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DYNAMIC MAPS OF TARTOUS PORT BASED ON REMOTE SENSING AND GIS

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Abstract

The Earth's surface is covered with 72% water. This fact alone emphasizes the importance of improving maritime situational awareness, the ability to recognize events, circumstances, and activities within, and affecting the maritime environment which is nowadays of paramount importance for safety and security. In order to achieve the task of 'Maritime Surveillance' or simply marine object detection, we need a structured approach that combines different study areas. This approach has been applied for achieving this study based on combining satellite imaginary and cartographic methods besides maritime detection methods.

The free, full and open data policy of the EU's Copernicus programme has greatly increased the amount of remotely sensed data accessible to both operational and study activities. Therefore, this study focuses on the use of Copernicus's Sentinel-1 radar satellite as the routine data acquisition of Sentinel-1 has made it possible to investigate and analyze the longtime series, many months to more than one year. Thus, the Sentinel-1 data has been combined to the ship self-reporting data (AIS) which is considered as the core of building every port ship movement's database.

Applying these methods has given new insights into human activities at sea. However, in order to get an insight into the presence and distribution of both reporting and non-reporting ship traffic, a combination of Sentinel-1 images and the ship reporting data is needed. These non-reporting ships includes small ships and may also include large ships of which, for some reason, no AIS reports are received (i.e., blackout problem). The combination of the Sentinel-1 images and the ship reporting data forms a useful tool that has been applied in this work to detect and emphasize the Unknown ships.

Index Terms— maritime surveillance, ship detection, Sentinel-1, daily port database, Synthetic Aperture Radar, Automatic, Identification System, Complex logical work.

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1. Introduction

Today maritime transportation represents 90% of global trade volume. The safety and security challenges are therefore of high precedence at the international level (Michele Vespe et al., 2012). According to the International Convention for the Safety of Life at Sea (SOLAS, regulation 19), "*All ships of (300) gross tonnage and upwards engaged on international voyages and cargo ships of (500) gross tonnage and upwards not engaged on international voyages and passenger ships irrespective of size shall be fitted with an automatic identification system (AIS)*" (IMO (International Maritime Organization), 2001). This regulation means that not all sailing vessels are carrying AIS, for that it is impossible to detect all the moving objects on the water body such as (small ships, fishing boats.). These vessels can restrict the process of the maritime surveillance, as it is defined by the ability to monitor all activities at sea to support the efforts related to security (e.g., the irregular sea border crossing, and smuggling of illegal goods), safety (e.g., Search and Rescue), environmental and sustainability aspects (e.g., fishing control, and pollution) (Aayush Grover et al., 2018).

Under those circumstances the surveillance has been controlled by two types of systems: the cooperative or reporting system and the non-cooperative system.

In the cooperative system, vessels themselves report their identities, location and speed. This can be performed through one of these options: Automatic Identification System (AIS), Long Range Identification, Tracking (LRIT) or Vessel Monitoring System (VMS). These data are important for situational awareness. It also makes it much easier to collect and process data that would otherwise only be obtained by interrogation (via the maritime VHF radio or through a boarding).

The non-cooperative monitoring systems do not require cooperation from the side of the ship. According to this system, data can be obtained in different ways based on where the sensors are located, for example: coastal, shipborne, airborne, or spaceborne. The acquired data can determine the vessels from the background sea clutter without the dependence on the vessels' cooperation (Carlos Santamaria et al., 2017).

The satellite-borne sensors allow the detection of non-carrying AIS ships such as smaller fishing ships and ships which are sailing illegally in the surveyed area such as illegal fishing and piracy (Aayush Grover et al.,2018).

This research focuses on the satellite-borne sensors method for detecting ships' positions using Sentinel-1. This satellite provides images of the Earth surface including the water area such as (seas, oceans ..) by the radar wavelengths which can be proper for the ship detection independent of the weather and day/ night conditions. For that, Sentinel-1 is a useful tool for maritime surveillance to become aware for the ship movements at sea (European Cmmission , 2016).

This satellite has been launched on the 3rd of April 2014 and became one of the main tools of the European Space Agency (ESA) for the European Copernicus program. The agency has been established for performing environmental, economic, public and security services (Velotto et al., 2016).

This study also focused on creating a map using the geographic information system (GIS). This system helped us in creating this map, compiling geographic data, analyzing mapped information and managing geographic information in a database. regarding that, a map of Tartous port was created using the GIS software under the aim of visualizing the marine traffic within this area. However, for making this visualization clear and understandable both the navigational and cartographic map elements were combined to the resulted map.

This ships traffic data that will be visualized has been obtained based on utilizing the Sentinel-1A database with an acquired port database that consists of daily port ship movement reports. Therefore, these port data have been combined with the extracted satellite data under the purpose of accumulating and identifying all the detected ships' information in an accurate way. Finally, with using this method both the cooperative and non-cooperative ships were exploited and paired with each other in the observed time period. In other words, create a harbor map that – with its dynamics – helps readers to better understand the marine traffic in the harbor.

2. Study Area

The area of interest of this study is the Mediterranean Sea (Tartous port, Syria). The study period is almost one full year 2018, from 13. January to 25. December 2018.

2.1 Country general view

Syria is located on the eastern of the Mediterranean Sea, between longitudes (35°43’, 42°25’E) and latitudes (32°19’, 37°20’N). The area of the country is about 190 000 m^2 with the Iskenderun and Golan Heights included. It is bordered in the north by Turkey, in the east and southeast by Iraq, in the south by Jordan, in the southwest by Palestine and in the west by Lebanon and the Mediterranean Sea as it is shown in (Figure 1). Syria has 14 Governorates (mohafazats) including Damascus, the capital city. The governorates are divided into a total of fourteen districts, which are further divided into sub-districts (Ghaleb- Abbas, 2010).

Figure 1: Map of Syria showing the borders, (Austrian Federal Ministry, 2015)

Source: Collins World Explorer Premium, Natural Earth

Syria has been considered as an important transport linking point because of its location between the three continents: Asia, Africa and Europe, and its coast on the Mediterranean Sea in 183 km length (Enad, 2010), syria mainly consists of four physiographic regions: the coastal, mountain, interior and the desert (Ghaleb- Abbas, 2010).

- The coastal plain: which is located between the mountains and the sea covering the area from Turkey in the north to Lebanon in the south along the Mediterranean Sea. This region is the focus of the present work.
- The highland and mountains: this region extend from north to south parallel to the Mediterranean coast such as the Jabal an Nusayriyah mountains.
- The interior region: this region includes the plains located in the east side of the highlands and the plains of Damascus, Homs, Hama, Aleppo, Hassakeh and Daraa.
- The desert plains (Badiah) in the southeastern part of the country, adjoining Jordan and Iraq.

2.2 City of study view

The Syrian coastal extends over the area between the Turkish border in the North to the Lebanese borders in the south on the eastern coast of the Mediterranean. It has a total area of 5070 km^2, Tartous province lies at the southern part of the Syrian coast (Figure 2 & 3), its coastline covers over nearly 90 km, the Tartous Governorate occupies an area of 1963 km^2. It has an island (Arwad) which located a few kilometers off its shoreline and it is the only inhabited island along the Syrian coast (Ghaleb-Abbas ,2010)

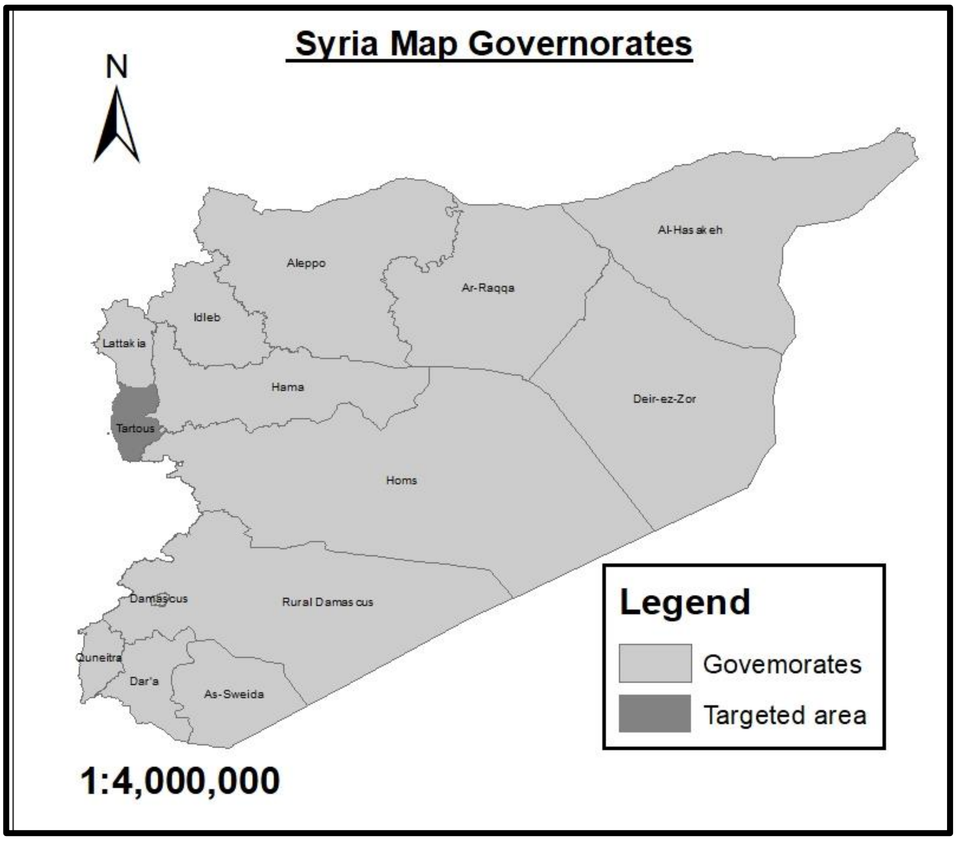

Figure 2: Syria Map Governorates

Figure 3: Tartous Governorate

Source: (Ghaleb Faour, Abbas Fayad, 2010)

2.3 Tartous port

Tartus is a city located on the Mediterranean coast of Syria. It is considered as the second largest port city in Syria. The city of Tartous is the capital of the Tartous governate, it has a population of 283 571 (2014 census). The Tartous governate also plays a strategic economic role by hosting two of Syria's three major ports, Tartous, and Banyas (the third is located in Latakia) as well as the Banyas Refinery and Power Plant and the Tartous Cement Plant. Syria's ports have reached maximum operating capacity over the past few years - in part due to Syria's increasing role as a major transit point for goods traveling to Iraq (Wikipedia contributors, 2017).

2.3.1 General background

Tartus port occupies an area of 3 000 000 m^2 which is divided into a marine zone with 1 200 000 m^2 and a land zone with 1 800 000 m^2. The entrance channel of

Tartus port has a width 200 m and depth 14.5 m. The highest tidal range in the port is 50 cm (Saeed, 2014)

The main design of the port had been done by a Danish ports design company (Camp Zach company) and the construction started in 1/5/1960 by a group of Arab and foreign companies according to the last updated designs in that time which included the essential needs of the port from the loading, discharging and storing facilities. However, the primary stage was accomplished in 1966 and at the end of 1966, the investment has been started in a limited way by a single quay with a length of 500 m and a limited number of mechanisms, warehouses (Syrian Arab Republic Ministry of Transport, 2014).

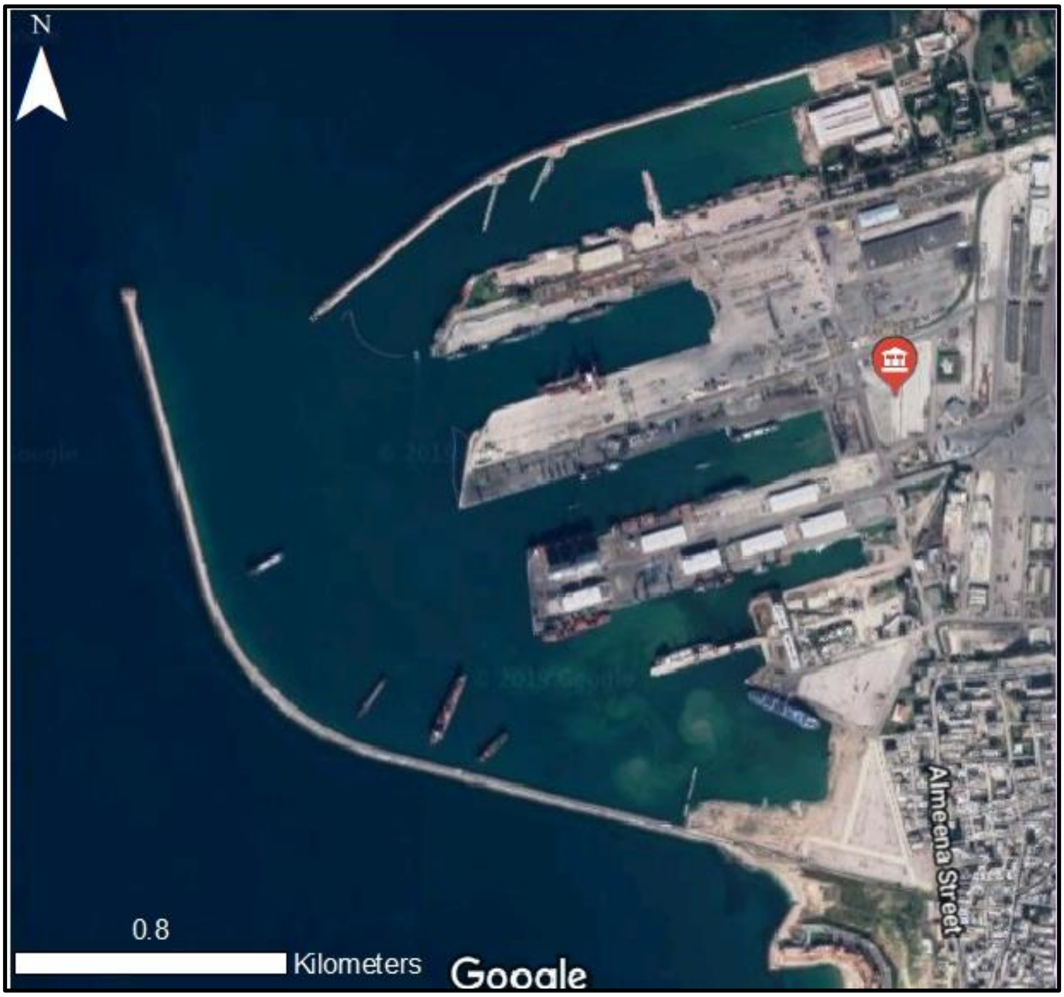

Figure 4:Satellite image of Tartous port

Source: Google earth

2.3.2 The port infrastructure

The port protected by two breakwaters, the length of the main breakwater is 2650 m with a depth[1] of 13 m and the length of the secondary breakwater is 1620 m. These breakwater structures are constructed near the coast as part of coastal management, particularly to protect the inner anchorage area from the weather and longshore drift effects (Saeed, 2014).

The port has three main moles (A, B, C), which act as the piers of the port (Figure 5). The pier is a manmade construction in the waterbody, basically supported by well-spaced piles or pillars. They are designed to let the tides and currents flow comparatively obstructed, also the separated piles of a quay can perform as a breakwater. According to the UFC Piers (wharves) provide:

- Berths with appropriate dredge depths for ships.
- Secure mooring for vessels berths.
- Transfer points between water carriers (ships) and land transport (vehicles) for both cargo and/or passenger ships.
- Facilities for maintenance; and specialized purposes. For that each of the piers (moles) has several berths.

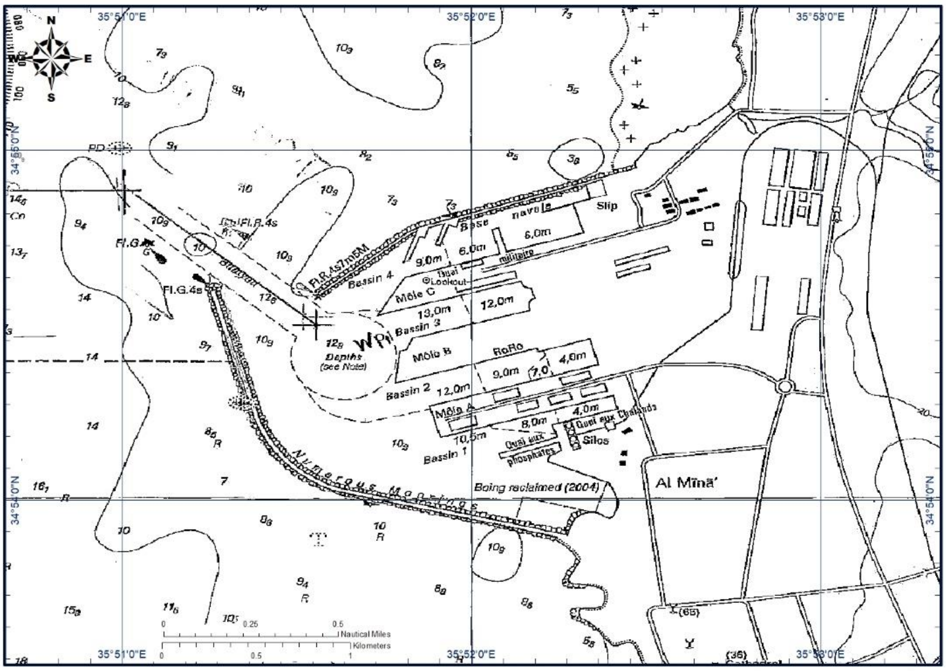

Figure 5:Map Map of Tartous port showing the infrastructure, based on a raster map (Ports in Syria, 2012)

[1] The depth of the breakwater is the distance from the top or surface to the bottom of the breakwater and usually it is designed with taking in consider the difference in level between high and low water.

