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Case Report

The Ortelius Incident in the Hinlopen Strait—A Case Study on How Satellite-Based AIS Can Support Search and Rescue Operations in Remote Waters

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Abstract: In this paper, Automatic Identification System (AIS) data collected from space is used to demonstrate how the data can support search and rescue (SAR) operations in remote waters. The data was recorded by the Norwegian polar orbiting satellite AISSat-1. This is a case study discussing the *Ortelius* incident in Svalbard in early June 2016. The tourist vessel flying the flag of Cyprus experienced engine failure in a remote part of the Arctic Archipelago. The passengers and crew were not harmed. There were no Norwegian Coast Guard vessels in the vicinity. The Governor of Svalbard had to deploy her vessel *Polarsyssel* to assist the *Ortelius*. The paper shows that satellite-based AIS enables SAR coordination centers to swiftly determine the identity and precise location of vessels in the vicinity of the troubled ship. This knowledge makes it easier to coordinate SAR operations.

Keywords: tourism; polar; search and rescue; SAR; Arctic; Svalbard; AISSat-1; Ortelius

1. Introduction

On Friday 3 June 2016 at 12:30 am local time, the tourist vessel *Ortelius* reported engine trouble in the vicinity of the Vaigatt Islands in the Hinlopen Strait. This strait separates the main islands of Spitsbergen and Nordaustlandet in Norway's Svalbard archipelago [1–3]. There were 146 persons on board, out of which 105 were passengers. The Governor's vessel, the *Polarsyssel*, was sent to the region to tow the *Ortelius* back to Longyearbyen where it arrived in the evening of Sunday 5 June. Neither the *Ortelius* nor her passengers were reported to be in any danger during the incident.

In this paper, the *Ortelius* incident is used as a case study to show how satellite-based Automatic Identification System (AIS) can help establish situational awareness and support search and rescue operations in remote waters like the Arctic and Antarctica.

The purpose of the Automatic Identification System (AIS) is to increase safety at sea [4]. It transmits information about the ship and voyage. All ships of 300 gross tonnage and upwards that are engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages, and all passenger ships, irrespective of size, must have and use AIS. The requirement became effective for all ships by 31 December 2004. Ships equipped with an AIS transponder must keep it in operation at all times, except when international agreements, rules or standards provide for the protection of navigational information. Military vessels do not have an obligation to shine an AIS transponder, but may choose to do so. These regulations are implemented through the International Maritime Organization (IMO).

The transmissions take place in the VHF band. As a rule of thumb, the distance to the radio horizon of VHF transmissions can be calculated by taking the square root of the height of the antenna measured in meters and multiplying this number by 4124. Mountains, islands and other obstacles will reduce the effective range. It turns out that the AIS signals can also be received by satellites in low Earth orbit. Norway has therefore pursued satellite-based AIS to increase situation awareness in the North Atlantic and Arctic Ocean, which are that nation's main area of interest.

Satellites in polar orbits have global coverage. This is an advantage over satellites in geostationary orbit, which only see approximately one third of the Earth's surface. A geostationary satellite is located 36,000 km over the equator, approximately 1/10 the distance to the Moon. Such satellites are much more complicated and expensive to maintain and launch than small satellites in low Earth orbit. The advent of relatively simple and inexpensive micro-, nano- and pico-satellites gives small countries access to services that used to be available for superpowers only.

Ice melting from man-made climate change has opened the Arctic as a high-end tourist destination. Areas that used to be blocked by ice contain beautiful landscapes and natural resources like oil, natural gas and minerals that are of great interest to private and state actors. The increased traffic in the High North led to the Arctic Council adopting the "Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic" in 2011 [5]. The Arctic nations have divided the Arctic into national areas of responsibility, where "Each party shall promote the establishment, operation and maintenance of an adequate and effective search and rescue capability within its area (of national responsibility)".

Article 7.3b of the Agreement states that "if a search and rescue agency and/or (Rescue Coordination Center) (RCC) of a Party receives information that any person is, or appears to be, in distress, that party shall take urgent steps to ensure that the necessary assistance is provided". This paper shows that satellite-based AIS enables the Rescue Coordination Center to quickly get an overview of ships in the vicinity of a disabled vessel. This knowledge enables the RCC to plan the SAR operation in a very effective way.

