Community Connectivity and Remoteness in Arctic SAR

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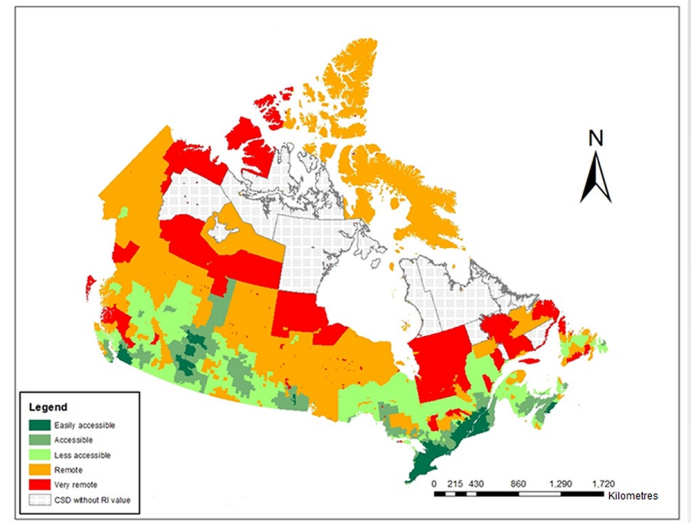
DALHOUSIE UNIVERSITY

Introduction - 0

- The maritime remoteness and accessibility of a polar class ship's destination (community, port, SAR location) is one of the most important considerations when planning transit operations in polar waters.
- Remote maritime regions are often characterized by:
  - reduced availability of navigational aids,
  - extended emergency response times,
  - and an extremely low density of maritime activity.
- Maritime remoteness and accessibility in the polar regions remains poorly defined in the literature and is without a widely accepted method of measure that can be applied uniformly over a wide area.
- This study proposes the use of POLARIS ice-risk adjusted ship transit times between ports, communities, and SAR locations as a proxy indicator of maritime remoteness and accessibility.

Introduction - 1

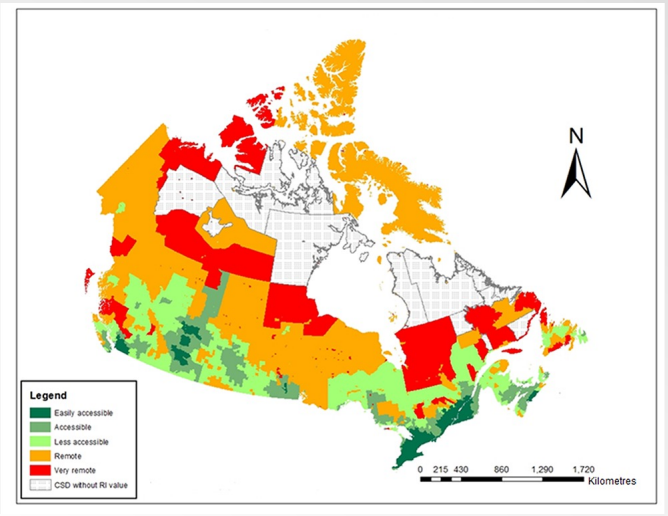
- Remoteness is commonly measured in distance, time, or transportation cost between a location and a point (s) of reference
- Remoteness is widely used as a proxy indicator of community accessibility
- Existing measures focus on the proximity of smaller communities to essential services and larger population centers using existing transportation infrastructure (road, rail, air, ferry, etc.).
- In practice, transportation distance and time are typically calculated using commercial sources and services, such as the Google Maps Applications Programmers Interface (API).



Source: Statistics Canada

Introduction - 2

- The lack of transportation infrastructure in northern Canada, and the exclusion of maritime transportation, has resulted in many arctic communities not receiving an official Remoteness Index (RI) value
- This study attempts to overcome the current limitations of the Canadian RI to measure the remoteness and accessibility of arctic communities (or SAR location) by incorporating maritime transportation into calculations of remoteness and accessibility
- Our research combines sea ice analysis, navigational risk assessment, and the analysis of historical vessel traffic data to determine year-round ice-risk adjusted transit times throughout the arctic, which serve as a proxy indicator of remoteness and accessibility



Source: Statistics Canada, 2017

Canadian Index of Remoteness (RI) - 1

- RI is determined by two key parameters: (1) the proximity to all population centers within a given radius; and (2) the population size of each population center, used as a proxy of service level.
- RI is the summation of the sizes of the population centers that can be reached from a community (or SAR location), divided by the proximity (transportation cost).
- The Google Maps API is used to generate a travel distance matrix, $D_{i,k}$, which contains the travel distances between each reference point, i and population center k.
- A_k is the size of population center k , determined using population census data.

$$RI_i = \sum_{k=1}^{n} \frac{A_k}{D_{i,k}}$$

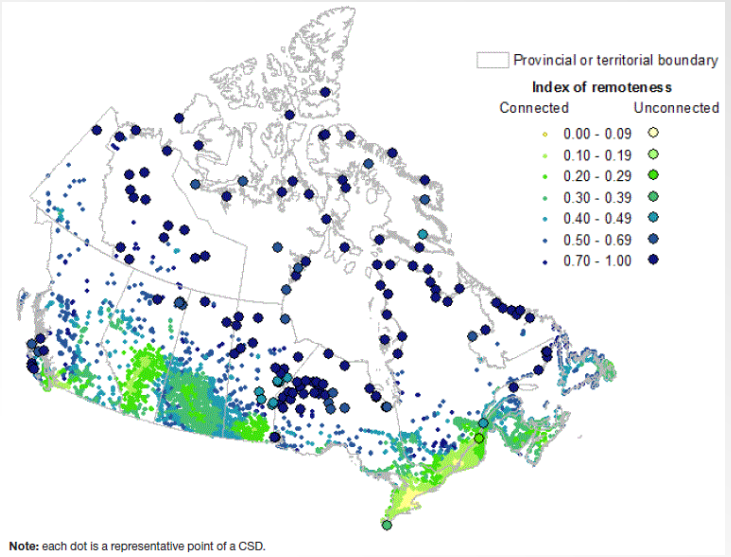
RI_i = Remoteness index of community i

$D_{i,k}$ = Distance matrix between each reference point i and population center k

A_k = Size of population centre k

Canadian Index of Remoteness (RI) - 2

- The three major limitations of the existing Statistics Canada Canadian measure of remoteness are that:
  - communities must be well-connected
  - there is no variation in transportation cost due to temporal influences
  - Maritime transportation is not considered
- The current measure relies on year-round fixed transportation distance and time between two geographic locations to represent proximity, calculated using the Google Maps API
- When considering maritime transportation, the time of year, ship design characteristics, sea ice condition, and planned route strongly influence travel time and cost and must all be considered.