The port has 22 berths with different lengths and depths regarding their services. The berth is a space at a wharf (pier) that would be occupied by one ship to dock or anchor for many purposes such as (loading, discharging, maintaining), it doesn't have a fixed size, but it would rather depend on the size of the ship which it will serve (Wikipedia contributors, 2019).

According the (Figure 5), the Tartous port is divided into three moles and each mole divided into berths. Some of them are split further into many parts where all these parts are serving the same purpose of the main berth. Based on the official descriptions (Saeed, 2014) these purposes are the followings:

- Mole (A): it has 5 main berths some of them are divided into blocks such as the berths number (2 and 4). Specifically, this mole equipped with electric winches along the railway lines as it is shown in (Figure 6). In addition to six warehouses for storing the light goods. It is also provided with special silos for the exporting and importing grains' processes with a capacity of 85,000 tons at the depth of 12 m. However, the berths number 1 and 2 with their parts are facilitated for serving only the military ships and crafts.

Figure 6:Picture showing part of the electric winches serving Mole (A)

(Saeed, 2014)

- Mole B: it serves on both sides. The southern side which has 2 main berths (9 and 10) including their blocks and the northern side which also has two main berths (6 and 7) with their blocks. The length of the southern side is 890 m with a depth of

4–12 m, the berths equipped with electric winches for Cargo Handling. The length of the northern side is 540 m with a depth of 12–13 m, this side designed specifically for serving both container and RORO ships[2]. Moreover, it is equipped with a large concrete zone established specifically for storing the containers (Figure 7), two bridge cranes[3] with a capacity of 40 tons, two cranes (Gantry) and a railway with a length of 850 m for storing and handling the containers.

Figure 7:The large concrete container zone

(Saeed, 2014)

• Mole C: the length of this pier 660 m with a depth of (12-13) m and it is provided with an area for berthing of RORO ships and large ships, which can carry 60 thousand tons. This area equipped with a railway for transportation (import-export and transit) different types of goods. There is also a freshwater network serving all berths in addition to a fresh water tank with a capacity of 200 tons.

Figure 8: A picture showing the discharging of RORO ship (Saeed, 2014)

[2] Vessels designed to carry wheeled cargo, such as cars.
[3] A type of machine, generally equipped with a hoist rope, wire ropes or chains, can be used both to lift and lower materials and to move them horizontally

3. Research Methodology:

The methodology procedure in this research involves two main phases (Figure 9). The first phase is the data collection and preparation which is divided into two steps regarding the way of how these data have been obtained: port or satellite database. The second phase is the data analysis and interpretation which includes three steps: First, the method of creating the port map followed by the way of extracting and analyzing the ships detections points, and finally, the way of importing them to the GIS environment.

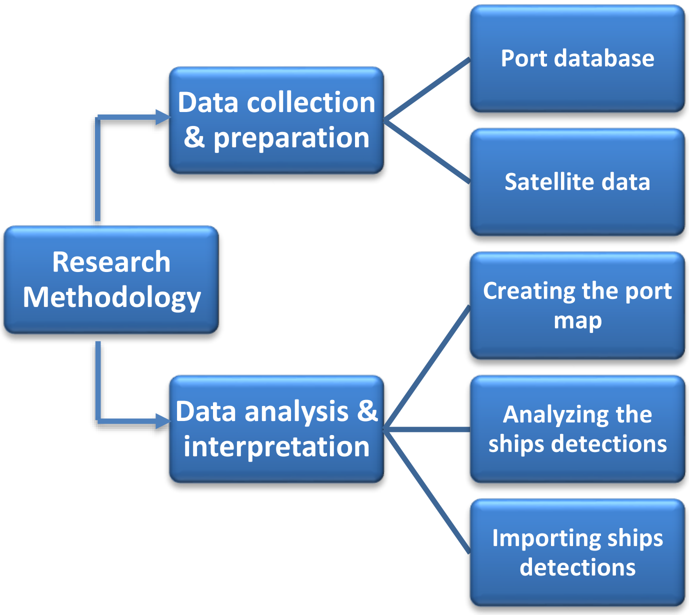

Figure 9:Flowchart of the research methodology.

3.1 Methods for data collection & preparation

The following paragraphs will introduce the methods used to collect data during the research presented within this thesis.

3.1.1 Port Database

3.1.1.1 General view

The port is an area on land and water whether on the sea, ocean or river which serves through its equipped facilities as a transport station for the cargo ships to load and discharge their cargo (Barnes, 2013).

One of the important sources which has been used for building this research was the ship movements database. These data records have been obtained directly from the official website page of Tartous port which represents the daily movements of the vessels entering and leaving. It even provides data about the waiting ships inside or outside the port in the anchorage area.

Every port around the world should record the movements of the ships once they enter the country's territorial water. This term refers to the breadth of the country's territorial sea that is established up to a limit not exceeding 12 nautical miles[4] measured from baselines (Figure 10). This extent is determined as every country's right according to Article (3) of UNCLOS[5] (UNCLOS, 1958).

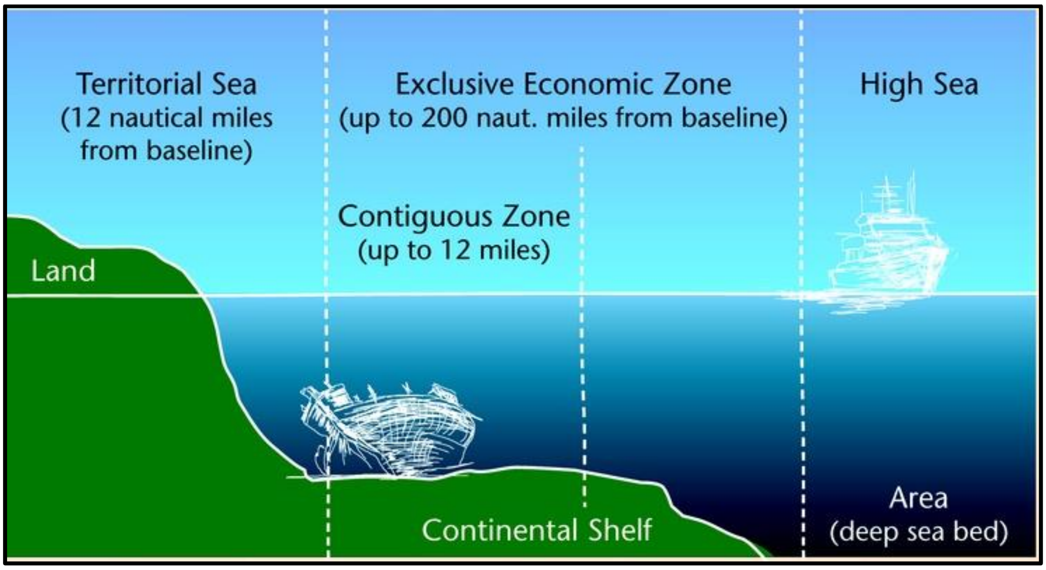

Figure 10: world Maritime Zones

Source: UNESCO (www.unesco.org)

3.1.1.2 Vessel Traffic Services (VTS)

Port data records mainly is gained depending on the daily reports of the port VTS center. This center is responsible for receiving the vessels reports whenever they reach the reporting point within the territorial water. These reports should be transmitted by ships on the public VTS channel using the VHF[6] and contain the ship's name, call sign, destination and intention and its draught[7]. Moreover, the center can also provide communication links between ships and other port services, such as pilotage or tug[8] services (PRAETORIUS, 2014).

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[4] A unit used in measuring distances at sea, equal to 1,852 meters

[5] United Nations Convention on the Law of the Sea

[6] A transmitting and receiving device which works on the range of radio frequency electromagnetic waves (radio waves) from 30 to 300 megahertz (MHz).

[7] the distance between the surface of the water and the lowest point of the vessel

[8] is a type of vessel that maneuvers other vessels by pushing or pulling the ships either by direct contact or by means of a tow line for tugging or pulling vessels that cannot move by themselves

In the light of the ship movements reports, these daily records have been collected from the official Tartous port website which covers the period between the 2nd of January 2018 to the 28th of December 2018. The collected data was in Arabic as it is the official language of the Syrian Arab Republic. Nevertheless, a translation for all the daily reports was done and the results were arranged in the ship movements' database for the whole year. For example, the Table 1 below represent one of the original Arabic port reports for the ship movements in the date of 02/01/2018 with its translated version. The translations were done by me for all the collected data.

Syrian Arab Republic
Ministry Of Transport
Tartous port General Company

الجمهورية العربية السورية
وزارة النقل
الشركة العامة لمرفأ طرطوس

حركة الملاحة في مرفأ طرطوس ليوم الثلاثاء ٢٠١٨/١/٢

م	أسماء السفن العاملة	اسم الوكيل الملاحي	تاريخ الوصول الفعلي	نوع البضاعة	العائدية	طريقة التشغيل	تاريخ الترصيف	كمية البضاعة المشحونة (طن)	الرصيف
1	SEA DOVE	شيبكو	27/12/2017	قمح	عام	مباشر	28/12/2017	35000	9
2	ANWAR-A	نجمة البحر	30/12/2017	حديد	خاص	……	31/12/2017	2527	9
3	RASHA-B	أسرى	27/12/2017	صويا	خاص	مباشر	27/12/2017	7400	14
4	SAKARYA	الجزائري	22/12/2017	أرز	خاص	مباشر	23/12/2017	16842	14

م	أسماء السفن الواصلة	نوع البضاعة	اسم الوكيل الملاحي
1	BALTFLOT-14	زيت	أي-إم-إس
2	RUKAYA 3	حديد	شيبكو
3	LIBAN	ملح	عبر المتوسط
4	CAPTIN ABEDA	شعير	اليمق
5	ALHANI	خشب	الفاضل
6	DANO	خشب	الفاضل

No	Name of the ship	Name of the Shipping Agent	The actual date of arrive	Type of cargo	Private / governmental	Method of cargo handling	The date if berthing	Amount of cargo (TON)	Berth number
1	SEA DOVE	Shiko	2017/12/27	Wheat	Governmental	Direct	2017/12/28	35000	9
2	ANWAR-A	Sea star	2017/12/30	iron	Private	……..	2017/12/31	2527	9
3	RASHA-B	Asra	2017/12/27	Soya	Private	Direct	2017/12/27	7400	14
4	SAKARYA	The Algerian	2017/12/22	Private	Governmental	Direct	2017/12/23	16842	14

No	Name of ships reported	Type of cargo	Name of the owner
1	Baltfolt-14	oil	A-M-S
2	RUKAYA 3	Iron	Shiko
3	LIBAN	Sat	Al Meditranian
4	CAPTIN ABEDA	Barley	Alyamak
5	ALHANI	Wood	Alfadel
6	DANO	Wood	Alfadel

Table 1. Port ship movements report for 02/01/2018 source:

http://tartousport.gov.sy/ships_movement.php

3.1.1.3 AIS (Automatic Identification System)

One of the main VTS center activities is to use AIS as one of the various sensors which support the process of the ships monitoring and keeping an awareness of any possible threats within the vicinity of the port. Accordingly, it is obvious that AIS is playing an important role in controlling and managing the traffic in the area (PRAETORIUS, 2014).

The Automatic Identification System (AIS) is a worldwide automatic positioning system based on fitting a small device to the ships for receiving and continuously transmitting radio signals. These transmitted signals notify other ships and shore stations which have the AIS receivers about its presence and its accurate position (Figure 11).

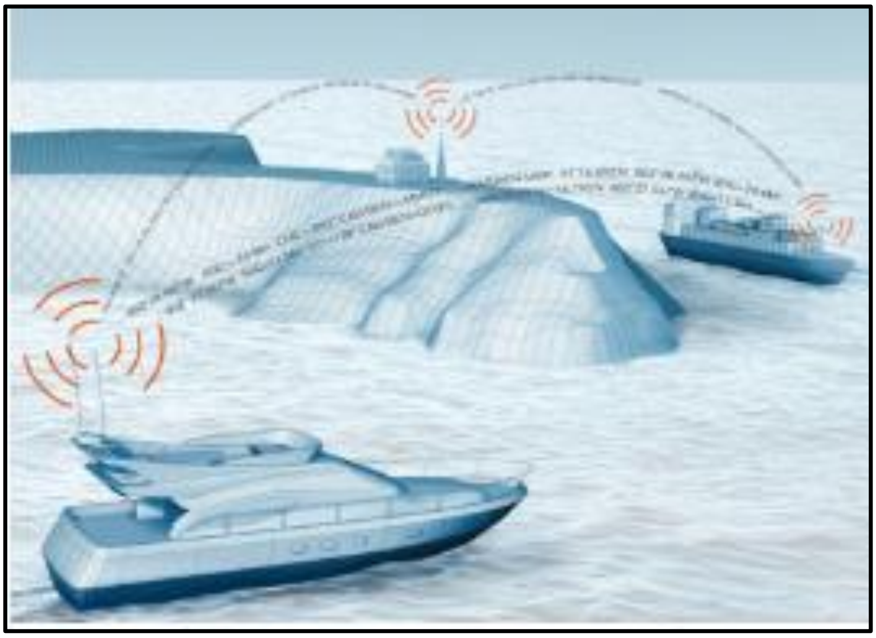

Figure 11: AIS working principles.

Source: (IMO, 2019)

"*AIS was initially intended to assist ships in avoiding collisions, and the port and maritime authorities in monitoring traffic and ensuring better surveillance of the sea*" (HERVE, 2012). This system allows vessels to be tracked but also to predict their movements, for instance, predicting the estimated time of arrival. One of the vital advantages of using this device that it provides precise data on the position of ships in real time renders. That makes it possible to maintain an efficient traffic monitoring to react more quickly in the event of an accident or danger. Moreover, having accurate information on hazardous cargoes or, indeed, to improve surveillance of vessels and raise the level of safety.

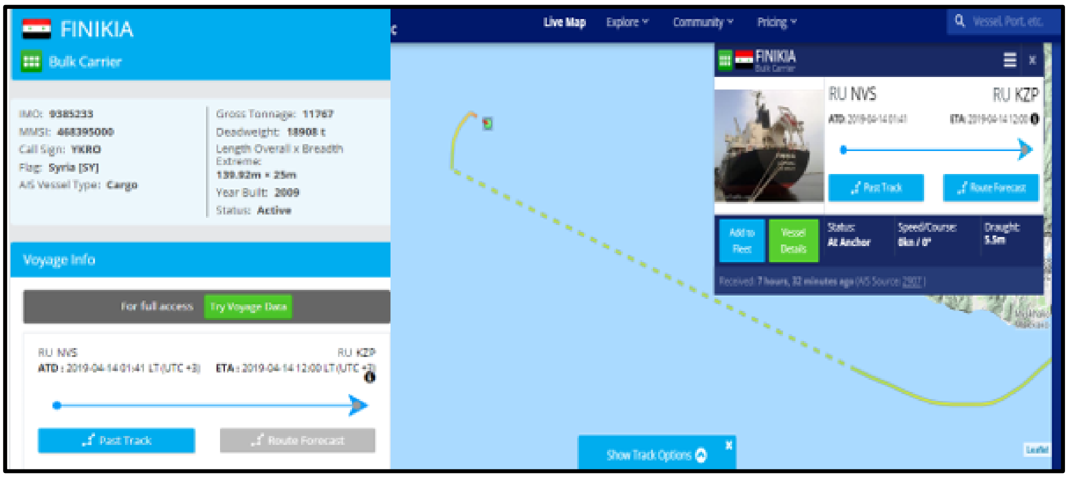

Figure 12: Marine traffic website, FINIKIA SHIP obtained information.

source: www.marinetraffic.com

One of the challenges that occurred during the process of collecting the port data was that these AIS data were not complete (i.e., ships' ID numbers, and positions). Although, Tartous port uses AIS and the missing data exists, such kind of information is not permitted to be provided for the users on the website. Therefore, the website “Marine Traffic” was used to find this kind of information especially this website is an open free system to use which depends on AIS for providing its data (Figure 12).

This website is a very good example of the dissemination of information. It provides data, partly free of charge and in real-time for the movement of ships for the required area (HERVE, 2012).

Figure 12. shows an example of how the information of the ship can be extracted from the “Marine Traffic” website. In this example FINIKIA ship was queried as one of the frequent vessels of transporting cargo from and to Tartous port. The website provided all the AIS information related to this ship. Moreover, it also represents the old sailing track for the ship between the last port to the targeted port. For that, this method was a useful and reliable method for filling the missing data.

3.1.2 Satellite data.

3.1.2.1 General view

Satellite data was the core of this study which has been extracted from the downloaded satellite images. These images were collected by using the Copernicus Open Access Hub which provides complete, free and open access user interface to Sentinel-1 and other satellite images (Figure 13).

