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***Abstract*—This work aims at automatically identify and extract the region covered by the upwelling waters in the costal ocean of Morocco using the well known region-growing segmentation algorithm. The later consists in coarse segmentation of upwelling area which characterized by cold and usually nutrient-rich water near the coast. The complete system has been validated by an oceanographer over a database of 30 Sea Surface Temperature (SST) satellite images of the year 2007 obtained from Advanced Very High Resolution Radiometer (AVHRR) sensor onboard NOAA-18 satellite serie, demonstrating its capability and effectiveness to reproduce the shape of upwelling area.**

***Keywords*—Upwelling, Sea Surface Temperature, AVHRR, Segmentation, Region Growing.**

I. Introduction

The coastal ocean of Morocco, located in the western boundary of the North Atlantic, is characterized by the presence of upwelling phenomenon. In fact, under the influence of northeasterly wind and the persistence of Ekman transport along the Moroccan coastline, the surface waters are replaced by cold, less salty and nutrient-rich deep waters, reflecting the signature of upwelling phenomenon.

The Moroccan coastal upwelling is a part of the canary current system, characterized by persistent and variable upwelling all around the year [1], which promote primary productivity and consequently play a major contribution in the fisheries management and also in the study of the oceanic circulation [5][2].

Thermal infrared image of the ocean is a widely applied technique in the detection of coastal upwelling [10][3][15]. In particular, the Sea Surface Temperature (SST) images obtained from Advanced Very High Resolution Radiometer (AVHRR) are frequently used to detect and study the main thermal upwelling front, separating the cold waters near the coast and warmer offshore waters [14].

Several techniques and algorithms have been proposed to the problem of objectively detecting the upwelling region in SST images. Some of the most popular approaches include the use of the neural networks [6] in order to labeling the SST images. Then, a statistical coefficient were used to determine the existence of upwelling, but approaches based on histogram analysis [13][3] and Fuzzy c-means [14] have also been developed.

More recently, Tamim [23] has demonstrated that the application of any of the two classification strategies, fuzzy or hard, to the SST images give a satisfactory and similar results for the identification of upwelling area in Moroccan coastal upwelling. The approach has used the Fuzzy c-means and Otsu algorithms to identify the upwelling region, followed by the application of region-growing process to the labeled image in order to extract the upwelling area from the remaining offshore waters.

The objective of this paper is to provide a simple, fast and efficient tool for the detection and extraction of the upwelling area in the coastal ocean of Morocco, that automatically process a large amount of SST images daily collected and consequently, replace the labor-intensive and time consuming visual inspection made by the oceanographers for each image.

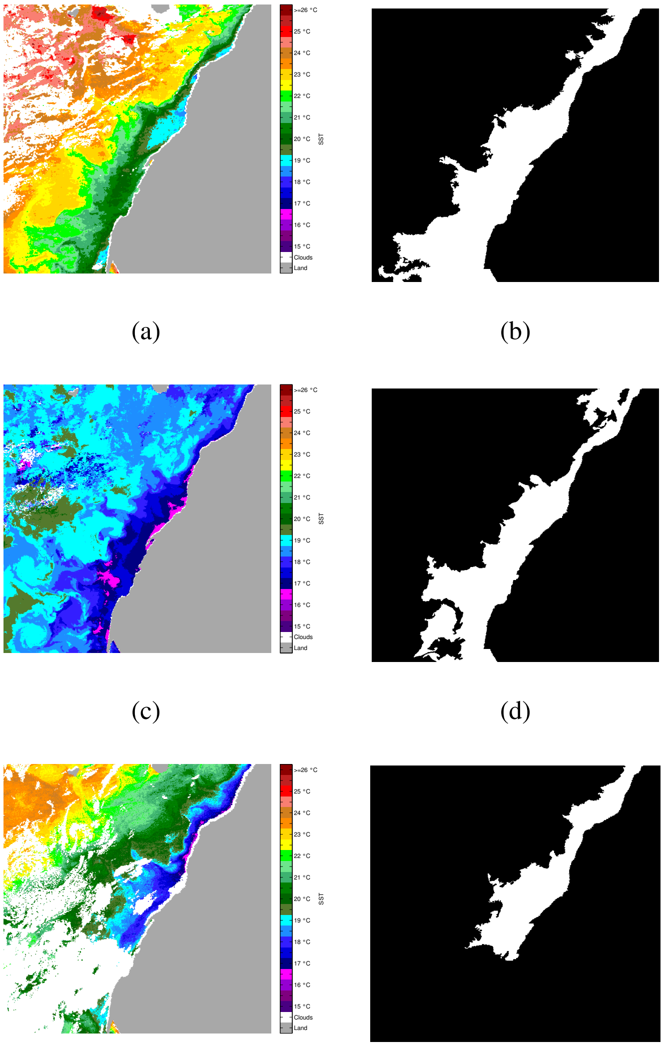
The remainder of this work is structured as follows. In section 2 we introduce the database and the geographic area of interest used in this study. In section 3 we describe the proposed methodology. Section 4 highlights the results and the validation of the algorithm. Concluding remarks and future works are in section 5.

