SHIP DETECTION ON ENVISAT ASAR DATA: RESULTS, LIMITATIONS AND PERSPECTIVES

Guillaume Hajduch [(1)], Patrick Leilde [(1)], and Vincent Kerbaol [(1)]

[(1)] *BOOST Technologies, 135, rue Claude Chappe, 29200 Brest, France*

1. ABSTRACT

Ship detection is a crucial application for global monitoring for environment and security. It permits to monitor traffic, fisheries, and to associate ships with oil discharge. Nevertheless, each of those applications has specific constraints in terms of spatial coverage and resolution, radiometric quality, and contrast between vessels and ocean. By choosing adapted modes, polarisation and processing level ENVISAT/ASAR gives access to a wide range of data which can be optimally processed for specific applications. This paper address specific ship detection algorithms which have been developped for various demanding applications and extensively tested on ASAR data.

First, typical ship detection schemes and strategy are presented. Past research efforts on automatic target detection in SAR imagery have clearly demonstrated that no single detection algorithm will produce satisfactory results with sufficient detection sensitivity and small false alarm rate. Thus, ship detection systems generally consist of four stages: preprocessing; land masking; prescreening; and discrimination. In 2004, the demonstration of a ship detection as a add-on of oil spill detection service using ENVISAT ASAR Wide Swath images was defined and implemented in close cooperation with CEDRE over the French Zone de protection Ecologique (ZPE) in the Mediterranean Sea with such a four stage decomposition

Second, advanced processing for ship detection are addressed. Those specific processing take advantage of the huge amount of information that can be retrieved from low level product. For example some false alarm may be discarded by detecting azimut ambiguities and short life cycle events may be rejected by examining their effects on successives looks. The interest of using such advanced processing is illustrated on some examples, including coastal regions.

Third, under favorable conditions, additionnal information on detected ship targets may be retrieved, allowing to implement some basic classification. Typical dicriminant parameters are ship lengths, speed, and radar cross section. A basic classification strategy is proposed.

Eventually, all those detection and classification algorithm need to be tested to identify the advantages and drawbacks of different approaches, to strengthen final system robustness. This was the scope the project DECLIMS, Detection and Classification of Marine Traffic from Space, which is conducted by the EC Joint Research Centre. Preliminary results will be presented including mapping of european scale marine traffic.

2. INTRODUCTION

While BOOST Technologies staff are involved in a wide range of projects concerning SAR oceanography, the majority of our projects can be categorized under the following categories of long-term activities : calibration and validation [1], research on Doppler centroïd anomaly [2], processing of SAR images for measurement of ocean waves and currents [3], [4], and oil spill monitoring [5]. For the purpose of working on those kind of project, we developed a software for meteorological and oceanographic SAR images analysis [5], and we collected few hundreds of ASAR images. Ship's artifacts can be observed on those images and their detection is of particular interest for both performing geophisical analysis and by itsef to monitor traffic, fisheries, and to associate ships with oil discharge. We thus decided to develop a set a ship detection algorithms.

This paper address specific ship detection algorithms which have been developped for various applications concerning our activities and extensively tested on our set of ASAR data. First, typical ship detection schemes and strategy are presented and some limitations are discussed. Second, advanced processing for false alarm discrimination are addressed. Those specific processing take advantage of the huge amount of information that can be retrieved from low level product.

Proceedings of SEASAR 2006, 23-26 January 2006, Frascati, Italy,
(ESA SP-613, April 2006)

For example some false alarm may be discarded by detecting azimut ambiguities and short life cycle events may be rejected by examining their effects on successives looks. Third, under favorable conditions, additionnal information on detected ship targets may be retrieved, allowing to implement some basic classification. Typical dicriminant parameters are ship lengths, speed, and radar cross section. A basic classification strategy is proposed. Eventually, we present some results of our ship detection processing related to mapping of european scale marine traffic.

3 Overview of Ship Detection Strategies

Past research efforts on automatic target detection in SAR imagery have clearly demonstrated that no single detection algorithm will produce satisfactory results with sufficient detection sensitivity and small false alarm rate [6]. Thus, ship detection systems generally consist of five stages (see Figure 1):

1. *Land Masking*: using a shore-line database with a buffer zone included to limit the processing of ship detection to sea area. Land masking is important not only for the obvious reason that only ships in the ocean are of interest but also because ship detectors can produce high numbers of false alarms when applied to land areas [6]. Accurate land masking is generally difficult due to inaccuracy of recorded coastline, misregistration of SAR images and tidal variations.