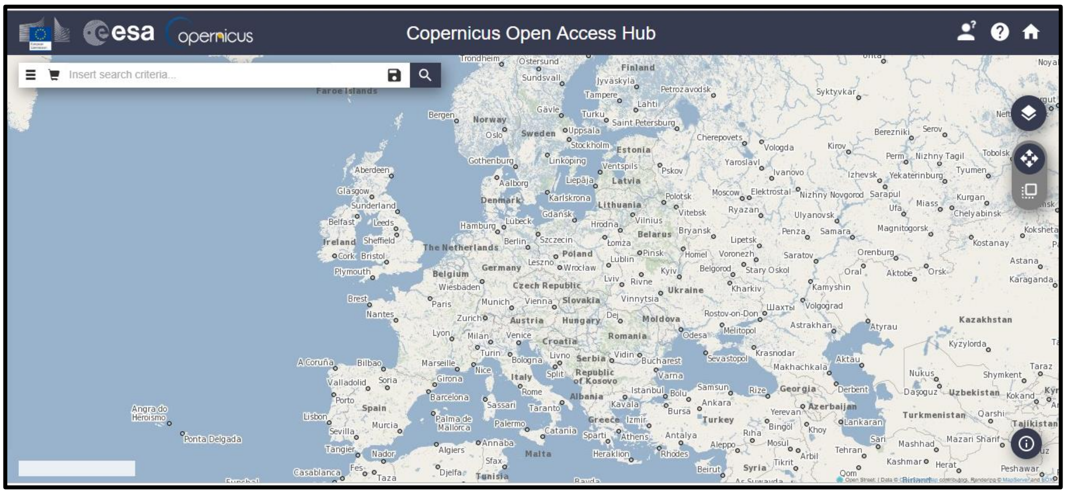

Figure 13: Copernicus Open Access Hub

Copernicus Open Access Hub is the website for the Copernicus Earth observation program managed by the European Space Agency (ESA). ESA is an intergovernmental organization created in 1975 for the purpose of developing Europe’s space capability and ensuring the benefits of that space investment on the citizens of Europe and the world. ESA organizes the acquisition and delivery of Earth observation data from space with the successful launch of Sentinel-1A in 2014 following by Sentinel-1B in 2016. The series of Sentinel satellites delivered a wide range of environmental and civil security data (ESA, Copernicus Open Access Hub , 2014).

3.1.2.2 SAR Geometry

Synthetic Aperture Radar (SAR) technology is an airborne or spaceborne side-looking radar system that utilizes the flight path of the platform to simulate an extremely large antenna or aperture electronically and that generates high-resolution remotely sensed imagery.

Recently, SAR data is one of the most used remotely sensed data regarding that it can be applied in the different fields of study such as agriculture, flood mapping, soil moisture, forestry, terrain analysis, oceanography, Ship Monitoring, snow and glacier mapping, geology etc.

It is defined as an active-sensor technology that uses microwave energy to illuminate the surface of earth. These waves penetrate clouds which means it isn't affected by the weather conditions. Because of that, it is considered as one of the most efficient imaging systems (Fletcher K. , 2007).

Nowadays, SAR systems are categorized into three systems based on the microwaves bands that are used. These bands strongly relate to the ground resolution of the imagery that they generate (Ferretti et al.,2007). These categories are:

- C band systems with 5.3 GHz
- L band systems with 1.2 GHz
- X band systems with 10 GHz

According to this research, the first band (C-band) was used by the selected SAR satellite (Sentinel-1) which will be explained in the next section.

In contrast, SAR systems are also categorized into three main groups based on the operating modes which relied on the capability of controlling the antenna radiation pattern. Regarding the SAR categorized modes, the "stripmap operation mode" considered as the most fundamental one. Wherein this mode, the satellite fitted with radar that has an antenna indicated to the Earth's surface in the plane perpendicular to the orbit. In other words, the pattern is fixed to one swath, thus, imaging a single continuous strip as shown in (Figure 14) (Ferretti et al.,2007).

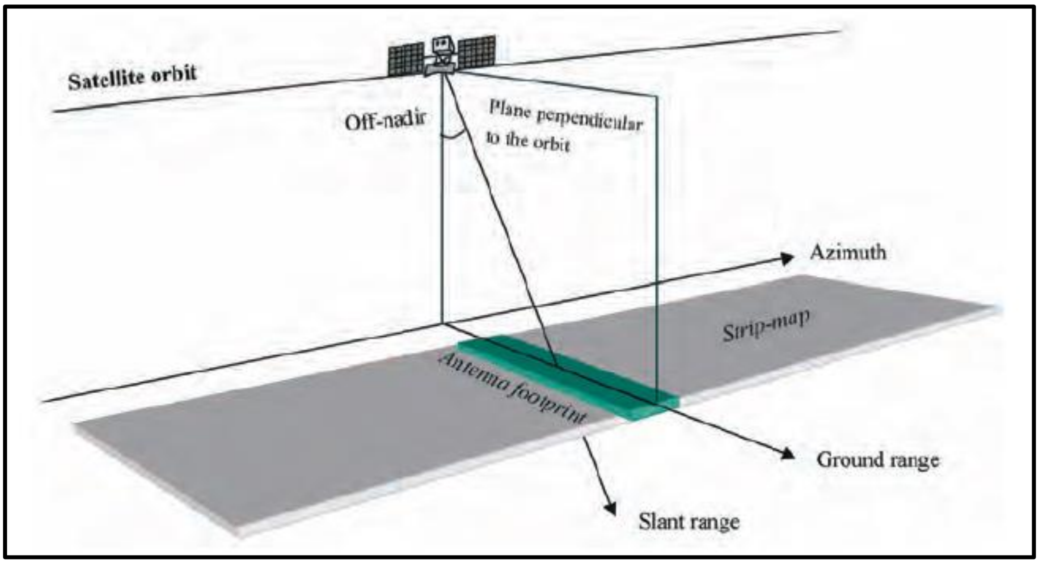

Figure 14: A SAR system from a satellite (The STRIP-MAP MODE)

Source: (Ferretti et al.,2007)

On the other hand, there are two more SAR operational modes that can be used: ScanSAR and Spotlight modes. In general, the difference between all these mentioned modes that if a wider swath is required, the ScanSAR mode system can be the best option to be utilized although if a better azimuth resolution is required, the Spotlight mode can be operated (Ferretti et al.,2007).

3.1.2.3 The Sentinel-1 satellite

3.1.2.2.1 Overview

ESA is served by a family of dedicated satellites called Sentinels. The first two successful missions were in 2014 and 2016 in launching Sentinel-1A and Sentinel-1B respectively. Both Sentinels are identical and carry onboard a C band SAR device that was explained before and share the same orbit plane with a 180° orbital phasing difference. Specifically, the Sentinel-1 is in a near-polar, sun-synchronous orbit with twelve days repeat cycle and 175 orbits per cycle for a single satellite (Fletcher K. , 2012).

Sentinel-1A is fitted with an advanced synthetic aperture radar (SAR) that works in respective specific modes to provide accurate imagery for Europe's Copernicus programme. This accurate data can be used in different applications, for instance, monitoring the oceans which includes detecting the ships positions, sea ice or oil spills (ESA, ESA sentinel online, 2015).

Moreover, it provides images for all global landmass, coastal zones and shipping routes with a high resolution and covers the global oceans with swaths. It is especially designed to work in a pre-programmed free operation mode. The advantage of these provided images that they are not affected by the weather and day/night conditions because of using the C-band's microwaves (ESA, ESA sentinel online, 2015).

Figure 15: Sentinel-1 radar vision,

source: ESA/ATG medialab

3.1.2.2.2 Sentinel-1 parameters

Sentinel-1 operates in four exclusive acquisition modes (ESA, 2000-2019):

- Interferometric Wide swath (IW): It is the main acquisition mode over land, especially, it meets most service requirements that make it the reliable option to be applied to this research. under this circumstance. This mode was used for serving this study.
- Stripmap (SM) In this mode, the ground swath is illuminated by a continuous sequence of microwaves pulses while the antenna beam is pointing to a fixed azimuth angle and an approximately fixed off-nadir angle. This mode can be used only in exceptional cases (emergencies).

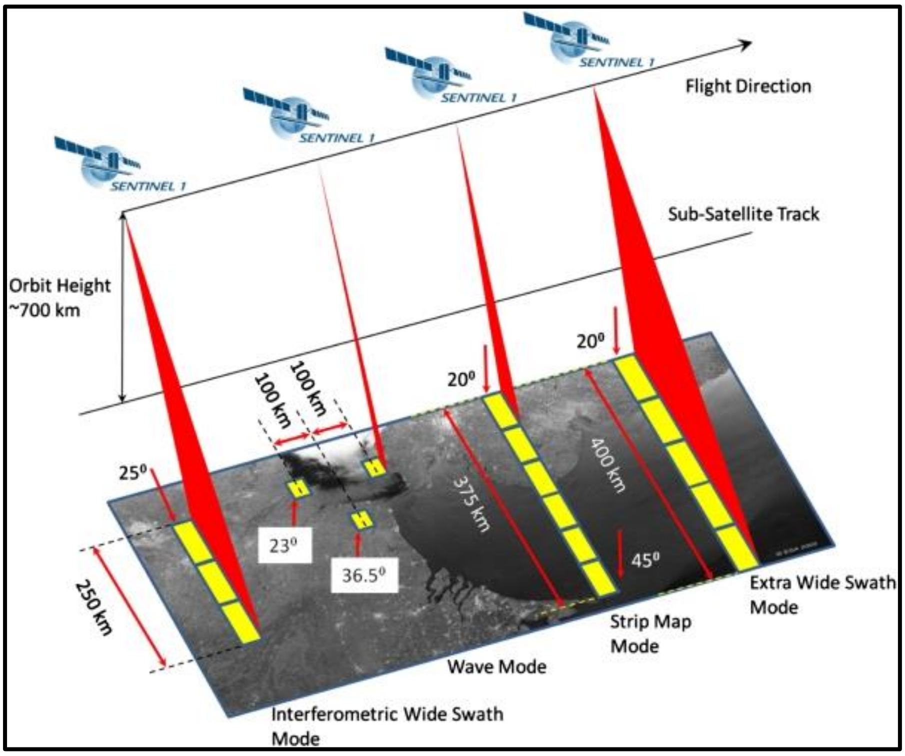

Figure 16: Sentinel-1 's modes

Source: (ESA, ESA sentinel online, 2015)

- Extra-Wide swath (EW) In this mode, the TOPSAR technique is applied to acquire data over a wider area than for IW mode using five sub-swaths. This mode typically acquired over sea-ice, polar zones and certain maritime areas, especially for ice, oil spill monitoring and security services.
- Wave (WV). In this mode, larger vignettes and a 'leapfrog' captured pattern as shown in Figure 16. It consists of several vignettes and each one of them is contained in an independent image within the product which can be processed separately.

Overall, the stripmap (SM) mode is mainly used for emergency management, the extra wide (EW) mode is used primarily for marine applications in polar regions, oil spill detection, and security. Wave (WV) mode is intended for climate modeling. Interferometric wide (IW) is the main acquisition mode over land and meets most service requirements. (Fletcher K. , 2012)

SAR method is classified as one of the active systems because it uses active sensors for providing its own energy source concerning the illumination process. These sensors classified as one of the remote sensing sensors types which can be used and fitted on the satellites (Figure 17). These two types of sensors are:

- Active sensors are the sensing devices that create their own electromagnetic energy that is transmitted by the sensor transmitter towards the terrain and interacts with the terrain producing a backscatter or a reflection of energy (Wikipedia contributors, 2019).

  The returned signal should be recorded and measured by the sensor's receiver especially because it provides information about the earth's surface. The spaceborne active sensor satellites such as Sentinel-1 are included in different remote sensing applications and observation of the Earth's physical body and its atmosphere.

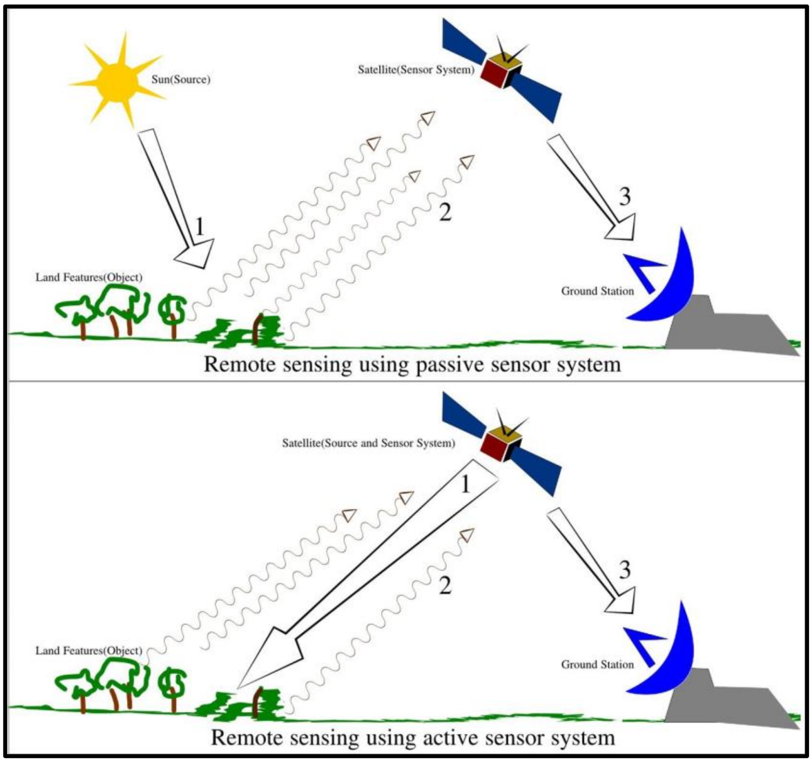

Figure 17: Illustration of remote sensing (Active & Passive system)

source: (Arkarjun, 2013)

- Passive sensors are the devices which detect and measure radiation from the Earth's surface. These radiations are defined as the reflection of the sunlight by the object or surrounding areas. this energy is emitted from the sun as it is their energy source, especially, they don't create their own energy (Wikipedia contributors, 2019). In general, satellites equipped only with passive sensors are not able to work through clouds. However, many of spaceborne passive sensor satellites are used in different remote sensing applications such as Sentinel-2.

As can be seen in the Figures 18 and 19, these are real examples have been recorded during to this study for two different satellite images by the two different types satellite sensors which have been mentioned before (Active and Passive).

Figure 18: Sentinel-2 satellite image.

Source: Copernicus Open Access Hub

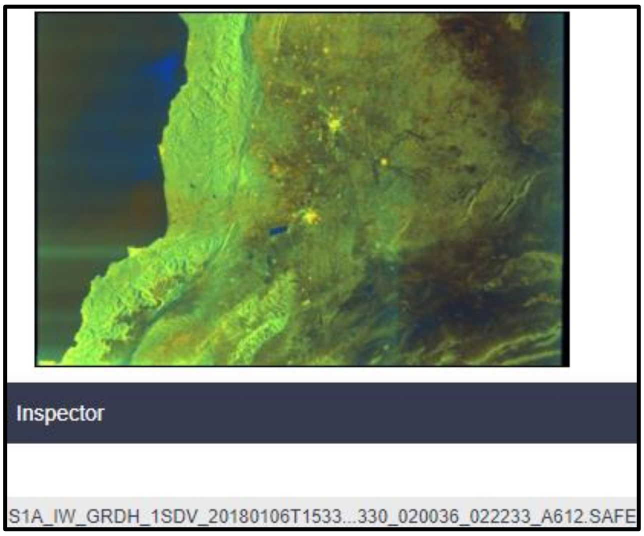

Figure 19: Sentinel-1 satellite image

Source: Copernicus Open Access Hub

In details, (Figure 18) shows a satellite image captured by Sentinel-2 which uses the Passive sensors. In contrast, (Figure 19) presents a satellite image taken by Sentinel-1 which works with the Active sensors. The point is that both images were recorded in the same day 2018/01/06 for the same area (the study location) by the different satellite systems but, in fact, Sentinel-2's image was not useful for this research because of the clouds which covered the targeted area. However, Sentinel-1's image was totally clear and accurate. For this reasons, Sentinel-1 SAR system has been applied in this study as the most appropriate method for obtaining clear and accurate satellite images that are not affected by the weather or day/night conditions. Which makes it ideal for precise location of ship activities on the sea.

3.2 . Methods of data analysis and interpretation

This research has been accomplished applying different sorts of techniques and software for collecting and analyzing the data. Starting with obtaining the exact port database of the ship movements relating to the year of 2018. Followed by designing a detailed map of the study area combining both nautical and cartographic maps. Ending with interoperating and indicating the positions of the detected ships on the map according to the entire perspective year. In other words, the workflow of this research has been achieved by two main steps as the (Figure 9) represents.

In order to achieve this methodology, the following software and supporting tools are used:

- ESRI ArcGIS 10.2.
- Excel 2016.
- SNAP 6.0
- Global Mapper

3.2.1 Creating the port map

In this stage, the methods of creating the final port map will be represented from the first step with the georeferencing to the last step of the final accomplished design (Figure 20).

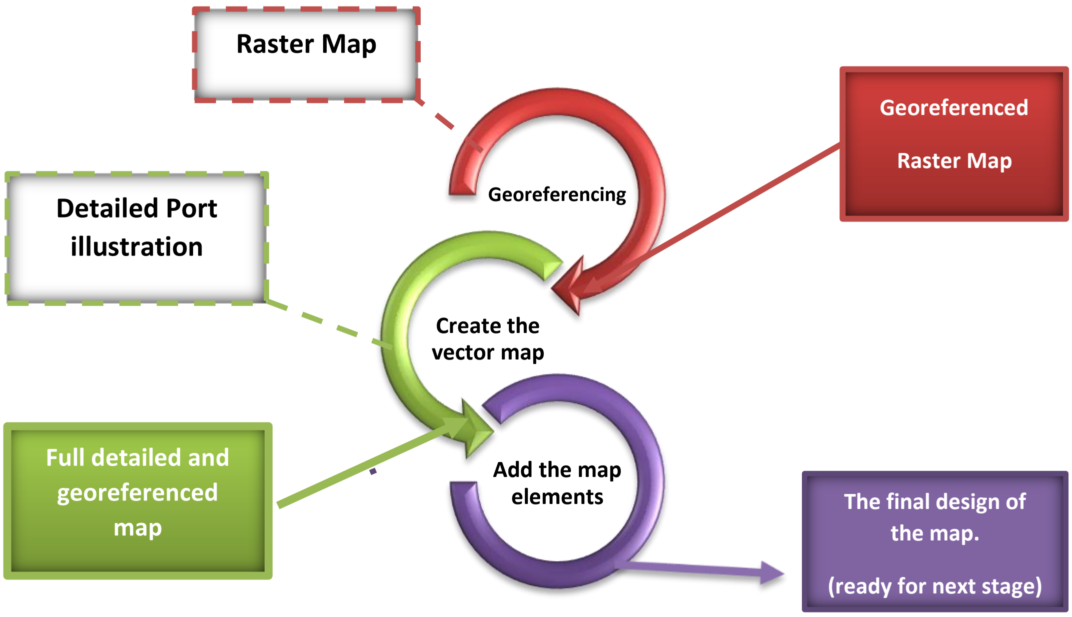

Figure 20: The Steps of creating the port map

1-The Georeferencing step

Most GIS projects demand georeferencing some raster data such as digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps. In this research, the raster data was a scanned map (chart)[9] with the title: PORTS of SYRIA (Ports in Syria, 2012).This scanned map contains navigational charts for all the Syrian ports. It is one of the maps which are used for navigating and sailing in the sea.

