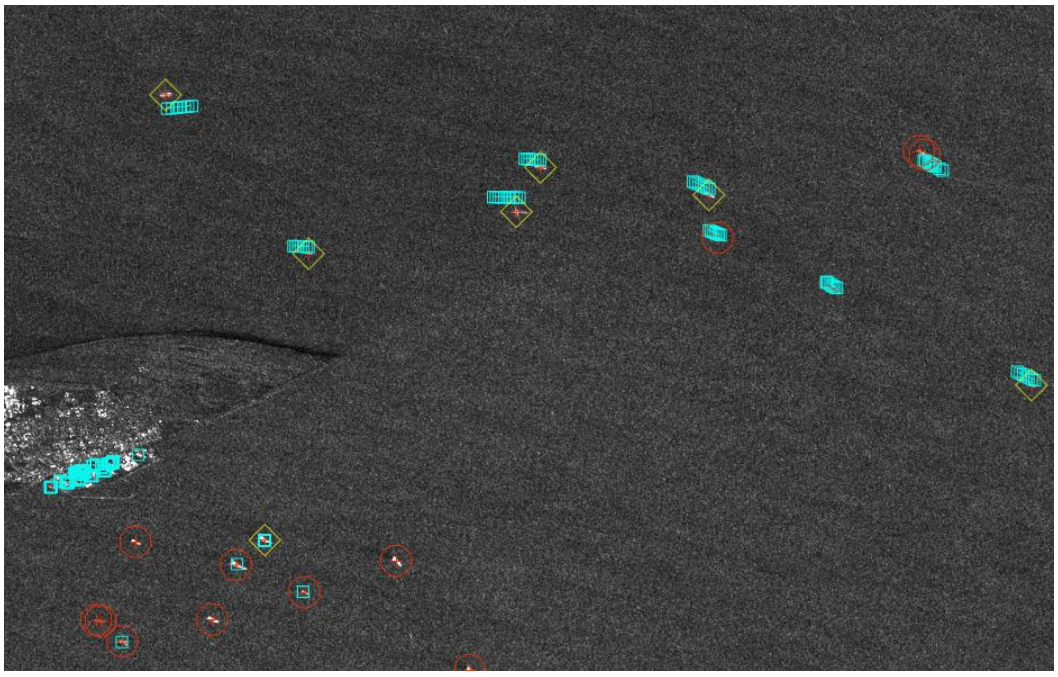
SAR ESSENTIALS TUTORIAL:
SHIP DETECTION AND AIS MATCHING



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1. INTRODUCTION

The **SAR Essential** module provides a dedicated workflow called ***SAR Ship Detection*** for ship and vessel detection over water bodies from Synthetic Aperture Radar (SAR) satellite images. In case marine information from Automatic Identification System (AIS) is available, the detected targets can be matched to the ship position and voyage trajectory from the AIS messages.

The ship detection algorithm is based on a two-parameters Constant False Alarm Rate (CFAR) detector approach, a form of the Adaptive threshold algorithm. The goal is to identify brighter areas or "targets" of significant backscatter (from the statistical point of view), stronger than defined surrounding background. To avoid spurious effects, a guard window around the potential target (Figure 1) is discarded during this comparison (Crisp, 2004).



Figure 1. The concept of the Adaptive threshold algorithm as a base for the SAR Ship Detection workflow

In the basic approach, all windows are moved one pixel at a time across the whole image. The algorithm requires an adaptive threshold for the target brightness in comparison to the statistics of the surrounding area. Pixels with backscatter value above the threshold are considered as significant backscatters, i.e. ships. The targets identified as having higher backscatter are exported to a new shapefile.

In case a file with information derived from the AIS is available, the location of the SAR-detected targets can be compared with the information from the AIS messages. AIS is a mariner digital positioning system developed for identification, tracking, search and rescue operations of vessels. The requirements to the AIS are defined by the Intentional Convention for the Safety of Life at Sea (SOLAS[1]), specifically regulation V/19, of the International Maritime Organisation (IMO[2]). AIS messages are aiming at exchanging and providing information about the vessel's identity, position, speed and course, along with other relevant information.

This document guides the reader through the *SAR Ship Detection* workflow by a step-by-step example. The reference software version used throughout the tutorial is SAR Essentials version 1.2.0, running under ENVI 6.3 with a standard (GIS-like) interface, installed on Windows 11, 64bit.

Paragraphs like this one, showing a hand on the left side, indicate a practical step that the user should perform to proceed with the tutorial.

[1] https://www.imo.org/en/ourwork/safety/pages/ais.aspx
[2] https://www.imo.org/en

2. DATA FOR SHIP DETECTION

2.1. SAR DATA REQUIREMENTS

The *SAR Ship Detection* workflow gives the possibility to open SAR images in slant or ground range coordinates (Level 1, 2 or 3) in original formats such as manifest.safe, *.h5, *.xml, *.n1, *.e1, *.e2, IMG*, *.nitf, *.ntf, and others. It also supports processing of images in the SAR Essentials general format (e.g., *.sml files), imported from other workflows, such as those produced by the *SAR Basic Data Processing* tool.

The SAR image used for *SAR Ship Detection* should meet the following requirements:

- The data must be properly calibrated. Radiometric calibration aims to convert the backscatter intensity into a normalised radar cross-section. As a result, the strength of the radar signal is expressed using the conventional measure by the coefficients sigma naught or beta naught (in dB). These coefficients represent reflectivity per unit and depend on system parameters such as the antenna gain pattern and range-spreading loss. After calibration, radar data acquired by different sensors, in different acquisition modes, at different times, or generated by different processors can be directly compared and their brightness consistently analysed.
- If the input data are in slant range coordinates, the workflow automatically performs both geocoding and calibration internally.
- If the input data are geocoded, they must be already properly calibrated.

Proper calibration requires that the parameters supplied by the data provider are accurate. The compatibility check therefore includes a quality-control step to verify the correctness of these calibration parameters. These parameters are checked during the *Import* process (see Section 3.4).

2.2. AIS DATA FORMAT

The Automatic Identification System (AIS) files are obtained from the mariner digital positioning system for identification and tracking of vessels. The AIS information is grouped to static, dynamic and voyage related. The AIS marine traffic information loaded to the workflow will be converted into set of shapefiles. Static messages will be stored in a point-type shapefile, while the dynamic messages (positions) belonging to the Maritime Mobile Service Identity (MMSI) code of the vessel will be merged with the corresponding static messages and stored as polylines in a second track shapefile. Another point-type shapefile will be generated for messages from stations, if present.

The AIS traffic data that can be used by the *SAR Ship Detection* tool within SAR Essentials as an additional function. The workflow gives opportunity to load AIS data in a format among several predefined standards listed in Section 5.1, but also to define a custom template for the messages from the AIS. This can be done in the section *Custom AIS Preferences* of the *SAR Essentials Management* tool (Figure 2).

