Detection of Marine Fronts; a Comparison between Different Approaches Applied on the SST Product Derived from Sentinel-3 data

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ABSTRACT

Fronts, which are sharp boundaries between distinct water masses, play a substantial role in managing biodiversity of marine species and preserving a resilient ecosystem. The overarching aim of this study is to compare different methodologies for detecting marine fronts. Many marine fronts are identifiable by their strong temperature gradient. For that reason, this study tests how two different edge detection methodologies (Laplacian and Canny) performs on detecting marine once applied on the Sea Surface Temperature (SST) product of the Sentinel-3 SLSTR instrument. In a few words, the results of this study showed that the Laplacian edge detection overestimates fronts, while the Canny Edge detection algorithm underestimates them. It worth highlighting though that the results are significantly improved using the appropriate filtering and/or image enhancements. The results of the Canny Edge detection algorithm were improved when a histogram equalisation image enhancement was applied before the Canny Edge and the results of the Laplacian detector were improved with median filtering.

Keywords: Marine Fronts, Sea Surface Temperature, Sentinel 3, Edge Detection, Comparison

1. INTRODUCTION

Marine fronts are sharp boundaries between water masses with distinct variations in surface temperature, density, salinity, colour and/or surface slope. The presence of two side by side water masses with different properties produces motion and their flow patterns create zones that are enriched with food and resources for marine organisms.[1] In contrast, climate change negatively affects fish distributions and the productivity of marine species. It is therefore of high importance to monitor fronts for preserving a resilient marine ecosystem (e.g. introducing fishing limitations). Earth Observation imagery collected from space contains valuable information for delineating waves that extent to the sea surface. This narrow regions between two different masses are identified by their high gradient.[2] There is a number of edge detection algorithms able to detect high gradients and has been used for identifying marine front (e.g. Sobel,[3] Laplacian[4] and Canny).[5]

In a few words, this study looks into automated ways of detecting marine fronts. It compares the results of two approaches implemented and examines how the results can be improved using the appropriate filtering and image enhancements. Section 2 provides information of the area and image used for testing. Section 3 briefly explains the algorithms used, while Section 4 contains the results of the algorithms and the various tests implemented.

2. MATERIALS AND STUDY AREA

The input of the framework implemented is the Sea Surface Temperature (SST) product of the Sentinel-3 SLSTR instrument. According to the specifications, the SST is obtained by means of the three infra-red channels (3.74, 10.85 and 12 m) after been highly calibrated. This product is provided freely by the Copernicus Online Data Access.

For this paper, a small area was selected to test the influence of the application of different approaches, filters and image enhancements. As shown in Figure 1, this area lies in the east Mediterranean sea. The sea cover is approximately $830000 km^2$. Additionally, the selected image was acquired by Sentinel-3A on the 9th of September 2017 and have a very low cloud coverage. It worth mentioning though that for the completion o the SEO-DWARF project, the entire coverage of marine surface will be processed.

