Marine and Maritime Monitoring in the Arctic

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The Arctic Sea Ice coverage has diminished in late summer by more than 50% since the start of satellite monitoring in 1979. The reduction has opened up transport possibilities along the North Coast of Russia that will significantly reduce transport times between Europe and the Far East. The reduction of ice cover and thickness is continuing and makes it realistic to envisage large parts of the Central Arctic Basin being potentially sailable within a few decades. There is observed change in the large sea stocks in the Barents Sea. Currently over 85% of the sea traffic north of the Arctic Circle is at times in Norwegian waters. Norway has put a large effort in managing this traffic, among others by launching its own Automatic Identification System (AIS) satellite, starting a marine surveillance system (BarentsWatch) as well as an extensive use of radar satellites. An increase of polar marine traffic may lead to discussions that the surrounding nations may require broad-band communication due to Search and Rescue issues.

I. Introduction

Population wise, Norway is a small country with 0,07% of the world population. Economically in absolute terms it is among the 25 wealthiest countries and at the top per capita. Geographically it covers vast areas spanning from about 56 to 83 degrees northern latitude. In Europe, the land and sea areas Norway has to manage is only surpassed by Russia. Specifically a dominant portion of the generated wealth in Norway comes from the seas, in oil and gas production as well as fisheries and fish farming. For oil and gas and fish farming the Norwegian contribution to the world production is respectively 2,3 and 1,7%.

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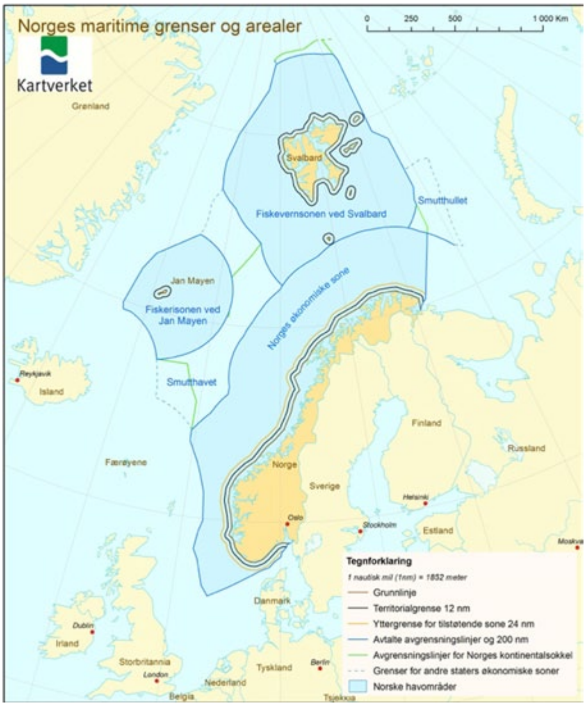
Figure 1 Norwegian northern areas.



