4. Near-real time monitoring of marine aggregate extraction using AIS data

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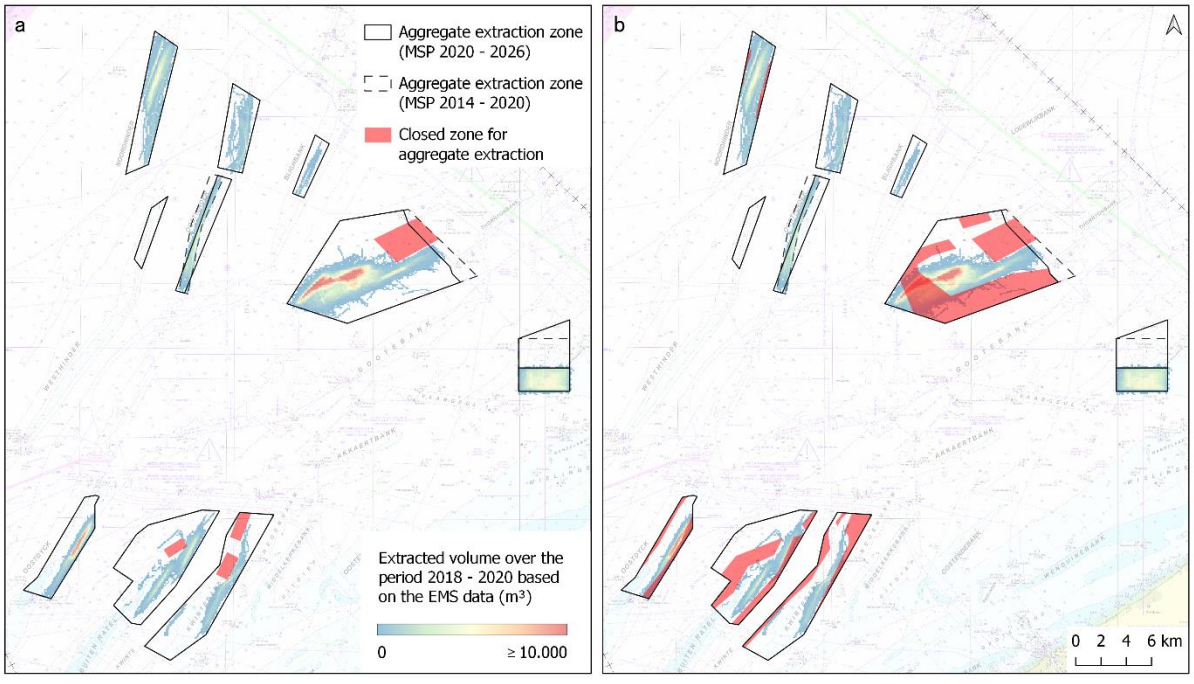
4.1. Context

On the 1st of January 2021, the new reference level for sand extraction entered into force mainly to preserve the integrity of the seabed within the framework of the Marine Strategy Framework Directive (Degrendele et al., 2021, this contribution). As a result, the closed zones for sand extraction were drastically adapted (Figure 1). This was particularly the case for the sand extraction zone located on the Thorntonbank (sector 1a), where a large part of the area that was intensively extracted over the last years was closed (see Wyns et al., 2021, this contribution). A close monitoring of sand extraction activities at the start of 2021 was required to verify the compliance of the sand extraction activities to the new closed zones, and correct the concessionaires if necessary.

Figure 1. Evolution of the closed zones for aggregate extraction. (a) Closed zones before 01/01/2021. (b) Closed zones for the period 01/01/2021 – 31/12/2021. MSP = Marine Spatial Plan.

Background: Agentschap voor Maritieme Dienstverlening en Kust - Vlaamse Hydrografie (2014).



Since more than 20 years, sand extraction activities in the Belgian part of the North Sea are controlled and monitored using an Electronic Monitoring System (EMS); a closed and sealed system onboard of the aggregate extraction vessels that automatically records, among others, the date, time, geographical position, speed, status of the dredging pump(s) and dredging activity (Van den Branden et al., 2017). The

EMS has proven its great value for the control and monitoring of sand extraction activities over the last years (e.g. Degrendele et al., 2010; Roche et al., 2017; Wyns et al., 2021). However, the time between the acquisition, processing and delivery of the data does not allow for a near-real time monitoring of sand extraction activities. The latter is particularly useful at the moment when the legislation changes (e.g. modification of closed zones or sand extraction sector), to rapidly identify and avoid infringements.