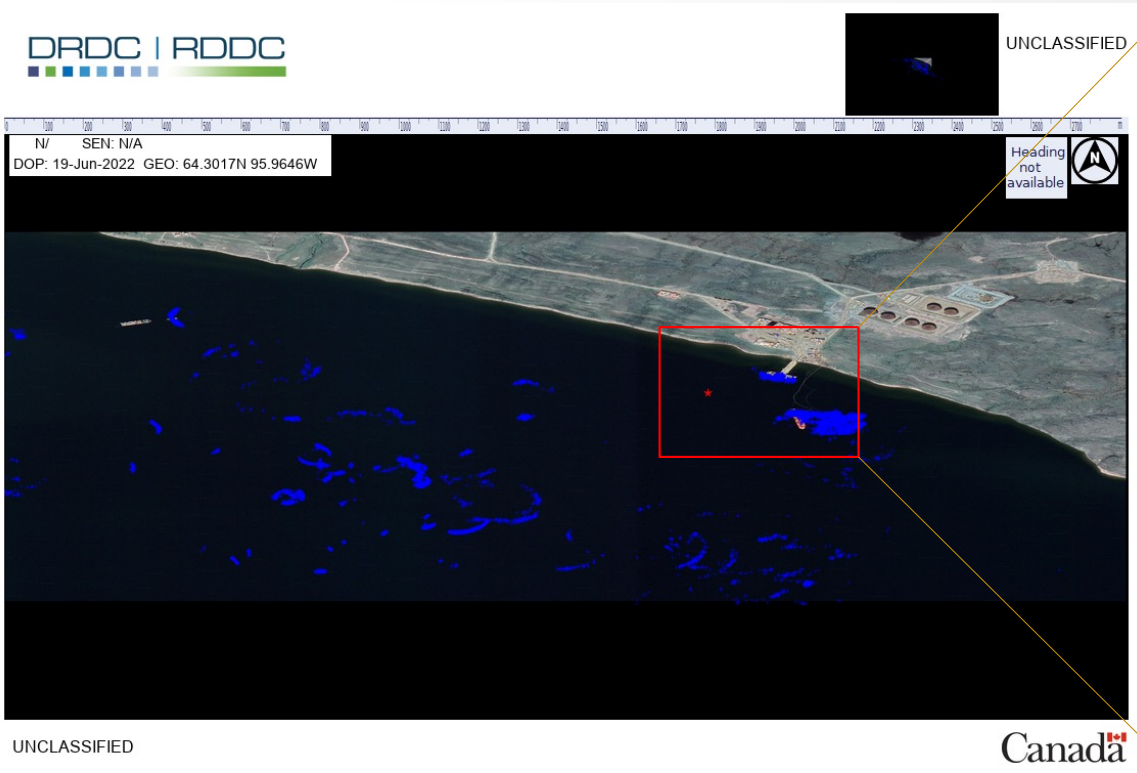


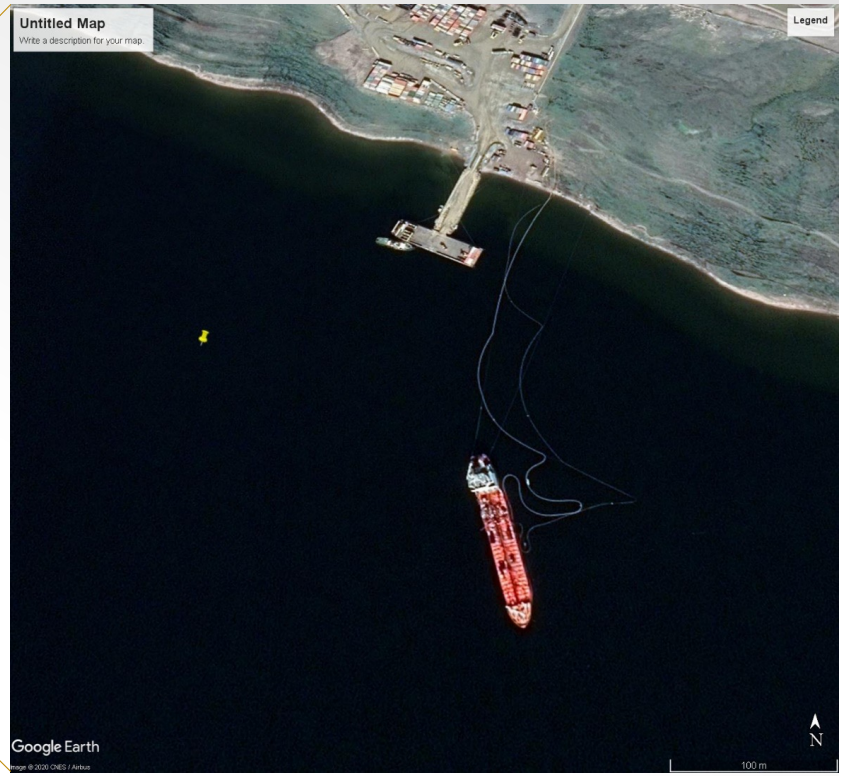
Eastern Arctic Trusted Routes Graph

- The greatest challenge of including maritime transportation in quantitative studies of remoteness is the relatively unconstrained nature of navigation at sea.
- To overcome this challenge, Dalhousie University worked with expert navigators from the CCG and RCN to compile a list of trusted routes connecting several communities of interest in the eastern arctic.
- The routes were used to create a trusted routes graph, effectively constraining the feasible paths between origin and destination
- AIS data and K-means clustering was used to identify anchorage locations near arctic coastal communities to serve as the community node location in our trusted routes graph.