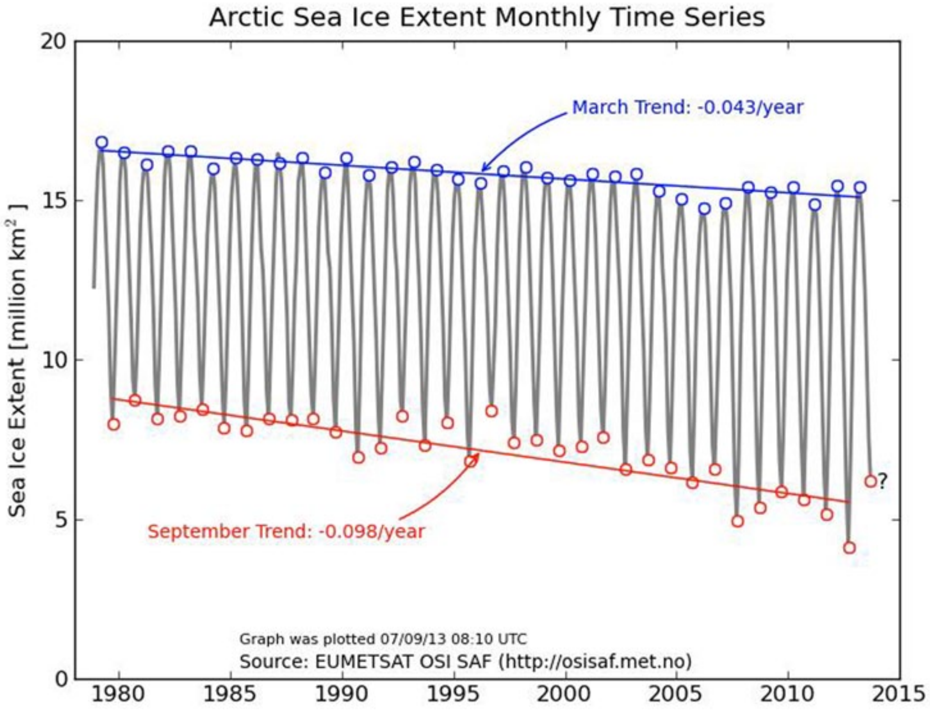
Somewhat crudely expressed, it can be said that Norway is a small country that is blessed with the management of an area better suited for a big power. This is clearly a significant challenge and the successful handling of this challenge is the basis of the strong economic position of Norway. It is also clear that this success requires extensive use of modern and adapted technology, as in an extensive use of space technology. Because of the high latitude of Norway the coverage from polar orbiting satellites of the northernmost part of the Norwegian area is better than any other global area with population and high activity. Due to this fact, the largest ground station for satellites has been developed on Svalbard by KSAT and the Norwegian Space Centre. The Norwegian space priorities are given in a White Paper decided by the Norwegian Parliament in June 2013[1].

The Barents Sea fish stocks are jointly managed by Norway and Russia and are among the best managed large fish stocks globally. The development of oil and gas exploration and exploitation are slowly moving north in the Barents Sea part of the Norwegian waters. Additionally there is in addition to the fishing

1 <www.regjeringen.no/nb/dep/nhd/dok/regpubl/stmeld.html?id=742>, Meld. St. 32 (2012–2013) "Mellom himmel og jord: Norsk romvirksomhet for næring og nytte", English version late 2013.

traffic an extensive sea transport, both in the coastal near waters and long distance further offshore traffic. It is clear that the unfortunate reduction of the summer sea ice area in the Arctic will have significant impact on the possibilities for transport, oil and gas exploitation. In addition, the fisheries and the sizes and positions of the fish stocks may shift significantly.
For the observed sea ice thickness, from both satellite and in situ measurements, the change is even more dramatic with drastic reductions leaving very little sea ice with ages above 2 years. The general disappearance of ice is not uniform over the Arctic, with the dominant loss at lover latitudes and on the Russian side of the Arctic. For several years both the Northern Sea Route and the North West Passage have been open for vessel traffic.

Figure 2 Arctic Sea ice coverage in March and September showing the clear reduction trends[2].



2 <http://saf.met.no/p/ice_extent_graphs.php>.

The use of the Northern Sea Route significantly reduces the sailing time from Europe to Japan, China and South Korea. The relative reduction of travelling time for vessels travelling from Northern-Norway is even greater. In 2012 a total of 46 ships travelled the route. In 2013, even with a higher sea ice concentration than the previous year, the first vessel with gas from the Statoil Snøhvit gas field just north of the Norwegian mainland travelled eastward in the beginning of July.

Norwegian and Russian scientist do annual catches of the different main species in the Barents Sea to evaluate the status of the different stocks. On the basis of this sampling together with the fisheries, models are created to set the catch quota. From the catches it is clear that the stocks are healthy, but clear movement of some species is seen. As an example the cod now exists abundantly in the proximity of Svalbard, most probably as result of the observed heating of the sea. It is however clear that even if larger parts of the central Arctic Ocean becomes more or less ice free this may not lead to a large migration of several species into this area. The large depths limit the feeding possibilities for species like cod.

Norwegian authorities have been relatively slow to open up the northern part of the EEZ for oil and gas exploration with currently only two fields in production. However, in September 2013, a major field was discovered South-West of Bjørnøya. On the Russian side there is one of the largest known gas fields, Stockman. The exploitation of this latter field has been put on hold, mainly due to low gas prices. However, also the large distance to shore and the potential drifting of ice are issues that increase the costs.