The term "georeferencing" means the process of assigning coordinates which are referenced to their corresponding positions on the surface of the Earth to each pixel of the raster (Figure 21). Usually, these coordinates are acquired by doing field surveys by collecting coordinates with GPS devices. These coordinates (X, Y) are the link locations on the raster dataset with locations in the spatially referenced data (ESRI, 2018).

In order to achieve this and by using (ESRI ArcGIS 10.2). First, the datum is selected to model the surface of the Earth which is the World Geodetic System

[9] A nautical chart represents hydrographic data, providing very detailed information on water depths, shoreline, tide predictions, obstructions to navigation such as rocks and shipwrecks, and navigational aids.

(WGS), specifically the revision: WGS-84[10]. Then the latitude and longitude coordinates on the datum surface were projected on the scanned raster map.

Figure 21: Georeferencing process

2-Create the vector map for the port

Digital spatial data can be expressed in one of the two systems called raster or cell system and vector or point system. Basically, the point of creating the vector map based on the raster one is because that the vector data has vertices and paths, which means the graphical output will be more aesthetically pleasing. Besides, it gives higher geographic accuracy especially because the data is independent from the spatial resolution.

However, briefly, the difference between vector system and raster system is that the vector system data is divided into three types: point, line and polygon. In 2D systems data points are expressed by single pair of (x, y) coordinates, lines by a series of (x, y) coordinate pairs and areas by a series of (x, y) coordinate pairs where first and last points are same.

[10] It is the reference coordinate system used by the Global Positioning System and established in 1984 and last revised in 2004.

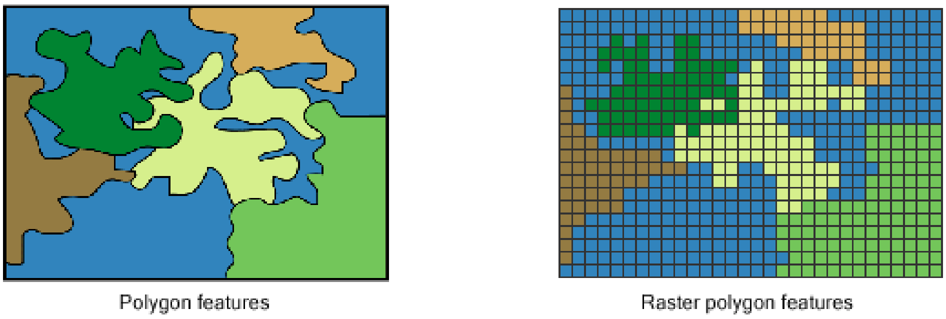

Figure 22 : Example about the difference between Vector and Raster data

source: http://desktop.arcgis.com/en/

In raster system the data is known also as grid data because points are represented by single cells, lines by a sequence of neighboring cells and area by a collection of contiguous cells. This means that raster data is a cell-based data (Figure 22) (GIS Lounge, 2000).

Accordingly, the vector map of Tartous map has been accomplished using the ArcMap which contains all the required data features (points, lines and polygons) distributed into layers which are shown into the Legend of the map (Figure 23).

This legend includes the whole different data features and symbols which are used to create this map. However, the final map considered as the base for representing the positions of the ships coming and leaving the port.

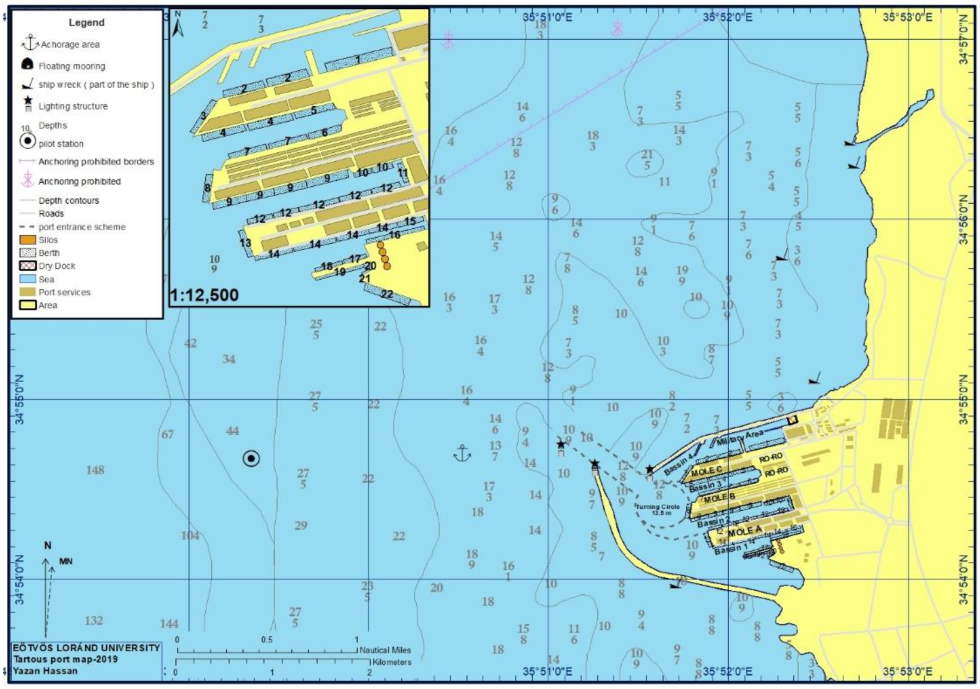

Figure 23: Final designed map for Tartous port. source: ESRI ArcGIS 10.2.

(Figure 23) represents the final designed map for the Tartous port, this map was created based on two main sources; the first source was the obtained raster map as it is mentioned before and the second source is the below illustration. This illustration was taken from one of the mandatory books that every ship must have called (Guide to port entry). (Figure 24). This book contains all the information which all vessels may need to enter any port in the world.

In details, the raster map was the base map for drawing the vector features of the port and its infrastructures in addition to assign the depths and sea levels. While all other port details have been determined and drawn considering the obtained illustration Such as the berths with their numbers, the blocks of the warehouses, soils and other vital port services. At the end of this step, a complete map of Tartous port was ready to use for simulating the port ship movements on it.

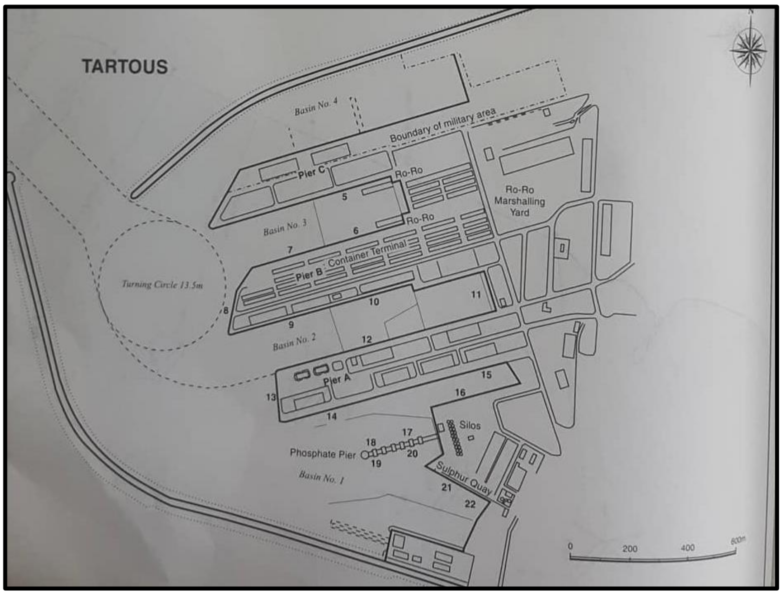

Figure 24: illustration of the port.

source: (GUIDE TO PORT ENTRY, 2014)

According to this photo and the acquired data, the port berths database has been prepared and assembled using Excel program. This database will support the research in identifying the ships' names and demonstrating the final result of this research. From the table below, it is important to notice that the data of the berths (1.2.3) is not totally complete because these berths are within the military area of Tartous port. However, these data are not important for this research and it won’t affect the results.

Berth'sNO	Depth of the berth (m)	length of the berth(m)
1	6	NG
2	9	NG
2	6	NG
3	13	110
4	10.75	210
4	12	240
5	10	210
6	10.5	220
7	12.2	160
7	12	160
8	12	55.27
9	8	150
9	11	180
9	10	180
9	9	150
10	4	115
10	4	115
11	4	134.99
12	4	115
12	8	170
12	10.7	240
12	7	130
12	4	115
13	7.5	150
14	10	200
14	4	100
14	7.5	150
14	7.5	150
15	4	100
16	4	299.8
17	8	81.15
18	9	268.59
19	9	268.59
20	10	50.5
21	11	74.54
22	11	238

Table 2: The port berths database

3.2.2 Extracting and Analyzing the positions of the detected ships

In order to understand the phase of Extracting and Analyzing the positions of the detected ships, the below graph has been created to identify each step has been done through it.

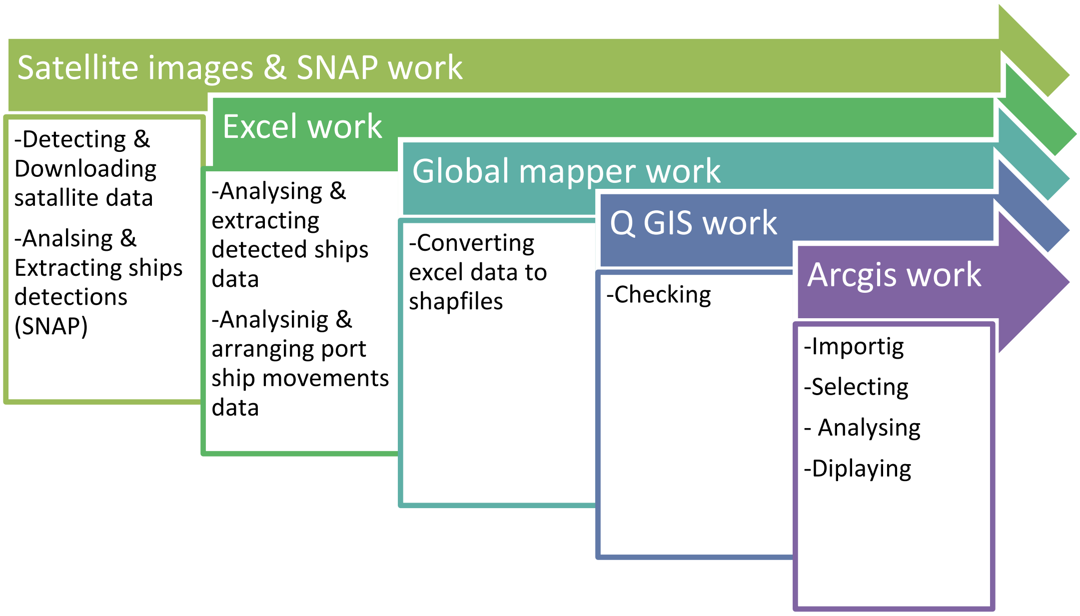

Figure 25: The workflow

1. Satellite images & SNAP work

Satellite data was the main source of this research that has been acquired from the downloaded satellite images. These images were obtained by using the Copernicus Open Access Hub which provides complete, free and open access to Sentinel-1 and other satellites. Moreover, this web-based system designed to provide data users with distributed mirror archives and bulk dissemination capabilities for the Sentinels products.

According to this web-based system, the user should indicate the approximate location of the work area by navigating and drawing the search rectangle around it as the (Figure 26) shows.

This system gives the user the opportunity to choose which satellite is to be used and define its parameters. For instance, in this study, the Sentinel-1A has been chosen for the ship detection mission concerning that Sentinel-1A pictures are not affected by the weather conditions which was discussed earlier. On the other hand, the selected Sentinel's parameters were defined such as the type of the product as a GRD product and the IW sensor mode since this mode meets most of the service requirements that makes it the most reliable option to be applied. Additionally, the sensing period was also defined as it is considered the searching key in this system that depends on the images capturing date for storing and achieving them. Therefore, determining the exact time will be the key of retrieval those archived images.

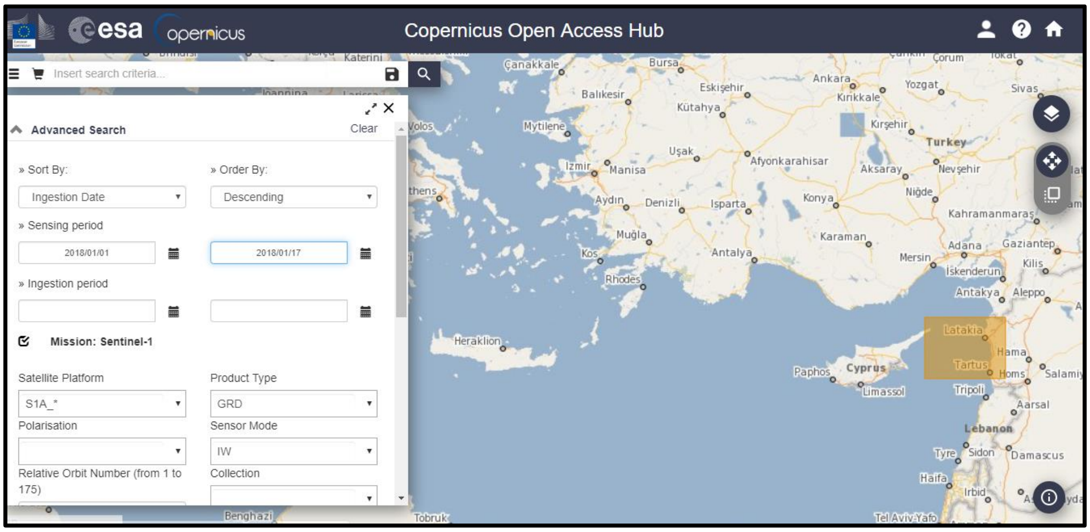

Figure 26: process of downloading satellite images using Copernicus Open Access Hub

Regarding the selected parameters, the system will provide all the possible satellite images which have been taken and stored depending on the exact search area and period defined. The result will be many satellite images that cover the selected area completely or partially. Therefore, not all the provided satellite images are suitable for the study as may some of the pictures cover places that are not required (Figure 27).

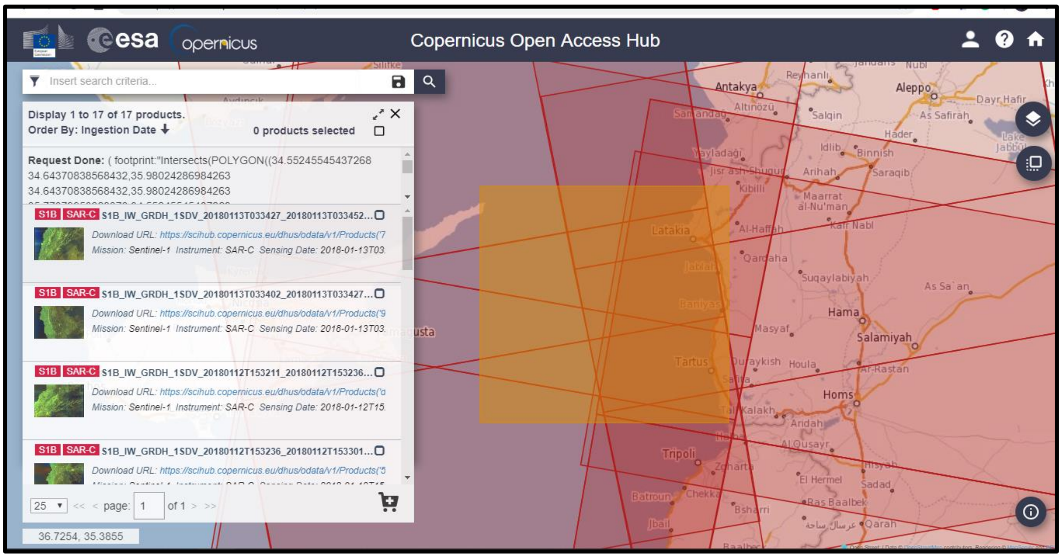

Figure 27: The provided satellite images according to the specific area and period

After selecting and downloading the required satellite images, the detected ships' positions should be extracted from them and this mission can be done by using Sentinel Application Platform (SNAP) system. This system supports the process of opening and analyzing the Sentinel-1 images using its processing tools.

According to this phase, all the downloaded images were displayed one by one using SNAP opening product tool as it is shown in (figure 28). It is important to notice that the displayed images appear "upside down" as it is represented in the figure below. We can see on the right side that the acquired image is like a mirror image of the one on the left side (the real picture) and that because the scene was obtained during ascending pass[11] and the view presents the pixels in order of data acquisition as the image is not yet projected into cartographic coordinates.