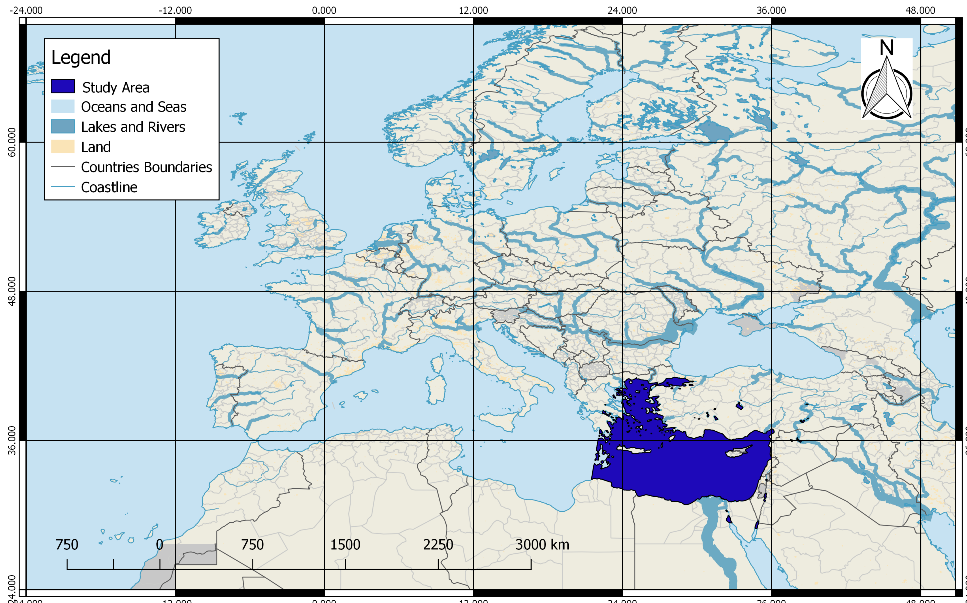


Figure 1: Location of the study area

3. METHODOLOGY

In this study, we implemented, tested and compared two approaches of detecting fronts; the Laplacian and the Canny edge detectors. Appropriate filtering and image enhancements are also applied to improve the results. Figure 2 depicts the processing pipeline. At first, the two filters (median and image enhancement) may be applied or not, once or multiple times. Finally, one of the edge detection algorithms is applied. This section briefly explains how these algorithms work, while the following one gives an overview of the results.

3.1 Edge Detection Approaches

3.1.1 The Laplacian convolution

As mentioned earlier the fronts can be identified by their high gradient difference. There are many convolution kernels that can be applied for detecting edges. For example, the two Sobel kernels use the first derivative to identify gradient differences either horizontally or vertically, but not simultaneously. In contrast, the Laplacian kernel uses the second derivative for searching zero crossings and can therefore detect both vertical and horizontal edges simultaneously. For that reason, the Laplacian kernel is used in this paper. Nevertheless, this kernel is very sensitive to noise, because it uses the second derivative. This sensitivity to noise is depicted in the results.