II. Space Infrastructure Availability

For all of the cases described above the availability of suitable Earth Observation data is essential. For fisheries management and for safety and security issues, the knowledge of the position of the involved vessels is crucial. For shipping, oil and gas exploration and all other vessel traffic the detailed knowledge and evolution of the ice cover is essential for safety and security. For all high Arctic Operations accurate navigation and positioning information is required. A central element for operations is the availability of broadband communication. This lack of element north of about 75 degrees north can be a limitation for an increased activity further north.

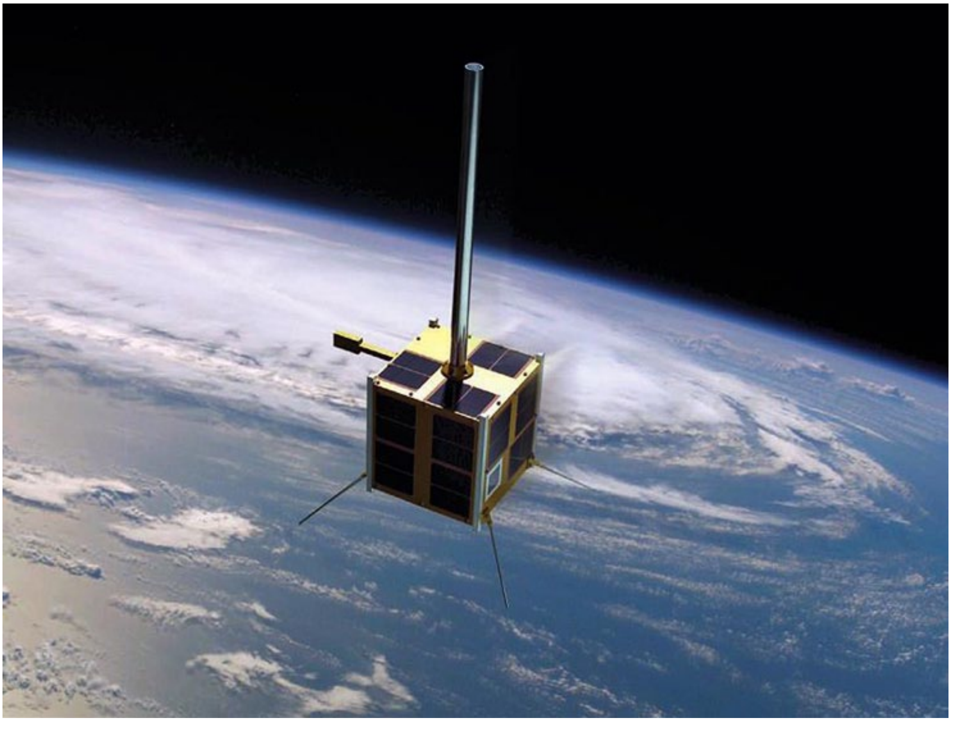
Many scientific missions have created a broad knowledge about the high Arctic, but it is clear that increased continuous activities in the Arctic will require operational space systems that the users can rely upon. NOAA and EUMETSAT have created the operational system related to meteorology that now provides the required input for forecasts and modelling. The European Copernicus system is on the verge of doing the same for several other earth observation parameters, including Synthetic Aperture Radar (SAR). SAR observations are specifically important in the Arctic to provide detailed ice imaging through dark and cloudy situations. On the civilian side no guaranteed access system

has existed, even if several different systems in practice have provide such a capability (ERS, ENVISAT, Radarsat, Terrasar and several others).
NASA, ESA, JAXA systems have provided scientific space infrastructure that together have provided and still provides important information that is used operationally. China and India is on the verge to provide Earth Observation systems that can be used operationally.
Concerning navigation and positioning the GPS and Glonass systems provide global coverage. These military systems will soon be complemented by the civilian European Galileo systems.
On specific important measurements in the Arctic, like AIS measurements there are several providers. Exact Earth provides commercial available data, while Norway has decided to have its own publicly owned system.
In total it seems that the majority of the necessary Earth Observation data required for the Arctic has been available and will be available in the near future. An important exception is a requirement of having long term measurements of sea ice thickness as provided by ICESAT and Cryosat.
The great lack of space infrastructure to serve the high Arctic is in broadband telecommunication. Above 75 degrees where GEO satellites cannot provide broadband, we only have the narrow-band IRIDIUM system running with its follow up in the final planning phase. For safe and useful broadband availability a system of HEO satellites is required.