[11] It means the satellite was moving from south to north direction looking to the east.

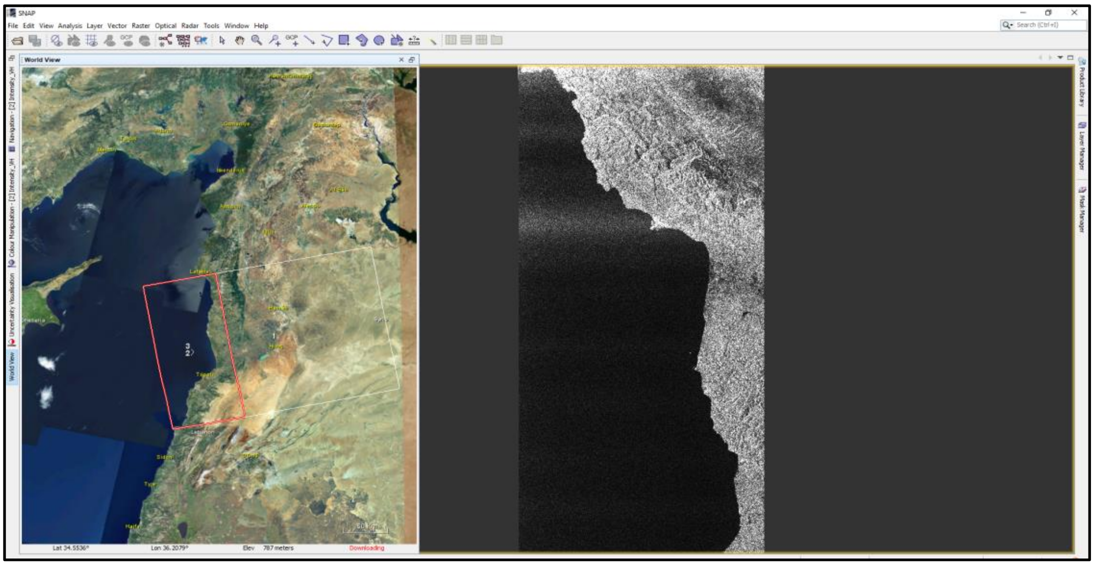

Figure 28: the acquired image displayed "upside down"

SNAP software has many tools for enhancing and analyzing the imported satellite images such as the snipping (subset) tool which is a helpful tool for reducing the processing time in further steps and it is recommended when the analysis is focused only over a specific area and not the complete scene. In Figure 28, we can see in the world overview window how the original image with the white frame was occupying

unnecessary areas but then by using this tool the size of the image has been determined to be covering only our Area of Interest (AOI) (the overlaid image with red frame).

The next step was applying the precise orbit files to the snapped images (Figure 29). In this step, the accurate orbit files that are available days-to-weeks after the creation of the product can be applied to improve the orbit state vectors which are provided in the metadata of the SAR products. These vectors are usually not precise but they can be refined by using the accurate satellite position and velocity information which can be provided by the precise orbit files (S.p.A., Italia, 2018).

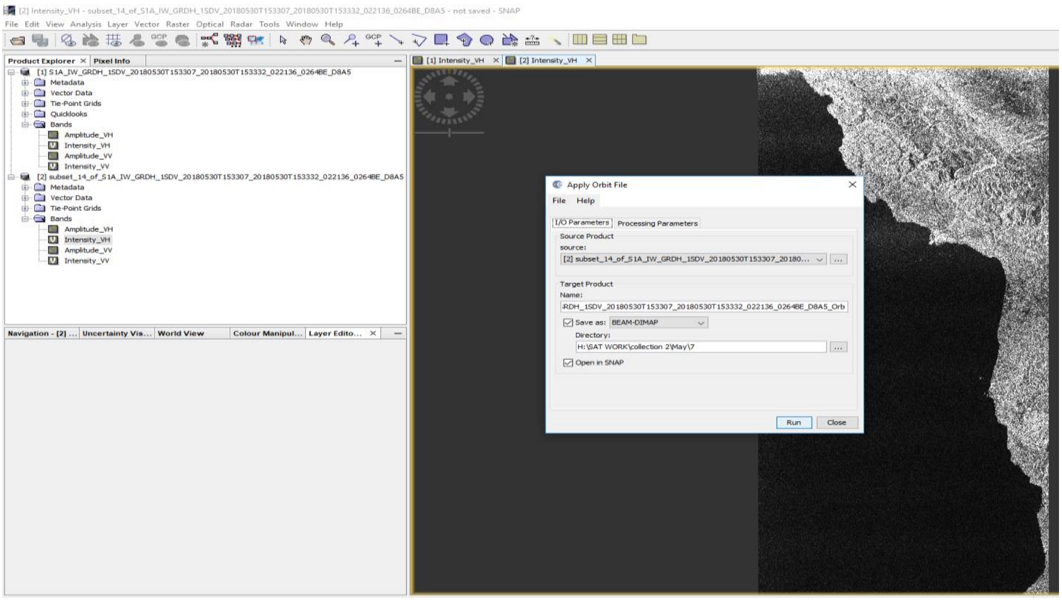

Figure 29: Applying orbit files on the subsisted images for enhancing the accuracy of the satellite image.

The final step in this phase is to run the ship detection algorithm. In this step many criteria have been determined such as choosing the sea mask to avoid false target detections on the land. In addition to selecting the size of the targeting window to filter out false targets on the sea mask (Figure 30). Here in this study the minimum size of the window was 30 m. Therefore, all targets with dimension smaller than this threshold were eliminated.

Additionally, the radiometric calibration has been applied for enhancing the quality of the SAR imagery regarding that regular SAR data processing produces level-1 images that do not have radiometric corrections and significant radiometric bias remains which are required for the pixel values to reliably represent the radar backscatter of the reflecting surface. Moreover, this calibration has been applied for comparing the SAR images obtained by different sensors or obtained by the same sensor but at different times, in different modes or processed by different processors (S.p.A., Italia, 2018).

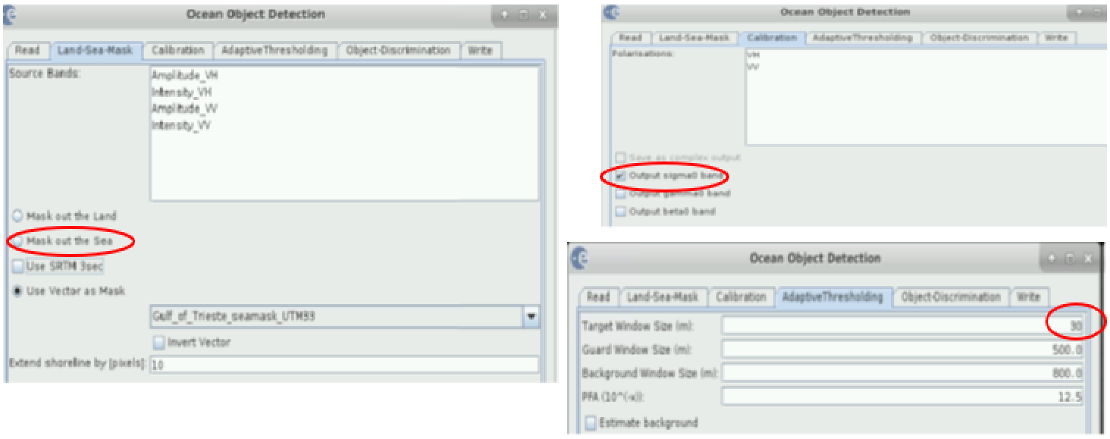

Figure 30: The determined criteria for applying the ship detection algorithm

The result of applying these steps on each satellite image using the SNAP system produced a huge number of images that contain many red circles indicating all the detected targets (ships) in the chosen areas. (Figure 31). However, the remarkable point in this performance that this detecting process is not 100% accurate. This issue will be discussed in detail within the result chapter.

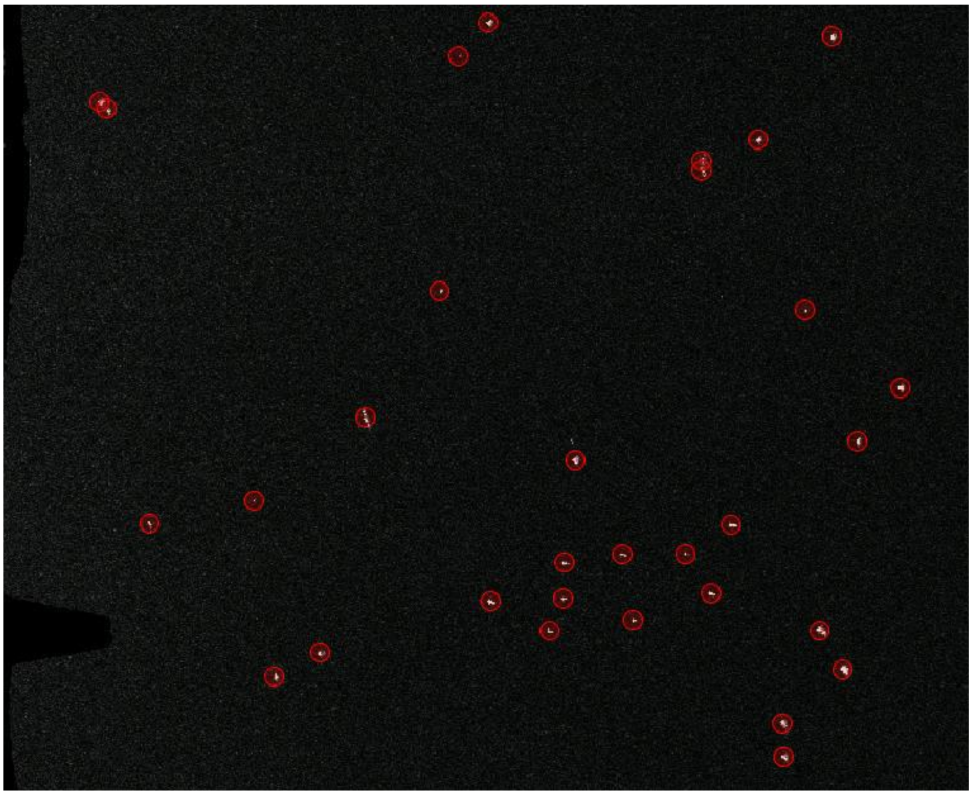

Figure 31: The detected targets (ships) within the area selected.

2. Attribute Extraction in Excel

In this step, the MS Excel program was used for organizing and analyzing all the extracted data from the satellite images, and for all the acquired data from the port website. Specifically, after the analyzing process in SNAP, a huge number of targets have been detected because of applying this process for a long period (1 year). Therefore around 8 satellite images have been obtained for each month. However, the resulting data has been acquired in an attribute form as the (Figure 32) shows.

[1] Intensity_VH | [2] Intensity_VH | [3] Intensity_VH | [4] Sigma0_VV | [4] ShipDetections

ShipDetections	geometry	Detected_x	Detected_y	Detected_lat	Detected_lon	Detected_width	Detected_length	style_css
target_000	POINT (499 4)	499	4	33.885	35.521	50	40	fill: #ff0000;...
target_001	POINT (380 ...	380	22	33.884	35.507	50	50	fill: #ff0000;...
target_002	POINT (579 ...	579	36	33.889	35.528	10	30	fill: #ff0000;...
target_003	POINT (330 ...	330	42	33.885	35.502	50	30	fill: #ff0000;...
target_004	POINT (587 ...	587	47	33.89	35.529	80	80	fill: #ff0000;...
target_005	POINT (293 ...	293	85	33.889	35.497	70	30	fill: #ff0000;...
target_006	POINT (305 ...	305	93	33.89	35.498	80	60	fill: #ff0000;...
target_007	POINT (558 ...	558	99	33.894	35.525	50	50	fill: #ff0000;...
target_008	POINT (623 ...	623	99	33.895	35.531	50	50	fill: #ff0000;...
target_009	POINT (406 ...	406	103	33.892	35.508	40	40	fill: #ff0000;...
target_010	POINT (357 ...	357	141	33.895	35.502	70	70	fill: #ff0000;...
target_011	POINT (622 ...	622	151	33.9	35.53	50	60	fill: #ff0000;...
target_012	POINT (624 ...	624	167	33.902	35.53	70	40	fill: #ff0000;...
target_013	POINT (304 ...	304	186	33.898	35.496	40	40	fill: #ff0000;...
target_014	POINT (282 ...	282	231	33.901	35.492	70	50	fill: #ff0000;...
target_015	POINT (272 ...	272	231	33.901	35.491	20	30	fill: #ff0000;...
target_016	POINT (610 ...	610	257	33.909	35.526	50	50	fill: #ff0000;...
target_017	POINT (778 1)	778	1	33.889	35.55	210	30	fill: #ff0000;...
target_018	POINT (648 ...	648	50	33.891	35.535	60	60	fill: #ff0000;...
target_019	POINT (642 ...	642	55	33.892	35.535	40	40	fill: #ff0000;...
target_020	POINT (969 ...	969	63	33.898	35.569	40	30	fill: #ff0000;...
target_021	POINT (115...	1155	65	33.901	35.589	50	40	fill: #ff0000;...
target_022	POINT (924 ...	924	92	33.9	35.564	50	50	fill: #ff0000;...
target_023	POINT (623 ...	623	99	33.895	35.531	50	50	fill: #ff0000;...
target_024	POINT (915 ...	915	111	33.901	35.562	50	40	fill: #ff0000;...
target_025	POINT (122...	1228	116	33.907	35.595	60	50	fill: #ff0000;...
target_026	POINT (848 ...	848	121	33.901	35.555	60	60	fill: #ff0000;...
target_027	POINT (834 ...	834	143	33.903	35.553	50	60	fill: #ff0000;...
target_028	POINT (631 ...	631	145	33.9	35.531	80	70	fill: #ff0000;...

Figure 32: Attributes of the detected targets

These attributes include many data but the most demanded among them were the exact latitudes and longitudes of the detected targets. These coordinates were extracted and organized into tables using Excel to be prepared for the converting the data into a geodatabase (shape-file).

Also, the ship movements data that have also been obtained for serving this study were arranged in an Excel sheet and the missing data were accumulated using the "Marine Traffic" website which provides all the reliable and required information of the ships as it was explained earlier (Figure 33).

Date	Name of the Ship	Type of cargo	Amount of cargo Carried (tone)	Platform No	IMO NUMBER	Width (m)	Length (m)	Type	Date o berthing
2018-01-02	BALT FLOT-14	oil	6419	19	9804215	16.86	140.85	OIL Tanker	2018 01 13
2018-01-07	RAINBOW-H	iron	3632	9	7521132	15	91	GENERAL CARGO	2018 01 07
2018-01-09	KAN-2	coal	16508	14	N/A	N/A	N/A	GENERAL CARGO	2018 01 18
2018-01-09	NADALENA	Barley	3822	12	8215754	16	97	GENERAL CARGO	2018 01 14
2018-01-09	NARSES	wheat	5400	9	8204119	15.5	91.5	GENERAL CARGO	2018 01 15
2018-01-09	KAN-2	coal	16508	14	N/A	N/A	N/A	GENERAL CARGO	2018 01 18
2018-01-13	FINIKIA	wheat	16761	12	9385233	25	139.92	BULK CARRIER	2018 01 25
2018-01-19	RAINBOW-H	phosphate	N/A	19	7521132	15	91	GENERAL CARGO	2018 01 19
2018-01-21	BALT FLOT-14	oil	6419	19	9804215	16.86	140.85	OIL Tanker	2018 02 12
2018-01-22	CHLPROGRES SOR	sugar	10032	22	8130681	32.24	189.01	GENERAL CARGO	2018 01 25
2018-01-24	PATIRIOTIC	oils	8988	13	N/A	N/A	N/A	OIL Tanker	2018 01 24
2018-01-24	PATIRIOTIC	oils	8988	13	N/A	N/A	N/A	OIL Tanker	2018 01 24
2018-01-24	MSB-1	Gypsum board	3128	14	7602699	13.64	96.6	GENERAL CARGO	2018 01 25
2018-01-24	ALPHA LIVE STOCK	life stock	N/A	12	7021821	13.59	92.21	LIVESTOCK	2018 01 25
2018-01-29	STELLA DI MARE	iron	4441	14	8410380	15.7	88.6	GENERAL CARGO	2018 01 30

Figure 33: The arranged and accumulated data of the port movements in the Excel sheet

3. Global mapper & QGIS work

According to this step, all the CSV (Comma separated values) files made in Excel for the arranged SNAP data attributes were imported into the Global Mapper for the purpose of creating and exporting them into shapefiles (Figure 34).

These shapefiles are vector data formats for storing the location, shape and attributes of geographic features. Therefore, the detected ship's coordinates were the base used for determining the location of the points feature shapefiles (ships). The reliability of these exported shapefiles was checked using QGIS tool.

