Survey on the Use of Automated Products in Operations

Summary Report

Introduction

The process of producing ice charts for maritime operations involves the delineation and classification of sea ice and the identification and location of icebergs. Fundamentally, this is a remote sensing problem aided by numerical modeling of ice dynamics and evolution. As the volume of earth observation data from satellites has increased, so has the accuracy of near-real time ice analysis charts. Ice Services have realized for some time that, as the volume of data continues to increase, the ability of human analysts to make use of it all will reach a limit. It will simply be impossible for humans to manually assimilate and integrate all of the data to produce the best analysis possible.

Despite this well recognized need and many years of research, ice chart production remains a largely manual process critically dependent on the expertise of a relatively small number of human ice analysts. It is not clear how much assistance these analysts get from automated processes allowing their expertise to be deployed where it is most effective.

Under this hypothesis that automated analysis of satellite data is not as beneficial as it could be to Ice Service operations, and ultimately to maritime users, IICWG-XXII in September 2021 will feature a two-hour session to discuss the issue and what could be done to improve the use of automated analyses in the future. To validate this hypothesis and develop background for the session, a survey of Ice Services was conducted in June 2021. The survey was distributed to all Ice Service heads and responses were received from the Services of Argentina (SHNA), Australia (BOM), Canada (CIS), Chile (SMAC), Denmark (DMI), Finland (FMI), Norway (NIS), Russia (AARI), Sweden (SMHI), and the United States (NIC) as well as the British Antarctic Survey (BAS) and the International Ice Patrol (IIP).

Summary Discussion

Of the 12 responses received, 10 Ice Services report using automated image products in their operation. While this is a promising response, a drill down into the answers is revealing.

Low Resolution Sea Ice Products

The most mature automated product for sea ice monitoring is based on low-resolution (3-12km) passive microwave data such as AMSR2. Various implementations of this product have been available for many years and are the mainstay sea ice input for Numerical Weather Prediction and climate monitoring. However, as an ice information product for maritime operations, it is of limited use. Five of the 12 responding Ice Services issue sea ice edge and/or concentration products based on passive microwave data mainly because there is nothing better available in their areas of interest. This is an important default sea ice product in areas such as the Southern Ocean, where it

is the only near-real-time data available. The predominant uses are domain awareness, long range planning and strategic navigation (i.e. route selection days in advance).

Medium-High Resolution Sea Ice Concentration/Classification Products

All of the ice services use medium-high resolution (<1km) SAR data in their operations to support shipping and maritime operations. However, with a couple of notable exceptions described below, there is only limited use of automatically generated products based on SAR or optical data. SMAC is the only Ice Service that issues SAR-based sea ice edge and classification products in a "hands off" manner. A few Ice Services use automated SAR ice edge/classification products as trial fields or initial conditions or guidance to be reviewed and completed by human analysts. AARI notes that this saves 30-60 minutes of analyst time and SNHA reports variable timesavings. The other Ice Services generally feel that the automated products contain too many inaccuracies and artifacts to be of use. They say it is more efficient for the human analyst to produce an ice information product directly from the image than attempting to identify and correct problems in the automated product.

Sea Ice Thickness Products

FMI and AARI both use "sea ice thickness for thin ice" products based on SMOS and similar data. FMI issues this product to mariners for tactical navigation and operation planning in a hands-off manner that is considered one of the success stories of automated products. Unfortunately, the product is only valid for ice less than 50 cm thick so, although well suited to the Baltic Sea, it is of limited use in the Polar Regions.

Iceberg Detection

Five of the Ice Services use target detection software based on high resolution SAR and/or optical imagery. This is the most promising, widely used automated product. Targets detected automatically in SAR data are presented to human analysts for validation as icebergs or removal as ships or false targets. The analysts also ensure that previously identified icebergs have not been missed by the detection software. This manual editing process can be significant depending on the number of targets and icebergs involved but does save time and helps to ensure that icebergs are not missed. The time saved allows IIP analysts to devote more time to ensuring the accuracy of icebergs near the all-important North Atlantic iceberg limit.