2. *Preprocessing*: applying calibration factors and performing some image wide enhancement algorithms to make further prescreening stage easier and more accureate. Calibration of SAR image is also needed for further estimation of ship radar cross section (RCS)

3. *Prescreening*: generally applying a simple moving window adaptative threshold algorithm to detect bright points. Wake detection is generally not considered as the primary indicator [7]of ship artifacts as wakes are not seen for roughly 37% of all ship targets [7]. A classical Constant False Alarm Rate (CFAR) is preferred due to its robustness and simplicity and detected pixels are then clustered for detecting extended ship targets. A basic geometry for CFAR sliding window is presented in Figure 2 : the area under test (target box) is surrounded by a guard area and then a background area. The purpose of the guard area is to ensure no part of an extended target is included in the background area and hence that the background area is representative of the background statistics. Thus, dimensions of target, guard and background areas in pixels domain have to be adapted to image resolution in both range and azimuth directions, and to minimal an maximal dimensions of ship under consideration.

4. *Discrimination*: rejecting some false alarms using target measurements or characterisation of specific oceanographic or meteorological phenomena

5. *Estimation*: perform estimation of detected ship parameters for classification purpose

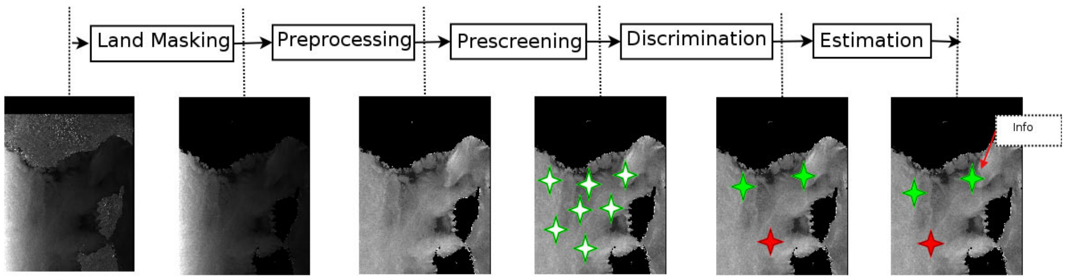


Figure 1: Ship Detection Strategy

4 False alarm discrimination

False alarm discrimination is a crucial stage of the ship detection strategy. It is clear that bright point detection is not sufficient and is by itself unable to reject "bright" events related to oceanographic events (swell, breaking waves, eddies, steep fronts...), meteorological events (rain cells, wind rows...) or to SAR image artifacts (side lobes, azimuth ambiguities...).

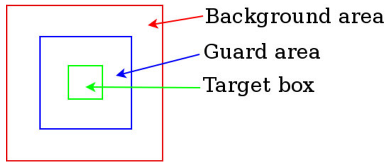
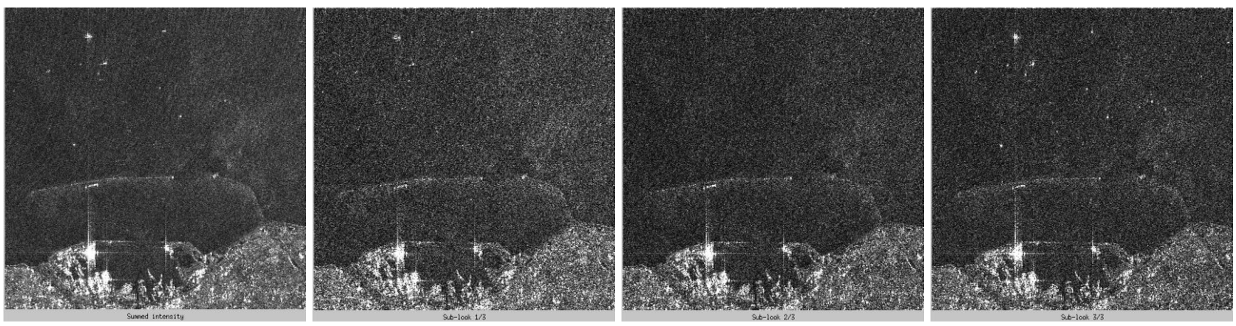


