction algorithms have been developed to estimate the contribution of the tide to the waterline horizontal shift and to generate tidal-corrected waterlines having more consistency in time (e.g. [3, 4]).

Tidal-correction algorithms assume that the beach slope is constant. However, in meso and macrotidal environments, beaches usually present a convex profile within the intertidal zone, with sometimes bars and rips emerging at low tide. Consequently, tidal-correction algorithms can sometimes fail at compensating the tidal effect especially for waterline derived from satellites images taken near low tide [5].

Another strategy to face this limitation consists in creating composite waterlines from a set of subsequent satellite-derived instantaneous waterlines taken over a rolling period long enough to cancel sea level variation effects (e.g. [2]). However, such rolling period are typically of one year, which prevents from addressing shoreline changes occurring on timescales from days to seasons. For these reasons, it is necessary to investigate other approaches to extract the shoreline position from satellite imagery that suits to meso and macrotidal environments [6].

This communication explore how the boundary between the wet sand and the dry sand visible in satellite images can reflect the position of the mean high water (MHW) shoreline along the meso to macrotidal Cap Ferret sand spit, SW France (Fig. 1a). For that purpose, MHW shorelines extracted from several lidar surveys are compared to wet/dry lines extracted from satellite images taken at dates close to those of the lidar surveys. A comparison with non-corrected satellite-derived waterlines is also provided.

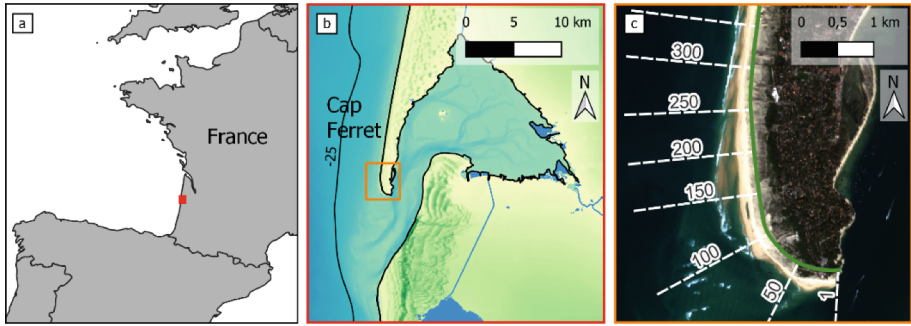
## 2 Data and Methods

### 2.1 Topographic Surveys and Shorelines

Six MHW shorelines were extracted from six lidar surveys acquired over the Cap Ferret sand spit by the coastal observatory of the Nouvelle-Aquitaine region (SW France) between 2014 and 2021 [7]. Along the open coast of Cap Ferret sand spit, the MHW elevation is approximately 1.9 m NGF IGN69 (official French vertical datum), which corresponds to an elevation of about 1.5 m above mean sea level [4].

### 2.2 Satellite Images

Wet/dry lines and waterlines were extracted from Sentinel-2 (ESA) and Landsat 8 (NASA/USGS) images. The satellites images were selected in such a way that their acquisition dates were very close from lidar acquisition dates with a maximal delta of  $\pm 7$ -days.



**Fig. 1.** (a, b) Location map of the Cap Ferret sand spit and the study area (orange rectangle). (c) Sentinel-2 image acquired on the 11/10/2017 zoomed over the study area. White dashed lines denote some of the transects used to extract the wet/dry line from satellite images. The green curve indicates the baseline defining the transect origin.

### 2.3 Image Classification

Satellite images were classified into 8 classes using a supervised classification algorithm based on a multi-layer perceptron neuronal network and inspired from the approach given in [3]. To enable extraction of both the waterlines and wet/dry lines the following classes were used: deep water; shallow water; wave foam; very wet sand; slightly wet sand; dry sand; vegetated dunes; others (urbanized areas and dense vegetation). Distinct classifiers were trained and applied separately for Sentinel-2 and Landsat 8 images. For both classifiers, the training was based on pixel labelling over 12 images. Post-processing was applied to clean classified images. This includes light smoothing of class boundaries and removal of every isolated small patches of a class located within wider patch of a different class.

