POLAR ICE: White Paper

Conclusions from the POLAR ICE project and its context in an evolving polar landscape

Nick Walker (28/07/2016)

1 POLAR ICE Overview

The FP7 POLAR ICE[i] project has developed a system for integrating and delivering satellite derived ice information products to operators working in the economically and environmentally important Arctic and Antarctic regions. POLAR ICE has been supported by the European Commission's FP7 programme[ii] and was undertaken by European and Canadian companies and institutes, who are all partners in the Polar View Earth Observation Limited (PVEO) company. It is the aim of PVEO to commercialise the service that has been developed as a part of POLAR ICE.

Access to sea ice information derived from satellite earth observation data is critical to support the increasing numbers of Arctic and Antarctic shipping and off-shore operations and to protect the rapidly changing polar environment. The POLAR ICE project has achieved its overall aims. A robust integrated ice information system has been developed capable of providing the best available products to end users operating in polar regions. Significant advances have been made to the range of available ice information products (in particular for ice forecasts, ice pressure and ice thickness products), including improving the spatial and temporal resolutions of products and expanding the regions for which they are available. Furthermore the POLAR ICE data integration system allows Polar operators to individually tailor the products to meet their specific working requirements and the product visualisation systems allow the end users to view and manipulate multiple images in a consistent manner.

A key part of the POLAR ICE project has been the engagement with end users who work in polar regions. A system is unlikely to have any impact if it is not properly aligned with what potential end users want. Thus the project's end user engagement began with an initial requirements gathering phase which provided useful input to help shape the design of both the products and the overall system functionality. Later a series of demonstrations were conducted in which selected end users made use of the POLAR ICE system in situ within their working environment. End users were chosen for the demonstrations to cover a range of applications, geographic regions and ice management requirements.

2 The Polar context

The context for the POLAR ICE project, i.e. the polar regions themselves are constantly evolving. Even during the relatively short time span (2.5 years) of the project, which began in January 2014 and ended in June 2016, there have been several economic and political factors which have changed significantly, which were not easily predictable. Meanwhile, predictably, climate change continues to have an effect on the polar regions. These factors are summarised below in relation to how they have impacted on the POLAR ICE project and how they might impact on a possible future service.

2.1 Economic

During the course of the POLAR ICE project the price of oil has approximately halved (from ~$100 to ~$50 per barrel), with the majority of the fall occurring in the second half of 2014. Prior to the oil price drop there was an increasing interest in oil exploration in the Arctic, which has now substantially slowed down. None of the POLAR ICE demonstrations were conducted directly with oil

and gas companies; however, several of the demonstrations were associated with support for oil and gas exploration. The feedback received from these companies was that they expected to be less active in the future and therefore saw less need for a POLAR ICE service, in addition to the fact that they see their overall economic outlook as uncertain.

A further consequence of the downturn in the price of oil was the unwillingness of oil and gas companies to collaborate with the POLAR ICE project in relation to work concerning how ice information could assist in oil spill clean-up operations. Previously this had been seen as a priority at a time of expanding interest in Arctic oil and gas exploration, but it quickly became seen an unnecessary expense after it became clear that their Arctic interests would be diminishing, and their overall economic positions were worsening.

However, the fact remains that large reserves of oil and gas exist in the Arctic[1] and the human race is no less dependent on fossil fuels than it was two and a half years ago. The main factor in driving down the price of oil has been the global downturn in the world economy. In time this may change again.

2.2 Political

2014 saw a Russian military intervention in Ukraine, which has prompted a number of countries and international organisations, including the European Union, to apply sanctions against individuals, businesses and officials from Russia and Ukraine.

During the course of the POLAR ICE project two opportunities arose for demonstrations, which were subsequently discontinued because of the political situation with Russia. In one instance the POLAR ICE project partners were concerned that a possible demonstration might be in contravention of EU sanctions and in the other a demonstration ended because the end-user was unable to continue its programme of work, which involved transporting gravel from northern Norway to the Yamal Peninsula in Russia for the construction of the new Sabetta port and liquefied natural gas (LNG) plant.

Relations between Russia and the EU will probably normalise eventually, but might be subject to further ups and downs along the way.

