

COASTAL CHANGE DETECTION FROM SATELLITE RADAR (SENTINEL-1)

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INTRODUCTION

The high frequency acquisition and broad area covered by new satellite missions (e.g. Sentinel-1 and Sentinel-2) provide high amount of information that allows for the monitorization of coastal processes in several time and spatial scales. In the past few years, the potential of using satellite-derived shorelines obtained from optical sensors to detect coastal changes has been deeply explored (Vos et al., 2023). However, less attention has been given to the use of shorelines derived from Synthetic Aperture Radar from satellite (SAR-SL) and few studies have been dedicated to develop and assess SAR-SL accuracy (e.g. Tajima et al., 2019; Zollini et al., 2023).

From 2020 to 2023, experts in Earth Observations and end-users responsible for coastal monitoring from 5 different countries jointly developed the project Coastal Erosion from Space funded by the European Space Agency (ESA) with the aim of assessing the ability of satellite derived products to detect coastal changes (e.g. results from Gomes da Silva et al., 2022 and Paz-Delgado et al., 2022). Following that project, a collaborative work between SAR experts and end-users was developed with the aim of enhancing the understanding of SAR-SL from Sentinel-1 and to assess their potential application to detect coastal change. The results from such a collaboration are presented here through three pilot case studies with different environmental characteristics (e.g. different backshore type and met-ocean conditions). All three sites are located in tidal beaches of the European Atlantic coast, where the probability of cloud cover is high. This allowed to assess the skill of SAR-SL in different environments and in sites that represent a challenge for shoreline detection from optical satellite sensors.

METHODS

The assessment of SAR-SL was done in two main phases: i) shorelines extraction, carried out by SAR EO experts and ii) validation and interpretation by local experts in coastal processes.

SAR-SL from 2015 to 2022 were obtained from Sentinel-1 images. The processing of SAR-SL extraction included:

- georeferencing of SAR images,
- image treatment and SAR-SL extraction using the Kittler threshold (Kittler and Illingworth, 1986) and
- filtering SAR-SL timeseries based on shorelines density (heatmaps).

The shorelines were applied to detect changes in three tidal beaches located in the coasts of Spain, Ireland and United Kingdom, and the results were compared to changes

observed in the ground. At each site, the validation procedure was designed according to the local settings and to the available ground truth data.

RESULTS

The amount of available SAR-SL (i.e. Sentinel-1) at the three sites was 93% higher than shorelines obtained from optical sensors (i.e. from Sentinel-2 images with 0% cloud cover for the same period) (Figure 1). This result highlights the potential advantage of using SAR data for detecting coastal change, as SAR detection is independent on light (detection during day and night) and it is not affected by clouds (detection independent on the weather).

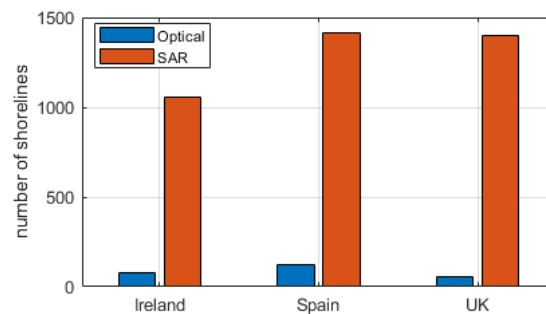


Figure 1: Number of shorelines obtained from SAR (Sentinel-1 images) and optical (Sentinel-2 images with 0% cloud cover).

SAR-SL were compared to coastal morphological processes, such as long-term changes in the vegetation line, interannual changes in a beach profile and interannual beach rotation. Coastal change obtained from SAR-SL were also correlated to the occurrence of extreme total water level events (e.g. Pearson coefficient of 0.51 in the coast of Spain).

Up to date, the complexity inherent to the interpretation of the SAR signal did not allow for the identification of the actual feature that characterizes the shoreline in SAR images (e.g. water-sand interface, wet-dry sand boundary, vegetation line) as the SAR signal is affected by the terrain dielectric constant. At the three sites studied here, the SAR-SL were located in the upper part of the beach, mostly in areas higher than the high-water mark.

The results suggest that the local configuration of the coast and the satellite orbit have an effect in the process of extracting shorelines from SAR images. For example, differences in shoreline position from ascending and descending orbits were observed in two of the three sites

which are backed by high coastal features, such as cliffs and dunes. This occurs because SAR detection is affected by the incident angle of the SAR signal and the ground morphology due to several phenomena, such as i) foreshortening, ii) layover and iii) shadow (Figure 2). Further investigation on the role of the main orientation of the coast, the coastal topography, the type of backshore, and the soil moisture are currently in development.

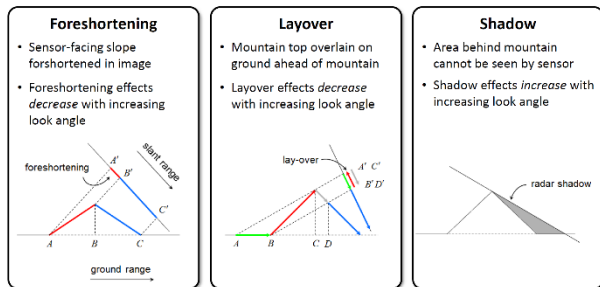


Figure 2: Distortions observed in SAR images due to side looking SAR over a non-plane ground (source: hyp3-docs.asf.alaska.edu/guides/introduction_to_sar).

CONCLUSIONS

The results from this work allowed to reach the following conclusions:

- A collaborative work between SAR EO experts and end-users, experts in geomorphology, demonstrated the potential of using SL derived from SAR Sentinel-1 to detect coastal morphological processes in several temporal scales, such as long-term changes in the vegetation line, interannual changes in a beach profile, interannual beach rotation and changes induced by extreme TWL.
- The results also highlighted the main advantages of using SAR data in comparison with optical data, such as the possibility to monitor high frequency coastal processes, as shoreline time series from SAR Sentinel-1 present higher amount of data (and higher frequency) than those obtained from optical Sentinel-2.
- SAR-SL were located on ground higher than the high-water mark in the three sites. More studies are necessary to identify the actual footprints that characterize the shoreline in SAR images. SAR-SL detection was affected by local coastal typology, and further investigation on the role of the main orientation of the coast, the coastal topography, the type of backshore, and the soil moisture are currently in development.

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