Note: The custom AIS format template must be pre-defined in the *SAR Essentials Management* tool before opening the *SAR Ship Detection* workflow.

Note: The template file specifies the order of the fields in the custom AIS CSV file. Type of the data in the fields is predefined, while here only the order of the fields in the CSV file can be modified. The number associated to the field name will correspond to the consecutive record (column) in the CSV file template (values by default are given).

Note: Not all parameters are visible through the workflow.

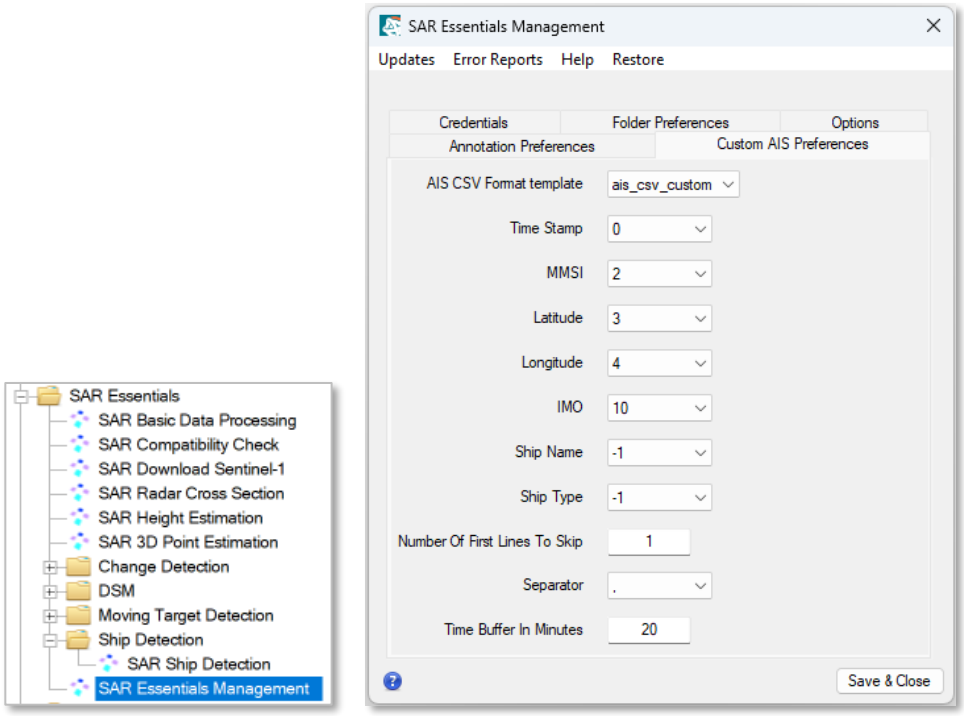


Figure 2. SAR Essentials Management tool and its section Custom AIS Preferences

The modified template will be saved as a new custom AIS template and will be stored in the user folder (C:\Users\XXX\.idl\sarmap\sar_essentials-XXX\format_ais_csv_custom.txt).

The AIS template can be later recalled from the *SAR Ship Detection* workflow – see Section 5.2.

2.2.1. AIS CSV Format Template

Two predefined AIS Comma Separated Values (CSV) file templates – *ais_csv_DK* and *ais_csv_NOAA*, can be loaded, modified, and selected (Figure 4). These AIS data formats correspond to the file distributed freely by two agencies:

- US National Marine Electronic Association (NMEA) – details for the standard NMEA data can be found here https://www.nmea.org/nmea-0183.html
- Danish Maritime Authority (http://aisdata.ais.dk/) – details about the structure of the file can be found here: http://aisdata.ais.dk/!_README_information_CSV_files.txt and
- US National Oceanic and Atmospheric Administration (NOAA) that can be found here https://coast.noaa.gov/htdata/CMSP/AISDataHandler/2024/index.html

Alternatively, a custom CSV template for AIS data can be chosen via *ais_csv_custom*.

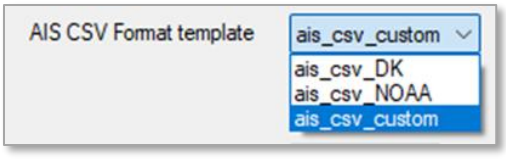


Figure 3. AIS templates in SAR Essentials Management tool

2.2.2. Time Stamp

The Time Stamp presents the full Coordinated Universal Time (UTC) date and time (dynamic parameter), when the position is received by the AIS and registered by the Electronic Position Fixing System (EPFS). The date-time format is YYYY-MM-DD HH:MM:SS (ISO 8601 format) – example: 2021-12-31 23:59:59.

2.2.3. MMSI

This field represents static information that contains the Maritime Mobile Service Identity (MMSI) number of the vessel (nine-digit AIS identifier). The first digit of an MMSI depends on the kind of station. MMSIs starting with any number between 2 to 7 refer to ship stations. The initial digit of a ship station determines the area of origin of the vessel:

Ship station identifier in the MMSA number	Area of origin of the vessel
2	Europe
3	North America, Central America and Caribbean
4	Asia
5	Oceania
6	Africa
7	South America

The next 2 digits mark each MMSI country-specific code. As a result, the first three digits of the MMSI, known as Maritime Identification Digits (MID), correspond to the flag of the vessel.

2.2.4. Latitude

This is a dynamic parameter representing the geographic latitude coordinate (Coordinate system WGS84) of the vessel in decimal degrees (range from -90 to +90, North = positive, South = negative).

2.2.5. Longitude

This is a dynamic parameter indicating the geographic longitude coordinate (Coordinate system WGS84) of the vessel in decimal degrees (range from -180 to +180, East = positive, West = negative).

2.2.6. IMO

INO is a unique number of the vessel (not changeable) assigned by the International Maritime Organisation (IMO[3]). It is a 7-digit number that is a part of the static information.

2.2.7. Ship Name

Name of the vessel (up to 20 characters) - static information.

2.2.8. Ship Type

The ship type of the vessel is represented by a 2-digit numeric code and/or labelled as shown in the columns below:

[3] https://www.imo.org/

Code	Label
1	Reserved
2	Wing In Ground
3	Special Category
4	High-Speed Craft
5	Special Category
6	Passenger

2.2.9. Number of First Lines to Skip

Number of the first lines of the imported file to be skipped in case of a specific file text header. In case no description text is included, 0 must be entered.

2.2.10. Separator

CSV field separator - it can be selected between "(Undefined)", "," and ";".

2.2.11. Time Buffer in Minutes

This field identifies the total time buffer to consider during AIS import relative to the time extracted from the reference SAR image, if provided as additional input during CSV data import.