III. Norwegian Space Infrastructure Use in the Arctic

Norway has been in the fore-front of using space infrastructure to monitor its vast sea areas. This applies specifically to ship and oil spill monitoring and the general use of the multi-mission capabilities from the ground stations in Northern Norway and Svalbard. Concerning monitoring of fish stocks in the Arctic, satellites can only be used indirectly to investigate temperatures, current shears and algae blooming. This has however been useful in complementing in-situ measurements.
The main lack in the Norwegian high Arctic is the absence of broadband communication for mobile and remote locations. A broad study on the development of a HEO communication systems is currently being carried out.
Norway has extensively used the capabilities provided by our membership in ESA to provide information about the marine activity in our waters. The SAR data from ERS-1, ERS-2 and ENVISAT have built up our capability to monitor vessels and oil pollution on the sea surface. Through a bilateral agreement with Canada, adequate data from Radarsat and Radarsat 2 have complemented the ESA data. Copernicus will provide the main component for data in the future and Norway has started discussions with several international potential partners for additional data input.
The SAR data give positions for all ships in the observed area. The combination of national ground stations and an efficient data processing system provide these data to the authorities in near real time. This information requires no collaboration for the ships themselves, but has been very efficient in the

Figure 3 The 8 kg Norwegian AISSat-1, -2, -3.



management of fisheries and security issues. However, the SAR data do not identify which ships we observe.

To ensure better knowledge about the marine traffic in our waters the Norwegian Space Centre together with Norwegian Defence Research Establishment (FFI) and the Norwegian Coastal Authorities launched an AIS (Automatic Identification System) satellite in 2010. The same year a similar instrument was mounted on the ISS[3].

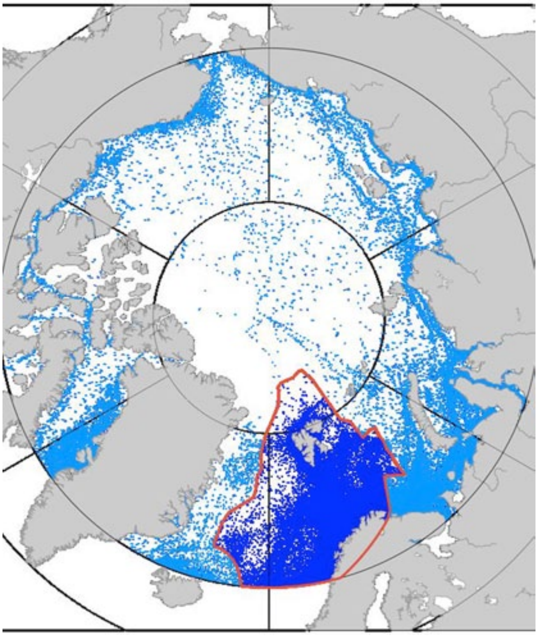
The AIS space infrastructure requires that the ships follow the IMO rules for having this anti collision system in operation. The combination of the non-cooperative SAR system with the collaborative AIS system has proved to be very effective operationally. Combining the information give the Coast Guard very good data basis to efficiently deploy its resources for fisheries management.

The Norwegian Government has implemented a real time monitoring system that integrates the total information of its northern seas, centred on the Barents Sea. This system, named BarentsWatch incorporates the available space and in situ measurements in an openly available website (<www.barentswatch.no>).

The data provided later in this paper solely comes from the operational AISSat-1. A copy for of this satellite, AISSat-2 is ready for launch scheduled for the

3 <www.romsenter.no/eng/content/search?SearchText=AIS>.

