

THE AUTOMATIC IDENTIFICATION SYSTEM (AIS) AS A DATA SOURCE FOR STUDYING MARITIME TRAFFIC

Ronan Kerbiriou¹, Laurent Lévêque¹, Aboozar Rajabi², Arnaud Serry¹

(¹University of Le Havre – UMR 6266 IDEES)

(²University of Le Havre - LITIS)

(ronan.kerbiriou@univ-lehavre.fr, leveque.lh@gmail.com, aboozar.rajabi@univ-lehavre.fr, arnaud.serry@univ-lehavre.fr)

ABSTRACT

The Automatic Identification System (AIS) is an automatic tracking system used on as a tool to increase navigation safety and efficiency as well as vessel traffic management. It enhances maritime safety and security. AIS' contributions are undeniable in spite of some deficiencies and technical restrictions.

This article presents the impacts and uses of AIS technology that can provide useful information to study maritime traffic, especially for the scientific community and port authorities. This desktop study is carried out in the framework of the implementation of a platform to reconstruct shipping routes using AIS data.

KEY WORDS

Automatic Identification System, AIS, maritime traffic, Research Platform, World maritime trade, Strategy of shipping companies

1. INTRODUCTION

Maritime transportation, the means used for 90% of international exchanges, is protected by several safety devices such as the development of maritime surveillance systems (Vandecasteele, Napoli, 2011).

Nowadays, vessels take on board more and more aid to navigation systems. The aims of these systems is to simplify the positioning of vessels with regard to their environment (Devoegele, 2009). Amongst these technologies, one must cite the ARPA¹ radars that facilitate the relative

positioning with other vessels in order to aid navigators in their choice of maneuvers, and information and mapping systems. AIS (Automatic Identification System) receivers have of late been making an appearance in gateways. They manage the sending and receiving of GPS positions, speed, course, type, time and place of arrival of ships, towards and from the surrounding vessels. These shipboard or on-shore systems are all the more important the heavier the maritime traffic is, and which increases in the key transit points like straits and canals or in the congested areas of ports (e.g. North Sea). AIS is a system of data exchange between ships that was made mandatory by the International Maritime Organization (IMO) in 2004. AIS presents

¹ ARPA: *Automatic Radar Plotting Aid*

advantages for maritime transportation actors: improvements in safety, improvements in the management of fleets and navigation. Its distribution also presents numerous advantages in seaway management. However, the generalization of AIS poses problems of confidentiality for ship-owners, indeed for safety. In effect, the data transmitted by AIS are available to all, including the scientific community.

The work presented is a synthesis of a reflection conducted during the development of a research platform for the analysis of maritime traffic and the assessment of the vagaries of maritime transportation, the CIRMAR platform. This tool makes it possible to envisage multiple operational applications that concern navigational safety as well as maritime economy, analysis of the strategies used by maritime actors or the environmental impact of maritime traffic.

The article is based essentially on a documentary analysis of existing studies but also on in-depth bibliographical research which is both technical and within the field of human sciences even if there is a scarcity of Francophone literature dedicated to this new technology. The first part of the article puts forward a definition of AIS including its characteristics and objectives. The second part intends to highlight the contribution made by this system and its use. The third part focuses on the use of the data produced by AIS. Emphasis is given to the CIRMAR project which aims to construct and exploit a platform of data integration and application development based on the reconstruction of shipping routes using AIS signals transmitted by vessels of over 300 gross tonnage. The fourth section focuses on the case of the Adriatic Sea. By means initially of an empirical approach, the focus of this article, therefore, is to identify the relevance of AIS for the maritime and scientific communities.

2. CHARACTERIZATION OF THE AUTOMATIC IDENTIFICATION SYSTEM (AIS)

2.1. A Tool Designed for Security

The IMO helps with safeguarding the life at sea, improving the safety and efficiency of maritime navigation as well as protecting the marine environment. It attaches great importance to the development of systems that aim to facilitate and make maritime navigation safe by means of numerous groups working on electronic tools. So as to increase maritime safety, the IMO has adopted mandatory regulations concerning the installation of automatic identification systems capable of providing information from one vessel to another as well as to on-shore authorities. These regulations form part of Chapter V of the SOLAS² convention.

These regulations have been adopted by most of the world's merchant shipping fleet and concern principally all passenger ships whatever their size and vessels of a gross tonnage equal to or exceeding 300 tonnes (grt³) making international voyages.

Based on the automatic exchange of communications by VHF radio⁴ between vessels on the one hand, between vessels and marine surveillance centers on the other and more recently via satellites, it enables identification of transmitting vessels in real time. This is included in the adoption of the ISPS code⁵ by the IMO, an international code for the safety of ships and port facilities which, besides establishing AIS, provides, inter alia, the appointment of safety officers, setting up safety plans or traceability of goods in transport units. There are, in fact, 2 classes of AIS:

- Class A transponders are mandatory on board merchant ships exceeding 300 tonnages and all passenger ships meeting SOLAS standards (merchant navy, ferries,

² Safety of Life at Sea

[<http://www.imo.org/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-%28SOLAS%29,-1974.aspx>].

³ grt: the gross registered tonnage is one of the units of measurement for a vessel's transportation capacity.

⁴ Very High Frequency/VHF is the part of the radio spectrum ranging from 30 MHz to 300 MHz.

⁵ International Ship and Port Facility Security is an international code.

etc.). The Class A AIS system is used for the exchange of several types of signal that contain different information: information on the ships' characteristics, their position, speed and course, their draught, type of cargo and destination (Cf. Figure 1).

- Class B transponders concern small ships that are not required to comply with SOLAS conventions (recreational vessels, fishing vessels of less than 15 meters, etc.), so as to enable them to adapt voluntarily to the AIS system.

2.2. Operation and Technical Characteristics of AIS

The AIS system uses a transponder which transmits and receives in VHF. It also includes a GPS receiver which records the position and details of movement.

Transmission and reception is carried out continuously and autonomously (Fournier, 2012). It transmits both static information of identification and type on the vessel and dynamic information on position (Cf. Figure1), and information relating to the voyage on the nature of the cargo and ports of departure and destination. Generally, ships receive information in a radius of 15-20 nautical miles. Terrestrial stations located at higher altitudes can extend this radius to 40-60 miles, according to obstacles and weather conditions.

