NRC Canadian Arctic Shipping Risk Assessment System (CASRAS): report for fiscal year 2022-23

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NRC Canadian Arctic Shipping Risk Assessment System (CASRAS): Report for Fiscal Year 2022-23

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Executive Summary

In the Canadian Arctic, many communities depend heavily on shipping for dry cargo and fuel. The safety and efficiency of 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* in the period April 1, 2022 to March 31, 2023 (government fiscal year 2022-23).

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 are compilation of environmental data and mariner knowledge, and development and sharing of tools to accurately predict short-term and longer-range sea ice conditions.

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, Department of National Defence, and Environment and Climate Change Canada. These groups have collaborative agreements with NRC and provide funding and support that is outside of the NTCF project. In addition, NRC began discussions with new collaborators and user groups who will apply CASRAS in search and rescue research and operations. All CASRAS user groups regularly provide feedback and information, which NRC uses to improve the system and for the benefit of all user groups. In this way, NRC provides its own contributions to the NTCF project.

The main development for CASRAS in fiscal year (FY) 2022-23 was the addition of long-range ice forecasts to the system. NRC developed a machine-learning system to generate daily forecasts of sea ice presence probability up to 90 days into the future, and these are integrated into CASRAS. Updated software with this new functionality was deployed to all end users in June 2023. This allows users to view and analyze seasonal predictions of ice presence along a planned route. Seasonal forecasts allow for risk assessments that include the effect of climate trends on ice formation and break-up. This new capability complements NRC's high-resolution, regional short-term forecasts of ice thickness, concentration, ridging and pressure, which were integrated in CASRAS in FY21-22.

General development of the CASRAS software continued in FY22-23, including bug fixes and incorporation of datasets of interest to the stakeholders. Work also continued on the new CASRAS web application, which will allow users to view select, high-interest data sets online. The beta version of the web platform will be tested with end users in 2023.

Table of Contents

Executive Summary iii
Abbreviations vi
1. Introduction 1
1.1. About CASRAS and the NTCF Project 1
1.2. Project funding 2
1.3. Project timeline 3
1.4. Project participants and collaborators 3
2. Project progress to date 4
2.1. Summary of progress 4
2.2. Improvements to CASRAS software and data sets 5
2.3. Integration of long-range sea ice forecasts 5
2.4. Development of a new CASRAS web app 7
3. Climate resilience 9
4. Communications activities conducted during the fiscal year 9
5. Next steps 11
6. Acknowledgements 11
7. References 11

List of Figures

Figure 1. Left: CASRAS software being used onboard a vessel in summer 2017 (image courtesy of Captain D. Fowler); right: launch screen of CASRAS software. 1
Figure 2. Example view of several datasets in CASRAS. Community conservation and land use plans are shown as black outlines on the map. 1
Figure 3. Primary shipping routes (black lines) used by the 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. 2
Figure 4. Timeline of CASRAS NTCF project. 3
Figure 5. Daily operational process for producing SIFNET forecast products. 6
Figure 6. Example of a SIFNET forecast visualized in the CASRAS system. 7
Figure 7. View of the NRC daily Ice Dynamics Forecast model output within the CASRAS web application in Tableau. Each of the multiple regional operational runs are merged into a single map. Each polygon contains a variety of attributes that can be viewed; ice concentration (areal coverage) is shown. 8

List of Tables

Table 1. Summary of communications activities in FY 2022-23 10

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

FY: Government of Canada Fiscal Year (starting April 1 of each year)

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

SAR: Search and Rescue

SIFNET: Sea Ice Forecasting Neural NETwork

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). Figure 1 shows CASRAS being used onboard a vessel, along with the main user interface of the software. Figure 2 shows an example view of some data sets within CASRAS.

Figure 1. Left: CASRAS software being used onboard a vessel in summer 2017 (image courtesy of Captain D. Fowler); right: launch screen of CASRAS software.