In order to closely monitor the compliance of the sand extraction activities to the new closed zones, an additional monitoring system based on Automatic Identification System (AIS) was developed. The AIS was developed in the 1990s to improve navigation safety and preventing collisions between vessels by exchanging in real-time key information such as ship identity, position, time, course, and speed between vessels and the land through the use of AIS transmitters and receivers (Spire Maritime, 2021). The applications of AIS are diverse and include among others (1) navigation safety, (2) traffic management, (3) ship behaviour analysis, (4) ship emission analysis, (5) trade analysis and (6) ship and port performance analysis (Spire Maritime, 2021; Yang et al., 2019). Within the framework of marine aggregate extraction monitoring, AIS data is used in among others Denmark and France (ICES, 2016; Miljøstyrelsen, 2021).

AIS data provides mainly information on the position of vessels. AIS data of aggregate extraction vessels therefore does not contain any information on extraction activities, in contrast to the EMS. Consequently, in order to gain insights on aggregate extraction activities from AIS data, aggregate extraction should be first inferred from the spatio-temporal information provided by the AIS data.

The aim of this contribution is to

- present an approach to infer aggregate extraction from AIS data,
- provide a first quantitative assessment of the accuracy and reliability of the proposed approach and
- present some of the applications of AIS data for the monitoring of aggregate extraction activities in the Belgian part of the North Sea, alongside with the EMS.

4.2. Identifying aggregate extraction from AIS data

Considering that aggregate extraction commonly occurs at low navigation speeds (in the order of 1 – 3 knots), a parametric model was developed to identify aggregate extraction from a detailed time-series analysis of the vessel speed (Figure 2).

The model accounts for the typical extraction speed and duration of each vessel based on historical EMS data (or an average value if no EMS data is available). The location of the AIS records is considered as well in the model to avoid the identification of aggregate extraction within the mainland (i.e. within harbours and inland waterways) and within a distance of 5 kilometres from the coast (e.g. records related to the anchorage of a vessel or beach nourishment activities). Figure 3 illustrates key elements that are considered in the model.

The results presented in this contribution are based on AIS data acquired from Marine Traffic with a temporal resolution of 2 minutes when the vessel is in movement (when the vessel is not in movement, the temporal resolution of the data is lower). The proposed approach can be applied to other spatio-temporal datasets, as long as it comprises at least (1) an identifier of the vessel (e.g. name, MMSI-number (Maritime Mobile Service Identity)- or IMO-number (International Maritime Organization)), (2) a timestamp and (3) a position (e.g. latitude-longitude or another coordinate system). The proposed approach is therefore not limited to AIS data.

The management of the AIS data, the identification of aggregate extraction and the creation and export of useful information (e.g. GIS layers, volume grids, maps, graphs and summary tables) is implemented in Python and is completely automatized to assure a simple and rapid processing of the data.

Figure 2. Characteristic speed (time series) of aggregate extraction vessels. (left) Time series of the vessel speed showing the records that are reported as extraction by the EMS (red bars) and the records located inland or within 5 kilometer from the coastline (grey bars). (right) Map showing the speed of the corresponding records.

Background: Agentschap voor Maritieme Dienstverlening en Kust - Vlaamse Hydrografie (2014).

