NRC Canadian Arctic Shipping Risk Assessment System (CASRAS): Report for Fiscal Year 2021-22

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Executive Summary

In the Canadian Arctic, communities are heavily dependent on ships for dry cargo and fuel. The safety and efficiency of these marine operations can be enhanced through better access to environmental data and regional information. The present report summarizes the progress on the project *CASRAS: A Tool for NWT Marine Trade Corridor Efficiency, Reliability and Safety* during the period April 1, 2021 to March 31, 2022 (government fiscal year 2021-22).

The Canadian Arctic Shipping Risk Assessment System (CASRAS) is a map-based software tool for viewing and analyzing Arctic data – with a focus on ice – relevant to shipping operations. The platform was initially developed through internal funding from NRC's Arctic Program. In 2019, Transport Canada selected CASRAS as a project to be funded under the National Trade Corridors Fund (NTCF). The aim of this 5-year project is to build upon the CASRAS platform and provide enhanced tools to northern partners – to improve marine trade corridor efficiency, reliability and safety in the western Arctic. The main activities include compilation of environmental data and mariner knowledge, and integration of short-term and longer-range ice hazard forecasts.

The CASRAS software was used by the Government of the Northwest Territories in the 2022 Arctic summer shipping season for their marine activities including community resupply. CASRAS is also currently used by groups at Transport Canada, Canadian Coast Guard and Department of National Defence. These groups have collaborative agreements with NRC and provide funding and support that is outside of the NTCF project. All CASRAS user groups regularly provide feedback and information, which NRC uses to improve the system and bring benefits to all user groups. In this way, NRC provides its own contributions to the NTCF project.

The main development for the CASRAS software in FY21-22 was the addition of short term, regional ice forecasts to the system. Updated software with this new functionality was deployed to all end users in June 2022. Previously, users had access to historical data and daily ice charts. Now, NRC's Ice Dynamics Forecasting System is being used to generate 2-day, high-resolution ice forecasts that are integrated into CASRAS. This allows users to view and analyze the predicted ice thickness, concentration, ridging and pressure along a planned route.

General development of the CASRAS software continued in FY21-22, including bugs fixes and incorporation of datasets of interest to the stakeholders. Notably for FY21-22, NRC collaborated with the Canadian Hydrographic Service to obtain bathymetry data in a format that can be displayed in CASRAS. This allows CASRAS users to view public, non-navigational hydrographic survey (multi-beam) bathymetric data for the Arctic. Other new features include capability to view ice risk indices modified based on observation of decayed or ridged ice, and capability to view US ice charts in addition to the Canadian charts.

Development is also ongoing for NRC's Sea Ice Forecasting Neural NETwork (SIFNET) system, whose products will be incorporated into CASRAS beginning later in FY22-23. This will provide users with a longer range (up to 90 day) forecast of the likelihood of ice presence. Seasonal forecasts allow for risk assessments that include the effect of climate trends on ice formation and break-up.

Finally, in FY21-22 work began on a new CASRAS web application with some key data sets from the CASRAS platform. The present software is available only on USB hard drives, which limits NRC's ability

to deploy to multiple end users. End users, especially those from younger generations, have commented that a web app would be heavily utilized.

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Abbreviations

CASRAS: Canadian Arctic Shipping Risk Assessment System

CCG: Canadian Coast Guard

CHS: Canadian Hydrographic Service

CIS: Canadian Ice Service

ECCC: Environment and Climate Change Canada

Government of NT – MTS: Government of Northwest Territories – Marine Transportation Services

IRC: Inuvialuit Regional Corporation

NRC: National Research Council Canada

NTCF: National Trade Corridors Fund

TC: Transport Canada

TC-MSS: Transport Canada - Marine Safety and Security

DND: Department of National Defence

DRDC: Defence Research and Development Canada

RCN: Royal Canadian Navy

1. Introduction

1.1. About CASRAS and the NTCF Project

The Canadian Arctic Shipping Risk Assessment System (CASRAS) was developed by the NRC to provide individuals and organizations with a stand-alone software platform for collecting and analyzing Arctic marine information relevant to shipping and icebreaking operations. Development of the software began in 2014 as an internal project under NRC's Arctic Program. The ultimate objective has been to empower users to assess Arctic marine risks and increase the safety of shipping activities. Background information on the CASRAS project can be found in Charlebois et al. (2017) and Kubat et al. (2017). The system was also referred to in Greenwood and Kubat (2018).

In 2019, the NRC received funding to launch the next phase of CASRAS development and deployment with Territorial partners under Transport Canada's National Trade Corridors Fund (NTCF). This project builds upon the learnings of previous deployments of the CASRAS software platform with the Canadian Coast Guard and Memorial University and is introducing novel technologies to the marine industry and Territorial partners. Specifically, the CASRAS NTCF Project seeks to integrate regional marine information and advanced sea-ice forecasting tools in order to improve the efficiency, reliability and safety of marine trade in the Western Arctic corridors.

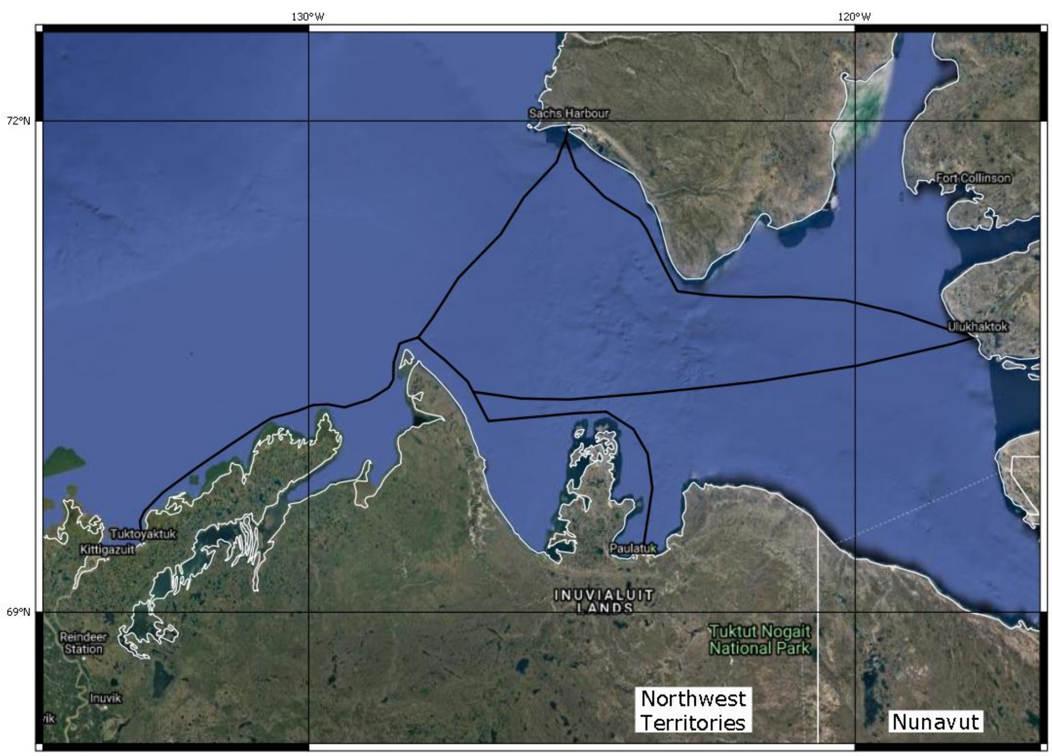


Figure 1. Primary shipping routes (black lines) used by Government of Northwest Territories Marine Transportation Services for delivery of goods to communities of the Canadian Western Arctic and Inuvialuit Settlement Region. Approximate routes courtesy of Tom Maher.

1.2. Project funding

The 5-year CASRAS NTCF project runs from fiscal year (FY) 2019-20 through 2023-24. It is jointly funded by TC and the NRC, with TC funding no more than 54.55% of the total eligible expenditures up to a maximum of $900,000 over the project lifetime. NRC is providing its own contributions through internal research and development expenditures, efforts on related projects, and grants to academic collaborators. The project team has also formed partnerships and collaborations to enhance the project. These partnerships are in the form of in-kind contributions, data sharing agreements and software use agreements.

