AISSAT-1 – 2 YEARS OF SERVICE

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ABSTRACT

The Automatic Identification System (AIS) has proven to be a valuable tool for monitoring maritime activities coastal waters. In order to extend the coverage to open seas, several organizations are now deploying AIS receivers on mobile platforms. In 2010, the Norwegian Defence Research Establishment (FFI) started operations with two AIS receiver systems in a near-polar low Earth orbit: The nano-satellite AISSat-1 and the NORAIS Receiver on the International Space Station

AISSat-1 was built as a service demonstrator to provide extended AIS coverage in the Norwegian High North. The satellite communicates with a ground station on Svalbard, providing real time delivery of data over the Arctic. In addition, recorded data can be downloaded, providing global coverage.

In this paper, we will describe the status of AISSat-1 after almost 2 years of operations, since launch July 12th 2010. The paper focuses on experience gained though operating the nano-satellite as a service provider. Furthermore, we address some of the challenges associated with AIS data reception in the Arctic from space, and conclude with remarks on issues related to the use of nano-satellites in operational services.

1 BACKGROUND

This paper looks at the Norwegian nano-satellite AISSat-1. In addition to the satellite, Norway also has an AIS receiver (the NORAIS Receiver) onboard the International Space Station (ISS). AISSat-1 will have two years of operations on July 12 2012. This paper provides a look into the operations of the satellite, which is handled by the Norwegian Defence Research Establishment (FFI).

The Automatic Identification System (AIS) is a system where vessels transmit information about identity, position, heading, nature of cargo, destination etc. on dedicated frequencies in the maritime VHF band. Maritime surveillance has traditionally been performed by maritime patrol aircraft, Coast Guard and Navy vessels, coastal radars, and later also satellite Synthetic Aperture Radar imagery. Introduction of AIS by the International Maritime Organization has provided an additional source of maritime traffic information. The AIS ship-to-ship and ship-to-shore reporting system is intended to increase the safety of life at sea and to improve control and monitoring of maritime traffic. Norway has around 40 AIS stations along the coast, receiving AIS messages out to about 40-60 nautical miles off shore [1].

The Norwegian space based AIS assets were developed based on national needs for better monitoring of the ocean areas outside Norway. These ocean areas under Norwegian jurisdiction amount in total to more than 2 million square kilometres. A large part of this area is within the Arctic region, with a fragile environment and often with challenging sailing conditions near ice and

in rough weather. The region is an important fish habitat and as such has a high level of maritime activity all year. In summer time, there are also many cruise ships operating in the waters around Svalbard. The region is also believed to be rich in oil and natural gas and it is expected that related activities in the High North will increase. In a strategy document for the development of the Norwegian High North presented at the end of 2006 [2], the Norwegian government stated that it will be a national responsibility and priority to strengthen the monitoring of maritime activities in the High North.

With funding from the Norwegian Space Centre, FFI began working on a Norwegian service demonstrator satellite, AISSat-1, in 2006. FFI had then already for several years been looking at the concept of receiving AIS signals from space [3],[4].

AISSat-1 is a 6 kg nano-satellite built by the University of Toronto Space Flight Laboratory (UTIAS/SFL) in Canada. It has one single AIS antenna pointing out from the spacecraft. The platform has full attitude control, enabling the antenna to be pointed in any direction. An AIS receiver from the Norwegian company Kongsberg Seatex is used for receiving the AIS messages. The ground station antennas are located on Svalbard (78° North) enabling contact with the satellite in all orbits. The satellite is operated from the mission control centre (MCC) located at FFI and the AIS data is delivered to the Norwegian Coastal Administration (NCA) who is both end user and responsible for further distribution.

AISSat-1 was launched with the Indian PSLV rocket on July 12, 2010. The successful launch put the satellite into a 635km sun-synchronous orbit. Contact was established with the satellite during the second orbit and the first AIS messages were received the same afternoon.

2 OPERATIONS

AISSat-1 operations are controlled from a mission control centre (MCC) located at FFI. The MCC primarily utilises software developed by UTIAS/SFL, the tracking programme “Tracker” from Sumus Technology Limited and dedicated software developed at FFI. A screen shot from the MCC can be found in Figure 1.