II. Geographic study area and satellite data

A dataset of 30 AVHRR SST images of the year 2007, covering the southern part of Moroccan Atlantic coast, spans from $20°38'$ - $28°27'$N and $11°17'$ - $23°0'$W, constitutes our database. This dataset were received and processed at the Royal Center of Remote Sensing (CRTS) of Morocco, including geometric, atmospheric and radiometric corrections, and also include the land and cloud masks. The algorithm developed to generate the cloud mask uses a sequence of multispectral contrast, spectral, and spatial signature threshold tests to perform the classification of the pixel as cloud pixel [22].

Each SST image is defined by 770×990 pixels, with a spatial resolution of 1.1×1.1 km, and each pixel represent a temperature in degree Celsius. The color scale is applied to our database, in order to help the oceanographer, getting the best contrast definition for a good visualization of upwelling area.

Fig. 1(a), (c) and (e) shows three representative SST images selected from our database, illustrating 3 different upwelling



(a) (b)

(c) (d)

(e) (f)

Fig. 1: SST images obtained on (a) 2007-09-11, (c) 2007-01-01 and (e) 2007-08-14, showing different upwelling scenarios; (b), (d) and (f): corresponding binary images results of the region-growing process.

scenarios encountered in the present study : 1) SST images with a well defined upwelling structures in terms of sharp and strong thermal fronts (Fig. 1(a)), separating two water masses of constant temperature; 2) SST images with weak and smooth thermal fronts (Fig. 1(c)); 3) SST images where the presence of cloud contamination affect the continuity of upwelling along the coast (Fig. 1(e)).

The gray color region on the right side of each SST images in Fig. 1(a), (c) and (e) corresponds to Moroccan land, whereas the white pixels in the ocean correspond to cloud pixels.

III. The Proposed Algorithm

A. *Region growing process*

Automatic image segmentation is considered one of the most critical steps in image processing which involves the partitioning of a given image into a number of homogeneous regions according to a given criteria. The common procedure is to compare one pixel with its neighbors. If a similarity criterion is satisfied, the pixel can be set belong to the cluster as one or more of its neighbors.

The existing segmentation approaches can be approximately categorized into region-based methods [4], thresholding techniques [12][19][20], edge-based segmentation [16][11], clustering-based techniques [21][17] and hybrid techniques [18][8][7]. In particular, region-based segmentations which includes the region growing algorithm has been widely investigated for this purpose as a mechanism to separate the object from the background [9].

In this work we are interested in the corse segmentation of upwelling region, in order to extract the upwelling area which characterized by low temperature values near the coast.

The region growing technique examines neighboring pixels of initial points which are called the seed points, and determines whether the adjacent pixel should be added to the region.

The advantage of such method is its capability to directly determine the upwelling area, without incorporating more or less post-processing steps to eliminate the existing cloud pixels or reducing the fine structures distributed randomly in the oceans.

The pixels in the same region are labeled by the same index and the pixels in other regions are labeled by a different index. All these labeled pixels are called the allocated pixels, and the others are called the unallocated pixels.

Let I be the set of all unallocated pixels which are adjacent to a region R.

$$I = \{(x,y) \notin R | N(x,y) \cap R \neq \emptyset\} \tag{1}$$

where $N(x,y)$ are current neighboring pixels of point (x,y) and R is the homogenous region.

The difference between an unlabeled pixel's $(x,y) \in I$ and the homogenous region's mean R, is used as a measure of similarity :

$$\delta(x,y,R) = |g(x,y) - g(X_c,Y_c)| \tag{2}$$

where $g(x,y)$ denotes the temperature values of the testing pixel (x,y) and $g(X_c,Y_c)$ represents the mean value of the homogeneous region R, with $\delta(X_c,Y_c)$ the centroid of R.