1.3. Project participants and collaborators

To date, the NRC has engaged with key project participants from the Government of Northwest Territories (Department of Infrastructure - Marine Transportation Services, the Canadian Coast Guard, Transport Canada (Transportation and Infrastructure Programs, and Marine Safety and Security), and the Inuvialuit Regional Corporation. Through presentations, meetings and information exchanges, the CASRAS NTCF project team has gathered data to continue to align development tasks with end-user needs. Details of these engagements are provided in Section 4 of this report.

In-kind from Government of Northwest Territories' Marine Transportation Services to date has included valuable information on vessel operations and knowledge gaps in the Western Arctic. CCG has also provided information on those topics from the point of view of their vessel operators in that region. In the summer of 2021, Government of NT - MTS used CASRAS onboard their vessels and in their offices to complement their operations. Separately from the NTCF project, NRC has signed technical service and software use agreements with CCG, TC-MSS, and DND-DRDC. These groups are using CASRAS onboard vessels and/or in their offices, and providing feedback on system performance and applicability of the information to Arctic marine operations. TC-MSS is providing information on their Places of Refuge and Arctic pleasure craft safety initiatives. Developments arising from these arrangements are incorporated back into CASRAS for the benefit of the NTCF project.

NRC is also actively collaborating with other government departments to improve the CASRAS platform. In FY21-22, the project team worked with the Canadian Hydrographic Service to obtain public bathymetry data in a format which could be ingested by CASRAS. The Canadian Ice Service provides access to historical and current ice charts, which constitute an important data set in CASRAS.

1.4. Project timeline

The CASRAS NTCF project consists of several phases or components including:

- **Project design**: consultation with stakeholders to assess gaps in knowledge or in available tools; formulation of project plans including the use of CASRAS by partners; assessing feedback on CASRAS platform
- **Development of datasets**: compilation of datasets of interest to partners, and integration with the CASRAS platform
- **Integration of short-term ice forecasts**: integration of high resolution 2-day ice forecast products, from an existing NRC technology, with CASRAS for the Western Arctic

- **Integration of seasonal ice forecasts**: development of new technology for predicting ice presence at a longer (seasonal) range, and integration with CASRAS
- **Ice forecast validation**: validation of the short-term and longer-range ice forecasts, with feedback from end users
- **Training**: provision of training on the CASRAS platform to end users.

The approximate timeline for the components of the CASRAS NTCF project is shown in Figure 2.

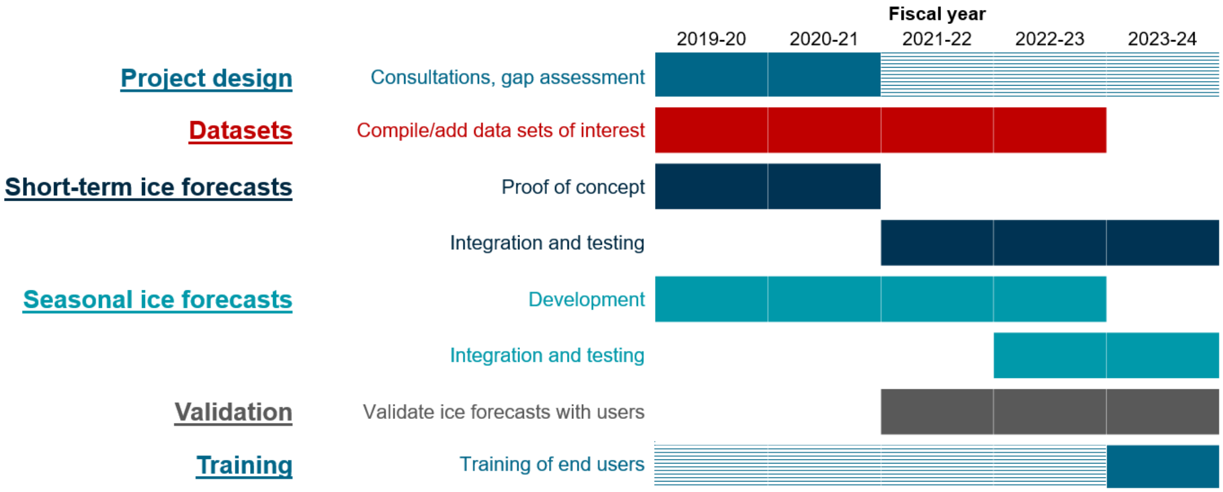


Figure 2. Timeline of CASRAS NTCF project.

2. Project progress to date

2.1. Summary of progress

At the end of FY2019-20, the project design stage, including feedback obtained from stakeholder consultations, had concluded. Consultations of a more detailed nature took place with project partners in FY2020-21, as well as signing of agreements as needed. A proof of concept was demonstrated for the integration of NRC short-term (2-day) Ice Dynamics Forecasting System products, and NRC collaborated with CHS to obtain bathymetry data in a format which can be displayed in CASRAS. A collaboration agreement was formed with University of Waterloo to aid the development of NRC's seasonal ice forecast system.

In FY2021-22, NRC completed integration of its short-term (2 day) Ice Dynamics Forecasting System products in CASRAS. Ice forecast maps can now be read, displayed and analyzed in CASRAS. Development is ongoing for the Sea Ice Forecasting Neural NETwork (SIFNET), whose products will be incorporated into CASRAS later in the project. Also in FY2021-22, the integration of bathymetry data was completed so that CASRAS users can now view public, non-navigational hydrographic survey (multi-beam) data collected by CHS onboard numerous vessels.

2.2. Project design and collaborations

The project design stage essentially concluded in April 2021, although ongoing input from stakeholders will continually be assessed as the project evolves. For example, additional datasets of interest to partners will continue to be integrated into the CASRAS platform as time allows. The overall aim of the CASRAS NTCF project is to integrate regional information and advanced sea-ice forecasting tools in order to improve the efficiency, reliability and safety of marine trade in the Western Arctic corridors.

NRC has focussed on bringing partners into the CASRAS collaboration to the mutual benefit of all. NRC's current partners on the CASRAS project, with a brief summary of their involvement, are:

- Government of NT - MTS: have been provided CASRAS software for their use and evaluation in the Western Arctic.
- TC-MSS: are using CASRAS to support their regulatory role; will provide in-kind data on Potential Places of Refuge to be incorporated into the platform by NRC, and shared with all end users.
- DND-DRDC and RCN: CASRAS is used in the Atlantic Research Centre, for operational support to the RCN, research and training purposes, and onboard vessels including the new Arctic Offshore Patrol Vessels. HMCS Harry DeWolf used CASRAS heavily during its sea trials in ice in winter 2021.
- CCG: CASRAS is used onboard CCGS Sir Wilfrid Laurier, which operates in the Western Arctic region, as well as onboard several other CCG vessels and in the Montreal Regional Operations Centre.
- ECCC-CIS: Ice Service Specialists are using CASRAS as part of their support to CCG when onboard Arctic-going vessels.

In addition, feedback from all partners is regularly sought and used to enhance CASRAS and guide its development.

2.3. Development of CASRAS software and datasets

During FY2021-22, development of the CASRAS system and its datasets was ongoing. A number of improvements were made to the software performance and fixes made to identified bugs. Existing datasets and documentation were updated or augmented as needed. Figure 3 shows CASRAS being used onboard a vessel, along with the main user interface of the software. CASRAS presently contains 81 datasets and over 220,000 files, for a total of approximately 250 GB of data. An example view of some datasets within the CASRAS software is shown in Figure 4. Some new features added to CASRAS in FY2021-22 are highlighted in the sections below.

Figure 3. Left: CASRAS software being used onboard a vessel in summer 2017 (image courtesy of Captain D. Fowler); right: launch screen of CASRAS software.