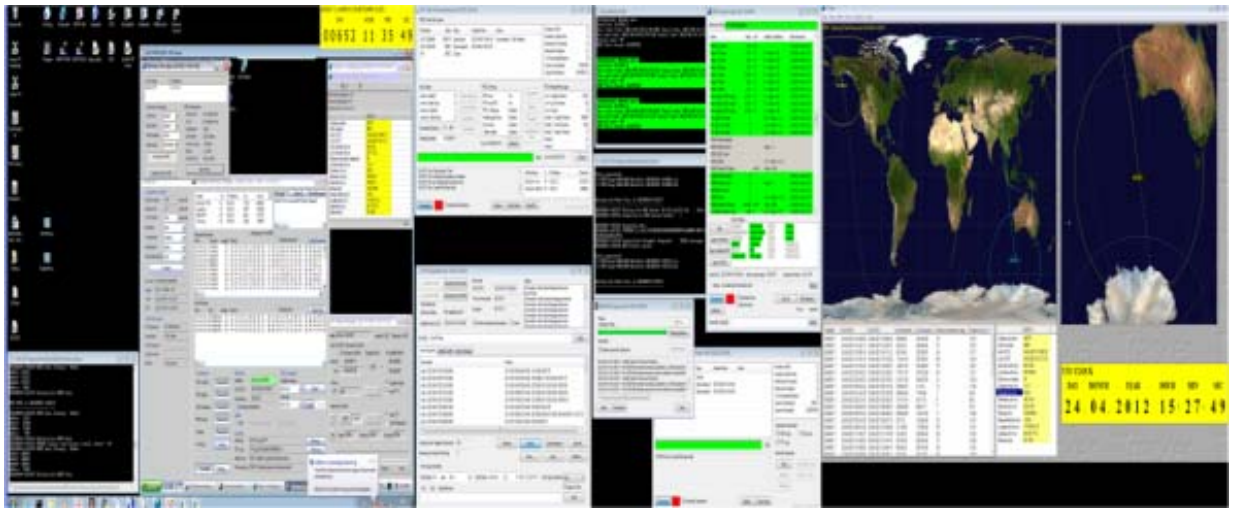

Figure 1. AISSat-1 MCC.

The MCC runs autonomously most of the time. Status e-mails are generated during each contact with AISSat-1, notifying the operators if anything is wrong. The satellite is run by time tagged

commands generated once a week. Any manned operations take place during normal working hours, and the operators are scientists at FFI. If everything runs nominally, the only manual operations happen once a week when the clock and two line elements (TLE) onboard AISSat-1 are updated, and when new time tagged commands are generated and added to an upload queue.

FFI has developed dedicated software for generating time tagged commands related to the payload operations. The downlink antenna at SvalSat is shared with another satellite, and files with antenna availability are distributed from Kongsberg Satellite Services once a week. The time tagged command programme uses the ground access files, the latest TLE, a list of target areas for operations (since summer 2011 global observations have been used) and payload specific settings to generate time tagged commands. Figure 2 provides a screen shot showing conflicts where some passes are lost or only partially available because of a conflict with the other satellite using the downlink antenna.

