

INDES

Product User Manual - Vessel detection

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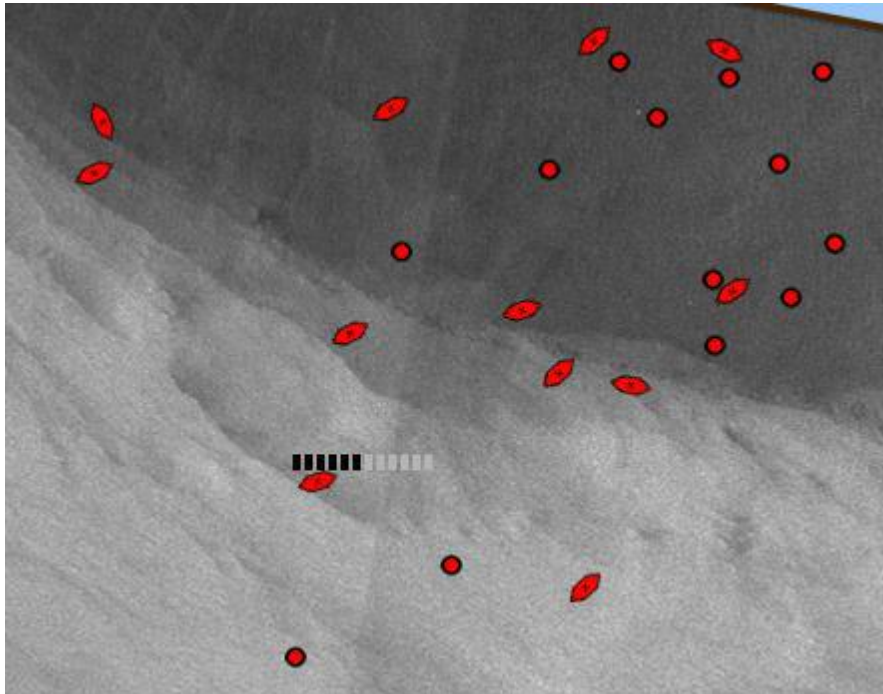


1. PURPOSE

This document presents the information needed by users for the **vessel detection** products provided in the frame of the Indeso project.

This document is organized as follows:

- Chapter 2; processing: input data and method applied.
- Chapter 3; the product description, with the different files provided, the nomenclature
- Chapter 4; how to download products.



2. PROCESSING

2.1. INPUT DATA

Images are taken from Radarsat-2 satellite.

2.2. METHOD

The concept of IUU monitoring is based on the joint use of radar satellite imagery and Vessel Monitoring System (VMS). All vessels (above a reasonable size) are detected by radar satellite over a monitored area. Cooperative vessels are transmitting VMS signal while non-cooperative vessels are spotted by radar imagery but do not report their positions through VMS. These non-cooperative vessels are potential poachers.

The service uses the ship detection reports generated in near-real time (typically in less than 30 min after satellite pass) by the Satellite Receiving Station in Perancak and merge them with the existing VMS.



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2.2.1. AREAS OF INTEREST

For IUU fishing monitoring, 3 areas of interest (AOI) have been selected:

Name	Area size
Arafura sea	2000 km ²
Natuna sea	2402.12km ²
Sulawesi sea	3616km ²

At this stage they are coarse areas of interest and they will be defined more precisely by applications users before the start of the application.