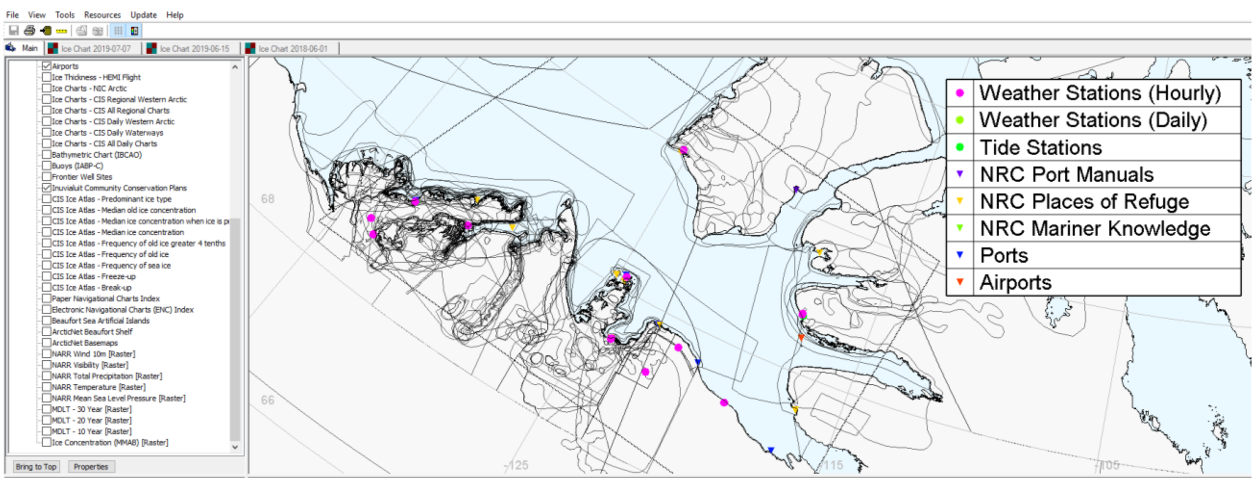


Figure 4. Example view of several datasets in CASRAS. Community conservation and land use plans are shown as black outlines on the map, but do not appear in the legend.

2.3.1. CHS non-navigational bathymetry

The NRC team worked with the Canadian Hydrographic Service (CHS) to obtain permission to include their publicly-available bathymetry data in the CASRAS platform. Access to good bathymetry data has been noted by project stakeholders as an area of interest. The NONNA products represent a consolidation of digital bathymetric sources managed by the CHS – mainly hydrographic survey, or multi-beam, data that has been collected by CHS onboard numerous vessels such as those of the CCG.

CASRAS presently includes all available CHS NONNA data at 100 m and 10 m spatial resolution for the Arctic domain. Example views of the NONNA 10 m data for the Western Arctic is shown in Figure 5.

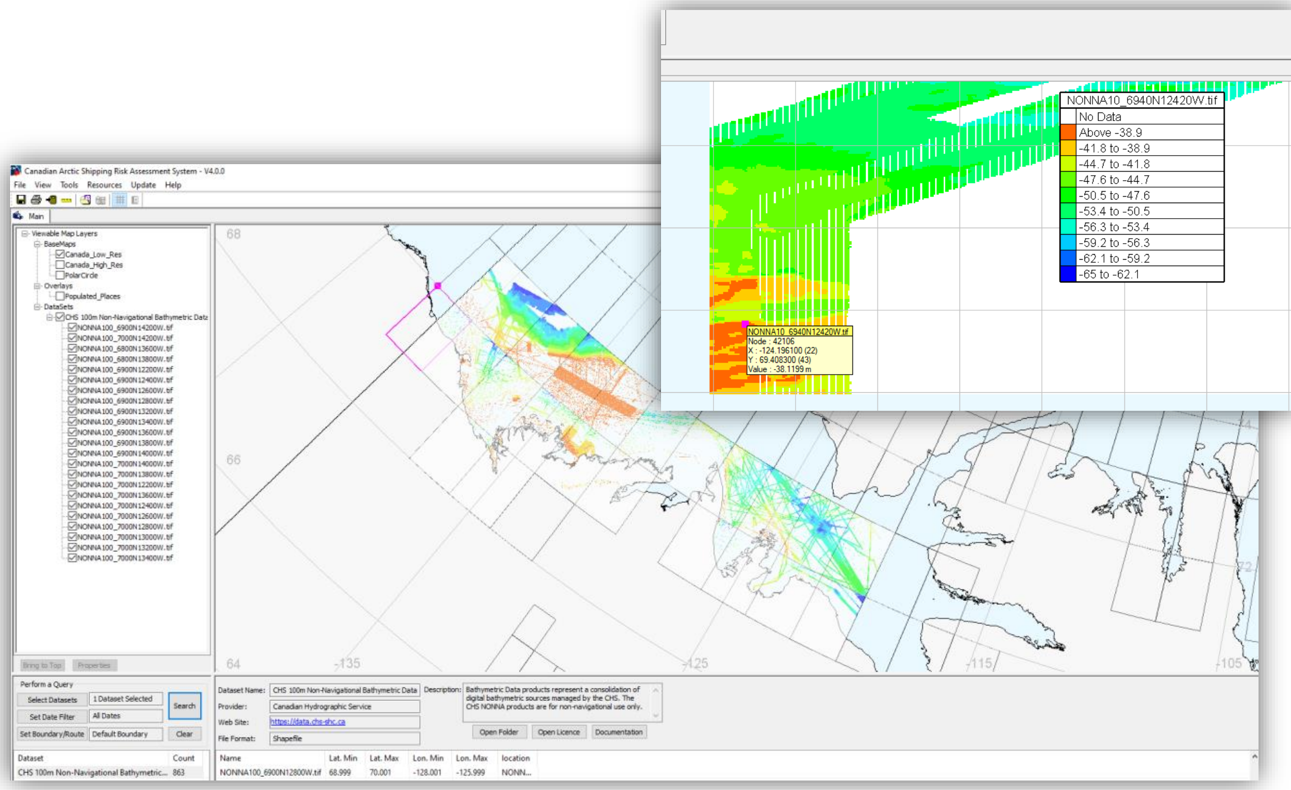


Figure 5. Example views of CHS non-navigational (NONNA) data at 100 m resolution (large image) and 10 m resolution (inset image) within the CASRAS platform.

2.3.2. Display and analysis capability for USA National Ice Centre charts

At the request of one of the CASRAS user groups, the team added the capability to view and analyze ice charts from the US-based National Ice Centre (NIC). NIC charts are produced weekly and give a full circumpolar view of ice conditions. This compliments the existing Canadian Ice Service charts (which are regional and higher-resolution) already in CASRAS. As with CIS charts, CASRAS users can analyse NIC charts in the system to view and analyze the available attributes within the ice chart.

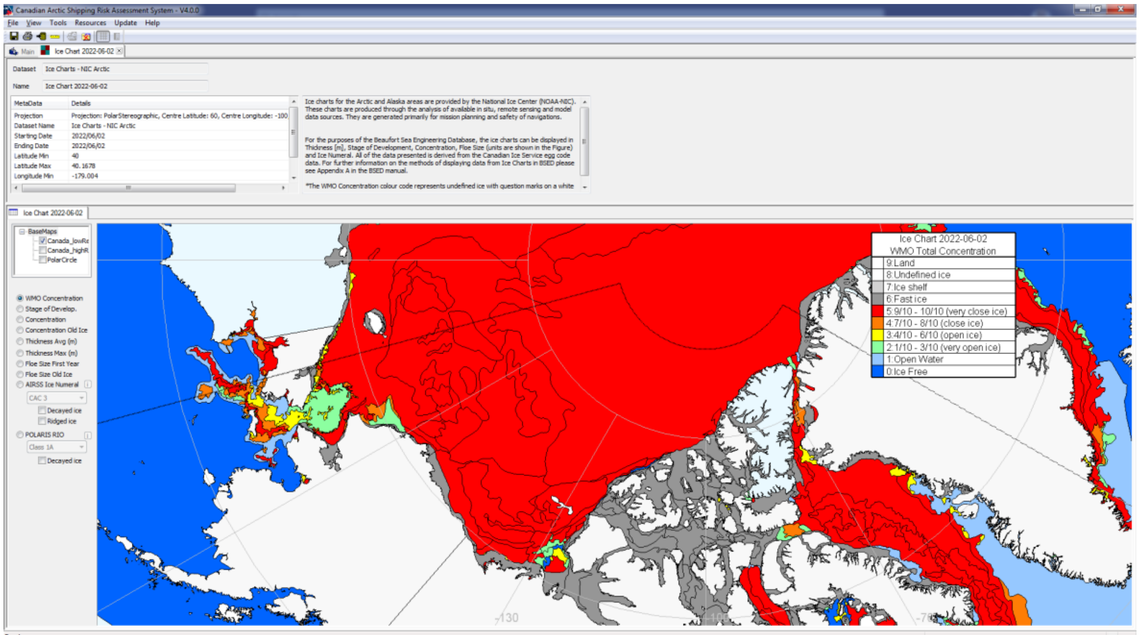


Figure 6. Example of NIC chart for 2 June 2022, viewed within CASRAS.