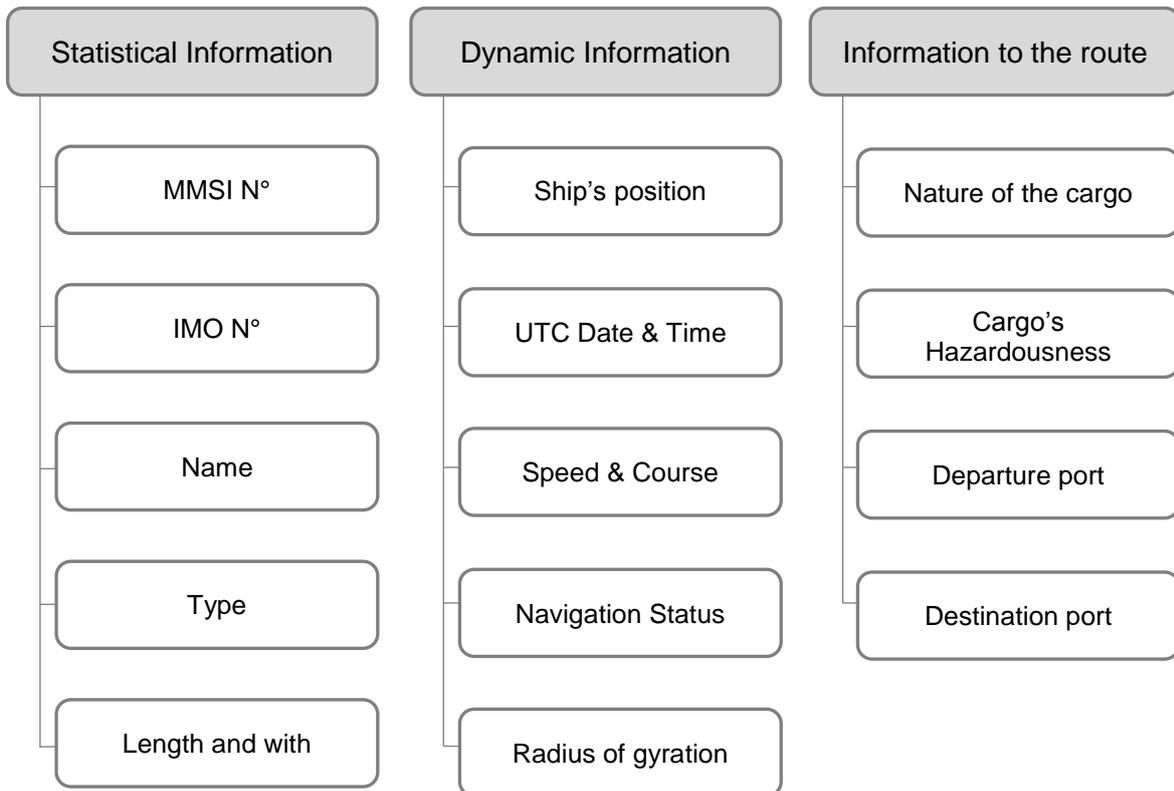


Figure 1. Nature of AIS data

Source: Le Guyader, Brosset, Gourmelon, 2011.

Launches of AIS satellites have been carried out since 2009 therefore considerably reducing the number of white areas (Chen, 2013). So, the latest change to the AIS technical standard includes a message specifically designed for AIS

reception from satellite (AIS SAT). Any vessel equipped with AIS today is easily trackable, and this at any moment wherever it may be. The generalization of AIS does not entail removing the use of

pre-existing systems and they are complementary:

- In addition to shipboard systems, Vessel Traffic Services (VTS) actively monitor maritime traffic;
- The Global Maritime Distress and Safety System coordinates all the radio-communications means for rescue, nowadays paired for safety purposes with the Ship Security Alert System.

The objective is to combine the pre-existing data coming from these sub-systems with an integrated system commonly called Vessel Traffic Monitoring Information System.

2.3. Objective of Control and Maritime Security

Owing to the new dimensions of all kinds of traffic and flows increasingly irrigating the whole planet, the management maritime traffic has become a major contemporary issue (Faye, 2005). In fact, one of the challenges of the maritime community now is how to conciliate the surge in marine shipping while at the same time guaranteeing the protection of marine resources in a context of climatic change. In highly frequented waters, active surveillance of maritime traffic has taken on an even greater meaning.

Maritime security and safety cover a wide and expanding area: from the management of commercial traffic to the fight against piracy, including sea rescue, counter-terrorism and the protection of port infrastructures. Recent measures aim to reinforce maritime safety with reference to the protection of life at sea, the preservation of transported goods, the protection of the vessel and prevention of collision. Often confused with security, safety is defined as a state of protection against threats or dangers coming from outside. In the maritime domain, safety can be defined as the prevention of unlawful acts liable to have a negative impact on the proper functioning of the supply chain and the safety of persons and goods (Fournier, 2012). Nevertheless, in practice, this classification is not inexplicable. As a matter of fact, an event linked to one of

these notions can have repercussions on the whole of the maritime system.

3. CONTRIBUTIONS OF AIS AND USE OF DATA

The primordial contributions of AIS are in the field of maritime security and safety. The AIS system makes it possible to locate the great majority of vessels throughout the world. Therefore, several new services are available for the authorities or ship-owners, such as global maritime surveillance or constant knowledge of their boats' positions (Prévost, 2012). Community websites have sprung up, allowing thousands of ships to be followed throughout the world.

3.1. AIS Efficiency

"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" (They, 2012). This system enables vessels to be traced but also to anticipate their movements. Availability of precise data on the position of ships in real time renders it possible to manage traffic efficiently, to react more swiftly in the event of an accident or incident, while having more precise information on hazardous cargoes or indeed to improve surveillance of vessels in the interests of safety.

The use of AIS as an aid to navigation is a precious source of information not only with regard to ships but also with regard to all the navigational aid beacons (Świerczyński, Czaplewski, 2013). AIS is placed notably as a relevant tool for the protection of the marine environment. Pollution from ships can take two principal forms. It occurs accidentally or through deliberate discharges, i.e. tank-cleaning operations and disposal of waste oils (Serry, 2013). In the former situation, AIS systems have a potential ability to reduce the frequency of polluting accidents linked to navigation by simply supplying an update of information concerning ships. Similarly, they can shorten the response

time in the face of accidents by supplying information about the situation in near-real-time. AIS is therefore an important asset for the protection of the marine environment. (Schwehr, Mc Gillivray, 2007).

Illegal discharges are the second cause of pollution of the marine environment. The impacts of these discharges are not as considerable as those of maritime disasters and consequently have not been of great concern. However, this form of pollution could be substantially reduced and AIS technology can make a contribution. For example, the Helsinki commission has been using AIS data since 2005 (HELCOM AIS) to assess the risks of hydrocarbon discharges associated with specific vessels (Cf. Figure 2). Today, Automatic Identification System also be able used to estimate ships emissions. Jalkanen et al purposed a modeling system for maritime traffic exhaust emissions of NOx, SOx, and CO2 in the Baltic Sea area based on data obtained from AIS receivers (Maimun, 2013).

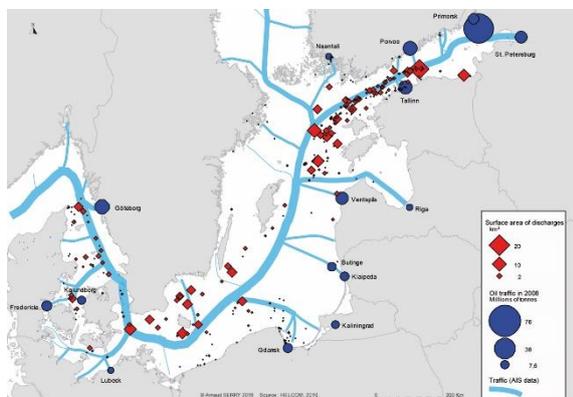


Figure 2. AIS, matching tools between traffic and maritime discharges

This program has the ability to integrate AIS in order to create a link between ships and the discharges identified, for the purpose of criminal prosecution. For example, Lloyds of London has already used AIS data from the AISLive⁶ service in legal proceedings involving accidents of ships.