### 2.4 Wet/dry Lines and Waterlines

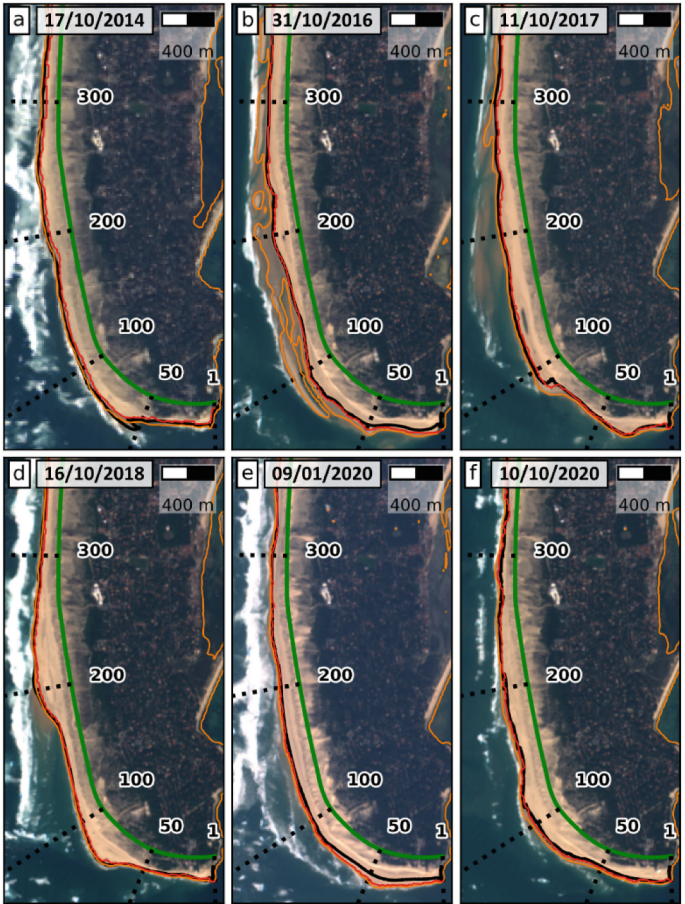
The wet/dry line was defined as the boundary between pixel areas of marine and wet classes (deep water; shallow water; wave foam; very wet sand; slightly wet sand) and pixel areas of dry classes (dry sand; vegetated dunes; others). Extraction was made from each classified images at pixel scale using a set of cross-shore transects that discretizes the coast in the longshore direction with an alongshore spacing of 10-m along the transect origin baseline (Fig. 1c). In case multiple wet/dry boundaries are found along a transect, the most offshore wet/dry boundary among those not located seaward of any pixels belonging to the very wet sand and marine classes was kept. Following this rule ensures that we do not select a wet/dry boundary that could be located on a dried sandbar detached from the upper dry beach.

Waterlines were extracted from each satellite images using the method given in [3]. For each satellite images, this requires the computation of the optimal threshold in Modified Normalized Water-Index (MNDWI) values that best distinguishes pixels belonging to the water classes from pixels belonging to sand classes. Then, for each satellite image, the waterlines were delineated using a contouring method applied to the image-derived MNDWI raster based on the corresponding threshold. In the comparison with the MHW

shorelines shown later, the most inshore intersection between the waterlines and the cross-shore transects mentioned above was kept. Taking the most inshore intersection minimizes the distance between the waterline and the MHW shoreline.

### 3 Results

Satellite-derived wet/dry lines and waterlines along with their corresponding satellite images and lidar-derived MHW shorelines are represented in Fig. 2.



**Fig. 2.** Comparison between satellite-derived wet/dry lines (red curves), satellite-derived waterlines (orange curves) and lidar-derived MHW shorelines (black curves) for six match-ups. (a) Landsat 8 image of 17/10/2014. (b, c, d, e, f) Sentinel-2 images of 31/10/2016, 11/10/2017, 16/10/2018, 09/01/2020 and 10/10/2020, respectively. The green curve indicates the baseline defining the transect origin.

Visually, the wet/dry lines follow pretty well the MHW shorelines for all dates and capture the shoreline undulations that are sometimes present along this sand spit (e.g. Fig. 2c and d). The waterlines show similar abilities, except when extracted from the image acquired on 31/10/2016 near low tide (Fig. 2b). Waterlines extracted from that image are clearly influenced by the presence of emerging ridge-runnel systems. Even with a water-level correction, it can be anticipated that for such low water levels, satellite-derived waterlines cannot be used to derive accurately the MHW shoreline and its alongshore variability.