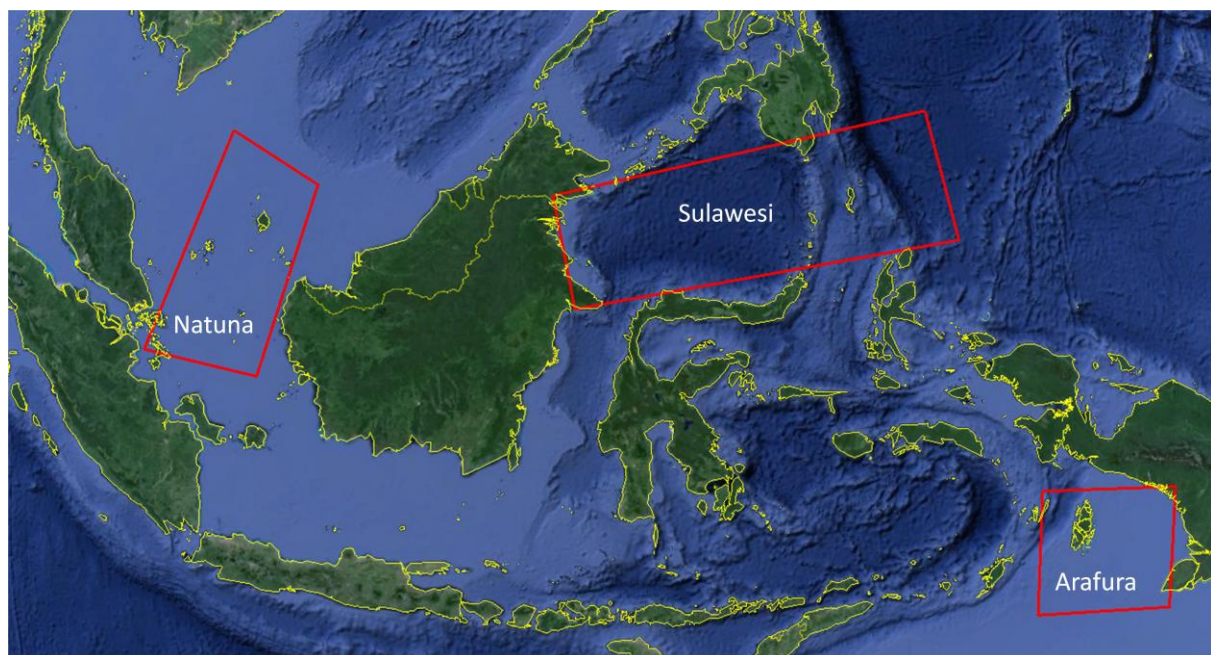


Figure 1 Location of the AOI for IUU fishing application

2.2.2. METHOD

2.2.3. SHIP DETECTION (SARTOOL SHIP)

The ship detection process is an automated process where the result can be greatly improved with supervision from the Radar Analyst to validate or refuse the results of automatic detection.

The automatic part of vessel detection process is performed by SARTool software, using its dedicated Ship module. SARTool is designed by a CLS team of radar experts. SARTool has proven high level of performance to detect sharp features of interest in the radar scene, and produce user-friendly reports for end users. SARTool, including all the software and accompanying documentation, is provided under the terms and conditions of SARTool License. SARTool name is a registered Trademark.



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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 that are also implemented within SARTool:

1. **Pre-processing** addressed by data ingestion and calibration process. This refers to applying calibration factors and performing some image-wide enhancement algorithms to make further prescreening stage easier and more accurate. Calibration of SAR image is also needed for further estimation of ship Radar Cross Section (RCS). The pre-processing may also include compensation geo-location inaccuracies if the corresponding mis-registration estimates are previously specified as an input parameter.
2. **(Land) masking**: enabling to focus on area of interest. The land masking is applied using a shoreline 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 near coast areas due to the tide. Accurate land masking is generally difficult due to inaccuracy of recorded coastline, mis-registration of SAR images (if not previously estimated and compensated) and bad knowledge of the tidal area.
3. **Pre-screening**: this step is performed by applying a CFAR (Constant False Alarm Rate) detector aiming to a fast restriction of the detection problem to a small number of target candidates for further investigation.
4. **Discrimination and parameter estimation**: in order to both reject false alarms related either to instrumental artefacts, meteo-oceanic artefacts or pre-screening inaccuracies and to estimate vessel parameters (length, route, radar cross section...) and cinematic parameters (wake detection and speed estimation)

2.2.3.1. DISCRIMINATION OF FALSE ALARMS

The purpose of this stage is to reject candidate targets likely to be associated with erroneous detection. The origin of those false alarms can be associated to instrumental artefacts or meteo-oceanic artefacts.

Nadir ambiguities

We illustrate the problem of Nadir ambiguities on the figure below. This phenomenon is related to specular reflexion at Nadir position and intercepted by secondary elevation lobes of antenna. Nadir ambiguities can frequently be observed in Radarsat-2 for various modes. The occurrence of such an effect increases when the platform passes over low wind speed areas.