2.3. TUTORIAL DATA

The functionality of the tool is demonstrated with an example using data from a common archived file **SAREssentials_ShipDetection.zip** within the *SAR_Essentials_dataset* subfolder:

1. **sentinel1_146_20161016_165333021_IW__VV_slc_list_geo.dat** within the archived folder **SAREssentials_ShipDetection.zip**, obtained from a sample of the Sentinel-1 image S1A_IW_SLC__1SDV_20161016T165331_20161016T165358_013518_0159FB_866C.SAFE.zip over the Skagen Odde peninsula in Denmark. The image is provided with courtesy of the European Space Agency (ESA) and was accessed on 30 September 2025 through the Copernicus Browser[4]. The data are distributed under the Regulation (EU) No 377/2014 and the Commission Delegated Regulation (EU) No 1159/2013, in agreement with the Copernicus Sentinel Data Policy, ESA/PB-EO(2013)30, rev. 1, and Art. 7 of the Regulation 1159/2013. The footprint of the extracted Sentinel-1 image used in the example is shown with a red polygon in Figure 4.
2. **aisdk_20161016_053-054.csv** – a sample of AIS file from the Danish Maritime Authority (DMA5) for 16 October 2016, downloaded from the DMA AIS Data[6] web site. The file is in CSV format.

The Sentinel-1 image has the following characteristics:

Date	Orbit	Observation direction	Azimuth resolution	Range resolution	ILOS*	ALOS*	Image format	Frequency Band
16.10.2016	ascending	right	13.842m	3.692 m	39.1°	79.8°	SLC	C

* ILOS – incidence angle, measured between the Line-of-Sight (LOS) and the vertical to the ellipsoid; ALOS – azimuth of the projection of the LOS directions, measured clockwise from North.

[4] https://browser.dataspace.copernicus.eu/
[5] https://www.dma.dk/
[6] http://aisdata.ais.dk/



Figure 4. Footprint of the extract of the Sentinel-1 image (red polygon) used in this tutorial. The data cover the northernmost part of Denmark – the Skagen Odde peninsula, the Skagerrak strait, the Albæk Bay and Port of Skage. The figure is displayed as an overlay in Google Earth Pro 7.3.6, *Image© 2025 Airbus from 14.12.2015*

3. DATA PREPROCESSING

Open the **SAR Ship Detection workflow** from *SAR Essentials –> Ship Detection* (Figure 2, left).

3.1. INPUT DATA

The ***SAR Ship Detection*** workflow can be found in the list of *SAR Essentials* tools (folder ***Target Detection***) in the specialised module within the *ENVI toolbox* (Figure 5, left). The first step includes the preprocessing of SAR images (Figure 5, right). Optional parameters for the exported results can be set during this step.

3.1.1. Input Image

The *Input Image* operation transforms the original SAR image into the general *SAR Essential* format that consists of:

- a binary file without extension,
- a *SAR Essential* *.sml ASCII header file,
- and a *.hdr *ENVI* header file.

If the image has already been imported by another SAR Essential process, it can be opened in this workflow step by choosing its *.sml file in the … *Browse…*. Alternatively, it can also be loaded from the *Data Manager* if it is already open.

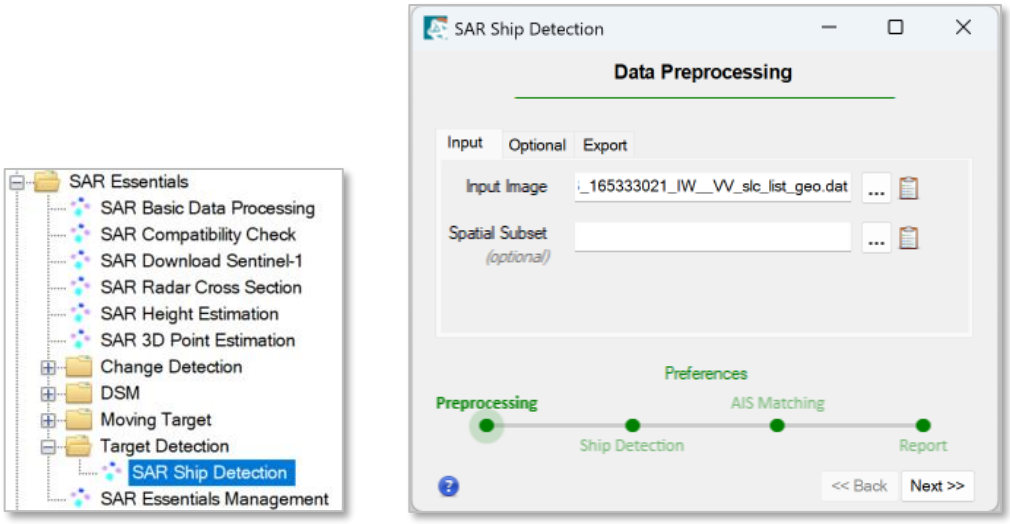


Figure 5. SAR Ship Detection workflow and input parameters for Data Preprocessing window

Use the ... Browse... button in the Data Preprocessing window to navigate to the SAR Essentials installation folder stored on your computer and the SAR_Essentials_dataset subfolder. Select the abovementioned training Sentinel-1 images as Input Image (Figure 5, right).

3.1.2. Spatial Subset

Optionally, the image range can be cropped to exact dimensions. For this purpose, a polygon in geographic coordinates with the Area of Interest (AOI) in vector format (*.shp, *.kml or *.kmz) can be added in the *Special Subset* field.

3.2. OPTIONAL PARAMETERS

3.2.1. Output Coordinate System

As an optional parameter, the *Output Coordinate System* for the output results can be selected (Figure 6). By default, the World Geodetic System (WGS) 1984 is set. Moreover, the ... *Browse...* button leads to a list of Predefined Coordinate Systems and tools for creating a new one.

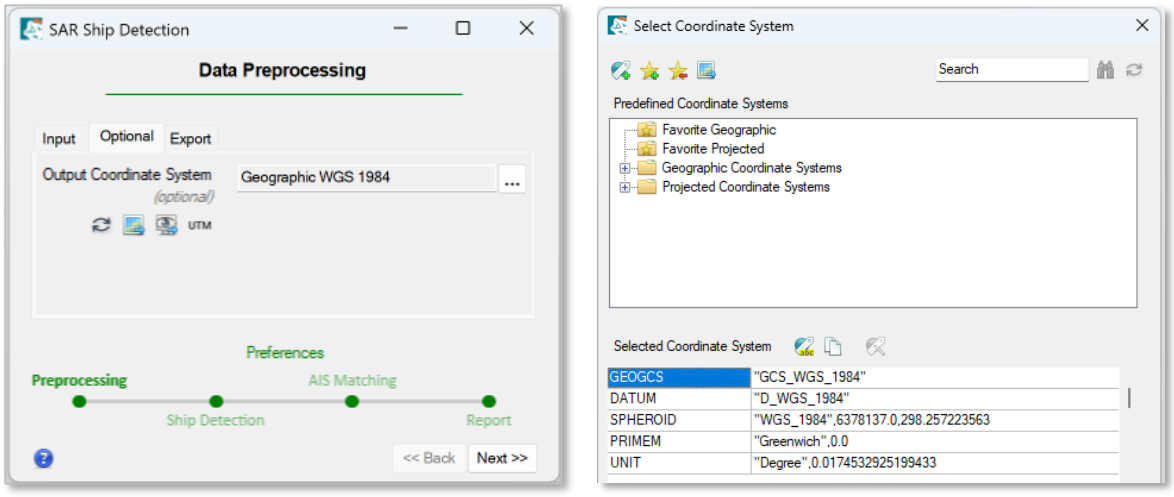


Figure 6. Optional parameters in the Data Preprocessing step of the SAR Ship Detection workflow

Leave the Output Coordinate System to WGS 1984 (default).