⁶ <http://www.aislive.com/>

AIS is expected to become an important element in the fight against marine pollution caused by ocean traffic, all the more so as, together with satellite and aircraft detection techniques, AIS coverage is growing both along the shoreline and out at sea, thus making it possible to reduce the ability of ships to unlawfully discharge hydrocarbons at sea.

3.2. Some Problems and Limits

“If the advantages of the new technologies are undeniable, as long as these advances form part of economic and social life, they run up against the risk of violations of privacy and individual liberties” (Deboosere, Dessouroux, 2012).

3.2.1. Technical Limits

Merchant ships of under 300 tonnages are exempt from the system which limits AIS’s capacity with regard to maritime surveillance. The great drawback at present is linked to the fact that the majority of small ships are not equipped and can therefore not be detected nor detect other boats using this system. Nor does the system enable them to detect fishing net buoys and any other unusual floating object (Dujardin, 2004).

AIS is considered to be the best system of detection currently used in all ports worldwide, but it does not make it possible to detect every ship (Zouaoui-Elloumi, 2012). As a matter of fact, AIS reliability is far from perfect. The captain can cut off the system. There is no provision for duplication of equipment. It can break down or be defective, providing false indications. VHF links can deteriorate in certain conditions and, according to the position and altitude of the transmitting antenna on the ship and the 20 nautical miles of depth, equipment might not be covered. Information relative to the voyage on the nature of the cargo and the ports of departure and destination is entered manually on board. It could be erroneous, voluntarily or not. The majority of errors detected is essentially a result of omission (Harati-Mokhtari, Wall, Brooks and Wan, 2007).

Then, a much debated issue concerns the use of AIS for the purpose of radio communications between ships to agree on maneuvers in order to avoid a collision. AIS will not change ARPA's status of being the principal tool used to assist the navigator in collision avoidance maneuvers, not only because all ships will not be equipped with AIS, but also because of the system's limitations. AIS and ARPA are in fact complementary and should be used in conjunction with one another, even if AIS provides more complete information than shipboard radars. Besides, reception of AIS signals via satellite is affected by interference from certain phenomena that do not exist or whose effect is limited when the reception is on ground level, like a higher noise level or collisions between AIS signals. The most effective way to avoid these "slot collisions" is to reduce AIS congestion. This is not possible on the existing AIS channels, given the ever-increasing number of AIS users, but could be accomplished if other channels were used for this new message.

Lastly, the system is potentially vulnerable to more sophisticated attacks:

- The system is vulnerable to intentional or unintentional interference because the technical characteristics are public (Dujardin, 2004), notably in high-traffic areas;
- Intentional broadcast of erroneous information (fictitious ships, duplication with real ships);
- Transmission of computer viruses (AIS is managed by a mini computer).

The situation of a maritime area can therefore not be controlled exhaustively with AIS. As a matter of fact, AIS must be integrated in E-Navigation. Furthermore, one of the principal concerns is "consistency between the principle of freedom of movement on the seas with respect for a framework of increasingly regulated activity" (Terrassier, 2004). In effect, the high seas are often defined as a marine area which, in principle, eludes any sovereignty. Surveillance of maritime traffic in real-time seems to partially challenge this age-old freedom of navigation.

3.2.2. AIS and Piracy

Maritime piracy is not a new phenomenon but, faced with an increase in it, especially in the Gulf of Aden, we are entitled to question the apparent inability of the multinational marine force to fight effectively against these pirates. In effect, these sea bandits do not appear to encounter any difficulties in detecting their potential targets.

The existence of a vast network of information in the principal ports of the Middle East and East Africa is a proven fact (Auzon, 2013). At the same time, the system is increasingly frequently used by modern-day pirates (Salim Chebli, 2009), in order to locate their potential targets. All these data are in fact available, of course, to all the officially authorized listening services but to anybody else as well. In its current form, the system does not allow the possibility to choose the direction and transponder to which the AIS information is sent. This simplifies the pirates' work and suggests that they have command of these technologies. Besides, certain groups of pirates make a considerable profit which allows them to invest money, most notably in better technological systems and training. (Dumouchel, 2009). The mother ships are consequently equipped with the latest technology in the field of detecting in space which enables them to target and organize an attack with great accuracy by taking a targeted ship by surprise and dispatching speed boats which are sometimes undetectable.

Another, simpler, solution exists, that of an autonomous terminal, marketed freely and designed for amateur yachtsmen. For a few hundred euros, any potential pirate can see, on his screen, any ships within a radius of twenty or so miles around his position. All that is needed is for pirates to be in the right position to cover the usual itineraries of maritime traffic and choose their prey according to the name of the ship, its cargo or its destination.

Furthermore, the AIS system can also be used to broadcast false information that can be fabricated with relative ease. The aim of these misleading messages

(distress signal, wrong locality of the ship, etc.) is essentially to attract attention and lead the ships targeted into a trap.

Prevention remains a key element in the fight against maritime piracy (Salim Chebli, 2009). Yet, even when navigating without lights, ships remain detectable through their VHF transmissions linked to AIS. In this case, the solution is to deactivate the AIS system of vessels entering at-risk areas such as the Gulf of Aden which are often also areas of heavy traffic in which recourse to AIS is primordial in order to reduce risks of collision.

3.2.3. Socio-Economic Activities and Consequences

Owing to its rapid development, AIS is a fantastic tracking tool. Together with information agencies, ship-owners were the first to take possession of it: it enables them to track their fleet from land and ensure that the logistics are optimum. If the data are free of charge as regards observation of AIS positions in real-time, this has no legal force especially for accessing archived databases. Recordings of arrival and departure are also provided by the Lloyd's Register Fairplay for commercial purposes in the framework of their Sea-web database⁷ (Kaluza, Kölzsch, Gastner, Blasius, 2010). These big groups provide AIS information on a global scale but access to it is fee-based and relatively costly. For example, the Lloyd's List possesses the world's largest network of AIS receivers.

Furthermore, open AIS information creates fears of commercial espionage. Maritime companies and shippers in fact wish to remain as discreet as possible regarding commercial data and information. Imparting information other than the automatic transmission of certain data such as the ship's destination or its ETA⁸ makes them fear the risk of commercial espionage.

⁷ www.sea-web.com

⁸ ETA denotes Estimated Time of Arrival, a term often used by freight and express parcel delivery companies. By convention, the ETA is given in the recipient's local time.