If the similarity criterion $\delta(x,y,R)$ is less than a predefine threshold t, the pixel (x,y) is allocated to the respective region R. Else, it is obvious that the pixel is substantially from the cluster R found so far, so that the pixel (x,y) is not belonging to the upwelling region R but rather in the warmer water in offshore direction. This process continues until the unlabeled pixels that are neighboring to the region R, could not be added to the cluster.

B. Parameters intialization

The first step in the region growing process is to select a set of seed points as additional input. The segmentation results depends on the choice of the position and the number of those initial points.

In the case of upwelling detection, the selection of the initial points are based on the scientific knowledge and the well-known spatial distribution of the coastal upwelling of Morocco. Indeed, the initial points are chosen near the coastline, in order to correspond to upwelling sources, based on the fact that all the segmented pixels pertaining to the upwelling must have connectivity to the coastline. Additionally, three seeds points are used for the whole database, in order to take into account the variability of the upwelling temperature value along the coast.

Fig. 2(a),(c) and (e) shows the position of the three selected seeds points (black color) overlaid on original images in Fig. 1(a),(c) and (e).

After selecting the initial points, the region is then grown from these seed points to adjacent points depending on the similarity criterion δ. The success of the subsequent region growing segmentation process depends on the choice of the threshold t defined previously. This threshold has been selected, in order to obtain 2 regions with similar populations of pixels belonging and not belonging to the upwelling structures (Fig. 1(b)(d)(f)).

In this sense, the value of the threshold t has been fixed for all the database and the value of 2 is used to check whether the region growing method can yield satisfactory segmentation results to identifies the area covered by upwelling waters in SST images.

Fig. 2(b),(d) and (f) shows the results of the segmented upwelling area with our proposed algorithm in which the main upwelling front was automatically contoured with the black color.

The methodology developed to detect and extract the area covered by upwelling water can be summarized by the diagram shown in Fig. 3.

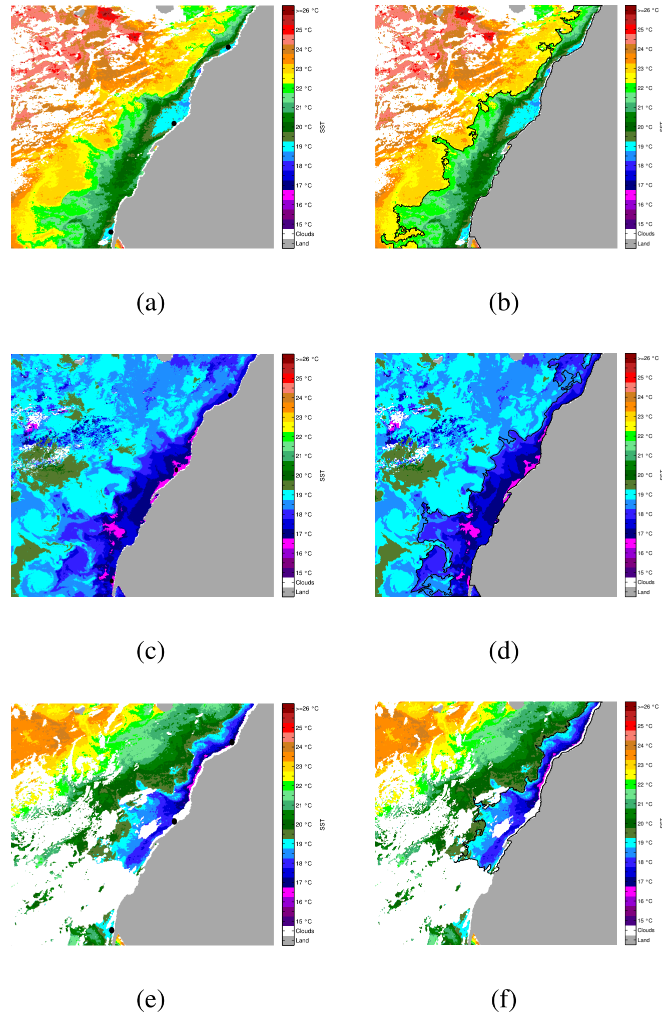


Fig. 2: (a),(c) and (e) : Visualization of the three seeds points overlaid on the original images in Fig. 1(a)(c)(e); the corresponding upwelling zone automatically contoured by the proposed region growing algorithm : (b), (d) and (f).

