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Data acquisition differences between two AIS receiving antennas

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Abstract: Raw AIS messages are key to interpret the validity of AIS messages used in science for maritime spatial planning purposes. The Barcelona School of Nautical Studies has hosted two AIS antennas, storing raw messages systematically since 2019. Surprisingly, the number of received messages differs from one antenna to the other one. This manuscript aims at identifying the differences between the messages received by each antenna and the origin of these differences. Raw data from March 2023 is used and compared to meteorological variables in the range of the antennas. The older and worse located antenna seems to provide more and larger-distance messages. Results suggest there is no correlation between meteorological variables and the observed differences between antennas.

Keywords: AIS; maritime spatial planning; signal analysis; vessel traffic services;

1. Introduction

The analysis of spatial use made by merchant vessels has received an increasing attention in the past decades. It was first the IMO who introduced the mandatory regulation for merchant vessels over 300 GT on international voyages and all passenger vessels to have an on-board Class A AIS transceiver in 2002 (International Maritime Organization, 2002). The SOLAS convention of 2002, was agreed by 167 states, which flag 99% of merchant vessels (considering gross tonnage), and the introduction of the AIS transceivers was done under the safety concern. Later on, in 2014 all fishing vessels with Length Over All (LOA) above 15m and operating in the European Inland Waterways were also required to have a Class-A AIS onboard system.

The AIS is a tracking system used by Vessel Traffic Services. Messages are broadcasted primarily on two dedicated VHF channels and can be detected either by terrestrial antennas or using satellite-based receivers. Satellite AIS (S-AIS) solves the main coverage problem of terrestrial AIS (T-AIS) in open sea but, according to (Greidanus et al., 2016), the high-temporal-resolution provided by T-AIS can be lost when transmitting the data to satellites.

Although AIS was originally designed to improve safety in the sea (Silveira et al., 2013), researchers have identified the great capacities it provides to develop Maritime Spatial Planning tools. For instance, Aarsæther & Moan performed sea traffic analysis using AIS data (Aarsæther & Moan, 2007). In the same line, March et al. used S-AIS data to demonstrate how the global pandemic of Covid-19 had an important impact on maritime traffic (March et al., 2021) .Jalkanen et al. developed a method (Ship Traffic Emission Assessment Model, STEAM) to estimate vessel-related pollutant emissions using AIS data as the main dynamic source and Lloyds registry data to obtain engine-related variables (J. P. Jalkanen et al., 2012; J.-P. Jalkanen et al., 2009) . They have later used the STEAM method to model underwater noise (J. P. Jalkanen et al., 2018) and have recently included a module to estimate pollutant discharges to water (J.-P. Jalkanen et al., 2021). Other work used T-AIS to assess new methods on mitigating propeller scouring action (Castells-Sanabra et al., 2020; Llull et al., 2020).O'Hara et al. detail the state of the art of researchers using AIS for assessing the impact of vessel traffic on marine ecosystems (O'Hara et al., 2023) . In particular, McWhinnie et al. propose the use of S-AIS in the Salish Sea to propose specific spatial management policies to reduce impact between vessel activity and a specific species of cetaceans (Southern Resident Killer Whales) (McWhinnie et al., 2021) . Finally, in the field of nautical applications, Wu et al. use AIS historic data as a guidance for autonomous vessels (Xu et al., 2019) .

However, the use of AIS data has yet to be extended to port management, with some incipient work published in the last 2 years. Mujal-Colilles et al. presented an initial work on harbour basin occupancy rates (Mujal-Colilles et al., 2021).Fuentes makes use of AIS data to generate bunkering activity statistics, which usually take place nearby the ports (Fuentes, 2021). Also, using the same technique (Density-Based Spatial Clustering of Applications with Noise, DBSCAN), Lee et al. uster the trajectories generated by T-AIS transceivers in the Port of Busan, South Korea, and its vicinities (Lee et al., 2021) .Steenari et al. follow the same path but uses the DBSCAN to detect mooring sites (Steenari et al., 2022). Also, Mujal-Colilles et al.used raw T-AIS along with the STEAM method to compare the reduction in maritime traffic due to Covid-19 and the correspondent pollutant emissions in the Port of Barcelona and its surroundings (Mujal-Colilles et al., 2022) .