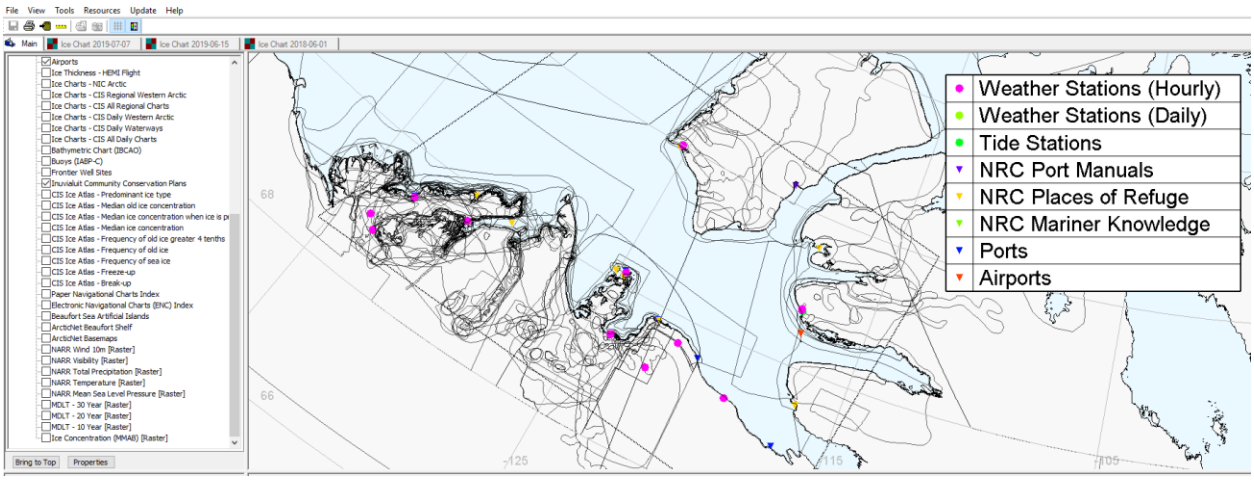

Figure 2. Example view of several datasets in CASRAS. Community conservation and land use plans are shown as black outlines on the map.

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. The primary Western Arctic shipping routes used by the Government of Northwest Territories Marine Transportation Services are shown in Figure 3.