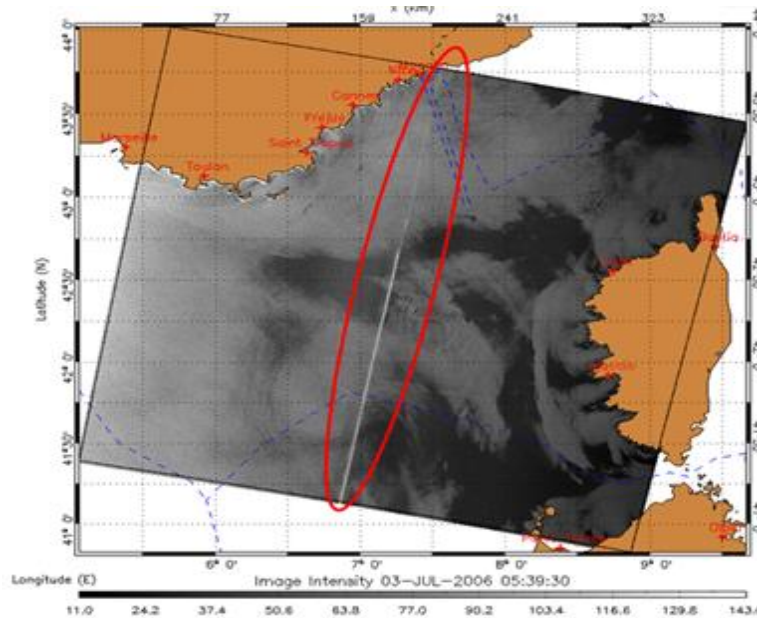


Figure 2: Illustration of Nadir ambiguity

SARTool takes benefits of the full set of metadata of the SAR Level 1 products in their native format in order to locate the image area prone to be corrupted by Nadir ambiguities. The detected echoes in this area are then flagged as ambiguities and may be rejected prior the generation of detection reports.

Azimuth ambiguities

Azimuth ambiguities are another phenomenon which is related to observation of strong scatterers within antenna side lobes in azimuth direction. This effect is illustrated in the figure below.

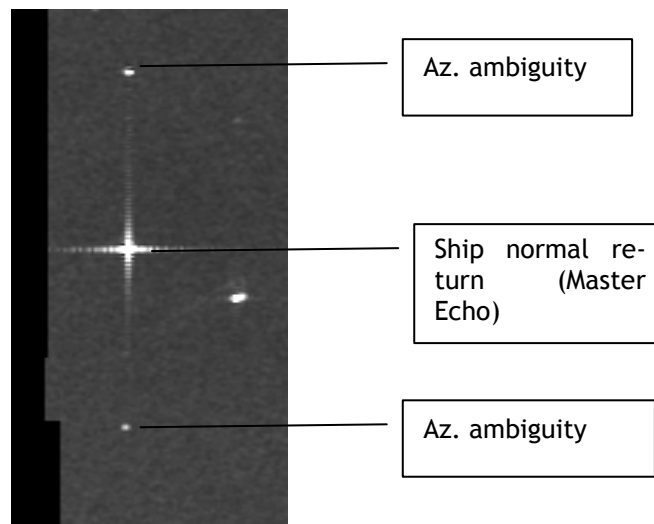


Figure 3: Illustration of azimuth ambiguity

SARTool takes benefits of the full set of metadata of the SAR Level 1 products in their native format in order to estimate this azimuth ambiguous distance dynamically for all pre-screened echoes. It is then easy to locate pre-screened echoes which are aligned in the azimuth direction and located at this specific distance. Additional checks are applied in order to ensure the best pairing between the master echo and its azimuth ambiguous counterparts:

- Radiometric test: it is known that the azimuth ambiguous sidelobes correspond to weaker echoes. The echoes identified as azimuth ambiguous contribution must then be associated to a stronger master echo. A minimum radiometric ratio (depending on each sensor) must then be checked.
- Squint test: some sensors including Radarsat-2 acquire data with a specific squint inducing a specific alignment between the master echo and the corresponding ambiguities.