Figure 2: Example of basic geometry for CFAR sliding window

In this section, we present a method to discriminate azimuth ambiguities or bright points related to breaking waves on single look complex (SLC) images. It is well known that first order variations of azimuth spectrum of a SAR image are related to the antenna lobe of the SAR sensor in the azimuth direction. Those variations refer to attenuations of power received from the unambiguous part of the area of interest during integration time. Concerning ambiguous returns in the azimuth direction, we can consider that their corresponding received power is approximately constant during integration time. By extracting successive sublooks from an SLC images it is then possible to observe image brightness variations related to those azimuth ambiguities (see Figure 3 and related to variation of signal to ambiguity ratio :

- First image is the result of incoherent addition (multi looking) of the three successive sub-looks. Bright points at the top are related to azimuth ambiguities corresponding to strong backscattering in an urban area (here the city of Cherbourg, France)
- The tree other images are successive sub-looks of the same area. While the first and last sub-looks images contain azimuth ambiguities, the second (center sub-look) contain fewer azimuth ambiguities due to a better signal to ambiguity ratio.



(a) Multi Looked image (b) Sub Look 1/3 (c) Sub Look 2/3 (d) Sub Look 3/3

Figure 3: Variation of azimuth ambiguities through successive sub-looks

False alarm detection related to azimuth ambiguities can then be easily rejected on SLC images by performing sub-looks extraction and analysing brightness variations through those successive sub-looks. On the same way, discrimination of short life time events like breaking waves may be performed.

5 Results

In 2004, the demonstration of a ship detection as a add-on of oil spill detection service using ENVISAT ASAR Wide Swath images was defined and implemented in close cooperation with CEDRE over the French Zone de protection Ecologique (ZPE) [5]. We thus developped tools to automatically process a set Wide Swath (WS) products [5].

It is generally difficult to assess accuracy of ship detection because only few ground truth information are available concerning ship position. Nevertheless the DECLIMS project [7], should be an opportunity to share valuable informations related to groundtruth.

Visual analysis can be however used to oversee performance assesment by performing ship detection on a set of SAR images over high ship traffic density area like Europe. Some results are presented in Figure 4 and followings.

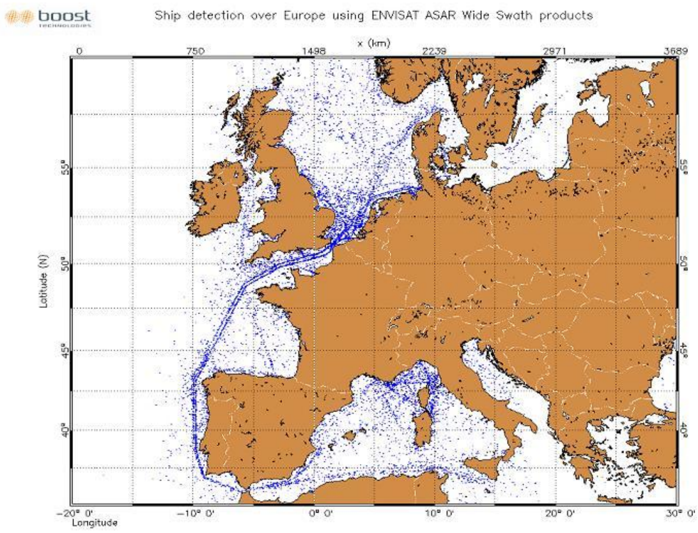


Figure 4: Ship detection over Europe using ENVISAT ASAR Wide Swath products (Overview)

Main traffic separation schemes can clearly be delineated by ship detection :

- Traffic from Gibraltar to the Channel and the Ouessant fairway Figure 5
- Traffic in mediterranean sea Figure 6
- Traffic from the Channel to Dutch and German harbours Figure 7

Moreover, validity of our ship detection algorithm can be monitored by analysing the histogram of incidence angle for detected ships. Figure 8 clearly illustrates that high incidence angle is preferred for ship detection, which corresponds to theoretical considerations on ship detections [7]. The slight decrease of the number of detected ships for "extreme" incidence angle is related to side effect on ENVISAT ASAR Wide Swath images.