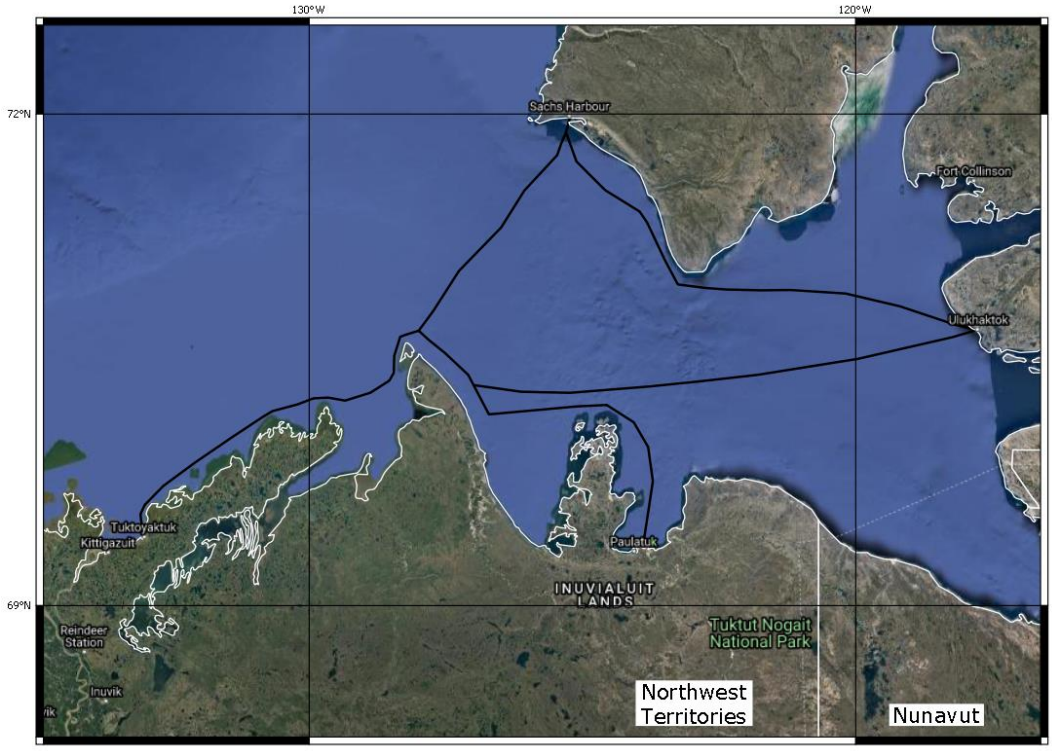

Figure 3. Primary shipping routes (black lines) used by the Government of Northwest Territories Marine Transportation Services for delivery of goods to communities of the Canadian Western Arctic and Inuvialuit Settlement Region. Approximate routes courtesy of Tom Maher.

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 to contribute a minimum in kind value of $750,000 over the project lifetime, through its own contributions or by third parties to the project. 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 provide in-kind contributions, through data sharing agreements and software use agreements.

1.3. 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 4.

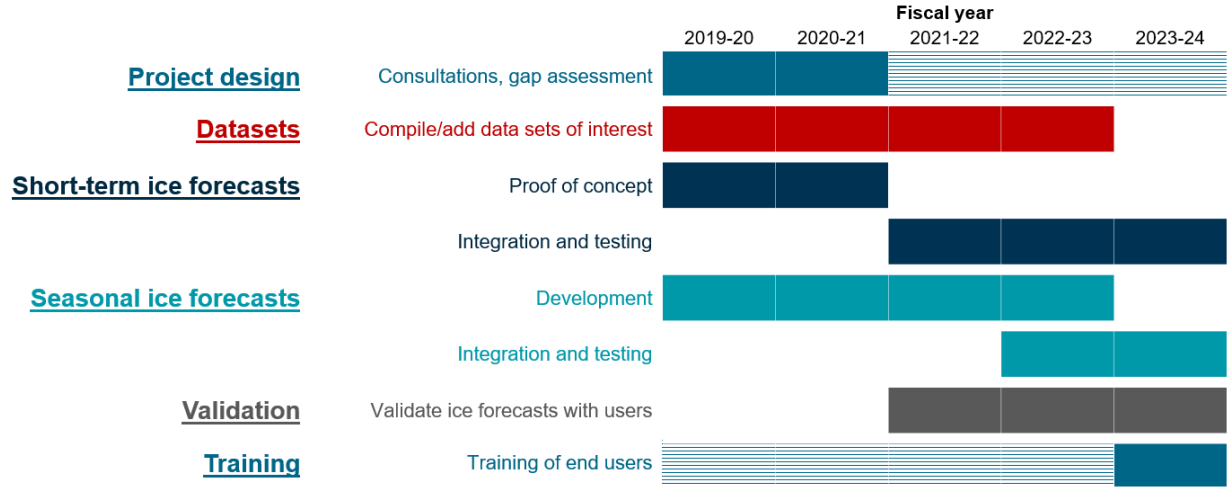

Figure 4. Timeline of CASRAS NTCF project.

1.4. Project participants and collaborators

To date, the NRC has engaged with key project participants from the Government of Northwest Territories, the Canadian Coast Guard, Transport Canada, Department of National Defence, Environment and Climate Change Canada, 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.

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 research and operational support to the RCN, for personnel training, and onboard vessels including the new Arctic Offshore Patrol Vessels.
- CCG: CASRAS is used onboard up to five CCG icebreaking vessels each year (including CCGS Sir Wilfrid Laurier, which operates mainly in the Western Arctic region), 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 and in the Montreal Regional Operations Centre.

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

NRC is also actively collaborating with other government departments to improve the CASRAS platform. 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.

In FY22-23, NRC began discussions with potential new collaborators and user groups who will apply CASRAS in search and rescue research and operations.

2. Project progress to date

2.1. Summary of progress

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 bulk of the stakeholder consultations are summarized in the FY 2019-20 annual report (Charlebois et al., 2020). Consultations of a more detailed nature took place with project partners in FY 2020-21, as well as signing of agreements as needed, as summarized in the FY 2020-21 annual report. In that year, 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 FY 2021-22, NRC completed integration of its short-term (up to 48 hours) Ice Dynamics Forecasting System products in CASRAS. Also in FY 2021-22, the integration of bathymetry data was completed so that CASRAS users can now view public, non-navigational hydrographic survey (NONNA) data collected by CHS onboard numerous vessels. The FY 2021-22 activities are summarized in Sudom et al. (2023b).