Lastly, if tracking of a fishing fleet is initially ensured by the system of coverage via satellite, the Vessel Monitoring System, which monitors the entirety of activity of European shipping boats of over 12 meters, within the scope of the joint management of resources, the AIS system can be used for this activity. Its usefulness has already been recognized in areas where commercial traffic and fishing activities are considerable, even if fishermen do not appreciate having their positions made public and are sometimes reluctant to fit the equipment.

4. AIS AND SCIENTIFIC RESEARCH

The data obtained from AIS systems, in fact, constitute a new wealth of information not only for the maritime community and the wider public but for research scientists as well. They comprise a potential source of information on maritime traffic, essentially commercial traffic. Consequently, broadcasting it in real-time makes a real contribution especially to the scientific community.

4.1. A Recent Source with as yet Restricted Use

The state of the art, essentially founded on Francophone literature, brings to the fore works based principally on the subject of security (Fournier, 2012) or on the frequentation of specific, mainly coastal spaces (Bay of Brest, marine coastal areas and insular areas). Moreover, the analysis of works, reports, academic and research studies confirm the relative scarcity of works in Human Sciences and highlights a fragmented literature which approaches subjects like international maritime law, physics, signal processing, geopolitics and many others (Fournier, 2012).

As for the far more extensive literature in English, it is a relatively different situation. More research has been done on AIS on different spatial scales both global (Shelmerdine, 2015), regional (Cairns, 2005) and local (Perkovic, Gucma, Przywarty, Gucma, Petelin, Vidmar, 2012).

As appears in studies done by Richard L. Shelmerdine (Shelmerdine, 2015), the research focuses on surveillance of itineraries taken by maritime transport and the intensity of shipping traffic (Eriksen, Høye, Narheim, Meland, 2006), the prevention of maritime accidents and the detection of unusual situations (Kao, Lee, Chang and Ko, 2007) and on the environmental impacts of maritime traffic (Jalkanen, Johansson, Kukkonen, 2013).

So, the Eastern Research Group (ERG) used a Geographic Information System (GIS) to map and analyze both individual vessel movements and general traffic patterns on inland waterways and within 9 miles of the Texas coastline. ERG then linked the vessel tracking data to individual vessel characteristics from Lloyd's Register of Ships, American Bureau of Shipping, and Bureau Veritas to match vessels to fuel and engine data, which were then applied to the latest emission factors to quantify criteria and hazardous air pollutant emissions from these vessels. The use of AIS data provides the opportunity for highly refined vessel movement and improved emissions estimation, however, such a novel and detailed data set also provides singular challenges in data management, analysis, and gap filling, which are examined in depth in this paper along with potential methods for addressing limitations (Perez, 2009).

Some researchers also use AIS to study ships compartments due to meteorological circumstances. For instance, the Baltic Sea is a seasonally ice-covered sea located in a densely populated area in northern Europe. Severe sea ice conditions have the potential to hinder the intense ship traffic considerably. Thus, sea ice fore- and nowcasts are regularly provided by the national weather services. In their study, Löptien and Axell provide an approach by comparing the ship speeds, obtained by the AIS, with the respective forecasted ice conditions. They find that, despite an unavoidable random component, this information is useful to constrain and rate fore and nowcasts. More precisely, 62–67% of ship speed variations can be explained by the forecasted ice properties

when fitting a mixed-effect model (Löptien, Axell, 2014).

The website Marine Traffic ⁹ is a very good example of the dissemination of information. It provides information, partially free of charge and in real-time, on the movement of ships in an almost global area of coverage (Thery, 2012). It is part of an academic project whose objective is to gather and disseminate these data with a view to exploiting them in various domains. This is an open project and the organizers are constantly looking for partners prepared to share data from their region so that they can cover more maritime areas and ports worldwide. Marine Traffic has disclosed it has no less than 5 million monthly users. Everyone can explore at leisure each of the areas for which the information is available. This exploration is made all the more interesting in areas where traffic is concentrated like in the English Channel (Cf. figure 3), the most frequented maritime route in the world. The Marine Traffic website shows a spectacular image of it. For example, Marine Traffic places 44 500 vessels of all types on the globe and 650 ships in the central Channel simultaneously, at time t (Cf. figure 3).

Beyond showing maritime itineraries, Marine Traffic also provides the means by which to observe the movement of vessels in ports, provided that they are equipped with AIS stations.

⁹ <http://www.marinetraffic.com>

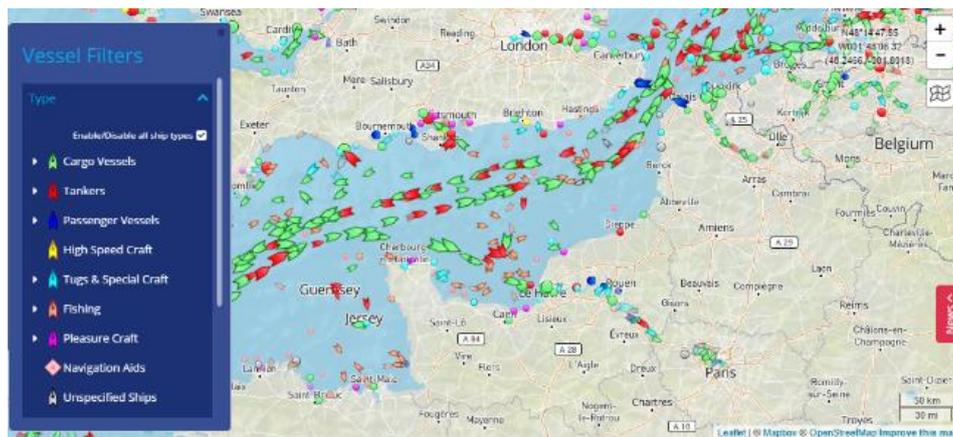


Figure 3. Ships in the English Channel according to the Marine Traffic website (2 March 2017 / 09.35)

Source : <http://www.marinetraffic.com>

The AIS system being an open one, it has given rise to sites other than Marine Traffic like the British site ShipAIS. The sites broadcasting AIS information, therefore, have a great advantage, that of making it possible to visualize maritime traffic in real-time free of charge. In terms of research, the interest of these sites of visualization of AIS data is certainly more important than making archived databases available but it makes it possible namely to compare the reality of marine traffic with the rhetoric coming from shipping companies by checking, for example, the vessels operating on regular lines. By linking this information with a shipping database, it is additionally possible to determine the capacities offered by these same maritime lines.