3.3. EXPORT PARAMETERS

The tool gives the opportunity to define the following settings for the results of the *Ship Detection* processing (Figure 7):

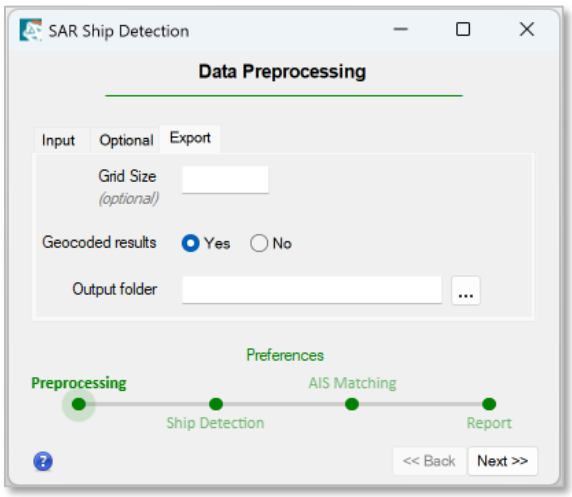


Figure 7. Export settings in the Data Preprocessing step of the SAR Ship Detection workflow

3.3.1. Geocoded Results

If the input SAR image is in slant range, the output results (both raster and shapefiles) will be geocoded when the option *Yes* is marked. Otherwise, the results will be saved in slant range.

Note*:* The geocoding does not preserve the full resolution of the input SAR data. The ground range pixel of the geocoded exported image is degraded following the scheme:

Actual grid size [m]	Grid size of the geocoded raster [m]
< 0.5	1.0
1	2.0
2	3.0
5	5.0

The resolution is degraded by default during geocoding. However, the needed resolution of the output data can always be set in the grid size field.

3.3.2. Grid Size

Defining a grid size value implies the application of a certain multilooking factor during the processing. Multiple looks Intensity images are generated by averaging over range and/or azimuth resolution cells.

The grid size value can be inserted manually or automatically. In case the grid size box is left empty, the grid size value is automatically assigned:

- In case the grid size is manually defined, *SAR Essentials* displays a warning whenever the inserted value is lower than half of the nominal SAR resolution automatically estimated (over-sampling) or higher than 25 times of the nominal SAR resolution automatically estimated (under-sampling).

- When the grid size is automatically inserted, the output grid size of geocoded products is approximately determined by the spatial resolution of the nominal SAR spatial resolution and the applied multilooking factor. The multilooking factor is estimated from the nominal resolutions in the range and azimuth directions to achieve squared pixels. The aim is also to preserve the maximum spatial resolution of the multilooked product.

3.3.3. Output Folder

This parameter is optional. A chosen folder can be assigned to store the results from the workflow via the … *Browse…* button. Otherwise, the output files will be saved in the *Output Directory* set in the *ENVI Preferences* (see "SAR Essentials tutorial: Getting started" for more details).

3.4. COMPATIBILITY CHECK

The selected image will be imported in SAR Essentials after confirming the first step of the *Ship Detection Data Preprocessing*. If the image is in an original SAR format, it will be transformed into SAR Essentials binary format (with associated *.sml and *.hdr files). The imported image will be loaded in the *ENVI Layer Manager* and visualised in the *ENVI View* window.

Select the Next >> button to confirm the settings for the data preprocessing and pass to the next step of the SAR Ship Detection workflow (Figure 8).

Click the Zoom to Full Extent button in the Toolbar to view the full extent of the imported Sentinel-1 image – *_geo.dat:

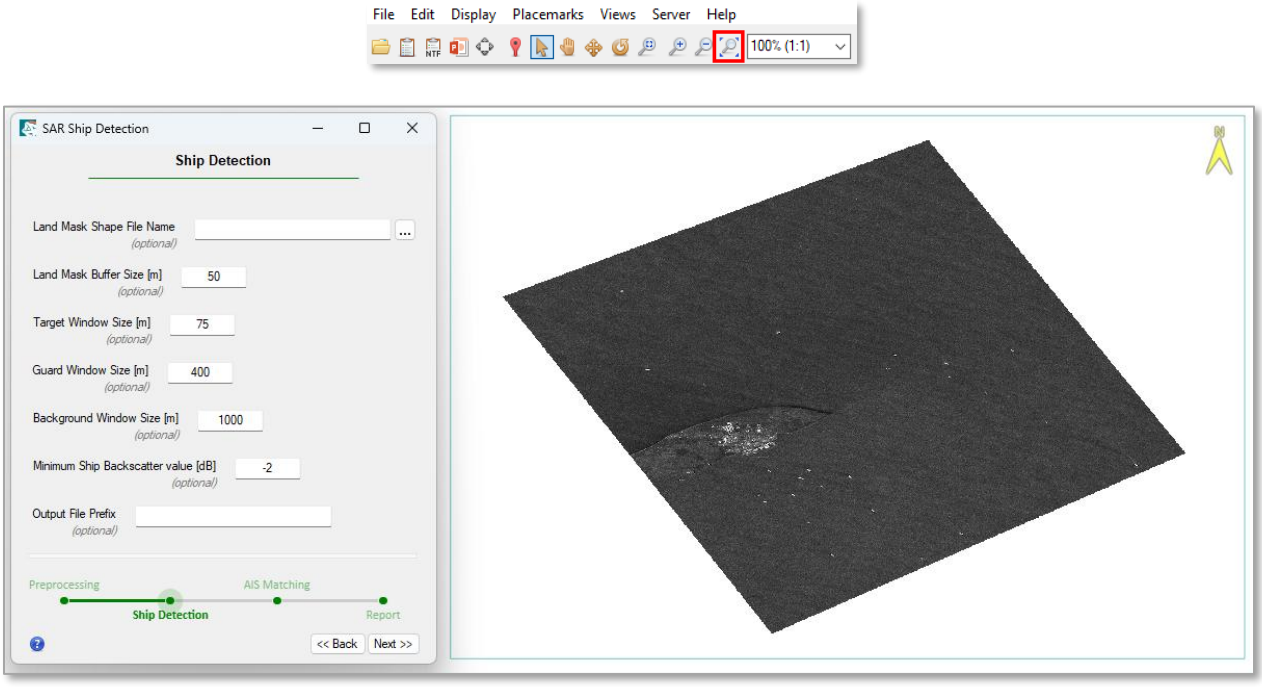


Figure 8. The SAR image loaded in the ENVI View window and the window with Ship Detection parameters

During this procedure, a compatibility check for this image is also performed. The results of the check are saved in the Output folder, in a text file named ***processing_report.txt*** (Figure 9). The file contains information about the image properties and a verification report indicating whether the data meet the criteria required for this processing.