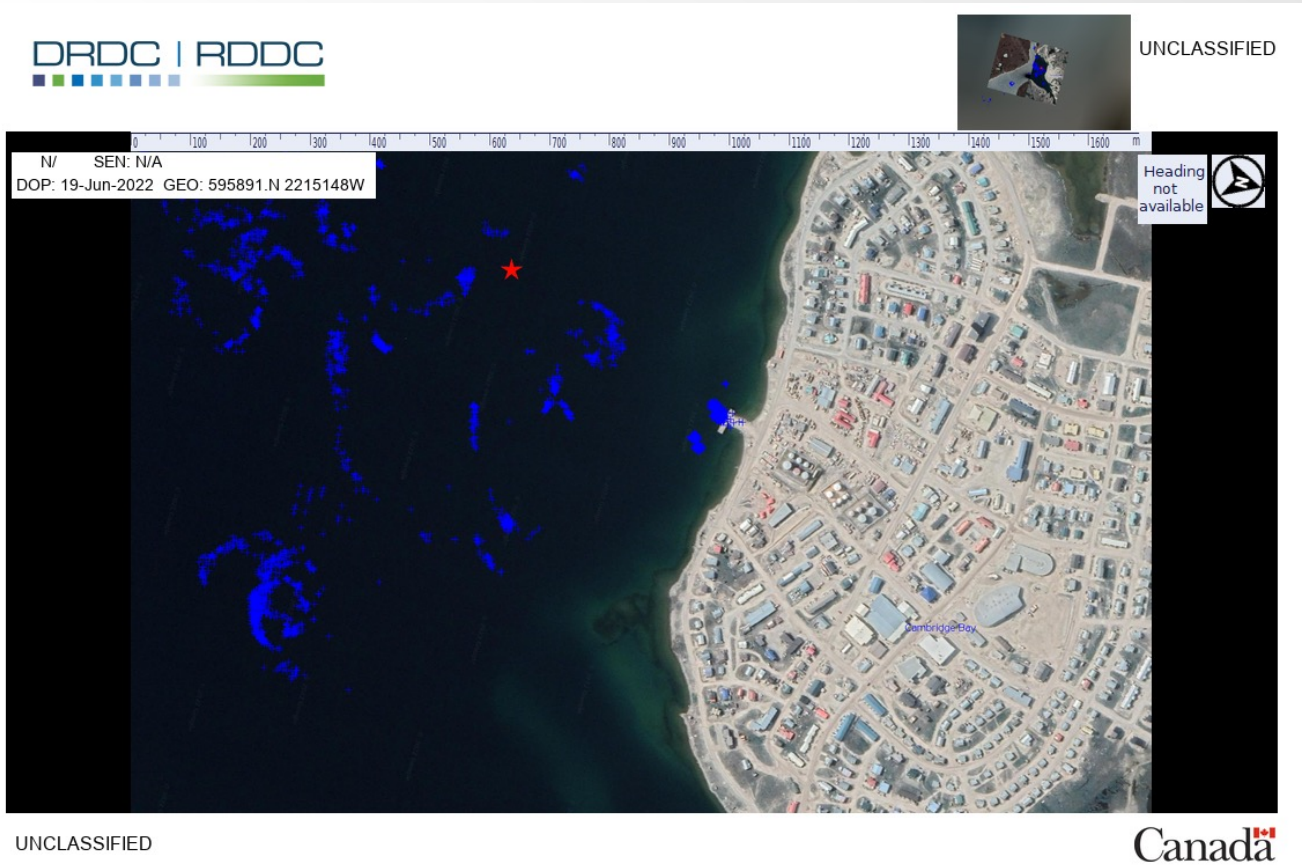
TO/FROM	Resolute	Pond Inlet	Clyde River	Pangnirtung	Iqaluit	Cape Dorset	Igloolik	Repulse Bay	Rankin Inlet
Reference Point	R1	R2	R3	R4	R5	R6	R7	R8	R9
Nuuk	R10	R11	R12	R13	R14	R15	R16	R17	R18
Nanisivik	R19	R20	R21	R22	R23	R24	R25	R26	R27
Churchill	R28	R29	R30	R31	R32	R33	R34	R35	36

Maritime Node Location – Baker Lake





Maritime Node Location – Cambridge Bay



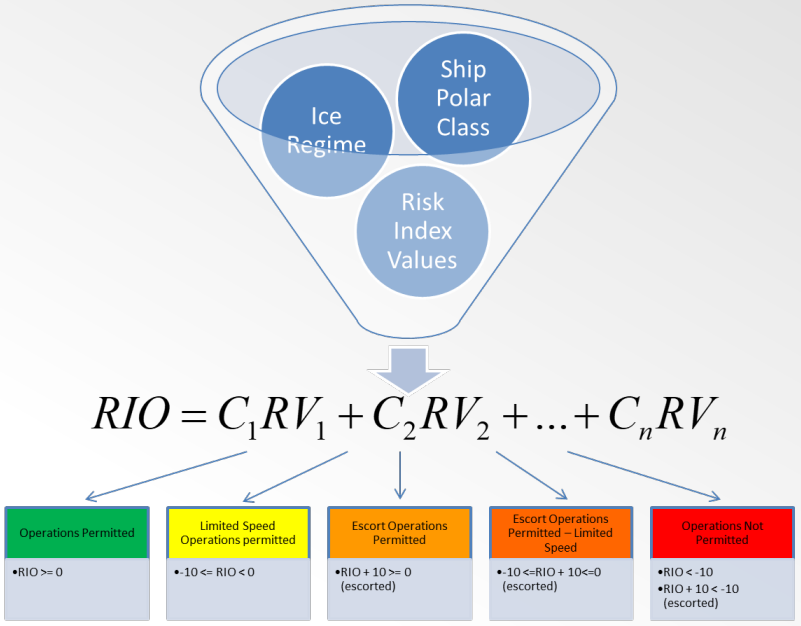
Maritime Node Location - Iqaluit

Maritime Node Location - Igloolik

Maritime Node Location – Pond Inlet

The Polar Operational Limits Assessment Risk Indexing System (POLARIS)