4.2. Plainly Stated Potential

A greater use of AIS data is made possible thanks to the development of a network of stations covering more and more coastal areas, providing new possibilities to the mapping of transport activity. "Several studies carried out at the Institut de recherche de l'école navale (IRENAV) are based on the exploitation of AIS data with the aim of detecting unusual situations (risks of collision) and of qualifying the behaviour of vessels in real time. Thanks to the availability of AIS data, it is possible to

identify, quantify and map navigation lanes of vessels" (Le Guyader, Brosset, Gourmelon, 2011). The method, founded on a spatial analysis within a geographical information system (GIS) combined with a database server, makes it possible to reconstruct each vessel's trajectory in such a way as to identify the navigation lanes then to match the daily traffic in its temporal and quantitative dimensions. It is therefore possible to complete the maritime transport map which has been traditionally directed towards analyzing maritime networks and flows globally, towards recording the departure and arrival ports or analyzing the spatial influence of maritime transport. "In a global approach to running maritime activities, this information can be analyzed with other information describing the operation of nautical and fishing activities, in order to characterize their interaction and bring to light potential conflicts. In the medium term, applying maritime traffic tracking systems to the entirety of activities involving different types of vessels, as intended in the framework of E-Navigation, will no doubt represent a precious data source as an aid for navigation in real-time, fishing management and contribute to the integrated management of the sea and coast" (Le Guyader, Brosset, Gourmelon, 2011).

Furthermore, the Envisia device is an illustration of the relevance of AIS data.

Created by the CETMEF (Centre d'études techniques maritimes et fluviales) at the initiative of the French State, it is a gathering and archiving system for a whole series of data, including AIS data, supplied by computer servers and coastal facilities (Guichoux et al., 2011). This system is already in use for identifying areas of high traffic density and therefore improving assessment of the risks linked to marine traffic, identifying coastal areas that can be developed or measuring the pressure of human activities on the marine environment.

The use of AIS is based on a multi-scaled character; spatial scales (local/global) and temporal (short term/long term) of the information produced by AIS signals linked to other bases. This makes operating functions possible in a variety of areas. A potential application of archived AIS data, therefore, consists in extracting statistics of the voyage time for a population of ships (Mitchell et al, 2014).

The availability of a reliable and consistent data source has proved difficult in order to make it possible to build a picture of flows of exchange in the short, medium and long terms, at both regional and global scales. Maritime companies' schedules are very heterogeneous and subject to the above-mentioned vagaries, and movements recorded by the port authorities' harbor master's offices are very difficult to gather without considerable means. The availability of archived AIS data opens interesting perspectives for the characterization of maritime activities on spatial, temporal and quantitative levels. There is great potential of AIS to contribute to scientific research: analysis of the maritime itineraries taken by vessels, estimation of vessel discharges, identification of port calls and duration, analysis of maritime companies' strategies, mapping vessel flows, analysis of interactions with the vessel's environmental elements such as climatic conditions, state of the sea or density of traffic.

The automatic character of transmitting vessel positioning signals and the generalization of this to all ships of over 300 tonnage provides an opportunity to

track and analyze the vessels' itineraries. Once this source of information has been properly checked through matching it with external data with regard to vessels and ports, it opens the way to reasoning on a global scale as well as on the scale of port approaches, in real-time as well as long term. With regard to scientific research, it represents, for example, the possibility to test traffic models, be they predictive or dynamic, long or short term, which could also be of interest to port authorities. As for the professional world of shippers and logistics providers, it represents the possibility of better apprehending the vagaries of maritime transport which, by comparison with terrestrial logistics, is often seen as a "black box". It is also the opportunity to equip themselves with tools for evaluating the positioning of ports in a global network of port calls so as to direct their local logistics arrangements according to the partner countries.

4.3. CIRMAR: A Research Platform Using AIS Data

Geo-economic entry in the use of AIS signals request a number of methodological and technical issues. Some related to the duration of observation which must be long enough to account for seasonal trends, others related to the geographic scope, which must be comprehensive if you want to account for the economic gap between different regions of the globe. All this requires the accumulation of large masses of data. Arises also the question of the intrinsic quality of the data transmitted by the AIS signals.

The CIRMAR device is based on affiliation to a collaborative network. It allows to develop and test processing of analysis tools and representation of the data.

Nowadays, the amount of data in our world is exploding and analyzing large data collections – so called big data – is unavoidable and has tremendous benefits. In maritime-related fields, the AIS messages could be considered as big data due to the huge amount of data transmitted every day. Therefore, a proper platform is

needed to receive, decode, clean, store and analyze AIS messages.

Our project is made of some different phases. During the first phase, AIS messages are received by an antenna which is installed at University of Le Havre. The received messages of each day are stored in a file with a proper file name that shows the arrival date of messages. We also use the messages stored on AISHub which are from all around of the world. As the received messages are coded, a Java application using an open source library decodes the messages and make them ready to be stored. We ignore messages which includes errors like checksum error. For this project, only AIS message types 1, 2, 3, 4, 5, 18 and 19 are interesting, so we ignore the other ones. The next step is to store AIS messages in the database.

For this project, we have collected the AIS messages from the second half of 2015 and we have many files which are larger than 2GB, each of them including more than 10000000 AIS messages. This is why we consider it as the big data. We developed an application which reads the collected files and stores decoded AIS messages in our MongoDB database. The MongoDB is a kind of NoSQL databases which is suitable for big data application. In addition, we have also made a web-based user interface using Ruby on Rails web framework to let geographers and other people from logistics and related fields access and work with the stored data. In the future, we will add some other big data technologies to facilitate working with the data and provide analyzing tools.

Speaking about data treatment, the two major obstacles to produce information for geo-economic issues are the amount of data to process the quality of data and particularly static data. Even if they are of small size (39 characters for example) the number of AIS messages received, led to the formation of large amounts of data. A relevant analysis of marine traffic must also consider to the best of the seasonality of flows (Peak season, Chinese new year) and at least the duration of the transit times for the longest roads. The volume of data

to decode and then analyze is therefore considerable.

Regarding data quality, most of the problems relate to information that are populated on each trip by an operator on the ship. They concern the reference to the port of destination, the navigation status, the draught of the ship and ETA (estimated time of arrival). Positioning and road information transmitted automatically, entering the static information in the transponder is a subsidiary operation compared to other more crucial operations for navigation, especially during the approach or departure from the port.

So, use of aggregated material from AIS messages to analyze maritime trade flows must be based preferably on dynamic data (positioning and road), which are more reliable than the static ones. That information must be validated by external data: therefore, we use a database of ships via the MMSI number and a referenced geo database on ports (Lévêque, 2016).

So, during the treatment, the first step is to decode all the messages. The amount of data to process may require to allocate treatment on several sessions and machines to avoid excessive wait times. The results serve as a base for different types of analyses: port performance analysis (duration of call and ship size...), shipping companies' strategies, maritime network study, regional markets analysis.

5. ADRIATIC SEA CASE STUDY

At the time when Central Europe becomes more closely integrated into international commerce, new markets take shape for the ports of the Adriatic Sea. Though still with modest tonnage levels compared to their counterparts in the North Sea and the Western Mediterranean, these ports, given European perspectives and recent dynamism tied to new ambitions. The Adriatic Sea becomes more transport-intense.

AIS data allows different geographical approaches. In the case of the Adriatic Region, we can develop some examples of treatment and uses (Note that this work is

in progress and therefore still incomplete results).

Thanks to the AIS data and in relationship with external databases, we determined all container ships that called at a BSR port between January 1st 2016 and December 31th 2016. We kept the first 10 ports by their container traffic to refine the analysis.