The author is aware of only one paper that quantifies tourist traffic in the European Arctic. Aase and Jabour (2015) [6] studies three areas in the European Arctic using AIS satellite data obtained between 2010–2014. One of these regions is the waters north of 80° N in the Norwegian SAR area of responsibility between 0 and 35° E. This region is located just north of Spitsbergen.

The number of tourist vessels north of Svalbard increased from 15 in 2010 to 22 in 2013. It then dropped to 20 in 2014. This is most likely an organic fluctuation in the tourism industry, with more or less ships each season highly dependent on market demand. The first tourist vessel was seen north of 80° N on 1 June in 2012, on 4 June in 2011 and 2013, and on 9 June in 2014. AISSat-1 was launched after the start of the 2010 tourist season, so there is no first date for 2010. There is no obvious pattern to determine when the season ends. The last tourist vessel was seen north of 80° N on 22 September 2010, while the tourist season lasted until 7 October in 2011. Tourist vessels were seen north of 82° N in both 2011 and 2012. A vessel is out of reach from geostationary communication satellites at this latitude. Lack of broadband communications complicates SAR operations.

2. Materials and Methods

The Technology

The Norwegian satellite AISSat-1 was launched on 12 July 2010 [7] as secondary payload on an Indian rocket. As of 24 April 2017, the satellite flies in an orbit where the altitude changes between 610 and 626 km [8]. It is inclined with the equator by 98.0°. The satellite will hence pass over different areas in the Arctic and Antarctica for each orbit. This can explain why the numbers in Table 1 change. When a ship is outside the field of view of the satellite, the AIS transmissions will not be recorded. On the next pass, the path of the satellite has changed, and the vessel may be seen. The satellite records the time when a transmission is received by assigning a time stamp in J2000.0 format. J2000.0 equals the number of seconds passed since noon GMT on 1 January 2000.

Data is downloaded from AISSat-1 when the satellite passes over the town Vardø in Norway's northernmost county, Finnmark. Some AISSat-1 passes in the Arctic take place below the horizon seen from Vardø, and there are hence some gaps in the data flow.

Table 1. Table showing the number of Type A and B transponders seen in the 200 km area of interest surrounding the Ortelius in passes on 3 June 2016.

Ground Time (J2000-Format)	Ground Time (UTC)	Number of Class A Transponders	Number of Class B Transponders
518210407	07:19:03	17	0
518216384	08:58:40	19	0
518222190	10:35:26	17	0
518227993	12:12:11	15	0
518233702	13:47:20	14	3
518239380	15:21:57	15	0
518245043	16:56:19	15	2
518250739	18:31:15	15	0
518256482	20:06:58	10	0
518262252	21:43:08	16	0
518268049	23:19:45	15	1
518273856	00:56:32	13	0

The technical characteristics behind the AIS system are published in Recommendation ITU-R M.1371-5 [9]. In [10], Clazzer et al. analytically model the AIS Self-Organized Time Division Multiple Access (SOTDMA) traffic pattern at the satellite and investigate the realistic behavior of SOTDMA via simulations. Shelmerdine [11] demonstrates a procedure for the processing, analysing, and visualisation of AIS data with example outputs and their potential uses. Over 730,000 data points of AIS information for 2013 from around Shetland were processed, analysed, and mapped. Tools used included density mapping, vessel tracks, interpolations of vessel dimensions, and ship type analysis. The dataset was broken down by sector into meaningful and usable data packets which could also be analysed over time. Density mapping, derived from both point and vessel track data, proved highly informative but was unable to address all aspects of the data. Vessel tracks showed variation in vessel routes, especially around island groups. Additional uses of AIS data were addressed and included risk mapping for invasive non-native species, fisheries, and general statistics. Temporal variation of vessel activity was also discussed.

AIS equipment Class A is ship-borne mobile equipment intended to meet all performance standards and carriage requirements adopted by the IMO [12]. Class A stations report their position autonomously every 2 to 10 s depending on the vessel's speed and/or course changes. Position messages are transmitted every three minutes or less when the vessel is at anchor or moored. The static and voyage related messages are transmitted every six minutes. Class A stations are capable of text messaging safety-related information and AIS Application Specific Messages, such as meteorological and hydrological data, electronic broadcast Notice to Mariners, and other marine safety information.