In FY 2022-23, outputs of the Sea Ice Forecasting Neural NETwork (SIFNET), were incorporated into CASRAS so that users can view likelihood of ice presence up to 90 days into the future.

2.2. Improvements to CASRAS software and data sets

During FY 2022-23, development of the CASRAS system and its data sets was ongoing. Improvements were made to the software performance and fixes made to identified bugs. Existing datasets and documentation were updated or augmented as needed. CASRAS presently contains 83 datasets and over 250,000 files, for a total of approximately 291 GB of data.

The NRC Ice Dynamics Forecast model was integrated into CASRAS in FY 2021-22. Minor development and additional testing were undertaken to improve product metadata and aesthetic representation in CASRAS.

2.3. Integration of long-range sea ice forecasts

The CASRAS NTCF project plans included the development of a 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. In FY 2019-20, NRC funded a grant with the University of Waterloo through the AI4Logistics program. The objective of this grant was to accelerate the development of SIFNET by hiring a full-time post-doctoral candidate, in collaboration with Dr. Andrea Scott as academic principal investigator. In FY 2021-22, 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.

During FY 2022-23, three significant milestones were achieved in relation to long-range ice forecasts: (1) operationalization of the SIFNET model, (2) integration of SIFNET products within CASRAS, and (3)

updating the AI4Logistics grant in collaboration with the University of Waterloo to explore new methods for enhancing the system.

The first milestone in FY 2022-23 involved the operationalization of the SIFNET model. Once the machine-learning model was trained, validated and the results peer-reviewed and published, the next step was to use the model operationally. The SIFNET model is now executed on a daily basis to forecast the probability of ice presence in the Northwest Territories domain for the next 90 days (see Figure 5). Each night, the system downloads the necessary input variables and generates gridded sea ice presence forecast products. To minimize bandwidth requirements, the files are compressed before being made accessible to end users. Finally, the forecast products are uploaded to an FTP server for public access.

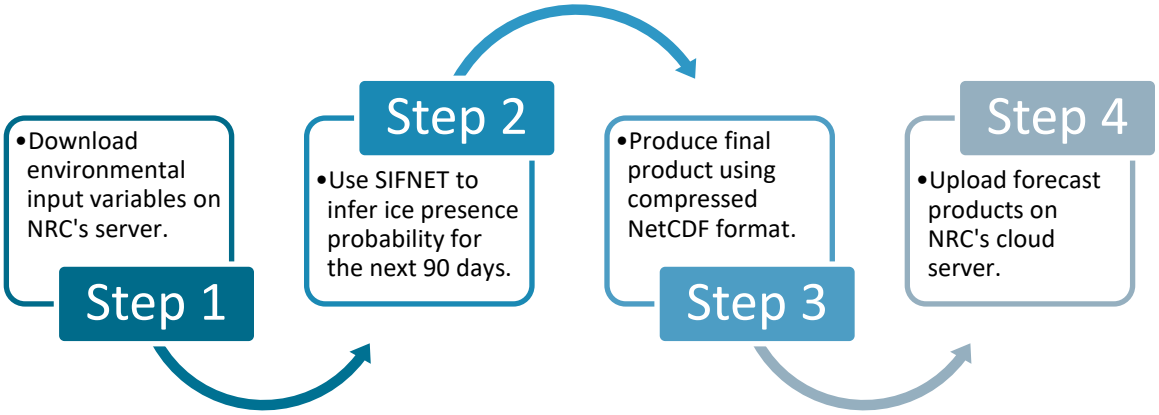

Figure 5. Daily operational process for producing SIFNET forecast products.

The second FY22-23 milestone involved the integration of SIFNET products directly within the CASRAS interface. The ice presence forecasts, ranging from 1 to 90 days in the future, have been fully incorporated and deployed to end users in the latest version of the CASRAS software (see Figure 6). This integration allows users to conveniently download and visualize the products. Similar to other spatiotemporal datasets within CASRAS, users can zoom in on specific areas of interest, overlay or draw routes, animate the forecast, and extract timeseries at specific locations. This availability of seasonal sea ice presence information within CASRAS facilitates advanced planning of vessel operations in the Western Arctic.