Figure 4 The daily averaged position of vessels north of the Arctic Circle over nearly a three-year period. The colour in the Norwegian waters is enhanced for clarity.



end of 2013. The Norwegian Coastal Authorities have funded a third copy that the Norwegian Space Centre expects to launch during 2014. In addition a new somewhat larger satellite platform has been procured. It will contain a development of the AIS receiver as well as a Norwegian electrical field instrument and an advanced Swiss Total Solar Irradiance instrument. In total Norway plans to be self-sufficient with space based AIS measurements until 2020.

IV. Elements Describing the Arctic Ship Traffic

The Norwegian AIS receivers on AISSat-1 and on ISS provide a global coverage of vessels on the high seas 14 times a day. Norway mainly uses this information to monitor the vessel traffic in the Arctic. As described in the introduction Norway sees both the opportunities and the risks associated with increased activity in the high Arctic due mainly to reduction of sea ice near or in our waters.
We have looked into our extensive data set from AISSat-1 for ship traffic north of the Arctic Circle for the period July 2010 to May 2013.
Figure 4 clearly gives the indication that the dominant part of the vessels are within the limits showing the total of the Norwegian waters. These include the

Figure 5 Daily ship count north of the Arctic Circle. A running mean of 30 days have been applied to the data points.

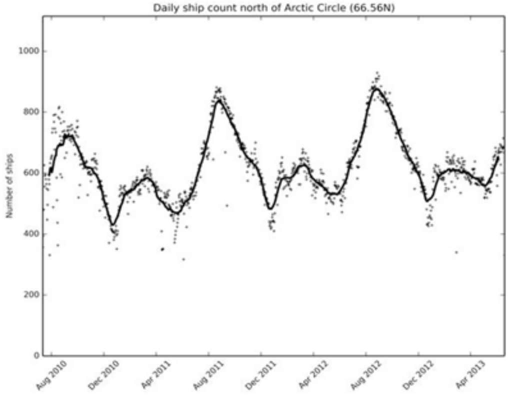
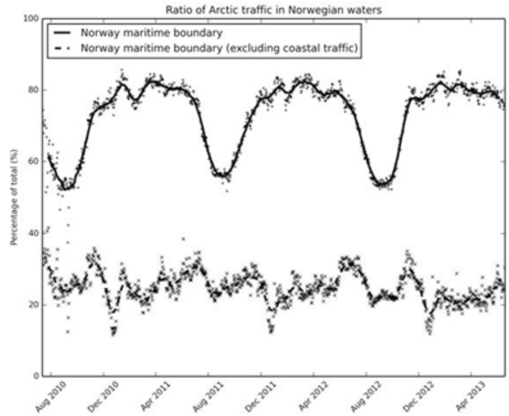


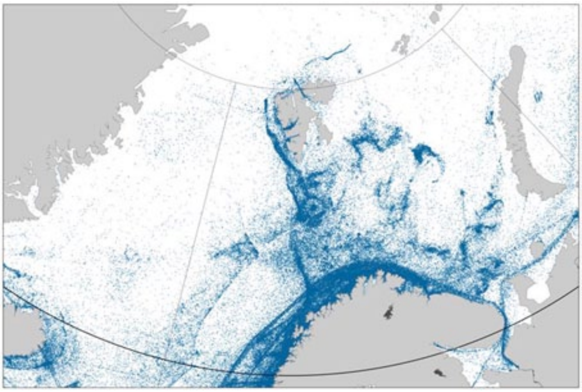
Figure 6 The ratio of ships North of the Arctic Circle that are in Norwegian waters. The upper curve includes all ships in Norwegian waters, while the lower curve excludes Norwegian coastal traffic.



inner water, the EEZ, the fisheries protection zone around Svalbard, the fishing zone around Jan Mayen and the extension areas related to the continental shelf. Figures 5 and 6 show the daily ship numbers north of the Arctic Circle and the fraction of the traffic in the Norwegian waters. We see a clear seasonal variation that is related to the ice coverage.