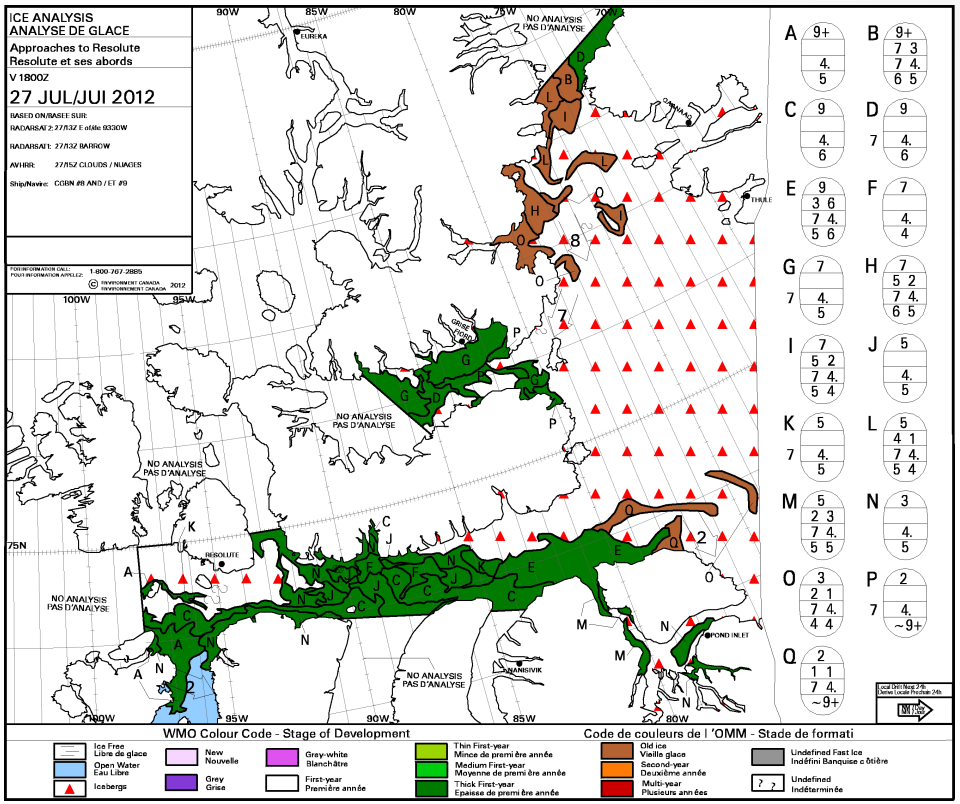
- POLARIS provides a risk assessment framework for determining ship operational limits in ice
- Its use is recommended as part of the International Maritime Organization (IMO) POLAR CODE
- The output of POLARIS is referred to as the Risk Index Outcome (RIO)

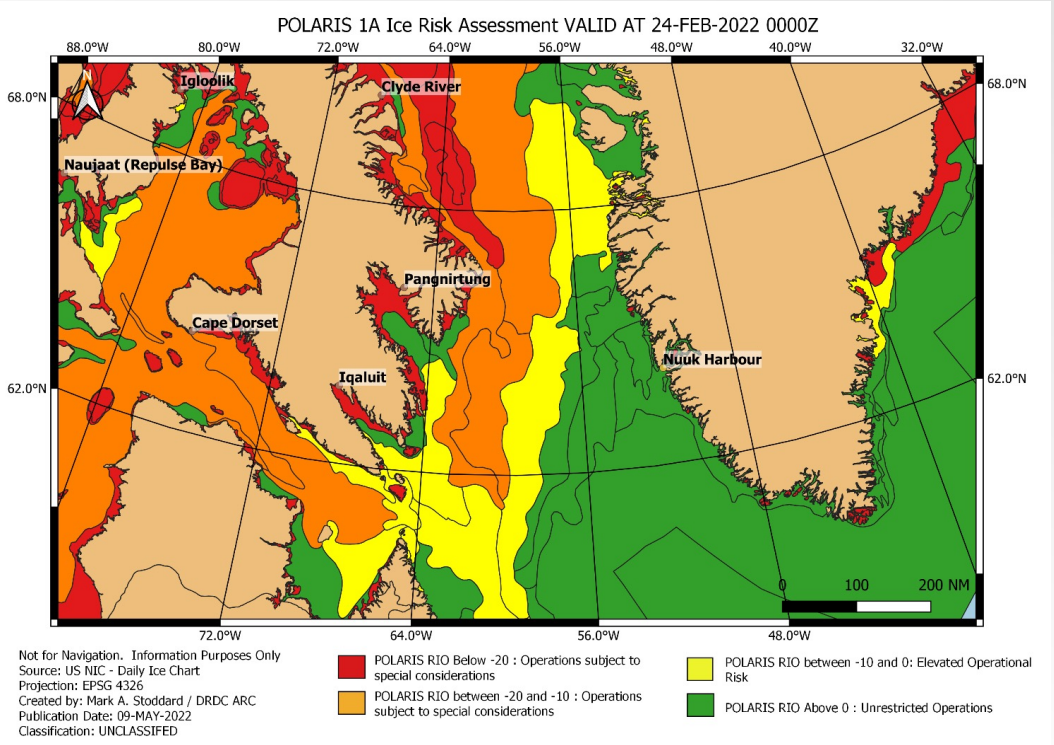


Deck Plate POLARIS Assessment

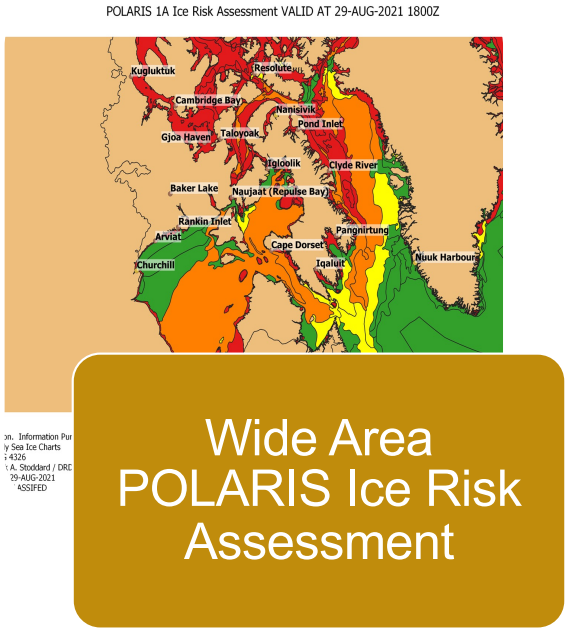
Ice Regime	Polar Ship Category	Ice Class	RIO	Result
	A	PC1	17	OP
		PC2	13	OP
		PC3	13	OP
		PC4	6	OP
		PC5	2	OP
	B	PC6	-5	ONP
		PC7	-12	ONP
4/10 Second Year Ice, 3/10 Thick First Year Ice (Decayed), 3/10 Ice Free	C	IAS	-12	ONP
		1A	-19	ONP
		1B	-19	ONP
		1C	-22	ONP
		Not Ice Strengthened	-26	ONP