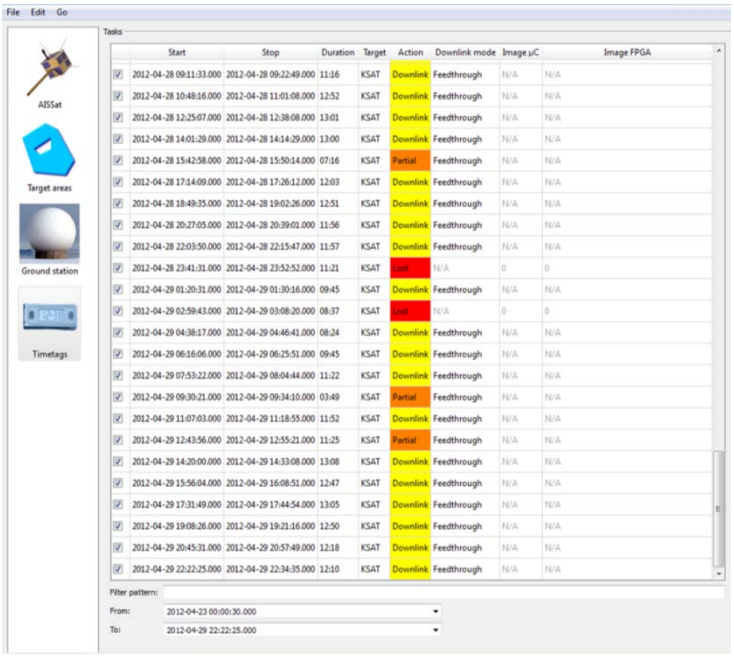

Figure 2. AISSat-1 Time tagged command generating programme.

The MCC is only operated during normal working hours. If a problem occurs on a Friday evening, the issue might not be fixed before Monday morning. Then a trained operator normally can get the satellite up and running in operational mode during one to two passes. The downtime for AISSat-1 in minutes in 2011 is shown in Figure 3. Even though the MCC is not manned 24/7, the AISSat-1 uptime for 2011 was better than 97 percent, which is regarded as sufficient to meet most end user requirements in a demonstration phase.

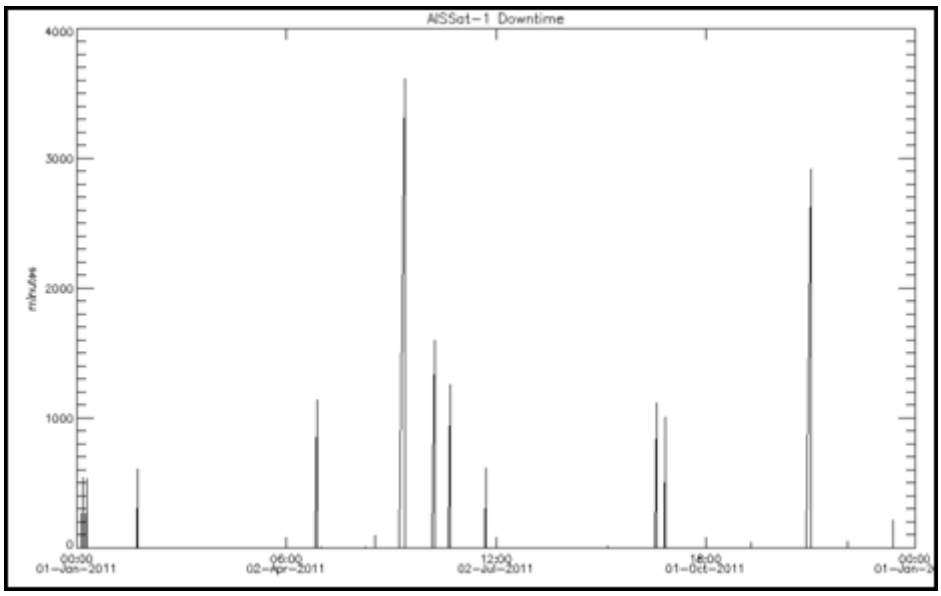

Figure 3. AISSat-1 downtime 2011.

The main task of AISSat-1 is to deliver satellite AIS data to the Norwegian Coastal Administration (NCA). AISSat-1 is designed to have two basic observation modes. When the satellite is in contact with the Svalbard ground station AIS messages from vessels within the satellite's field of view are forwarded to the NCA and MCC in real time (< 1sec latency). This mode basically makes a maritime situational picture available to Norwegian authorities in real time. The programme forwarding AIS data from the MCC to the NCA also plots the AIS positions in Tracker to give a visual confirmation that everything is working properly. An example of how "live" data received during a single pass is shown in Figure 4.