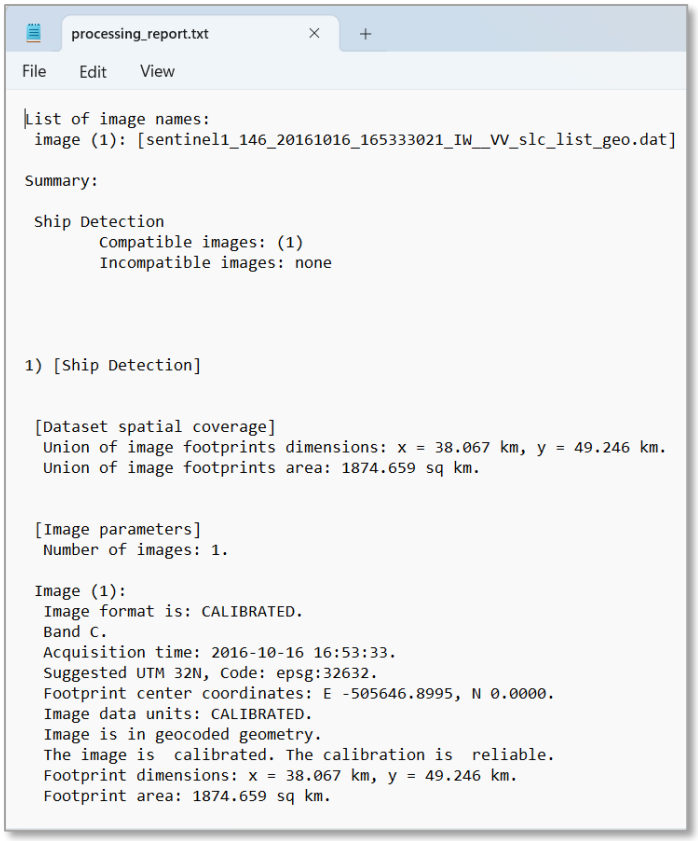


Figure 9. Report on the compatibility of the data used in the SAR Ship Detection example

The window of the workflow goes to the next step – *Ship Detection* (Figure 8, left).

4. SHIP DETECTION

The *SAR Ship Detection* step contains the following stages:

- Masking out the land areas based on an optional reference shapefile;
- Identification of target areas of significant backscatters;
- Extractiing the targets of interest into a shapefile.

At this step of the workflow, the window sizes for the Adaptive threshold algorithm for ship detection from a SAR image can be set and modified, as well as the minimum average backscatter value (Figure 8, left).

4.1. LAND MASK SHAPE FILE NAME

This parameter is optional. It allows avoiding areas inside of given polygon(s) from a loaded shapefile.

Note*:* If no mask is loaded, the software will automatically apply a mask from the installation folder of *SAR Essentials*. This mask is derived from OpenStreetMap repository (© OpenStreetMap contributors). These data are licensed under the Open Database License (ODbL). A copy of the modified dataset is available here https://www.openstreetmap.org/. For more details, see *Copyright and License and Open Data Commons Open Database License* (ODbL) — *Open Data Commons: legal tools for open data* and the document **Third-party software and libraries** of *SAR Essentials* installation package.

4.2. LAND MASK BUFFER SIZE

An optional buffer area might be defined around the provided polygon with land mask by specifying the buffer distance in meters. A pre-set value is displayed depending on the input file.

For the case of the Sentinel-1 tutorial data, the pre-set value is 50, which means that a buffer of 50 meters will be defined around the polygons, automatically downloaded as a land mask from the OpenStreetmap repository.

4.3. TARGET WINDOW SIZE

The dimensions of the target(s) to be detected can be defined in meters (Figure 1). A pre-set value is displayed depending on the input file.

The recommended *Target Window Size* value for the tutorial image used in this example is set to 75 meters.

4.4. GUARD WINDOW SIZE

In order to remove double targets, a window (in meters) around the target window (Figure 1) can be defined so that these pixels will be not taken into account in the background estimation. A pre-set value is displayed depending on the input file.

The pre-set value for the *Guard Window Size* in this example is 400 meters.

4.5. BACKGROUND WINDOW SIZE

The size in meters of the window used to estimate the background value (Figure 1) can be entered here. A pre-set value is displayed depending on the input file. The proper size of the window is strongly related to the density of the vessels in the AOI. This means that this parameter should be modified so that as less as possible targets are influencing the statistics of the background window. If this window size is modified, the *Guard Window Size* should be resized accordingly.

An appropriate value for the *Background Window Size* here is 1000 meters and it is already set.

4.6. MINIMUM SHIP BACKGROUND VALUE

This is the threshold in dB of the minimum backscatter value for the central pixel of the target window to be considered as a target (ship). The value presents the backscatter coefficient transformed from linear unit to dB by

$$10*\log_{10}(\text{LinearValue}).$$

A pre-set value is displayed in the workflow depending on the input file.

Note*:* When the input images are in linear scale (as is usually the case), the conversion shown above must be applied to determine the threshold, which is expressed in dB.

Normally, most ships exhibit consistently high backscattering across their entire surface. Other vessels exhibit inconsistent backscattering, as in the example below (Figure 10, left). This may cause the software to identify multiple points for the same ship. In the case of the Sentinel-1 image, accepting the default value of -2 dB would result in multiple detections per ship as shown in the left image below. Decreasing the Minimum Ship Backscatter Value to -6 dB addresses this issue. However, it should be kept in mind that decreasing the minimum backscatter value may result in more false positives.