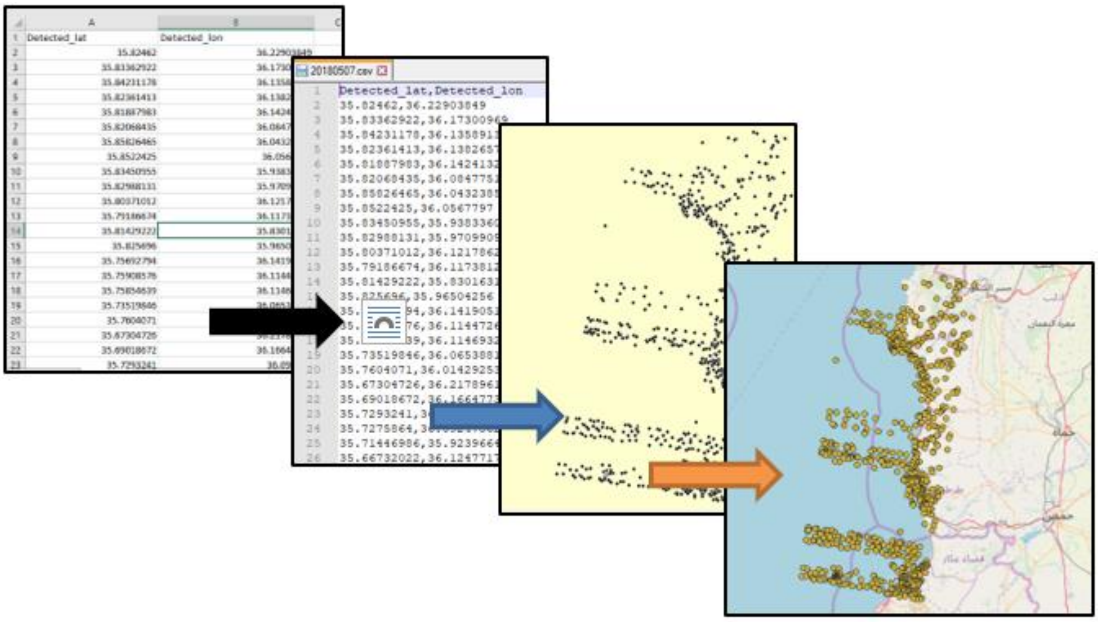

Figure 34: Steps of converting the satellite excel data into shapefile.

4. ArcGIS work

In this final phase, several actions have been performed for modelling the final product and extracting the result. These implemented actions have been assigned according to series of steps as the figure of the workflow before showed. However, all these actions were applied by using different ArcGIS software tools.

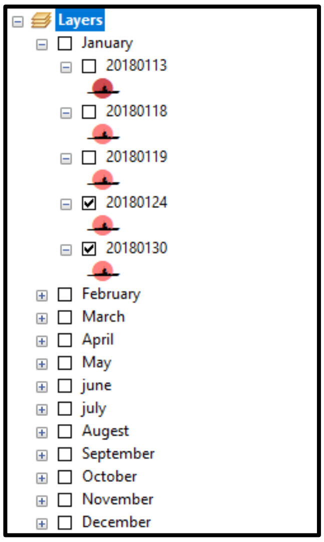

Figure 35: Ships points layers

Starting with the first step of importing data. In this step the accomplished design map was imported because it is the base map representing the ship movements within the study area followed by importing all the extracted and analyzed ships points to be overlaid on it. These points were separated and arranged into groups of periods (months) since the original satellite images were also acquired into periods (Figure 35). However, these groups facilitated the mission of monitoring and indicating the ship movements in the port which gave us the opportunity of analyzing the commercial traffic in the port.

For getting the specific ship points' attributes, the selection step was applied by using one of the ArcGIS tools (select by location tool). This is one of the ArcGIS tools which allows us to select features based on their spatial relationships to other features within the same layer. That means for the aim of particularly selecting the detected ships within the port area of study, we need to apply this selection tool.

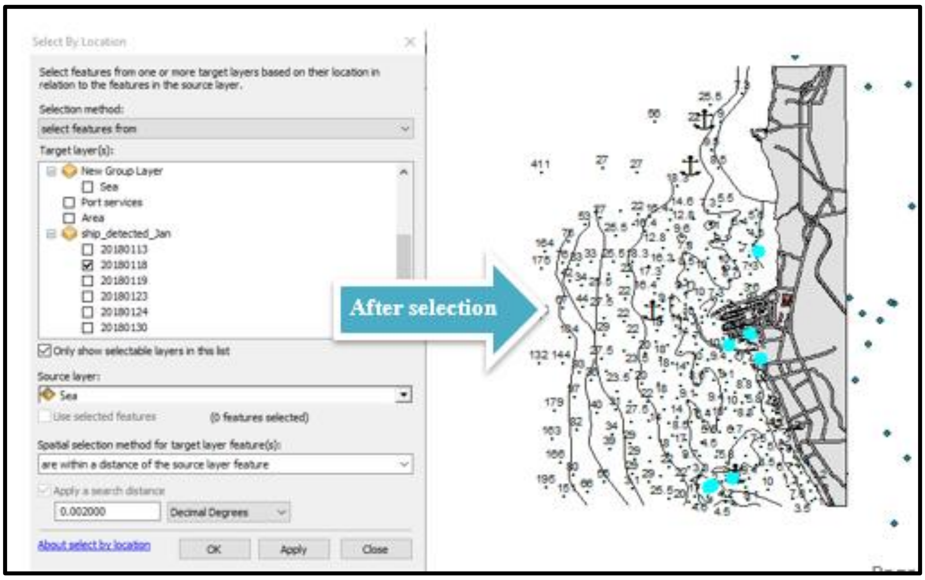

Figure 36: Selection by location

Consequently, the targeted feature layers were the ship points especially these points were extracted from the satellite images as the detected targets for the whole sea area within the image borders. In addition, the source layer that the selection is based on was the sea area of our map (Figure 36).

According to that, this selection has been applied one by one for each day of the data obtained. So, the result was an accurate and defined data for the ship movements within the area. These selected points represent all the ships positions within the area but that does not mean that all these detected vessels are coming to this exact port.

That's why, the core of this phase was the step of analyzing all these displayed ships' data for distinguishing the ships that are approaching the port for loading or discharging from other ships. In order to identify and distinguish whether the ship is coming to Tartous port or not, a complex logic work has been performed for defining the identity of each selected ship point based on combining and analyzing the acquired port database of the ship movements with the attributes of the selected vessels points.

This identification process has been achieved based on two main factors (time and location). By these two factors, the names and statuses of the ships have been defined and represented on the map.

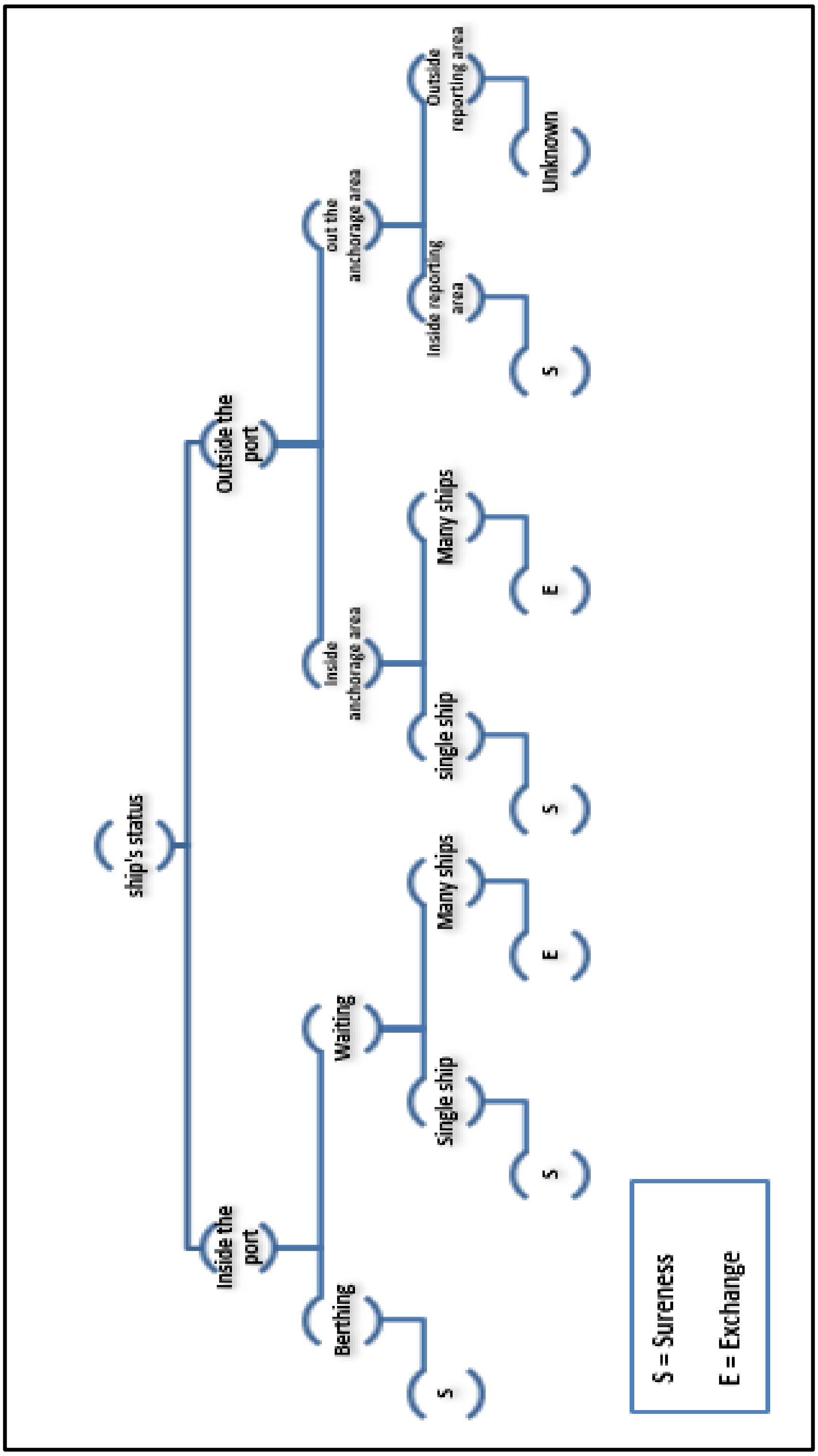

Figure 37: Ship statue identification

From the graph above, we can understand that there are two main statuses relating to the ship's position: inside the port and outside the port. If the ship has been detected within the area of the port, that means it should be either berthing or waiting to berth.

In the berthing situation, we can easily identify the name of the ship taken from the port ship movements database by checking the berthing day and the berth's number.

In the other case of waiting inside the port, we have two statuses: the first status is when the vessel is waiting alone inside the port, in this case, we can surely extract the name of the ship from the port database based on measuring the waiting period. while the second status is when many vessels are waiting inside the port and here it is impossible to distinguish the exact name of each vessel. That's why a new column is created in the ship's attributes with the title of the alternative ship name. This column refers to the other potential names for the same ship point, for instance, in the figure below, we can see that in the date of 24/01/2018 two ships were waiting inside the port (ORHAB-Y and RAOUF-M). Thus, this method has been applied and the column of alternative name (Altr_Name) has been created with typing the letter (E) in the "sureness" column.

Table

20180204

FID	Shape *	date	NAME	sureness	Altr_Name	Type of cargo	Amount of cargo Carried	Platform No
0	Point	20180204	UNKOWN	_		_	_	_
1	Point	20180204	RAOUF-H	E	ORHAN-Y	corn	5750	12
2	Point	20180204	ORHAN-Y	E	RAOUF-H	corn	5750	14
3	Point	20180204	BALT FLOT 14	S		oil	6419	19
4	Point	20180204	UNKOWN	_		_	_	_
5	Point	20180204	UNKOWN	_		_	_	_
6	Point	20180204	UNKOWN	_		_	_	_
7	Point	20180204	UNKOWN	_		_	_	_
8	Point	20180204	UNKOWN	_		_	_	_
9	Point	20180204	UNKOWN	_		_	_	_
10	Point	20180204	UNKOWN	_		_	_	_

Figure 38: Ships detected within a specific day 2018/01/24.

On the other hand, when the ship is detected outside the port zone there will be two main statuses: 1) outside the port but within the anchoring area; 2) or outside both port and anchoring area. The first status of the ship waiting inside the anchorage is divided into two cases relating to the number of the ships waiting. If only one ship was waiting in the anchoring area, its name will be indicated using the port database.

While in the case of many ships were waiting, the same defining method which has been used in the example before but with measuring the waiting period in the anchorage rather than the waiting period inside the port which is usually characterized as it is limited and determined by the port authorization especially that "the key cost driver in maritime trade is time. The longer a vessel is in port, the higher the costs for the consignment of cargo on board". For that, it is costly compared to waiting outside the port anchoring area (United Nations, 2016).

In the second situation, the ships were detected outside the anchoring area either in the reporting zone or outside the reporting zone. Regarding the first assumption, the same method of using the port's records has been applied based on searching about the ships that were reporting their location at the same date. While in the second assumption, any vessel detected outside reporting and anchoring area will be defined as an unknown ship.

After applying all these phases, a final design map of the Tartus port and its surroundings was generated, overlaid with point data-layers of the detected ships from the year 2018. In addition to that, full data attributes for all the detected ships have been generated. These attributes include all important identification data such as (names, ID numbers, lengths, widths and so on).

4. The Results

4.1 Overview

This chapter outlines the final result of this research starting with an illustration of the final design of the map with its elements. In this section, the complete design of the map and its adopted elements will be reviewed with an explanation of the reasons behind choosing each one of them. Then, it debates the result of analyzing the final satellite data from different aspects. The final acquired satellite data will be discussed and this discussion will be supported and demonstrated with some graphs. However, this review is based on comparing the satellite data after and before applying the suggested logical work that is explained in detail in the research methodology chapter. Eventually, the final data visualization section, where the detected ships' positions will be visualized on the final design of the map showing the dynamic movements of the ships during the whole year of 2018.

4.2 The final map design

This study concentrated on creating a map that contains both the navigational and cartographic map elements with the aim of simulating the marine traffic of Tartous port on it. The difference between map and chart is that the map is a graphic representation of selected features of the Earth surface that shows land areas, political subdivisions, and topography. Based on that, the targeted users or readers for this kind of representation should not always be professionals. On the contrary, the chart is a special- purpose map that usually designed for a form of navigation, such as air and marine navigation. Additionally, marine charts show water areas and provide information about depths, aids to navigation, shorelines, physical features, and other useful and essential information.

In details, the map has been created based on a copy of the raster chart of Tartous port which was discussed earlier in the research methodology chapter. Accordingly, the resulted map maintained the main structure of the chart by applying both the geographical coordinates grid and the WGS84 projection which was determined by the obtained raster map (Figure 39).

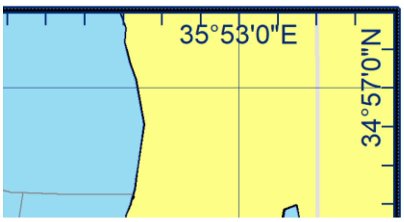

Figure 39: Part of the used grid style in the resulted map

On the other hand, the cartographic map elements were also combined on the resulted map as a way for changing the standard view of the chart from a complicated special-purpose design to an understandable and multi-usable one. Consequently, the benefit of doing that was: making this kind of maps useable for representing, serving and implementing different kinds of projects related to nature, hydrology, economy, and simulation (e.g. simulating the marine traffic).

In order to make this map simple for understanding, some cartographic elements were added to it, such as the legend which is a visual explanation of the symbols used on the map, that includes a sample of each symbol (point, line, or area), and a short description of what the symbol means.

Moreover, applying the "Extent Indicator" in ArcGIS, which is a method to show the extent of one data frame within another data frame for making this larger extent area recognizable to the map reader. In the figure below, we can see that the map locater here represents the port berths numbers to make this important part of the map reorganizable for the reader.

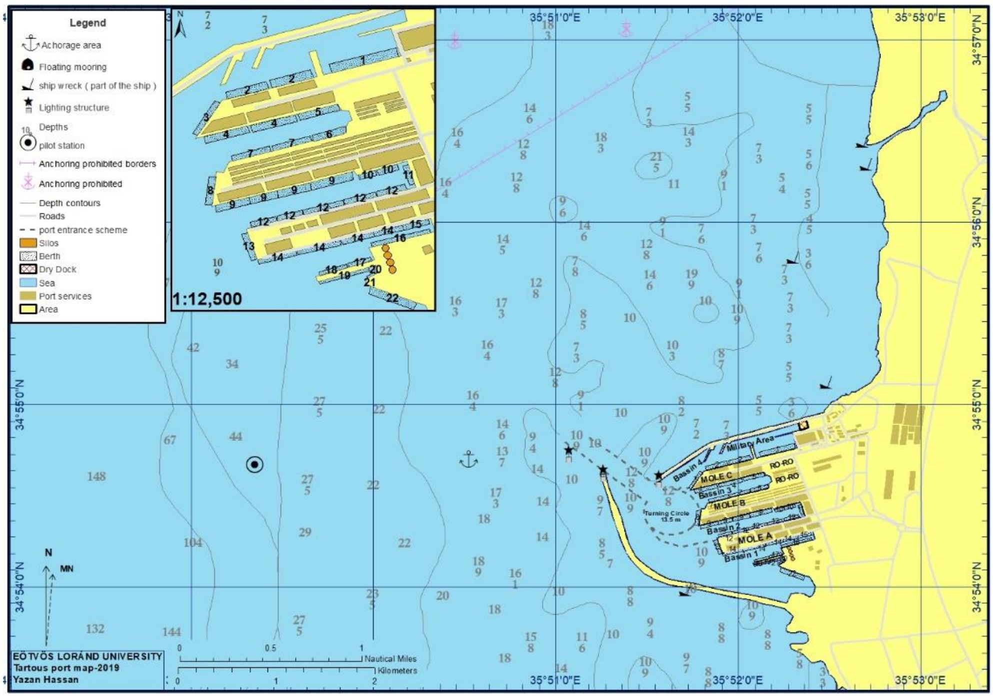

Figure 40: The final map.

Finally, based on the created chart of Tartous port, we can clearly simulate the port's marine traffic. Especially this chart presents the depths, berths and the directions which are the essential factors for accurately displaying the ship movements.

4.2 Ship detection and the correlation result

The following section shows the results of an analysis of the Sentinel-1 coverage in the area of study to illustrate the full monitoring capabilities of the Sentinel-1 constellation in a time window from 2 of January to 28 of December 2018 (i.e., 66[12] days, approximately six complete orbit cycles).