POLARIS using Wide-area Sea Ice Analysis

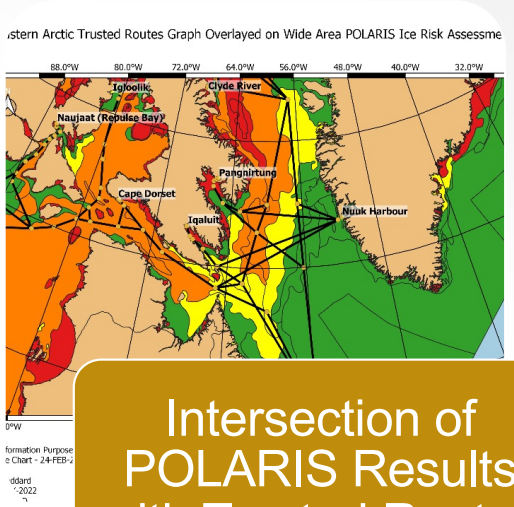




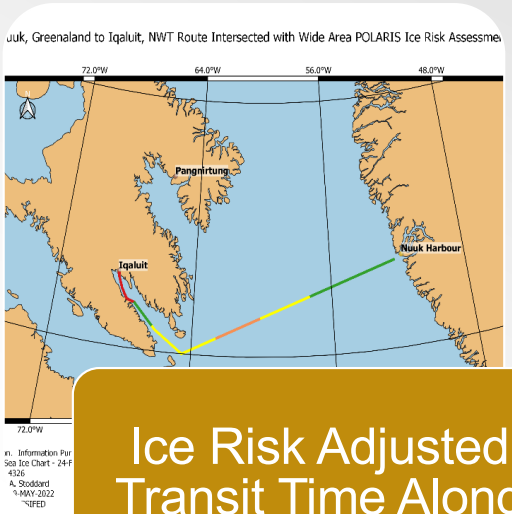
Ice Risk Adjusted Transit Time using POLARIS



Wide Area POLARIS Ice Risk Assessment

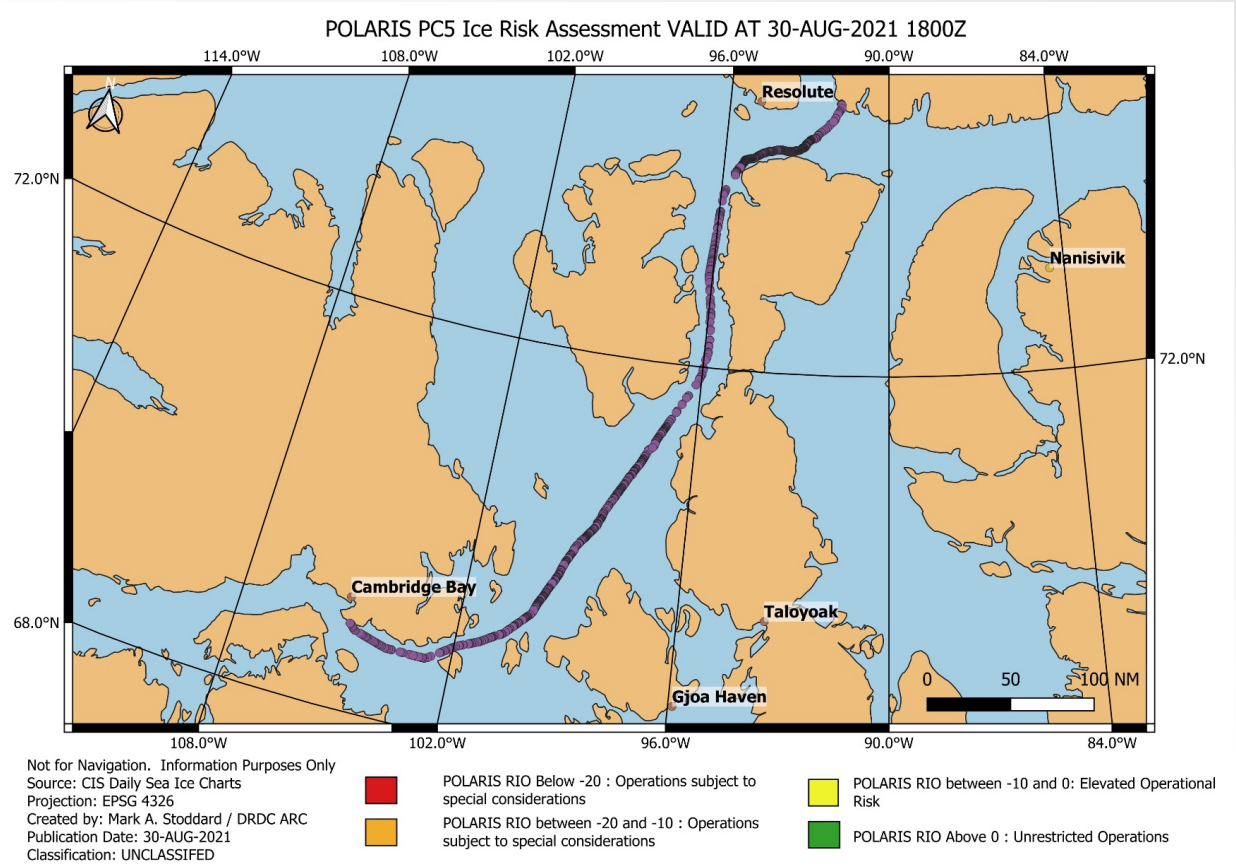


Intersection of POLARIS Results with Trusted Routes Graph (TRG)