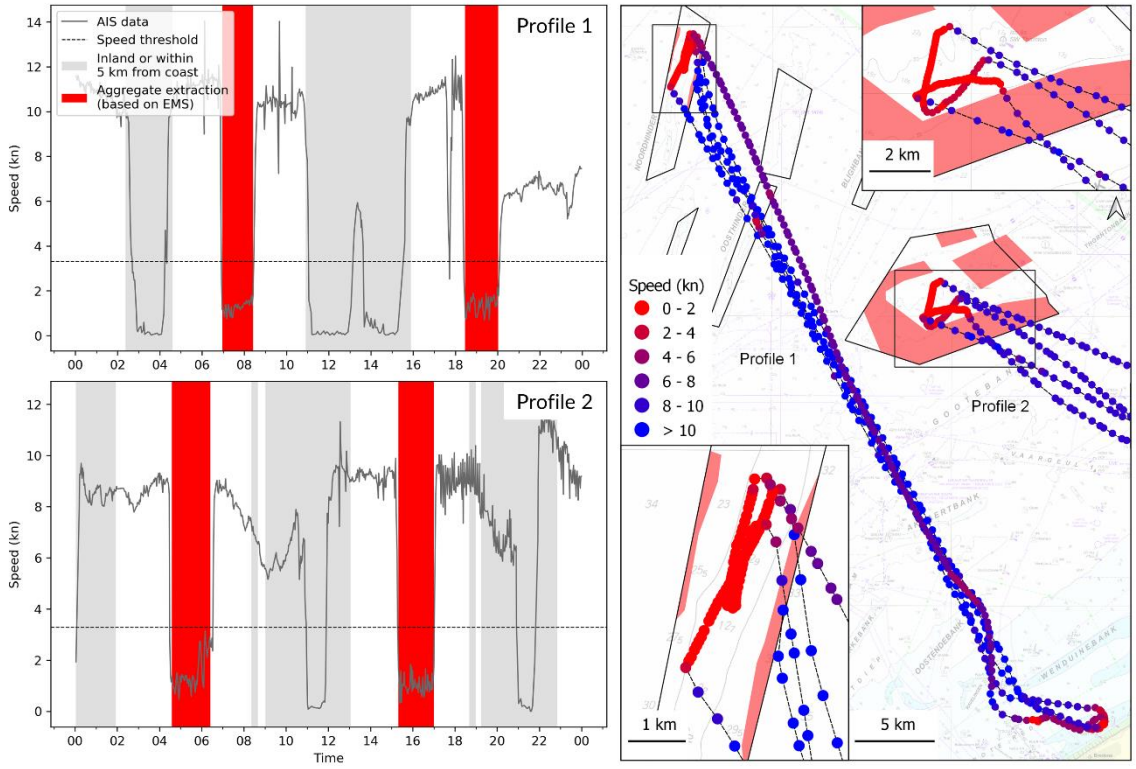
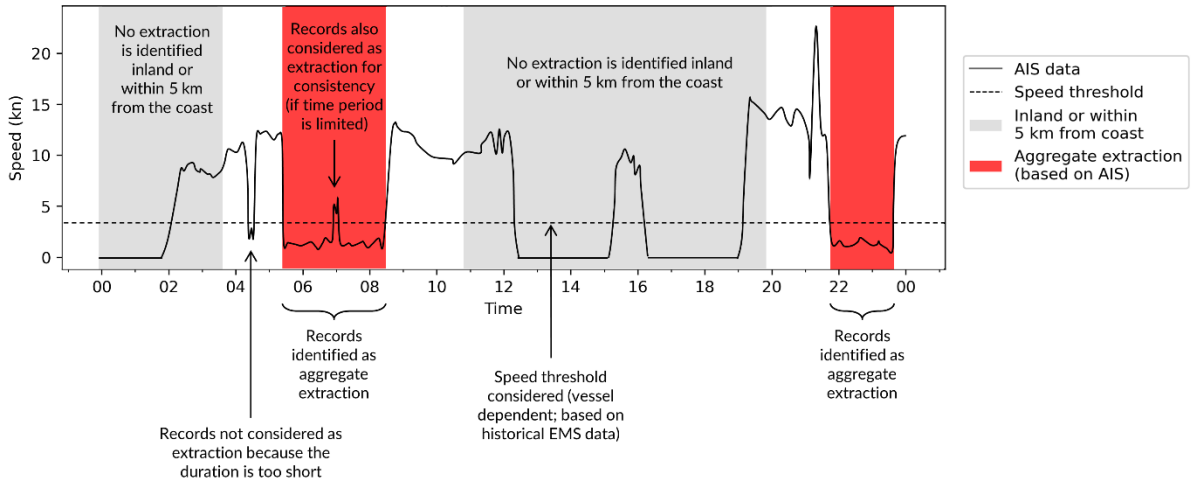


Figure 3. Overview of key elements that are considered in the model.



4.3. Preliminary assessment of the model

A preliminary assessment of the model is performed by comparing the identified extractions with the extractions reported by the EMS for the period 01/11/2020 – 31/08/2021 (10 months).

Figure 4 shows the AIS and EMS records that are identified as extraction, as well as grids of the extracted volume for the period considered. Both the AIS and EMS grids of the extracted volume were obtained by subdividing for each extraction sequence the hopper capacity over the number of records. The hopper capacity of the aggregate extraction vessels is based on the values included in the EMS configuration.

The extractions identified based on the AIS data are consistent and overall comparable with the extractions reported by the EMS (Figure 4a,b). Both grids of the extracted volume show very similar patterns (Figure 4c,d), and indicate that the intensity of the extraction is also correctly captured based on the AIS data. The cumulative extracted volume per extraction zone is as well comparable (Figure 5). Two notable differences between the AIS- and EMS based extractions are indicated with the numbers 1 and 2 in Figure 4a and c. The uncommon time series of the vessel speed before and/or after the actual extraction resulted in an incorrect identification of the extraction (Figure 6).