2.3.3. Enhancement to AIRSS Ice Numeral and POLARIS Risk Index Outcome analysis

In FY2021-22, at the request of CASRAS users, a new capability was added to the system for the display of modified risk indices based on the condition of the ice. “Decayed” sea ice has warmed and weakened in the spring/summer season, and thus generally poses less of a hazard to ships than colder ice of the same thickness. If decayed ice is observed from a vessel, guidelines allow for a reduction of the risk index and potentially for the vessel to travel into areas that otherwise would not be recommended. Ridged ice is the opposite: pressure ridges can impede vessel transit more so than level ice. In CASRAS, the Ice Numeral calculation may now be modified for either decayed ice or ridged ice, according to AIRSS guidelines (Transport Canada, 2018). For POLARIS calculations (International Maritime Organization, 2015), a modified Risk Index Outcome may now be displayed in CASRAS for decayed ice. POLARIS does not include a modifier for ridging. Figure 7 (blue arrow) shows the new toggle buttons in the CASRAS ice chart analysis display.

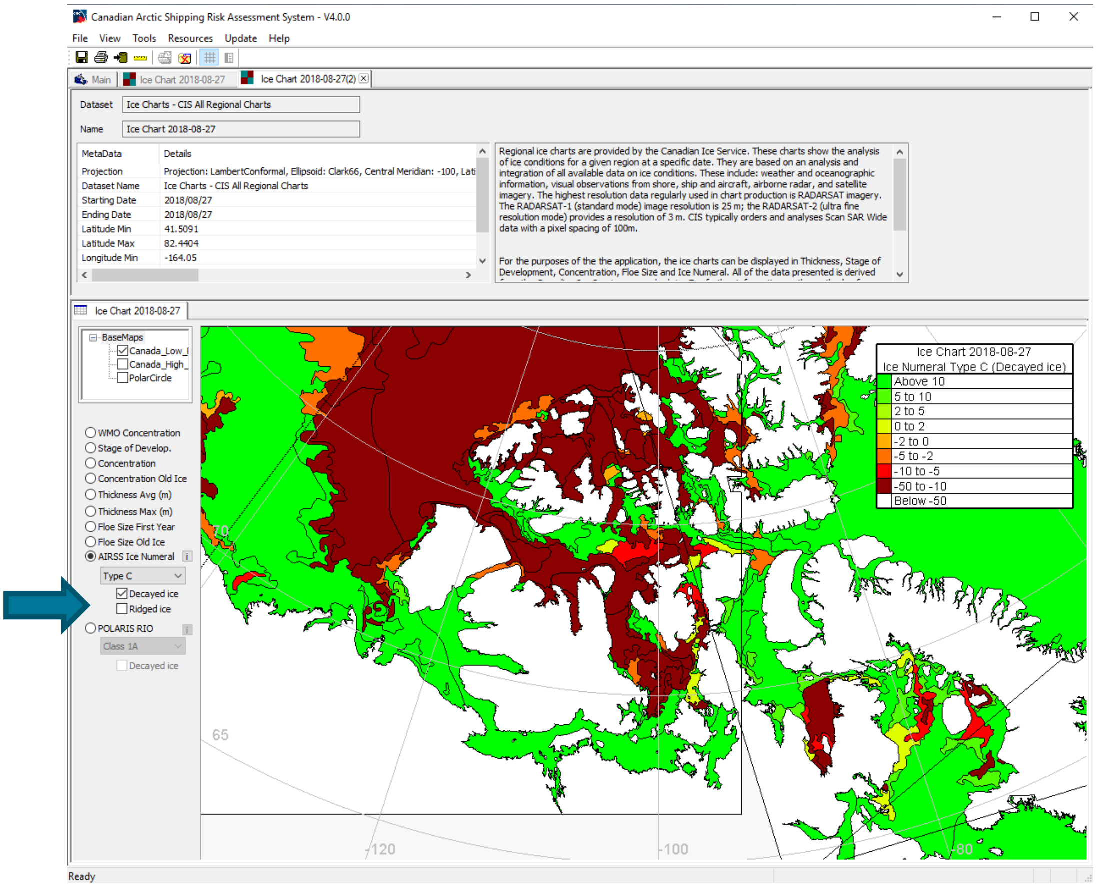


Figure 7. Example analysis of ice conditions for 27 August 2018 for a Type C vessel. The AIRSS Ice Numeral is calculated with a decayed ice modifier.

2.4. Integration of short-term sea ice forecasts

Northern shipping operations depend on up-to-date knowledge of ice conditions. Development and sharing of tools to accurately predict ice movement is an important part of the CASRAS NTCF project. Availability of information to assess short-term ice dynamics has been noted as a gap by vessel operators and Captains in the Western Arctic, as well as in most other Canadian regions with ice. In FY2020-21, a proof-of-concept for the integration of short-term sea ice forecasts into CASRAS was completed. In FY2021-22, the ice forecasts were fully integrated and deployed to end users in the latest version of the CASRAS software.

An existing technology, the NRC Ice Dynamics Forecasting System, is used to generate products that are ingested by CASRAS. Figure 8 shows an example output from the Ice Dynamics Forecasting System for the Western Arctic. This forecasting system gives high resolution, regional, 2-day ice forecast products which have been used operationally by industry and government partners for a number of years (for more information on the governing equations used in the model for ice dynamics and thickness evolution, see Kubat et al., 2016). The system inputs, general overview of the numerical model concept, and products are summarized in Figure 9. Several examples of sea ice dynamics forecasts as viewed inside CASRAS are shown in Figure 10 for the Western Arctic, and Figure 11 for the Eastern Arctic.

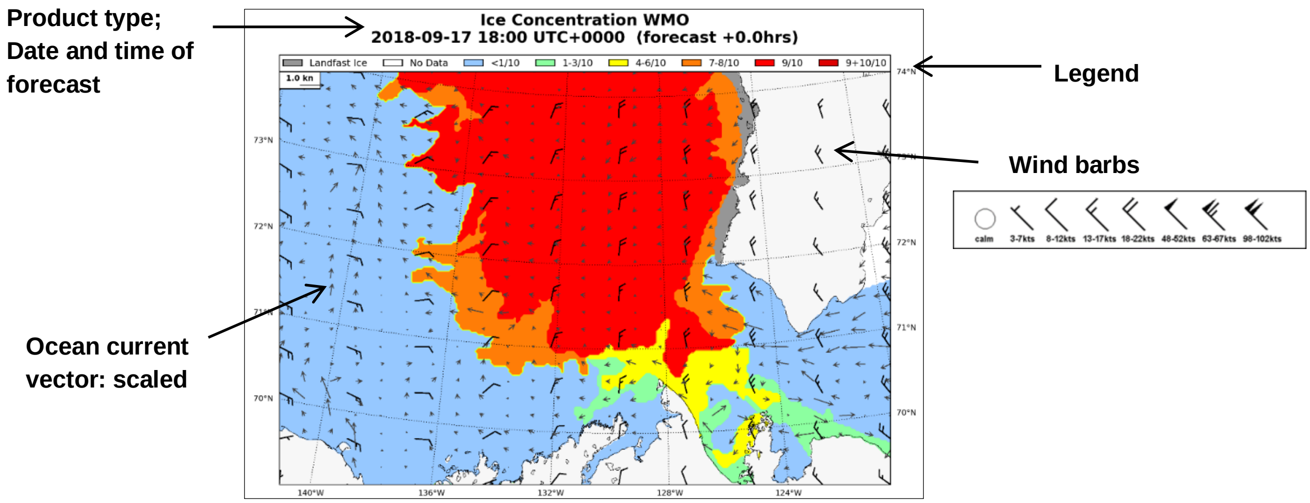


Figure 8. Example of one output (ice concentration) from NRC Ice Dynamics Forecasting System.