Forecast Products

Seven of the 12 Ice Services use automated forecast products in their operation to produce short-, medium-, and long-term forecasts. Generally, the automated products are used by human forecasters as guidance in generating information for end users, although at least SMHI publishes the automated forecast on its website without human intervention. Besides forecasts of sea ice concentration and/or type, and sea ice and iceberg drift forecasts, three of the Services use automated products to issue warnings of sea ice pressure and abnormal ice conditions.

The Future of Automated Products

Almost all of the Ice Services surveyed reported that automatically generated ice information products would be beneficial in their operations. Several reported that work is underway within their organizations to develop the capabilities to incorporate automated products in their workflow. Products mentioned include:

- Sea ice classification from SAR
- Ice edge delineation – ice/water discrimination
- Estimation of ice concentration, particularly in the marginal ice zone
- Ice deterioration and thickness during the melt season
- Improvements in iceberg detection
- Sea ice drift and pressure forecasts

It is important to note that Ice Services need these products at a scale that is of use to navigation and maritime operations – typically less than 1 km resolution – and often finer.

The Ice Services are well aware of the many automated products that have been developed in research institutions. The main reasons that these have not been adopted in operations are a lack of detail, accuracy and robustness at the scales needed by mariners. These problems are most evident near the ice edge and during the melt season – precisely where and when the greatest number of mariners are in the vicinity of ice and need accurate ice information.

These deficiencies observed qualitatively by the Ice Services result in a lack of confidence in automated products. Many of the automated products currently available lack rigorous, published validation and verification to counter this lack of confidence.

Many Ice Services also report technical limitations and the lack of development and implementation resources as impediments to a greater use of automated products.

Conclusion

All of the Ice Services – even those not currently using automated products – are keen to take greater advantage of automation. Their main point is that doing so must provide measurable gains and greater efficiencies or improvements in the quality and quantity of their ice information services. With the notable exception of iceberg detection, this has not yet been demonstrated to be possible. Nevertheless, all of the Ice Services continue to undertake developments, as their resources permit, to make continual improvements in their processes and keep discerning eyes on advancements in the research community that will be of benefit.

ACRONYMS

AARI	Arctic and Antarctic Research Institute, Russia	IIP	International Ice Patrol
BAS	British Antarctic Survey	NIC	National Ice Center, United States
BOM	Bureau of Meteorology, Australia	NIS	Norwegian Ice Service, Norwegian Meteorological Institute
CIS	Canadian Ice Service	SMAC	Servicio Meteorológico de la Armada de Chile
DMI	Danish Meteorological Institute (Greenland)	SMHI	Swedish Meteorological and Hydrological Institute
FMI	Finnish Meteorological Institute	SHNA	Servicio de Hidrografía Naval de Argentina

Survey Responses

The survey questions are repeated below. A summary of the responses follows each question.

1. Do you use any automated image products in your ice service operation? YES / NO

   SMHI and NIC reported that they do not use automated image products.

2. What types of automated image products are used in your production processes?
   a. Sea ice edge delineation from low resolution (> 1 km) data such as from passive microwave or scatterometer?
   Three Ice Services indicated that they use AMSR2 data – SHNA, BOM and AARI.

   b. Sea ice concentration or type classification from low resolution (> 1 km) data such as from passive microwave or scatterometer?
   Four ice services (SNHA, BAS, NIS, AARI) responded that they use AMSR2 data for this purpose. In addition to the three Services that use it for ice edge delineation, NIS uses a 3.125km resolution product from AMSR2.

   c. Sea ice edge delineation from medium to high resolution (< 1 km) data such as SAR or optical?
   SMAC and AARI are the only Ice Services using these automated products. FMI responded that they have the product available but that it is not requested by users and is not used in ice charting.

   d. Ice/water discrimination from medium to high resolution (< 1 km) data such as SAR or optical?
   Only SMAC and BAS make use of this automated product. FMI reports having it in a development phase.

   e. Classification of sea ice into multiple ice types from medium to high resolution (< 1 km) data such as SAR or optical?
   Only SMAC indicated using this product.

   f. Sea ice thickness for thin ice from passive microwave interferometry (SMOS and SMAP), thermal infrared optical, or altimetry (CryoSat-2, Sentinel-3 and ICESAT-2)?
   AARI and FMI responded that they use this product.

   g. Iceberg density from low resolution (> 1 km) data such as from passive microwave or scatterometer?
   No Ice Service uses this product.

h. Iceberg location from medium to high resolution (< 1 km) data such as SAR or optical?