Figure 4. AIS (a) and EMS (b) records identified as extraction for the period 01/11/2020 – 31/08/2021. Extracted volume (considering the hopper capacity) based on the AIS (c) and EMS (d) records for the same period.

Background: Agentschap voor Maritieme Dienstverlening en Kust - Vlaamse Hydrografie (2014).

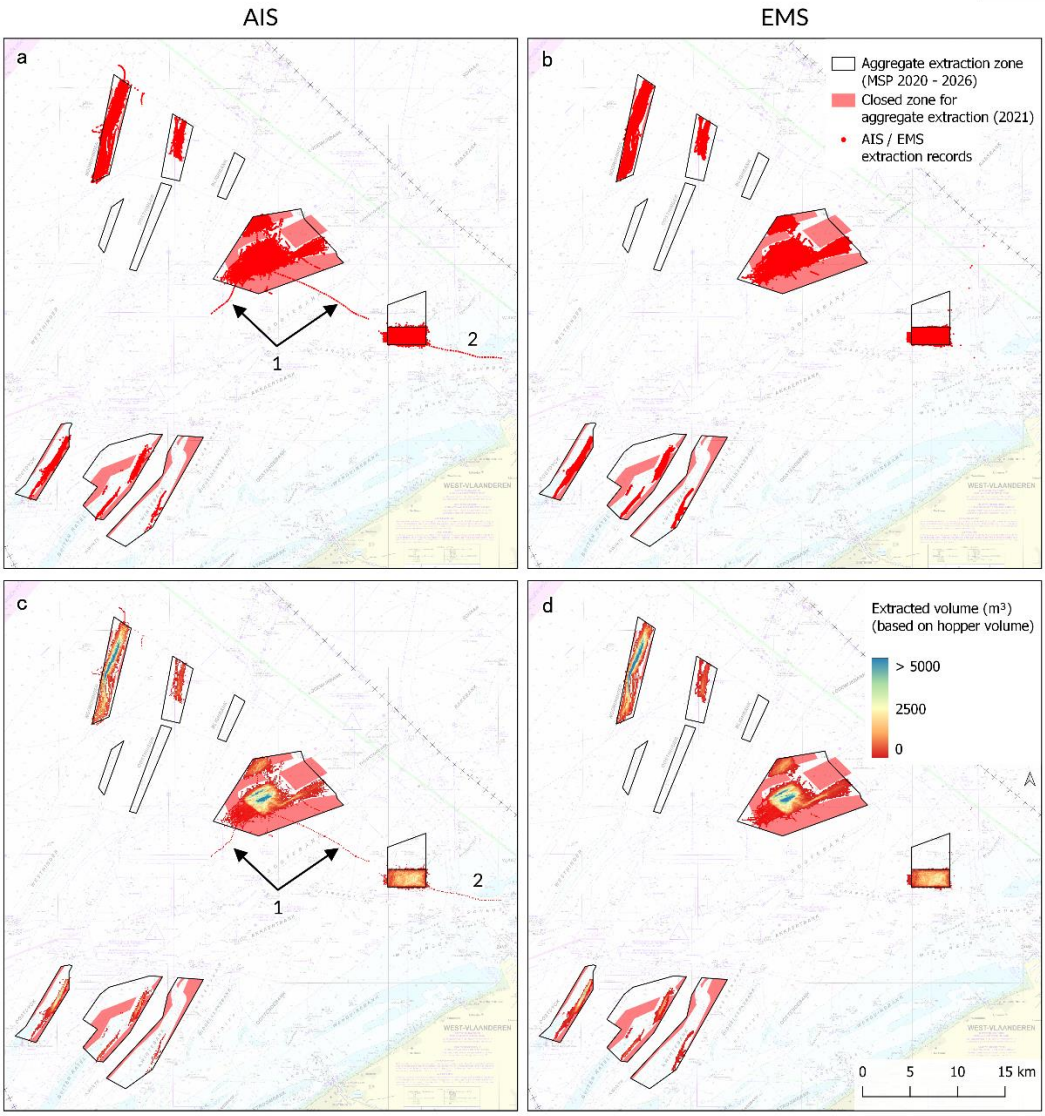


Figure 5. Cumulative extracted volume over the period 01/11/2020 - 31/08/2021 for each extraction zone. The estimation of the extracted volume is based on the hopper capacity.