2.3 Climate change

The world's climate is continuing to change, leading to a diminution in Arctic sea ice. This change is therefore a continuation of the steady state which was entirely predictable, unlike the economic and political changes. The continuation of this trend is illustrated in *Figure 1* which shows the June Arctic sea ice extent values from 1979 to 2016, i.e. ending at the culmination of the POLAR ICE project. Arctic sea ice extent during June 2016 averaged 10.60 million km^2, which is the

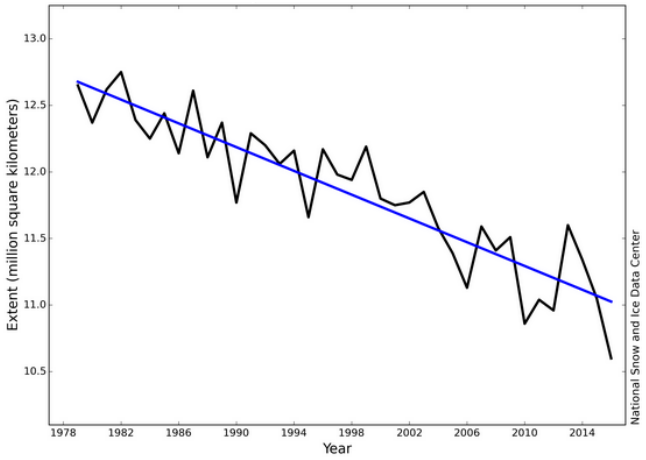

Figure 1. Average June monthly Arctic sea-ice extent. June 1979 to June 2016. Credit: National Snow and Ice Data Center.

[1] A US Geological Survey in 2008 estimated the natural gas reserves and 13% of its undiscovered oil.

lowest for this month over the period for which satellite records exist. So far, for 2016, March is the only month that has not set a new record low for Arctic-wide sea ice extent.

In general, the monthly June ice extent for 1979 to 2016 shows a decline of 3.7% per decade. It is likely that this trend will continue into the future, or possibly accelerate, because of various feedback mechanisms.

As was identified at the start of the POLAR ICE project the reduction in the Arctic ice extent increases the feasibility of shipping making use of the northern sea passages (east & west) to save time in comparison to longer southerly routes. Two of the POLAR ICE demonstrations involved vessels travelling across the northern sea passages; one across the North West Passage (over Canada), the other using the Northern Sea Route (over Russia). The decrease in the price of oil makes these shorter routes slightly less attractive than was previously the case, but, in general, the same incentives prevail and it is expected that transport will continue to increase in the Arctic. This will apply for cargo vessels, but also to ice breaking vessels travelling to and from operations. The POLAR ICE project demonstration involving the Tor Viking vessel's voyage through the Northern Sea Route (Figure 2) provided a particularly successful example of how having better access to sea ice information can make Arctic shipping voyages safer and more efficient.

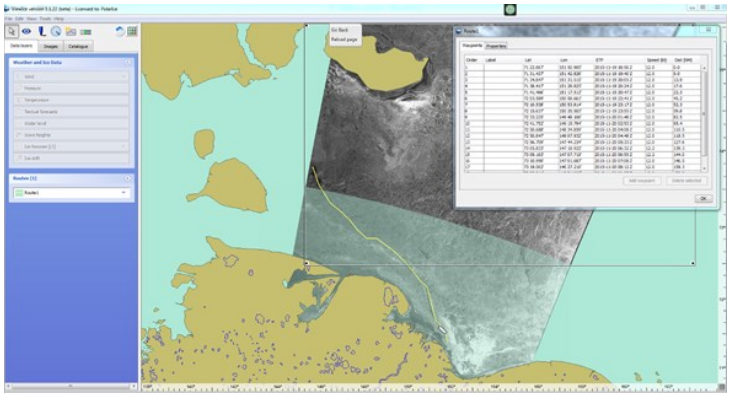

Figure 2. Route planning using the POLAR ICE ViewIce system for the Tor Viking passage over the Northern Sea Route.

The continued reduction in the Arctic ice extent and longer seasons of navigation is also expected to lead to further expansion in ship traffic for polar tourism. This is seen as a key area where accurate and timely sea-ice information is vital, because the prospect of a large passenger vessel sinking in either Arctic or Antarctic waters could very easily lead to a very large loss of life.

3 Demonstrating impact with Polar operations

Several specific aspects of the POLAR ICE service have been identified as having made a real impact on their working operations by the end users taking part in the project's demonstrations. These are summarised below under the headings: Sentinel-1 SAR imagery, Sea-ice Forecasts and Integration & Visualisation.