CIS, IIP, SMAC, DMI, and AARI all said they use this product. CIS and IIP noted that they use the C-CORE Iceberg Detection Software/System (IDS) as the core of the automated target detection process to extract targets from SAR data for the human analyst to accept or reject as icebergs. Sentinel-1, RCM, and Radarsat-2 are the primary data sources used. IIP also incorporates Sentinel-2 data.

i. Any others? Please specify.
CIS automatically extracts marine surface winds from all incoming SAR data. Products are made available through a dedicated web portal and shared broadly within the Meteorological Service prediction centres.

DMI uses a joint auto-generated CIS/DMI SIGRID3 product for the Northwest Atlantic. The most recent regional analysis is on top. They noted that yesterday's ice distribution is always the best and most accurate starting point for any update.

3. For each of the automated image products that you use, please indicate the extent to which they are used? For example:
   a. Issued to users in a completely "hands-off" manner with no human oversight?
   Three Ice Services provide some products in a "hands-off" manner. SMAC's automated products are issued this way. FMI produces an automated sea ice thickness chart that is issued without human action. DMI notes that a few selected users receive auto-generated satellite quicklooks in their mailbox.

   b. Quality inspection by human experts with authority to prevent dissemination.
   Three other Ice Services issue automated products after human inspection. BOM and AARI issue sea ice edge or concentration products generated from low resolution data. NIS issues the University of Bremen low resolution sea ice concentration product in this way.

   c. Quality inspection by human experts with ability to edit the product before dissemination.
   CIS, IIP, DMI and AARI produce iceberg location products originally generated automatically but with human editing to remove false targets or add missed icebergs from the database.

      i. How much time does this editing typically take?
      CIS reports that the time to process each image is reduced from 30 to 5 minutes because of the automation. IIP reports that their editing takes 20-45 minutes. DMI says that editing and dissemination of the product takes about 2 hours. AARI reports that product editing takes 30-60 minutes.

d. Used as a "trial field" or initial draft to be completed by human analysts?
SHNA, DMI, and AARI use automatically generated products as initial draft products to be completed by human analysts. DMI notes that automatically generated targets and polygons need significant manual editing before being sent to ships – a process that takes about 2 hours.

i. How much time does use of the automated draft save the analyst?
AARI notes that this saves the analyst 30-60 minutes while SHNA indicates that the time saved depends on the extent of the analysis area and the availability of other resources.

e. Used as reference by human analysts but not an integral part of the final product?
NIS and BAS use low resolution products as reference for human analysts.

4. For the automated image products that you do use substantially hands-off (a or b above), please describe the intended use for the product (e.g. tactical/strategic navigation, short/long range planning, domain awareness).
The predominant intended uses are domain awareness, long range planning and strategic navigation. SMAC and NIS note short range planning of a few days. DMI notes that some advanced mariners are able to use products to monitor changes and for tactical navigation. FMI says that its ice thickness product is used for tactical navigation and operation planning.

5. For any of the automated image products that you do not use substantially hands-off (c,d,e above), please identify the reasons that they are not used more (e.g. technical limitation, lack of confidence, insufficient detail/accuracy, redundant).
SHNA, CIS, IIP, DMI, NIS, and AARI cite insufficient accuracy and detail, or a lack of confidence as the main reasons they do not make more use of automated products. SHNA, SMAC, BAS, BOM, and AARI report having technical limitations. FMI says that users (icebreaker officers) get better information from plain SAR imagery than from automated products.