For Class A equipment, AIS position reports are transmitted as Messages types 1, 2 and 3 [13]. The messages contain the vessel's Maritime Mobile Service Indicator (MMSI) number. This is a unique nine-digit number that identifies the vessel that transmits the message. These messages also inform about the vessel's navigational status, like "under way using engine", "at anchor", "restricted manoeuvrability", "moored" or "aground". In these messages, one can also find information about the rate of turn, speed over ground, position accuracy, longitude, latitude, course over ground and true heading. A time stamp indicating the time of download in J2000.0-format is added to the data files by the satellite software.

Class A ship static and voyage-related data are transmitted in AIS Messages type 5. These messages contain the ship's MMSI number, and also the IMO number, call sign and ship name. They also inform about the type of ship and cargo type, overall dimension, type of electronic position fixing device, estimated time of arrival (ETA), maximum present static draught, and destination.

AIS equipment Class B is ship-borne mobile equipment that is interoperable with all other AIS stations, but does not meet all the performance standards adopted by the IMO. Like Class A stations, they report every three minutes or less when moored or at anchor, but their position is reported less frequently or at less power than for Class A equipment. The vessel's static data is reported every six minutes. Class B equipment does not send any voyage-related information. It can, however, receive safety related text and application specific messages. Class B transponders use a different communications protocol than Class A transponders.

Class B position reports are transmitted as AIS messages types 18 and 19. They include the vessel's MMSI number, speed over ground, position accuracy, longitude, latitude, course over ground, true heading and some technical information. Messages type 19 also include the ship's name and information about the type of ship and cargo.

Messages type 24 are Class B static data reports. They consist of two parts, A and B. Part A includes the MMSI number and the vessel's name. Part B also includes the MMSI number, in addition to the type of ship and cargo type, vendor ID, call sign, dimension of ship and type of electronic position fixing device.

All these AIS messages contain the transmitting vessel's MMSI number. This information is used in this work to identify the vessel. AIS messages types 1 and 18 contain a time stamp and the position of the vessel in latitude and longitude. AIS messages types 5 and 24 contain the vessel's name, call sign, IMO number and destination. From AIS messages types 1 and 18 the time stamp, MMSI number and position are extracted to text files in .txt format, which are readable in MatLAB and can be used to plot positions in Google Maps.

The Norwegian Coastal Administration (NCA) (Name in Norwegian: *Kystverket*) owns the AISSat data sets. The NCA determines if an applicant shall get access to the data. The global data base is administered by *Forsvarets Forskningsinstitutt* (FFI). The FFI provides the data sets for free as password-protected zip files when access has been granted. The data sets shall not be used for commercial purposes.

By using the map published in the first online news articles [3], the position of the *Ortelius* was estimated to be 79.4° N 19° E. FFI generously provided a data set with AISSat-1 readings of positions within a radius of 200 km from this position obtained on 3 June. The first batch of data was downloaded at 07:19 UTC on 3 June, the last at 00:56 UTC on the 4th of June. The data set contains downloads from 12 passes over Vardø (Table 1).

AIS messages types 1, 5, 18 and 24 are used in this study. The unzipped text files are read into an Excel spreadsheet. For messages type 1, the J2000.0 time stamp, MMSI number and position (longitude and latitude) are used. The data set was divided into 12 subsets, where each subset was the data downloaded from each pass. The NDRE generously converted the J2000.0 time stamp into UTC time. In each of these subsets, only the first position sent from a vessel is used.

3. Results

Table 1 describes 12 satellite passes over Svalbard on the 3rd and 4th of June 2016. Table 1 shows the times when the data download began in both J2000-format and time given in UTC. Norwegian, i.e., Central European, summer time is two hours ahead of UTC time. The two last columns show the number of Class A and Class B transponders found in the downloaded batches of data. A data set was downloaded five minutes (UTC 10:35:26) after the *Ortelius* reported her engine problems (UTC 10:30). 17 Class A and 0 Class B transponders were found in that batch of data. The data set contains information from the two passes before Ortelius reported her accident, downloaded at 07:19 and 8:58 UTC. In the download received at UTC 08:58, 19 Class A transponders were seen. The maximum number of Class B transporters was seen in the 13:47 pass. Three transponders were seen. This day the satellite saw four unique Class B transponders (Figure 4).

Tables 2 and 3 show information about the vessels seen in the downloads starting at 08:58:40 and 10:35:26. Only data from the first Type 1 message received from each ship is used. Column 1 shows the time in J2000.0 format when AISSat-1 received the first message from the vessel. Column 2, Groundtime, tells when the first message was received by the radio receiver in Vardø. Columns 3 and 4 provides the vessel's unique MMSI number and name. Columns 5 and 6 give the first position recorded from the vessel in each pass. The positions are plotted in Google maps in Figures 1 and 2.