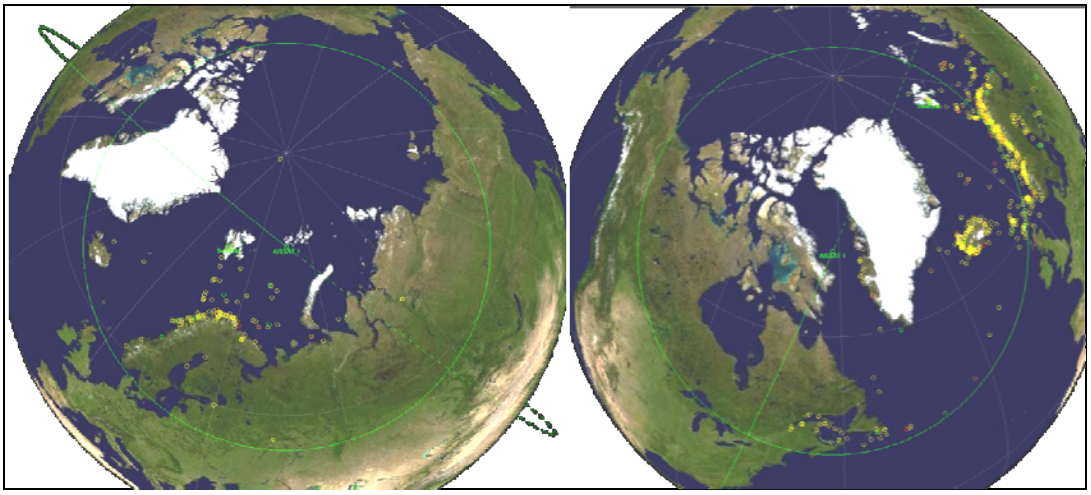
Figure 4. AISSat-1 single pass real-time data.

AISSat-1 also has a store-and-forward mode that enables the satellite to map AIS vessels around the globe several times a day. AIS messages observed and stored during each orbit are sent to ground as soon as contact is established with the Svalbard ground station. Operationally, the live data is given priority, so the downloaded stored data is forwarded from the MCC only after the contact with the Svalbard ground station has ended. These AIS data are also plotted in Tracker to show the progress of what is being forwarded to the NCA. Figure 5 shows an example where one full orbit has been processed and forwarded. A text in the upper right corner shows how many AIS messages were found in the file and how many were forwarded to the NCA. The green colour of the text indicates that all messages where forwarded, and that the link to the NCA is working.

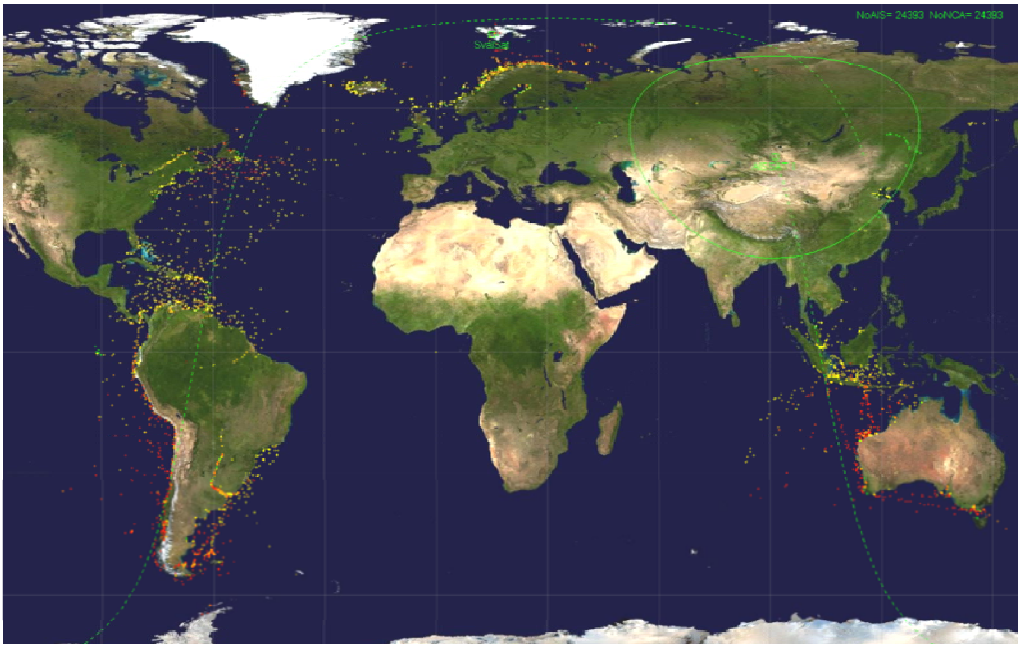

Figure 5. AISSat-1 single orbit AIS data.