From Figure 6 we can see that the seasonal variation of the ratio not including the Norwegian coastal traffic is relatively stable, that is showing highest activity

Figure 7 The daily mean positions of all ships in Norwegian waters over the 2010-2012 period.



in the ice-free months. The real implication of these numbers is that between 55% and 85% of vessels north of the Artic Circle are in Norwegian waters. The largest values in the ratio of the total number of ships occur in wintertime when other areas to a large extent are ice covered. It is thus a clear result of the fact that the ice cover in Norwegian waters is relatively low. If we do not take into account the Norwegian coastal traffic the fraction in other Norwegian waters is on average slightly more than 25% during the whole period.

Figure 7 show the traffic pattern around the northern coastlines over more than two years. Several distinct features are clearly seen for the traffic of Norwegian and foreign vessels. Along the coast the fare lanes set up by the Norwegian Coastal Authority are clearly distinguishable. The limit to the Norwegian inner waters along the coast is seen, this also applies to Bjørnøya, Jan Mayen and Svalbard. In the western part of the Barents Sea and going south in the Norwegian Sea there is a large number vessel travelling or fishing just outside the 200 miles limit.

A large fraction of the ships in or around the Barents Sea are large fishing vessels. In Figure 8 we have divided the vessels into two groups, Norwegian vessels are in red and in blue are all the other vessels.

We see the extensive Norwegian traffic in the region north of Svalbard and in the Svalbard fjords. Investigating the type of vessels and the season of traffic show that this is dominated by shrimp catching in from October to the end of January. The expansion into this season is only possible because of the effect of relatively hot water in the West Spitsbergen Current keeping these areas ice free. However, this may be dangerous operational wise as these ships at nearly 82 degrees north has no broad band to enable the transmission of detailed ice forecasts.

Figure 8 Norwegian vessels are show in red.

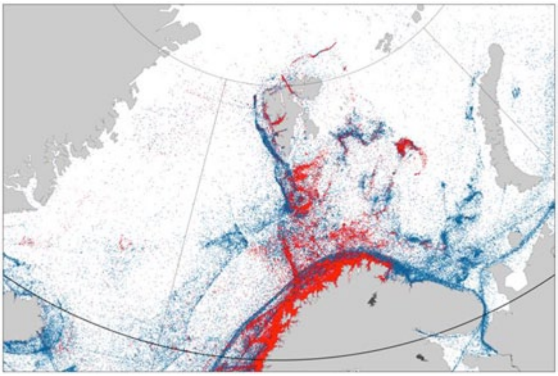
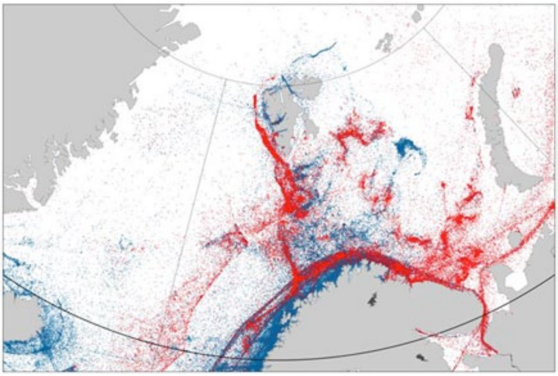


Figure 9 Russian vessels are show in red.

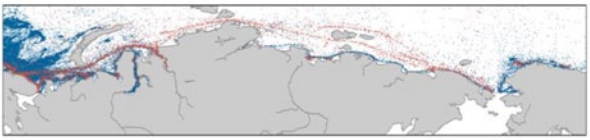


We also clearly see that the Norwegian traffic, being mainly fishing vessels, mainly operate in the Norwegian fishing sectors and internationally available fishing areas.

In Figure 9 we have changed the colour legend and show all the Russian registered vessels in red as compared to the others in blue. Comparing the content in Figures 8 and 9 it is clear that ships from Norway and Russia dominate the total amount of traffic in the area. We see strong concentration of Russian vessels in the Russian area of the Barents in the shipping lanes along the Russian and Norwegian coastlines. In addition there is extensive fishing in the fisheries protection zone around Svalbard. This is done in agreement with Norwegian authorities according to the fisheries agreement between Norway and Russia.