Figure 4. Container traffic of Adriatic Sea Ports in 2015

At first, we can use AIS data not only to obtain quite generic information like the number of port calls in a certain period and/or a specific area (Figure 2) but also the number of operators involved in maritime transportation. It is also interesting to focus on ships to monitor maritime roads, their adaptations to weather or economic imperatives. In the figure 5, we can observe a difference between the north and the South of the Adriatic Sea. For example, we observed the presence of 44 operators in the port of Venice and it represented 18% of port of calls. On the contrary, the Port in the South of the Adriatic Sea had less than 10 operators and represented less 4% of ports of calls. This observation is related to the economic dynamism of the area.

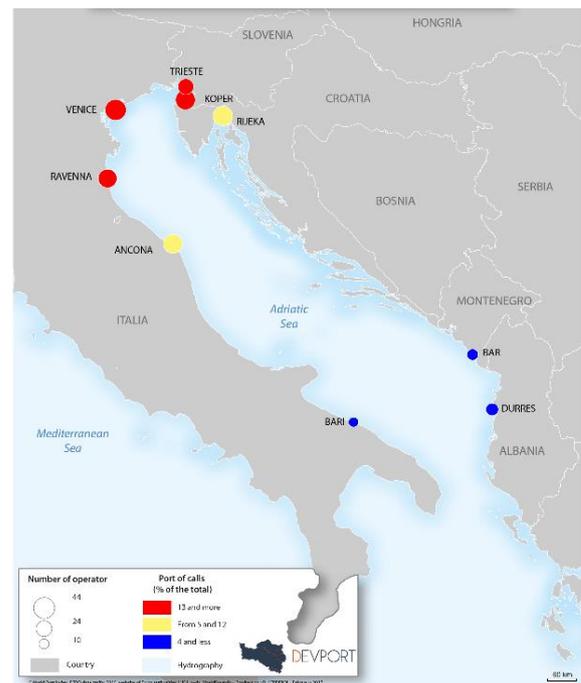


Figure 5. Container ships' port calls and operators from January 1st 2016 to December 31th 2016

According to our data, we can establish that in the studied period, 68 different operators have provided containerized services to ports. From our geo-economic point of view, we can go further in analyzing operators, their strategies or their networks. Indeed, the choice of companies, their presence (or not) in ports are good indicators for understanding the functioning of the port system and to evaluate its potential.

So some companies like Joy Marine have quite local strategies with ships calling only in Bari when others like MSC propose services to almost all the ports. In addition, it is also possible to determine the capacity offered by each company in each port. For instance, during the period of the study, Maersk Line offered a capacity of 518 011 TEU in the port of Koper and 527878 in Rijeka but only 4740 TEU in Venice. It is an interesting way to focus on the three different types of actors present in the region: some major ones in the feeder field like Sea Consortium, some global carriers (MSC or CMA-CGM) and regional ones (Tarros SpA, Bia Shipping...). Furthermore,

the mapping of maritime lines' networks is another opportunity offered when data on flows are available: we can map the real network of services proposed by each operator in the Adriatic Sea. It clearly indicates that companies have different strategies: global carriers concentrate their flows on some ports like Koper which apparently has a regional hub when companies specialized in feeder services have a more decentralized network (Figure 6).

For example, we mapped the capacity offered by COSCO in 2016. It is concentrated in the North of the Adriatic Sea principally in the ports of Koper, Trieste, Venice and Rijeka. COSCO uses the ports of Piraeus and Ayios Nikolaos (Greece) like a hub as it is the owner of these ports. Afterward, it transfers the goods to the Adriatic Sea. The behavior of COSCO matches with analyzes on the precedent map and a concentration of the calls is on the ports of the North of Adriatic Sea.



Figure 6. Sea Consortium capacity offered by COSCO from January 1st 2016 to December 31th 2016

Nodaway, the question of port competitiveness is crucial for port authorities and operators. It especially includes port operation efficiency level, handling charges, reliability or landside accessibility. Regarding the Adriatic Sea ports, we can analyze operation efficiency using the duration of port calls given by AIS data. The results must be apprehended with caution, do not hesitate to remove data that appear abnormal. For instance, discarding prolonged stops (one week or more), dedicated to the maintenance of ships. The critical examination of results is imperative, especially if one wants to start in evaluating port performance (Lévêque, 2016).

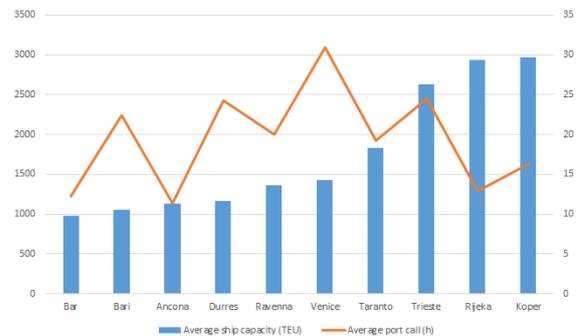


Figure 7. Comparison of container ships' capacity and duration of port call in Adriatic Sea ports

Adriatic container ports appear very different (Figure 7): three ports in particular, Koper, Rijeka and Trieste, are served by ships offering a bigger capacity than in the other ports. Combining this analyses to operator's strategies is also interesting.

By integrating the port traffic in the research process, it is possible to estimate the average length of handling of a TEU in each port. In that case study, container traffic has been weighted by the share of traffic RoRo but it should be borne in mind that these are estimations and that finer port statistics would be required to obtain a more accurate result.

It appears that container terminal efficiency is very variable in the Adriatic ports (Table XX): in the ports of Koper or Bar, it takes four times less time than in Rijeka to

operate one TEU. The less efficient port seems to be the Italian port of Bari. It is also possible to compare the Adriatic situation to other regional cases. It clearly shows that handling speed in the Adriatic is quite slow. Average operational speed is 2.17 min per TEU when it is 1.56 in the Baltic sea in the same period. Of course, such analysis could be refined with the number of cranes in each terminal for instance.

Table 1. Results of AIS data exploitation for some Adriatic ports

Ports	Number of Calls	Average TEU's per call	Average speed per TEU (minute)
Ancona	463	385.5	1.78
Bar	42	933.0	0.79
Bari	144	249.5	5.40
Durres	165	630.7	2.31
Koper	683	1157.7	0.84
Ravenna	567	431.8	2.79
Rijeka	361	554.3	3.75
Trieste	605	836.4	1.76
Venice	686	816.8	2.27