4.2.1 Ship traffic in the vicinity of Tartous port

In this study, the port data has been combined with the extracted satellite data under the purpose of accumulating and identifying all the detected ships' information in an accurate way. This acquired port data was the core of the validation process concerning the detected ship model assumptions.

Month	Total number	Ship status			In percetage			
		(S)	(E)	(Unknown)	S	E	Unknown	Defined ships
January	65	8	9	48	12%	14%	74%	26%
February	72	8	6	58	11%	8%	81%	19%
March	95	4	16	75	4%	17%	79%	21%
April	107	10	17	80	9%	16%	75%	25%
May	85	4	15	66	5%	18%	78%	22%
June	91	8	15	68	9%	16%	75%	25%
July	61	7	9	45	11%	15%	74%	26%
August	60	15	14	31	25%	23%	52%	48%
September	57	3	17	37	5%	30%	65%	35%
October	46	7	6	33	15%	13%	72%	28%
November	48	7	11	30	15%	23%	63%	38%
December	41	7	9	25	17%	22%	61%	39%

Table 3:Number of ships detected per month with classification

Consequently, from the table above we can see the final result of this logical validation method. This table presents the total number of ships detected per month and how these ships were classified into three main groups according to their statuses as what is discussed before in the previous chapter. The graph below was created to illustrate the table data in a graphical way. However, we can see that in the first half of the year, the number of ships detected was much larger than in the second half of the same year of 2018 which can be noticed by following the blue line graph that represents the total numbers of ships with respect to the months of the year. Accordingly, the highest number of the detected ships within this year was in April

[12] Sentinel-1 will be in a near-polar, sun-synchronous orbit with a 12 day repeat cycle and 175 orbits per cycle for a single satellite

where the line graph reached a peak of 107 ships. Then how this number gradually decreased to reach its lowest level at the end of the year with 41 ships.

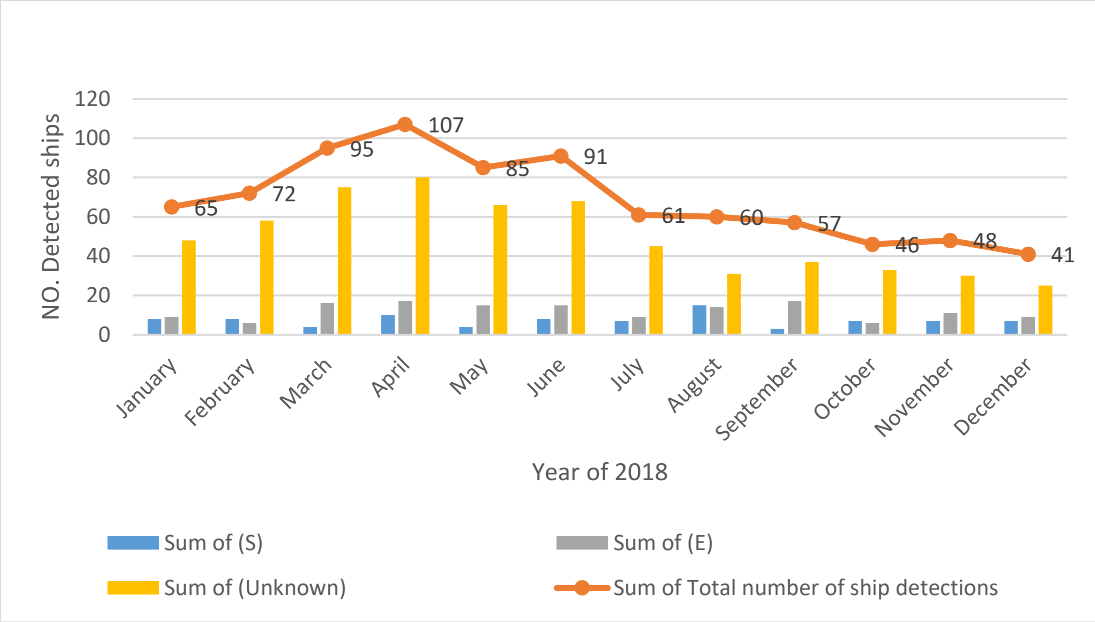

Figure 41: The graph of Number of ships detected per month with classification.

Even though the important point here is that not all these detected ships were coming to Tartous port, therefore, the ship's status logical work has been applied for identifying and validating these resulted data accurately. According to this logical work the bar chart below (Figure 42) was created for representing the percentages of ships that have been identified. Whereas, the term identified ships refers to the ships detected in both statuses (Sureness and Exchange) while the rest are Unknown ships which are not relevant for our study.

However, after performing an elimination of the undefined ships, the outcome showed the contrary (the traffic of the second half of the year is heavier than in the first half of the year of 2018). The highest percentage of traffic was in August with 45%.

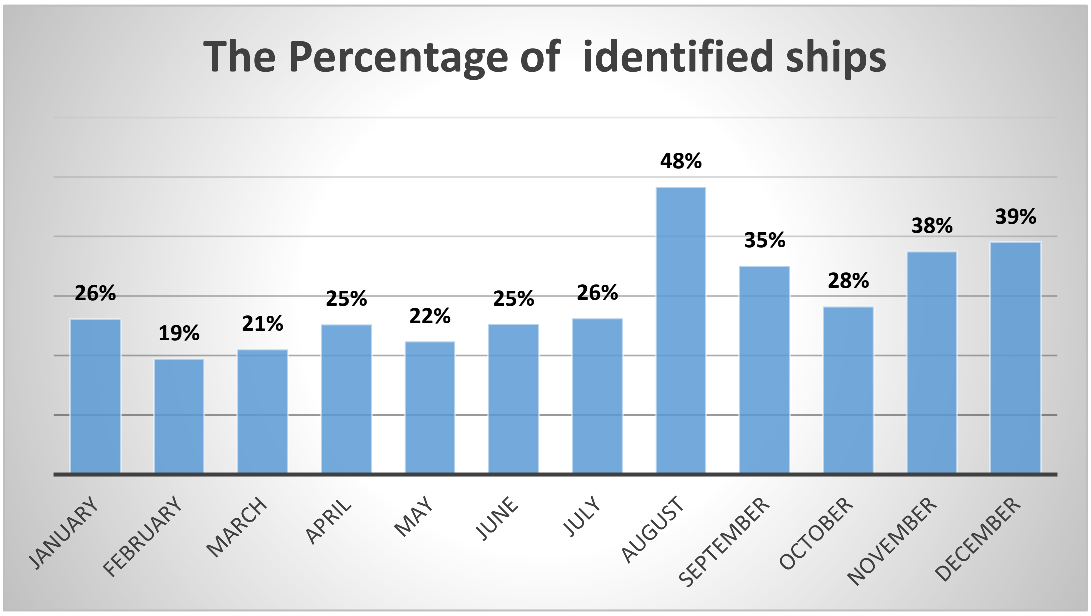

Figure 42: bar chart of percentage of identified ships per month

To make the analysis more convenient and understandable, the results were calculated in percentage for each status and represented into three pie charts (Figure 43, 44).

These pie charts illustrate the proportion of vessels detected according to the three classifications statuses in 2018. These classes have been formed based on a logical work explained earlier. According to the two charts in Figure 43, we can see that the most active months in this year were in the second half of it, while in the first half of the year, the lowest percentage of the port activity occurred, and this totally opposes the result above.

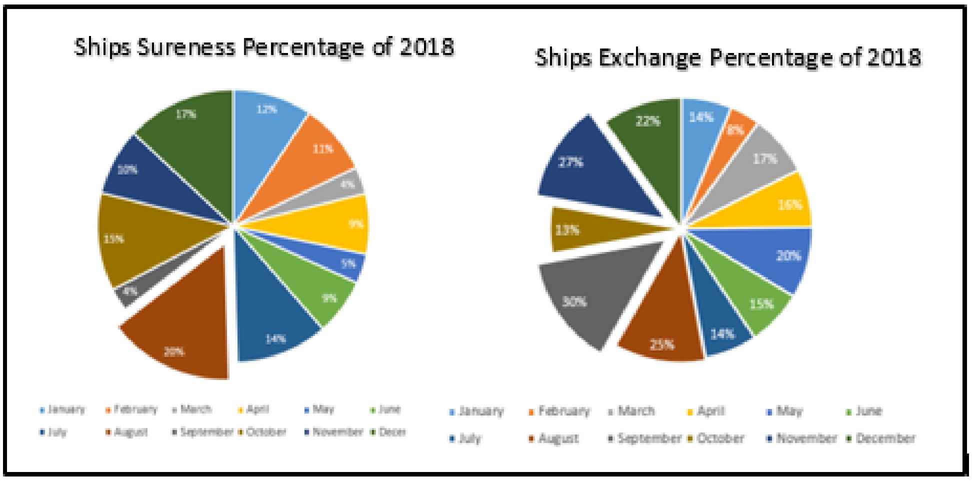

Figure 43: Pie charts of the ship's percentage for both statuses'

The first pie chart represents the percentage of ships certainly detected and identified in 2018. Looking at this chart, it is clear that the highest percentage of identified ships coming to the port was in August with 20%. While the lowest number was in both March and September with 4%. However, the second chart illustrates the proportion of ships coming to the port and defined under the exchange category for many reasons explained before. Nerveless, we can see that the number of ships coming to the port was at its highest percentages during both September and November with 30% and 27% respectively. While in February the number of ships was at its lowest percentage 8%.

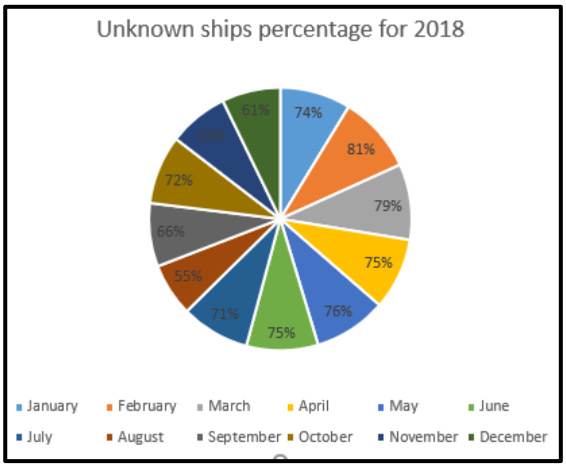

Figure 44: Pie chart of Unknown ships percentage for 2018

This third pie chart represents the proportion of the unknown ships that were detected within the area of the port (i.e., fishing boats). These boats were also detected by the Sentinel-1 beside the identified ships. This usually happens because of its function which allows the detection of ships non-carrying AIS, such as smaller fishing boats and vessels which are sailing illegally in the surveyed area such as illegal fishing and piracy (Aayush Grover et al.,2018). In addition, some ships were detected outside the port area and they were categorized as unknown ships concerning that they are maybe cargo ships, but their destination is not Tartous port.

However, from this chart, we can see that the overall percentage of the unknown ships that were detected during this year were mainly high with 80% in February. The purpose of representing these percentages was to show the efficiency of the sentinel-1 in detecting almost all type of vessels concerning any selected area.

In contrast, it shows the importance of securing and monitoring the port area of these kinds of vessels which can be one of the main risks of maritime traffic. In other words, last studies discussed the great risk of small boats as they are not fitted with AIS and their big percentage which can certainly increase the risk of collisions with them. Therefore, navigators and the port authorities shall be always aware that there are a huge number of non-SOLAS ships sailing around the world without knowing anything about their identities (JUNZHONG, 2004).

4.2.2 Ships inside the port

The bar graph below has been created based on measuring the number of ships berthed in the port to the numbers of the berths. Overall, we can see that the berths with the numbers 14, 9, 12 were the most active berths during this year. While some berths were completely not working or there was no data available representing their performances such as the berths 1, 2, 3, 4 which are located within the military area.

In detail, we can see that the most working berth among these berths was the berth number 14 with 97 ships, followed by the berths number 9 and 12 with a number of ships 91 and 84 respectively. In contrast, the berth number 18 was serving the lowest number of ships during this year with 2 ships only, followed by berths number 13 and 7 that were also less active with 6 ships only.

Overall, all these percentages are not 100% accurate unless having complete satellite data images for the whole year, in other words, daily satellite images covering the whole perspective year. This issue will be discussed later in the conclusion as it is one of the challenges which any researcher could face while using the satellite data.

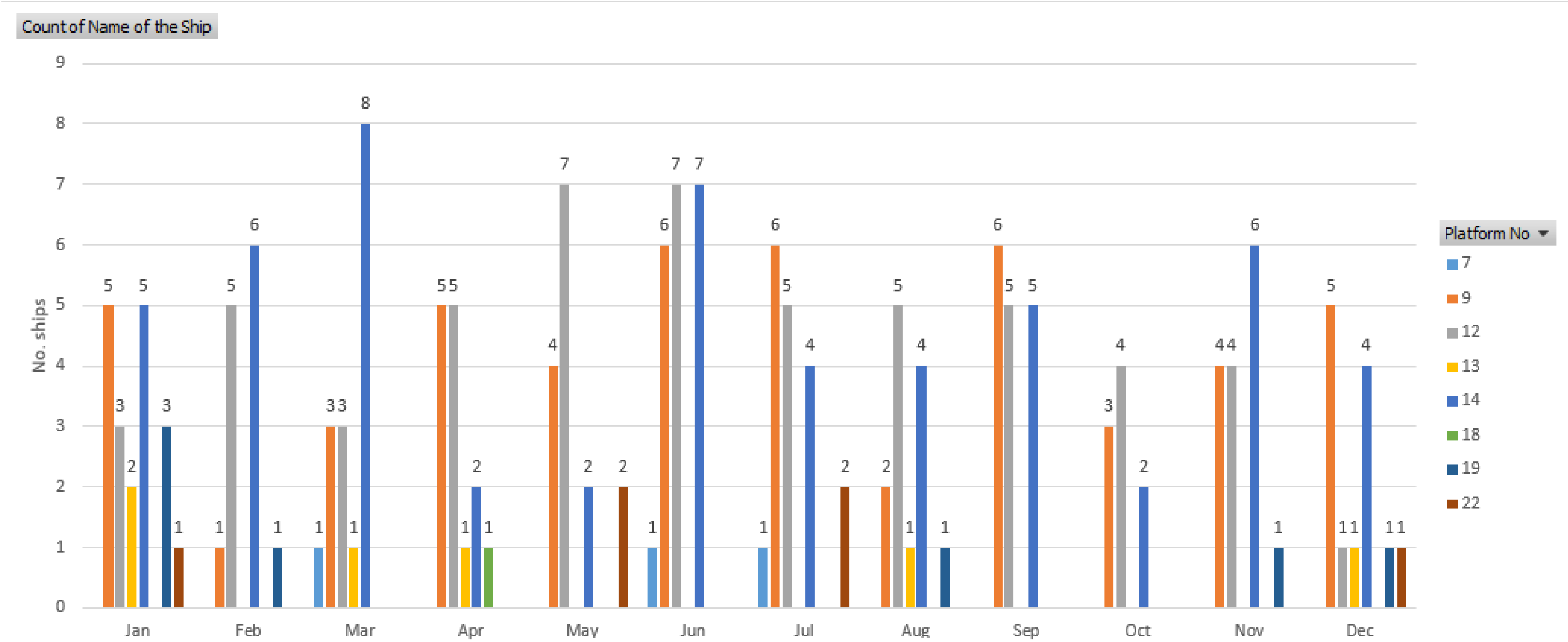

Figure 45:ships to berths ratio per month in 2018

4.3 Final data Visualization

However, the result was too many ships were detected and Identified per month within this year. Therefore, the pictures below represent only the most active four months during the year of 2018 and regarding the size of pages and for proper visualization, the legend and the overview of the port are represented separately as the figure below shows.

In figure (47), it was necessary to minimize the size of ship points concerning the heavy traffic this month and for proper visualization.