Table 2. Vessels seen in the 8:58 UTC download from AISSat-1 on 3 June 2016. The positions are plotted in Figure 1.

J2000 Time	Ground Time	MMSI	Ship Name	Latitude (° N)	Longitude (° E)
518197774	518216384	257716000	Norvarg	78.194901667	14.518225
518197769	518216384	257785000	Norbjorn	78.2271	15.626295
518197743	518216384	258499000	Polargirl	78.228463333	15.607216667
518197769	518216384	259383000	Kvalstein	78.415078333	15.091848333
518197716	518216384	308198000	Sea Endurance	79.755633333	14.0061
518197797	518216385	209778000	Ortelius	79.857116667	17.901213333
518197874	518216385	228016600	Polaris I	79.000926667	12.226958333
518197813	518216385	231219000	Billefjord	78.228133333	15.609723333
518197966	518216385	257564000	Polarsyssel	78.243046667	15.542806667
518197919	518216385	257958900	Elling Carlsen	78.228358333	15.607108333
518197813	518216385	258301500	Longyear 2	78.229455	15.595758333
518197808	518216385	265339000	Origo	78.675666667	14.424033333
518197969	518216385	265472000	Stockholm	79.694685	12.072846667
518197840	518216385	265511830	Malmo	78.228395	15.63347
518197817	518216385	309336000	NG Explorer	78.349136667	19.403083333
518203825	518216386	230359000	Letto	78.66142	26.515886667
518203679	518216386	246337000	Antigua	78.229641667	15.599933333
518203756	518216386	259560000	Aurora Explorer	78.228448333	15.606318333
518215390	518216388	982575641	Munin	78.243265	15.545936667

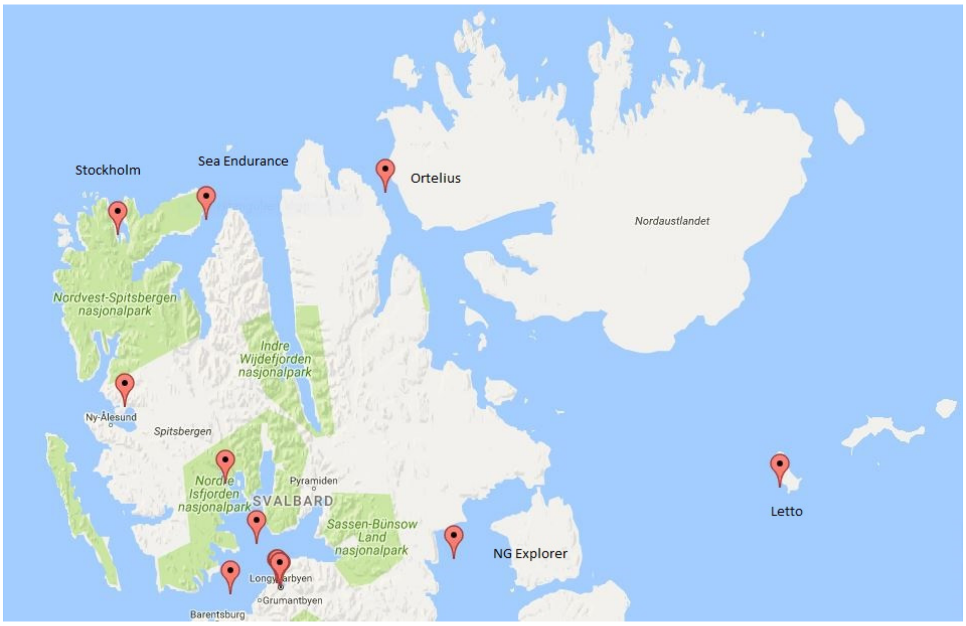

Figure 1. The location of the vessels seen in the 8:58 UTC download plotted in Google Maps. This was the most recent dataset available when the *Ortelius* reported engine problems.

Table 3. Vessels seen in the 10:35 UTC download from AISSat-1 on 3 June 2016. The positions are plotted in Figure 2.