The ability of the wet/dry lines or the waterlines to reproduce the MWH shorelines was assessed using the cross-shore position of these features along the cross-shore transects (Fig. 1c). Results for all matchups and per matchups are given in Tables 1 and 2, respectively. Globally, the use of wet/dry line enables to retrieve the shoreline with a landward bias of 6.7 m and root mean squared error (RMSE) of 20.0 m. Using the non-corrected waterline significantly decreases the skills, with a seaward bias of 26.7 m and a RMSE of 38.8 m. Excluding the matchup of 10/2026 (satellite image acquired near low tide) may improve slightly these skills.

**Table 1.** Global skills of the satellite-derived waterline and wet/dry line at reproducing the MWH shoreline.

Shoreline proxy	Bias	RMSE	R <sup>2</sup>
Waterline	-26.7	38.8	0.75
Wet/dry line	6.7	20.0	0.87

**Table 2.** Skills of the satellite-derived waterline and wet/dry line at reproducing the MWH shoreline per matchup.

Satellite image date	Shoreline proxy	Bias	RMSE	R <sup>2</sup>
17/10/2014	Waterline	-7.9	13.8	0.96
	Wet/dry line	27.5	30.5	0.94
31/10/2016	Waterline	-69.8	78.4	0.39
	Wet/dry line	-4.4	21.5	0.80
11/10/2017	Waterline	-27.4	33.2	0.84
	Wet/dry line	14.1	18.8	0.94
16/10/2018	Waterline	-6.7	9.5	0.98
	Wet/dry line	12.1	15.1	0.97
09/01/2020	Waterline	-20.9	25.4	0.98
	Wet/dry line	-5.8	16.4	0.97
10/10/2020	Waterline	-27.7	29.4	0.96
	Wet/dry line	-3.6	12.7	0.94

For some specific matchups, for which satellite images were acquired with high water levels, the non-corrected waterline reproduces better the MHW shoreline than what the wet/dry line can do (Table 2, 10/2014 and 10/2018). For the 10/2014 matchup, the water level including tide and wave runup was slightly higher than the MHW elevation. This causes the wet/dry mark on the beach to be at elevations well higher than the MHW elevation and explains why the skills obtained with the wet/dry line are poor.

## 4 Conclusions

Our results suggest that the use of the wet/dry line as a proxy of the MHW shoreline at meso-macrotidal Cap Ferret sand spit could provide better results with more consistency. It allows using more safely satellite images acquired near low tide with no need of post-processing and visual controls, which are required when the waterline is used. However, for satellites image acquired at high water levels (e.g. higher than the MHW elevation) it seems preferable to use the waterline to derive the MHW shoreline. We anticipate that the accuracy of state-of-the-art satellite-based shoreline-detection algorithms could be significantly increased for meso and macrotidal coasts if the wet/dry line is also taking into account.

## References

1. Pardo-Pascual JE, Almonacid-Caballer J, Ruiz LA, Palomar-Vázquez J (2012) Automatic extraction of shorelines from Landsat TM and ETM+ multi-temporal images with subpixel precision. *Remote Sens Environ* 123:1–11
2. Luijendijk A, Hagenaars G, Ranasinghe R, Baart F, Donchyts G, Aarninkhof S (2018) The state of the World's Beaches. *Sci Rep* 8(1):6641
3. Vos K, Harley MD, Splinter KD, Simmons JA, Turner IL (2019) Sub-annual to multi-decadal shoreline variability from publicly available satellite imagery. *Coast Eng* 150:160–174
4. Castelle B et al (2021) Satellite-derived shoreline detection at a high-energy meso-macrotidal beach. *Geomorphology* 383:107707
5. Konstantinou A, Scott T, Masselink G, Stokes K, Conley D, Castelle B (2023) Satellite-based shoreline detection along high-energy macrotidal coasts and influence of beach state. *Mar Geol* 462:107082
6. Vos K et al (2023) Benchmarking satellite-derived shoreline mapping algorithms. *Commun Earth Environ* 4(1):345
7. Nicolae Lerma A et al (2022) Decadal beach-dune profile monitoring along a 230-km high-energy sandy coast: aquitaine, southwest France. *Appl Geogr* 139:102645

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