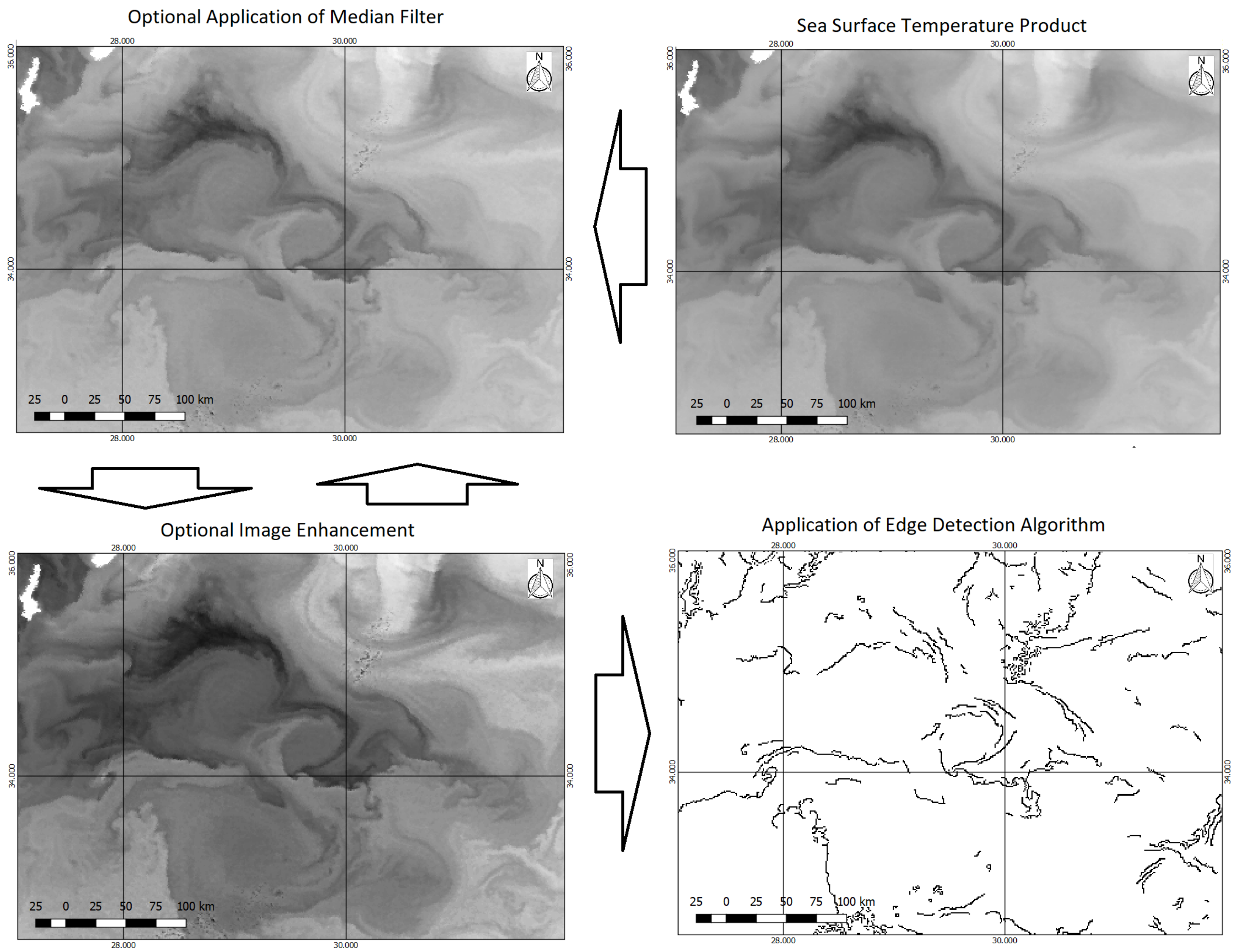


Figure 2: Processing pipeline: the input is the SST product, which is optionally filtered using a median filter and/or image enhancement and finally an edge detector is applied. The filters may be applied multiple times.

3.1.2 Canny Edge Detection

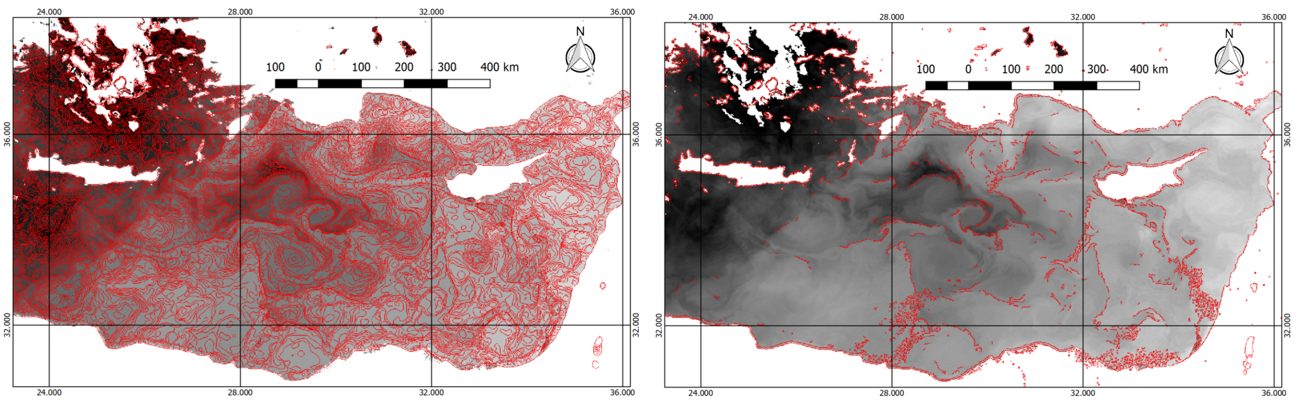
According to Shrivakshan et al, 2012,[6] who tested various edge detection algorithms on an image containing a shark, the Canny Edge performs better under noise condition. Canny Edge was, therefore, selected as one of the algorithms to be tested for computing marine fronts. In a few words, the Canny Edge is a multi-pass algorithm. After applying Guassian noise removal, it uses the Sobel edge detection in both directions to get the gradients of each pixel. Then it finds local maxima and finally, it uses thresholds for removing edges with low gradient.[7]

3.2 Filtering

Furthermore, appropriate filtering can significantly improve classification results. In this paper, two different types of filtering has been used; the median convolution kernel and a histogram equalisation image enhancement. The median was chosen over a Gaussian kernel, because it is able to remove salt and pepper noise without blurring this noise into the image. The results of each algorithm tested (Laplacian, Canny) has been improved using filters. Nevertheless, different types of filtering work better on different algorithms and that was demonstrated in the following section.