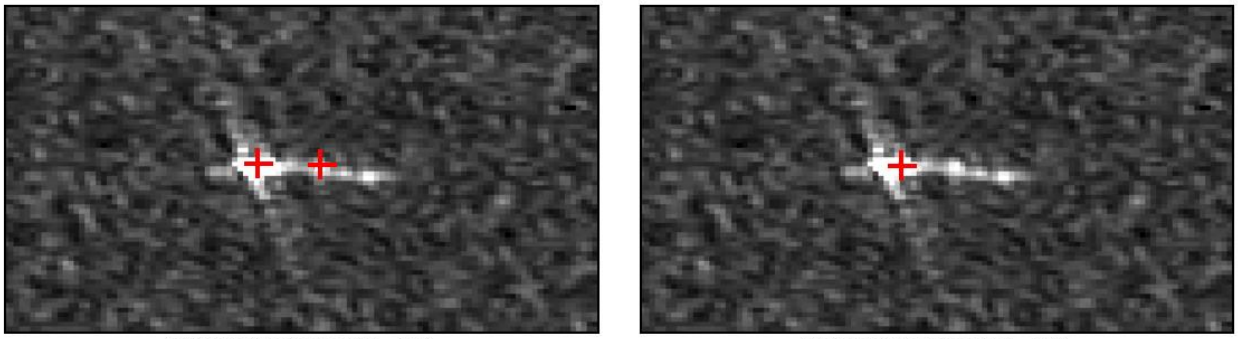


Figure 10. The SAR image loaded in the ENVI View window and the window with Ship Detection parameters

4.7. OUTPUT FILE PREFIX

A differennt prefix for the output files can be given here. Otherwise the prefix will be taken from the file name of the input image.

Add Skagen in the field for Output File Prefix, leave all other parameters values by default and click the Next >> button.

4.8. RESULT OF THE SHIP DETECTION ESTIMATION

The *Ship Detection* will mask out the land areas, identify the target areas of significant backscatters based on the parameters set above, and extract the targets of interest into a shapefile. The shapefile with the identified targets will be loaded in the *Layer Manager* and visualised in the *ENVI View* window (Figure 11). Then the workflow goes to the next step – *AIS Matching*.

Click the Zoom to Full Extent button in the Toolbar to view the full extent of the shapefile with the detected targets – Skagen_sar_ship_detection.shp:

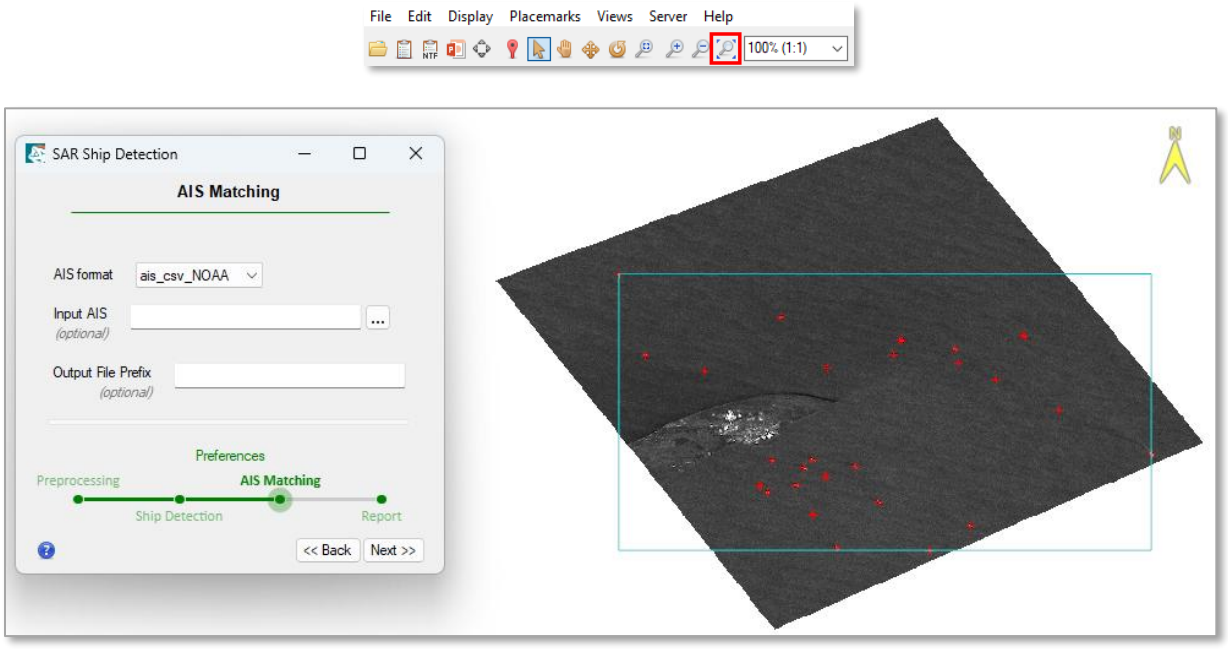


Figure 11. The SAR image loaded in the ENVI View window and the window with Ship Detection parameters

- Observe the result of the Ship Detection step (Figure 11, right). Effects as those shown in Figure 10 can be noticed. Use the << Back button to navigate to the Ship Detection step.
- Change the Minimum Ship Backscatter Value to -6 dB (Figure 12) and re-generate the shapefile with the detected vessels to avoid identification of multiple points for the same ship (click Next).

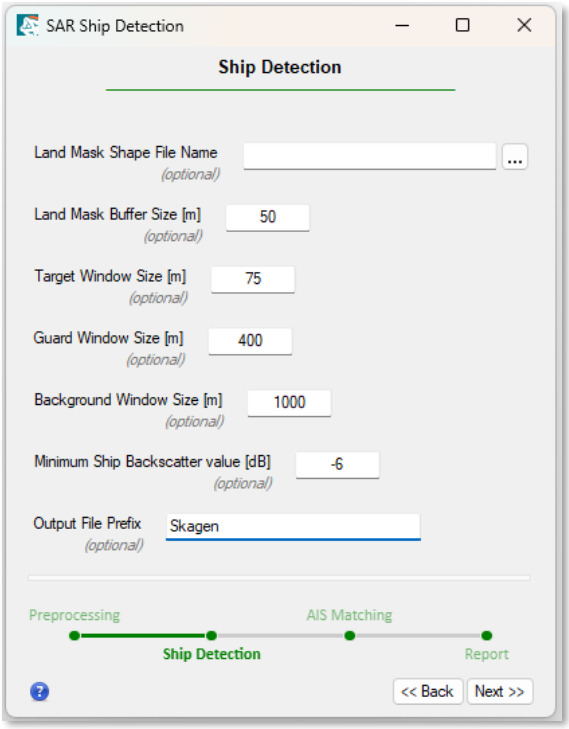


Figure 12. Ship Detection parameters preferred for the tutorial example

Once a satisfying result is achieved, move to the next step of the *SAR Ship Detection* workflow, namely *AIS Matching*.

5. AIS MATCHING

The *SAR Ship Detection* workflow gives an opportunity to compare and match the detected from a SAR image vessels with an available external marine information from the Automatic Identification System (AIS) for the ship position and voyage trajectory. This step is optional and can be skipped if no AIS file is loaded by clicking the Next >> button.

Otherwise, AIS information might be loaded either from binary file or from a CSV file that follows a specific predefined structure of fields like the AIS messages.