3.1 Sentinel-1 SAR imagery

It is well known that satellite borne Synthetic Aperture Radar (SAR) is particularly well suited for monitoring sea ice. For approximately 10 years ESA's Envisat satellite provided a plentiful supply of SAR data which was heavily used for polar sea ice monitoring. After Envisat was lost in 2012 the only practical alternatives for SAR data were provided by commercial operators, which introduced a cost element, which unless it was covered by national or international agreements meant that it was significantly more difficult to incorporate in operational systems. The POLAR ICE project coincided with the launch of ESA's satellite Sentinel-1a (April 2014) leading to a new freely available source of

SAR data imagery, which has been used extensively in the POLAR ICE project. Furthermore Sentinel-1b was launched in April 2016 and being, more-or-less a replica of Sentinel-1a will approximately double the acquisition revisit frequency, which will have a significant impact on its usefulness for users, especially with regard to the derived ice information products which involve tracking ice motion. However, Sentinel-1b arrived too late to be used in the POLAR ICE demonstrations.

During the development stages of the POLAR ICE project Sentinel-1a SAR data was incorporated into several of the ice information products, including ice thickness, ice drift and pressure. However, the SAR imagery itself was also packaged into simple SAR image products that were heavily subscribed during each of the end user demonstrations. These products took two forms: individual swath acquisitions and mosaics, formed by mosaicking multiple SAR swaths together over a given time frame (normally one to three days). In either case (individual swath or mosaic) the products were made available according to the end users' specifications in terms of their region of interest and the resolution (and hence data volume).

Several end users from the POLAR ICE demonstrations provided feedback regarding the impact the Sentinel-1 data had on their applications.

Figure 3. The Norwegian Coast Guard's KV Svalbard in the harbour at Longyearbyen, Svalbard.

The end users from the Tor Viking vessel reported that they would not have attempted to make their voyage through the Northern Sea Route in December 2015 without the aid of near-real-time satellite SAR imagery. The imagery assisted them in finding leads through the ice and helped them to avoid heavy ice, which was important for saving time and ensuring a safe journey. Furthermore it was reported that being able to find leads within the ice in some cases had led to increases in speed from 5 to 12 knots.

As a part of the Norwegian Coast Guard demonstration (Figure 3) in the high Arctic in February 2016 the Sentinel-1 products were found to be especially useful for assessing which regions contained higher and lower concentrations of sea ice, which can have a big impact on the fuel required to make progress. One of the features of the demonstration was the ship's crew's keenness to see the latest SAR data as soon as possible.

Figure 4. The Swedish Maritime Administration's vessel I/B Oden, which took part in the POLAR ICE Demonstration in the Nares Strait.

For the SPRS Petermann demonstration in the Nares Strait in August 2015 (Figure 4) it was reported that: "we had enormous help from the POLAR ICE system's ability onboard to download satellite images".

The Arctic fishing vessel, Yttersia AS, which took part in a demonstration in September 2015 also reported that Sentinel-1 data was especially useful for their applications. In general, fishing vessels navigate in the region close to the ice edge and sometimes going into leads in the ice, but they are not generally robust enough to break through ice. Therefore, the detail provided by a SAR image is much more instructive than just having a simple line which

approximately indicates where the boundary lies between sea ice and open water.

3.2 Sea-ice Forecasts

The sea ice forecasts provide the Danish Meteorological Institute (DMI) were found to be particularly useful in several of the demonstrations. The POLAR ICE project has provided a mechanism for the first time for distributing sea ice forecast information to Arctic navigators. The forecasts themselves contain information concerning ice drift, ice thickness distribution and ice deformation for up to five days into the future.

One of the ice management concerns affecting the seismic survey in the Greenland Sea, which was a part of a POLAR ICE demonstration in August & September 2015 (Figure 6) involving the Finnish icebreaker IB Otso, was the proximity of a large volume of "fast-ice" which was fixed in place along the eastern coast of Greenland. In general it is known that fast-ice in this location will eventually break free and travel southwards in the direction of where the survey was being conducted. It is therefore very valuable to have an understanding of when this significant change in ice conditions is likely to happen. As a part of the demonstration the ice forecast was able to predict this event and therefore to be better prepared for it.

Figure 6. POLAR ICE running on the Finnish icebreaker Otso's bridge off the coast of Greenland.

Figure 5. Using the ice forecast products to establish the prevailing ice drift to locate the vessel's position within the ice floes.

During the Norwegian Coast Guard demonstration in the high Arctic (Figure 5) the importance of timeliness of the data arriving and the role of forecasts became very apparent.