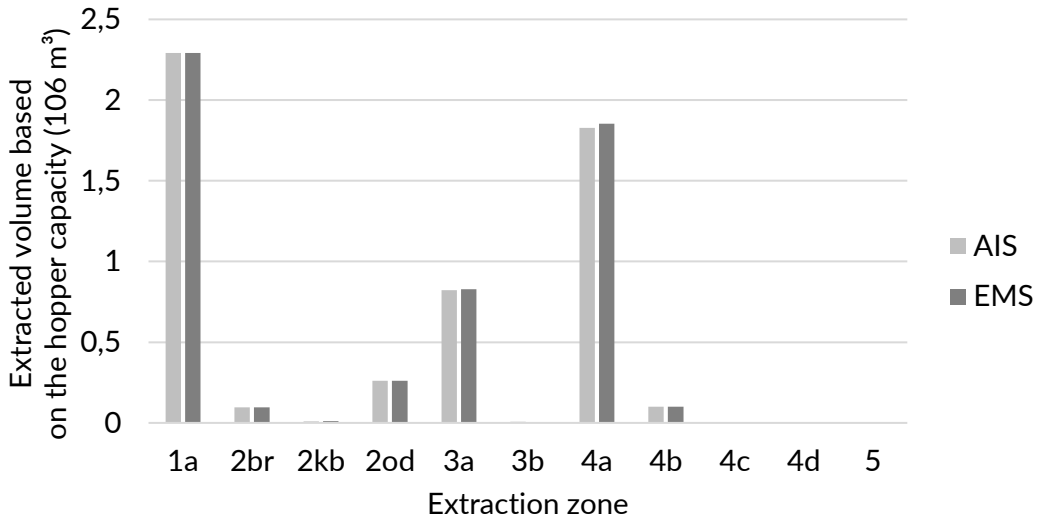


Figure 6. Incorrect identification of aggregate extraction by the model. Cases a and b correspond to extraction 1 and 2 in Figure 4 a and c, respectively.

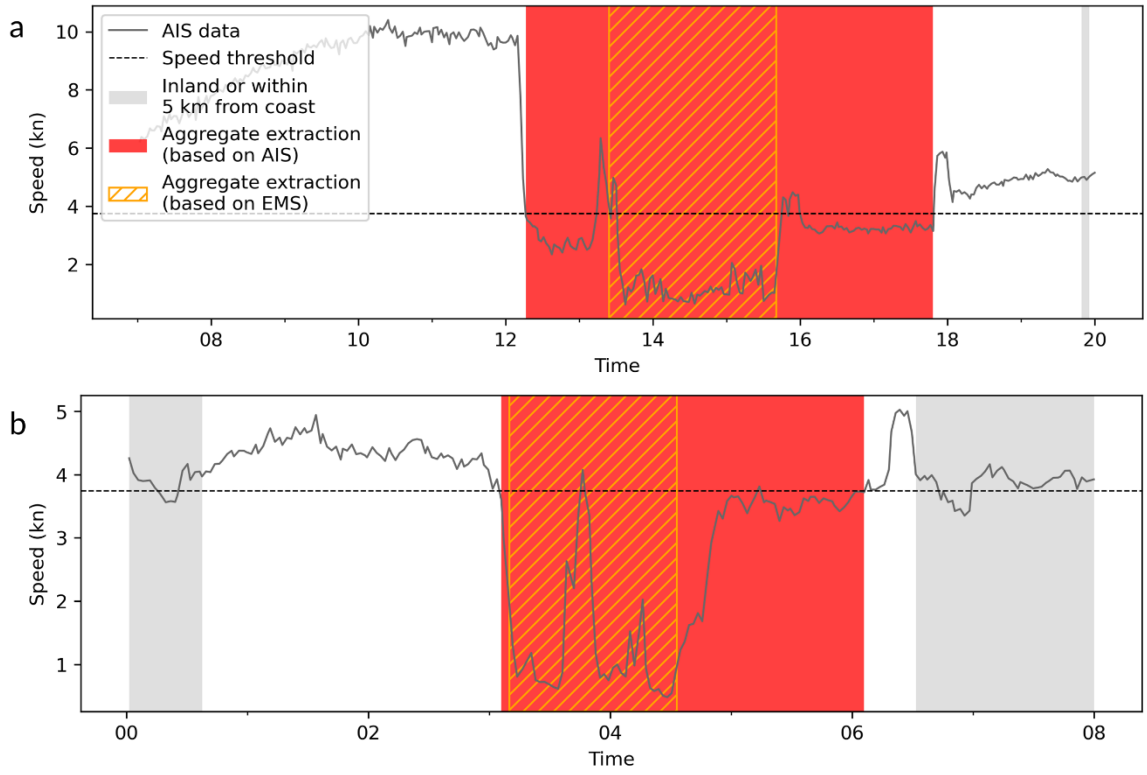
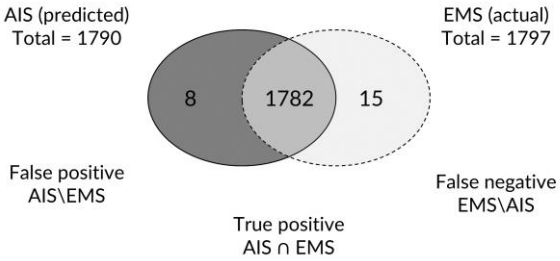