The MCC also includes a computer that monitors an AIS web map server provided by Christian Michelsen Research (CMR) for the NCA. Thus, the MCC can also verify that the AIS messages have been properly included into the AIS system at the NCA. An example of a global plot from this CMR/NCA web map is given in Figure 6.

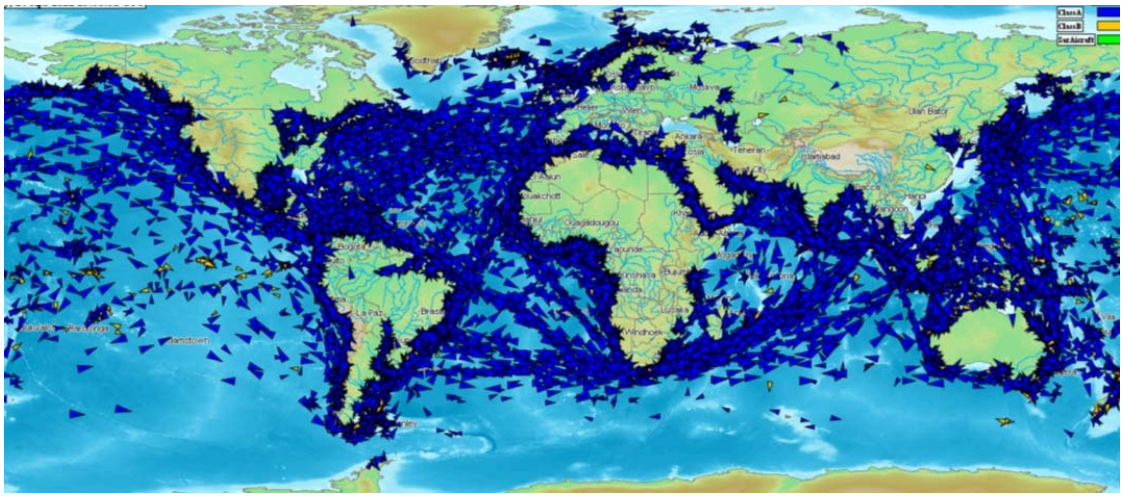

Figure 6. CMR/NCA global AISSat-1 data map.

In general, the payload operations of AISSat-1 during the first two years of operations can be divided into three periods as shown in Figure 7. The first AIS messages from AISSat-1 were forwarded to the NCA already on the afternoon the day of the launch. From early on, live AIS data were gathered. UTIAS/SFL had in the first month's responsibility for the commissioning of the satellite, but unless the satellite needed to operate in a special mode due to the commissioning, live AIS data were provided when the satellite was in contact with Svalbard.

Figure 7. AISSat-1 operations.

During the end of the commissioning period and running mostly until the 2nd quarter of 2011, time tagged commands where running the "live" mode in the High North as well as running global observations once per week. Periodically, also other target areas were observed regularly, e.g. the Horn of Africa and Japan after the tsunami in March 2011. From June 2011, updates on internal communication rates onboard AISSat-1 provided by UTIAS/SFL, enable continuous global observations.

3 GPS

A secondary payload onboard AISSat-1 is the GPS receiver. The main rational behind including it was to provide an accurate clock for the AIS receiver. Because of the power budget, the GPS is normally on for just part of the orbit. For some test periods, however, it has been operated for longer intervals. An example of the clock stability with the GPS is shown in Figure 8. The figure shows one day of AIS message and when within an AIS timeslot a message has been received. An AIS timeslot is 26.6 ms long and that is the time frame of the coloured plot on the y-axis. A drift in the time onboard would have resulted in the plot having a slope which would be steeper with higher clock drift. The plot shows a kind of time of arrival measure for all the vessels which have time GPS time synchronised AIS transponders. The light green bottom area represents AIS messages received from just under the satellite, while the more blue area further up represents AIS messages received from the horizon as seen from AISSat-1.