J2000 Time	Ground Time	MMSI	Ship Name	Latitude (° N)	Longitude (° E)
518215514	518222190	231219000	Billefjord	78.40383	16.231346667
518215513	518222190	257716000	Norvarg	78.234521667	15.58116
518215513	518222190	258301500	Longyear 2	78.229436667	15.595971667
518215515	518222190	259383000	Kvalstein	78.238475	15.600005
518215514	518222190	265339000	Origo	78.6755	14.423383333
518215514	518222190	309336000	NG Explorer	78.312518333	19.353716667
518215520	518222190	982575641	Munin	78.24277	15.543858333
518221167	518222192	209778000	Ortelius	79.195583333	19.60105
518221271	518222192	230359000	Letto	78.661575	26.517788333
518221264	518222192	231219000	Billefjord	78.621325	16.639601667
518221318	518222192	246337000	Antigua	78.229663333	15.600031667
518221376	518222192	257958900	Elling Carlsen	78.228355	15.60712
518221283	518222192	258499000	Polargirl	78.228463333	15.607218333
518221340	518222192	265511830	Malmo	78.228398333	15.633618333

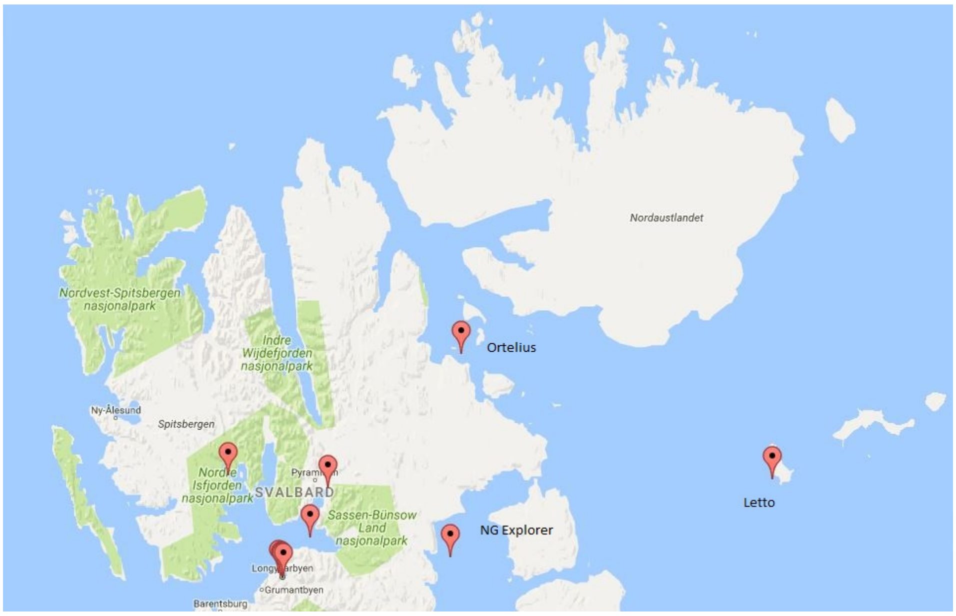

Figure 2. The vessels seen in the 10:35 UTC download. This was the first received data set after the *Ortelius* reported engine problems. The *Ortelius* has moved significantly from the position in Figure 1.

In Figure 2, the vessels observed during AISSat-1s first pass over Svalbard after the *Ortelius* notified the authorities about her engine problems are plotted in Google Maps. Neither the *Stockholm* nor the *Sea Endurance* are seen in this data set. There are several possible explanations for this. Both vessels may have been sailing close to land, and hence entered radio shadows behind mountains which have prevented the radio signals to reach the satellite. The ship antennas may have been mounted in unfavourable places on the vessels. Co-channel interference or atmospheric/ionospheric interference are also possible explanations. The satellite may also have flown at more eastern longitude, and hence not seen the vessels.

The AIS data show that there were 24 vessels with Class A AIS transponders in the region of interest. Their positions are illustrated in Figure 1. Figure 1 shows that there were four vessels that could reach the *Ortelius* in reasonable time if it had stated an emergency. The *Stockholm* and the *Sea Endurance* were sailing in the fjords of north-western Spitsbergen. The *National Geographic Explorer* was sailing along the eastern coast of Spitsbergen. The *Letto* was sailing near Svenskøya Island.

The other vessels were located on the western coast of Spitsbergen, near the settlements Ny-Ålesund, Longyearbyen, and Barentsburg. It would take time for these ships to sail to the rescue of the *Ortelius*.