AIS data can be acquired through several world-wide commercial providers, although the data might be preprocessed to avoid duplicates between antennas, eventually with time standardization, and is usually an expensive product. It contains both terrestrial and satellite AIS data with world range coverage. In parallel, raw AIS messages can be recorded using local antennas, which is a much cheaper process but with less coverage (mean range ~50nm; maximum range ~120nm). The processing steps of the raw data provide the user with the detailed knowledge of the data filtering and mining process. However, the installation of the antenna is key to obtain high quality data. The Barcelona School of Nautical Studies (FNB) hosts two AIS terrestrial antennas installed in different locations and heights. This manuscript aims at finding the differences between the two antennas.

2. Methods

The Barcelona School of Nautical Studies has hosted an AIS antenna for the last 10 years. After an update on the recording system, data is hourly stored since September 2019 and is decoded using an open source code (pyAIS.py) and preprocessed following the standards described in (ITU-R, 2014). An acquisition of a new antenna in 2021(AIS2) located in an apparent better position both in plane and vertically, see Figure 1, was originally thought as a renewal of the old antenna. However, previous to the final removal, a comparison study is being carried out in order to see if both antennas are complementary.

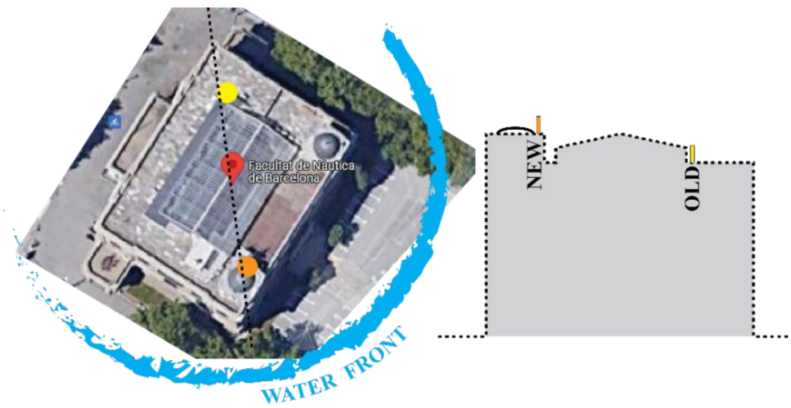

Figure 1. Location of the new and old antenna in plane view (left) and in vertical view (right).

Old AIS antenna is a VHF antenna connected to a SeaTraceR AIS Class B Transponder S.287. The new AIS antenna, provided by IHS-Markit, is a Cardiod Dipole Array Antenna connected to a Comar SLR-350N receiver. The pipeline to decode and run an initial pre-process step is shown in Figure 2. Raw data from the both receiving systems is decoded using a python script to access the specific information contained in each of the messages. Therefore, the information can be manually selected from raw messages based on the fields contained in each message type. AIS broadcasts 27 different messages. The details of the information contained in each message can be found in (ITU-R, 2014). So far, only dynamic messages of type 1-3 and 18, and static messages 5 and 24A&B have to be decoded using 70% of the information contained. For instance, Communication State, RAIM Flag, from messages 1-2-3 and 18 and AIS Version Indicator or Call Sign from messages 5 and 24B are not considered. Once decoded from raw messages, the information is stored in ASCII files ready to be used for detailed analysis, each type of message in a separate file. As an example, one month of data in raw messages is ~1GB . Afterwards, each type of message is filtered following the instructions given in (ITU-R, 2014) for bad data in each field, which represented a total of 2% of the initial data.