IV. Results analysis on the whole database

A total of 30 SST images were assessed in order to evaluate the results of our proposed method. The performance of our algorithm has been tested by an oceanographer. This evaluation was based on the scientific and technical knowledge of the coastal ocean of Morocco.

Throughout this evaluation, we used 4 grades : "Bad", "Poor", "Good" and "Excellent", to check if the proposed segmentation yield to a satisfactory results without losing any significant upwelling information. "Excellent" was attributed when the upwelling is correctly identified, and "Bad" was assigned when the upwelling area is not well delimited.

Regarding the segmentation results of the SST images, Fig. 4 shows that the grade "Bad" is not attributed at all. For the grade "Poor" the value of 6 % was reached, demonstrating the robustness of our algorithm in terms of overestimation and underestimation of upwelling region boundary. Fig. 4 also reveals that 46 % of the grades "Good" and "Excellent" was achieved. Overall, 93 % were reached by the two grades "Good" and "Excellent" together.

After the evaluation of the region growing method, over this representative database, we can conclude that the proposed algorithm have provided a satisfactory and promising results. More importantly, the quality obtained by this very simple and well-known method suggest that it can be used as a precise tool for the coarse segmentation of upwelling area.

V. Conclusion and future work

The present paper has been focused in the application of region growing algorithm to the problem of automatically detecting and extracting the area covered by the upwelling waters in SST images. The oceanographer evaluation of 30 SST images of the year 2007, revealed promising regarding the quality of segmentation results of upwelling area. Albeit

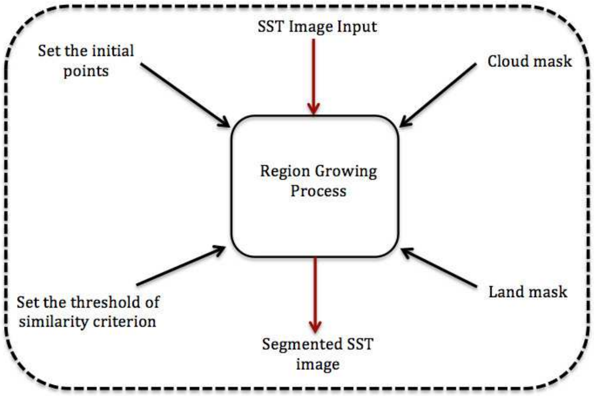


Fig. 3: Simplified block diagram of the automatic detection of upwelling region

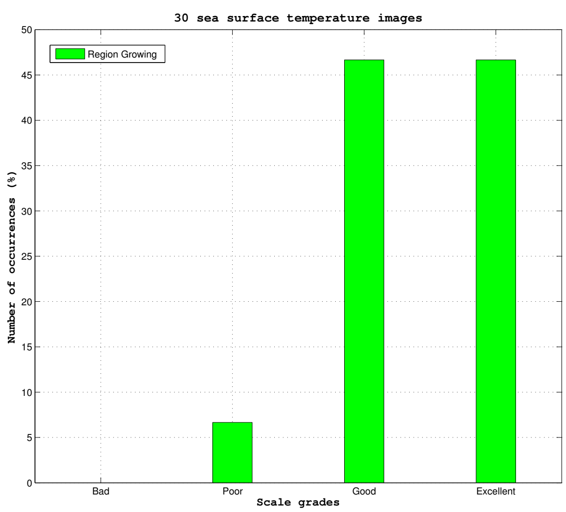


Fig. 4: Qualitative evaluation made by the oceanographer of segmentation results produced by region growing method applied on the 30 SST images.

elementary, this method can be used effectively for the detection of upwelling region in coastal ocean of Morocco.

Future work includes the application of the proposed method to more SST images in order to validate and improve the effectiveness of our method for detecting the upwelling region. Another goal is the application of this method to the chlorophyll concentration images obtained by the ocean color satellite sensors so as to demonstrate the robustness of our algorithm for both physical and biological data.

References

[1] A. Atillah, A. Orbi, K. Hilmi, and A. Mangin. Produits opérationnels d'océanographie spatiale pour le suivi et l'analyse du phénomène d'upwelling marocain. *Geo Observateur*, 14:4962, 2005.

[2] A. Bakun. Fronts and eddies as key structures in the habitat of marine fish larvae : opportunity, adaptive response and competitive advantage. *Scientia Marina*, 70(S2):105–122, 2006.