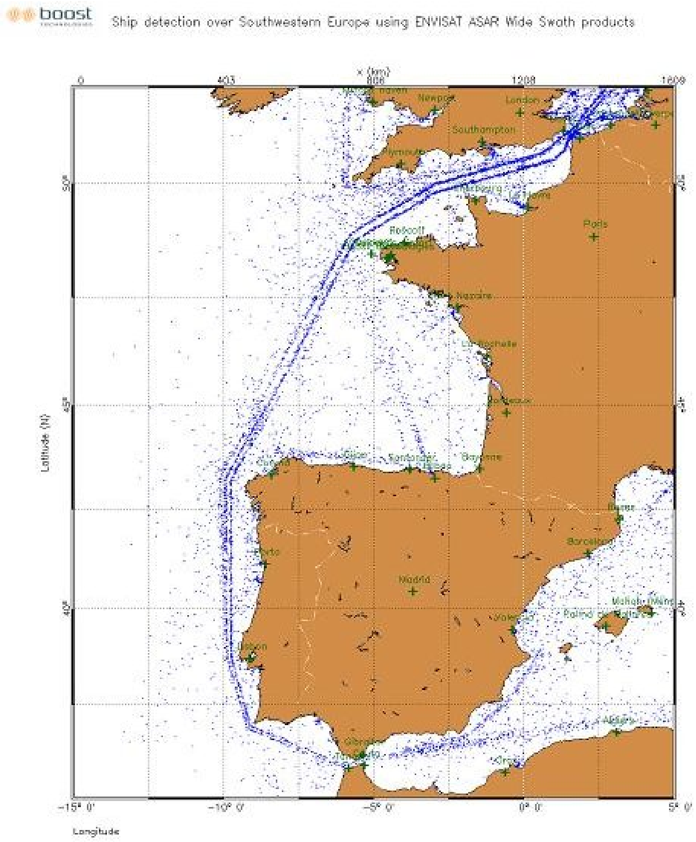


Figure 5: Ship detection over Europe using ENVISAT ASAR Wide Swath products (Atlantic Ocean)

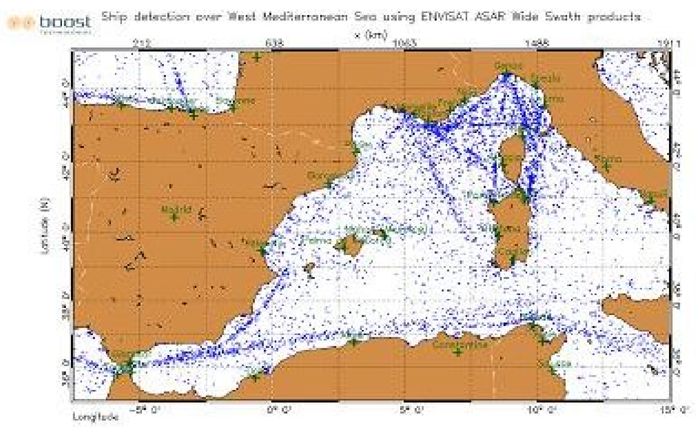


Figure 6: Ship detection over Europe using ENVISAT ASAR Wide Swath products (Mediterranean Sea)

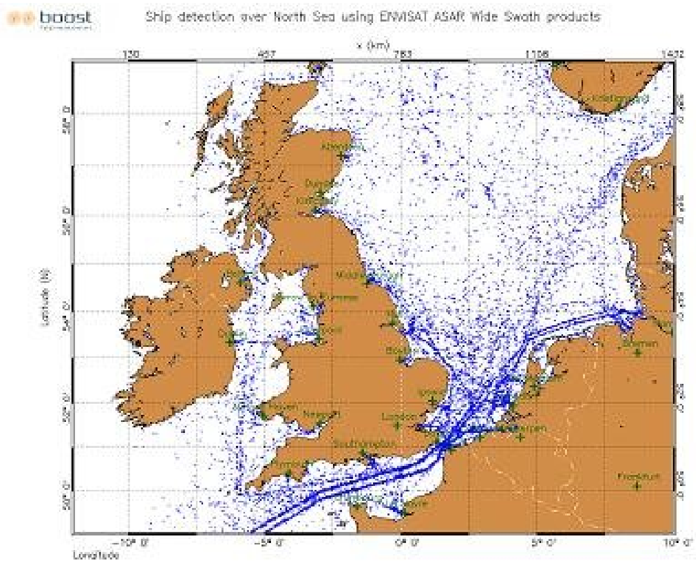


Figure 7: Ship detection over Europe using ENVISAT ASAR Wide Swath products (Channel)