The corresponding echoes are then flagged as ambiguities and may be rejected prior the generation of detection reports.

Radiometric ambiguities

Other artefact of ship detection process can be related to area of inhomogeneous sea clutter or bad hypothesis on probability density law. This kind of artefact can easily be addressed by a trained classifier using a basic feature vector including radiometric measurements on target candidate. The most important parameter in this classification is the maximum radar cross section of the detected echo.

SARTool takes benefits of the full set of metadata of the SAR Level 1 products in their native format in order to perform a radiometric calibration of the data during the pre-processing stage of the detection scheme. SARTool ship is thus able to perform this radiometric analysis.

The corresponding echoes are then flagged as ambiguities and may be rejected prior the generation of detection reports.

Ghost targets

At this point, we can illustrate the effect of so called “ghost targets” which are in fact related to short lifetime events which can be only observed during a small part of the integration time. They can be either affected to azimuth ambiguities or sea spikes. In order to reject this kind of artefact it is possible to consider the content of sub-looks extracted from Single Look Complex (SLC) product. The content of such sub-looks is illustrated on the figure below for three sub-looks and the corresponding multi-look image. We can see here that some azimuth ambiguities just appears and disappear from one sub-look to another and are stèaked in the multi-look images corresponding to classical detected products. By performing an analysis of cross-correlation between sub-looks is easy to reject those ghost targets.

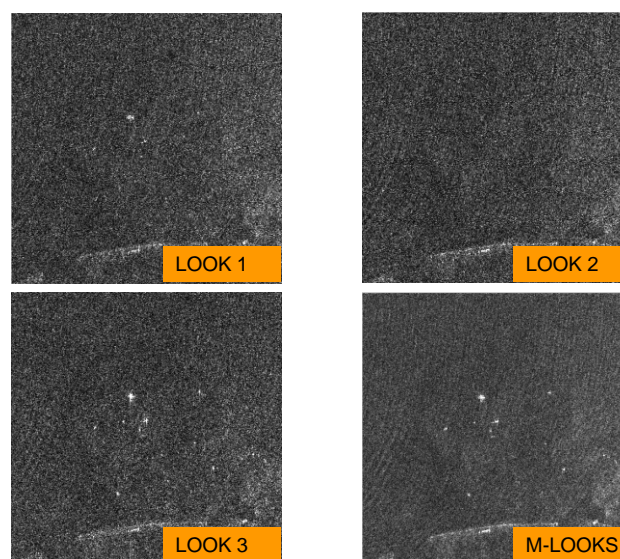


Figure 4: Behavior of azimuth ambiguity on sub-looks

2.2.3.2. ESTIMATION OF PARAMETERS

Length and route estimation

The detected echoes are clustered based on morphologic considerations on vessel shapes. This stage allows merging all pixels belonging to the same vessel. The direction of the vessel center line is thus estimated and finally its length.

Radar Cross Section

The maximum value of the clustered pixels together with the maximum Radar Cross Section (RCS) is extracted from the full resolution image and exported in the generated reports.

Wake detection, route and speed estimation

For each detected echo, wake detection is performed in the vicinity. The search distance is dynamically computed based on maximum vessel speed and its distance from the sensor. The wake detection algorithm is based on the detection of the full wake pattern including both the turbulent wake and the Kelvin wake, after conversion of the product by applying a Hough transform.

The consistency of relative positions of the echo and its wake are checked (direction of the wake compatible with the relative Doppler shift of the echo). Incidentally, during this check the radial velocity of the echo is computed based on its azimuth shift relatively to the wake position. This radial velocity is interpreted knowing the wake direction in order to estimate the complete horizontal speed of the vessel.

As an output of this wake detection stage, the corrected position of the vessel with respect to its detected wake is provided together with its originally detected position. Providing those two positions allows a full traceability of the detection and a better interpretation of the results at latter supervised stage regarding correlation of echoes with AIS tracks (see following sections).