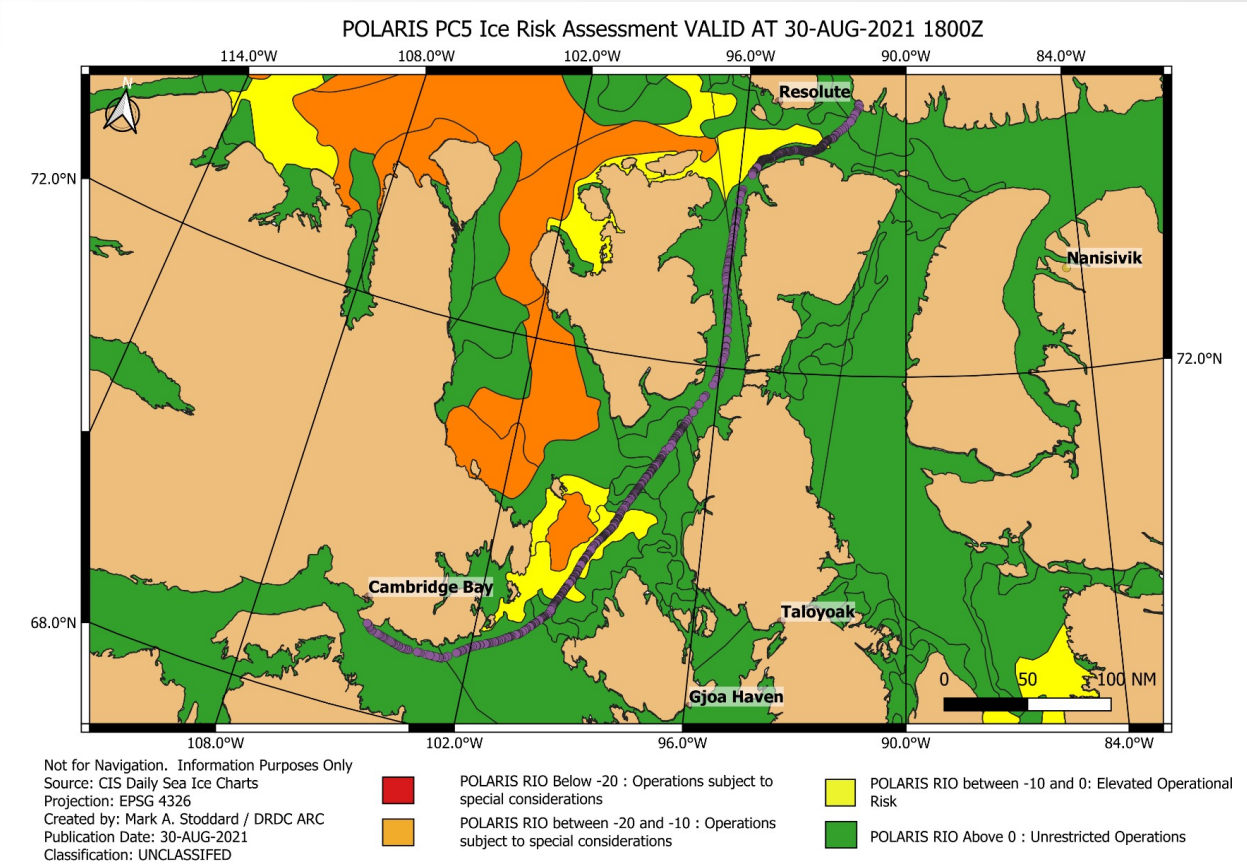


Ice Risk Adjusted Transit Time Along TRG Route

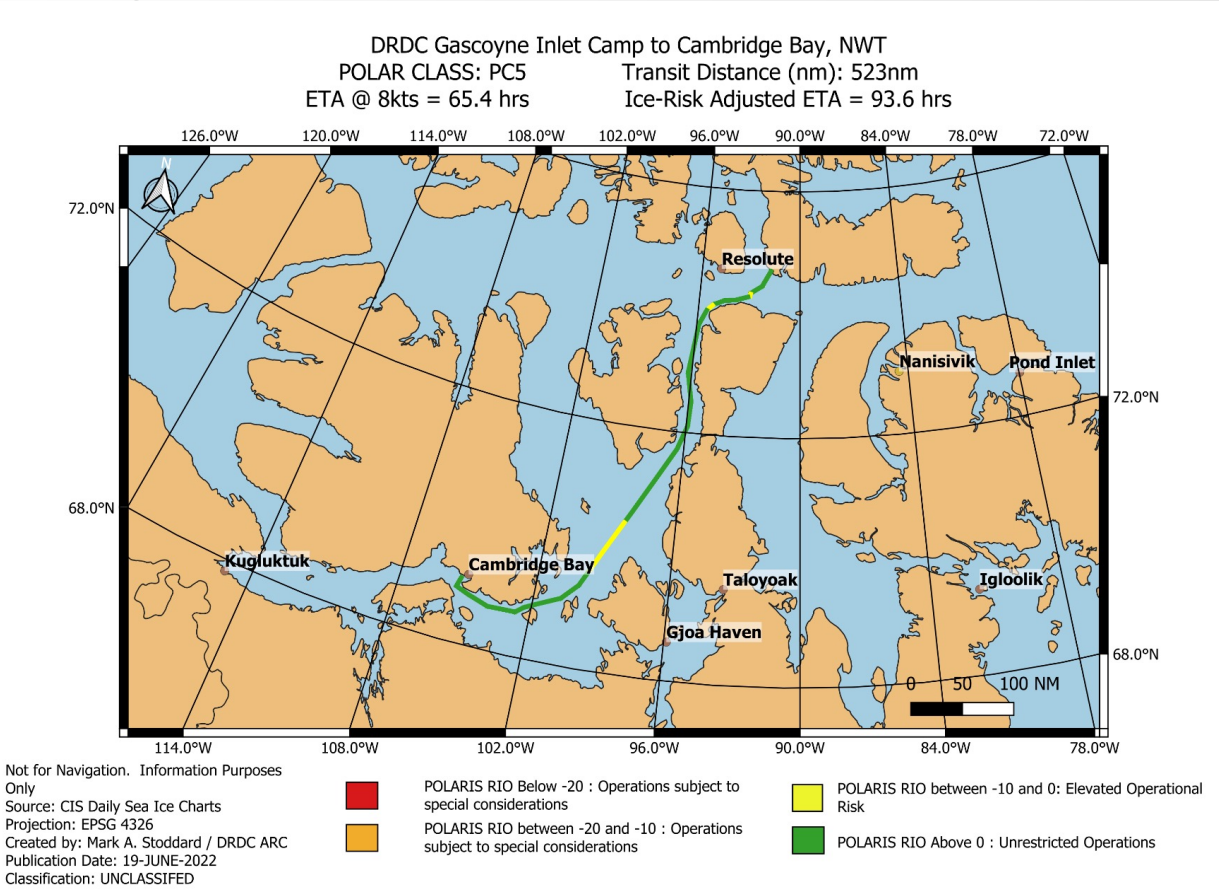
Ice Risk Adjusted Transit Time In Pictures