5.1. AIS FORMAT

There is the choice among the following predefined AIS templates (Figure 13):

- **ais_binary_nmea**: a standard for data from the US National Marine Electronic Association (NMEA[7]). Details can be found here https://www.nmea.org/nmea-0183.html

[7] https://www.nmea.org/

- **ais_csv_DK**: corresponds to the structure of the AIS historical CSV data provided by the Danish Maritime Authority (DMA[8]): http://aisdata.ais.dk/. Details about the structure of the file: http://aisdata.ais.dk/!_README_information_CSV_files.txt
- **ais_csv_NOAA**: AIS data in CSV format from the US National Oceanic and Atmospheric Administration (NOAA[9]) that can be found here https://coast.noaa.gov/htdata/CMSP/AISDataHandler/2024/index.html
- **ais_csv_custom**: a CSV structure that can be manually configurated in the dedicated panel in *SAR Essentials Management* tool (see Section 2.2 of this tutorial for more details).

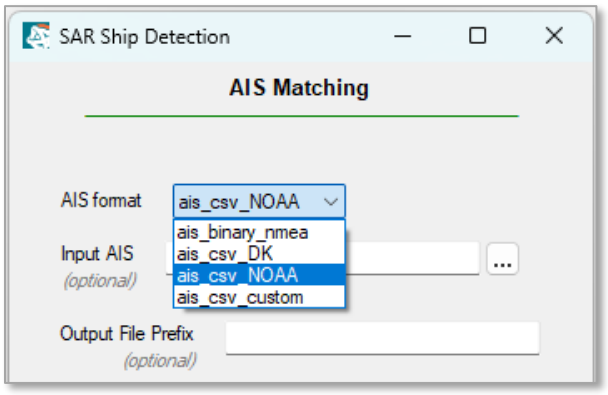


Figure 13. AIS Matching – available pre-defined AIS formats

Note*:* The custom template AIS format must be pre-defined in the *SAR Essentials Management* tool before performing this *Ship Detection* workflow.

✍ Select ais_csv_DK in AIS format (Figure 14).

5.2. INPUT AIS

If a file with AIS information is loaded here, the targets detected as ship or other vessels over the water bodies in the SAR image during the *Ship Detection* step will be matched with the AIS information.

✍ Use the ... Browse... button to navigate to the training AIS file aisdk_20161016_053-054.csv and load it into the Input AIS (Figure 14).

5.3. OUTPUT FILE PREFIX

A different prefix for the output files can be given here. Otherwise the prefix will be taken from the file name of the input image.

✍ Keep the Skagen entry in the Output File Prefix field (Figure 14).

[8] https://www.dma.dk/
[9] https://www.noaa.gov/

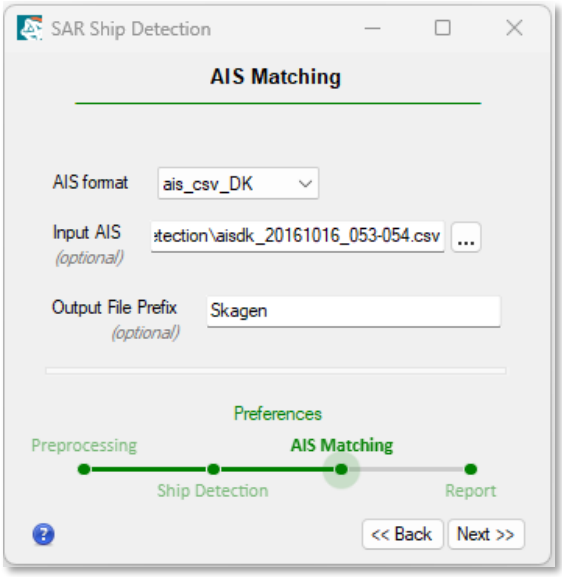


Figure 14. AIS Matching – parameters for the tutorial example

Click the Next >> button so the processing will continue further (Figure 14) to the generation of the final results.

6. RESULTS

The final panel of the *SAR Ship Detection* workflow contains the **Report** (Figure 15) from the Compatibility check for the imported image (see Section 3.4). If the generated results from the processing are acceptable, the process can be finalised by the Finish button. Otherwise, corrections in the used parameters can be done by going << Back to the workflow steps.

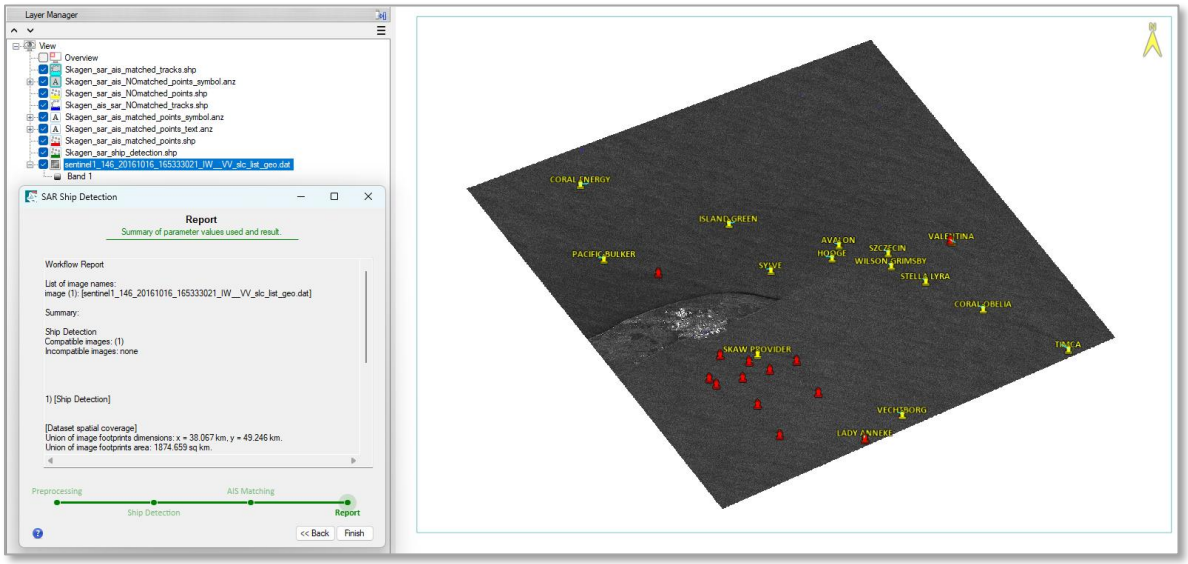


Figure 15. Final step of the SAR Ship Detection workflow – SAR image compatibility report and resulted shapefiles

6.1. MATCHED POINTS

Ship locations detected from the SAR image which match AIS records are stored in a point shapefile named **Skagen_sar_ais_matched_points.shp**. Records from the example are marked with red crosshair symbols (Figure 16, up). Ship names and marker symbols can be visualized by turning on the associated layers in the *Layer Manager* (Figure 16, down) – **Skagen_matched_points_text.anz** and **Skagen_matched_points_symbol.anz**.