4. RESULTS AND DISCUSSION

As shown in Figure 3, the Laplacian kernel overestimates the results, while the Canny underestimates them. Additionally, Table 1 shows how the results of the two edge detection approaches are influenced with filtering. Table 1 depicts how the results of the Laplacian detector are significantly improved using a median filter. This happens because it uses the second derivative for detecting zero crossing and it is therefore very sensitive to noise. In contrast the results of the Canny Edge were worsen using a median filter because the edges are blurred and therefore less distinguishable. The Canny Edge algorithm was improved with the histogram equalisation that enhances the features of the image.



(a) Laplacian convolution kernel applied, once the median filter (9x9) has been applied twice to significantly reduce noise.

(b) Canny edge detection applied, once the images has been enhanced three times using histogram equalisation.

Figure 3: Results of each algorithm implemented. The lines are the predicted marine fronts and they are plotted on top of the original SST image. Different and appropriate filters are applied according to the requirement of each algorithm.

5. CONCLUSIONS

In this study, we compared the performance of two edge detection algorithms for detecting fronts using the SST product of Sentinel 3. The algorithms selected are the Laplacian detector because is able to detect edges in both horizontal and vertical directions simultaneously and the Canny edge since it was shown to perform the best on a project with an image of a shark.[6]

It was showed that the Laplacian Edge detector overestimates thermal fronts, while the Canny Edge detector underestimates them. Nevertheless, appropriate filtering improves the results. Each one of the two approaches was improved using different type of filtering. The Laplacian was improved using the median filtering, while the Canny using histogram equalisation for image enhancement.

The test were performed on the SST product of Sentinel 3 on a single area that lies in the east Mediterranean sea. In the future, the algorithms need to be tested on more areas and on images acquired on different dates in order to better evaluate the performance of the algorithms.