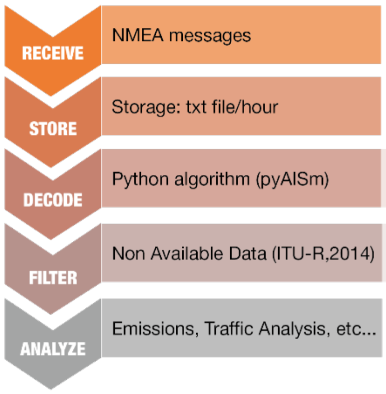

Figure 2. Pipeline for the storage and initial cleaning process of the raw AIS messages

The initial analysis of raw AIS messages led to a key parameter that is normally granted by researchers using non-raw AIS data: the time stamp. According to the (ITU-R, 2014) dynamic messages only contain the second in which the message was broadcasted by the AIS vessel antenna. The entire UTC time stamp is sent through messages 4 with a frequency of 4 minutes. The coordination between dynamic messages (with a broadcasting frequency ranging from 2 seconds to 3 minutes) complicates the merging of the time-stamp. This problem was solved by including four digits at the end of each NMEA message, including the raspberry local minute and second when the message was received. Comparing these two time-stamps, 15 % of the messages are received apparently after they are sent -which is physically impossible-, of which a 12% are messages with 1 second of error. Hence, we added a 1-second tolerance to our pipeline to include these messages (Mujal-Colilles et al., 2021).

3. Results and Discussion

Table 1 shows the comparison of the number of messages initially received by each antenna starts and the evolution of the total number of messages in the different steps contained within the initial pre-process script. The Old-AIS records 18% more Class A-dynamic messages than the New-AIS. Similarly, the Old-AIS captures 14% more Class A-static messages. The evolution of the dynamic messages filtered throughout the process does not change significantly between the two antennas, indicating, for instance that any of the antennas records more points on land than the other.

Conversely, there is an important difference between antennas regarding Class B messages: the Old-AIS records 5 times more dynamic messages than the New-AIS. However, when messages containing all NaN's are removed this difference is reduced significantly with Old-AIS having 1.5 times of Class B dynamic messages compared to New-AIS. This means that Old-AIS receives up to 80% of Class B-dynamic messages with missing values, rendering these messages unusable to extract information on the vessel information.

Table 1. Evolution of the number of messages in the first pre-process data. Data from March 2023

			Old-AIS	**New-AIS**
Class A	Dynamic	Initial number of messages	8914426	7537810
		Remove all NaN's	8903505	7529370
		Remove duplicates	8875421	7511744
		Points on land	8834420	7476788
	Static	Initial number of messages	632820	557857
		Remove duplicates	4880	4621
		Remove daily duplicates	4262	4018
Class B	Dynamic	Initial number of messages	3618691	705876
		Remove all NaN's	997508	694243
		Remove duplicates	996764	693762
		Points on land	967763	676476
	Static	Initial number of messages	346016	226608
		Remove duplicates	4145	3449
		Remove daily duplicates	4134	3431

Looking into detail on the temporal evolution of the differences between antennas, Figure 3, there seems to be a clear anticorrelation between AIS classes. This is, the days with maximum differences on Class A AIS, are coincident with the days with minimum differences on Class B, and vice-versa. Moreover, days with maximum differences between Old and New AIS are the days with more Class A messages (usually mid-week) whereas Class B has peaks of maximum messages at the beginning of the weeks (Mondays and Tuesdays).

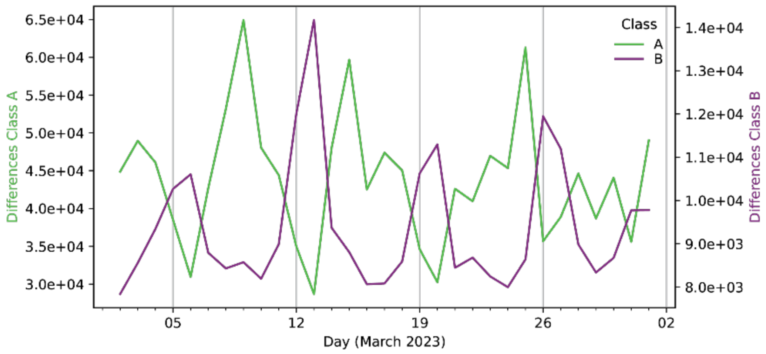

Figure 3. Absolute daily differences evolution on messages received between Old-AIS and New-AIS depending on the AIS Class during March 2023. Vertical lines indicate Mondays.