It should be noted that the high activity outside the 12 mile zone around Svalbard is mainly for fishing cod. From the catches and from the results of the Norwegian Marine Research Institute the cod stock is expanding northward

Figure 10 Ship traffic in the Northern Sea route. The red points give the long distance traffic. In the eastern area, this traffic is dominated by ships travelling the full transit.



and eastward[4], thus providing more extended catching areas. Much of the Russian traffic in the Svalbard fjords is for legal transferring of catches from fishing vessels to cargo ships.

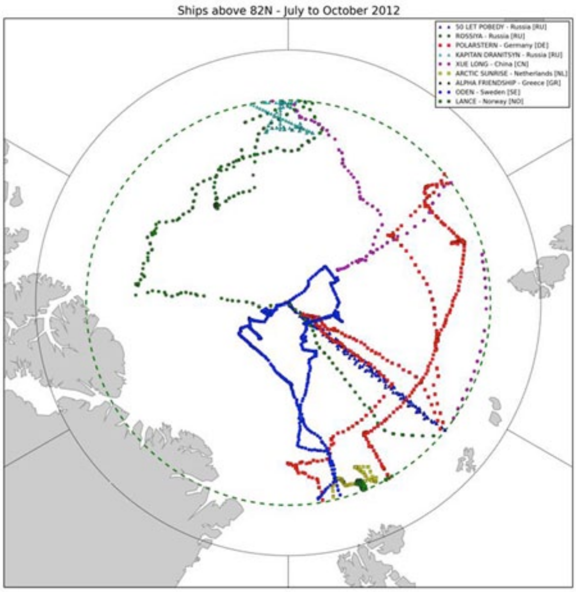
The reduced ice allows for an extended traffic along the north coast of Russia. It is expected that the traffic in 2013 will be more than doubled compared to the value in 2012. A number above 100 transits may be achieved. All the transits are regulated by the Russian authorities and imply support from heavy-duty ice-breakers. Even if the ice covers continues to be reduced with the current rate, the need for ice-breakers will continue for the near future through the Russian waters, at least at the edges of the season. Figure 10 shows the daily mean positions of ships during the 2010-2012 seasons. The dominant numbers come from the 2012 season.

The more direct route going north of the Russian water may open up for traffic of more ice hardened vessels within fifteen years. This would reduce the travelling time even more and would reduce the cost of icebreaker support. It may however be more risky because of limited communication, and poor ice forecasts as well as the safety of having a nearby ice-breaker. In addition the season would be shorter. If the gains are, in total, positive for a transporter, this traffic will come.

During 2012 there was extensive icebreaker activity in the central Arctic Ocean as shown in Figure 11. Much of this traffic was in connection with charting the sea floor and understanding the interaction between the diminishing ice cover and both the atmosphere and sea. From satellite measurements as well as the results from these scientific cruises it is clear that the area that will open first in the Arctic Ocean will be in the Norwegian/Russian sector. A probable entrance to the Arctic Ocean for a traverse will be close to Svalbard, probably on the East side. This can be seen in the image reproduced in Figure 12 of the sea ice area for late September 2013. Even if this is not the lowest area observed, a potential path is seen from the east side of Svalbard towards the Bering Strait.

4 "Potential movement of fish and shellfish stocks from the sub-Arctic to the Arctic Ocean", A. Babcock Hollowed, B. Planque and H. Loeng, Fisheries Oceanography, Vol 22, Issue 5, Pages 355-370.

Figure 11 Research vessels (and two recreational vessels) going north of 82 degrees during 2012.