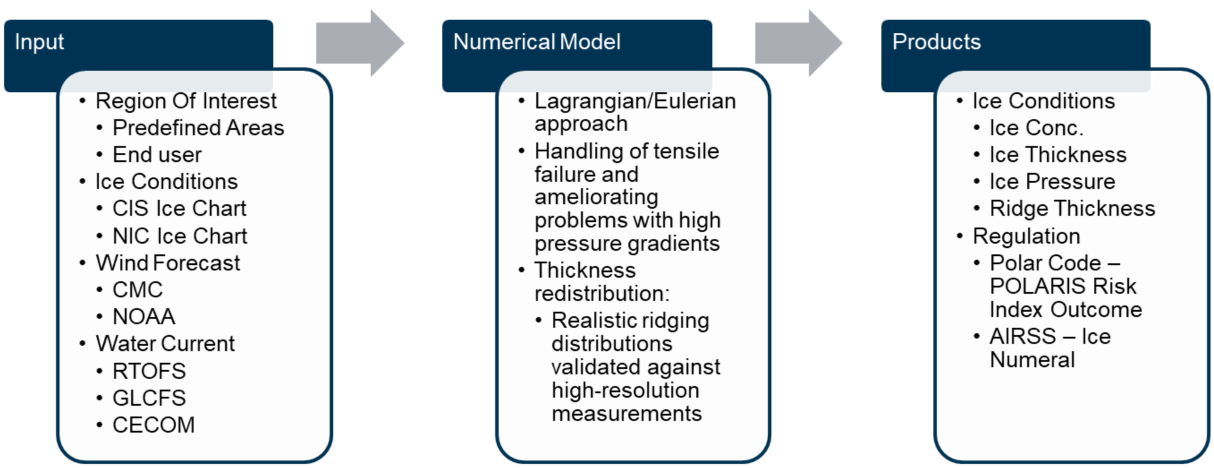


Figure 9. Overview of NRC Ice Dynamics Forecasting System inputs, numerical model concept, and output products.

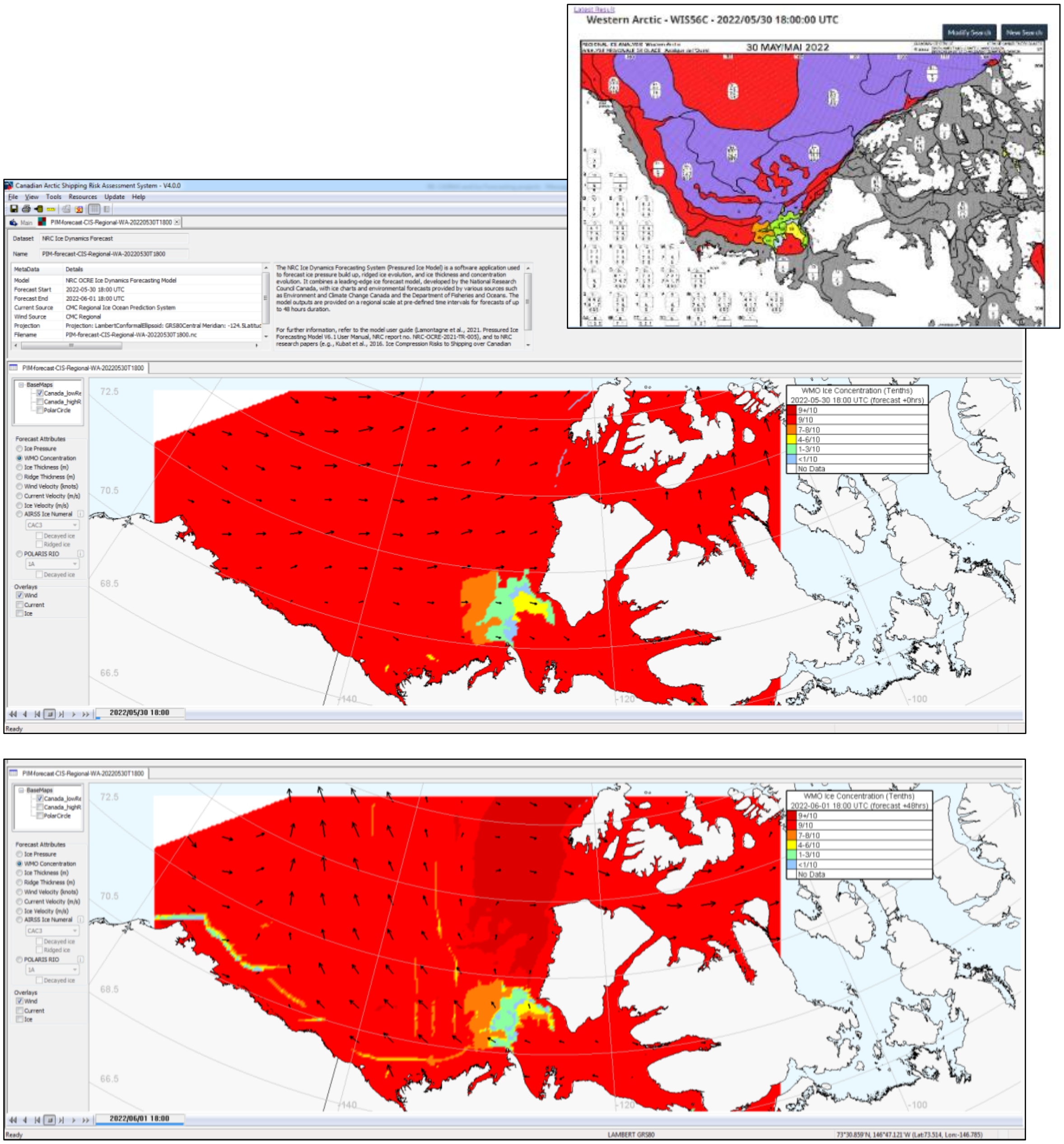


Figure 10. Example of NRC Ice Dynamics Forecasting System outputs for western Arctic (30 May – 1 June, 2022) viewed in CASRAS. Top: large map shows initial ice concentration, interpreted from the CIS ice chart (inset image). Bottom: 48-hour forecast of ice concentration. Arrows indicate the direction of ice movement.