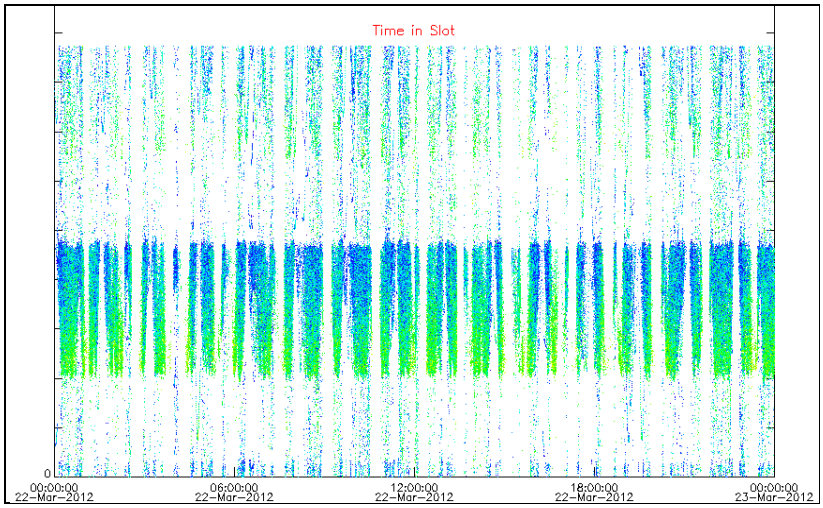

Figure 8. AISSat-1 one day Time in Slot plot with GPS on.

Position information is also stored from the GPS when it is on, with a sample resolution of about one minute. Eq.1 shows a simple formula for an average height above a spherical Earth.

$$\boldsymbol{h = \sqrt{P_x^2 + P_y^2 + P_z^2} - 6378km} \quad (1)$$

In Eq.1 P_x, P_y and P_z are GPS positions in x, y and z coordinates. The figure can show how the orbit change over the year. Figure 9 shows the calculated **h** above for AISSat-1 from November 2010 to November 2011.

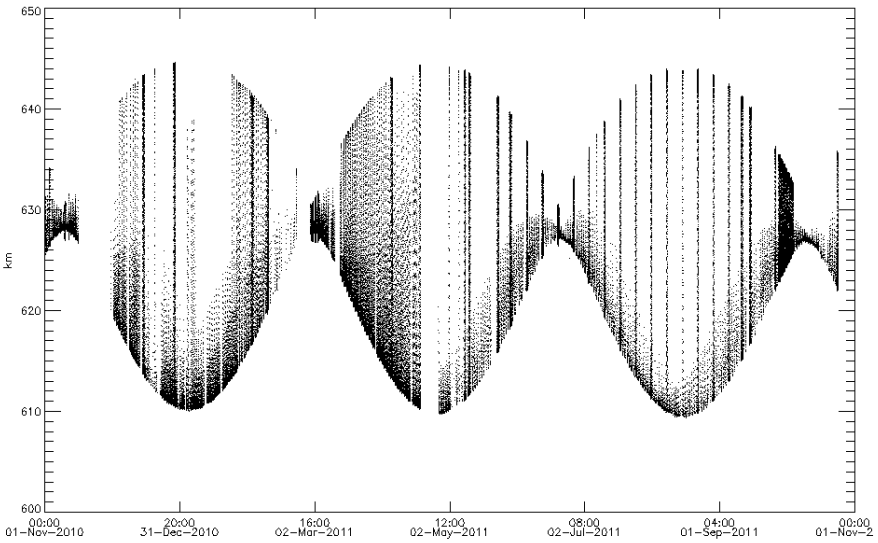

Figure 9. AISSat-1 GPS height above spherical Earth.

4 AIS DATA COLLECTION

The AIS receiver onboard AISSat-1 is provided by Kongsberg Seatex. It is a software defined radio, which enable updates to the firmware. Currently, upgrades are being tested on the NORAIS receiver onboard the International Space Station, and the objective is to also implement these on AISSat-1 during the third year of operations. This section takes a more detail look at the AIS service provided by AISSat-1.

4.1 REAL TIME COVERAGE

The main focus area for AISSat-1 is the Norwegian waters in the High North. This is covered by the real time mode which runs during contact with the ground station on Svalbard. Figure 10 shows the coverage area of this real-time mode. The figure shows all positions received during one year of operations in this mode.