Figures 2 and 3 show the ships seen in the 10:35 and 12:12 UTC downloads. It should be noted that the vessels *Stockholm* and *Sea Endurance* are not seen in the 10:35 download, while the *National Geographic Explorer* and the *Sea Endurance* are not seen in the 12:12 UTC data (Table 4).

Four unique vessels were shining Class B transponders and transmitting AIS messages types 18 and 24. Figure 4 shows that all were located in the Isfjorden region on the west coast of Spitsbergen, and would probably not be able to support the *Ortelius* in a SAR operation.

Table 4. Vessels seen in the 12:12 UTC download from AISSat-1 on 3 June 2016. The positions are plotted in Figure 3.

J2000 Time	Ground Time	MMSI	Ship Name	Latitude (° N)	Longitude (° E)
518221298	518227993	265339000	Origo	78.675481667	14.423423333
518226957	518227995	209778000	Ortelius	79.195453333	19.60193
518227003	518227995	230359000	Letto	78.59905	26.655235
518227003	518227995	231219000	Billefjord	78.64916	16.435135
518227078	518227995	246337000	Antigua	78.229676667	15.599943333
518227021	518227995	257564000	Polarsyssel	78.257716667	15.496866667
518227078	518227995	257785000	Norbjorn	78.227035	15.626483333
518227136	518227995	257958900	Elling Carlsen	78.228366667	15.607118333
518227103	518227995	258301500	Longyear 2	78.229458333	15.59592
518227122	518227995	258499000	Polargirl	78.228461667	15.607258333
518226988	518227995	259383000	Kvalstein	78.290006667	14.942508333
518227008	518227995	259560000	Aurora Explorer	78.327628333	15.561741667
518226971	518227995	265472000	Stockholm	79.824723333	11.941258333
518227261	518227995	265509140	Freya	78.243206667	13.846441667
518227120	518227995	265511830	Malmo	78.228373333	15.633635

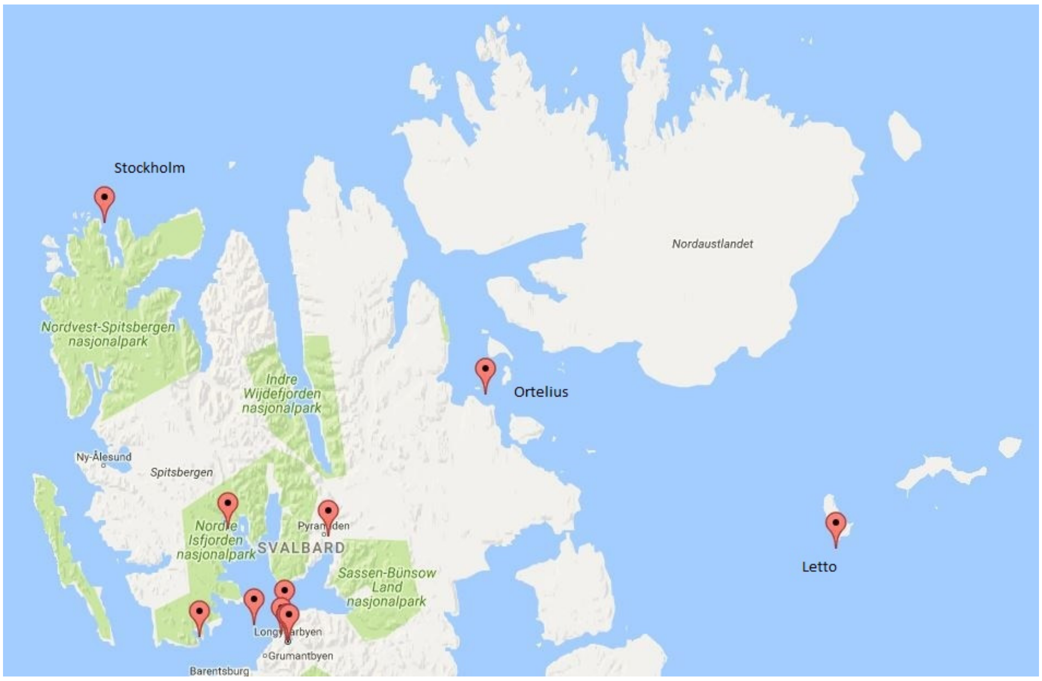

Figure 3. The vessels seen in the 12:12 UTC download. Note that neither the *Sea Endurance* nor the *National Geographic Explorer* are seen in this data set.