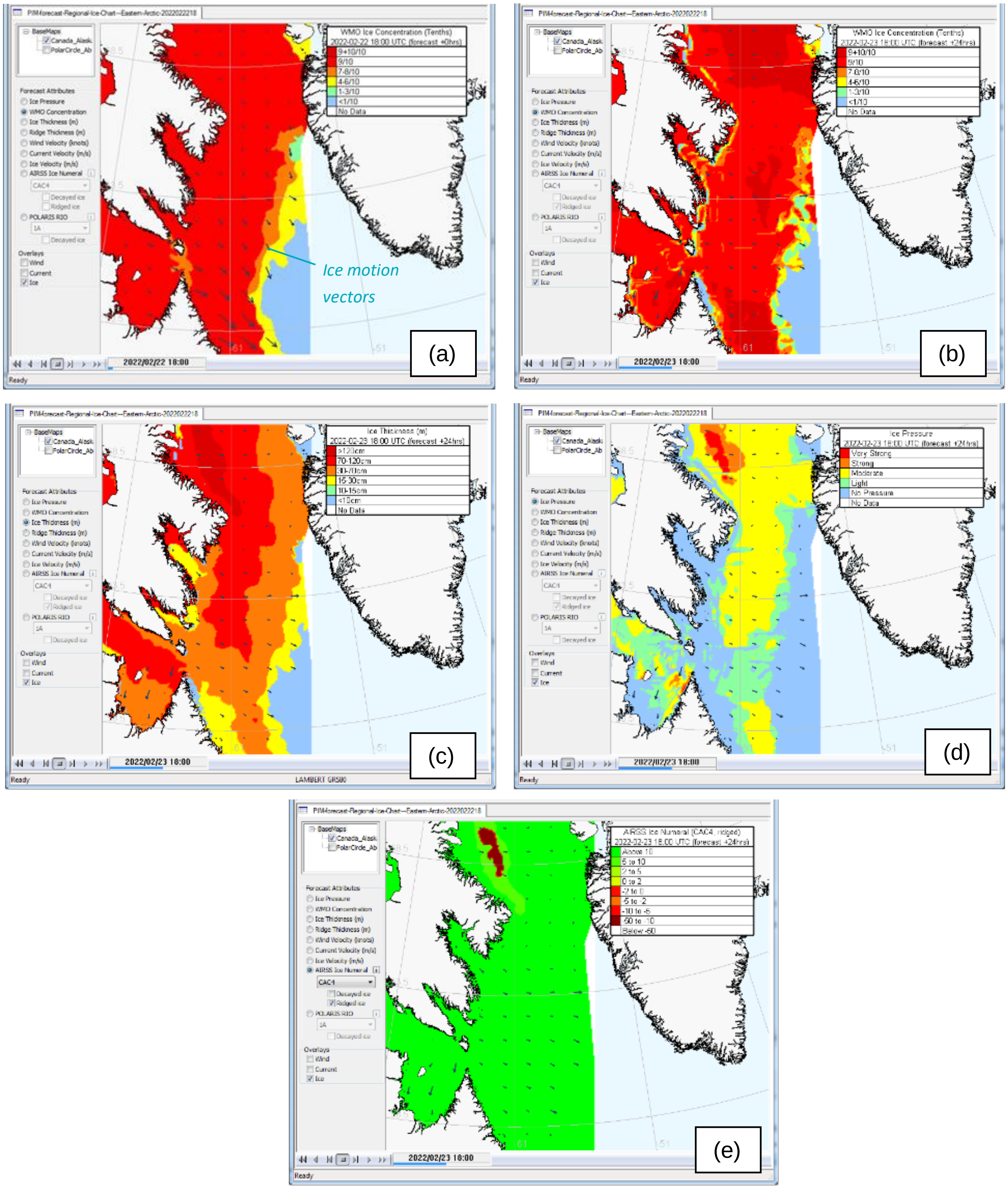


Figure 11. Examples of NRC Ice Dynamics Forecasting System outputs for the eastern Arctic for February 22, 2022, as viewed in CASRAS. Shown are (a) initial ice concentration; (b) 24-hour forecast of ice concentration; (c) 24-hour forecast of ice thickness; (d) 24-hour forecast of ice pressure; (e) 24-hour forecast of AIRSS Ice Numeral for a CAC4 vessel in ridged ice. Ice Numerals give an indication of go (green) and no-go (red) conditions for the given vessel, based upon forecasted ice conditions.

2.5. Integration of seasonal ice forecasts

Advance planning of shipping operations depends on longer-range ice forecasts. In addition to the short-range ice dynamics forecasts described above, the NTCF project included the development of new technology for predicting ice presence at a longer (seasonal) range and integration with CASRAS. In 2018, NRC initiated the development of the Sea Ice Forecasting Neural NETwork (SIFNET), an artificial intelligence or machine-learning approach to predicting the presence of sea ice up to 90 days in advance (Lamontagne et al., 2020).

During FY2021-22, NRC finalized the development and validation of the first SIFNET model prototype. The paper by Asadi et al. (2021) was presented virtually at the International Machine Learning Society conference in July 2020. This publication was followed by the journal paper by Asadi et al., (2022) describing the SIFNET model architecture, validation framework and model accuracy. This major milestone was accomplished in collaboration with the University of Waterloo. Dr. Andrea Scott was the academic principal investigator, and Dr. Nazanin Asadi was hired as a full-time post-doctorate funded through a grant from NRC's AI4Logistics program.

The proposed system provides daily spatial maps of sea ice presence probability for lead times up to 90 days using a spatio-temporal forecasting method based on sequence-to-sequence learning. The general network architecture is shown in Figure 12. The basic model required as input met-ocean conditions over the last 3 days, and forecast daily ice presence probability over the next 90 days. An improved ("augmented") version of the system also ingests as input the ice presence climatology to improve the accuracy.

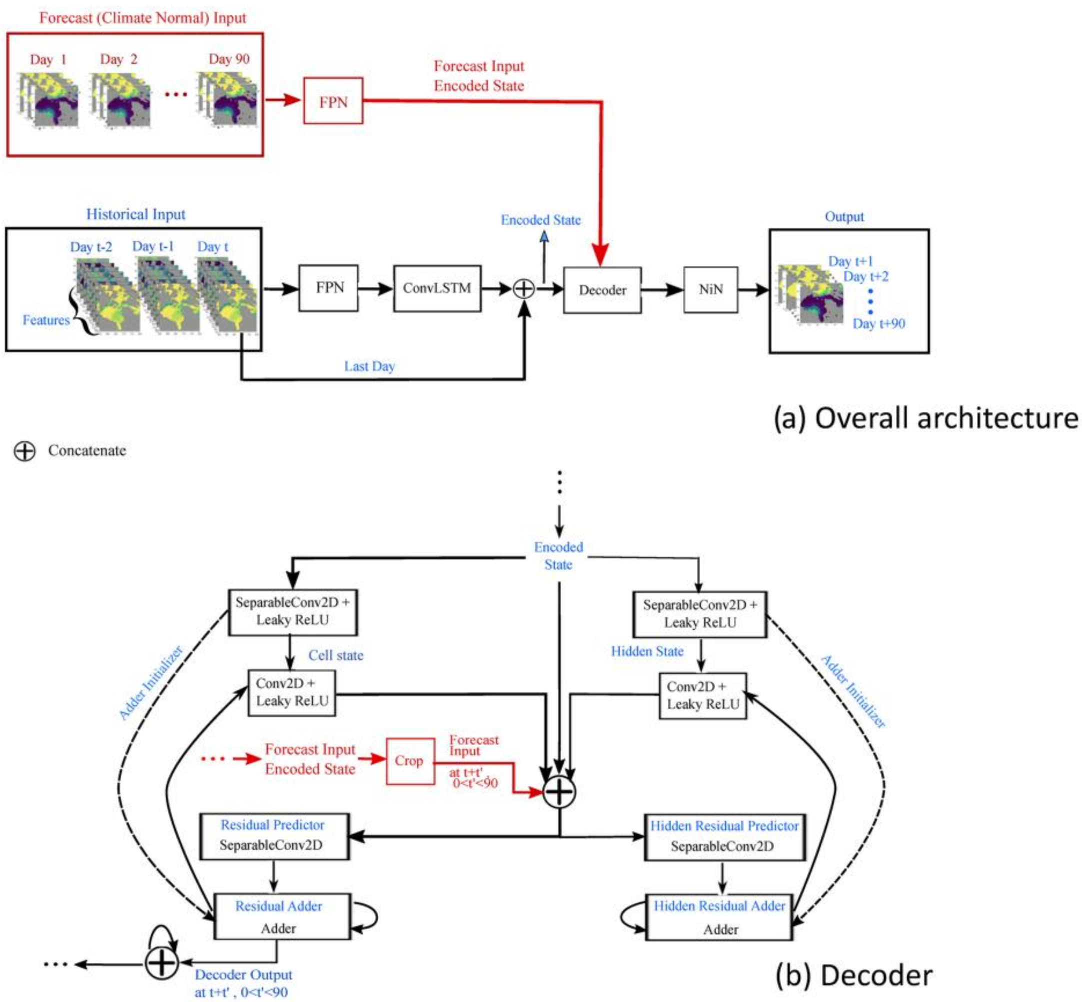


Figure 12. Overall network architecture (a) and custom decoder (b) of SIFNET model. The red portion refers to the additional components required for the augmented model. (Asadi et al., 2022)

Many vessels carrying out dry cargo or fuel deliveries are not ice-strengthened or cannot conduct specific operations in ice-infested waters. The capabilities of the SIFNET model to forecast the probability of sea ice presence will provide additional information to shipping operators to manage their risk based on the likelihood of ice presence on their planned route, up to 90 days in advance. An example of a probabilistic output from SIFNET is illustrated in Figure 13. An extensive validation framework has shown high variability in the forecast skill depending on the month of the year and the lead time. The augmented version of the SIFNET model generally gives more accurate forecasts than using the climate normal for all months in short lead times, while converging for most of the months toward the climate normal at longer lead times (Figure 14).