Figure 7 shows the results of the cross-validation between the extractions that were identified based on the AIS data (prediction) and the extractions reported by the EMS (reference) for the considered period.

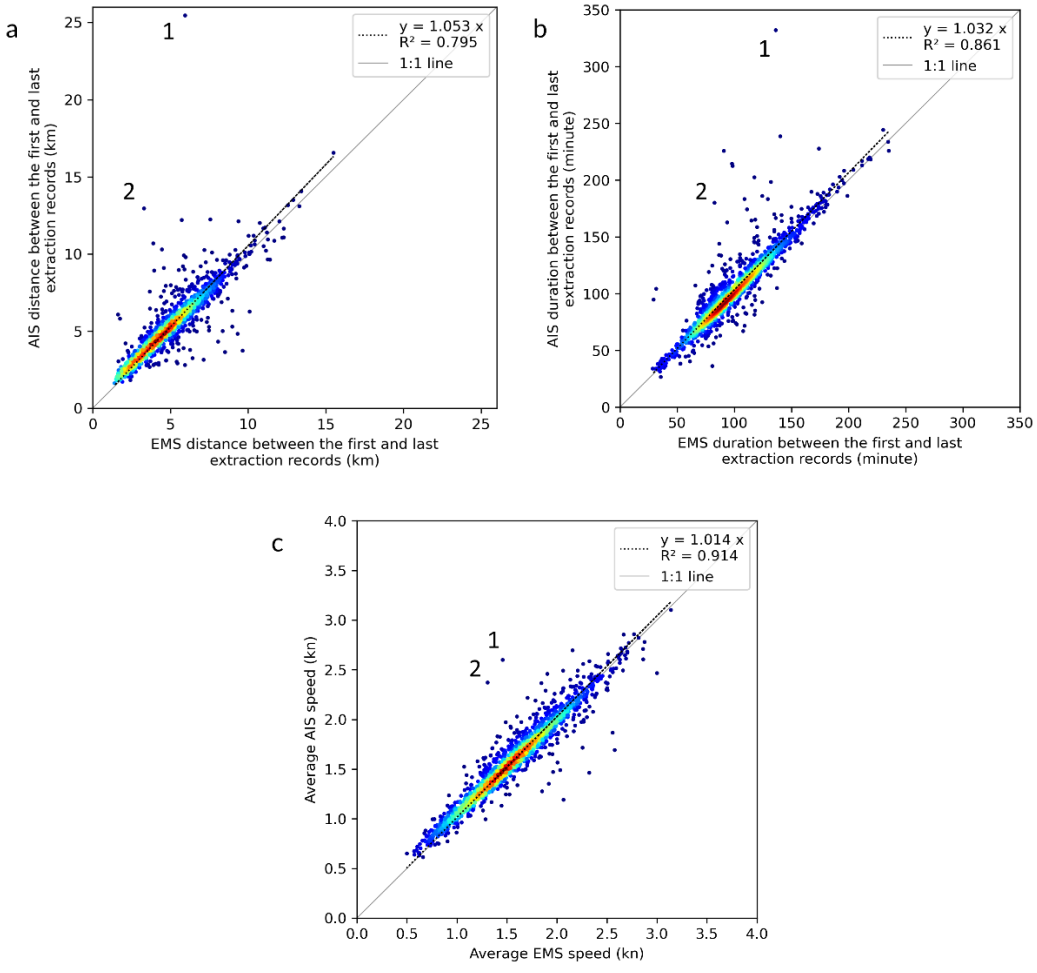
About 99.2% of the extractions reported by the EMS are identified based on the AIS data. A detailed comparison of the distance, duration and average speed between these corresponding extractions that were identified based on the AIS data and reported by the EMS indicates that a large majority of the extractions is correctly identified (Figure 8). A limited number of extractions are not correctly identified, as illustrated in Figure 6.