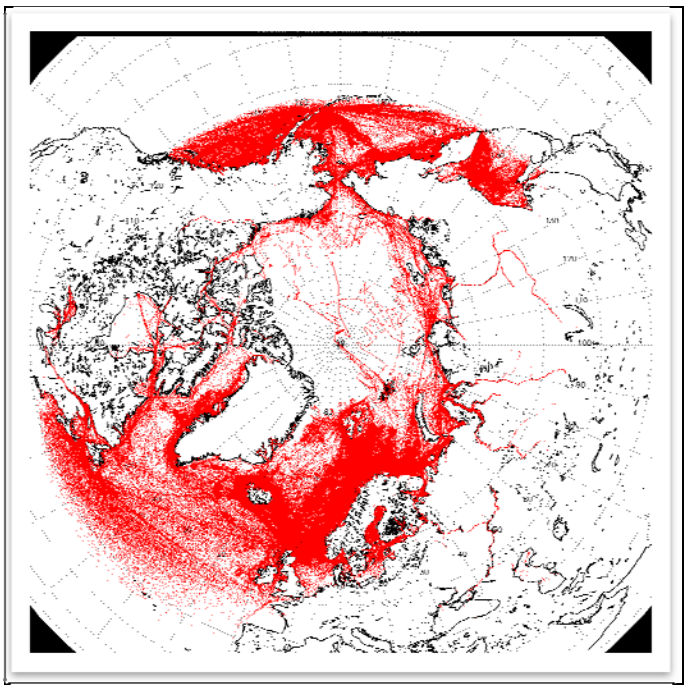

Figure 10. AISSat-1 real-time coverage area.

The Arctic is an interesting area and it is expected that because of the light and ice conditions the activity will vary over the year. To illustrate this, Figure 11 shows two months of activity for three different periods of the year. April and May 2011, August and September 2011 and December and January 2011/12. A clear maximum in traffic can be seen the August-September time frame, when the polar ice cap is at its smallest.

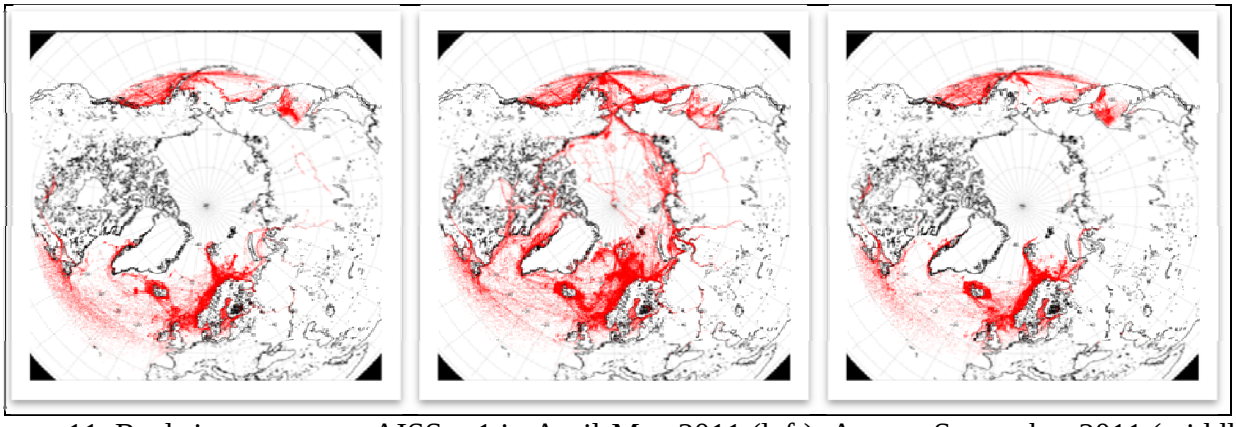

Figure 11. Real-time coverage AISSat-1 in April-May 2011 (left), August-September 2011 (middle) and December-January 2011/12 (right).

4.2 GLOBAL COVERAGE

Figure 12 shows a plot of the global vessel observations in September 2011. For September 2011 a total of 13.5 million AIS position messages were received from AISSat-1 giving an average of 450,000 per day. Close to 49,000 different MMSI numbers (IDs) where observed in the same time period.