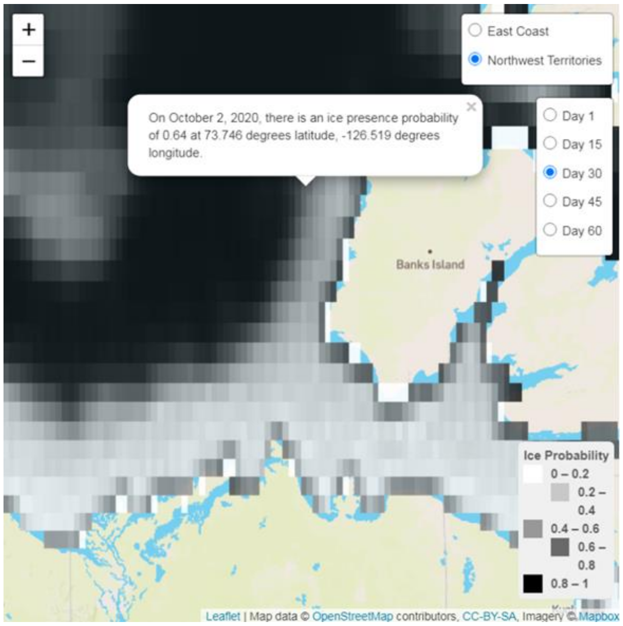
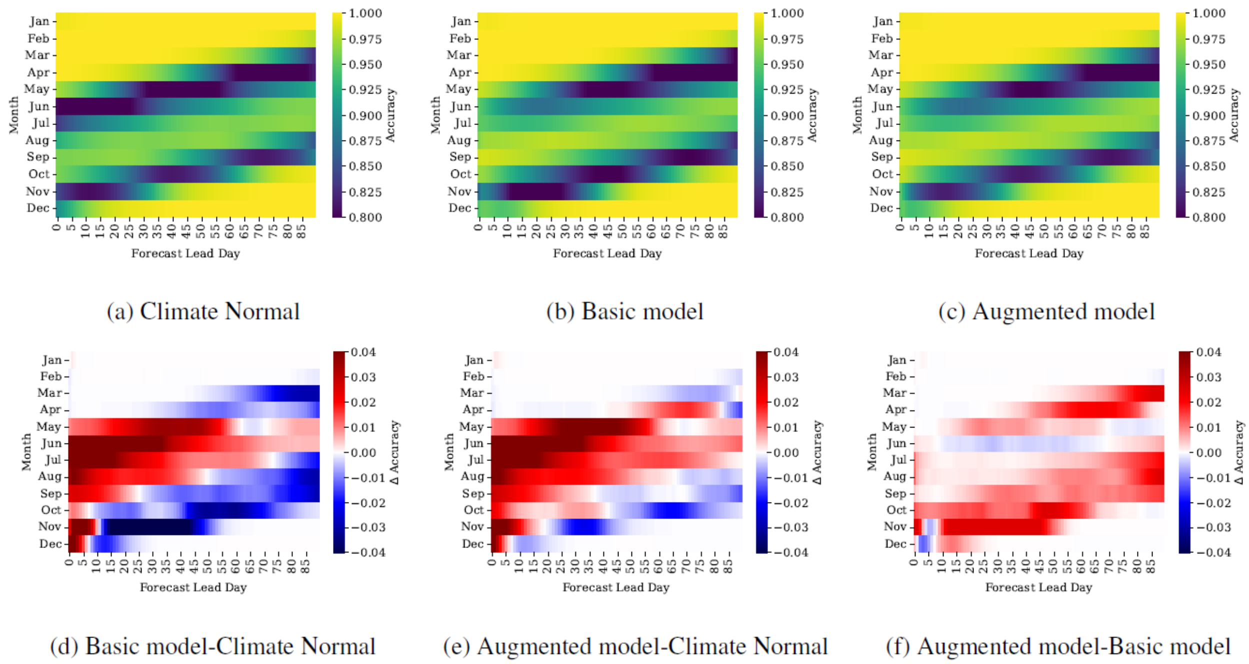


Figure 13. Example prototype output from SIFNET, showing a 30-day forecast of probability of ice presence (at concentration greater than 15%) in the Western Arctic region.



(a) Climate Normal (b) Basic model (c) Augmented model

(d) Basic model-Climate Normal (e) Augmented model-Climate Normal (f) Augmented model-Basic model

Figure 14. Binary sea ice presence accuracies as a function of lead time for the Hudson Bay region. Top row panels show the binary accuracy of each model (a)-(c) while bottom row panels show the differences in binary accuracy between the models (d-f). The Augmented model is trained with additional 90-day Climate Normal input. Most differences are observed in the break-up and freeze-up seasons. (Asadi et al., 2022)

2.6. Development of a new CASRAS web app

A key objective of the CASRAS NTCF project is to provide enhanced tools to western Arctic partners to improve marine trade corridor efficiency, reliability and safety. The present stand-alone, hard drive based system can only be supplied to a limited number of end users. Development of a web application would help to mitigate that concern, as well as providing a simpler user interface. As a starting point, a co-op computer science student was hired for the summer 2021 term to investigate the possibilities for a web portal. A platform was chosen and development of the beta version of the CASRAS web app is currently underway.

2.6.1. Selection of web app platform

Work on the CASRAS web application started during the summer of 2021. A co-op student was hired with the goal to provide the CASRAS team with a technical report outlining the state of web development products, recommendations for product selection and demonstration prototypes. A central tenet was that some aspects of the CASRAS desktop functionality needed to be replicated in the web application.

Development of secure and robust web systems is not a trivial undertaking. Utilizing cloud resources to provide public access can also be challenging within a Government environment. In addition to initial development, the long term plans to maintain and support the system must be considered. A risk reduction approach was taken with the aim to reduce or eliminate the need for writing new code, and utilize already developed tools, systems and code libraries.

The co-op student began by defining core CASRAS functionalities (i.e. map-centric data display and interaction, user creation of vessel routes, ice analysis over vessel routes). These were used as evaluation criteria to ensure consistent review of the various contenders for web product. The initial no-code/low code product scan revealed that several vendors offered a complete solution to develop and deploy web applications with spatial support. Further investigation led to a relatively new product offering: Software as a Service (SaS). Utilizing a SaS provider reduces risk in terms of needing to develop, secure and administrate the underlying technology to serve a web application. SaS provides the tools needed to develop the web applications. SaS service is typically a subscription payment model.

The co-op student undertook a technical evaluation of SaS providers which seemed to fit the needs: Carto Builder, ArcGIS Online and Tableau. Multiple criteria – such as browser-based support for spatial data, map-centric display, allowing a user to add a vessel route, analysis and plotting capability – were evaluated. In addition, a basic prototype to display and manipulate Canadian Ice Service (CIS) ice charts was developed to understand what code functionality was provided. Each provider was then reviewed by the CASRAS team. Carto Builder and Tableau were selected for a second phase of prototype development. These prototypes focused on recreating the CASRAS desktop ice chart display, plots and adding a vessel route. Both Tableau and Carto Builder lacked the ability to allow users to dynamically create vessel routes on the main map display. While disappointing, it is a very specific feature of CASRAS. Discussions with engineers at both vendors acknowledged this was their first time having received such a feature request. Tableau engineers provided several workaround solutions, which, while not perfect, exhibited a desire by the vendor to assist and understand our unique issues.