6. Do you use any automated forecast products in your operation?
a. Forecasts of sea ice concentration and/or type?
i. Short range (1-5 days)
FMI, SMHI, NIC, CIS, NIS, and AARI all use automated products for sea ice forecasts. Generally, the products are used by forecasters as guidance in generating information for end users, although SMHI also generates automatic forecast products for their webpage.

ii. Medium range (6-30 day)
SMHI, CIS, and NIS use automated products for 7-10-day sea ice forecasts.

iii. Long range (>30 day)

CIS, SHNA, NIS, and AARI use automated products as guidance for seasonal sea ice forecasts.

b. Iceberg density forecasts?

None of the Ice Services produce iceberg density forecasts.

c. Sea ice and/or iceberg drift forecasts?

FMI, SMHI, CIS, NIS, and AARI issue sea ice and/or iceberg drift forecasts based on model outputs. IIP uses iceberg drift and deterioration models to produce 24- and 48-hour forecasts of iceberg positions for particular vessels.

d. Sea ice or iceberg hazard forecasts?

NIS uses neXTSIM and GOFS3.1 on an evaluation basis to provide sea ice proximity warnings for fixed platforms in the Barents Sea.

i. Ice pressure

FMI and AARI issue ice pressure warnings and CIS is in the process of validating an ice pressure warning.

ii. Port or chokepoint congestion

No Ice Services issues this type of warning.

iii. Conditions exceeding those normally expected

FMI, CIS and AARI issue warnings for unusual conditions.

e. Any others? Please specify.

CIS issues warnings of rapid lead closing.

7. Are there other automated products that would be beneficial to your operation?

Almost all of the Ice Services reported that automatically generated ice products would be beneficial in their operations. Sea ice classification from SAR, ice edge, marginal ice zone, ice/water segmentation, estimation of ice concentration, ice deterioration and thickness during melt, iceberg detection, and sea ice drift and pressure forecasts were all mentioned as needed products.

a. What is currently preventing their use?

A lack of detail, accuracy and robustness at scales needed by mariners, contributing to a lack of confidence, are noted as the primary reasons that automated products are not used more. This is particularly true in the vicinity of the ice edge and during the melt season. Ice Services require verification that automated products meet the accuracy requirements of their product standards.

Several Ice Services say that technical limitations and a lack of resources for development and implementation prevent greater use of automated products in operations.

8. Do you have any other comments on this subject?
   In order to be useful in operations, Ice Services point out that use of an automated product must provide a time or quality advantage over a manual production process. Except for a few notable exceptions, particularly iceberg detection, this has not been shown to be the case thus far.

   The automation used at IIP is designed to strike an appropriate balance between allowing the computer to reduce the amount of time that analysts must spend downloading imagery and executing repetitive, standardized procedures. The goal is to automatically detect and filter through targets, allowing the analyst more time to evaluate and make decisions on the classification and fate of critical icebergs in BAPS i.e., those close to the transatlantic shipping lanes.

   CIS notes that ECCC researchers working on Numerical Weather Prediction have developed some robust approaches to ice (and wind) data assimilation, and that while these are using SAR, they rely on coarser scale statistics (i.e. 1-2 km). With NWP outputs often being used for ice forecasting (rather than imagery directly), automation in NWP using SAR as an input is another way in which data is already being used effectively in support of ice center operations and ice forecast products.

   NIS suggests that there seems to be too much focus on seeking a single algorithm and sensor to do everything, rather than breaking the problem down into smaller components that stand a better chance of success, e.g. separate algorithms and potentially different sensor sources for ice edge, fast ice, drift ice thickness and type, different seasons, etc. A more heuristic approach is needed, similar to that of the analyst.

   For general awareness of Arctic/Antarctic sea ice, some model data may be "good enough". Obviously, this "good enough" threshold needs to be evaluated, explored and ultimately verified. The level of detail that is needed for actual mariners would always need to be a separate product from the model data. Perhaps it is time to consider this as a viable option to putting in the intensive analyst production of charts and move on to specialized tailored support or support of each operational center's national interests.

END OF SURVEY
Thank-you for your response.