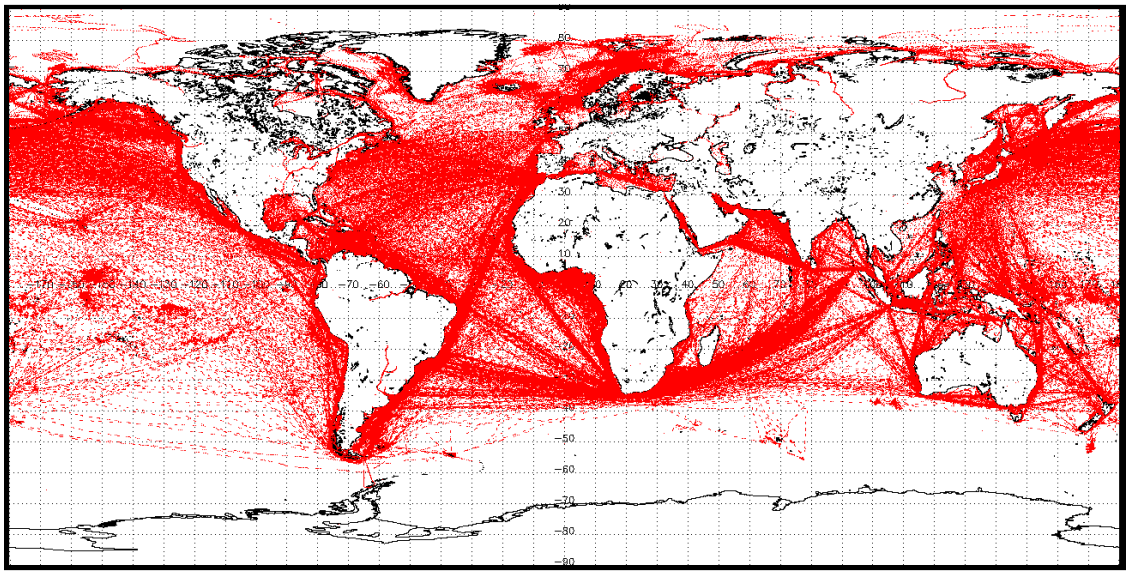

Figure 12. Global AIS observations from AISSat-1 in September 2011.

5 AISSAT-2

AISSat-2 is a copy of AISSat-1, and is currently entering into final testing at UTIAS/SFL. The satellite will be launched in 2013 and will provide an added service to the one currently operated by AISSat-1 alone. During normal operations the addition of AISSat-2 will give a higher update rate of satellite AIS messages to the end users. Globally a system of two AIS satellites will also detect more vessels per day.

Also the uptime of the overall system is likely to increase with the addition of a second satellite. It is not likely that the satellite will experience problems at the same time, and thus even if one satellite is not operational over a weekend, the service will still be provided by the second satellite. Also a second satellite will still provide an operational service in case of a total loss of the other satellite.

6 CONCLUSIONS AND FUTURE OUTLOOK

AISSat-1 is a very successful operational nano-satellite, and has shown that a nano-satellite with a total mission budget of 3-4 million EUROs can provide a service that is able to meet many users' operational requirements globally. The contribution of the satellite to the Norwegian monitoring of the maritime activities in the High North was clearly recognised when an update document on the Norwegian visions and strategies for the High North was publisher at the end of 2011 [11], where the AISSat-1 satellite was both mentioned and used as one of the illustrations.

Except for one weekly interaction for uploading new time tagged commands, new orbit element information and adjust the onboard clocks, the operations of AISSat-1 after 2 years are mainly hands-off. Both the satellite and the on-ground software and hardware are working excellently, enabling FFI to focus more on research than on operations. For the end users, the addition of AISSat-2 in 2013 will improve the uptime even further. It will also enable the use of one of the satellites to more dedicated experiments looking at the signal environment or improved antenna pointing strategies, as there then will be a second satellite which can be used in the current best operational mode.

AISSat-1 has already provided an exceptional data set for both research and operational use, and looks set to continue this for the foreseeable future.

7 REFERENCES

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