Figure 4 shows the georeferenced differences between messages received by each antenna depending on the AIS class. Apparently the range from Old-AIS antenna seems also larger than the range of the New-AIS antenna. We have selected two specific days from Figure 3, specifically 9th of March, when differences between Old and New-AIS are maximum for Class A, and 13th of March for Class B, to see if the differences in ranges are also significant and, if so, check any possible correlation with weather variables.

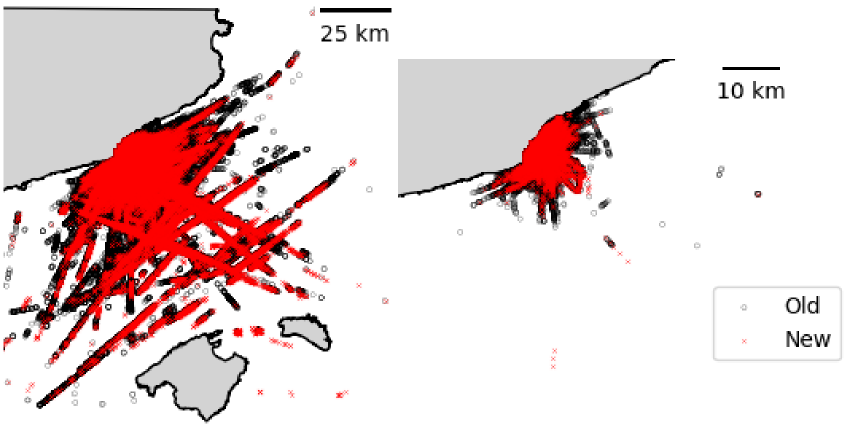

Figure 4. Comparison of georeferenced dynamic messages between Class A (left) and Class B (right). Messages received March 2023.

Figure 5 (top figures) shows the hourly evolution of maximum range for each antenna on the selected days. Clearly, Old-AIS has larger maximum range, 5 nm on average, which represents around 10% of the maximum range in the day. Although from Figure 5a, it apparently seems that the maximum range is correlated with maximum wind speed with wind coming from the North-East, Figure 5b contradicts the former conclusion because maximum range does not coincide with either wind-speed or wind direction. In fact, in Figure 5b, when wind direction is maximum and comes from the North-East, the maximum range on March 13th is reaching the lower values on the day.