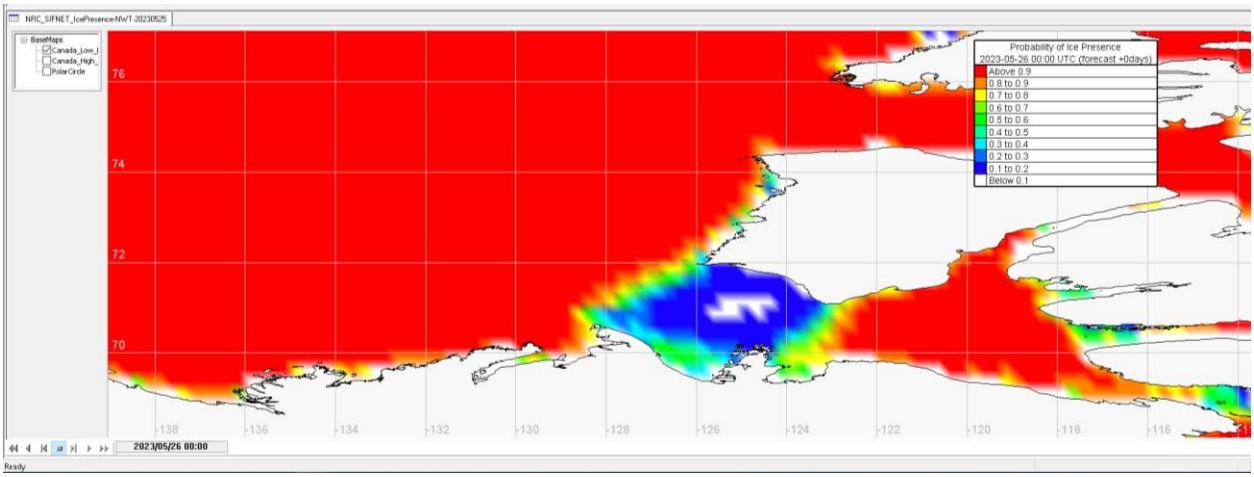

Figure 6. Example of a SIFNET forecast visualized in the CASRAS system.

The final milestone in FY22-23 focused on restructuring the AI4Logistics grant with the University of Waterloo, prompted by the departure of the post-doctoral fellow involved in the initial work. The grant was reprofiled and extended to accommodate two new highly-qualified personnel: a full-time Master's student a part-time PhD student. Building upon the development of the initial SIFNET prototype, two major improvements are currently being investigated in collaboration with the University of Waterloo. The Master's student's research concentrates on reducing the memory and computational resources required to expand the geographical coverage to the entire northern hemisphere. Graph-based convolutional neural network architectures are being explored as a means to yield high-resolution products for shipping corridors, while reducing spatial resolution where ice conditions are highly stable with limited shipping activities. Concurrently, the PhD student is developing a new framework to forecast scalar values, such as ice concentration and ice thickness, at a sub-seasonal scale along with estimation of the associated uncertainties. Although both research activities are currently at a low Technology Readiness Level (TRL), successful improvements will be incorporated in future releases of SIFNET and integrated into CASRAS, subject to validation and publication.

2.4. 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 CASRAS software is available only on USB hard drives, which limits NRC's ability to deploy to a large number of end users (due to time required to set up and support physical systems). The web application also allows the CASRAS team to take advantage of features and capabilities already built into online platforms, leading to shorter development time for NRC and faster data processing time for end users.

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. The Tableau platform was chosen, and NRC moved forward with building the CASRAS web application. In addition to the historical CIS regional ice chart dashboard providing chart selection by date, region and ice chart attributes (e.g. ice concentration, stage of development or thickness), the NRC Ice Dynamics Forecast model output was integrated into a new dashboard, shown in Figure 7.