While Carto Builder was easy to use and the user interface aesthetically pleasing, Tableau could most closely replicate the core functionalities of CASRAS. There were more options in Tableau for manipulation of the data source, visualizations, and customized analyses. Additionally, Tableau is used within the Canadian government, and its data servers in Canada are certified by SSC for Protected B information, which greatly reduces the security risk in storing data with them. In the end, Tableau was selected as the SaS provider to move forward with building the CASRAS web application.

2.6.2. Summary of progress in development of CASRAS web app in Tableau

The initial development is focused on replicating the desktop CIS regional ice chart viewer. This allows a user to select any regional (e.g. Hudson Bay or Western Arctic) ice chart by both date and region. Selection of specific ice chart attributes (e.g., ice concentration or stage of development) trigger an update of the map display. Selection of a specific ice polygon opens a dialog showing additional information from the polygon. Standard map functions such as pan and zoom have been enabled. Figure 15 shows the prototype CASRAS web application as viewed on a laptop, tablet and cell phone.

3. Climate resilience

In the development and execution of this project, climate resilience is an important consideration. The SIFNET seasonal ice forecasting system described in Section 2.5 generates products which include the effects of a changing climate. At present, without such a system, organizations which plan vessel operations would typically rely on climate normals or historical ranges of ice-free dates from previous years. Climate normals are used to summarize the average climatic conditions of a location, typically generated from the past 30 years of historical data. As we know, Canada's climate is changing, and even more rapidly so in the Arctic (Bush and Lemmen, eds., 2019). The SIFNET system integrates the latest environmental data – the conditions from the past 3 days – to generate a forecast of the likelihood of ice presence in the coming days and months. This approach gives a picture of the expected ice break-up and freeze-up dates of the season that is based on sound data analytics and is more accurate than relying on historical data only. Initial outputs from SIFNET will be available to CASRAS users in the summer 2023 shipping season.

CASRAS can be used to evaluate the effects of climate change on sea ice. Barrette and Sudom (2022) used CASRAS to examine trends in sea ice formation and break-up dates in Hudson Bay. It was found that the ice cover in that region has required more time to develop into a fully established ice cover – specifically, an increase of 3 to 4 days per decade. Ice break-up initiation has also begun earlier in the spring/summer; that shift is estimated at about 5 days per decade. This study was funded by Infrastructure Canada's Climate-Resilient Buildings and Core Public Infrastructure Initiative.

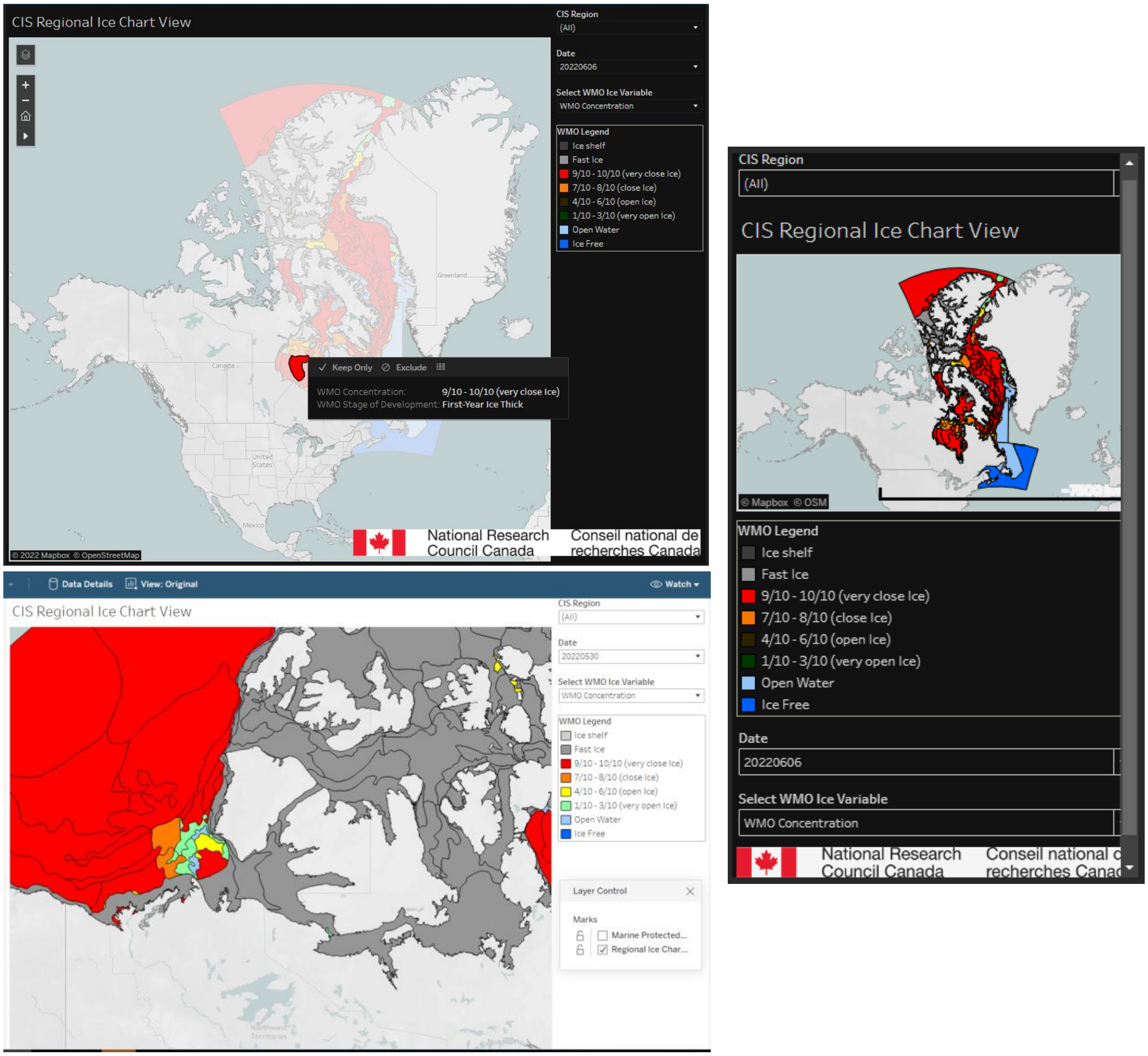


Figure 15. Regional ice charts in the CASRAS web app prototype, viewed from various web-capable devices. Top left: viewed from a laptop. Bottom left: viewed from a tablet. Right: viewed from a cell phone.

4. Communications activities conducted during the fiscal year

A summary of communications activities related to this project conducted during FY 2021-22 is given in Table 1.

Table 1. Summary of communications activities

Date	Event	Location/format	Participants	Additional information
May 26-28, 2021	Canadian Marine Advisory Council – Prairie and Northern Regions (CMAC-PNR) Spring Meeting	Virtual meeting	TC, DFO, CCG, CHS, NRC, Arctic shipping industry (community resupply and Arctic marine tourism), Northern community members and organizations	An overview of CASRAS and its use with shipping partners was given to meeting attendees
Sept 21, 2021	NRC-OCRE external evaluation	Virtual meeting	NRC, external panel reviewing NRC-OCRE activities	An overview of CASRAS was given as an example of a key project in NRC's OCRE research centre
Dec 1, 2021	Meeting of NATO working group Applied Vehicle Technology AVT-367	Virtual meeting	Canadian and international members of NATO AVT-367 from shipping industry, research and academia	An overview of CASRAS projects was given to meeting attendees

5. Next steps

NRC will continue to meet regularly with project partners and end users to confirm that CASRAS and related tools and products are meeting their needs, and adjust these offerings as needed. The NRC team will assess feedback from project partners on datasets and tools, and investigate new capabilities noted to be of interest. At the same time, NRC will ensure that the project activities continue to meet the overall objectives of the NTCF project.

The longer-range (seasonal, up to 90 day) forecasts, will be integrated with the CASRAS system in FY22-23, followed by iterative data product improvements from end-user feedback. Simultaneously, iterative model improvements will be made using new methods (spatial resolution, duration, accuracy), and deployed back to end users.

The NRC team will also make some CASRAS datasets available through the new CASRAS web app in 2023.

6. Acknowledgements

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