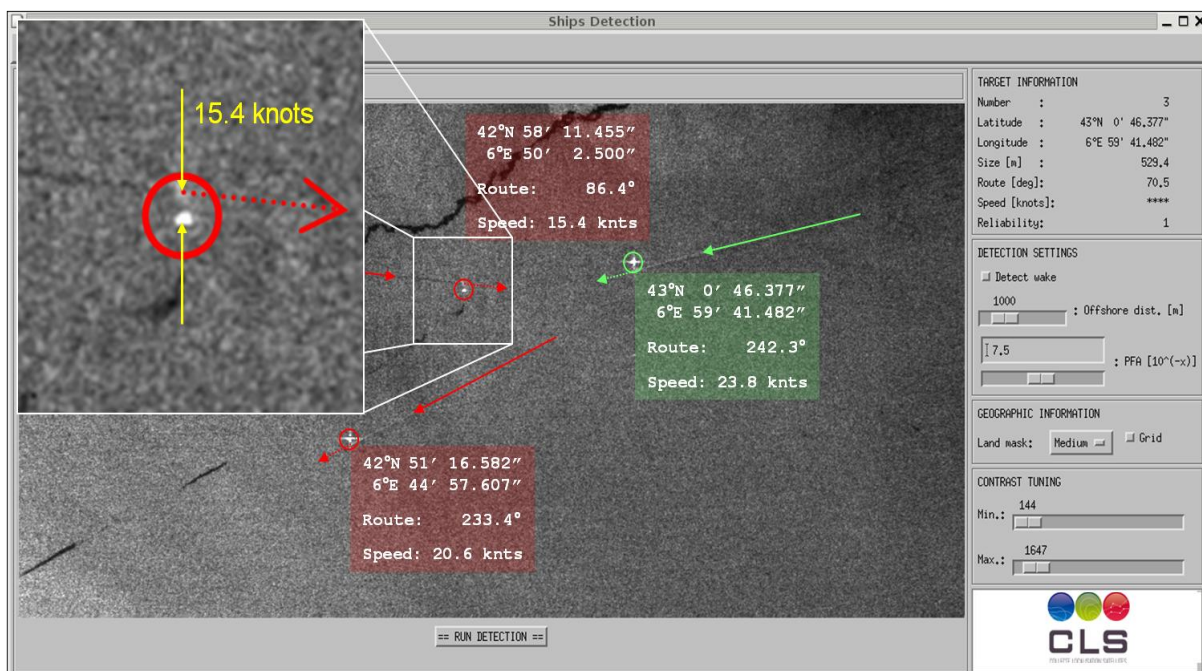


Figure 5: Example of wake detection and speed estimation

2.2.3.3. RADAR ANALYST VALIDATION

Once the automatic detection is completed, the Radar Analyst shall display the product and review all detected ship in order to indicate the confidence level and possibly discard false detections. When this Supervision is completed, SARTool shall proceed with the distribution of Ship Detection Reports.

2.2.3.4. SHIP DETECTION REPORT

The format of the report is GML (Geometry Meta Language) with a set of imagettes (PNG format) of the detected vessels. The Ship Detection Reports typically includes:

- Date/source
- Latitude/Longitude of the detected echo with and without Doppler correction
- Confidence level (Reliable / Non reliable)
- Characterization (size, heading, speed if available)
- Target type
- Imagette (optional)
- Correlation status (correlated vessel, SAR only detection)
- Doppler shift correction flag (Applied/ Not applied)
- Maximum pixel and RCS values

3. DESCRIPTION OF THE PRODUCT SPECIFICATION

3.1. PRODUCT GENERAL CONTENT AND SPECIFICATIONS

The vessels SAR-detected can be visualized and selected via Maestro INDES website, giving access to the following parameters:

Qualification	Date	Length	Heading	Qualification Name	Comment
True	2014/07/29 20:30:46 UTC	219.00m	354.70 deg northe	Unknown	

3.2. ACKNOWLEDGMENTS

Original INDES Products - or Value Added Products or Derivative Works developed from INDES Products including pictures - shall include the following credit conspicuously displayed and written in full:

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4. HOW TO DOWNLOAD A PRODUCT

The vessels product is only available for visualization on maestro Indeso website.
The selection can be done by date, time, and technical parameters.