Modifications were made to the NRC Ice Dynamics system to improve support for the GIS Shapefile format and allow the model forecasts to be integrated into the CASRAS web application. The model provides regional, ship-scale, ice dynamics forecasts (e.g. ice concentration, stage of development, ice thickness, ridging and ice pressure) at a set interval up to a 48 hour period. The model is run on a daily schedule on NRC servers for regions corresponding to Canadian Ice Service ice charts. Model results are then uploaded to the CASRAS web application.

The beta version of the CASRAS web app is now being finalized before testing with end users later in 2023.

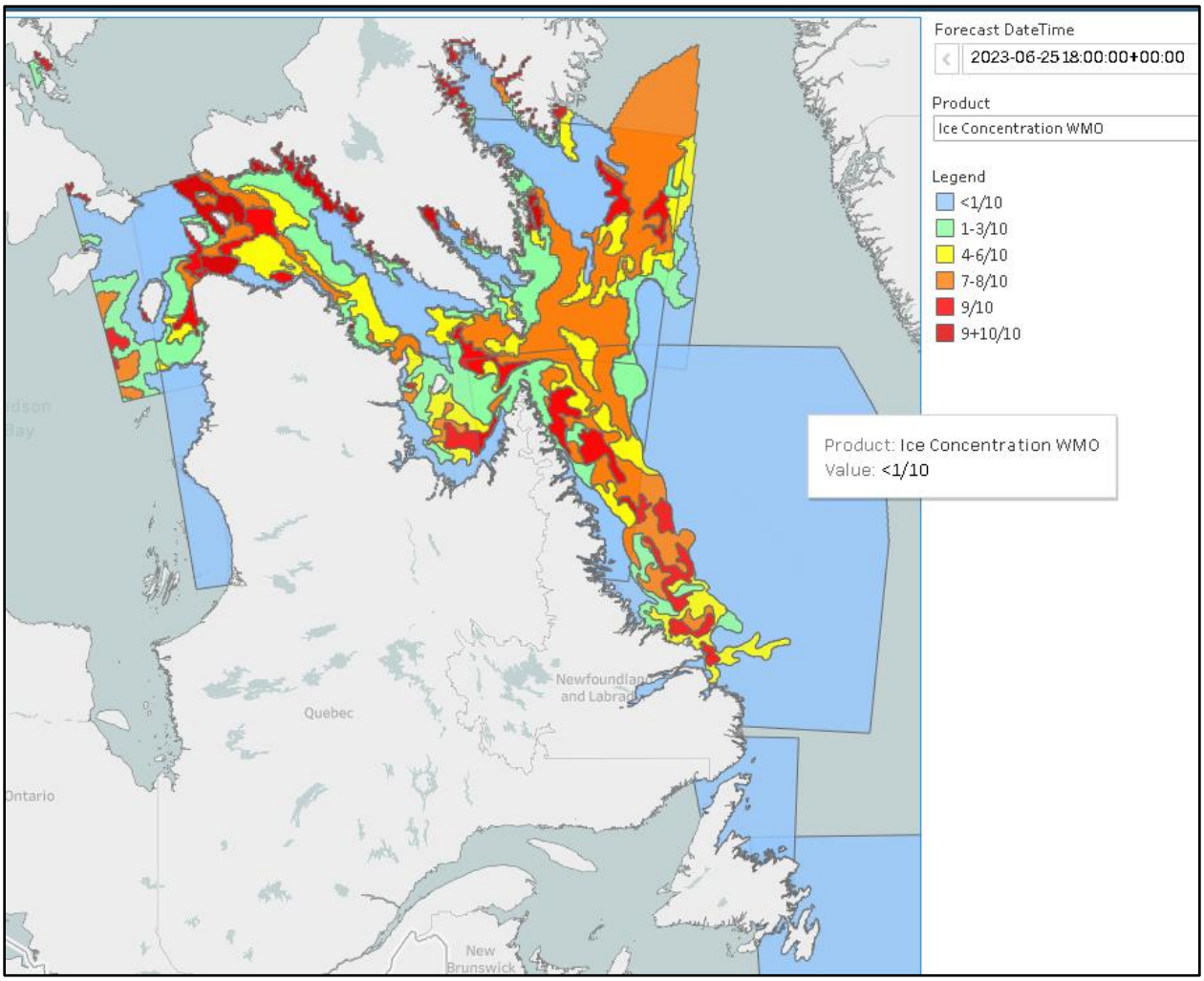

Figure 7. View of the NRC daily Ice Dynamics Forecast model output within the CASRAS web application in Tableau. Each of the multiple regional operational runs are merged into a single map. Each polygon contains a variety of attributes that can be viewed; ice concentration (areal coverage) is shown.