Figure 7. Summary of the results of the cross-validation of the identified records based on AIS data and the reported extraction by the EMS over the period 01/11/2020 – 31/08/2021.



About 0.8% of the extractions reported by the EMS are not identified based on the AIS data and proposed model (false negative cases; Figure 7). An uncommon time series of the vessel speed and the restrictions on the extraction duration implemented in the model explains why these extractions were not identified (Figure 9).

Figure 8. Scatter plots of the distance (a) and duration (b) between the first and last extraction record, and average speed (c) between the extractions trips identified based on AIS data (y-axis) and the reported extractions by the EMS (x-axis). The numbers 1 and 2 correspond respectively to case a and b in Figure 6.



About 0.4% of the extractions that were identified based on the AIS data are not reported by the EMS (false positive cases). The incorrect identification of aggregate extraction and the identification of a single extraction reported by the EMS as a series of extractions explain some of these cases (Figure 10). Some of the identified extractions are possibly related to cases where technical anomalies occurred during dredging (i.e. breakdown of a part of the dredging equipment). This is further investigated at the moment of writing.

Figure 9. Example of cases where the extraction could not be identified by the model (false negative cases).

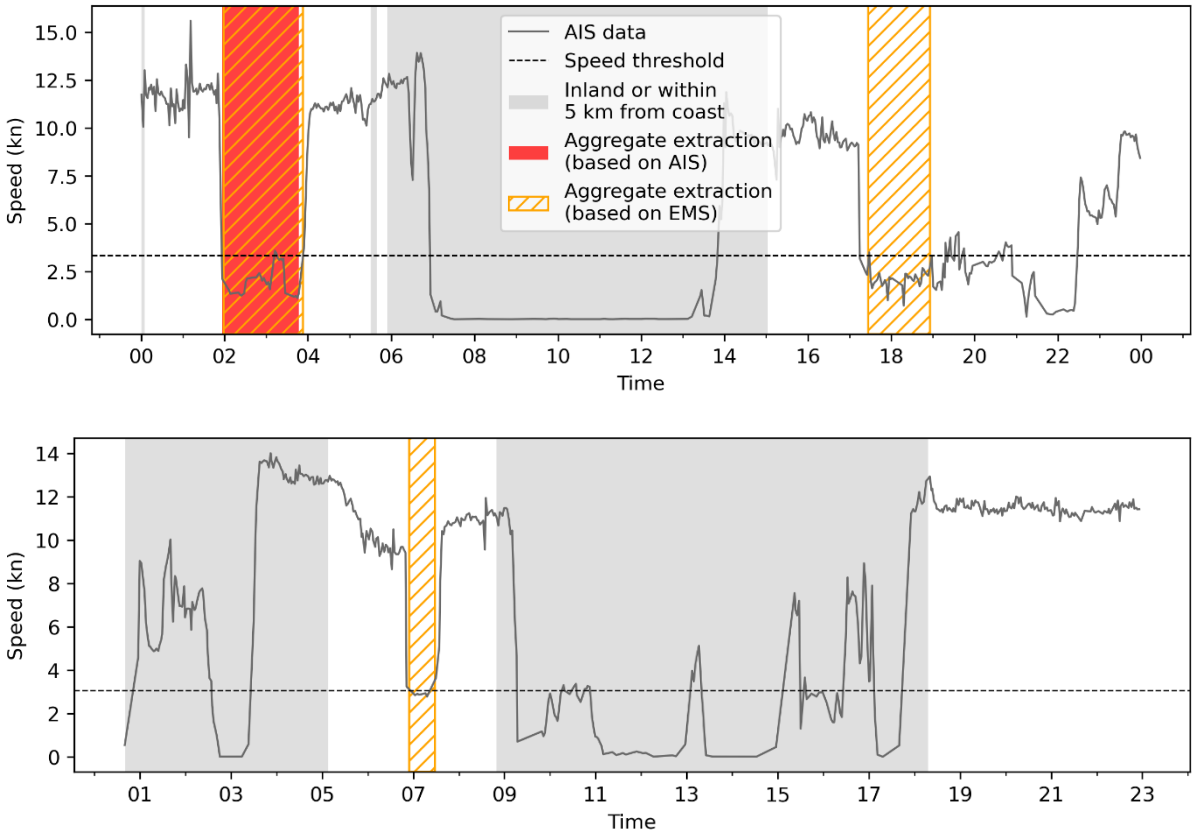
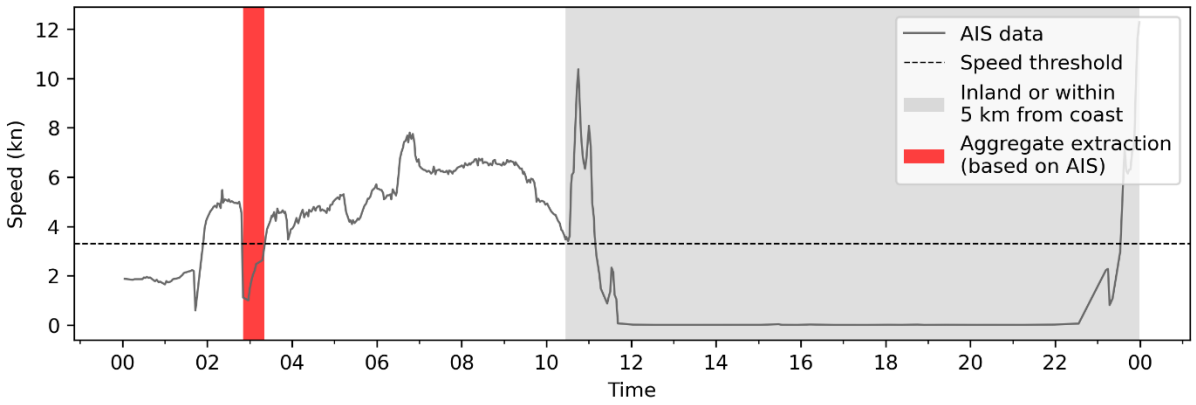