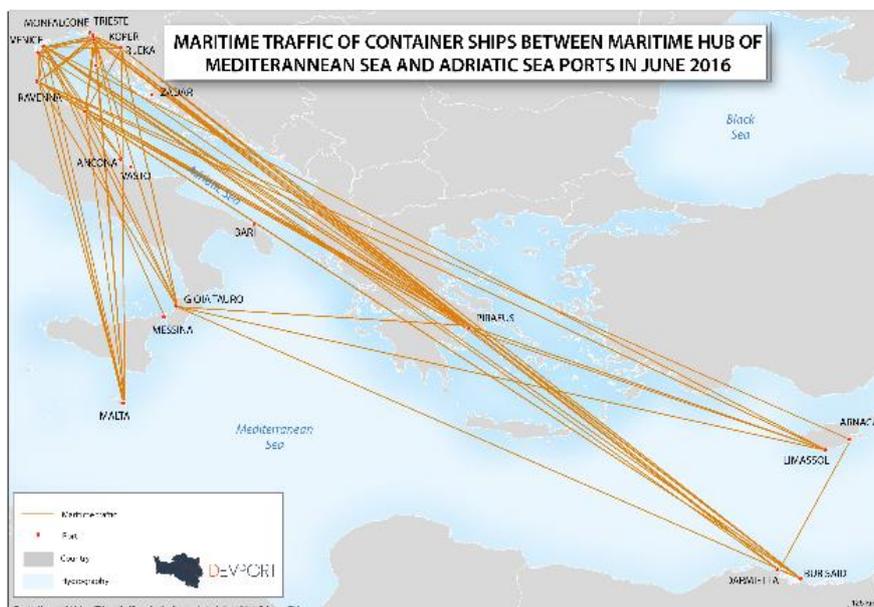
As explained, we are connected on the AIS HUB system and we record data all around the world. The following analyzes use these data and are based on the month of June 2016. To make the studies reliable, it is needed to cover at least 3 months

corresponding at a complete rotation. So, some results would change. As the project has started recently and is in its first phase, we are trying some possibility analysis and this part should be considered as exploratory. We extracted data of calls in the Adriatic Sea Ports and maritime hub of the eastern part of the Mediterranean Sea only if the containers ships came or went to the Adriatic Sea.

During June 2016, we recorded 168 containers ships in this area among which 106 are staying in the Adriatic Sea and 62 offered a connection with a hub of the Mediterranean Sea. The results are evaluated during a 3-month long study to be reliable. Indeed, some ships which were recorded only in the Adriatic Sea might be moved to a hub. Logically, the capacity in TEU is bigger for the ships connected with the hub (2751 TEU against 577 TEU for the ships intra-Adriatic Sea).

We can detail the results analyzing the strategies of the maritime operators. Indeed, the most present is MSC with 23 ships whose 17 with a call in a hub. MSC uses Gioia Tauro (Italy), Piraeus and Ayios Nikolaos (Greece) and Limassol (Cyprus) as its hubs. Maersk and COSCO are very present in the area with respectively 6 and 8 ships. COSCO being the owner of the Ports of Piraeus and Ayios Nikolaos uses this one exclusively as hub. Maersk ships are calling in the hubs of Bur Said (Egypt)

Figure 8. Maritime traffic of container ships between maritime hub of Mediterranean



and Gioia-Tauro (Italy) but mainly in direct with the largest containers ships. The third world ships operator, CMA CGM, is not very present in the area with only 2 ships record during the same period. CMA CGM is in the alliance "Ocean Alliance" with Sea and Adriatic Sea ports in June 2016.

COSCO, enabling it to use the Hubs in Greece and feeder of COSCO to deserve ports of the Adriatic Sea. In general, the most important hub is the port of Piraeus and Ayios Nikolaos with 32 ship stopovers.

During this month, we recorded 110 operators of containers ships. When we group them by nationality, we can observe an important presence of some countries. On the table below, we can observe 21 Turkish operators, 18 of Netherlands and 18 of Germany. Turkish and Dutch operators proposed a service intra-Adriatic. For German operators, it was balanced (9 operators offered a maritime connection with a hub and 9 was only intra-Adriatic). Analyzing the capacity in TEU proposed by nationality, it's logically the Switzerland with the presence of MSC and a total capacity of 2 million.

Table 2. Nationality of containers ships operators in June 2016

Country	HUB	INTRA	TOTAL	
	Number operators	Number operators	TEU sum	Number operators
Albania		1	416	1
Azerbaijan		1	450	1
Bulgaria		2	1 061	2
China	2	1	352 941	3
Cyprus	1		7 242	1
Denmark	1		918 758	1
Egypt	2	1	6 708	3
France	1		861 583	1
Germany	9	9	336 082	18
Greece	1	1	1 955	2
India		1	6 336	1
Israel		1	12 681	1
Italy	2	2	16 929	4
Lebanon	1	2	16 539	3
Lithuania	1		6 690	1
Marshall Islands	2	1	8 765	3
Morocco	1		5 634	1
Netherlands	5	13	57 310	18
Norway		3	10 381	3
Romania		2	2 038	2
Roumania	1		10 108	1
Russia		4	2 268	4
Switzerland	2		2 107 513	2
Taiwan	1		110 008	1
Turkey	5	16	92 610	21
Ukraine	1	4	14 289	5
United Arab Emirates	1	1	417 751	2
United Kingdom	2	1	51 117	3
USA	1		2 016	1
TOTAL	43	67	5 438 179	110

So, the Adriatic Sea case study shows some possibilities of using AIS in the field of geo-economic research.

6. CONCLUSION

Satellite Automatic Identification System (AIS) has quickly become an operational tool exploited by a large number of actors. In fact, it provides precious information, not only to crews but also to terrestrial

regulatory authorities, not forgetting individuals and research scientists. On-board security and safety for ships at sea are topical subjects owing to the growing number of acts of piracy. Among the tracking tools that exist for maritime traffic, AIS supplies information but does not reinforce ships' safety. On the contrary, it sometimes even appears that it is used by the very pirates themselves. In fact, the cause of the system's greatest defect comes from one of its main assets: the data are originally free of charge, free to use and thus difficult to monitor.

AIS technology has fundamentally changed the landscape for monitoring the maritime domain. Improving upon existing AIS technology already deployed aboard all large vessels and many smaller vessels around the globe, satellite AIS is truly revolutionary in providing a complete and global picture of the world's maritime shipping environment (Kocak & Browning, 2015).

The possibilities for exploiting information from AIS signals gives this device a character of global information. It is in fact:

- Multi-scaled, temporal and spatial,
- Multi-purpose: an aid to navigation, tracking of global economic flows, analysis of the behavior of economic players, behavior of sailors, interaction with the environment, etc.
- Multi-use: management of maritime lines, of traffic, of port calls, construction of indicators of reliability, performance, impacts on logistics chains, etc.
- Wealth of opportunity for theoretical developments in a large number of disciplines since it is, together with its air traffic counterpart, the only source of continuous tracking of moving objects on a planetary scale.

This enormous potential is being exploited within the CIRMAR project which aims to set up a platform to integrate the data and for application development founded on the use of AIS signals. This poses scientific challenges and results in the requirement of an interdisciplinary approach. First of all, to construct the platform for the acquisition of processing and availability of useable data according to the various ultimate aims

and uses. The scientific validating of AIS data involves the implementation of new tools in close relation to computer processing specialists. At the same time, it is necessary to apprehend as widely as possible the different types of exploitation that will be required for this platform and consequently, collaboration is indispensable with all the different disciplines and professions concerned: geography, economics, statistics, engineering sciences, logistics providers, seagoing personnel, etc. It is preferable that this collaboration be done at the earliest possible stage so as to determine specifications for each development envisaged as this will help to improve the services provided by the platform. Lastly, even if the results are immediately available, this is also a project built on the medium to long term together with archiving the data.