Ice Risk Adjusted Transit Time In Pictures

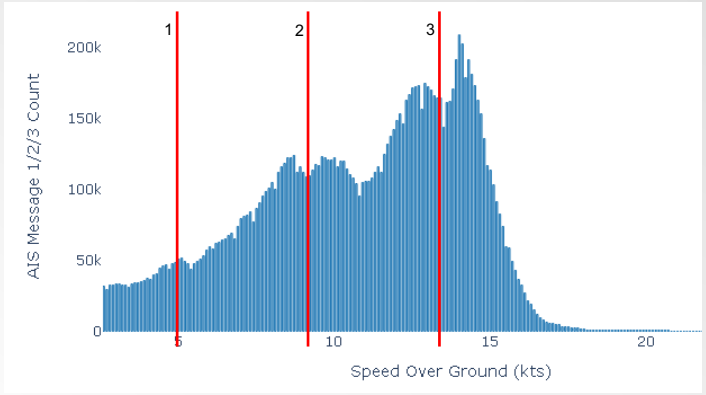


Ice Risk Adjusted Transit Time In Pictures

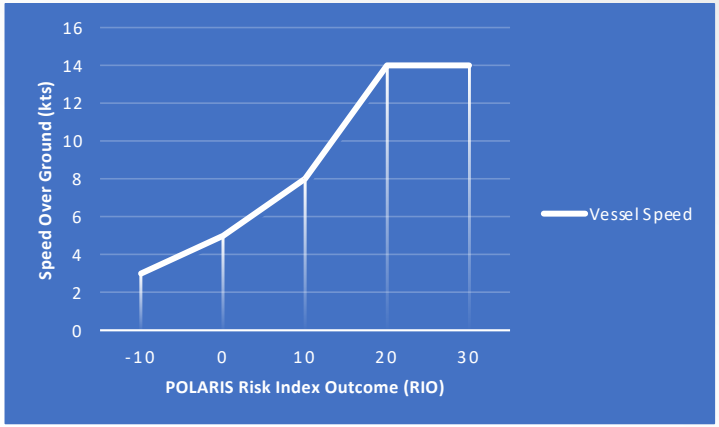


Vessel Speeds in Polar Waters

- A total of 22M S-AIS messages were used to produce a histogram of historical ship speeds within the Transport Canada AIRSS Control Zone.
- The result is a multi-mode histogram which we have chosen to treat as three modes to generate the following speed regimes:
  - 14kts (RIO = 20)
  - 8kts (RIO = 10)
  - 5kts (RIO = 0)
  - 3kts (RIO = -10 and below)
- Using linear interpolation between critical values, we produce a continuous speed curve as a function of RIO.
- Many other options exists to generate vessel speed curves!



Vessel Speed Histogram for study area of interest



Measuring Remoteness Using Ice-Risk Adjusted Transit times

- The Remoteness Index (RI) is determined by two key parameters:
  - A community's proximity to all other communities and ports on a given day of year (T_{kit})
  - The population size of each community and port, used as a proxy of service capacity of a community (A_k)
- A_k expresses the service capacity of a community, which is estimated by population size
- $T_{\mathrm{k,i},t}$ is a sparse matrix containing the ice-risk adjusted transit times between communities and ports

INDEXES

i = 1..13 (list of community/port origins)

k = 1 …13 (list of community/port destinations)

t = 1…365 (departure day of year)

r = 1..3 (Statistical aggregation of RIO (25th Percentile, Median, 75th Percentile))

DATA

A_k = Population size of community *k*

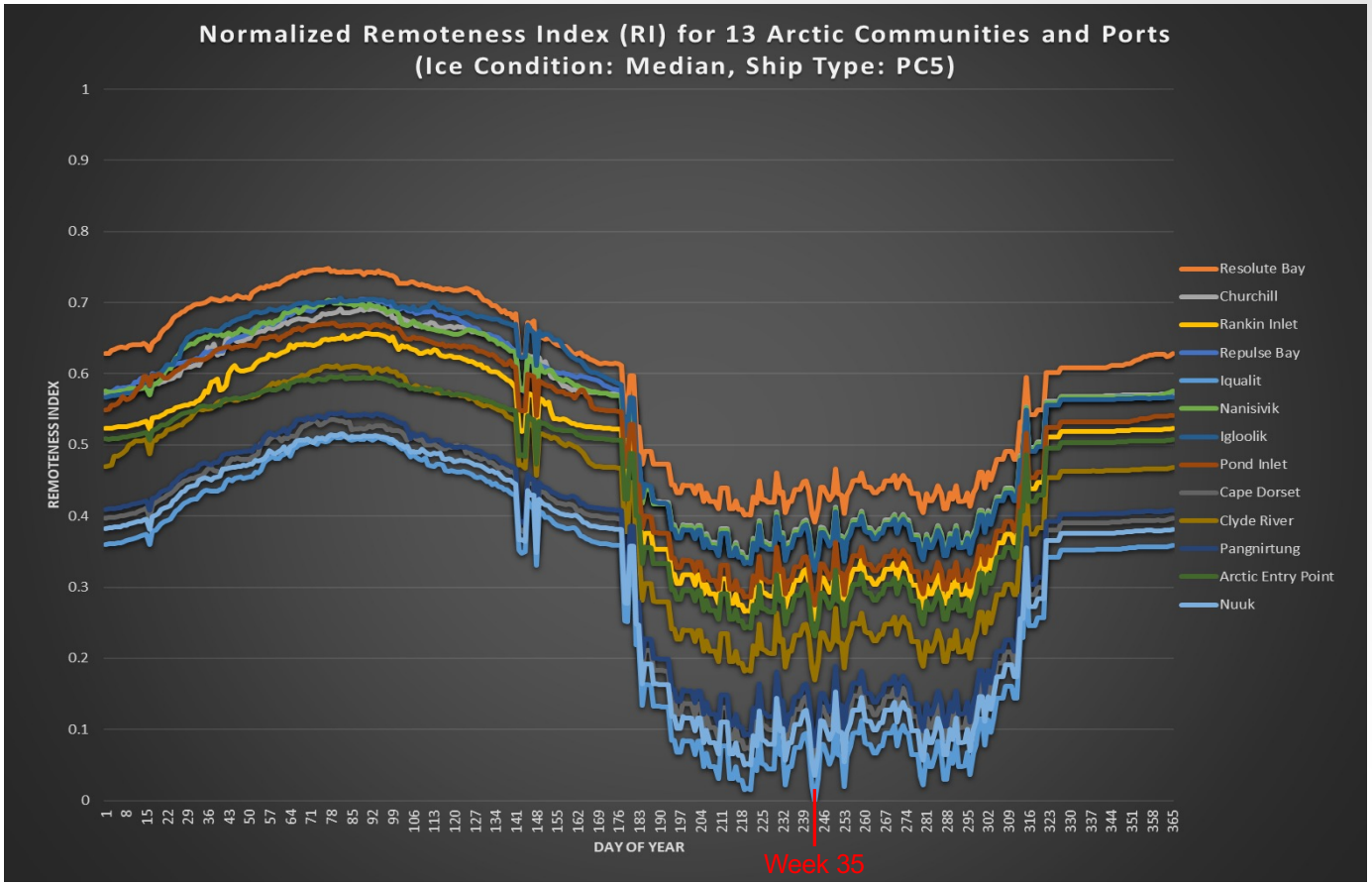
$T_{k,I,t}$ = Transit time from community *k* to community *i* on a given day of departure