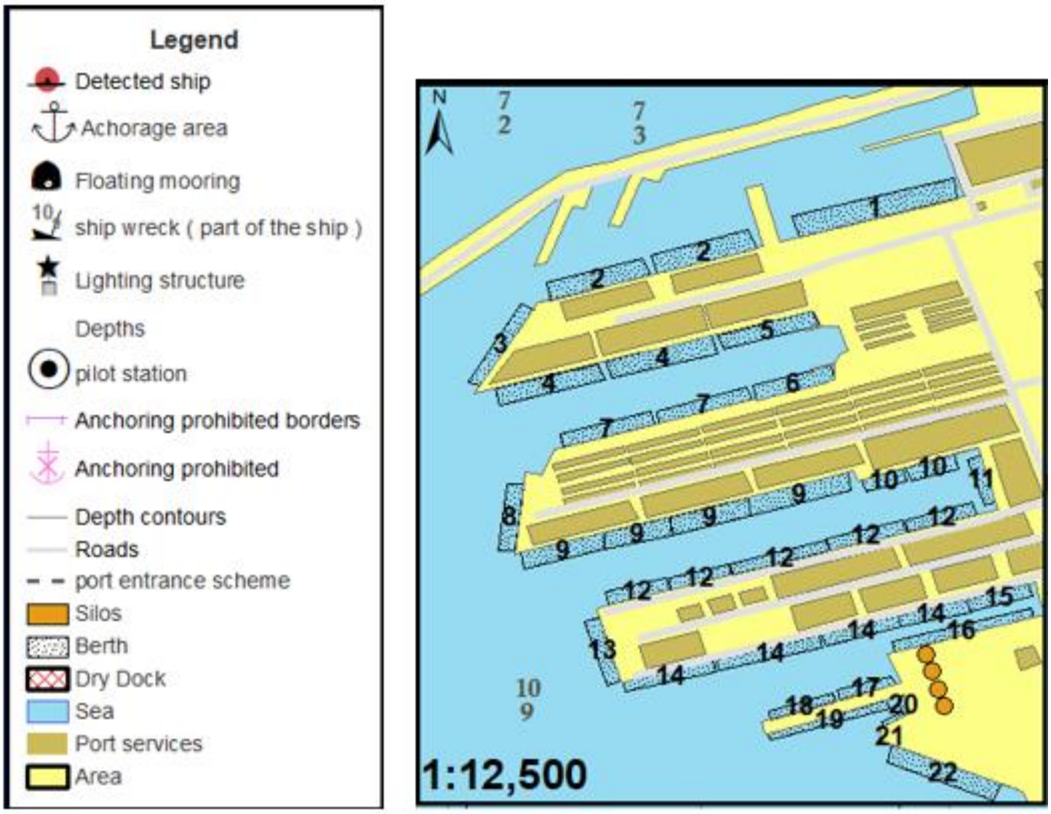

Figure 46: Legend and overview map of the original and full-size map

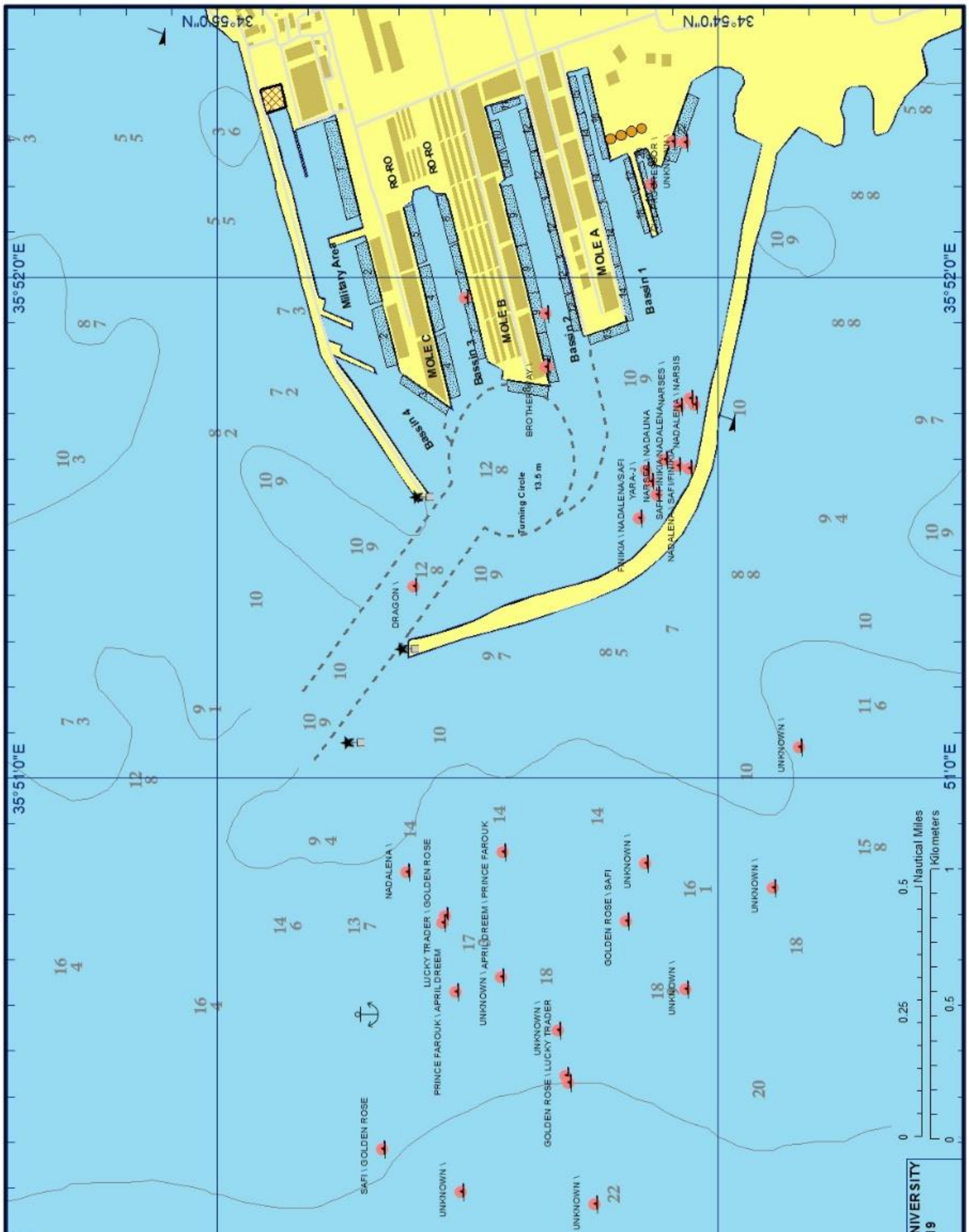

Figure 47:Marine traffic in August

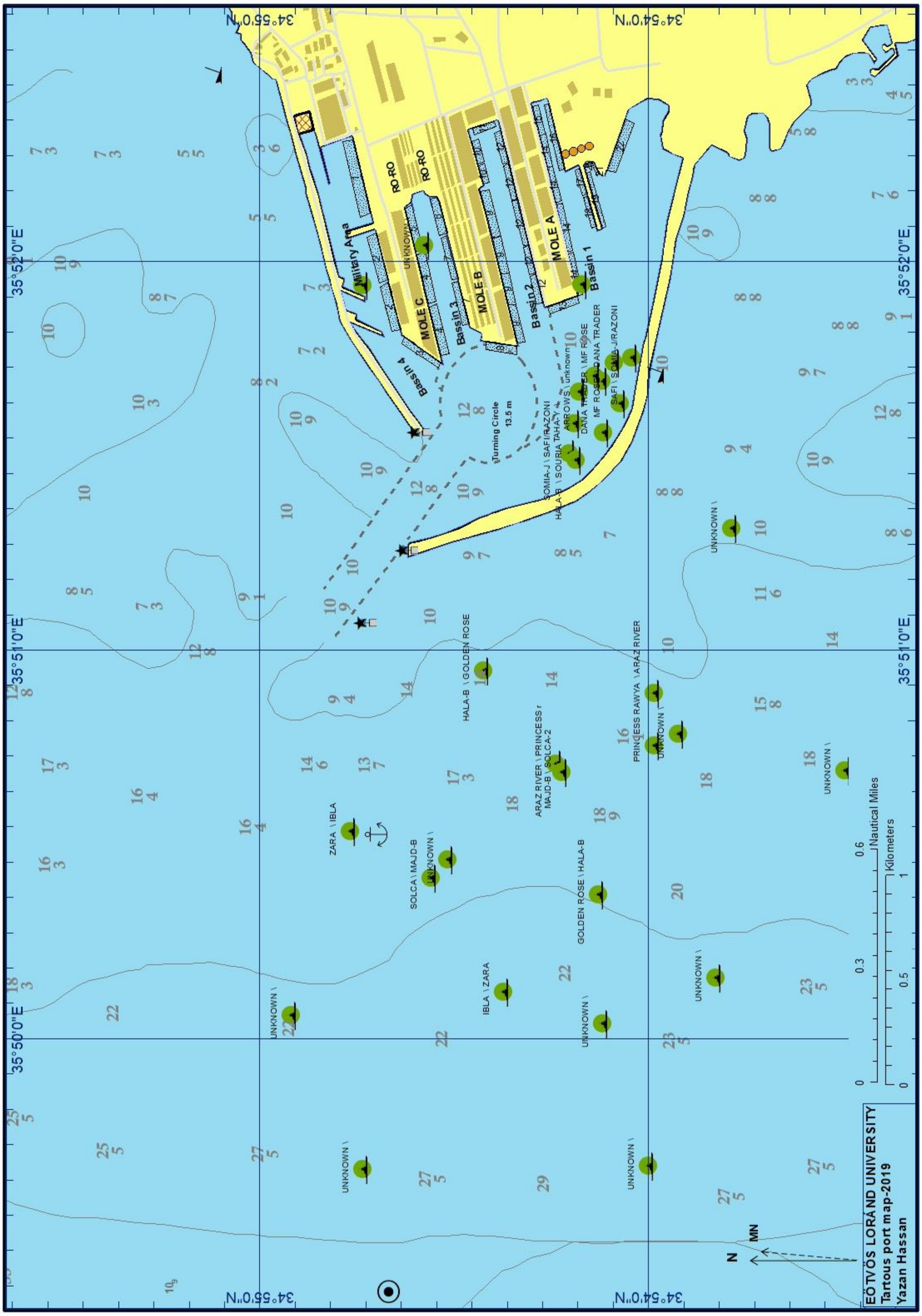

Figure 48:Marine traffic in September

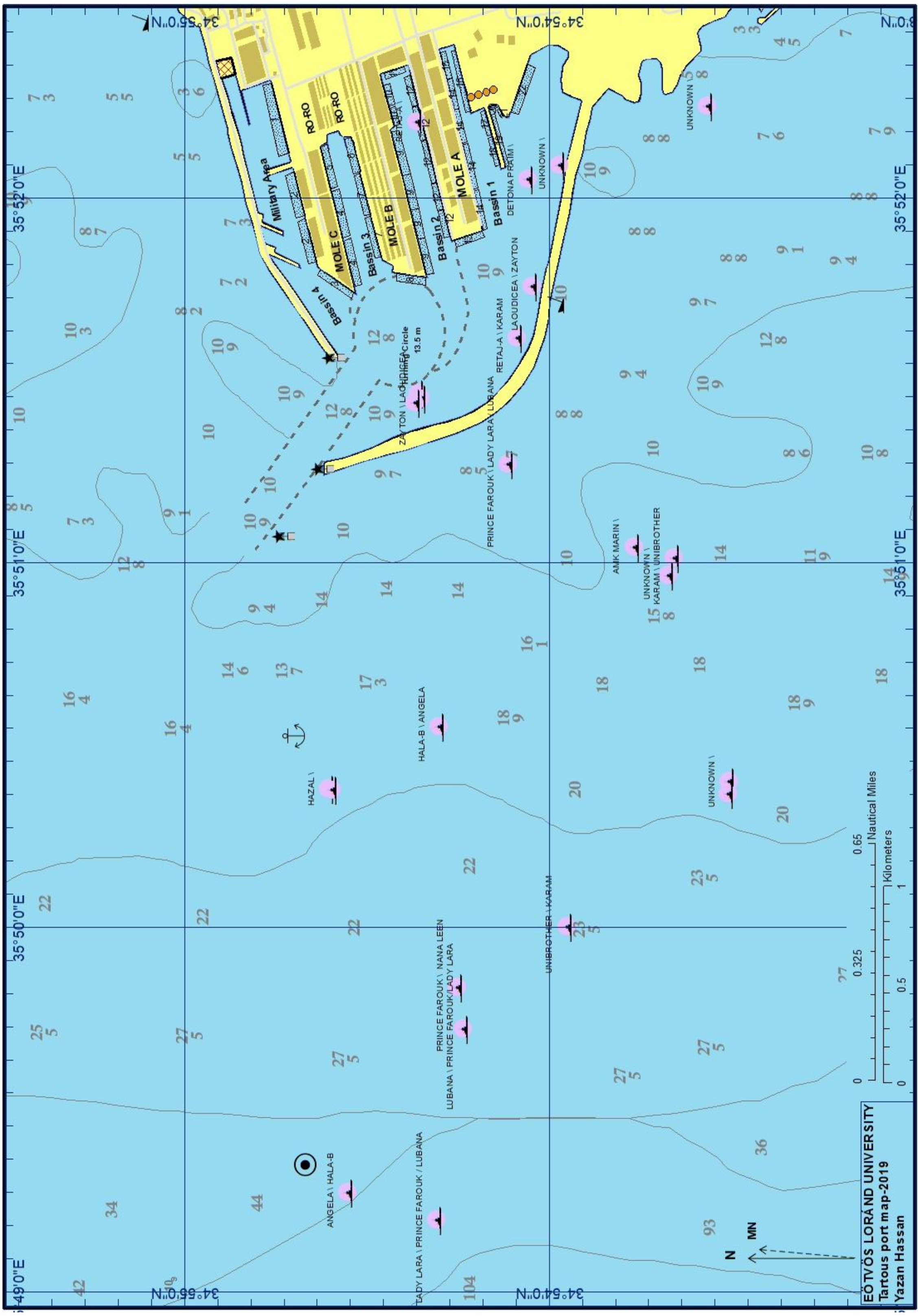

Figure 49:Marine traffic in November

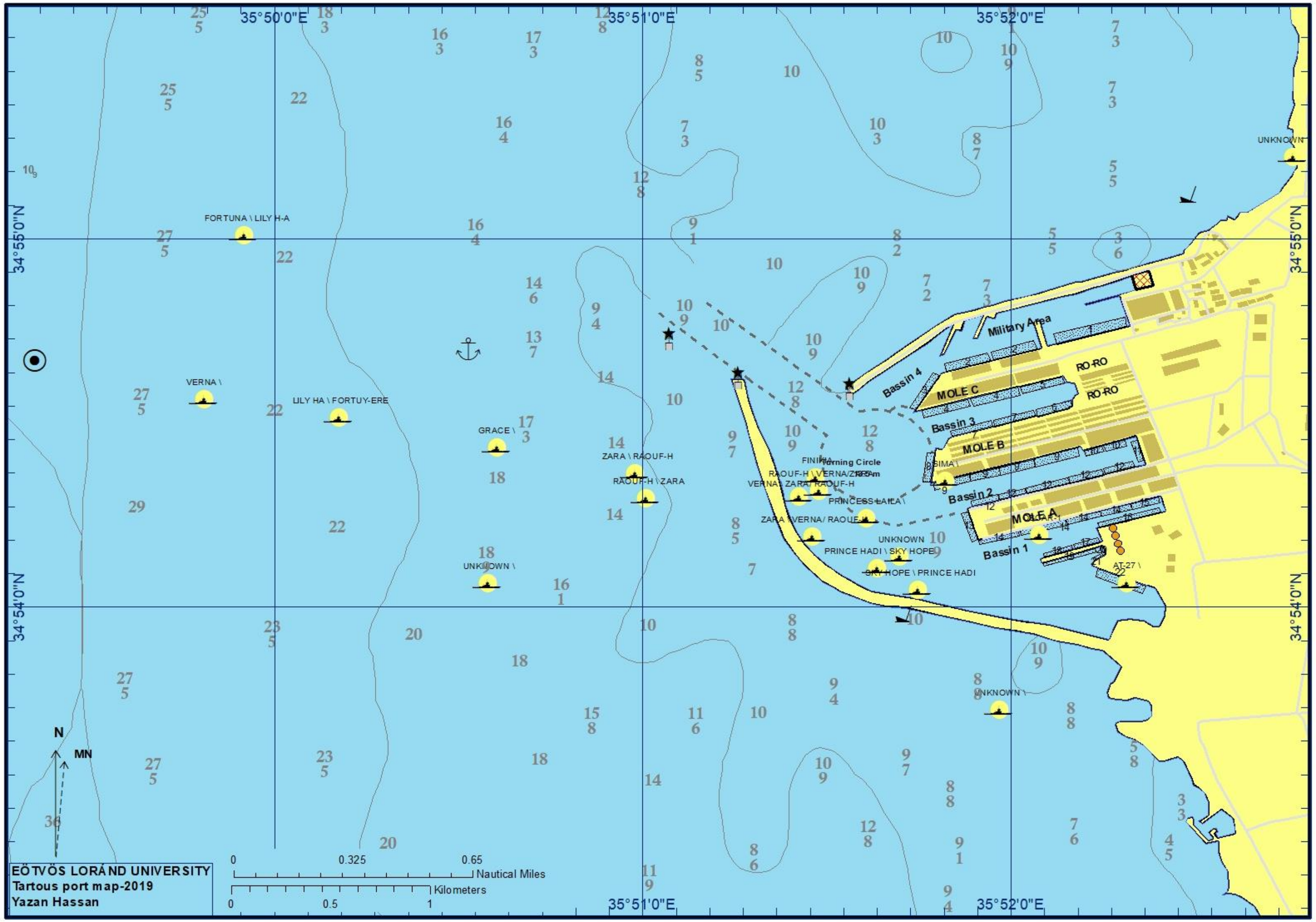

Figure 50:Marine traffic in December

5. Conclusion & Summary

In this study, marine traffic of Tartous port has been detected and monitored by using remotely sensed data, Sentinel-1 radar images in 2018 beside the comparable port ship movement reports.

In conclusion, of this thesis work, a dynamic map model has been created for representing the detected ships within the port area. The represented ships were filtered and categorized based on a complex logical work as the goal of the study was to make a clear dynamic visualization of marine traffic for the Tartous harbor.

The approach used in this research, can be completed in a more accurate way by obtaining all the missing port data that has been mentioned before and that can give a more accurate visualization of the whole marine traffic in that year. It is hoped that the results in this report can be helpful in improving maritime situational awareness, the ability to recognize events, circumstances, and activities within Tartous port. In addition to the development of the Copernicus maritime services as this research is based on using their provided satellite and software tools.

The main deficiency of the method was that upon the close inspection of the result, it was noticeable that a few very small targets were missing or falsely detected. This has occurred though the optimizing parameters to analyze the acquired data has been used. However, that was expected as these parameters can only achieve the lowest number of false detections and simultaneously the lowest number of missed targets, without eliminating them.

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DECLARATION

I, undersigned *FULL NAME* (NEPTUN CODE: *XYZ*), declare that the present master's thesis is my original intellectual product in full and that I have not submitted any part or the whole of this work to any other institution. Permissions related to the use of copyrighted sources in this work are attached.

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