6. ACKNOWLEDGEMENTS

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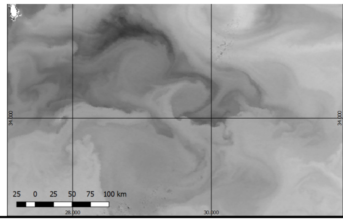
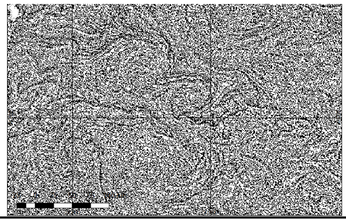
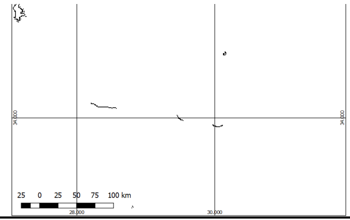
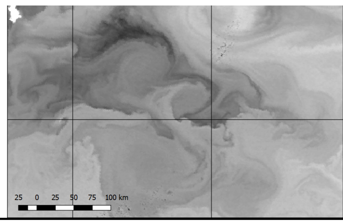
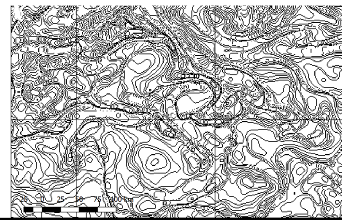
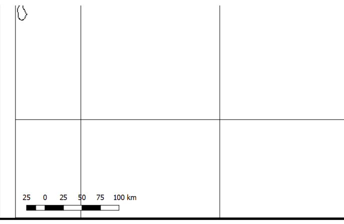
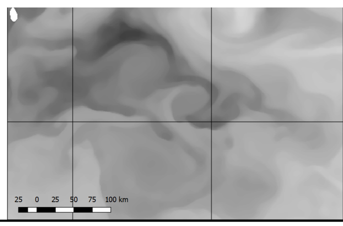
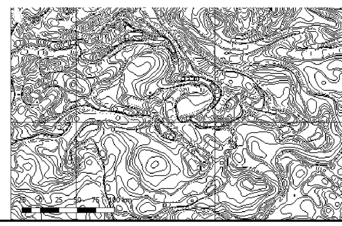
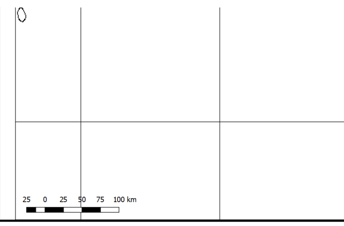
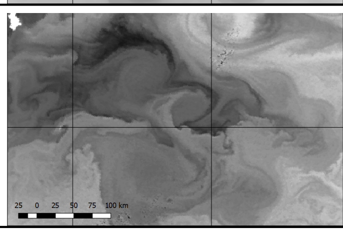
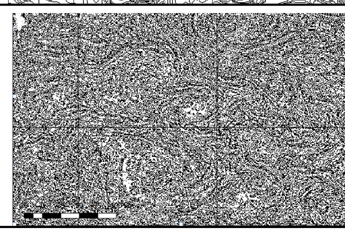
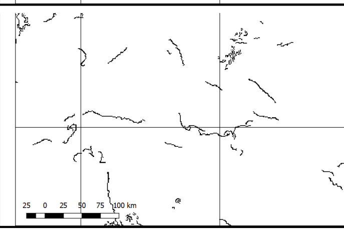
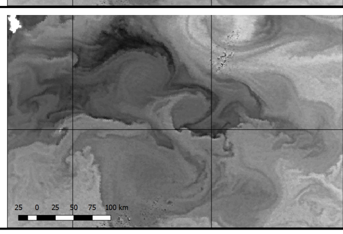
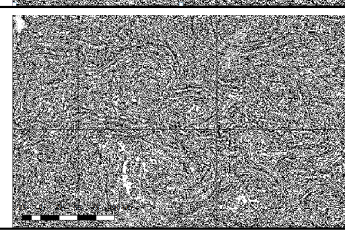
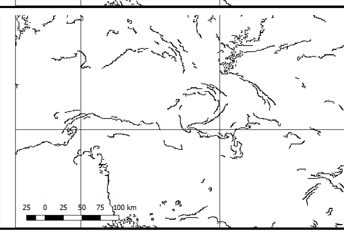
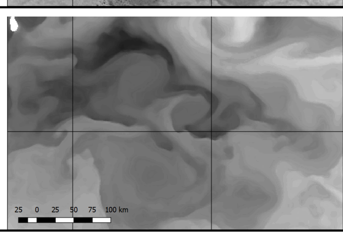
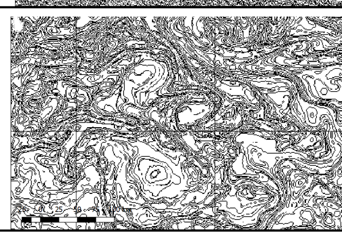
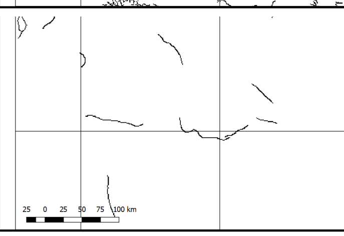
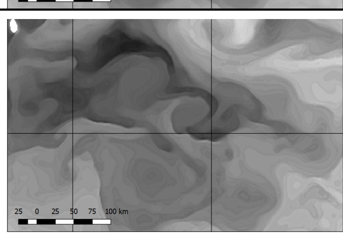
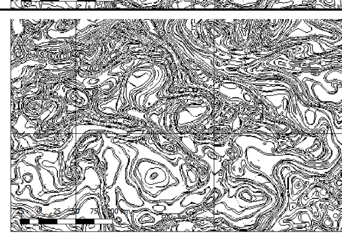
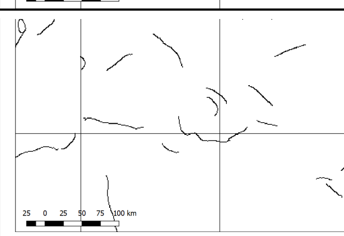
Table 1: Results of edge detection approaches

Filters	Image Before Processing	Laplacian	Canny
No filtering			
Median filter 9x9			
Median filter 9x9 applied twice			
Image enhancement			
Image enhancement applied twice			
Median filter 9x9 and image enhancement			
Median filter 9x9 and image enhancement (twice)			

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