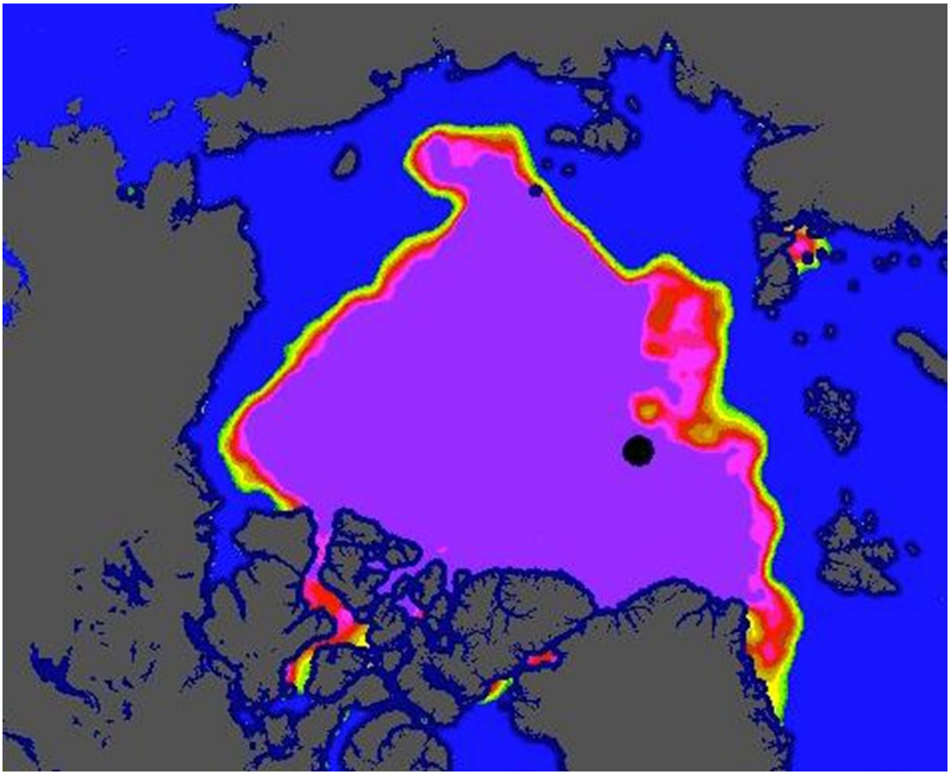


We must not underestimate the impact the coastal states regulations impose on the ship traffic. It is reasonable that Russia sets specific rules about the quality of ships travelling along their Arctic coast as well as the use of icebreakers. Under the Arctic Council, regulations have been made concerning the responsibility for search and rescue in the Arctic. One cannot exclude that this type of agreement may impose requirements concerning commercial traffic in more ice prone areas of the Arctic Ocean. These requirements would be based on a safety reasoning as well as environmental considerations.
A requirement of an adequate broad-band service may be a clear safety issue to impose on transarctic sailing.

V. Conclusions

For all ship traffic north of the Arctic Circle, 55-85% are in Norwegian waters. A large part of these areas have oil and gas resources as well as extensive and well manage fish stocks. Norway management of these areas require extensive use of satellite infrastructure. The dominant part of the needed space infrastructure comes from international cooperation. This satellite park uses to a great extent the ground stations established in Northern Norway and Svalbard. Historically the use of Satellite SAR has been the main source of information.

Figure 12 Minimum sea ice coverage in the Arctic from OSI SAF for 2013 (2).



From 2010 Norway launched its own AIS satellite that in close coordination with SAR imaging gives the full information about the vessel traffic in Norwegian waters. The AIS alone gives a near full coverage of vessels in the whole Arctic Ocean and bordering seas.

The reduces ice cover is an unfortunate result of global warming, but increases the possibilities for oil and gas exploration and exploitation closer to the pole. Additionally it seems as if the changing ice cover and increased ocean temperatures give rise to an areal extension of several renewable marine resources.

Apart from a sustainable harvesting of marine resources the biggest potential for environmental exploitation of the unfortunate sea ice reduction is in sea transport between Europe and Asia. An up to 50% reduction of travelling distance will give significantly less air pollution and sailing time in the four to five months of the sailing season. This must of course be weighted against an increased risk due to travelling in or close to ice-covered waters. It is clear that an extensive use of available and planned SAR satellites must be utilized to give better ice forecasts. These resources exist, but safe journeys close to the pole with hazardous cargo also requires the continuous availability of broad band communication. This does unfortunately not yet exist.

The availability of the Norwegian AISSat-1 has given a detailed picture of the sea traffic in the High Arctic. The continued investments from Norway in successive satellite platforms may extend this availability towards the time when transpolar transport becomes feasible and safe.