Sea ice is constantly moving because of winds, currents and tides. So the position of the ice might have changed substantially from that shown in a product that has taken several hours to arrive. The coast guard vessel, the KV Svalbard, encountered an example of this when tidal forces caused the gaps between the ice, which were clearly visible in a Sentinel-1 image in the morning, to have closed by the time a second image arrived later in the day. This illustrates that all of the non-forecast products are "historical" to some degree; therefore, in a changing ice environment the forecasts become very useful for providing information for "now".

One of the changes implemented after the Norwegian Coast Guard demonstration was to make the time steps in the ice forecasts finer in the near future and more coarse further into the future. This is

to allow sufficient temporal resolution to capture the tidal effects over the next couple of days, but to resort to a lower resolution (and hence a lower data volume) further into the future, when it is known that the forecast has a lower degree of accuracy anyway.

3.3 Integration and Visualisation

Significant feedback from the demonstrations was also received concerning the POLAR ICE integration and visualisation system as a whole.

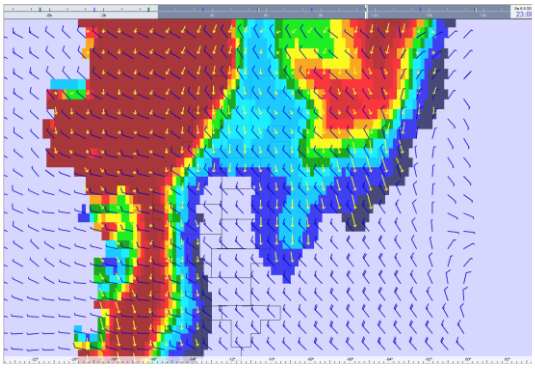

Figure 7. Forecast data in the Greenland Sea showing ice thickness, ice drift vectors and wind barbs were often displayed in POLAR ICE.

The seismic survey in the Greenland Sea was the first real opportunity to test the ice forecasts in the ViewIce visualisation system (Figure 7). Obviously forecast products require there to be a time dimension built into the system, which needs to be handled in a way that is intuitive for the end user. As a part of the seismic survey in the Greenland Sea the visualisation system was found to provide a good display of the forecast data, especially with regard to wind and ice drift.

Several of the demonstrations provided feedback concerning the value of having the vessel's position marked within the visualisation system. This allows the end user to quickly and intuitively see where they are in the context of both the background map and the ice conditions. Initially this functionality was not supported, but was introduced for the later demonstrations. Finally a tracking functionality was added which allows the user to see where they have been in the ice as well as where they are now.

The officers onboard the Ernest Shackleton demonstration in the Antarctic (Figure 8) provided very positive feedback on ViewIce and the data integration (IMS) system. The simplicity of ViewIce and the integration with the ordering & subscription was very well received.

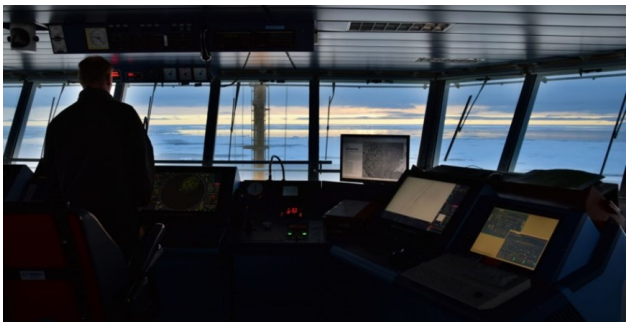

Figure 8. POLAR ICE running on RRS Ernest Shackleton.

Finally the innovation introduced for the Tor Viking voyage through the Northern Sea Route whereby the POLAR ICE products were made compatible with the vessel's Electronic Chart Display and Information System (ECDIS) system was reported as having made navigation easier.

4 Transitioning the POLAR ICE project into a sustainable service

The POLAR ICE project has also included a component devoted to examining the business case for transitioning the POLAR ICE project into a sustainable service. The POLAR ICE project will have the biggest possible impact into the future if this transition is successfully completed. A major part of the POLAR ICE project has been the end user engagement and particularly the end user demonstrations, which were conducted to test both the technical feasibility of the system, but also to gauge the

possible interest for future customers. At the time of writing the POLAR ICE Team, via the Polar View Earth Observation Limited company, is negotiating to provide the POLAR ICE service on a commercial basis in the Arctic.

5 Contact details

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[ii] POLAR ICE was supported by the European Union's Seventh Framework Programme (FP7). All opinions expressed are the authors.