Figure 10. Example of a wrongly identified extraction (false positive case).

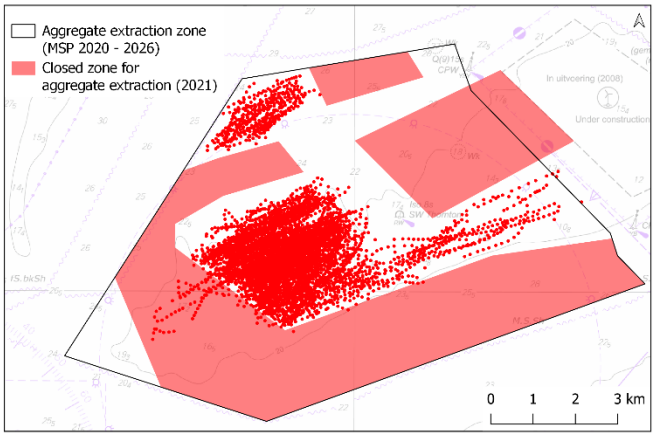


4.4. AIS: A complementary source of information for the monitoring of aggregate extraction

The previous section illustrated that AIS data can provide interesting and overall reliable insights with respect to aggregate extraction activities. The near-real time nature of the AIS makes this data particularly interesting for a number of applications. Two concrete applications of AIS data within the context of aggregate extraction are briefly described here.

AIS data is being used to closely monitor aggregate extraction activities, and in particular the control of the compliance of aggregate extraction activities to the new closed zone. At the start of 2021, the AIS data of the aggregate extraction vessels was regularly analysed to identify whether the new closed zones were well respected. The AIS data rapidly confirmed that the new boundaries were well respected, and that information on the new closed zones was well communicated (Figure 11).

Figure 11. AIS records identified as extraction over the period 01/01/2021 – 28/02/2021. Background: Agentschap voor Maritieme Dienstverlening en Kust - Vlaamse Hydrografie (2014).



The analysis of AIS data provides useful information for the organization of monitoring campaigns, such as recent information on the extraction intensity. The latter was used by researchers from ILVO to determine the location where a multibeam echosounder survey should be realized, and where sediment samples should be collected.

It is important to recognize the limitations of AIS data for the monitoring of aggregate extraction activities. First, AIS data does not contain any direct information on aggregate extraction activities, such as dredging activities or pump status in contrast to the EMS. The identification of aggregate extraction can therefore only be deduced from the spatio-temporal data, and this can be subjected to errors as highlighted in the previous section. Secondly, the AIS might be switched off, resulting in the invisibility of the vessel. Lastly, AIS might be subjected to data corruption due to for example hijacking, spoofing or maliciously corruption (Spire Maritime, 2021).

Therefore, AIS data should be seen as a complementary source of information for the monitoring of aggregate extraction activities, alongside with the EMS.

Acknowledgement

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