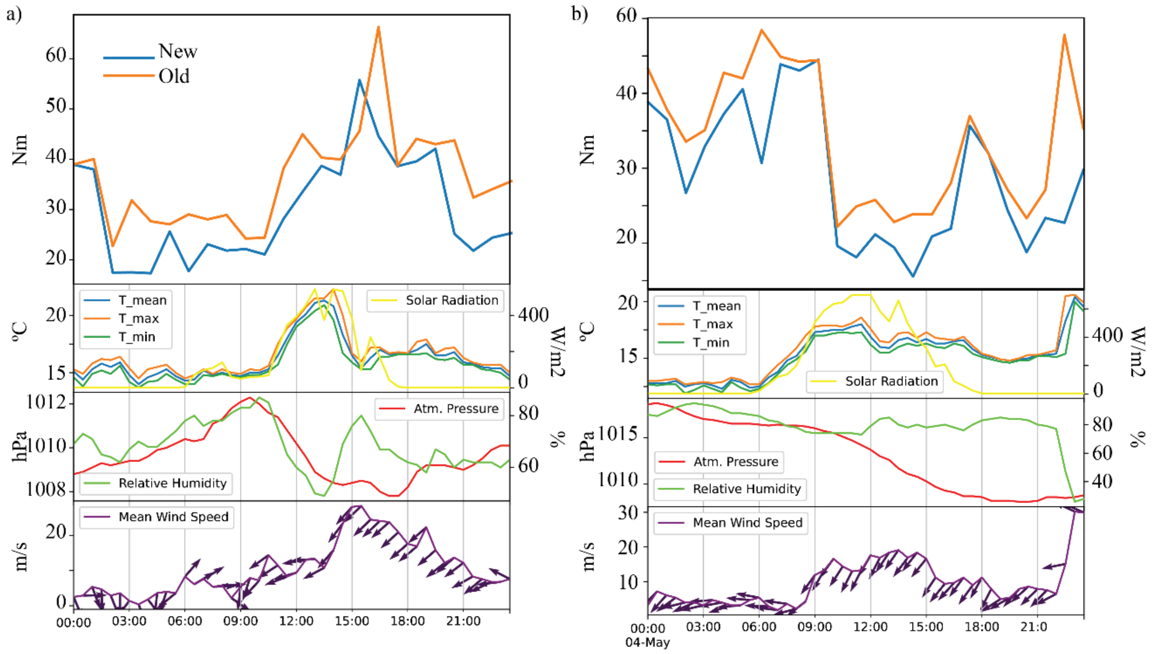

Figure 5. Maximum hourly range for each antenna and weather variables on a) 9th of March 2023 and b) 13th of March 2023. Weather data obtained from the Servei Meteorològic de Catalunya, station Port de Barcelona - ZAL Prat

The spatial distribution of maximum range differences between antennas might be helpful to see if the difference between antennas comes from the directionality of the antenna itself and is related to its orientation. This is plotted in Figure 6, where no clear differences in direction can be observed.

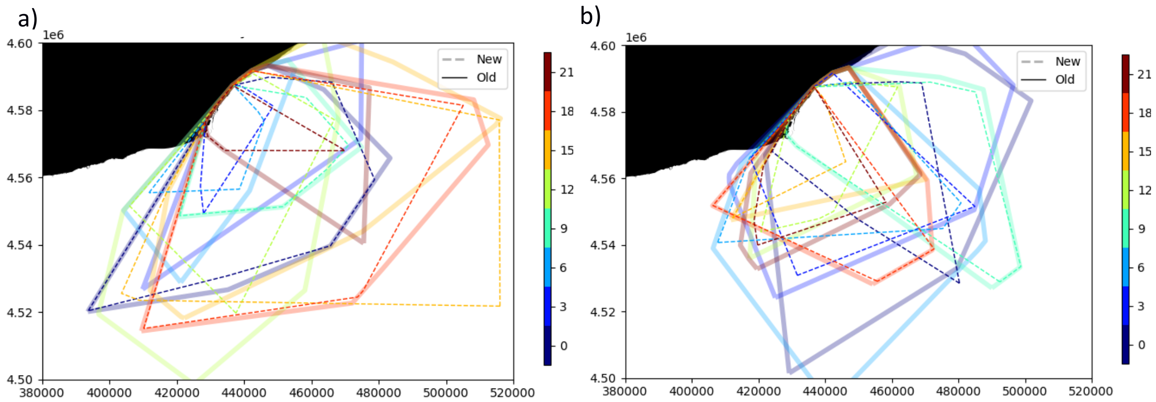

Figure 6. Convex hulls of hourly ranges for a) 9th of March 2023 and b) 13th of March 2023. Discontinuous lines from convex hulls created using New-AIS messages. Continuous thicker and transparent lines from convex hulls created using Old-AIS messages.

4. Conclusions

AIS data is becoming an important source for scientists and stakeholders to monitor the impact of maritime traffic industry. So far, studies mainly rely on data from private providers with no control on the initial processing of the AIS raw data. However, the real knowledge on raw AIS data is key to understand the gaps, the outliers and the processes to filter and interpolate it.

This manuscript has compared raw AIS data from two different antennas located at the same building in the Barcelona School of Nautical Studies. The Old-AIS antenna is located closer to the ground and further from the coastline, whereas the New-AIS antenna is in a better position. However, data from March 2023 suggests that the Old-AIS antenna is getting more messages and with a wider range.

When comparing the maximum ranges within a day with the meteorological conditions (temperature, wind speed and direction, relative humidity, atmospheric pressure and solar radiation) there seems to be no significant correlation that could indicate the source of the differences. Also, the antennas are not recording messages with a direction bias.

More research is needed to understand the differences between the antennas to optimize the position and orientation in order to get more and further messages.

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