DECISION VARIABLES

$RI_{i,t}$ = Maritime remoteness of community *i, on day t.*

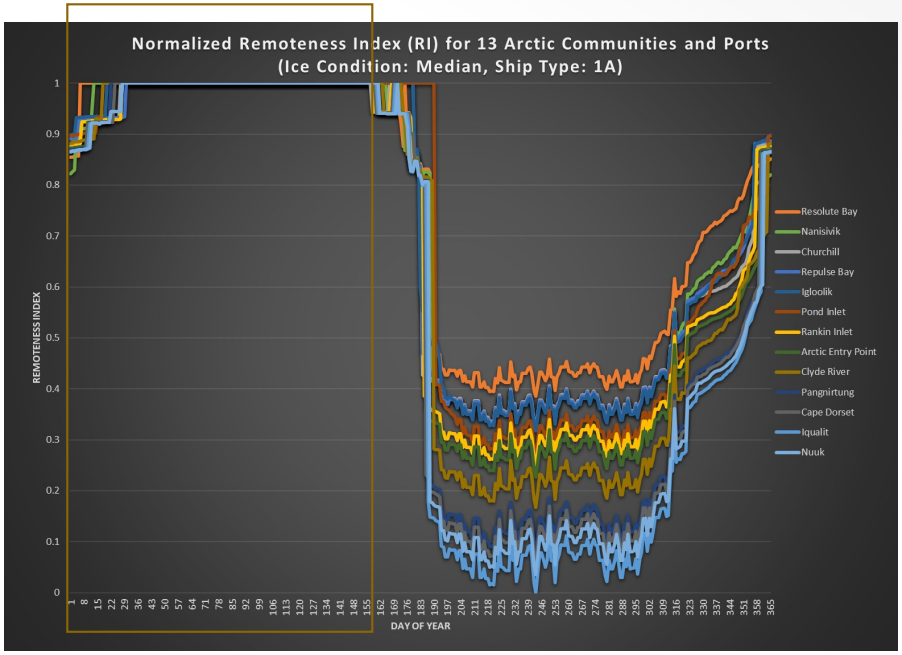
$$RI_{i,t(\ \ )} = \sum_{k=1}^{n} \frac{A_k}{T_{\mathrm{k,i},t}} \ \forall\, i \in I, t \in T$$

Arctic Community Remoteness Index (RI)



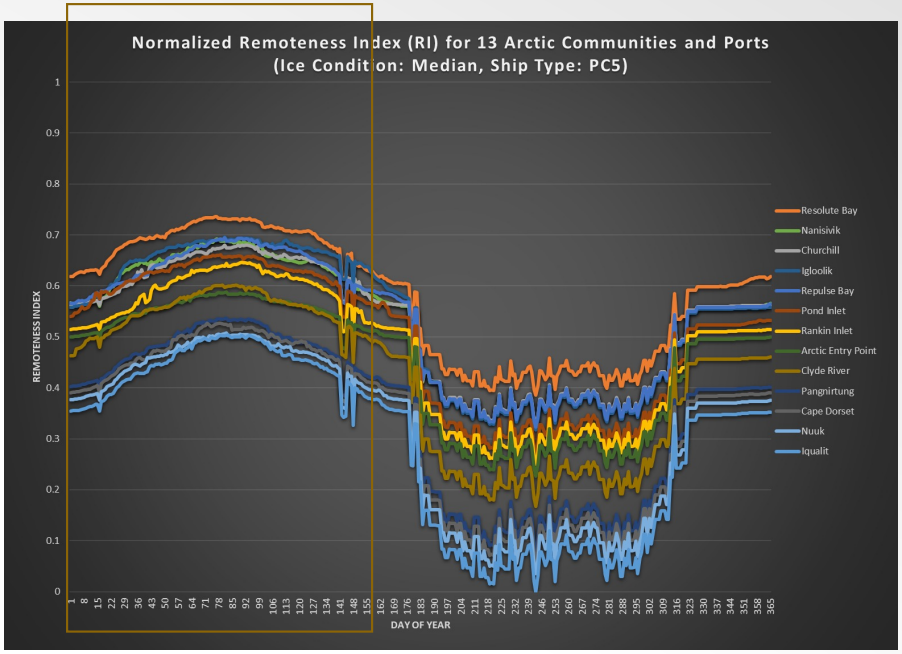
RI using different Polar Class ship types

Winter Months (January – April)



Polar Class 1A

Winter Months (January – April)



Polar Class PC-5

Conclusions

- Using ice-risk adjusted transit times to compute the RI enables the quantitative measure of year-round remoteness and accessibility of coastal communities in the arctic.
- The results of this study show that remoteness and accessibility varies significantly throughout the year, which is largely attributed to the harsh environmental conditions observed during most of the arctic navigational season.
- Work remains to further analyze our results and to better understand how these results can be used to support a variety of research applications, such as monitoring the impact of climate change on the remoteness and accessibility of northern coastal communities.