Figure 4. Location of vessels with Class B AIS transponders

4. Discussion

This case study shows that satellite-based AIS is a powerful tool in SAR operations in remote waters. The AISSat-1 satellite provided Norwegian authorities with data on the identity and position of vessels close to the ship that had run into problems. Fresh data were available just a few minutes after the *Ortelius* had reported the engine problems. The data sets show that there were four vessels in the vicinity that could assist in an emergency. The satellite orbits the Earth in approximately 100 min. The more satellites in orbit, the more frequent the updates. After the successful dual launch of NorSat-1 and -2 in July 2017, Norway has four polar orbiting satellites with AIS detectors.

It also shows that data from more than one pass should be studied to provide situational awareness. A ship is in the satellite's shadow when it is sailing behind an island, mountain or in a fjord and its transmissions will not be recorded. It may also be outside the footprint of the satellite, and its transmissions are hence not heard. The risk of losing vessels this way will decrease with the number of satellites carrying AIS receivers.

Not all ships may be suited to participate in a SAR operation. The International Code for Ships operating in Polar Waters (Polar Code) will enter force on 1 January 2017 [14]. The Code defines three categories of ships to operate in Polar waters:

Category A ship means a ship designed for operation in polar waters in at least medium first-year ice, which may include old ice inclusions.

Category B ship means a ship not included in category A, designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions.

Category C ship means a ship designed to operate in open water or in ice conditions less severe than those included in categories A and B.

It also defines ice conditions:

First-year ice means sea ice of not more than one winter growth developing from young ice with thickness from 0.3 to 2.0 m.

Medium first-year ice means first-year ice of 70 cm to 120 cm thickness.

Old ice means sea ice which has survived at least one summer's melt; typical thickness up to 3 m or more. It is subdivided into residual first-year ice, second-year ice and multi-year ice.

Thin first-year ice means first-year ice 30 cm to 70 cm thick.

The ice conditions in the waters surrounding the troubled vessel can be known by analysing satellite images [15], observations from Maritime Patrol Aircraft or from the vessel itself. Norwegian authorities receive data from the European Sentinel Earth Observation satellites and Canadian Radarsat satellites. The Sentinel satellites are equipped with optical and radar sensors. In case of a real emergency, one can safely assume that the Norwegian Air Force would task at least one of its P-3 Orion (soon P-8 Poseidon) Maritime Patrol Aircraft to the area to monitor the situation.

The ice and weather conditions in the SAR area may be so harsh that the RCC, for safety reasons, decide not to send any of the vessels in the vicinity of the ship in trouble to support it if they do not have a sufficient ice class. The identity of a vessel can be determined from its MMSI number, which is available in all AIS transmissions. The Regional Coordination Centres should have access to a data base where both the MMSI numbers and ice category are listed. This is a simple and efficient way to prevent Category C ships being tasked in SAR operations that require Category A or B vessels.

Not all waters along the coasts of Svalbard have been properly mapped [16]. Some waters along the south-eastern coast of Spitsbergen and the fjords of Nordaustlandet should be mapped better. A RCC should not send a vessel towards such dangerous areas.

In a real scenario, the *Letto* would probably be the first vessel to reach the *Ortelius* at the Vaigatt Islands. The distance is approximately 150 km, or 80 nautical miles. If sailing with a speed of 12 knots, it should reach the *Ortelius* in 7 h. The position in Figure 1 of the *Sea Endurance* is approximately 200 km (110 nm) from the *Ortelius*. The closest vessel is the *NG Explorer*, located near Dunérbukta on the east coast of Spitsbergen. To reach the *Ortelius*, the *NG Explorer* would have to go through the narrow Heley Sound between Spitsbergen and Barents Island, through the Freeman Sound between the Barents Island and the Edge Island, or sail the long journey south of the Edge Island.

5. Conclusions

This paper shows that satellite-based AIS is a powerful tool for coordinating SAR operations, especially in remote areas like the Arctic and Antarctica where land-based AIS is rare or non-existent. In this case, fresh position data were received just a few minutes after the Ortelius declared her emergency. This provided a good situational awareness. The analysis shows that not all ships appear in the data sets. It is hence recommended for RCC staff in future similar situations to go through recent data sets to verify that all vessels in the region of interest are known.

By using ice data from, e.g., radar satellites, an RCC can also determine if conditions make it unsafe for a vessel to participate in a SAR operation.

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