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 2.3 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 only on historical data. Initial outputs from SIFNET will be available to CASRAS users in the summer 2023 shipping season.

CASRAS has also been 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. CASRAS can also be used to assess historical navigability and expected ice conditions along a shipping corridor (Sudom et al., 2023a).

4. Communications activities conducted during the fiscal year

A summary of communications activities related to this project conducted during FY 2022-23 is given in Table 1.

Table 1. Summary of communications activities in FY 2022-23

Date	Event	Location/format	Participants	Additional information
May 25-26, 2022	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 update on CASRAS was given to meeting attendees
June 8, 2022	CASRAS NTCF Annual Update Meeting	Virtual meeting	NRC, TC, Government of NT, CCG, DRDC	NRC progress update on the CASRAS NTCF project for FY21-22
December 8, 2022	Posting on NRC LinkedIn page	Web publication	Public article	See post at: https://www.linkedin.com/posts/national-research-council_nrcarcticresearch-arcticsciencemonth-activity-7008089633980833792-ZCFR/
December 8, 2022	NRC website article on CASRAS	Web publication	Public article	See article at: https://nrc.canada.ca/en/stories/new-nrc-risk-assessment-software-helps-ships-navigate-safe-passage-through-arctic
November 30 – December 1, 2022	Canadian Marine Advisory Council – Prairie and Northern Regions (CMAC-PNR) Fall Meeting	Iqaluit, Canada	TC, DFO, CCG, CHS, NRC, Arctic shipping industry (community resupply and Arctic marine tourism), Northern community members and organizations	An update on CASRAS was given to meeting attendees
December 21, 2022	DND article that included CASRAS as one project supporting Canadian Armed Forces operations in the North	Web publication	Public article	See article at: https://www.canada.ca/en/department-national-defence/campaigns/defence-research-through-the-decades/arctic-science-month.html
February 9-10, 2023	NRC and Acfas 2023 Celebrating the Success of Women in STEM Symposium	Virtual symposium	Researchers and public	See article at: https://www.researchgate.net/publication/368408531_Planning_navigation_in_the_Canadian_Arctic_in_the_face_of_a_changing_climate_Amundsen_Gulf_ice_event_in_summer_2018
June 6, 2023	CASRAS NTCF Annual Update Meeting	Virtual meeting	NRC, TC, Government of NT, CCG, DRDC, ECCC, Dalhousie University, Leeway Marine	NRC progress update on the CASRAS NTCF project for FY22-23

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, were integrated with the CASRAS system in FY22-23, and will be improved this year based on end-user feedback. Simultaneously, iterative model improvements will be made using new methods (spatial resolution, duration, accuracy), and deployed back to end users.

Development of the CASRAS web app is ongoing, and the NRC team will deploy a beta version to some current CASRAS users in fall 2023. The app will display key data sets useful to shipping, including ice charts and ice forecasts.

The CASRAS team also plans to expand on the time-to-rescue data offerings within CASRAS through new collaborations with Dalhousie University and CCG's SAR group.

6. Acknowledgements

NRC gratefully acknowledges the support of Transport Canada's National Trade Corridors Fund. The Canadian Hydrographic Service and Canadian Ice Service are acknowledged for their time and effort in providing access to the data sets for use in the CASRAS project. Partners and stakeholders at the following organizations are thanked for their feedback into project and product development: Government of the Northwest Territories, Transport Canada Marine Safety & Security, Canadian Coast Guard, Inuvialuit Regional Corporation, Defence Research and Development Canada, and Royal Canadian Navy.

We also wish to acknowledge the dedication of Mr. David (Dave) Watson, a key member of the CASRAS team, who retired in the spring of 2023. Dave's hard work was crucial in the initial creation of the CASRAS platform, through to the development of new features up to the present time.

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