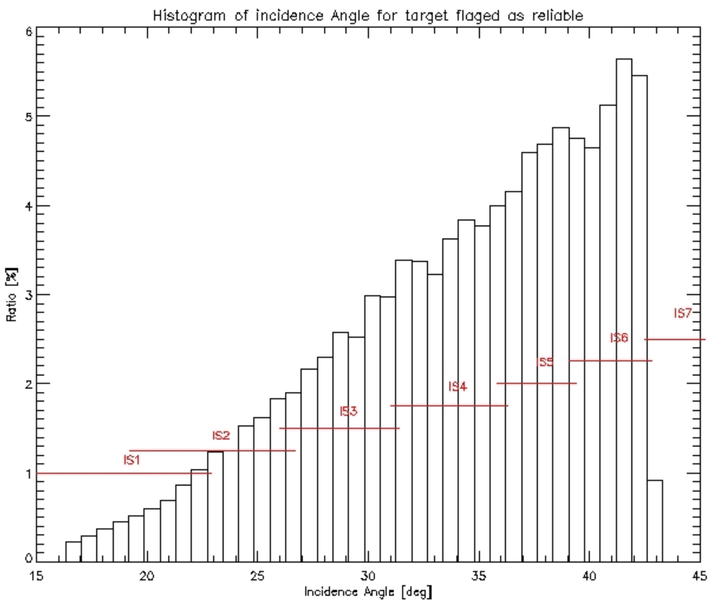


Figure 8: Histogram of incidence angle for detected ship targets

6 Conclusion

In this paper, we presented a short overview of general strategies for ship detection on SAR images. We proposed an algorithm to discriminate azimuth ambiguities (ghost targets) and short lifetime events (breaking waves...) from true ship artifacts by sub-looks processing of Single Look Complex images. We finaly presented some results of our ship detection algorithm by mapping the european scale maritime traffic. The ability to delineate main traffic separation schemes over Europe and the histogram of incidence angles for detected ships are visual indicators of the robustness of our algorithm. Other indicators like estimated ship routes for ships detected in traffic separation scheme could be also of interesting while waiting results of DECLIMS benchmarks.

References

[1] *ASAR Wave mode first geophysical results*, B. Chapron, F. Collard, H. Johnsen, and G. Engen, ENVISAT Calibration Review meeting, 9-13 September 2002. 1

[2] *Direct measurements of ocean surface velocity from space: Interpretation and validation*, Bertrand Chapron, Fabrice Collard, and Fabrice Ardhuin, Journal of Geophysical Research, 2005. 1

[3] *Proceedings of the Second Workshop Coastal and Marine Applications of SAR*, , June 2004. 1

[4] *Improved wind retrieval scheme for the generation of SAR level 2 wind products*, , SEASAR 2006 Workshop, January 2006. 1

[5] *Improved oil spill detection service over the French ZPE: developments and results*, Vincent Kerbaol, Fabrice Collard, Patrick Leilde, and François Parthiot, SEASAR 2006Workshop, January 2006. 1, 4

[5] *SARTool presentation*, BOOST Technologies, <http://www.boost-technologies.com/web/docs/SARTool_Brochure-en.pdf>. 1, 4

[6] *The State-of-the-Art in Ship Detection in Synthetic Aperture Radar Imagery*, D.J. Crisp, March 2004. 2, 1

[7] *DECLIMS Project*, JRC, http://intelligence.jrc.cec.eu.int/marine/declims. 3, 4, 4

[7] *Principles and performance of an automated ship detection system for spaceborne SAR images in coastal regions*, K. Eldhuset, IEEE Trans. on Geoscience and Remote Sensing, 1010-19, 1989. 3, 4, 4

[7] *Ship Detection by the RADARSAT SAR: Validation of Detection Model Predictions*, P.W. Vachon, J.W.M Campbell, C.A. Bjerkelund, F.W. Dobson, and M.T. Rey, March 1997, 48-59, Canadian Journal of Remote Sensing. 3, 4, 4