REFERENCES

AUZON OLIVIER (2013), La piraterie maritime est en baisse mais il ne faut pas baisser la garde, Diploweb, mars2013, <http://www.diploweb.com/La-piraterie-maritime-est-en.html>.

BEYER ANTOINE, SEVIN JEAN-CLAUDE (2008), Les ports-frontières de Trieste, Koper et Rijeka, futurs débouchés pour les conteneurs d'Europe centrale

CAIRNS WILLIAM R. (2005), AIS and Long Range Identification & Tracking, *Journal of Navigation*, 58, pp 181-189

CHEN YULI (2013), Will Satellite-based AIS Supersede LRIT? », *Marine Navigation and Safety of Sea Transportation: Advances in Marine Navigation*, CRC Press, pp. 91-94.

DEBOOSERE PATRICK, DESSOUROUX CHRISTIAN, 2012, « Le contrôle de l'espace et de ses usage(s) : avancées technologiques et défis sociaux », *Espace populations sociétés*, 2012/3, pp. 3-11.

DEVOGELE THOMAS (2009), *Système d'information géographique temporelle maritime: des distances linéaires à l'analyse temps réels des trajectoires*,

Université de Brest, Habilitation à diriger des recherches de Géomatique.

DUJARDIN BERNARD (2004), L'AIS et ses capacités de surveillance maritime, La revue maritime, n°467.

DUMOUCHEL ANNE-CLAIRE (2009), Les atteintes à la sûreté en haute mer, Mémoire de Master recherche en relations internationales, Université Panthéon-Assas-Paris II.

ERIKSEN TORKILD, HØYE GUDRUN, NARHEIM BJORN, MELAND BENTE JENSLØKKEN (2006), Maritime traffic monitoring using a space-based AIS receiver, *Acta Astronaut*, 58:5, pp. 37–49.

FAYE FRANCIS (2005), Une stratégie navale pour le XXI^e siècle La maîtrise de l'information sur mer, La Revue Maritime, 471, pp. 116-125.

FOURNIER MELANIE (2012), L'apport de l'imagerie satellitale à la surveillance maritime: contribution géographique et géopolitique, thèse de doctorat, Université de Montpellier 3.

GUICHOUX YANN & AL. (2011), ENVISIA – A scalable archiving system for AIS data storage, Global sharing of Maritime Data-IALA workshop 12-16 September, 2011.

HARATI-MOKHTARI ABBAS, WALL ALLAN, BROOKS PHILIP & WANG JIN (2007), Automatic Identification System (AIS): Data Reliability and Human Error Implications, *Journal of Navigation*, 60, pp. 373-389.

KALUZA PABLO, KÖLZSCH ANDRE, GASTNER MICHAEL T., BLASIUS BERND (2010), The complex network of global cargo ship movements, *Journal of the Royal Society Interface*, vol.7, No.48, 1093.

KOCAK D. M. & BROWNING P. (2015), Real-time AIS tracking from space expands opportunities for global ocean observing and maritime domain awareness, OCEANS 2015 - MTS/IEEE, Washington.

LE GUYADER DAMIEN, BROSSET DAVID, GOURMELON FRANÇOISE (2011), Exploitation de données AIS (Automatic Identification System) pour la cartographie du transport maritime, *Mappemonde*, N°104.

LÖPTIEN U. & AXELL L (2014), Ice and AIS: ship speed data and sea ice forecasts

in the Baltic Sea, *The Cryosphere*, 8, pp. 2409-2418.

MAIMUN Adi & AI (2013), Estimation and Distribution of Exhaust Ship Emission from Marine Traffic in the Straits of Malacca and Singapore using Automatic Identification System (AIS) Data, *Jurnal Mekanikal* n°86, pp. 86-10.

MITCHELL KENNETH NED & AL (2014), Waterway Performance Monitoring via Automatic Identification System (AIS) Data, Transportation Research Board (TRB) 93rd Annual Meeting, Chicago, 12-16 janvier 2014.

PEREZ HEATHER M. (2009), Automatic Identification Systems (AIS) Data Use in Marine Vessel Emission Estimation, 18th Annual International Emissions Inventory Conference, Baltimore, <https://www3.epa.gov/ttnchie1/conference/ei18/session6/perez.pdf>

PERKOVIC MARKO, GUCMA LUCJAN, PRZYWARTY MARCIN, GUCMA MACIEJ, PETELIN STOJAN, VIDMAR PETER (2012), Nautical risk assessment for LNG operations at the Port of Koper, *Strojniski Vestnik-J Mech Eng*, 58, pp. 607-613.

PREVOST RAOUL (2012), Décodage et localisation AIS par satellite, thèse de doctorat, Université de Toulouse.

SALIM CHEBLI ANTOINE (2009), La piraterie maritime au début du XXI^e siècle, Mémoire pour le diplôme d'Université de 3^eme cycle, Université Paris II.

SCHWEHR KURT, MC GILLIVARY PETER (2007), Marine Ship Automatic Identification System (AIS) for Enhanced Coastal Security Capabilities: An Oil Spill Tracking Application, Oceans07 MTS/IEEE, Vancouver.

SERRY ARNAUD (2013), Le transport maritime en mer Baltique, entre enjeu économique majeur et approche durable, *Revue d'études comparatives Est-Ouest*, n°44, 2013, pp. 89-123.

SHELMERDINE RICHARD L. (2015), Teasing out the detail: How our understanding of marine AIS data can better inform industries, developments, and planning, *Marine Policy*, vol.54, pp. 17–25.

ŚWIERCZYŃSKI S., CZAPLEWSKI K. (2013), The Automatic Identification System operating jointly with radar as the aid to navigation, *Zeszyty Naukowe Akademia Morska w Szczecinie*, 36, pp. 156-161.

TERRASSIER NICOLAS (2004), Les évolutions en matière de sécurité et de sureté dans le transport maritime : réglementation et enjeux économiques, ISEMAR.

THERY HERVE (2012), Marine Traffic Project, un outil d'observation des routes et des ports maritimes, *Mappemonde*, 104, <http://mappemonde.mgm.fr/num32/internet/int11401.html>.

VANDECASTEELE ARNAUD, NAPOLI ALDO (2011), La place du géodécisionnel dans les systèmes de surveillance maritime de nouvelle génération : Apport du géodécisionnel dans la surveillance maritime, SAGEO International Conference on Spatial Analysis and GEOmatics, Conférence internationale de Géomatique et d'Analyse, 3-8 juillet 2011, Paris.

ZOUAOUI-ELLOUMI SALMA (2012), Reconnaissance de comportements de navires dans une zone portuaire sensible par approches probabiliste et événementielle : Application au Grand Port Maritime de Marseille, thèse de doctorat, École Nationale Supérieure des Mines de Paris.