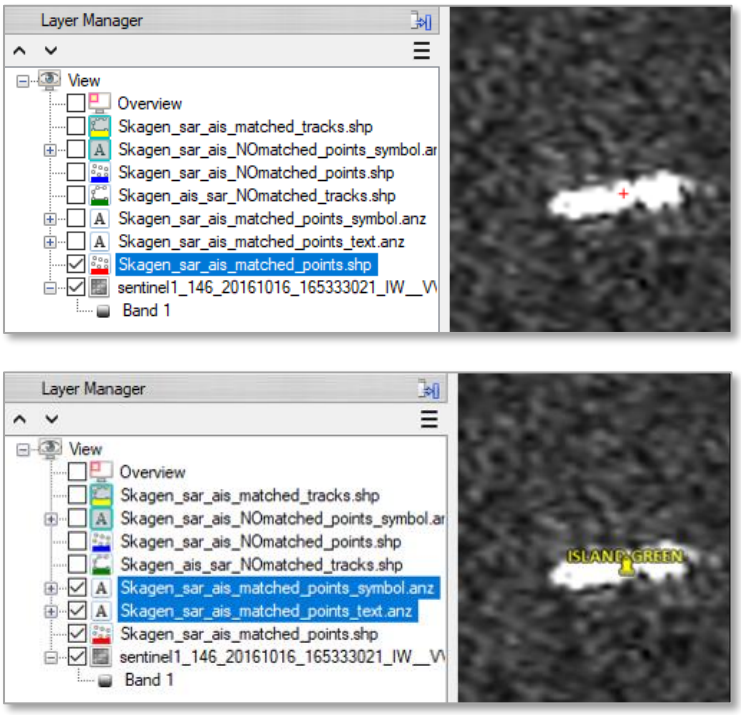


Figure 16. Matched points between SAR-detected objects and AIS ship records

6.2. MATCHED TRACKS

The AIS tracks matching the SAR-detected ships are stored in another polyline shapefile, which in this example is displayed in yellow – **Skagen_sar_ais_matched_tracks.shp** (Figure 17).

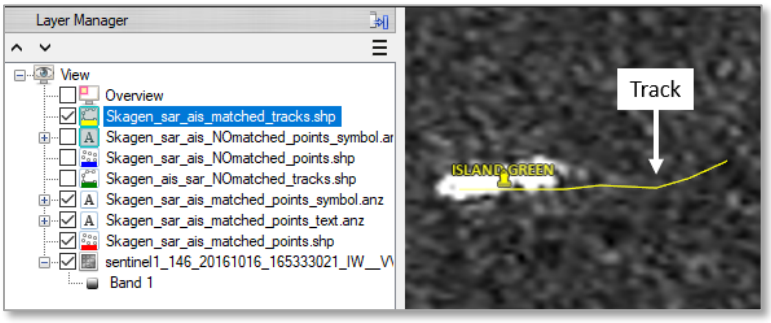


Figure 17. Matched tracks between SAR-detected objects and AIS track records

6.3. UNMATCHED POINTS

Detected ships with no matching AIS records are stored in a point shapefile named **Skagen_sar_ais_NOmatched_points.shp**. In the example, these records are marked with blue

crosshair symbols (Figure 18, up). To view red symbol markers instead, turn on the points-annotation layer **Skagen_sar_ais_NOmatched_points_symbol.anz**in the *Layer Manager*.

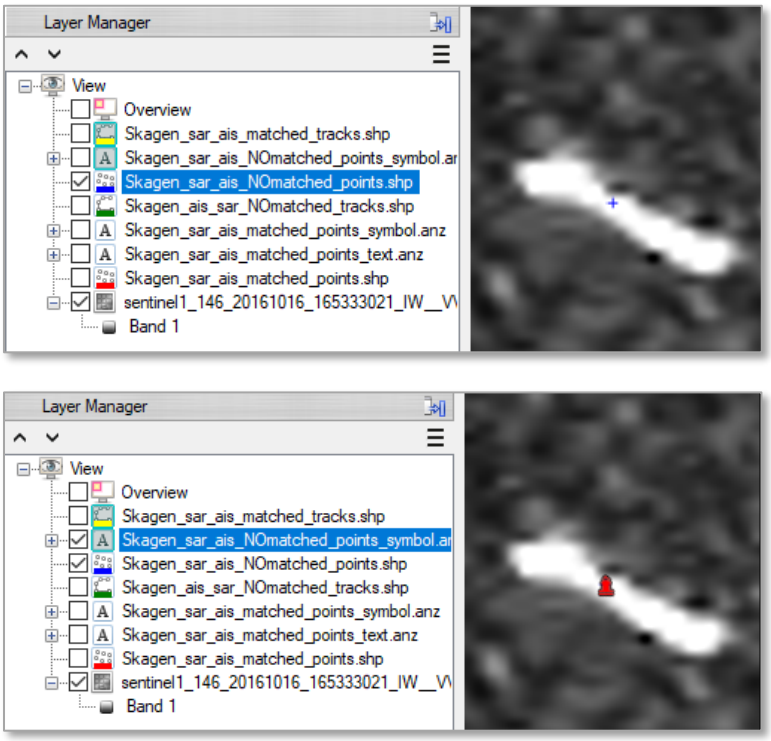


Figure 18. Unmatched points between SAR-detected objects and AIS ship records

6.4. UNMATCHED TRACKS

AIS tracks that do not match any SAR-detected ships are stored in a polyline shapefile named **Skagen_ais_sar_NOmatched_tracks.shp**. In this example they are displayed in green. Several small tracks are visible in the Skagen port but not in the open sea (Figure 19).

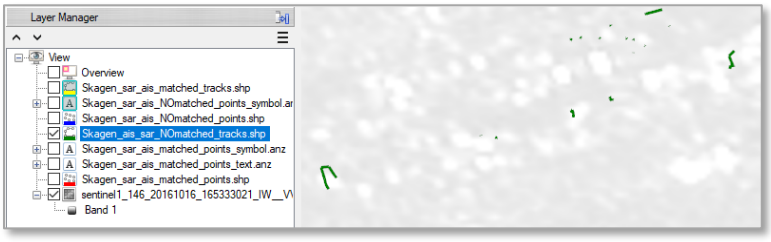


Figure 19. Unmatched points between SAR-detected objects and AIS ship records

RESOURCES

Crisp, D. J. "The State-of-the-Art in Ship Detection in Synthetic Aperture Radar Imagery." Australian Government, Department of Defence, Edinburgh, DSTO Information Sciences Laboratory, DSTO-RR-0272, 1-115 (2004)