[3] J. F. Cayula and P. Cornillon. Edge detection algorithm for SST images. *Journal of Atmospheric and Oceanic Techology*, 9:67–80, 1992.

[4] Yian-Leng Chang and Xiaobo Li. Adaptive image region-growing. *Image Processing, IEEE Transactions on*, 3(6):868–872, 1994.

[5] E. Chassot, S. Bonhommeau, G. Reygondeau, K. Nieto, J. J. Polovina, M. Huret, N. K. Dulvy, and H. Demarcq. Satellite remote sensing for an ecosystem approach to fisheries management. *Ices Journal of Marine Science*, 68(4):651–666, 2011.

[6] S. Chaudhari, R. Balasubramanian, and A. Gangopadhyay. Upwelling detection in AVHRR sea surface temperature (SST) images using neural-network framework. *IEEE International Geoscience Remote Sensing Symposium*, II:926–929, 2008.

[7] C. Chu and J. K. Aggarwal. The integration of image segmentation maps using region and edge information. *IEEE Trans. Pattern Anal. Machine Intell.*, 15:1241 1252, 1993.

[8] J. Haddon and J. Boyce. Image segmentation by unifying region and boundary information. *IEEE Trans. Pattern Anal. Machine Intell.*, 12:929 948, 1990.

[9] R.M. Haralick and L.G. Shapiro. Survey: Image segmentation techniques. *Computer Vision Graphics Image Process*, 29:100132, 1985.

[10] R. J. Holyer and S. H. Peckinpaugh. Edge detection applied to satellite imagery of the oceans. *IEEE Transactions on Geoscience and Remote Sensing*, 27(1):46–56, 1989.

[11] M. Kass and A. Witkin. Snakes: Active contour models. *In: Proc. 1st Internat. Conf. on Computer Vision*, page 259 267, 1987.

[12] Young Won Lim and Sang Uk Lee. On the color image segmentation algorithm based on the thresholding and the fuzzy c-means techniques. *Pattern Recognition*, 23(9):935 – 952, 1990.

[13] J. Marcello, F. Marques, and F. Eugenio. Automatic tool for the precise detection of upwelling and filaments in remote sensing imagery. *IEEE Transactions on Geoscience and Remote Sensing*, 43:1605–1616, 2005.

[14] S. Nascimento, P. Franco, F. Sousa, J. Dias, and F. Neves. Automated computational delimitation of SST upwelling areas using fuzzy clustering. *Computers and Geosciences*, 43:207–216, 2012.

[15] John J. Oram, James C. McWilliams, and Keith D. Stolzenbach. Gradient-based edge detection and feature classification of sea-surface images of the southern california bight. *Remote Sensing of Environment*, 112(5):2397–2415, 2008.

[16] P.L. Palmer, H.S. Dabis, and J. Kittler. A performance measure of boundary detection algorithms. In *Pattern Recognition, 1994. Vol. 1 - Conference A: Computer Vision amp; Image Processing., Proceedings of the 12th IAPR International Conference on*, volume 1, pages 17–21 vol.1, 1994.

[17] T. N. Pappas. An adaptive clustering algorithm for image segmentation. *IEEE Trans. Signal Process*, 40:901 – 914, 1992.

[18] T. Pavlidis and Y.-T. Liow. Integrating region growing and edge detection. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 12(3):225–233, 1990.

[19] P.K. Sahoo, S. Soltani, and A.K.C. Wong. A survey of thresholding techniques. *Vision Graphics Image Process*, 41:233 – 260, 1988.

[20] N. Sal and S. Pal. A review on image segmentation techniques. *Pattern Recognition*, 26:1277 – 1294, 1993.

[21] X. Shen, M. Spann, and P. Nacken. Segmentation of 2D and 3D images through a hierarchical clustering based on region modelling. *Pattern Recognition*, 31(9):1295 – 1309, 1998.

[22] Larry L. Stowe, Paul A. Davis, and E. Paul McClain. Scientific basis and initial evaluation of the clavr-1 global clear/cloud classification algorithm for the advanced very high resolution radiometer. *Journal of Atmospheric and Oceanic Technology*, 16(6):656, 1999.

[23] A. Tamim, K. Minaoui, K. Daoudi, A. Atillah, H. Hussein, M. F. Smiej, and D. Aboutajdine. A simple and efficient approach for coarse segmentation of Moroccan coastal upwelling. In *Proc. European Signal Processing Conference (EUSIPCO'13)*, Marrakech, Morocco, September 2013.